

TABLE OF CONTENTS

	Page No.
ACKNOWLEDGEMENTS.....	XI
LIST OF FIGURES.....	XXVII
LIST OF TABLES.....	XXXV
LIST OF ABBREVIATIONS.....	XXXIX
PREFACE.....	XLIII
CHAPTER 1: INTRODUCTION.....	1
1.1 INTRODUCTION	3
1.2 RESEARCH GAP	5
1.3 OBJECTIVES OF RESEARCH	5
1.4 RESEARCH IN BRIEF	6
CHAPTER 2: LITERATURE REVIEW.....	9
2.1 INTRODUCTION	11
2.2 BIO-MEDICAL TEXTILE	11
2.2.1 BACTERIA/MICROORGANISMS IN BIO-MEDICAL TEXTILES	15
2.2.1.1 Type of bacteria	15
2.2.1.2 Spreading of bacteria	16
2.2.2 PREREQUISITE FOR ANTIBACTERIAL BIO-MEDICAL TEXTILES COMPOSITES	16
2.2.3 METHODS FOR ANTIBACTERIAL FINISHING/TREATMENTS	17
2.3 NANOTECHNOLOGY AND NANOPARTICLES	20
2.3.1 FORTITUDE OF NANOTECHNOLOGY	21
2.3.2 CLASSIFICATION OF NANOMATERIALS	27

2.3.2.1	Classification based on composition	27
2.3.2.2	Classification based on dimension	31
2.3.3	SILVER NANOMATERIALS AND ITS APPLICATIONS	32
2.4	SYNTHESIS OF NANOPARTICLES	33
2.4.1	DIFFERENT METHODS USED IN THE SYNTHESIS OF NANOPARTICLES	34
2.4.1.1	Chemical and Physical synthesis methods	34
	I) Chemical and Physical synthesis of Silver Nanoparticles (AgNPs)	35
	II) Prevalent Chemical and Physical Synthesis Techniques for AgNPs	36
	III) Brief Summary for Work done on Physical and Chemical synthesis of AgNPs	39
	IV) Major Disadvantages of physical and chemical methods	41
2.4.1.2	Green synthesis of Nanoparticles	42
	I) Green synthesis of Silver nanoparticles (AgNPs)	50
	II) Brief summary on AgNPs synthesis by using plants	58
	III) Calotropis (Milkweed) as a Medicinal Herbs	59
	a) Phytochemistry of Calotropis procera	60
	b) Medicinal uses of Calotropis procera	61
	c) Synthesis of Nanoparticles using Calotropis (Milkweed)	63
	d) Synthesis of Silver Nanoparticles (AgNPs) using Calotropis (Milkweed)	64
2.5	TESTING AND ANALYSIS	65
2.5.1	PHYTOCHEMICAL ANALYSIS OF PLANTS EXTRACTS	65
2.5.1.1	Gas chromatography–Mass spectrometry (GC-MS)	66
2.5.2	CHARACTERISATION TECHNIQUES FOR NANOPARTICLES FORMATION	72

2.5.2.1	Visual analysis of Nanoparticles	72
2.5.2.2	Spectroscopic analysis of Nanoparticles	73
	I) X-Ray Diffraction (XRD) methods	73
	II) UV- Visible Spectroscopy	75
	III) Fourier Transform Infrared Spectroscopy (FTIR)	77
	IV) Particle size Analysis by Dynamic Light Scattering (DLS)	79
2.5.2.3	Microscopic analysis of Nanoparticles	79
	I) Scanning Electron Microscopy (SEM)	80
	II) Transmission Electron Microscopy (TEM)	82
	III) Energy Dispersive X-ray Spectroscopy (EDS or EDX)	83
2.5.2.4	Size distribution of nanoparticles by the Digital Image Processing Program/Software	84
	I) ImageJ Software	84
	II) Otsu' Thresholding	85
2.5.3	TESTING OF NANO-COMPOSITES MATERIALS	86
2.5.3.1	Physical assessments	86
	I) Mass per Unit Area (GSM – Gram per square meter)	86
	II) Thickness	87
2.5.3.2	Low-stress properties	88
	I) Fabric stiffness	88
	II) Crease recovery angle	90
2.5.3.3	Comfort-associated properties	90
	I) Air permeability	92
	II) Moisture Management Properties	92
2.5.3.4	UV Transmission properties	95
2.5.3.5	Antibacterial assessments	97

