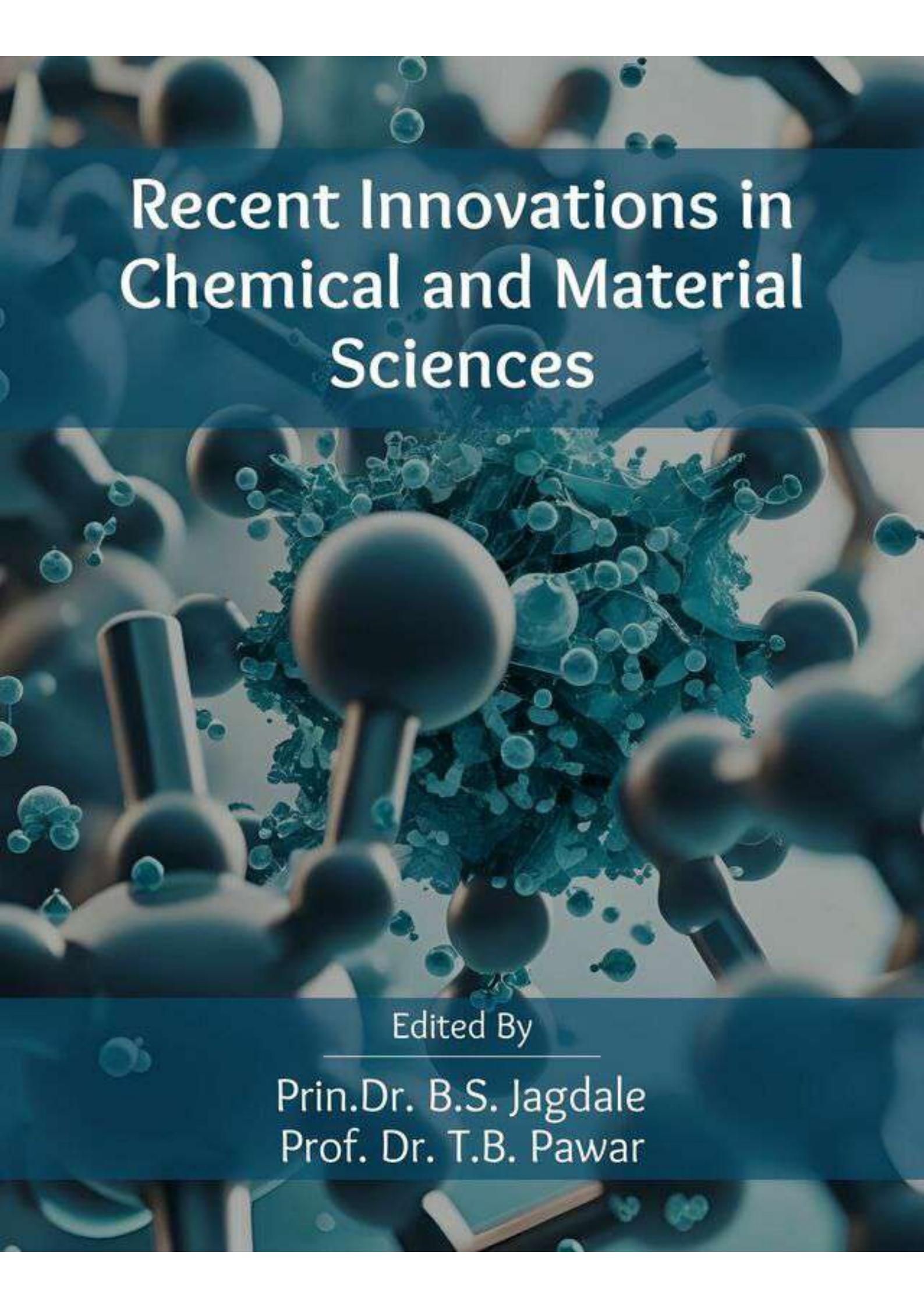


Recent Innovations in Chemical and Material Sciences

The background of the image is a dark blue color. It features a complex, abstract pattern of glowing, translucent molecular structures and chemical elements. These structures are composed of spheres of varying sizes and colors, primarily in shades of blue, green, and white. Interspersed among these molecular models are several pieces of laboratory glassware, including test tubes, flasks, and beakers, which are also illuminated with a similar blue-green glow. The overall effect is a futuristic and scientific representation of the field of chemistry and materials science.

