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Green Synthesis of ZnO Nanoparticles Using Leaves Extract of Quisqualis Indica (Madhumalti): Textile Effluent Treatment and their WQI Study

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Abstract: Industrial effluents, which often contain harmful pollutants such as organic compounds, heavy metals, and toxic chemicals, pose a serious environmental threat. These wastes are frequently discharged into water bodies without adequate treatment, leading to severe water pollution that harms aquatic life, ecosystems, and human health. Nanotechnology presents an innovative and effective solution for water purification, particularly in treating industrial waste. Nanomaterials, due to their high surface area, reactivity, and adsorption capacity, are highly effective in removing contaminants like heavy metals and dyes. This study focuses on the green synthesis of zinc oxide (ZnO) nanoparticles using Quisqualis indica and evaluates their efficiency in purifying industrial wastewater. Standard protocols were followed for both the synthesis and analysis. The results were promising: after treating textile effluents with the synthesized ZnO nanoparticles, the water became odourless and clear, with significant reductions in turbidity, total dissolved solids (TDS), chloride levels, and conductivity. These findings suggest that ZnO nanoparticles synthesized via green methods can serve as efficient adsorbents for industrial effluent treatment.
Keywords: Nanoparticle, Textile effluents, Treatment, water quality index

I. INTRODUCTION

Industrial effluents, containing a wide range of pollutants such as organic compounds, heavy metals, and toxic chemicals, represent a significant environmental concern. These effluents are often discharged into water bodies without adequate treatment, leading to severe contamination that threatens aquatic life, disrupts ecosystems, and poses risks to human health. Traditional wastewater treatment methods frequently fall short, especially when dealing with complex contaminants like oils, solvents, and heavy metals. As a result, there is an urgent need for more effective and sustainable wastewater treatment technologies to mitigate the harmful impact of industrial effluents on the environment (1).

Nanotechnology offers a promising and innovative solution for water purification, particularly in the treatment of industrial wastewater. At the nanoscale, materials exhibit enhanced surface area, reactivity, and adsorption capacity, which significantly improve the removal of hazardous pollutants such as heavy metals and dyes. Nanomaterials operate through various mechanisms, including adsorption and photocatalysis, making them highly effective in contaminant removal. The integration of nanotechnology in wastewater treatment contributes to the advancement of cleaner and more sustainable approaches, ultimately helping to safeguard both environmental and public health (2).

Metal-based nanoparticles, in particular, have garnered considerable interest due to their unique physical and chemical properties that distinguish them from their bulk counterparts. These properties—including enhanced electrical conductivity, catalytic activity, and optical characteristics—have broadened their application across biomedical, sensing, and optoelectronic fields (3). Among various synthesis techniques, green synthesis using plant extracts has emerged as an eco-friendly and viable alternative to conventional chemical and physical methods, which often involve hazardous reagents. Plant-mediated synthesis leverages the natural reducing and stabilizing agents found in phytochemicals, offering advantages such as biocompatibility, cost-effectiveness, and scalability.

This study focuses on the green synthesis of zinc oxide (ZnO) nanoparticles using the leaf extract of *Quisqualis indica*, commonly known as Rangoon creeper. Known for its rich phytochemical composition and broad therapeutic applications, *Quisqualis indica* has proven to be a promising candidate for the sustainable production of metal oxide nanoparticles (4). The present work explores the green fabrication of ZnO nanoparticles and evaluates their effectiveness in treating industrial wastewater, offering an environmentally friendly alternative for pollution control.

Fig.1: Plant- Quisqualis Indica (Madhumalti)

II. REVIEW OF LITERATURE

The literature review related to above work are given as following table:

Table 1. Table of Review of literature

S. NO.	TITLE	AUTHOR	YEAR	METHODOLOGY	FINDINGS (Result)	REFRENCE
1.	Current Trends in the application of Nanomaterials for removal of Pollutants from Industrial Wastewater Treatment	Geetha Palani et al.	2021	The authors conducted a systematic review of existing research on nanomaterials used for industrial wastewater treatment. They analyzed studies from major scientific databases, focusing on types of nanomaterials, and treatment efficiency.	The study found that nanomaterials are highly effective in removing pollutant from wastewater through mechanism like adsorption and photocatalysis.	1
2	Sustainable treatment of glass industry wastewater using Zinc oxide nanoparticles: antibacterial and photocatalytic efficacy	Yamini Vinayagam et al.	2025	The study synthesized biogenic nanomaterials using environmentally friendly biological method. These nanomaterials were tested for their ability to remove contaminants from industry wastewater, with their effectiveness evaluated through various pollutant removal mechanism.	The biogenic nanomaterials demonstrated high efficiency in removing pollutant from wastewater, showing potential as a sustainable and eco-friendly alternative to traditional chemical method.	2

