REVIEW ON CHEMICAL AND BIOLOGICAL APPLICATION OF IMIDAZOLE DERIVATIVES

Shubh laxmi[1]*, Jatolia S.N.[2]

Abstract

The naturally occurring imidazole core scaffold have shown interesting biological as well as physiochemical properties and consequently they have found several chemical, optical, pharmaceutical, and other useful biological applications. Imidazole moiety contains three carbon atoms, and two nitrogen with electronic-rich characteristics that are responsible for readily binding with a variety of enzymes, proteins, and receptors compared to the other heterocyclic rings. In this review, we have summarized all the pharmacological, biological and chemical applications of imidazole derivatives. Herein, we provide a thorough overview of the current research status of five membred imidazole-based compounds with a wide variety of biological activities including, anti-bacterial, antifungal, antiprotozoans, anti-parasitic, anti-cancer, anti-inhibitory, and anti-inflammatory. In this review, we have also discussed anti-oxidant, anti-corrosion behavior and luminescence properties of the imidazole derivatives.

Keywords: - Imidazole, heteocyclic, luminescent property

[1]*, [2]GCRC, P.G. Department of Chemistry, Govt. Dungar College (A-Grade), MGS University, Bikaner 334001. Raj. INDIA, Email Id: satyanarayanjatolia@gmail.com

***Corresponding Author: -** Jatolia S.N.
GCRC, P.G. Department of Chemistry, Govt. Dungar College (A-Grade), MGS University, Bikaner 334001. Raj. INDIA,

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INTRODUCTION

Imidazole (1,3-diaza-2,4-cyclopentadiene) is an nitrogen based-heterocyclic aromatic organic compound which was first discovered in 1840. The chemical formula of the imidazole molecule is $C_3H_4N_2$ which is a five-membered N-Heterocyclic compound having two nitrogen atoms in the aromatic ring (1-3). Imidazole ring, which is widely found in natural products, is one of the most important heterocyclic possess a vital role in medicinal chemistry, have been playing a important role in the treatment of numerous types of diseases and new derivatives are being energetically synthesized worldwide for medicinal use [4-8].These derivatives constitutes a very basic structural and fundamental building block of the various type of medical scaffolds demonstrated promising anti-cancer, anti-microbial, and anti-inflammatory activities (9).

The structural properties of the imidazole ring enhance their ability to form multiple drug–ligand interactions via vander Waals forces, hydrophobic forces and hydrogen bonds (10). Moreover, the imidazole moiety is a part of several naturally derived compounds, such as histamine, histidine, biotin, alkaloids, and nucleic acid, and it is also a part of Food and Drug Administration-approved drugs. Because of their important properties as therapeutics, fused imidazole derivatives have held a significant role in the medical field (11). The imidazole derivatives have shown various pharmacological activities, including antihyper-tensive, anti-fungal, enzyme inhibition, cardiovascular activity, etc (12-13). In last few decades, the imidazole compound has attracted the researchers and scientist around the globe, due to its high valued biological and chemical properties. Imidazoles are interesting group of heterocyclic compound having versatile biological activities such as antimicrobial, antibacterial, antifungal, anticancer, anti-inflamatory, antiparasitic, antiviral, anti-HIV, anticonvulsant, antiulcer activity etc. These days imidazole-based antibacterial drugs, such as 1-(2-hydroxyethyl)-2-methyl-5-nitroimidazole and 2-nitroimidazole have been used for trichomonacide applications. Also, some of the imidazoles such as metronidazole, clotrimazole, metrazole, and misonidazole are vital anticancer drug(14-15).

Polycyclic aromatic compounds are extensively used in medicinal and dye industry. In specific, nitrogen containing compound like amino-naphthalimide, [3] 2-(2'-hydroxy-5'- chloroph-enyl)-6-chloro-4(3H)-quinazolinone are used as fluorophores (16). Luminescent compounds have been widely used because of versatile applications in light emitting diode (LED), biosensors, and molecular logic gates. Luminescent properties of some imidazole based polycyclic aromatic compounds were determined. In common, poly-cyclic aromatic compound containing structures like phenanthrene, anthracene, in combination with small heterocyclic aromatic compound exhibited better luminescent properties.[17-19]

