

New technology provides environment friendly route for treating dye-contaminated wastewater

A sustainable, multifunctional machine learning enabled filter for wastewater treatment, developed by integrating green-synthesized zinc oxide (ZnO) nanoparticles with biodegradable polylactic acid (PLA) nanofibers, assisted by machine learning can provide an environment friendly route for treating dye-contaminated wastewater.

The discharge of persistent organic dyes from industrial activities, particularly the textile industry, represents an important environmental challenge because these compounds can be stable, toxic, and resistant to natural degradation. The research addresses the need for sustainable wastewater-treatment technologies.

Existing wastewater-treatment approaches such as adsorption, sedimentation and flocculation can separate pollutants but do not necessarily destroy them. Biological treatment can also be slow for highly stable dyes. Photocatalysis offers an attractive alternative because it can degrade pollutants under relatively mild conditions while using renewable energy.

However, conventional photocatalytic systems face several challenges: recovery of nanoparticle catalysts; separation of catalysts from treated water; electron-hole recombination; dependence on light availability; and the requirement for efficient catalyst-pollutant contact.

To tackle this challenge, a new technology developed by the Institute of Nano Science and Technology (INST) Mohali, autonomous institute of the Department of Science and Technology (DST) immobilised ZnO (zinc oxide prepared from natural sources) within porous PLA nanofibers and introduced mechanical excitation along with light. The mechanical vibrations generated piezoelectric polarization, which suppressed photogenerated electron-hole recombination and enhanced reactive-species formation. The work was published in the journal Advanced Functional Materials (Wiley).

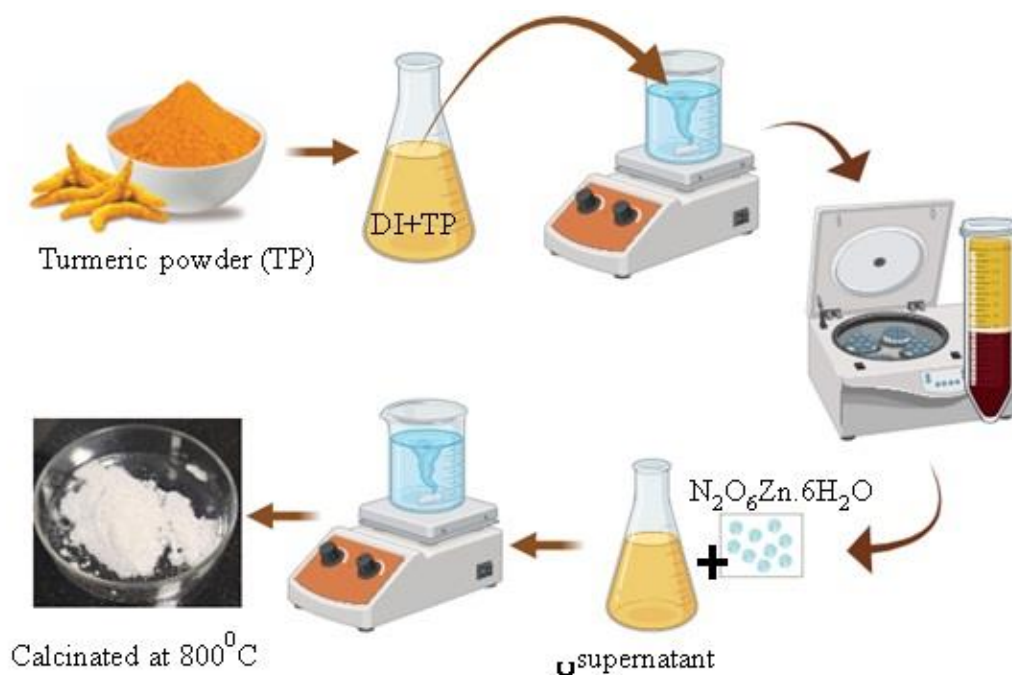


Fig 1: Schematic illustration of green-synthesized, highly crystalline ZnO nanoparticles using turmeric powder.

Dr. Aviru Kumar Basu's lab synthesised ZnO nanoparticles using turmeric extract, where naturally occurring bioactive compounds like curcumin, flavonoids and phenolic compounds acted as reducing and stabilizing agents, avoiding conventional synthesis routes involving harmful reagents.

The fabrication of PLA-ZnO nanofibers through electrospinning, produced a porous, high-surface-area and mechanically stable catalytic membrane rather than using ZnO as a freely dispersed powder. The integration of photocatalysis and piezocatalysis enabled pollutant degradation using both light and mechanical vibrations.

The PLA-ZnO nanofibers achieved 98.6% MB and 96.7% CR decolorization within 120 min under combined light and ultrasonic excitation. This new material also demonstrated antibacterial activity, achieving approximately 75% inactivation of *E. coli* and 71% of *S. aureus* after 6 h. Machine learning (ML) was integrated with the experimental study to predict dye-decolorization behaviour from parameters such as wavelength, time, catalyst amount, ultrasonic frequency, light intensity and dye concentration.

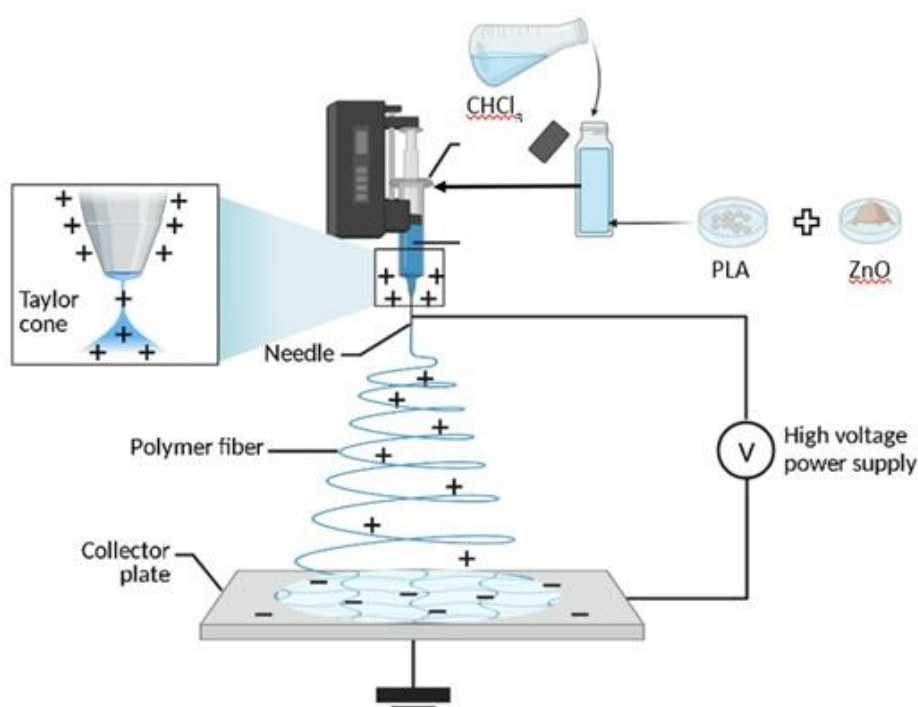


Fig 2: Schematic of PLA-ZnO nanofiber preparation using the e-spin method.

The developed PLA-ZnO nanofibers can be used for the treatment of wastewater containing persistent organic dyes and microbial contaminants, particularly those associated with textile and industrial effluents for cleaner and safer water. They can also be used for Photocatalytic and piezocatalytic environmental remediation as well as for antibacterial water-treatment membranes.

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