Dedicated

to

Maa, Deuta & Ba

TEZPUR UNIVERSITY

(*A Central University Established by an Act of Parliament*)

Napaam, Tezpur-784028, Sonitpur, Assam, India

Phone: +91-3712-267004 (O) **Fax: +91-3712-267005 (O)**

DECLARATION

I, do hereby declare that the thesis entitled "**Biobased superabsorbent hydrogels and their potential applications**", submitted to the Department of Chemical Sciences, Tezpur University, under the School of Sciences is a record of original research work carried out by me. All sources of assistance have been assigned with due acknowledgment. I, also declare that neither this work as a whole nor any part of it has been submitted to any other University or Institute for any kind of degree, diploma or award.

Ashok Bora

Place: Tezpur University, Tezpur **(Ashok Bora)**

Date: 12-12-2023

TEZPUR UNIVERSITY

(*A Central University Established by an Act of Parliament*)

Napaam, Tezpur-784028, Sonitpur, Assam, India

Dr. Niranjan Karak
Professor
Department of Chemical Sciences

Phone: +91-3712-267004 (O)
Fax: +91-3712-267005 (O)
Email: nkarak@tezu.ernet.in

CERTIFICATE OF SUPERVISOR

This is to certify that the thesis entitled "**Biobased superabsorbent hydrogels and their potential applications**" submitted to Tezpur University, in the Department of Chemical Sciences, under the School of Sciences, in partial fulfillment for the award of the degree of Doctor of Philosophy in Science is a record of research work carried out by **Mr. Ashok Bora** under my supervision and guidance.

All the help received by him from various sources have been duly acknowledged. No part of this thesis has been reproduced elsewhere for award of any other degree.

Place: Tezpur University, Tezpur

Date: 12-12-2023

(**Dr. Niranjan Karak)**
Professor
Department of Chemical Sciences
School of Sciences
Tezpur University

TEZPUR UNIVERSITY

(*A Central University Established by an Act of Parliament*)

Napaam, Tezpur-784028, Sonitpur, Assam, India

Phone: +91-3712-267004 (O) **Fax: +91-3712-267005 (O)**

CERTIFICATE OF EXAMINER

This is to certify that the thesis entitled "**Biobased superabsorbent hydrogels and their potential applications**" submitted to Tezpur University, in the Department of Chemical Sciences, under the School of Sciences, in partial fulfillment for the award of the degree of Doctor of Philosophy in Science has been examined by us on ..…… and found to be satisfactory.

The committee recommends for the award of the degree of Doctor of Philosophy.

Principal Supervisor **External Examiner**

Date: **Date:**

PREFACE

In the past few decades, the development of bio-based hydrogel has received a lot of attention to reduce the extensive usage of hydrogels derived from conventional petroleum sources, which pose serious threats to the sustainability of the ecosystem. In this aspect, a high biobased content hydrogel was prepared using starch and itaconic acid as renewable resources for various application fields. The hydrogel showed various properties, including high water swelling as well as water holding capacity and slow fertilizer release ability. Further, the wastepaper-derived cellulosic micro-reinforcing agent was prepared by simply applying alkaline treatment only and incorporated into the hydrogel matrix, showing enhanced water swelling as well as slow-release fertilizer properties. In addition to these, cellulose nanofiber was isolated from wastepaper applying simple treatments and further modified for use as a nano-reinforcing agent. Moreover, zinc oxide nanohybrid was produced using modified cellulose nanofiber as supporting material via an eco-friendly approach. The prepared nanomaterial and nanohybrid were introduced into the hydrogel matrix to obtain hydrogel with improved characteristics, making them suitable for use in the removal of dyes and heavy metal ions from water as well as for drug delivery. Thus, the current research work in the entitled thesis may bring up new possibilities in developing bio-based hydrogels with enhanced properties for various potential applications.

Ashok Bora

Place: Tezpur University, Tezpur **(Ashok Bora)**

Date: 12-12-2023

ACKNOWLEDGEMENT

I would like to deeply appreciate everyone who has been there for me throughout my entire Ph.D. tenure and in my life, in general.

First and foremost, I would like to convey my sincere gratitude to my research supervisor, Professor (Dr.) Niranjan Karak, Department of Chemical Sciences, Tezpur University for giving me the opportunity to carry out my research work. I am extremely thankful of his constant support, encouragement, guidance, and valuable advice at every single step of my Ph.D. work. He always guided me in the right direction, whenever I needed it. His sincere efforts and guidance have really benefitted my entire research career.

I would like to express my appreciation and respect to my doctoral research committee members Dr. Sajal Kumar Das and Dr. Sanjeev Pran Mahanta from the Department of Chemical Sciences, Tezpur University for their valuable advice and assistance throughout my Ph.D. research work.

I am also grateful to the present Head of the Department, Prof. Panchanan Puzari and former Head of the Department, Prof. Ruli Borah for allowing me to work on my research topic and their valuable advises throughout my research work at Tezpur University.

