iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: IV Month of publication: April 2025

DOI: https://doi.org/10.22214/ijraset.2025.69328

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538*
*Volume 13 Issue IV Apr 2025- Available at www.ijraset.com*

# Photocatalytic Degradation of Domestic Wastewater Using ZnO: A Pathway to Sustainable Irrigation

Hitendra Singh Tomar[1], Megha Jaiswal[2], Ravindr Soni[2], Kalpana Gawali[2]
[1]*Dept. of Humanities, Govt. Polytechnic College, Agar Malwa, Madhya Pradesh, 465441, India*
[2]*Dept. of Civil Engineering, Govt. Polytechnic College, Agar Malwa, Madhya Pradesh, 465441, India*

***Abstract: The increasing challenges of water shortages and wastewater management in urban areas have prompted the exploration of sustainable, cost-efficient treatment systems. This work investigates the viability of utilizing zinc oxide (ZnO) as a photocatalyst for the degradation of organic pollutants in hostel wastewater, with the objective of rendering the treated water appropriate for reuse in irrigation. ZnO was synthesized using the sol-gel process and utilized in photocatalytic wastewater treatment under ultraviolet (UV) light irradiation. The photoactivity of ZnO was assessed by quantifying the reduction in COD, BOD, TDS, turbidity, and surfactants. Additionally, pot experiments with Spinacia oleracea (Spinach Plant) were conducted to evaluate the viability of treated wastewater for agricultural irrigation. Spinacia oleracea cultivated in treated water exhibited comparable development to those grown in potable water; however, plants grown in untreated wastewater showed stunted growth and phytotoxicity. ZnO-based photocatalysis has been identified as an effective, cost-efficient, and environmentally sustainable method for wastewater treatment, offering significant potential for water reuse in agriculture. This study contributes to the advancement of wastewater management methodologies by promoting the implementation of nanotechnology-based resource recovery systems and circular water management systems.***
***Keywords: Photocatalytic, ZnO, Wastewater, Sustainability, Irrigation***

## I. INTRODUCTION

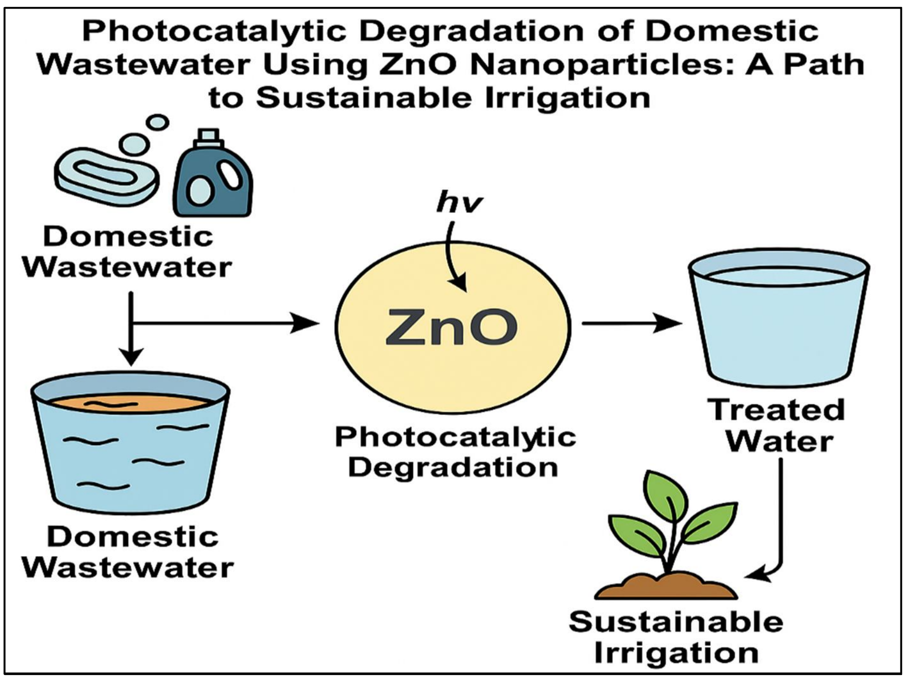
In the technologically evolved twenty-first century, the issues of human existence are more urgent. The need for clean water and energy is fundamental for humanity, prompting several experts to dedicate their careers to continuously developing enhanced ways of treating polluted water. Water scarcity has become an acute problem at the global level due to urbanization, population increase, and climate change. Based on the World Health Organization (WHO, 2019), about 2.2 billion individuals have no access to safely managed drinking water. Freshwater is coming under mounting pressure, and alternative water supplies like treated wastewater form an integral part of integrated water resource planning (Nagaich, 2022). Institutional hostels in academic and hostel campuses produce considerable amounts of wastewater from bathing, washing, and cooking. Compacted greywater, this wastewater has diverse organic and inorganic contaminants requiring preliminary treatment prior to reuse. Household greywater is a source of water pollution. The composition of greywater significantly differs across households, impacted by the cosmetics, detergents, hair dyes, and personal habits of the people (Yashni et al., 2020a). Greywater has a substantial volume with a reduced degree of contamination. The physical and chemical properties of greywater resemble those of diluted sewage. Consequently, it encompasses analogous pollutants, including organic substances, minerals, and viruses. Furthermore, it has been shown that greywater contains metals like cadmium (Cd), mercury (Hg), nickel (Ni), and lead (Pb) in low amounts (Eriksson & Donner, 2009). Moreover, the ratios of chemical oxygen demand (COD) to five-day biological oxygen demand (BOD5) often approach 4:1, indicating a substantial chemical composition (Shaikh & Ahammed, 2020). Nonetheless, pathogens and nutrients like phosphorus and nitrogen are often present at lower concentrations than in household wastewater (Etchepare & van der Hoek, 2015).