Edited By

Prin.Dr. B.S. Jagdale
Prof. Dr. T.B. Pawar

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Contents

CH.01 - CHROMENES AS ANTIMICROBIAL AGENTS: MECHANISMS, EFFICACY, AND FUTURE PERSPECTIVES	5
Abhijit Gaikwad ^{1*} , Dattatray Ghotekar ² , Archana Pangavhane ³ , Vishnu Adole ¹ and Akash Gaikwad ³	5
CH.02 - SYNTHESIS OF 2-ARYL-1,3-BENZAZOLES VIA CYCLOCONDENSATION REACTION BY USING PALLADIUM(II) AS AN EFFICIENT CATALYST	21
Mr. Ajit G. Nagarkar*.....	21
CH.03 - BIOFUELS VS FOSSIL FUELS: A CHEMICAL PERSPECTIVE ON SUSTAINABLE ENERGY	27
Amol S. Bhosale ^{*a} , Dipak V. Kumbhar ^b , Sanjay R. Kale ^a	27
CH.04 - RECENT MULTICOMPONENT SYNTHESIS OF TETRAHYDROBENZO[B]PYRANE.: A REVIEW	38
Archana B. Dhongade†*, Vishnu A. Adole††, Thansing B. Pawar††	38
CH.05 - "CHITOSAN-LOADED NOCOMPOSITE MATERIALS FOR BIOCIDAL AND PHOTOCATALYTIC ACTIVITY- A REVIEW"	48
Mr. Chetan V. Bhadane,.....	48
Dr. Arun M. Patil *	48
Dr. Arun M. Patil.....	48
CH.06 - SOLUBILITY AND DENSITY MEASUREMENT OF 2-NAPHTHOL IN PURE AND BINARY	49
Dr. Chandrakant S. Aher.....	49
CH.07 - SYNTHESIS OF NANOCOMPOSITES OF TRANSITION METALS AND THEIR APPLICATIONS IN GAS SENSING AND PHOTOCATALYSIS	64
¹ Charushila K. Nerkar, ² Dr. S. S. Chobe.....	64
CH.08 - PLANT MEDIATED SYNTHESIS PROTOCOL, PHOTOCATALYTIC DEGRADATION AND ANTIMICROBIAL ACTIVITY OF CEO ₂ NANOPARTICLES: A SHORT REVIEW	72
^{1,2} Kamalakar Ukharam Chavan, ² Prashant Bhimrao Koli*	72
CH.09 - SYNTHESIS OF GRAPHENE FOAM FROM BIOMASS SOURCES.....	84
Dr (Mrs) Deepali Parag Butala ^{*1} , Prof (Dr) Wagmode Shobha ^{*2}	84
CH.10 - "NANOTECHNOLOGY REVOLUTION: TRANSFORMING THE WORLD AT THE SMALLEST SCALE"	94
G. B. Yelmame ^{1*} , G. V. Suryawanshi ¹	94
CH.11 - SYNTHESIS AND CHARACTERIZATION OF NANOSTRUCTURE METAL OXIDES AND ITS APPLICATION: AN OVERVIEW	107
¹ Chaudhari Geeta Krushna, ² Chobe Santosh Subhash	107
CH.12 - BIOSYNTHESIS OF NANOMATERIALS AND THEIR BIOMEDICAL APPLICATION.....	114
Gorade Lalitaa, Dr. B. S. Desaleb, Dr. Vishnu Adolea.....	114
CH.13 - TITLE: HYDROTHERMAL SYNTHESIS, CHARACTERIZATION, AND APPLICATIONS OF INDIUM OXIDE.....	124
Mr. Jagdish N. Ghotekar ¹ , Dr. Yogeshwar R. Baste ²	124
CH.14 - NITROGEN HETEROCYCLIC COMPOUNDS IN MEDICINAL CHEMISTRY	133
^{1*} Jagdish Shriram Gangurde, ^{2*} Santosh S. Chobe.....	133
CH.15 - SOL-GEL SYNTHESIS Y ₂ O ₃ NANOPARTICLES FOR GAS SENSING APPLICATIONS	143
Dr. Vinayak Vishram Kadam.....	143
CH.16 - ADVANCEMENTS IN POLYANILINE: FROM SYNTHESIS TO SMART MATERIAL APPLICATIONS.....	151
Dr. Kamalakar K.Wavhal	151
CH.17 - INNOVATIVE APPROACHES AND CHALLENGES IN WATER TREATMENT AND PURIFICATION	161