3.	Waste pericarp of ananas comosus in green synthesis zinc oxide nanoparticles and their application in wastewater treatment	Nitin A. Mirgane et al.	2021	Extract is prepared by boiling pineapple pericarp in water. Mixed with zinc acetate dehydrate solution and heated to form ZnO nanoparticles. characterization done using UV-visible.	The synthesis ZnO NPs were nontoxic, high catalytic property and 10nm in size. It used as coating and stabilizing agent. Also used for wastewater treatment.	3
4.	Green synthesis of silver nanoparticles from the leaf extract of Quisqualis Indica L. for Enhanced Antibacterial Activity	Anandhalakshmi Jaya Shankar et al.	2022	The study used an aqueous extract of Quisqualis Indica leaves of synthesis silver nanoparticles (AgNPs). characterization was done using UV-vis spectroscopy, FTIR, SEM, and XRD. antibacterial efficacy was tested against E. coli and s. aureus using the agar well diffusion method	The synthesis AgNPs were spherical, crystalline, and averaged 50 nm in size. FTIR confirmed the presence of phytochemical aiding in reduction and stabilization	4
5.	Enhanced photocatalytic degradation of water pollutant using bio- green synthesis of zinc oxide nanoparticles (ZnO NPs)	Seerangaraj Vasantharaj et al.	2021	Extract of R. Tuberosa prepare by collecting leaves, boil in Erlenmeyer flask for 10 min. mix extract with zinc sulphate solution. Mixture change colour from light yellow to white colour.	The green preparation of ZnO NPs using R. Tuberosa extract without use of any toxic material. Characterization revealed existence of phytoconstituents in extract, which acted as stabilizing agents.	5

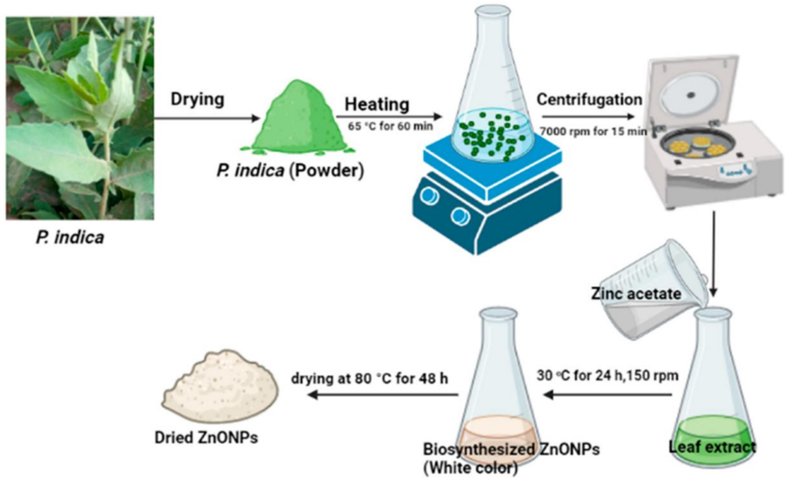

Fig.2: Reference Method for ZnO nanoparticle Synthesis- https://www.mdpi.com/molecules/molecules-28-04679/article_deploy/html/images/molecules-28-04679-g008.png

III. MATERIALS AND METHODS

A. Materials for Green synthesis of Nanoparticles

The materials used in this study shown by following table with their applications

Table 2. Material used and their applications

S.No.	Component	Materials Used	Quantity / Concentration	Role
1.	Fresh Quisqualis Indica plant	Leaves	10 gm	Reducing/ Crapping Agent
2.	Zinc acetate dehydrate $[Zn(CH_3COO)_2.2H_2O]$	Solution	2.5N	Precursor/ Source of Zn^{2+} ions
3.	NaOH	Solution	2.5N	pH controller
4.	Distilled water	Solvent	270 ml	Phytochemical extraction
5.	Textile effluent	Sample	100 ml	Treatment
6.	Whatman filter paper	-	-	Filtration
7.	Glassware	Flask, Beaker, Measuring, etc.	-	For experimental use
8.	Degi oven	-	-	Calcination of Nanoparticles
9.	Centrifuge Machine	-	-	Separation

B. Materials used in Treatment and Analysis

Table 3. Material used in treatment

S. No.	Parameters	Methodology	Chemical Used
1.	pH	pH meter	Buffer 10 pH Solution
2.	Conductivity	Conductivity meter	KCl solution
3.	Alkalinity	Titration method	0.02N H_2SO_4 solution, phenolphthalein and methyl orange indicator
4.	Chloride	Coulometric method	0.014N $AgNO_3$ solution, K_2CrO_4 solution
5.	Total dissolved solid	Tds meter	KCl solution

C. Methodology for Parameters

All the parameter analyse by the standard methods [], given as follows:

1) pH Meter

Begin by calibrating the pH meter using standard buffer solutions. After calibration, dip the properly washed and dried pH electrode into the sample solution. Allow the reading to stabilize. The display will show the pH value of the sample. Once the measurement is complete, carefully wash the electrode and store it in distilled water.