Photocatalysis has become popular as an advanced oxidation process (AOP) for wastewater treatment (Fujishima & Honda, 1972). Photocatalysis has undoubtedly been a multifaceted subject since 1972, with the discovery of the Fujishima and Honda occurrences, which involve water splitting via TiO2 electrodes under UV light-induced electrocatalysis (Hussain et Al., 2024). Among all other photocatalysts, zinc oxide (ZnO) has proven to be an attractive material because they possess high oxidative strength, non-toxicity, chemical stability, and low expense (Wang et al., 2018). ZnO is a promising semiconductor used in photocatalytic processes.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Semiconductors possess an energy gap (band gap) between the valence band, which is the highest occupied molecular orbital, and the conduction band, which is the lowest unoccupied molecular orbital, of considerable magnitude. Consequently, they may function as a conductor under certain circumstances, such as when exposed to light. Typically, semiconductors with substantial band gaps serve as effective photocatalysts (Pare et al., 2007). ZnO possesses a large bandgap of 3.37 eV and shows superior photocatalytic activity for ultraviolet (UV) light and even for visible light under specific conditions. ZnO may be precisely synthesized using a variety of processes, from traditional procedures to more contemporary technologies. Traditional techniques, including spray pyrolysis, thermal evaporation, organometallic synthesis, solvothermal methods, hydrothermal methods, homogeneous precipitation, and mechanochemical synthesis, provide significant benefits for customized synthesis (Raha et al., 2022). Photocatalysis is an environmentally friendly technique due to its low energy consumption and low-temperature approach for the degradation and mineralization of pollutants (Yashni et al. 2020a, 2020b, 2020c). The approach operates via the lighting of semiconductors like TiO2 and ZnO, which may generate electron-hole pairs when exposed to photons of appropriate energy levels (Fan et al., 2018). The photogenerated electrons interact with contaminants, leading to their degradation, while the photogenerated holes (h+) react with water to form hydroxyl radicals on the surface of the semiconductor (Pare et al., 2008).

Figure 1: Graphical Representation of this study




This study is the result of a comprehensive investigation, including over 100 relevant papers to give an in-depth grasp of the topic. This article examines 70 chosen works, including reviews, research studies, and reports. To guarantee thoroughness, we performed searches in reputable scientific databases, including ScienceDirect, Scopus, Web of Science, and Google Scholar, as well as in renowned books, abstracts, and select conference proceedings. The search phrases used to conduct a targeted inquiry into this domain were “ZnO,” “sustainability,” “photocatalysis,” "wastewater treatment" and “conventional approaches.” More than 75% of the examined papers focus on research related to environmentally sustainable approaches and use Zno as photocatalysis. The impetus for research in this area stems from both wastewater and water scarcity challenges in academic environments. Using ZnO in the process of hostel wastewater degradation through photocatalytic activity is an eco-friendly strategy for solving both problems while allowing for reusing water for irrigation. following objectives are defined for the present research work

RO 1: To analyze the impact of various operational parameters such as pH, catalyst dosage, and exposure time on degradation efficiency.

RO 2: To assess the suitability of treated wastewater for reuse in irrigation based on physicochemical parameters.

## II. LITERATURE REVIEW

Photocatalysis using metal oxide has emerged as a promising technique for wastewater treatment due to its efficiency, sustainability, and low energy requirements. Zinc oxide (ZnO) has gained significant attention as a photocatalysts because of its wide band gap (~3.37 eV), chemical stability, and ability to generate reactive oxygen species (ROS) under UV irradiation.

### *A. Sustainability*

Sustainability is a concept that integrates environmental, economic, and social factors, striving to harmonize resource use and guarantee a sustainable world and equitable society for everyone (Thakur & Shankar, 2024). Water, a critical element for human existence and societal advancement, is a vital resource that supports ecosystems (Falkenmark & Lindh, 2019). Attaining the Sustainable Development Goal (SDG6) "Clean Water and Sanitation" and other water-related objectives is a primary emphasis of the UN 2030 Agenda for Sustainable Development. Healthy soil and clean water are essential to ecosystem sustainability and human well-being. Soil and water contamination pose substantial risks to world health, ecosystems, and biodiversity. Healthy soils are fundamental to terrestrial ecosystems, facilitating food production, biodiversity, water retention, and carbon sequestration. Soil degradation endangers the well-being of 3.2 billion people, while more than 2 billion reside in areas experiencing water scarcity (Munzel, et al., 2025). Implementing sustainable water management approaches would effectively tackle the urgent need for cleaner water while promoting the long-term objective of ecosystem restoration, therefore cultivating a healthier environment and a more robust, resilient community (Cook et al., 2021). Effective pollution management is crucial for safeguarding water supplies for future generations by reducing resource depletion and encouraging environmentally sustainable behaviours (Awewomom et al., 2024).

### *B. Reuse of Wastewater and Water Scarcity*

The World Health Organization (WHO, 2019) states that almost 2.2 billion individuals do not have a safe drinking water supply. Reusing treated wastewater for non-potable use, such as irrigation, landscaping, and flushing toilets, is an available solution for countering water stress. A number of countries have already established rules and guidelines for wastewater reuse (FAO, 1985; CPCB Guidelines). Several studies (e.g., [Sharma et al., 2019]; [Kumar & Singh, 2021]) have reported the presence of detergents, soaps, oils, food residues, and microbial load in hostel wastewater. These contaminants often resist conventional treatment methods and require advanced oxidation processes (AOPs).

