

# **A study on candle soot for water remediations**

*A Thesis*

Submitted

by

**Vishvendra Pratap Singh (D17019)**

for the award of the degree of

**Doctor of Philosophy**



**SCHOOL OF ENGINEERING  
INDIAN INSTITUTE OF TECHNOLOGY MANDI  
Mandi, Himachal Pradesh -175001**

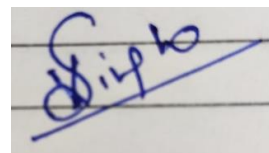
**September, 2020**

## Declaration by the Research Scholar

---

This is to certify that the thesis entitled “**A study on candle soot for water remediations**” submitted by me to the Indian Institute of Technology Mandi for the award of the degree of Doctor of Philosophy is a bonafide record of research work carried out by me in the School of Engineering, Indian Institute of Technology Mandi, under the supervision of Dr. Rahul Vaish. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

In keeping with the general practice of reporting scientific observation, due acknowledgements have been made wherever the work described is based on the findings of other investigators.



I.I.T. Mandi (H.P.)

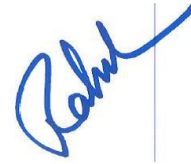
Vishvendra Pratap Singh

Date: 14-10-2020

## Thesis Certificate

---

This is to certify that the thesis entitled “**A study on candle soot for water remediations**” submitted by Mr. Vishvendra Pratap Singh to the Indian Institute of Technology Mandi for the award of the degree of Doctor of Philosophy is a bonafide record of research work carried out by him under our supervision in the School of Engineering, Indian Institute of Technology Mandi. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma. In keeping with the general practice of reporting scientific observation, due acknowledgements have been made wherever the work described is based on the findings of other investigators



Dr. Rahul Vaish  
Associate Professor  
School of Engineering  
IIT Mandi

Date:

## ACKNOWLEDGEMENT

---

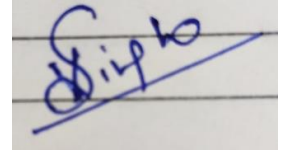
At the outset I remember the almighty for keeping me under his blessings. I pray to God that I need your presence in my soul till it exists.

I am immensely thankful to my Research Supervisors Dr. Rahul Vaish of the School of Engineering, Indian Institute of Technology Mandi. Without his support and guidance, it would not have been possible for me to complete my Ph.D research work within stipulated time. Dr. Rahul Vaish was always there to support my work and encourage me during my pursuit.

I also wish to acknowledge the members of doctoral committee, Dr. Vishal Singh Chauhan (Associate Professor, School of Engineering), Dr. Vishwanath Balkrishnan (Associate Professor, School of Engineering), and Dr. Venketkrishnan (Associate Professor, School of basic science) and, Dr. Atul Dhar (Associate Professor, School of Engineering) for their careful examination of the work and their invaluable comments and insights, which made a deep impact on my research.

I am grateful to the officials of numerous organizations who have allowed me to better understand their international venturing. They were willing to tell me both the good and the bad, for which I am thankful. They were kind enough to give me time to share valuable information and data, without which this study would have been incomplete. Standing by me, my respectable parents, showered blessing in all my academic quests, without which I would not have been here. I submit my gratitude to my whole family who always encouraged me to work hard for achieving academic targets. I have absolutely no hesitation in specially conveying warm thanks to my research colleague, Moolchand Sharma, Gurpreet

Singh, Rajkiran, Rajshekhar, and manish who supported me whole heartedly with their amazing love, support and advice. You provided eternal optimism and encouragement in me. Thank you to my closest ones my parents, my brother Arpit and my fiancé Anshika . You all are so precious to me. I could have never done this without your love and support. Thanks to all.



**Vishendra Pratap Singh**

## CONTENTS

---

<b>DECLARATION</b>	ii
<b>THESIS CERTIFICATE</b>	iii
<b>ACKNOWLEDGEMENT</b>	iv
<b>CONTENTS</b>	vi
<b>LIST OF FIGURES</b>	ix
<b>LIST OF TABLES</b>	xvi
<b>PREAMBLE</b>	xvii
<b>CHAPTER 1: INTRODUCTION</b>	1
1.1 Water pollution and remediations	1
1.2 Candle soot and its applications	14
1.3 Scope of the thesis	25
1.4 Objectives of the thesis	27
<b>CHAPTER 2: ADSORPTIVE REMOVAL OF DYES USING CANDLE SOOT AS AN ADSORBENT</b>	32
2.1 Introduction	32
2.2 Materials and methods	33
2.3 Results and disussion	36
2.4 Conclusions	52

<b>CHAPTER 3: CANDLE SOOT COATED POLYURETHANE FOAM FOR THE REMOVAL OF ORGANIC POLLUTANTS FROM WATER</b>	<b>55</b>
3.1 Introduction	55
3.2 Materials and methods	56
3.3 Results and discussion	57
3.4 Conclusions	76
<b>CHAPTER 4: A STUDY OF ELECTROWETTING BEHAVIOUR AND SWITCHABLE WETTABILITY OF CANDLE SOOT COATINGS</b>	<b>78</b>
4.1 Introduction	79
4.2 Materials and methods	80
4.3 Results and discussion	81
4.4 Conclusions	94
<b>CHAPTER 5: FLAME HEIGHT DEPENDENT ADSORPTIVE PROPERTIES OF CANDLE SOOT PARTICLES</b>	<b>98</b>
5.1 Introduction	98
5.2 Materials and methods	100
5.3 Results and discussion	102
5.4 Conclusions	120

<b>CHAPTER 6: SYNERGISTIC EFFECT OF ADSORPTION AND PHOTOCATALYSIS OF CANDLE SOOT COATED BaTiO<sub>3</sub> CERAMICS</b>	<b>123</b>
6.1 Introduction	124
6.2 Materials and methods	126
6.3 Results and discussion	128
6.4 Conclusion	142
<b>CHAPTER 7: INVESTIGATION OF DIESEL EXHAUST EMISSION SOOT PARTICLES FOR OIL-WATER SEPARATION AND REMOVAL OF ORGANIC CONTAMINANTS FROM WATER</b>	<b>146</b>
7.1 Introduction	146
7.2 Materials and methods	149
7.3 Results and discussions	151
7.4 Conclusions	171
<b>CHAPTER 8 CONCLUSIONS AND FUTURE SCOPE</b>	<b>175</b>