

Contents

Contributors xiv

Section I Fundamentals and basics of green and sustainable nanomaterials

Chapter 1 Environmental friendly and sustainable nanotechnology: Fundamentals 3

Bhawana Jangir and Gopal Kishor Varshney

1.1	Introduction.....	3
1.2	Environmental risks and impacts of nanomaterials.....	5
1.3	Regulatory frameworks for the safe use of nanotechnology.....	6
1.4	Environmental monitoring and risk assessment.....	7
1.5	Green chemistry and engineering principles.....	9
1.6	Green synthesis of nanomaterials.....	10
1.7	Plants mediated biosynthesis of nanoparticles.....	11
1.8	Biosynthesis of nanomaterials facilitated by microorganisms ...	18
1.9	Bacteria-assisted nanomaterial synthesis.....	19
1.10	Algae-assisted nanomaterial synthesis.....	20
1.11	Fungi-assisted nanomaterial synthesis.....	24
1.12	Yeast-assisted nanomaterial synthesis.....	26
1.13	Virus-assisted nanomaterial synthesis.....	28
1.14	Applications of environment-friendly and sustainable nanotechnology.....	30
1.15	Biomedical applications.....	31
1.16	Sustainable agriculture applications.....	31
1.17	Environmental remediation applications.....	32
1.18	Energy storage and conversion applications.....	33

1.19 Applications in cosmetics.....	34
1.20 Applications in automobiles.....	35
1.21 Conclusions and future scope.....	35
References.....	37
Further reading	46

Section 2 Fabrication strategies of sustainable nanomaterials

Chapter 2 Sustainable methods and approaches for the preparation of green nanomaterials: Fundamentals and advances 51

Sajini T. and Jebin Joseph

2.1 Introduction	51
2.2 Fundamentals of green nanomaterials.....	52
2.3 Green nanomaterials and their synthesis methodology	56
2.4 Factors influencing the green synthesis of nanomaterials.....	66
2.5 Characterization techniques for green nanomaterials.....	68
2.6 Applications of green synthesized nanomaterials	69
2.7 Challenges and future perspectives	73
2.8 Conclusion.....	74
References.....	75

Chapter 3 Methods for the conversion of biomass waste into value-added carbon nanomaterials: Recent progress and applications 87

Mohamed Jaffer Sadiq Mohamed and Mohammed Ashraf Gondal

3.1 Introduction	87
3.2 Experimental section.....	89
3.3 Results and discussion.....	92
3.4 Conclusion.....	99
Acknowledgments.....	100
References	100

Section 3 Recent advances for industrial applications of sustainable nanomaterials

Chapter 4 Metal–organic frameworks based nanostructures for energy conversion and storage 105

Muhammad Waqas Khan, Enamul Haque, Jian Zhen Ou and Nasir Mahmood

4.1	Introduction	105
4.2	Pristine metal–organic frameworks	108
4.3	Metal–organic framework composites	113
4.4	Metal–organic frameworks derived materials	117
4.5	Applications of MOF-based materials in energy conversion and storage	121
4.6	Conclusion and future perspective	153
	References	154

Chapter 5 Synthesis of green nanomaterials and their application in a platform for molecular sensing 167

Arijit Jana, Md Rabiul Islam and Pillalamarri Srikrishnarka

5.1	Introduction	167
5.2	Types of green nanomaterials	168
5.3	Synthesis of nanomaterials through green methods	176
5.4	Limitations associated with the industrial scale production	182
5.5	Green nanomaterials for sensing application	183
5.6	Conclusion and future perspective	192
	List of abbreviation	193
	References	193

Chapter 6 Sustainable application of nanomaterials for the agricultural industry 203

Manuel Palencia, Andrés Chamorro and Angélica García-Quintero

6.1	Introduction	203
6.2	Nanomaterials for efficient fertilization	204

6.3	Nanomaterials for efficient pest control	224
6.4	Applications of nanomaterials for the restoration of agriculture-related ecosystem services	241
6.5	Conclusions and final comments	247
	Acknowledgments	248
	References	248

Section 4 Sustainable nanomaterials for energy and environmental applications

Chapter 7 Green nanomaterials for removal of wastewater pollutants: A recent update

265

Rakesh Kumar Saini, Manviri Rani and Uma Shanker

7.1	Introduction	265
7.2	Needs of green nanomaterials	266
7.3	Classification of green nanomaterials	268
7.4	Waste-material-based green nanomaterials	276
7.5	Natural polymer-based/hydrogel-based	276
7.6	Application of green nanomaterials	278
7.7	Environment impact of green nanomaterials	284
7.8	Conclusions and future scope	285
	References	285

Chapter 8 Green and sustainable metal hexacyanoferrate nanomaterials for eradication of traditional and emerging contaminants

293

Uma Shanker, Rishabh and Manviri Rani

8.1	Introduction	293
8.2	Structure of metal hexacyanoferrates	294
8.3	Green synthesis	295
8.4	Classification of metal hexacyanoferrates	297
8.5	Mechanism of photocatalysis	299

8.6	Metal hexacyanoferrates' photocatalytic efficacy	301
8.7	Conclusions	310
	References	310

Section 5 Strategies for green innovation through nanotechnology

Chapter 9 Effects of green manufacturing and technological innovations on sustainable development 319

