Bench-Scale and Pilot-Scale Photocatalytic Inactivation of Viruses with Titanium Dioxide Nanoparticles

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Motivation

Published studies regarding concerns of emerging contaminants, particularly pharmaceuticals and endocrine disruptors, have led to increased public scrutiny of water quality. To address this, recent changes to water quality regulations, specifically the Long-term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) and the Stage 2 Disinfection Byproducts Rule (SBPDR), have forced water utilities to consider implementation of advanced treatment technologies to remain in full regulatory compliance. Enhanced coagulation and granular activated carbon (GAC) are currently considered the gold standard technologies for treating dissolved organic and disinfection byproduct precursors. However, there are several limitations for the advanced water treatment technologies, including large capital investments, high operating and maintenance costs, and operational challenges such as backwashing and reagent management. As a result, water utilities are considering alternatives, including low-temperature photochemical processes, for advanced treatment. In particular, the use of titanium dioxide (TiO₂) for photocatalytic disinfection has been studied extensively. However, the energy requirements for photocatalysis may be cost-prohibitive, but these low efficiencies may be an artifact of inefficient reactor configurations. To address some of these issues, this study compares UV and photocatalytic inactivation with respect to several potential surrogate bacteria (PRD1, phi-X174, and E. Coli) and three enteroviruses (poliovirus 1, coxsackievirus B6, and echovirus 12). In addition, this study demonstrates the application of an integrated cell culture quantitative polymerase chain reaction (ICC-qPCR) strategy for adenovirus and enterovirus distribution studies.

Background

TITANIUM DIOXIDE PHOTOCATALYSIS

• Inorganic TiO₂: 75% Anatase and 25% Rutile
• Individual particle size: ~23 nm
• Particle aggregation: 550 nm
• Pure rutile TiO₂ was used as a turbidity control

BACTERIOPHAGE – DOUBLE AGAR LAYER

• PRD1 (genotype PRD1, T4-like, M 8000, B 3000, S 8.8)
• phi-X174 (genotype X174, M 8000, B 1000, S 8.8)

VIRAL INACTIVATION IN THE PHOTO-CAT

• Poliovirus 1
• Coxsackievirus B6
• Echovirus 12
• PRD1

HUMAN VIRUSES – ICC-qPCR or ICC-qRT-PCR

• Adenovirus 4
• Consulturial BS (BS)
• E. coli (ECM)
• Poliovirus 1

INTEGRATED CELL CULTURE qPCR (ICC-qPCR)

For similar energy inputs, UV and photocatalysis achieved similar levels of inactivation for PRD1. Due to the high energy input, physical removal of the viruses and cells was observed. In addition, the TI02 Recycle reactor configuration reduced the effectiveness of photocatalysis, particularly for high TiO2 concentrations. This study demonstrates the use of UV and photocatalysis coupled with filtration exceeded the detection limit of the ICC-qPCR assay.

Results

BACTERIOPHAGE PHOTOCATALYTIC INACTIVATION IN THE COLLIMATED BEAM

In addition, this study demonstrates the application of an integrated cell culture quantitative polymerase chain reaction (ICC-qPCR) strategy for adenovirus and enterovirus distribution studies.

SUMMARY

• The literature suggests hydrosol radical specifically with alkenes, alkanes, and proteins. Based on the above conclusions, the Photo-Cat, there is a strong correlation between the treatment-photocatalyzed rapid removal of bacteria, and potentially other pathogens, which were initially present on the test surface. This study demonstrates the use of UV and photocatalysis coupled with filtration exceeded the detection limit of the ICC-qPCR assay.

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