APPLICATIONS

Antibacterial activities-

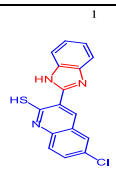
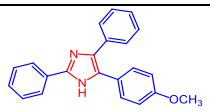
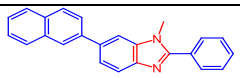
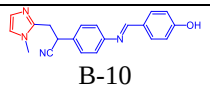
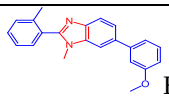
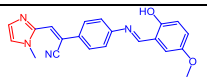
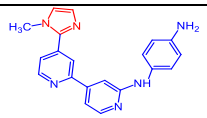
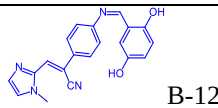
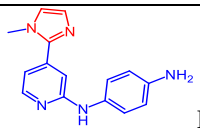
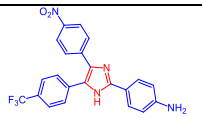
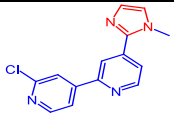
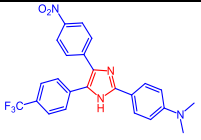
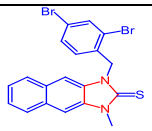
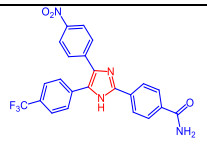
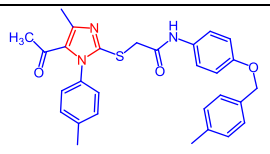
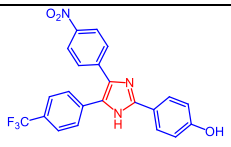
Velmurugan et al. synthesized thio-, chloro-, and hydroxyl-functionalized various imidazoquino-lines and were examined for their antibacterial activity against selected bacterial pathogens. They suggested the electron-withdrawing (-Cl) substituent containing imidazoquinoline B1 showed higher antibacterial and antioxidant activities than other imidazoquinolines and reached the effectiveness of the standard (20). A novel series of 1-methyl-2,6-diphenyl-benzoimidazole and 1-methyl-phenyl(o-tolyl) benzo [d]imidazole derivatives were synthesized from 4-bromobenzene-1,2-diamine and benzoic acid using palladium (II) acetate have been developed by Havale et al. (21) . The synthesized compounds were evaluated for their anti-bacterial activity against Gram-positive S. aureus and Gram-negative *E. coli* bacteria by using broth-dilution method. Among these compound B2, and B3 were the most effective against S. aureus and E. coli bacteria of all the tested compounds. Zina et al. have reported the biological activities of some imidazole derivatives. Antibacterial investigation exhibited potent activity against *S. aureus* and *E. coli* of B4, B5 and B6 compounds compared to tetracycline antibiotic (22).

The ability to detect hypochlorite (HOCl/ClO−) in vivo is of great importance to identify and visualize infection. Pham et al. (23) reported the use of imidazoline-2-thione (R1SR2/DSM) probes, which act to both sense ClO− and kill bacteria. Their investigation showed the DSM probe(B7) with ClO^- displayed antibacterial efficacy toward not only *Escherichia coli (E. coli)* and *Staphylococcus aureus (S. aureus)* but also methicillin-resistant *Staphylococcus aureus* (MRSA) and extended-spectrum ßlactamase–producing *Escherichia coli (ESBL-EC)*, that is, antibiotic-resistant bacteria. Drashti et al. have designed and synthesized 2-((5-acetyl-1-(phenyl)-4-methyl-1H-imidazol-2-yl)thio)-N-(4 ((benzyl) oxy)phenyl) acetamide derivatives. Antimicrobial activities of all the imidazole derivatives have been examined against Gram-positive and Gram-

negative bacteria and results showed that (B8) have appreciable antibacterial activity (24).

Magar et al. were designed a novel series of 2, 4, 5- trisubstituted imidazoles derivatives by using ultra-sonicator a green synthesis taking different aldehydes as substitutions. The compounds were screened for their anti-microbial activities against Staphylococcus aureus and Bacillussubtilis Gram negative Escherichia coli using cup-plate agar diffusion method in which 5-(4-methoxyphenyl)-2,4-diphenyl-1*H*-imidazole(B9) exhibited highest activity (25). Quasar et al. were employed a multi-step synthetic protocol to accomplish the synthesis of (2*Z*)-2-((*E*)-4-(benzylideneamino) phenyl)-3-(1-methyl-1*H*-imidazol-2-yl) acrylonitrile derivatives. The synthesized compounds were screened for in vitro antitubercular activity in which the compounds B10, B11 and B12 appeared promising activity (26). MoS2-supported-calix[4]arene (MoS2-CA4) nanocatalyst was used for efficient synthesis of 2,4,5-trisubstituted imidazole derivatives from 1-(4-nitrophenyl)-2-(4-(trifluoromethyl) phenyl) ethane-1,2-dione, aldehydes and ammonium acetate under solvent-free condition have been doveloped by Raghu et al. All synthesized compounds were evaluated for their in vitro antitubercular (TB) activity against *Mycobacterium tuberculosis* (Mtb) H37Rv. Among the screened compounds B13, B14, B15, B16 exhibited more potency than the reference drugs pyrazinamide, ciprofloxacin, and ethambutol (27).

