



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

Name of the Student : Satyam

Roll Number : 196106020

Programme of Study : Ph.D.

Thesis Title: Enzyme and device driven solutions for sustainable wastewater bioremediation and monitoring

Name of Thesis Supervisor(s) : Prof. Sanjukta Patra

Thesis Submitted to the Academic Division : BSBE

Date of completion of Thesis Viva-Voce Exam : 17-07-2025

Key words for description of Thesis Work : Advanced oxidation processes, Internet of Things, Fenton reaction, Phytotoxicity, *Pichia pastoris*, *Aliivibrio fischeri*, Wastewater, Bioremediation

SHORT ABSTRACT

The escalating global water pollution crisis, driven by industrial, agricultural, and urban activities, poses dire threats to ecosystems, biodiversity, and human health. Contaminants such as organic compounds, heavy metals, microbial pathogens, microplastics, and synthetic dyes, poses profound threats to ecosystems, biodiversity, and human health. Conventional water treatment methods, while effective to a degree, face limitations in cost, efficiency, and environmental sustainability, necessitating innovative solutions to address persistent and emerging pollutants. Additionally, plastic waste mismanagement and inefficient real-time monitoring hinder timely interventions. This thesis addresses these challenges through sustainable, innovative solutions that enhance environmental resilience. A key focus was developing enzyme-assisted systems to improve wastewater treatment. By optimizing the Hu-XO enzyme from *P. pastoris* to generate hydrogen peroxide in situ, a synergistic Fenton system was engineered, achieving >99% decolorization of dyes like Congo red and significant reductions in BOD (91.8%) and COD (86%). The process eliminated dependence on external H₂O₂ and acidic conditions and showed 99% antimicrobial efficiency, validated via bioluminescence inhibition and phytotoxicity assays. To tackle plastic pollution, protein engineering was employed to enhance PET hydrolases. The Mors1 PETase from Antarctic *Moraxella* TA144 was modified (K93I, E221I, R235F), producing Mors1^{MUT} with superior thermal stability and activity at pH 9, retaining 98% activity and achieving a 4.16-fold increase in PET hydrolysis efficiency. This reduces energy demands and enables scalable biological recycling. For safe drinking water, an energy-efficient, modular distillation system was developed using piezoelectric ultrasonic misting, thermoelectric Peltier modules, and UV-C sterilization. Built from biodegradable PLA, it achieved 83% water recovery, removing 490 mg/L NaCl, 1.5 × 10⁸ CFU/mL *E. coli*, 50 mg/L Congo red, and 60 μL/L toluene/o-xylene. Integrated VOC valves and precise temperature control minimized energy use, outperforming reverse osmosis systems. To support real-time water monitoring, a solar-powered, IoT-enabled device was designed with multiparametric sensors (temperature, DO, turbidity, TDS) and GPS. Built on open-source platforms (Firebase, Plotly.js), it eliminates recurring server costs and enables AI/ML-based analytics, empowering end-user with timely, actionable insights. Collectively, this work demonstrates the power of biotechnology, materials science, and digital tools

to holistically address wastewater challenges, promoting sustainable pollutant degradation, plastic recycling, water purification, and monitoring.