I am also thankful to Prof. N. S. Islam, Prof. T. K. Maji, Prof. R. K. Dutta, Prof. R. C. Deka, Prof. A. J. Thakur, Prof. A. K. Phukan, Dr. U. Bora, Dr. P. Bharali, Dr. K. K. Bania, Dr. B. Sarma, Dr. N. Gogoi, and Dr. M. M. Konai, faculty members of Department of Chemical Sciences, Tezpur University for their valuable suggestions and advices.

I extend my gratitude to Prof. M. Mandal, Department of Molecular Biology and Biotechnology for his cooperation during the course of my biological works. I have the pleasure to acknowledge Prof. P. Deb, Department of Physics, Tezpur University for his kind help in assisting with instrument analysis

I would also like to thank the office staffs of Department of Chemical Sciences, Tezpur University, for their kind help during my Ph.D. work.

I would like to take this opportunity to thank my seniors Dr. Geeti Kaberi Dutta, Dr. Dimpi Sarmah and my dearest lab members Nobomi Borah, Annesha Kar, Samiran Morang, Raghav Poudel, Kalyan Dutta and Kriti Yadav for their constant inspiration and help during my Ph.D. work.

I also want to thank my friends Subir Biswas, Bikash Kumar Kalita, Subham Paul, Dipankar Barman, Krishna Kamal Hazarika, Madhurjya Buragohain, Tanmoy Saikia,

Jugashree Gogoi, Jurita Baishya, Srutishree Sarma, Moumita Basumatary for their help and support during the course of my work.

I would also like to extend my deepest gratitude to all the senior and junior researchers of Department of Chemical Sciences, Tezpur University for their support during different stages of my research work.

I would like to express my heartfelt appreciation to Mrs. Susmita Karak for her great affection, which I continue to enjoy during my stay at Tezpur University.

Finally, I owe heartfelt gratitude to my parents, sister, brother-in-law and all my relatives for their blessings, support and constant inspiration during my entire journey.

Last but not the least, I would like to extend my thanks to Almighty for offering me a healthy and blissful life.

Ashok Bora

Place: Tezpur University, Tezpur (**Ashok Bora)**

Date: 12-12-2023

LIST OF ABBREVIATION AND SYMBOLS

AA	acrylic acid
AM	acrylamide
AN	acrylonitrile
ANOVA	analysis of variance
APS	ammonium persulfate
AUL	absorption under load
BD	bulk density
CAN	ceric ammonium nitrate
CFX	ciprofloxacin
cm	centimeter(s)
CNC	cellulose nanocrystal
CNF	cellulose nanofiber
CNW	cellulose nanowhisker
CR	cresol red
DMSO	dimethyl sulfoxide
EDX	energy dispersive x-ray
eV	electron volt
FESEM	field emission scanning electron microscope
FTIR	fourier transform infrared
g	gram(s)
h	hour(s)
HC	hydrogel composite(s)
HNC	hydrogel nanocomposite(s)
IA	itaconic acid
IPN	interpenetrating network

KPS	potassium persulfate
MAA	methacrylic acid
MB	methylene blue
MBA	*N, N*-methylene bisacrylamide
mCNF	modified-cellulose nanofiber
MG	malachite green
min	minute(s)
mL	milli litre(s)
MV	methyl violet
NPK	nitrogen, phosphorous and potassium
NM	nanomaterials
nm	nanometer
NP	nanoparticle
PAA	poly(acrylic acid)
PAM	poly(acrylamide)
PD	particle density
PFO	Pseudo-first-order
PIA	poly(itaconic acid)
ppm	parts per million
PSO	Pseudo-second-order
PVA	poly(vinyl alcohol)
q_{eq}	dye adsorption capacity
Q_{max}	maximum water swelling capacity
RL	root length
SA	sodium acrylate
SAH	superabsorbent hydrogel
SAHNC	Superabsorbent hydrogel nanocomposite

SEM	scanning electron microscope
SL	shoot length
SMCA	sodium monochloroacetate
SRF	slow-release fertilizer
t	time
TEM	transmission electron microscope
TGA	thermogravimetric analysis
USAH	urea encapsulated superabsorbent hydrogels
Vol	volume
WAC	water absorption capacity
WHC	water holding capacity
WP	wastepaper
WPP	wastepaper powder
XPS	X-ray photo electron spectroscopy
XRD	X-ray diffraction
Wt	weight
ZnO	zinc oxide
ZONH	zinc oxide/cellulose nanofiber nanohybrid
3D	three-dimensional
µL	micro litre(s)
%	percentage
°	degree
°C	degree centigrade
0-D	zero dimensional
1-D	one dimensional
2-D	two dimensional
a.u.	arbitrary unit

LIST OF SCHEMES

LIST OF FIGURES

LIST OF TABLES