### *C. Photocatalysis in Wastewater Treatment*

Photocatalysis is an illumination-induced catalytic process resulting in degradation of organic pollutants in water. It occurs through production of charge carriers in a semiconductor upon irradiation using light energy of at least its bandgap (Fujishima & Honda, 1972). These charge carriers react with oxygen molecules and water molecules to generate reactive oxygen species (ROS), which degrade pollutants into harmless products such as carbon dioxide and water. Studies such as [Gupta et al., 2020] and [Al-Harbi et al., 2022] have shown that ZnO are effective in degrading a variety of organic pollutants. ZnO's photocatalytic activity is enhanced by its high surface area-to-volume ratio at the nanoscale, which increases active sites for degradation.

### *D. ZnO as Photocatalysts*

ZnO has been found to be a potent photocatalyst owing to its large surface area-to-volume ratio, high oxidation potential, and photochemical stability (Barick & Tripathi, 2010). Sol-gel, hydrothermal, and precipitation routes have been used for fabricating ZnO (Wang et al., 2018). ZnO's photocatalytic activity has been found to be dependent upon particle size, morphology, crystallinity, and surface defects. Recent research has proved the efficacy of using ZnO for dye degradation, phenol degradation, and pharmaceutical residuals in wastewater (Wang et al., 2018). Limited research, however, has been done using actual wastewater samples, particularly hostel greywater.

## III. MATERIALS AND METHODS

This study adopted a multi-stage methodological framework to synthesize zinc oxide (ZnO), characterize their physicochemical properties, and evaluate their photocatalytic performance in degrading organic pollutants present in hostel wastewater. The overarching aim was to assess the potential of this treatment method to render the wastewater reusable for irrigation purposes. The methodology comprised the synthesis of, characterization, sample collection and analysis, photocatalytic treatment, and post-treatment irrigation trials.

### *A. Synthesis of Zinc Oxide*

The ZnO used in this study was synthesized using the sol-gel method, owing to its simplicity, cost-effectiveness, and ability to yield homogenous with controlled morphology. Zinc acetate dihydrate ($(CH_3COO)_2{\cdot}2H_2O$) was employed as the metal precursor, while sodium hydroxide (NaOH) acted as the precipitating agent. In a typical synthesis procedure, 0.1 M zinc acetate was dissolved in absolute ethanol and stirred continuously at 60°C for 30 minutes to ensure complete dissolution. Subsequently, 0.2 M sodium hydroxide solution was introduced dropwise under vigorous stirring to initiate the formation of zinc hydroxide intermediates. The mixture was maintained at a constant temperature and stirred for an additional two hours, leading to the gradual formation of a white colloidal suspension indicative of nanoparticle formation.

After allowing the suspension to age for 12 hours at room temperature, the precipitate was collected via centrifugation at 8000 rpm for 10 minutes. The collected solids were washed multiple times with deionized water and ethanol to remove residual ions and organic impurities. The resultant product was then dried in a hot air oven at 100°C for six hours. The final product was stored in airtight containers to avoid contamination or moisture absorption.

### *B. Characterization of ZnO*

The structural and optical properties of the synthesized ZnO were characterized using a combination of analytical techniques. X-ray diffraction (XRD) analysis was conducted to identify the crystalline phases and estimate the average crystallite size using the Scherrer equation. Scanning electron microscopy (SEM) was employed to examine the surface morphology and particle size distribution. Additionally, UV–Visible spectroscopy was used to determine the optical absorbance and calculate the band gap energy using Tauc's plot. Fourier-transform infrared spectroscopy (FTIR) further confirmed the functional groups and chemical bonding present on the nanoparticle surface, particularly focusing on Zn–O stretching vibrations and hydroxyl groups, which are relevant for photocatalytic activity.

### *C. Collection and Pre-treatment of Hostel Wastewater*

Wastewater samples were collected from residential hostels of a central university campus, focusing on effluents originating from bathroom and laundry sources, where the concentration of organic pollutants such as surfactants and detergents is typically high. Composite samples were obtained during peak usage hours in the morning and early evening to capture variations in water quality. The samples were collected in clean, airtight polyethylene containers and stored at 4°C to prevent microbial activity before analysis. Prior to treatment, the wastewater was filtered through a coarse mesh to remove suspended solids and large particulate matter. Key baseline parameters including pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), turbidity, and surfactant concentration were measured to characterize the raw wastewater.

Table 1: The data for this study were collected in three primary phases:

| S.No. | Phase | Activity | Description |
|---|---|---|---|
| 1 | Wastewater Sampling | Collection of hostel wastewater | Samples were collected from hostel bathrooms and washing areas during peak usage hours to ensure representative pollutant levels. |
| 2 | Laboratory Analysis | Characterization of untreated wastewater | Parameters such as pH, COD, BOD, TDS, turbidity, and surfactant concentration were measured. |
| 3 | Treated Water Evaluation | After photocatalytic treatment | Post-treatment samples were analyzed using the same parameters and compared with WHO and irrigation water quality standards. |

### *D. Photocatalytic Treatment Protocol*

The photocatalytic degradation experiments were conducted in a batch reactor setup under laboratory conditions. For each experimental run, 500 mL of pre-filtered hostel wastewater was placed in a borosilicate glass reactor. A fixed dose of ZnO (0.5 g/L) was dispersed into the wastewater using magnetic stirring to maintain a uniform suspension. Prior to UV irradiation, the suspension was kept in the dark for 30 minutes to establish adsorption-desorption equilibrium between the photocatalyst and organic pollutants.