Ms. Karishma Shershaha Sayyed	161
Ms. Pallavi Ankush Yewale	161
CH.18 - 4-FLUORO, 4-CHLORO AND 4-METHOXY PHENYL APPENDED THIAZOLE-PYRAZOLE-BENZOIMIDAZOLE CLUBBED DERIVATIVES: SYNTHESIS, ANTIBACTERIAL, ANTIFUNGAL, ANTIOXIDANT AND CYTOTOXICITY STUDY	167
Keshav B. Gangurde ^{1,*} , Vishnu A. Adole ²	167
Dr. Keshav B. Gangurde	167
CH.19 - MICROPLASTIC: ADVERSE EFFECT ON HUMAN HEALTH & ENVIRONMENT	184
Authers: Archana R. Kote, Maheshkumar Thorat, Avantika Patil	184
CH.20 - GREEN CHEMISTRY AND TECHNOLOGY	199
K. T. Padhyar ^{1*} , S. S. Chobe ¹ , N. B. Shirasath ¹ , N.B. Wadwale ¹ , R.S. Nirwan ^{1*}	199
CH.21 - SYNTHESIS OF HETEROCYCLIC APPENDED NEW CHALCONE AND THEIR ANTIMICROBIAL STUDY: AN OVERVIEW.....	206
¹ Gaikwad Lata Bhaurao, ² Dr. Kailas Haribhau Kapadnis, ³ Dr. Vishnu Ashok Adole.....	206
CH.22 - REVIEW PAPER: ESSENTIAL OILS FROM APIACEAE FAMILY PLANTS: EXTRACTION METHODS, CHEMICAL COMPOSITION, THERAPEUTIC PROPERTIES AND APPLICATIONS	215
Madhuri A. Kshirsagar ^{*1} , Dnyaneshwar D. Lokhande ¹ , Tushar A. Kshirsagar ²	215
CH.23 - REVIEW ON METHODS OF SYNTHESIS AND COMPARISON OF NANOMATERIALS	220
Mahendra Ramdas Thomare ^{1*} , Dr. Vishnu A. Adole ² , Dr. Kailas H. Kapadnis ³	220
CH.24 - AN OVERVIEW: NANOMATERIALS AND THEIR APPLICATION IN BIODIESEL PRODUCTION	230
Narendra M. Patil, Dinesh A. Patil, Manohar R. Patil*	230
CH.25 - A REVIEW: METHYLENE BLUE DYE DEGRADATION BY USING PURE & DOPED MN ₃ O ₄ NANOPARTICLES.....	231
Mansi H. Magar ^{1,2} , Vishnu A. Adole ² , Thansing B. Pawar ²	231
Mansi H. Magar	231
CH.26 - GREEN CHEMISTRY: SETTING SUSTAINABLE GOALS FOR THE FUTURE	239
S. M. Mathure ^{1*} , G. V. Suryawanshi ¹ , N. B. Wadwale ¹ , K. T. Padhyar ¹ , S. S. Chobe ^{1,2} , T. S. Savale ^{1*}	239
CH.27 - "STUDIES OF SOME BASICS PRINCIPLE, TYPES, MODELS & APPLICATIONS OF MOLECULAR DOCKING".....	247
Ankita M. Rayate ¹ , Manoj R. Gaware ²	247
CH.28 - GREEN AND SUSTAINABLE CHEMISTRY: TOWARD A CLEANER AND MORE SUSTAINABLE FUTURE.....	253
Dr. Narendra Ananda Dokhe,.....	253
CH.29 - "A SIGNIFICANT ROLE OF IONIC LIQUIDS IN GREEN CHEMISTRY".....	258
* ¹ Navanand B. Wadwale, ¹ Santosh S. Chobe, ¹ Kuldeep T. Padhyar, ¹ Nandkishor B. Shirasath	258
CH.30 - THE RELATIONSHIP BETWEEN FOOD CHEMISTRY AND NUTRITIONAL SCIENCE	265
Nutan V. Sadgir ^{a*} , Sunil L. Dhonnar ^a , Bapu S. Jagdale ^a	265
CH.31 - MICROWAVE ASSISTED MULTICOMPONENT REACTION FOR THE SYNTHESIS OF 2-AMINO-4H-CHROMENE DERIVATIVES	271
Pankaj H. Naikwadi ^{*1} , Narendra D. Phatangare ²	271
CH.32 - THIAZOLE: A VERSATILE SCAFFOLD IN DRUG DESIGN AND ORGANIC SYNTHESIS	280
Rahul A. Shinde ^{1*} , Vishnu A. Adole ² , Bapu S. Jagdale ²	280
CH.33 - HERBAL MEDICINES – A COMPREHENSIVE GUIDE	294
Dr. R.K.Pawar.....	294
CH.34 - PHOTOCATALYTIC DEGRADATION STUDY OF METHYLENE VIOLET USING NICKEL DOPED CERIUM OXIDE AS A PHOTOCATALYST UNDER SOLAR RADIATION	305