2) Conductivity Meter

Switch on the conductivity meter and allow it to warm up for 15–20 minutes. Set the function switch to the “Check” position. The display should read 1000; if not, adjust it using the CAL control knob. Then, set the function switch to the “Cell Constant” position and adjust it according to the value of the conductivity cell. Set the temperature control to match the actual temperature of the test solution. Insert the cleaned and dried conductivity cell into the beaker containing the sample solution, and connect it to the input socket of the conductivity meter. Switch the function to “Conductivity” mode and adjust the range switch to achieve maximum resolution. Note the reading displayed, which represents the conductivity of the sample solution.

3) Alkalinity

To determine the alkalinity of a water sample, first take a known volume (e.g., 50 mL) of the sample in a conical flask. Add a few drops of phenolphthalein indicator. If the solution turns pink, it indicates the presence of phenolphthalein alkalinity. Titrate this solution slowly with a standard acid solution, such as 0.02 N sulfuric acid, from a burette until the pink colour disappears. Record the volume of acid used at this point as *P* (in mL), which represents the phenolphthalein endpoint. Without removing the solution, add a few drops of methyl orange indicator. A resulting orange colour indicates the presence of methyl orange alkalinity. Continue titrating with the same standard acid until the solution changes from orange to a faint pink or red colour. Record the total volume of acid used as *T* (in mL), representing the methyl orange endpoint. Repeat the entire titration process multiple times to obtain concordant readings—consistent values within a small range—for improved accuracy. Use the average of these readings to calculate the total alkalinity using the formula:

Total Alkalinity (mg/L) = (B × N × 50,000) / Volume of Sample (mL)

where *B* is the average volume of acid used (T), and *N* is the normality of the acid.

4) Chloride Test

Take 10 ml of sample in a 250 ml conical flask and add 1 ml of K_2CrO_4.Titrate it with standard $AgNO_3$ Solution taken in burette. Add $AgNO_3$ Solution till reddish brown colour permanently appears. This is the end point of the titration. Volume of standard $AgNO_3$ solution used is noted as V_2 as concordant reading for the calculation purpose.

Table 4. Observation table for chloride

S, No.	Volume of water taken (mL)	Volume of Standard Hypo Used(mL)		Difference (mL)	Concordant Reading
		~~Initial Reading~~	~~Final Reading~~		
1.	10 mL	0.0	V		
2.	10 mL	0.0	V		V_2
3.	10 mL	0.0	V		

Chloride content in ppm = $\{(N_2 \times V_2)/50\} \times 35.5 \times 1000$ ppm Where, V_2 mL of standard $AgNO_3$ solution having known normality N_2.

5) Total Dissolved Solid

Remove the cover from the bottom of the tester, then turn on the unit by pressing the On/Off button. The display should read 1000. Insert the tip of the tester (the end where the cover was) into the water to be tested. A half inch or so deep is plenty. You'll ruin the meter if you submerge it too deeply. Read the numbers on the display. The number you see is the TDS (Total Dissolved Solids) of the water expressed in PPM (parts per million). The Hold button and the Temp button are features you probably won't need. Hold locks the number on the display so it won't go away and Temp measures the temperature of the water.

D. Methods for Green synthesis of ZnO Nanoparticles

1) Preparation of Plants Extract

Ten grams of *Quisqualis indica* leaves were thoroughly washed and then boiled in 50 mL of distilled water at 70°C for two hours. After boiling, the mixture was filtered to obtain approximately 16 mL of clear plant extract for further use.

Fig 3: Plant extract

2) Preparation of Precursor

To prepare a 2.5 N zinc acetate solution, 68.8 grams of dehydrated zinc acetate were dissolved in 250 mL of distilled water. Similarly, to prepare a 2.5 N sodium hydroxide (NaOH) solution, 10 grams of NaOH were dissolved in 250 mL of distilled water. These precursor solutions were used for the synthesis of zinc oxide nanoparticles.