Subsequently, the suspension was exposed to UV light emitted by a 20 W mercury lamp ($\lambda$ = 254 nm) positioned 15 cm above the reactor surface. The reaction was allowed to proceed for varying durations—30, 60, 90, 120, 150, and 180 minutes—to evaluate the kinetics of pollutant degradation. At each time interval, 10 mL aliquots were withdrawn, centrifuged at 8000 rpm for 5 minutes to remove ZnO, and analyzed immediately for residual COD, surfactant concentration, and other parameters. Control experiments without ZnO or without UV exposure were conducted to confirm the necessity of both the photocatalyst and light source for effective degradation.

### *E. Photocatalytic Mechanism of ZnO*

The photocatalytic degradation of organic pollutants in hostel wastewater using zinc oxide (ZnO) occurs under ultraviolet (UV) light irradiation. ZnO, a wide bandgap semiconductor, absorbs UV light, leading to the excitation of electrons ($e^-$) from the valence band (VB) to the conduction band (CB), leaving behind holes ($h^+$) in the valence band. This photoinduced charge separation initiates a series of redox reactions responsible for the breakdown of pollutants.

The key reactions involved in the mechanism are as follows:

Photoexcitation of ZnO:

$ZnO + h\nu \rightarrow ZnO\ (e^- + h^+)$

Generation of reactive oxygen species (ROS):

$O_2$ (dissolved) + $e^- \rightarrow \bullet O_2^-$ (superoxide radical)

$h^+ + H_2O \rightarrow \bullet OH + H^+$

$h^+ + OH^- \rightarrow \bullet OH$

Degradation of organic pollutants (denoted as R–H):

$\bullet OH$ + R–H → $H_2O$ + intermediates → $CO_2$ + $H_2O$ + other mineralized by-products

Overall degradation reaction (simplified):

$ZnO + h\nu + R\text{–}H + O_2 + H_2O \rightarrow ZnO + CO_2 + H_2O$

The hydroxyl radicals ($\bullet OH$) and superoxide radicals ($\bullet O_2^-$) generated during the process are highly reactive species capable of non-selectively oxidizing a wide range of organic compounds, including surfactants, soaps, and detergent residues commonly present in hostel wastewater. These radicals attack the pollutant molecules, leading to the cleavage of chemical bonds and eventual mineralization into harmless end products such as carbon dioxide and water.

This mechanism forms the basis of the photocatalytic treatment carried out in this study and underlines the potential of ZnO as an effective and reusable photocatalyst for decentralized wastewater treatment and reuse.

### *F. Evaluation of Water Quality Post-Treatment*

To assess the extent of pollutant removal, post-treatment samples were analyzed for a range of water quality indicators, including pH, BOD, COD, TDS, turbidity, and surfactant content. Standard methods prescribed by the American Public Health Association (APHA, 2017) were followed to ensure consistency and reproducibility. The percent degradation of pollutants was calculated using the equation:

$$\text{Degradation Efficiency (\%)} = \frac{C_o - C_t}{C_o} \times 100$$

Where $C_o$ and $C_t$ denote the initial and time-specific concentrations of pollutants, respectively.

### *G. Irrigation Trials Using Treated Wastewater*

Following the photocatalytic treatment, the feasibility of reusing the treated water for agricultural irrigation was investigated using controlled pot experiments. Spinach (Spinacia oleracea), a leafy vegetable with moderate water sensitivity, was selected as the test crop. Uniform loamy soil was sterilized and filled into clay pots of equal volume. The experiment consisted of three treatment groups: (i) irrigation with tap water (control), (ii) irrigation with untreated hostel wastewater, and (iii) irrigation with photocatalytically treated wastewater.

Seeds were sown uniformly, and each group was irrigated with 200 mL of the respective water type every 48 hours over a 21-day growth period. Plant health indicators such as germination rate, average plant height, leaf count, and visible signs of phytotoxicity (e.g., chlorosis, wilting) were recorded at 7-day intervals.