S.B. Rathoda*	305
B.L. Shindeb	305
V.N. Dhagec	305
CH.35 - BOOK CHAPTER NAME: NANOPARTICLES AND THEIR APPLICATIONS IN DIVERSE FIELD	320
Dr. Ravindra Haribhau Waghchaure	320
CH.36 - ANALYTICAL TECHNIQUES IN NANO-MATERIAL CHARACTERIZATION: A BRIEF REVIEW	329
R. M. Nikam ^{*1} , K. H. Kapadnis ² , B. K. Nikam ³ , G. B. Dhomse ⁴	329
CH.37 - NANOTECHNOLOGY IN ENVIRONMENTAL REMEDIATION: ADVANCES AND APPLICATIONS IN DYE DEGRADATION	338
Rohit Shankar Shinde ^{1*} , Vishnu Ashok Adole ² , Thansing Bhavsing Pawar ²	338
Dr. Rohit Shankar Shinde	338
CH.38 - PREPARATION AND CHARACTERIZATIONS OF MNO ₂ -SRO NANOSTRUCTURE BY SOL-GEL METHOD	349
Rushikesh Gorakh Bhamare ^{1*} , Janardan Maharu Shewale ²	349
Rushikesh Gorakh Bhamare	349
CH.39 - SYNTHETIC APPROACHES TO THIAZOLES :A BRIEF REVIEW	357
Aruna B. Salunke ^a , Ramesh S. Nirwan ^a , Nilesh D. Pingale ^b	357
CH.40 - DFT STUDY TO INVESTIGATE THE SOLUTE-SOLVENT INTERACTION BETWEEN SUCCINIC ACID, WATER, METHANOL AND THEIR COMBINATION.....	365
Sandip B. Nahire.....	365
CH.41 - SYNTHESIS, SPECTROSCOPIC ANALYSIS, AND THEORETICAL INSIGHTS OF A PYRIMIDINE-BASED MOLECULE: A DFT APPROACH	373
Sandip S. Pathade ^{*1} , Bapu S. Jagdale ²	373
CH.42 - NANOTECHNOLOGY FOR SUSTAINABLE DEVELOPMENT IN AGRICULTURE	384
Bapu S. Jagdale ¹ , Santosh S. Chobe ^{*1,2}	384
CH.43 - BIOADSORBENTS: A GREEN APPROACH TO ENVIRONMENTAL REMEDIATION	399
Satish Arvind Ahire ^{1*} , Ashwini Ashok Bachhav ² , Nutan Vitthal Sadgir ¹ , Charushila Khanderao Nerkar ¹	399
CH.44 - BOOK CHAPTER-CORE-SHELL NANOPARTICLES & ITS SYNTHETIC METHODS	405
Satyam Sham Bakare.....	405
Dr. Ravindra Haribhau Waghchaure	405
CH.45 - CARBON NANOMATERIALS: A DIVERSE FAMILY OF NANOSTRUCTURES.....	420
T. S. Savale ^{1*} , G.V. Suryawanshi ^{1*} , S. S. Chobe ^{1,2} , S. M. Mathure ¹	420
CH.46 - METAL AND NON-METAL MODIFIED GRAPHITIC CARBON NITRIDE (G-C ₃ N ₄) NANOCOMPOSITES: EFFICIENT PHOTOCATALYSTS FOR DYE DEGRADATION	434
Sumaiyya R. Sayyad ^a , Sachin G. Shinde ^b , Vishnu A. Adole ^a , Thansing B. Pawar ^a	434
CH.47 - SYNTHESIS AND MEDICINAL APPLICATIONS OF THIAZOLE AND ITS DERIVATIVES: A BRIEF REVIEW	445
Sagar K. Shinde ¹ , Vishnu A. Adole ¹	445
CH.48 - AN OVERVIEW ON NANOMATERIALS FOR ENVIRONMENTAL REMEDIATION	463
Trupti B. Shinde ^{a*} , Kailas H.Kapadnis ^b	463
CH.49 - SYNTHETIC ROUTE OF CHALCONE DERIVATIVES AND THEIR BIOLOGICAL ACTIVITIES: A REVIEW	474
Atul D.Tidke ^{a,b} , Vishnu A. Adole ^a , Kailas H. Kapadnis ^a	474
CH.50 - REVIEW ON SYNTHESIS OF NICKEL OXIDE NANOPARTICLES ITS METHODS AND	