Table-1-Antibacterial activity (B-1 to B-16)

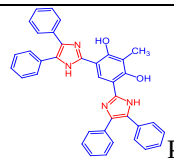
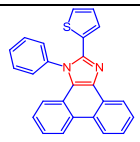
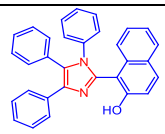
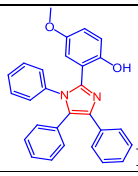
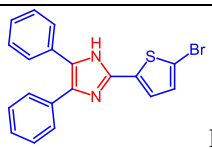
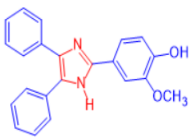
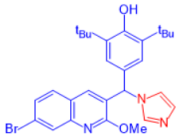
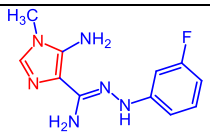
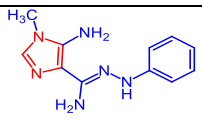
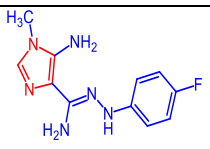
Structure	Activity	Structure	Activity
 B-1	Antibacterial activity *S. aureus, A. hydrophila, E. coli, K. pneumonia, S. paratyphi, S.typhi,* and *M. butyricum*	 B-9	Antibacterial activity *S.aureus, B. subtilis,* and *E. coli*
 B-2	anti-bacterial activity *S. aureus, E .coli*	 B-10	Antituberculosis activity *Mycobacterium Tuberculosis*
 B-3	anti-bacterial activity *S. aureus, E.coli bacteria*	 B-11	Antituberculosis activity, *Mycobacterium Tuberculosis*
 B-4	Antibacterial activity *S. aureus, E. coli*	 B-12	Antituberculosis activity *Mycobacterium Tuberculosis*
 B-5	Antibacterial activity *S. aureus, E. coli*	 B-13	Antituberculosis activity *Mycobacterium Tuberculosis*
 B-6	Antibacterial activity *S. aureus, E. coli*	 B-14	Antituberculosis activity *Mycobacterium Tuberculosis*
 B-7	Antibacterial E. coli, S. aureus , methicillin-resistant *Staphylococcus aureus*	 B-15	Antituberculosis activity *Mycobacterium Tuberculosis*
 B-8	Vancomycinresistant *Enterococcus,* Methicillin resistant *Staphylococcus aureus*(MRS)	 B-16	Antituberculosis activity *Mycobacterium Tuberculosis*

Antiprotozoans, Antiparasitic and Antifungal activities-

Three imidazoles: bis-imidazole, phenyl-substituted 1H-imidazole, and thiopene-imidazole for cellular toxicity were evaluated by Oluyomi et al. (28). The compounds were assessed for in vitro cytotoxic action. Their findings showed dose-dependent cellular toxicity involves likely impairment to redox balance and mitochondrial membrane potential in living cells, and altogether may boost their prospects as new and alternative anti-protozoan (P1, P2, P3). In developing nations, *Trypanosoma* spp. cause animal and human trypanosomiasis characterized with appreciable health and economic burden mostly. Oluyomi et al. demonstrating the potential of these new series of imidazoles to clear the systemic parasite burden in infected rats. Their *in vivo* study revealed that the imidazole compound (P4) not only cleared the systemic parasite burden but cured infected rats after no death was recorded (29). Toxoplasmosis is a common parasitic disease caused by Toxoplasma gondii. Adeyemi et al . were synthesized a series of new imidazole derivatives: bis-imidazoles , phenyl-substituted 1H-imidazole, and thiopene-imidazoles .their study revealed of the 26 compounds screened, (P5) exhibited significantly high selectivity towards the parasite versus the host cells (30). Ika et al. synthesize a Series of 2-aryl-4,5-diphenyl-1H-imidazole derivatives of 2-(4-hydroxy-3-methoxyphenyl)-4,5-diphenyl-1H-imidazole (1), 2-(4,5-dimethoxyphenyl)-4,5-diphenyl1H-imidazole (2) and 2-(4-methoxyphenyl)-4,5-diphenyl-1H-imidazole (3) and evaluated for their antimalarial activities against the chloroquinesensitive Plasmodium falciparum 3D7 strain. compound (P-6) could be considered to have good antimalarial activity with IC50 of 1.14 µM (31) . Deblina et al. developed a library of quinoline − imidazole hybrid compounds which have significant antimalarial activity was evaluated in both drug-sensitive and –multi drug-resistant (MDR) P. falciparum strain.