3) Synthesis of ZnO nanoparticles

Table 5: Different combinations of Zinc Acetate, NaOH and plant extract

S. No.	Zinc Acetate	NaOH	Plant extract
1.	20 ml	20 ml	4 ml
2.	18 ml	18 ml	6 ml
3.	40 ml	20 ml	6 ml

Each mixture was heated at 70°C for 1 hour, allowed to stand for 24 hours and then filtered using Whatman filter paper. The filtered solution was centrifuged at 4000 r.p.m. for 12 minutes. The resulting precipitate (ZnO nanoparticles) were oven dried at 400°C for 4 hours to yield powdered ZnO nanoparticles.

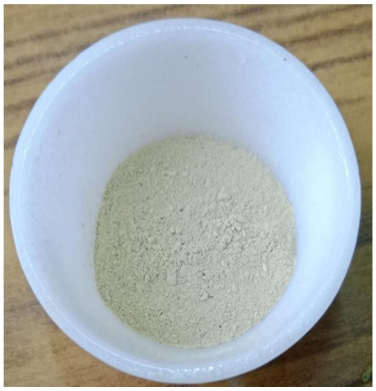

Fig. 4: ZnO nanoparticles

IV. RESULTS AND DISCUSSIONS

A. Analysis Result

Based on above experimentation of green synthesis of nanoparticles, characterisation of nanoparticles and textile effluent treatment and analysis results of treated water are discussed as follows:

Table 6: Effluent analysis before and after treatment

S. No.	Parameters	Before treatment	After treatment	WHO Standard
1.	pH	8.0	8.4	7.5
2.	Conductivity(mS)	21.5	6.9	250
3.	Alkalinity(ppm)	490	740	600
4.	Chloride(mg/L)	491.3	272.9	300
5.	Total dissolved Solid(mg/L)	135	111	500

Fig. 5 Textile effluent- Before Treatment After Treatment

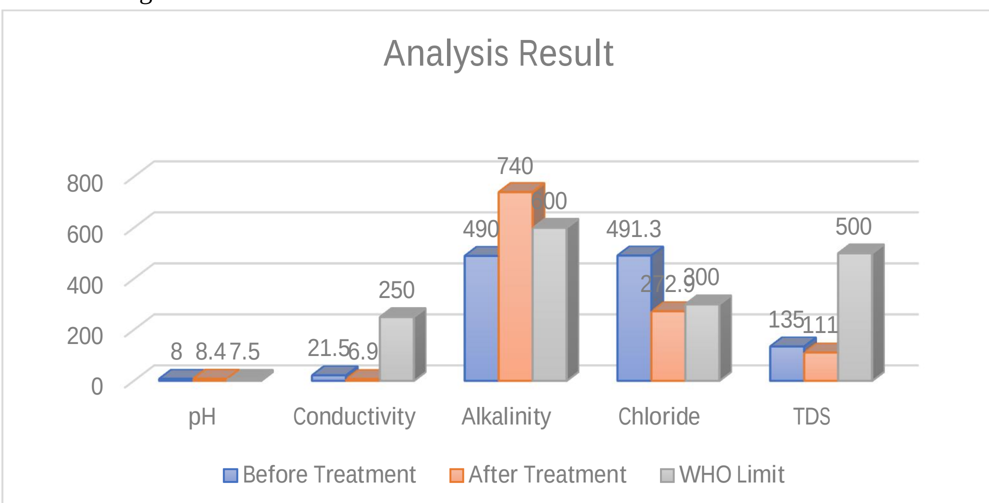

Fig. 5 Analysis result of water quality parameters

B. Effect of ZnO Nanoparticles on Effluent Parameters

After treatment with zinc oxide (ZnO) nanoparticles, several key parameters of industrial effluent showed significant changes. The pH of the effluent increased slightly from 8.0 to 8.4, likely due to the release of Zn^{2+} ions, which form hydroxides and contribute to increased alkalinity. Conductivity dropped notably from 21.5 mS to 6.9 mS, as ZnO nanoparticles facilitated the removal of dissolved ions and charged particles, thereby reducing the solution's ability to conduct electricity. The alkalinity of the effluent increased from 490 ppm to 740 ppm, a result of the partial dissolution of ZnO nanoparticles, which release zinc and hydroxide ions and enhance the water's alkalinity.

The chloride content decreased significantly from 491.3 mg/L to 272.9 mg/L, as ZnO nanoparticles—with their high surface area and amphoteric nature—effectively adsorbed chloride ions from the solution. Finally, the total dissolved solids (TDS) were reduced from 135 mg/L to 111 mg/L. This reduction can be attributed to the photocatalytic degradation of harmful organic compounds, such as dyes, under UV light, as well as the nanoparticles' ability to trap and remove pollutants from the effluent.