APPLICATIONS	486
Sunita Tore ^{a*} , Dr. V. A. Adole ^a , Dr. B. S. Desale ^b ,	486
CH.51 - CERIUM OXIDE (CEO ₂) FILM NANOSENSORS: A REVIEW	497
* ¹ Vinod S. Aaynor, ² Pankaj S. Pawar.....	497
CH.52 - "SYNTHESIS AND PHARMACOLOGICAL INSIGHTS OF CHALCONES: A VERSATILE SCAFFOLD"	498
Bhagyashri Bhima Waghmare ^{1*} , Ramesh Shankar Nirwan ² , Bapu Sonu Jagdale ³ , Nutan Vitthal Sadgir ⁴ ..	498
CH.53 - CHALCONES: A TREASURE OF PHARMACOLOGICAL POTENTIAL	505
Author's: Y.G. Patil ^{1*} , V. A. Adole ² , G.V. Suryawanshi ¹ , T. S. Savale ^{1*}	505
CH.54 - SYNTHESIS AND PHARMACOLOGICAL EVALUATION OF 2-(2- HYDRAZINEYL)THIAZOLE DERIVATIVES FOR ANTIBACTERIAL AND ANTIFUNGAL APPLICATIONS	511
Yuvraj R. Sable ^{1,2} , Vishnu A. Adole ^{1*}	511
CH.55 - NANOTECHNOLOGY ERA: A NEW FRONTIER FOR HUMAN ADVANCEMENT	516
G.V. Suryawanshi ^{1*} , A. V. Patil ² , S. S. Chobe ^{1,3} , Y. G. Patil ¹ , S.M. Mathure ¹ , T. S. Savale ^{1*}	516
CH.56 - GREEN SYNTHESIS OF NIO NANOPARTICLES AND THEIR BIOMEDICAL APPLICATION: A REVIEW.....	528
Sachin Shivaji Pawar ¹ , Pankaj Shankarrao Pawar ²	528

CH.54 - SYNTHESIS AND PHARMACOLOGICAL EVALUATION OF 2-(2-HYDRAZINEYL)THIAZOLE DERIVATIVES FOR ANTIBACTERIAL AND ANTIFUNGAL APPLICATIONS