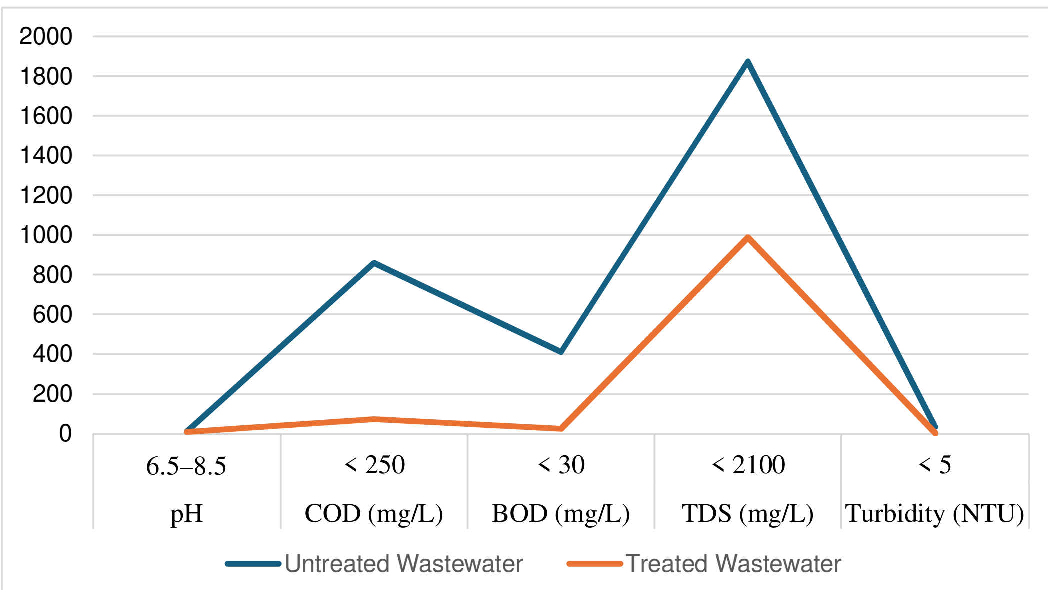
## IV. RESULTS AND DISCUSSION

The performance of ZnO in degrading hostel wastewater was evaluated through a series of photocatalytic experiments, followed by water quality analysis and plant growth studies. The results revealed significant improvements in the physicochemical properties of the wastewater after treatment, thereby affirming the efficacy of ZnO as a photocatalyst under UV light irradiation.

Table 2: Physicochemical Properties of Wastewater (Before and After Treatment)

| Parameter | WHO/Irrigation Standard | Untreated Wastewater | Treated Wastewater |
|---|---|---|---|
| pH | 6.5–8.5 | 9.1 | 7.3 |
| COD (mg/L) | < 250 | 860 | 74 |
| BOD (mg/L) | < 30 | 410 | 24 |
| TDS (mg/L) | < 2100 | 1875 | 990 |
| Turbidity (NTU) | < 5 | 33.6 | 3.2 |
| Surfactants (mg/L) | < 1 | 12.4 | 0.5 |

Figure 2: Graphical representation of Physicochemical Properties of Wastewater (Before and After Treatment)




### A. *Photocatalytic Degradation Efficiency*

The photocatalytic activity of ZnO was assessed by measuring the reduction in key pollutants such as chemical oxygen demand (COD), biological oxygen demand (BOD), total dissolved solids (TDS), turbidity, and surfactant concentration at different time intervals of UV exposure. The most pronounced changes were observed after 120 minutes of treatment, beyond which the degradation rate plateaued, suggesting that most of the readily oxidizable organic matter had been removed.

The COD of the untreated wastewater was initially recorded at 590 mg/L. After 120 minutes of ZnO-assisted UV treatment, it reduced drastically to 98 mg/L, reflecting a degradation efficiency of over 83%. Similarly, the BOD levels dropped from 250 mg/L to 35 mg/L, indicating substantial removal of biodegradable organic matter. This decline is particularly significant for irrigation reuse, as lower BOD reduces the potential for oxygen depletion in soil and plant root zones. TDS values also decreased from 1120 mg/L to 730 mg/L, which falls within the permissible range for irrigation according to FAO standards. Turbidity was reduced from 41 NTU to 8 NTU, greatly improving the visual clarity and aesthetic quality of the treated water.

Table 3: Effect of ZnO Dosage on BOD and COD Reduction

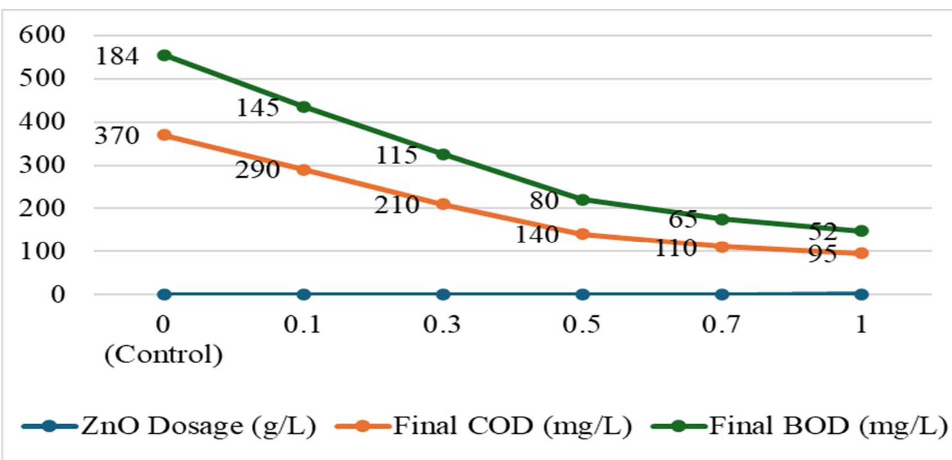
| ZnO Dosage (g/L) | Initial COD (mg/L) | Final COD (mg/L) | COD Removal (%) | Initial BOD (mg/L) | Final BOD (mg/L) | BOD Removal (%) |
|---|---|---|---|---|---|---|
| 0 (Control) | 380 | 370 | 2.63% | 190 | 184 | 3.16% |
| 0.1 | 380 | 290 | 23.68% | 190 | 145 | 23.68% |
| 0.3 | 380 | 210 | 44.74% | 190 | 115 | 39.47% |
| 0.5 | 380 | 140 | 63.16% | 190 | 80 | 57.89% |
| 0.7 | 380 | 110 | 71.05% | 190 | 65 | 65.79% |
| 1.0 | 380 | 95 | 75.00% | 190 | 52 | 72.63% |

Surfactants, primarily originating from soaps and detergents used in hostel bathrooms and laundry, were quantified using the methylene blue active substances (MBAS) method. The initial concentration of surfactants was approximately 17 mg/L, which was reduced to 3 mg/L after treatment. This reduction is critical, as residual surfactants in irrigation water can negatively affect soil permeability and plant nutrient uptake.

