

Abstract

The outbreak of the COVID-19 pandemic in 2019 resulted in a substantial rise in the global use of pharmaceutical compounds, particularly antivirals used or repurposed for the treatment of the disease. During the early phase, no specific drugs were available for COVID-19 therapy, leading to the off-label use of existing medications, while later the accelerated development and approval of new antiviral agents raised concerns regarding their environmental persistence and fate. This doctoral research focused on investigating the solar-light-driven degradation of selected antiviral compounds such as isoprinosine (IPN), ritonavir (RTR), and remdesivir (REM) in aquatic environment. The study examined direct photolysis, photocatalytic processes, and H₂O₂-assisted photolysis under simulated solar irradiation to evaluate the effects of environmental and operational parameters such as water composition, light intensity, catalyst dosage, pollutant concentration, and reaction time on degradation efficiency. Experiments were conducted using three different water matrices; Milli-Q, tap, and surface water to simulate real environmental conditions. Various photocatalysts, including TiO₂ P25, ZnO, SnO₂, Ag–TiO₂, and the composite SnO₂:ZnO system, were tested to compare their degradation efficiency. The results showed that direct photolysis alone was largely ineffective due to the structural stability and low solar absorptivity of the studied compounds, whereas photocatalytic and H₂O₂-assisted processes significantly enhanced degradation rates. Among the catalysts, TiO₂ P25 and SnO₂:ZnO composites exhibited the highest photocatalytic activity under solar irradiation. The study further evaluated the role of water matrix components and specific anions such as Cl⁻, SO₄²⁻, and HCO⁻ in modulating the degradation process and assesses the applicability of sunlight-activated photocatalysis as a sustainable method for environmental purposes. Kinetic studies indicated that the degradation of IPN followed pseudo-first-order kinetics, RTR fitted the Langmuir–Hinshelwood adsorption model, and REM followed a two-phase adsorption desorption dynamic model. The study demonstrated that water matrix composition and catalyst dosage strongly influenced overall degradation efficiency. These findings confirm that solar assisted photocatalysis represents a sustainable and energy-efficient approach for mitigating antiviral contamination, offering novel insights into the environmental behavior and removal mechanisms of COVID-19-related pharmaceuticals in aquatic systems.