I) Parallel Streak Method – AATTC 147-2004 Standard	98
II) Disc Diffusion Test (Agar Diffusion Test) – Swiss standard - SN195 920	99
III) Various others standards for antibacterial/microbial assessments	103
2.5.3.6 Toxicity analysis of Plant extract, green synthesized nanoparticles, and Nano-composites	105
CHAPTER 3: MATERIALS AND EXPERIMENTAL METHODS.....	107
3.0 INTRODUCTION	109
3.1 PHASE–I: ENGINEERING ELEMENTARY SET-UP AND CONFIRMING COMPETENCY OF NOVEL BIO-SYNTHESIZED NANOPARTICLES	110
3.1.1 MATERIAL	110
3.1.2 METHODS	111
3.1.2.1 AgNPs Synthesis methods	111
3.1.2.1.1 Chemical synthesis (CS) technique	111
3.1.2.1.2 Green synthesis (GS) technique	115
3.1.3 TEST METHODS	119
3.1.3.1 Visual colour change observation technique (VCCO)	119
3.1.3.2 Surface morphology analysis by Scanning Electron Microscopy (SEM)	119
3.2 PHASE–II: PREPARATION OF PROTOTYPE NONWOVEN @AgNPs/CP NANO-COMPOSITE AND VALIDATING ITS ANTIBACTERIAL ACTIVITY	121
3.2.1 MATERIALS	121
3.2.2 METHODS	122
3.2.3 TEST METHODS	123
3.2.3.1 AATCC-147 test methods for Antibacterial assessment	123
3.2.3.2 Structural assessment	129

3.2.3.2.1	Morphological assessment by Environmental Scanning Electron Microscopy (ESEM)	129
3.2.3.2.2	Elemental assessment by Energy Dispersive X-Ray Spectroscopy (EDAX)	129
3.2.3.2.3	Size distribution of nanoparticles	129
3.2.3.2.4	FTIR analysis	132
3.2.3.3	Physical and comfort-related properties	132
3.2.3.3.1	Physical assessment	132
3.2.3.3.2	Low-stress properties	136
3.2.3.3.3	Comfort-associated properties	137
3.2.3.4	UV Transmission properties	141
3.3	PHASE–III: OPTIMIZATION OF AgNPs/CP COLLOIDAL CONSTITUENTS' ADD-ON FOR ANTIBACTERIAL ACTIVITIES IN NONWOVEN @PV-AgNPs/CP NANO-COMPOSITES	142
3.3.1	MATERIALS	142
3.3.2	METHODS	143
3.3.2.1	Major scale trails	143
3.3.2.1.1	Testing and Analysis	145
3.3.2.2	Minor scale trails	145
3.3.2.2.1	Testing and Analysis	146
	A) Visual colour change observation (VCCO) of the AgNPs colloidal	147
	B) Antibacterial assessment by disc diffusion method (SN 195 920 standard)	147
	C) UV-VIS Spectroscopy of AgNPs/CP colloidal solutions	152
	D) Particle size analysis of AgNPs/CP colloidal solutions	153
	E) GC-MS analysis of CP leaves extract	155
	F) MTT assay cytotoxicity test	158

3.4	PHASE–IV: DEVELOPMENT OF NANO-COMPOSITES BY TREATING COMMONLY USED BIO-MEDICAL NONWOVEN TEXTILE WITH OPTIMAL AgNPs/CP COLLOIDAL & EVALUATING THEIR PHYSICAL AND FUNCTIONAL CHARACTERISTICS AS PER ASTM STANDARDS	160
3.4.1	MATERIALS	160
3.4.2	METHODS	163
3.4.2.1	AgNPs/CP treated samples preparation	163
3.4.2.2	CP leave extract treated samples preparation	163
3.4.3	TEST METHODS	163
	CHAPTER 4: RESULTS AND DISCUSSIONS.....	165
4.0	INTRODUCTION	167
4.1	PHASE–I: ENGINEERING ELEMENTARY SET-UP AND CONFIRMING COMPETENCY OF NOVEL BIO-SYNTHESIZED NANOPARTICLES	167
4.1.1	RESULTS ANALYSIS	167
4.1.1.1	Elementary Confirmation of AgNPs formation and Stability by VCCO	167
4.1.1.1.1	Chemical Synthesis (CS)	170
4.1.1.1.2	Green Synthesis (GS)	170
4.1.1.2	Surface morphological analysis (by SEM) of the Green synthesised AgNPs	171
4.1.2	PHASE–I: CONCLUSIONS	173
4.2	PHASE–II: PREPARATION OF PROTOTYPE NONWOVEN @AgNPs/CP NANO-COMPOSITE AND VALIDATING ITS ANTIBACTERIAL ACTIVITY	174
4.2.1	RESULTS ANALYSIS	174
4.2.1.1	Antibacterial assessment of the Nano-composite @PV-AgNPs/CP	174
4.2.1.2	Structural assessment of the Nano-Composite @PV-AgNPs/CP	178