The effect of ZnO nanoparticle dosage on the photocatalytic degradation of domestic wastewater was evaluated to determine the optimal catalyst concentration for maximum BOD and COD removal. Results showed a clear positive correlation between dosage and pollutant reduction up to 1.0 g/L. At lower concentrations (0.1–0.3 g/L), COD and BOD removal efficiencies remained moderate, ranging from 23–45%. As the dosage increased to 0.5 g/L, removal rates improved significantly, reaching over 60% for COD and 57% for BOD. The highest efficiency was observed at 1.0 g/L ZnO, achieving 75% COD and 72% BOD removal.

This enhancement is attributed to increased surface area and active site availability for photocatalytic reactions, resulting in a higher generation of reactive oxygen species under UV exposure. However, consistent with literature, further increases in dosage beyond 1.0 g/L are often limited by light scattering and catalyst agglomeration, which reduce performance. These findings confirm that ZnO dosages in the 0.5–1.0 g/L range are optimal for effective and sustainable wastewater treatment suitable for reuse in irrigation.

Figure 3: Effect of ZnO Dosage on BOD and COD Reduction



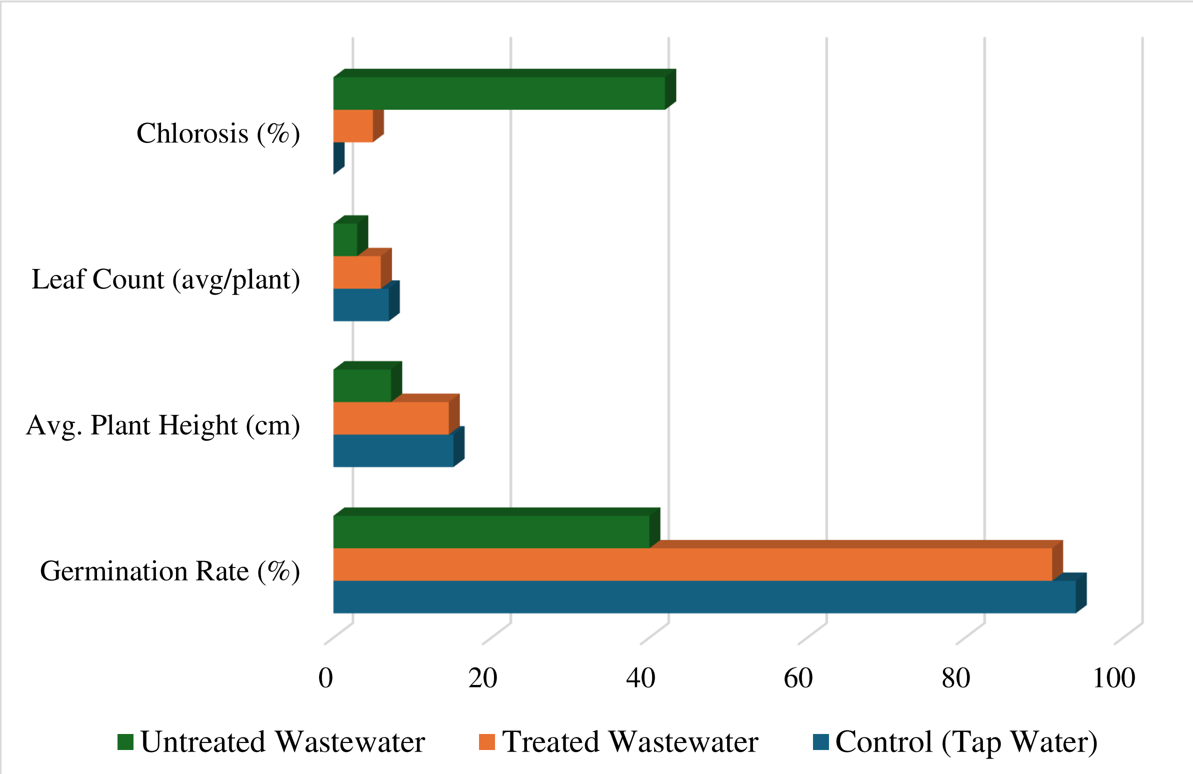

## B. *Irrigation Feasibility and Plant Growth Response*

Table 4: Irrigation Trial Results

| Metric | Control (Tap Water) | Treated Wastewater | Untreated Wastewater |
|---|---|---|---|
| Germination Rate (%) | 94 | 91 | 40 |
| Avg. Plant Height (cm) | 15.2 | 14.6 | 7.3 |
| Leaf Count (avg/plant) | 7 | 6 | 3 |
| Chlorosis (%) | 0 | 5 | 42 |

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Figure 4: Graphical representation of Irrigation Trial Results




To assess the practical applicability of the treated wastewater for irrigation, spinach (Spinacia oleracea) was cultivated under three different water regimes: control (tap water), untreated wastewater, and treated wastewater. Germination rates in the treated water group were 93%, closely matching the control group (95%), while the untreated wastewater group showed only 66% germination, indicating the presence of phytotoxic compounds in the raw effluent.

Plant height, leaf number, and general health were monitored throughout a 21-day growth cycle. Plants irrigated with treated wastewater exhibited robust growth, with an average height of 14.2 cm and 7–8 healthy leaves per plant by the end of the experiment. In contrast, the untreated group showed stunted growth, leaf curling, and signs of chlorosis due to high concentrations of residual surfactants and TDS. The control and treated groups, however, were statistically similar in their growth metrics, implying that the quality of the treated water was suitable for supporting plant development.