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ABSTRACT

The emergence of drug-resistant bacterial and fungal strains has created an urgent need for novel antimicrobial agents. In this context, 2-(2-Hydrazineyl)thiazole derivatives have attracted significant attention due to their potential pharmacological activities. This chapter outlines the synthesis and pharmacological evaluation of a series of 2-(2-Hydrazineyl)thiazole derivatives, focusing on their antibacterial and antifungal properties. The derivatives were synthesized using conventional methods, and their chemical structures were confirmed by spectral analysis techniques such as NMR, IR, and mass spectrometry. The antimicrobial efficacy of the compounds was evaluated against a range of clinically significant bacterial and fungal strains using standard in vitro assays. The results demonstrated that several derivatives exhibited promising antibacterial and antifungal activities, with certain compounds showing potent inhibition against both Gram-positive and Gram-negative bacteria, as well as fungi. The structure-activity relationship (SAR) analysis highlighted key molecular features that contribute to the enhanced antimicrobial activity of these derivatives. The findings suggest that 2-(2-Hydrazineyl)thiazole derivatives represent a promising class of compounds for the development of novel antimicrobial agents to combat resistant pathogens.

Keywords: Drug resistance, Pharmacological evaluation, 2-(2-Hydrazineyl)thiazole derivatives, Antibacterial activity, Antifungal activity, Novel antimicrobial compounds.

INTRODUCTION

The development of novel antimicrobial agents is critical in the face of increasing resistance to conventional antibiotics and antifungal drugs. In particular, bacterial and fungal infections continue to pose significant threats to public health, leading to an urgent need for new therapeutic options. Among various heterocyclic compounds, thiazole derivatives have gained considerable attention due

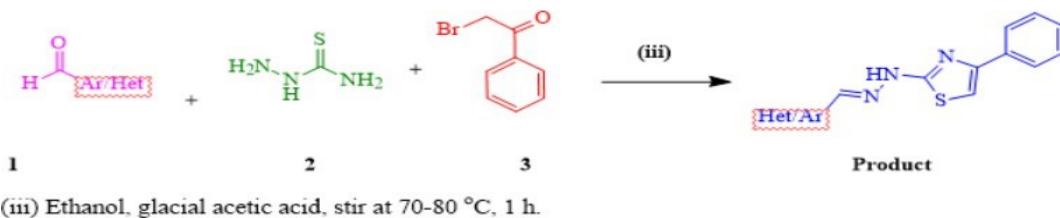
to their broad spectrum of biological activities, including antibacterial, antifungal, anti-inflammatory, and anticancer properties. The rapid increase in antimicrobial resistance (AMR) has become a major global health challenge, highlighting the urgent need for the development of new and effective antimicrobial agents. Bacterial and fungal infections, particularly those caused by resistant strains, are leading to high morbidity and mortality rates worldwide. Among the various classes of compounds being explored for their antimicrobial properties, thiazole derivatives have emerged as an important class of heterocyclic compounds due to their diverse biological activities, including antibacterial, antifungal, anticancer, and anti-inflammatory effects.

The introduction of hydrazine groups at the 2-position of the thiazole ring results in 2-(2-hydrazinyl)thiazole derivatives, a novel class of compounds with significant potential in medicinal chemistry. These derivatives combine the beneficial properties of both thiazole and hydrazine functionalities, which are known to interact with microbial cells in a manner that disrupts essential processes. This chapter focuses on the synthesis, characterization, and pharmacological evaluation of 2-(2-hydrazinyl)thiazole derivatives for their antibacterial and antifungal activities, highlighting their potential as candidates for the development of new antimicrobial therapies.

1. SYNTHESIS OF 2-(2-HYDRAZINYL)THIAZOLE DERIVATIVES

The synthesis of 2-(2-hydrazinyl)thiazole derivatives typically involves the condensation of a hydrazine-based reagent with a suitable thiazole precursor under mild reaction conditions. Various synthetic routes can be employed to optimize yield and purity while introducing substituents that can potentially enhance biological activity.

Reaction



Scheme 1 Synthesis of 2-hydrazinyl thiazole derivatives

2. GENERAL SYNTHETIC APPROACH

2.1. Preparation of thiazole core:

The synthesis of thiazole involves the cyclization of appropriate reactants, such as α -halo ketones or aldehydes, with sulfur-containing reagents like thiourea or thiosemicarbazide.