C. Water Quality Index (WQI)

The Water Quality Index (WQI) is used to conduct comparative assessments of rivers water contamination. It explains the health of the total water quality in a single numerical value, which makes it easier to pick appropriate treatment methods to address the problems that have been identified.

Table 7: Water Quality Index of effluent before treatment :

S. No.	Parameters	WHO Standards (S_n)	$1/S_n$	$\sum 1/S_n$	$K=1/(\sum 1/S_n)$	$W_n=K/S_n$	Ideal value (V_0)	V_n	V_n/S_n	$Q_n=(V_n/S_n)$ *100	W_nQ_n
1.	pH	7.5	0.133333	0.144333	6.928422467	0.923789662	7	8	1.066667	66.66	61.57981889
2.	Conductivity	250	0.004	0.144333	6.928422467	0.02771369	0	21.5	0.086	8.6	0.238337733
3.	Alkalinity	600	0.001667	0.144333	6.928422467	0.011547371	0	490	0.816667	81.66666667	0.94303528
4.	Chloride	300	0.003333	0.144333	6.928422467	0.023094742	0	491.3	1.637667	163.7666667	3.782148843
5.	T.D.S.	500	0.002	0.144333	6.928422467	0.013856845	0	135	0.27	27	0.374134813
			0.144333			1.0					66.91747556

Table 8: Water Quality Index of effluent after treatment:

S. No.	Parameters	WHO Standards (S_n)	$1/S_n$	$\sum 1/S_n$	$K=1/(\sum 1/S_n)$	$W_n=K/S_n$	Ideal value (V_0)	V_n	V_n/S_n	$Q_n=(V_n/S_n)$ *100	W_nQ_n
1.	pH	7.5	0.133333	0.144333	6.928422467	0.923789662	7	8.4	1.12	93.33	86.21728919
2.	Conductivity	250	0.004	0.144333	6.928422467	0.02771369	0	6.9	0.0276	2.76	0.076489784
3.	Alkalinity	600	0.001667	0.144333	6.928422467	0.011547371	0	740	1.233333333	123.3333333	1.424175729
4.	Chloride	300	0.003333	0.144333	6.928422467	0.023094742	0	272.9	0.909666667	90.9666667	2.100851657
5.	T.D.S.	500	0.002	0.144333	6.928422467	0.013856845	0	111	0.222	22.2	0.307621958
			0.144333			1.0					90.1264283

D. Correlation Coefficient

Table 9: Correlation coefficient-

Parameters	*pH*	*Conductivity*	*Alkalinity*	*Chloride*	*TDS*
pH	1				
Conductivity	-0.918721251	1			
Alkalinity	0.504418195	-0.122433822	1		
Chloride	-0.049987716	-0.348488174	-0.887594731	1	
TDS	-0.919314761	0.999998867	-0.123927905	-0.347076608	1

The correlation coefficient is calculated by the MS Excel software. In this study this correlation result significantly give a strong positive relation between pH and alkalinity this due to the Zn^{2+} ions and strong negative correlation between chloride and alkalinity, we can say that alkalinity is inversely proportional to chloride which present in water.

E. Characterization of ZnO nanoparticle

The green synthesis of ZnO nanoparticle using Quisqualis indica leaf extract were characterized using UV- visible spectrophotometer. The UV- vis analysis was performed to confirm the formation of ZnO nanoparticles. The absorption spectrum showed a sharp peak at 231 nm, which indicate the characteristics of ZnO nanoparticles.

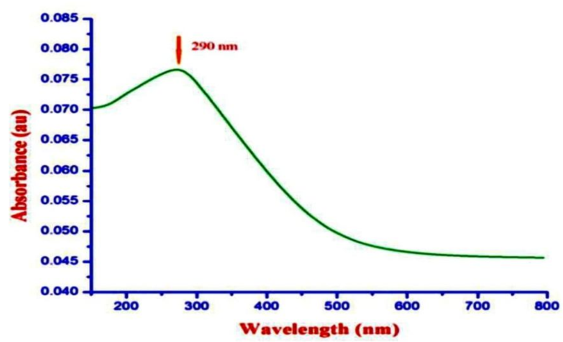

Fig. 6 UV-Vis analysis of ZnO nanoparticles

V. CONCLUSION

This study demonstrated that zinc oxide (ZnO) nanoparticles effectively remove dyes and organic pollutants from textile wastewater due to their photocatalytic and adsorptive properties. They offer a more affordable and environmentally friendly alternative to traditional treatment methods. However, further research is needed to address challenges such as environmental impact, recovery, and reuse, especially for large-scale applications.

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