Abstract

This research evaluates the effectiveness of physical, chemical, and biological methods for treating leachate from a landfill in Gujranwala City, Punjab, Pakistan. The leachate, highly toxic with elevated levels of salts (chlorides and sulfates) and heavy metals (arsenic, chromium, and cadmium), poses significant risks to groundwater and drinking water quality. Analysis revealed that key parameters—Electrical conductivity (EC), Total Dissolved Solids (TDS), turbidity, alkalinity, and hardness—exceeded WHO drinking water standards, with high chromium and cadmium levels raising carcinogenic concerns. The study tested various treatment methods at leachate dilutions of 15%, 30%, 60%, and 100%. Physical treatments (80 g/L) led to modest reductions in EC and TDS but increased turbidity and Dissolved Oxygen (DO). Among chemical treatments (O_3, H_2O_2/UV, H_2O_2/O_3, H_2O_2/UV/O_3 with 2 ml H_2O_2 per dilution and method), the H_2O_2/O_3 combination was most effective at the 15% dilution for reducing EC and TDS, while the H_2O_2/UV/O_3 method was superior for decreasing turbidity. Advanced Oxidation Processes (AOPs) showed reduced efficacy at higher dilutions, resulting in increased turbidity and inconsistent DO effects. Biological treatments were generally less effective, with *Pistia stratiotes* deteriorating rapidly and *Eichhornia crassipes* performing better at lower dilutions. The combination of *Pistia stratiotes* and *Eichhornia crassipes* at a 15% dilution achieved the highest removal rates for EC and TDS, and *Eichhornia crassipes* alone effectively reduced turbidity. Higher dilutions, particularly at 60%, led to reduced treatment efficacy. The study finds that lower leachate dilutions, especially at 15%, are more amenable to effective treatment. It underscores the necessity of a combined approach for comprehensive leachate management to address its environmental and health impacts.