2.2. Hydrazine substitution:

The thiazole ring is then functionalized by reacting it with hydrazine derivatives (e.g., hydrazine hydrate, 2-hydrazinylbenzenes) under solvent-free conditions or using suitable solvents like ethanol or DMF to produce the 2-(2-hydrazinyl)thiazole derivatives.

2.3. Functionalization:

The synthesized thiazole derivatives can then be further modified by adding various substituents (e.g., halogens, alkyl groups, or aromatic rings) at different positions to study their impact on the biological activities.

3. CHARACTERIZATION OF 2-(2-HYDRAZINEYL)THIAZOLE DERIVATIVES

Once the compounds are synthesized, their chemical structures must be confirmed using a range of analytical techniques. The most common methods for characterizing these derivatives include:

3.1. Nuclear Magnetic Resonance (NMR) Spectroscopy: Both ^1H -NMR and ^{13}C -NMR are used to determine the proton and carbon environments, providing key information about the structure of the synthesized compounds.

3.2. Infrared (IR) Spectroscopy: The FT-IR spectrum helps identify functional groups such as NH, C=N, and C=S, which are crucial for confirming the thiazole and hydrazine moieties.

3.3. Mass Spectrometry (MS): MS helps in determining the molecular weight and fragmentation patterns of the compounds.

3.4. Elemental Analysis: Provides confirmation of the elemental composition of the compounds.

3.5. Chromatography: Thin Layer Chromatography (TLC) and High-Performance Liquid Chromatography (HPLC) are used to assess purity and separation efficiency.

4. PHARMACOLOGICAL EVALUATION OF 2-(2-HYDRAZINEYL)THIAZOLE DERIVATIVES

After confirming the structures of the synthesized derivatives, their antimicrobial properties are evaluated through in vitro assays to assess their antibacterial and antifungal activities. The evaluation typically involves testing against a range of microbial strains to determine the spectrum of activity and potency.

5. ANTIBACTERIAL ACTIVITY

The antibacterial activity of the 2-(2-hydrazineyl)thiazole derivatives is assessed by measuring their ability to inhibit the growth of both Gram-positive and Gram-negative bacteria. Commonly used bacterial strains include *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae*. The minimum inhibitory concentration (MIC) of each compound is determined using methods such as broth microdilution or agar well diffusion. Compounds with lower MIC values are considered more potent. The mechanism of action is often explored by assessing the interaction of these compounds with bacterial cell membranes or intracellular components.

6. ANTIFUNGAL ACTIVITY

In addition to bacterial strains, the antifungal activity of the derivatives is evaluated against clinically relevant fungal pathogens, including *Candida albicans*, *Aspergillus niger*, and *Trichophyton*.

mentagrophytes. Methods for evaluating antifungal activity include the agar dilution method and microdilution assays.

7. TOXICITY AND SELECTIVITY

In addition to antimicrobial activity, the cytotoxicity of these compounds is assessed using normal mammalian cell lines to evaluate their safety profile. The selectivity index, which compares the antimicrobial activity to the cytotoxicity, provides an indication of the therapeutic potential of the compounds. Compounds with high antimicrobial activity and low toxicity to host cells are prioritized for further development.

8. STRUCTURE-ACTIVITY RELATIONSHIP (SAR) ANALYSIS

A key aspect of the development of new antimicrobial agents is the understanding of the structure-activity relationship (SAR). The SAR analysis involves correlating the chemical structure of the synthesized 2-(2-hydrazineyl)thiazole derivatives with their antimicrobial activity. This analysis allows researchers to identify structural features that contribute to enhanced potency, such as specific substituents on the thiazole ring, the positioning of the hydrazine group, or the incorporation of electron-withdrawing or -donating groups.

By optimizing these features, it is possible to design compounds with improved antimicrobial efficacy and reduced toxicity. The findings from SAR studies can guide future efforts in the development of 2-(2-hydrazineyl)thiazole derivatives as lead candidates for the treatment of resistant infections.