Maneesh Kumar Poddar, Vishnu Soman and Rumi Narzari

9.1	Introduction	319
9.2	Conventional synthesis methods and their drawbacks	320
9.3	Green synthesis techniques for nanoparticle production	321
9.4	Plant-mediated synthesis of nanoparticles	321
9.5	Microbial synthesis of nanoparticles	322
9.6	Fungal-mediated synthesis of nanoparticles	322
9.7	Microalgae-mediated synthesis of nanoparticles	325
9.8	Actinomycetes-mediated synthesis of nanoparticles	327
9.9	Microwave-assisted synthesis of nanoparticles	328
9.10	Ultrasound-assisted synthesis of nanoparticles	328
9.11	Characterization of nanoparticles synthesized via green route .	330
9.12	Applicability of green synthesized NPs	332
9.13	Conclusions	333
9.14	AI disclosure	333
	References	333
	Further reading	339

Section 6 Environmental health and safety aspects of sustainable nanomaterials

Chapter 10 Green nanomaterials: Environment, health, and safety aspects 343

Muhammad Iqhrammullah

10.1	Introduction	343
10.2	Sources of nanoparticles in environment	344

10.3 Environmental monitoring of nanomaterials	347
10.4 Toxicological assessments of nanomaterials	349
10.5 Exposure of nanoparticles to humans: routes and their health implications.....	350
10.6 Measures to prevent nanoparticles exposure.....	356
10.7 Green nanomaterials research.....	357
10.8 Regulatory Framework for Green Nanomaterials	361
10.9 Concluding remarks and recommendations	364
Acknowledgments	368
AI disclosure	368
References	369

Chapter 11 Assessment of health, safety, and economics of surface-modified nanomaterials.....379

Shubhangee Agarwal, Soniya Dhiman, Vinod and Himanshu Gupta

11.1 Introduction.....	379
11.2 Surface physical modification	381
11.3 Surface chemical method	382
11.4 Surface-modified nanomaterials for health, safety, and economic applications.....	383
11.5 Risks associated with surface-modified nanomaterial exposures	387
11.6 Adverse effects of surface-modified nanomaterials.....	388
11.7 Economics of surface-modified nanomaterials	389
11.8 Future aspects of surface-modified nanoparticles.....	390
11.9 Conclusion.....	391
References	392

Chapter 12 Analytical and toxicological aspects of nanomaterials in different product groups: Challenges and opportunities 397

Nikhil Thakur, Abhishek Kandwal, Bandna Bharti, Pawan Kumar, Arjun Kumar, Suresh Kumar and Harjinder Kaur

12.1 Introduction.....	397
------------------------	-----

12.2 Nanomaterials in product groups	399
12.3 Nanotoxicology	421
12.4 Assessments of safety in consumer products utilizing nanomaterials	424
12.5 Conclusion	426
References	427

Section 7 Biomedical applications of green nanomaterials: Convergence of green technologies

Chapter 13 Research trends in biomedical applications of green nanomaterials	441
---	------------

Surbhi Singh, Kunal Rohilla and Bhagwati Sharma

13.1 Introduction	441
13.2 Nanomaterials for phototherapy of cancer	442
13.3 Nanomaterials for drug delivery	456
13.4 Nanomaterials for antibacterial applications	461
13.5 Conclusion	467
References	468

Chapter 14 Green nanomaterials for advanced biosensors development	479
---	------------

Zina Fredj and Mohamed Bahri

14.1 Introduction	479
14.2 Green nanomaterials synthesis: A sustainable approach	481
14.3 Green nanomaterials in biosensors	485
14.4 Challenges and future prospects	493
14.5 Conclusion	494
References	495

Section 8 Challenges in assessing the impact of green nanotechnology for environmental sustainability

Chapter 15 An updated analysis of environmental sustainability metrics applied to the green synthesis of nanomaterials and the assessment of ecological risks associated with the nanotechnology 503

Manuel Palencia and Angélica García-Quintero

15.1 Introduction	503
15.2 Environmental sustainability and green nanotechnology	505
15.3 Green chemistry metrics and environmental sustainability assessment applied to nanotechnology	510
15.4 Perspectives and prospects in the analysis of nanomaterial sustainability	559
15.5 Conclusions	565
Abbreviations list	567
References	569

Chapter 16 The road to sustainable nanotechnology: Challenges, progress, and opportunities 579

Vandana Singh, Ankush Verma, Vaishali Kumar and Harsh Sable

16.1 Introduction	579
16.2 Fundamentals of nanotechnology	580
16.3 Sustainable development and nanotechnology	581
16.4 Challenges in achieving sustainable nanotechnology	583
16.5 Progress in sustainable nanotechnology	588
16.6 Opportunities for advancing sustainable nanotechnology	594
16.7 Case studies and success stories	601
16.8 Future directions and challenges	603
16.9 Conclusion	606
References	607

Section 9 Regulatory issues and legal aspect of sustainable nanomaterials

Chapter 17 Sustainable nanomaterials: Selected legal and regulatory issues 617

Manish Sharma, Harshita Laddha, Priya Yadav, Yachana Jain and Ragini Gupta

17.1 Introduction.....	617
17.2 Impact on human health and environmental concerns.....	621
17.3 Legal and regulatory aspects and initiatives.....	629
17.4 Conclusion.....	630
References.....	631
Index.....	637