A Sustainable Nanomaterial Synthesis Approach for Application in Dye Degradation and Bacterial Growth Inhibition

Thesis submitted in partial fulfillment

for the Award of Degree

DOCTOR OF PHILOSOPHY

by

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Dedication

In profound gratitude and with heartfelt appreciation, this thesis is dedicated to my loving family whose support and encouragement have been the guiding light of my academic journey. Their belief in me has been the source of strength and inspiration, and I cherish the love and blessings that have led me to this milestone.

CERTIFICATE

It is certified that the work contained in the thesis entitled **" A sustainable Nanomaterial synthesis approach for application in dye degradation and bacterial growth inhibition"** submitted by **Ravi Saini** has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

It is further certified that the student has fulfilled all the requirements of the Comprehensive Examination, Candidacy, and SOTA for the award of a Ph.D. degree.

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DECLARATION BY THE CANDIDATE

I, **"Ravi Saini",** certify that the work embodied in this Ph.D. thesis is my bona fide work carried out by me under the supervision of **"Dr. Pradeep Kumar" (Supervisor)** from July 2019 to June 2024 at the "**Department of Chemical Engineering & Technology",** Indian Institute of Technology (BHU), Varanasi, India. The matter embodied in this Ph.D. thesis has not been submitted to award any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the research workers whenever their works have been cited in my work in this thesis. I further declared that I have not wilfully lifted some other's work, paragraph, text, data, results, etc., reported in books, dissertations, thesis, etc., or available at websites and have not included them in this Ph.D. thesis and have not cited as my own work.

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It is certified that the above statement made by the student is correct to the best of my knowledge.

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List of Abbreviations and Symbols

AB 113	Acid Blue 113	BM	Biomass
BG	Brilliant Green	ZOI	Zone of Inhibition
MB	Methylene Blue	HR-XRD	High-Resolution X-ray
MG	Malachite Green		Diffraction
MO	Methyl Orange	SEM	Scanning Electron
CR	Congo Red		Microscope
CV	Crystal Violet	TEM	Transmission Electron
MV	Methyl Violet		Microscopy
RhB	Rhodamine B	FTIR	Fourier-Transform
RR 195	Reactive Red 195		Infrared
RG 19	Reactive Green 19	BET	Brunauer-Emmett-Teller
NPs	Nanoparticles	FWHM	Full Angular Width at
AOPs	Advanced oxidation		Half Maximum
	processes	JCPDS	Joint Committee on
EC	Electrocoagulation		Powder Diffraction
ECs	Emerging Contaminants		Standards
GO	Graphene Oxide	ROS	Reactive Oxidation
rGO	Reduced Graphene Oxide		Species
G-rGO	Green Synthesized rGO	PZC	Point of Zero Charges
HTC	Hydrothermal	RSM	Response Surface
	Carbonization		Methodology
HTL	Hydrothermal	CCD	Central Composite Design
	Liquefaction	ANOVA	Analysis of Variance
HTG	Hydrothermal Gasification	HHV	Higher Heating Values
HC	Hydrochar		

Symbol	Nomenclature
q_t	Adsorption capacity of the adsorbent (mg/g)
λ_{max}	Wavelength at which a substance has its maximum absorption
K_l	Langmuir constant (L/mg)
K_f	Freundlich constant (L/mg)
k_s	Sips constant (L/mg)1/m
k_p	Intra-particle diffusion rate constant (mg/g.min$^{1/2}$)
C_{wm}	Constant associated with the boundary layer thickness (mg/g)
K_i	Substrate inhibition constant (mg/L)
Q_m	Maximum adsorption capacity (mg/g)
Q_e	Equilibrium adsorption capacity (mg/g)
% R	Percentage removal
k	Reaction rate constant
V	Volume of the dye solution (mL)
w	Amount of adsorbent (g)
α	Absorption coefficient
β	Desorption constant
E_g	Energy band gap (eV)