4.2.1.2.1	Morphological assessment by Environmental Scanning Electron Microscopy (ESEM)	178
4.2.1.2.2	Elemental assessment by Energy Dispersive X-Ray Spectroscopy (EDAX)	178
4.2.1.2.3	Nanoparticles Size distribution	182
4.2.1.2.4	FTIR analysis of the Nano-composite @PV-AgNPs/CP	183
4.2.1.3	Physical and comfort-related properties	187
4.2.1.3.1	Physical properties	187
4.2.1.3.2	Low-stress properties	188
4.2.1.3.3	Comfort-associated properties	189
4.2.1.4	UV Transmission properties	196
4.2.2	PHASE–II: CONCLUSIONS	198
4.3	PHASE–III: OPTIMIZATION OF AgNPs/CP COLLOIDAL CONSTITUENTS' ADD-ON FOR ANTIBACTERIAL ACTIVITIES IN NONWOVEN @PV-AgNPs/CP NANO-COMPOSITES	200
4.3.1	MAJOR SCALE PILOT TRIALS	200
4.3.1.1	Results Analysis	201
4.3.1.1.1	Visual colour change observation (VCCO)	201
4.3.1.1.2	MTT assay cytotoxicity test of CP leave extract and pure CP latex	204
4.3.1.1.3	Antibacterial assessment of the samples treated with AgNPs colloidal solutions	209
4.3.1.2	Conclusion: Major scale Pilot trials	214
4.3.2	MINOR SCALE PILOT TRIALS	215
	<u>MINOR SCALE TRAIL: SET-I</u>	215
4.3.2.1	Results Analysis	215
4.3.2.1.1	Visual colour change observation	215
4.3.2.1.2	UV-VIS Spectroscopy	216

4.3.2.1.3	Particle size analysis of AgNPs/CP colloidal solutions	220
4.3.2.1.4	Antibacterial assessment of the PV-AgNPs/CP composites	222
4.3.2.1.5	Conclusion: Minor scale Pilot trails: Set-I	227
	<u>MINOR SCALE TRAIL: SET-II</u>	228
4.3.2.2	Results Analysis	228
4.3.2.2.1	Visual colour change observation of the AgNPs colloidal solutions	228
4.3.2.2.2	UV-VIS Spectroscopy	229
4.3.2.2.3	Particle size analysis of AgNPs/CP colloidal solutions	232
4.3.2.2.4	Antibacterial assessment of the PV-AgNPs/CP composites	236
4.3.2.2.5	MTT assay cytotoxicity test of AgNPs/CP colloidal solution and pure AgNO ₃	240
4.3.2.2.6	GC-MS analysis of CP leaves extract	242
4.3.2.2.7	Conclusion: Minor scale Pilot trails: Set-II	252
4.4	PHASE–IV: DEVELOPMENT OF NANO-COMPOSITES BY TREATING COMMONLY USED BIO-MEDICAL NONWOVEN TEXTILE WITH OPTIMAL AgNPs/CP COLLOIDAL & EVALUATING THEIR PHYSICAL AND FUNCTIONAL CHARACTERISTICS AS PER ASTM STANDARDS	254
4.4.1	RESULTS ANALYSIS	254
4.4.1.1	Antibacterial assessment of the Nano-composites	254
4.4.1.2	Structural assessment of the Nano-Composite	259
4.4.1.2.1	Morphological assessment by Environmental Scanning Electron Microscopy (ESEM)	259
4.4.1.2.2	FTIR analysis of the Nano-composites	261
4.4.1.3	Physical and comfort-related properties	271
4.4.1.3.1	Physical properties	271

4.4.1.3.2	Low-stress properties	276
4.4.1.3.3	Comfort-associated properties	281
4.4.1.4	UV Transmission properties	301
4.4.2	PHASE–IV: CONCLUSIONS	309
CHAPTER 5: CONCLUSIONS AND FUTURE SCOPE.....		311
5.1	CONCLUSIONS	313
5.2	RECOMMENDATIONS/SCOPE FOR THE FUTURE WORK	319
REFERENCES.....		321
APPENDICES.....		355
Appendix – I:	Results of Elemental assessment by Energy Dispersive X-Ray Spectroscopy (EDAX)	357
Appendix – II:	Results of the Antibacterial Test	359
Appendix – III:	Results of the Physical properties	359
Appendix – IV:	Results of the Low-stress properties	360
Appendix – V:	Results of the Comfort-associated properties	361
Appendix – VI:	Results of the UV Transmission properties	362
Appendix – VII:	Results of GC-MS analysis of CP leaves extract	363
Appendix – VIII:	Results of Antibacterial assessment of the Nano-composites	365
Appendix – IX:	Results of the Physical properties	367
Appendix – X:	Results of the Low-stress properties	368
Appendix – XI:	Results of the Crease Recovery angle (o)	371
Appendix – XII:	Results of the Comfort-associated properties	374
Appendix – XIII:	Results of the UV Transmission properties	377