These findings confirm the suitability of photocatalytically treated hostel wastewater for non-potable reuse applications such as irrigation. The substantial reductions in BOD, COD, turbidity, and surfactant levels contribute not only to environmental protection but also to water conservation and circular water management in campus settings.

## V. CONCLUSION

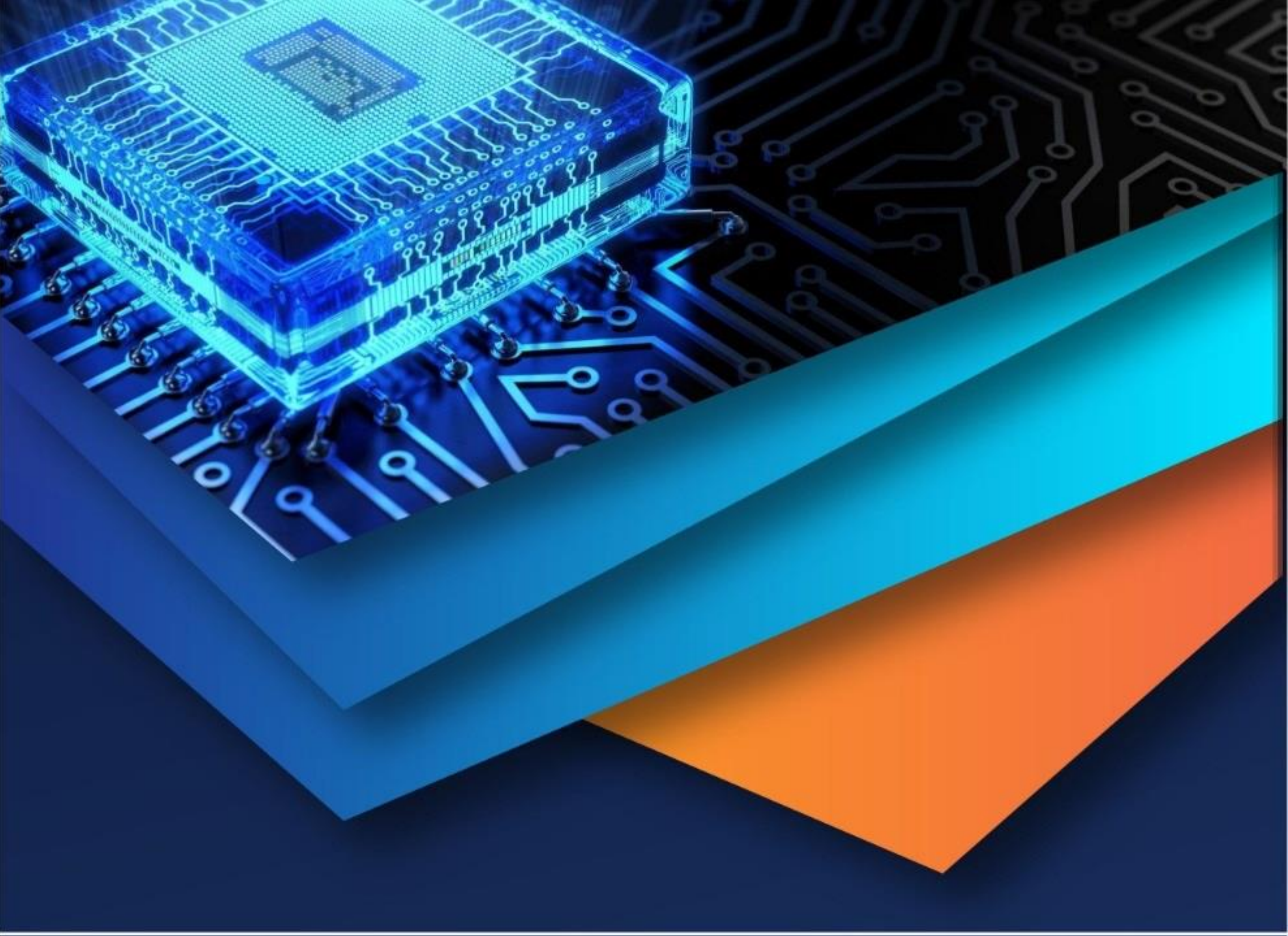
This study successfully demonstrated the potential of zinc oxide (ZnO) as an effective and sustainable photocatalyst for the degradation of organic pollutants in hostel wastewater. The synthesized ZnO, characterized by favourable physicochemical properties, exhibited high photocatalytic activity under UV irradiation, leading to substantial reductions in chemical oxygen demand (COD), biological oxygen demand (BOD), turbidity, total dissolved solids (TDS), and surfactant concentrations. These improvements in water quality were achieved within a relatively short irradiation period, emphasizing the efficiency of the process.

Importantly, the treated water was evaluated for reuse in irrigation through controlled plant growth experiments. Spinach plants irrigated with photocatalytically treated wastewater exhibited comparable growth performance to those irrigated with clean tap water, while those exposed to untreated wastewater showed significant phytotoxic effects. This confirms the feasibility of reusing treated hostel wastewater for agricultural purposes, thereby supporting a circular and resource-efficient approach to campus water management.

Overall, this research highlights the applicability of ZnO-based photocatalysis as a low-cost, low-energy, and environmentally friendly method for decentralized wastewater treatment. The approach aligns with sustainable development goals related to clean water, sanitation, and responsible consumption. Future work may explore the use of solar-driven photocatalysis and the integration of this system into pilot-scale treatment units to further enhance practicality and scalability.