CONCLUSION

The synthesis and pharmacological evaluation of 2-(2-hydrazineyl)thiazole derivatives have revealed their promising potential as antimicrobial agents. The combination of the thiazole ring with hydrazine functionality provides a versatile scaffold for designing compounds with potent antibacterial and antifungal activities. The compounds demonstrated significant efficacy against both bacterial and fungal strains, making them strong candidates for further development in the fight against antimicrobial resistance. Future studies will focus on optimizing the chemical structure, improving selectivity, and conducting in vivo studies to further assess the therapeutic potential of these compounds. As antimicrobial resistance continues to pose a global health threat, the development of novel compounds like 2-(2-hydrazineyl)thiazole derivatives represents a promising strategy to combat resistant infections and enhance the current arsenal of antimicrobial drugs.

REFERENCES

1. Chowdhury, K., Ahmad, R., Sinha, S., Dutta, S. and Haque, M., 2023. Multidrug-resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB) among children: Where we stand now. *Cureus*, 15(2).

2. Vishwakarma, D., Gaidhane, A., Sahu, S. and Rathod, A.S., 2023. Multi-drug resistance tuberculosis (MDR-TB) challenges in India: A review. *Cureus*, 15(12).
3. Wei, X., Yue, L., Zhao, B., Jiang, N., Lei, H. and Zhai, X., 2024. Recent advances and challenges of revolutionizing drug-resistant tuberculosis treatment. *European Journal of Medicinal Chemistry*, p.116785.
4. Nemala, S.K., Prava, P. and Vedula, G.S., 2023. Discovery of Structural prospects of novel bis di hydro pyrazole derivatives as Antitubercular agents: A Computational approach. *Research Journal of Pharmacy and Technology*, 16(7), pp.3239-3244.
5. Mohamed-Ezzat, R.A., Omar, M.A., Temirak, A., Abdelsamie, A.S., Abdel-Aziz, M.M., Galal, S.A., Elgemeie, G.H., El Diwani, H.I., Flanagan, K.J. and Senge, M.O., 2024. Synthesis, biological evaluation, and docking studies of pyrazole-linked benzothiazole hybrids as promising anti-TB agents. *Journal of Molecular Structure*, 1311, p.138415.
6. Bhanwala, N., Gupta, V., Chandrakar, L. and Khatik, G.L., 2023. Thiazole Heterocycle: An Incredible and Potential Scaffold in Drug Discovery and Development of Antitubercular Agents. *ChemistrySelect*, 8(46), p.e202302803.
7. Wang, J., Long, S., Liu, Z., Rakesh, K.P., Verma, R., Verma, S.K. and Kumar, K.S.S., 2023. Structure-activity relationship studies of thiazole agents with potential anti methicillin-resistance *Staphylococcus aureus* (MRSA) activity. *Process Biochemistry*, 132, pp.13-29.
8. Yan, W., Zheng, Y., Dou, C., Zhang, G., Arnaout, T. and Cheng, W., 2022. The pathogenic mechanism of *Mycobacterium tuberculosis*: implication for new drug development. *Molecular Biomedicine*, 3(1), p.48.
9. Liu, Y., Grimm, M., Dai, W.T., Hou, M.C., Xiao, Z.X. and Cao, Y., 2020. CB-Dock: A web server for cavity detection-guided protein–ligand blind docking. *Acta Pharmacologica Sinica*, 41(1), pp.138-144.
10. Beeke, A.D., 1993. Density-functional thermochemistry. III. The role of exact exchange. *J. Chem. Phys*, 98(7), pp.5648-6.
11. Bekhit, A.A. and Abdel-Aziem, T., 2004. Design, synthesis and biological evaluation of some pyrazole derivatives as anti-inflammatory-antimicrobial agents. *Bioorganic & medicinal chemistry*, 12(8), pp.1935-1945.
12. Khan, M.F., Alam, M.M., Verma, G., Akhtar, W., Akhter, M. and Shaquiquzzaman, M., 2016. The therapeutic voyage of pyrazole and its analogs: a review. *European journal of medicinal chemistry*, 120, pp.170-201.