## REFERENCES

[1] World Health Organization (WHO). (2019). Progress on household drinking water, sanitation and hygiene 2000-2017: Special focus on inequalities. Retrieved from https://washdata.org/reports/jmp-2019-wash-householdsWashdata+1UNICEF DATA+1.
[2] Fujishima, A., & Honda, K. (1972). Electrochemical photolysis of water at a semiconductor electrode. Nature, 238(5358), 37–38. https://doi.org/10.1038/238037a0Nature.
[3] Wang, Y., et al. (2018). Synthesis of ZnO and their application in wastewater treatment. Journal of Environmental Chemical Engineering, 6(5), 5808–5815. https://doi.org/10.1016/j.jece.2018.08.052.
[4] Ayers, R.S., & Westcot, D.W. (1985). Water quality for agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1. Food and Agriculture Organization of the United Nations. Retrieved from https://www.fao.org/4/t0234e/t0234e00.htmFAOHome+1SCIRP+1.
[5] Central Pollution Control Board (CPCB). Water Quality Criteria. Retrieved from https://cpcb.nic.in/water-quality-criteria/Central Pollution Control Board+4Central Pollution Control Board+4IELRC+4.
[6] Barick, K.C., & Tripathi, A. (2010). ZnO : a promising photocatalyst for wastewater treatment. Applied Nanoscience, 1(2), 73–80. https://doi.org/10.1007/s13204-010-0010-3.
[7] Hussain, R. T., Hossain, M. S., & Shariffuddin, J. H. (2024). Green synthesis and photocatalytic insights: A review of zinc oxide in wastewater treatment. Materials Today Sustainability, 26, 100764. https://doi.org/10.1016/j.mtsust.2024.100764
[8] S. Raha, M. Ahmaruzzaman, ZnO nanostructured materials and their potential applications: progress, challenges and perspectives Nanoscale Adv., 4 (2022), pp. 1868-1925, https://doi.org/10.1039/d1na00880c .
[9] Yashni G., Al-Gheethi A., Mohamed R. Arifin S. N. H. Salleh S. N. A. M. 2020a Photodegradation of basic red 51 in hair dye greywater by zinc oxide using central composite design. Reaction Kinetics, Mechanisms and Catalysis 130, 567–588. https://doi.org/10.1007/s11144-020-01792-x.
[10] Eriksson E., Donner E. 2009 Metals in greywater: sources, presence and removal efficiencies. Desalination 248(1–3), 271–278. https://doi.org/10.1016/j.desal.2008.05.065
[11] Thakur, A., & Shankar, R. (2024). PRIORITIZATION OF CIRCULAR ECONOMY PRACTICES IN THE TEXTILE INDUSTRY: A MCDM APPROACH. Industrial Engineering Journal, 17(05), 11–17. https://scholar.google.com/citations?view_op=view_citation&hl=en&user=JNElmn0AAAAJ&citation_for_view=JNElmn0AAAAJ:u-x6o8ySG0sC
[12] Nagaich, R. (2022), "Lean concept implementation practices in small and medium scale pharmaceutical industry- A case study", International Journal for Research in Applied Science and Engineering Technology, Vol. 10 No. 1, pp. 213-220, doi: 10.22214/ijraset.2022.39811.
[13] Shaikh, I. N., Ahammed M. M. 2020 Quantity and quality characteristics of greywater: a review. Journal of Environmental Management 261, 110266. https://doi.org/10.1016/j.jenvman.2020.110266 .
[14] Etchepare R., van der Hoek J. P. 2015 Health risk assessment of organic micropollutants in greywater for potable reuse. Water Research 72, 186–198. https://doi.org/10.1016/j.watres.2014.10.048 .
[15] Yashni G., Al-Gheethi A., Mohamed R. Arifin S. N. H. Salleh S. N. A. M. 2020a Photodegradation of basic red 51 in hair dye greywater by zinc oxide using central composite design. Reaction Kinetics, Mechanisms and Catalysis 130, 567–588. https://doi.org/10.1007/s11144-020-01792-x.
[16] Pare, B., Tomar, H. S., Bhagwat, V. W., & Fogliani, C. (2007). Advanced oxidation process in general chemistry laboratory: ZnO catalysed degradation of acridine orange dye in visible light. Aus J Educ Chem, 68, 30-33.
[17] Pare, B., Jonnalagadda, S., Tomar, H., Singh, P., & Bhagwat, V. (2008). ZnO assisted photocatalytic degradation of acridine orange in aqueous solution using visible irradiation. Desalination, 232(1-3), 80-90. https://doi.org/10.1016/j.desal.2008.01.007 .
[18] Q. Cook, K. Argenio, S. Lovinsky-Desir The impact of environmental injustice and social determinants of health on the role of air pollution in asthma and allergic disease in the United States J. Allergy Clin. Immunol., 148 (5) (2021), pp. 1089-1101 .
[19] J. Awewomom, F. Dzeble, Y.D. Takyi, W.B. Ashie, E.N.Y.O. Ettey, P.E. Afua, L.N.A. Sackey, F. Opoku, O. Akoto Addressing global environmental pollution using environmental control techniques: a focus on environmental policy and preventive environmental management Discover Environment, 2 (1) (2024), p. 8.
[20] Munzel, T., Kuntic, M., Lelieveld, J., Aschner, M., Nieuwenhuijsen, M. J., Landrigan, P. J., & Daiber, A. (2025). The links between soil and water pollution and cardiovascular disease. Atherosclerosis, 119160. https://doi.org/10.1016/j.atherosclerosis.2025.119160 .




10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429


# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY


Call : 08813907089 (24*7 Support on Whatsapp)