The enantiomer (P-7) had potent antimalarial activity over the other isomer, with IC50 of 0.10 µM (32). Systemic mycoses are one major cause of morbidity or mortality among debilitated individuals. Fatima et al. were elucidated the mechanistic action of three (Z)-5-amino-N'-aryl-1-methyl-1H-imidazole-4-carbohydrazonamides (F1,F2,F3) that have strong antifungal activity against Candida krusei and C. albicans ATCC strains (33).

Table-2-Antiprotozoan (P-1 to P-3), Anti-parasitic(P-4 to P-5), Anti-malarial (P-6 to P-7) Antifungal(F-1 to F-3) activity.

Structure	Activity	Structure	Activity
 P-1	Antiprotozoans activity	 P-4	Antiparasitic activity
 P-2	Antiprotozoans activity	 P-5	Antiparasitic activity
 P-3	Antiprotozoans activity	 P-6	Antimalarial activity
 P-7	Antimalarial activity	 F-1	Antifungal activity
 F-2	Antifungal activity	 F-3	Antifungal activity

Anticancer activities-

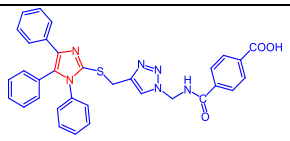
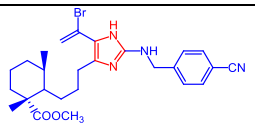
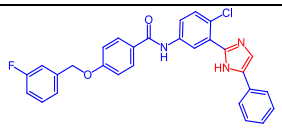
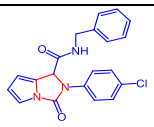
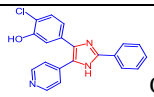
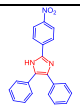
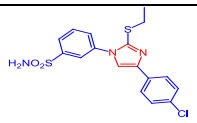
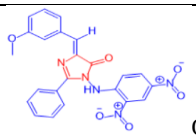
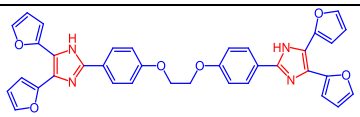
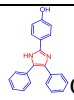
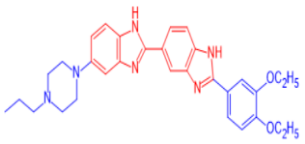
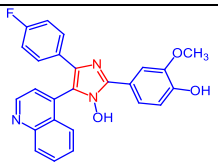
A series of new imidazole-1,2,3-triazole derivatives were designed and synthesized by Blewi et al. in 2021. The resulted adducts were investigated for their anticancer activity against four cancer cell lines (Caco-2, HCT-116, HeLa, and MCF-7) by the MTT assay. Their investigation showed C1 displayed potent cytotoxic activity against the cancer cell lines, especially MCF-7.The hedgehog (Hh) signaling pathway drives oncogenic transformation for a wide range of cancers, and it is therefore a promising target in cancer therapy. Chiyu et al. designed and synthesized a series of Hh signaling pathway inhibitors with phenyl imidazole scaffold, which were biologically evaluated. Compound C2 was identified to possess high potency. A new series of N-1 arylidene amino imidazole-2-thiones have been synthesized by Ali et al. Cytotoxic effect of the prepared compounds was carried out utilizing three cancer cell lines; MCF-7 breast cancer, HepG2 liver cancer, and HCT-116 colon cancer cell lines. Imidazole derivative C3 was the most potent of all against three cancer cell lines (34-36).

Cius et al. synthesized a Benzenesulfonamide-bearing imidazole derivatives containing 4-chloro and 3,4-dichlorosubstituents in benzene ring, and 2-ethylthio and 3-ethyl groups in imidazole ring and were evaluated for their cytotoxicity against human triple-negative breast cancer MDA-MB-231 and human malignant melanoma IGR39 cell lines by MTT assay. They were investigated 4-chloro substituents in benzene ring (C3) and 2-ethylthio in imidazole ring (C4) could contribute to their high anticancer activity (37). A synthesis of bis- and poly(imidazoles) by one-pot three-component reaction of 1,2-diketone with aldehydes and ammonium acetate in the presence of catalytic amount of ZnO nanocatalyst have been reported by Ali et al. The anticancer activities of the reported compounds were evaluated against human breast adenocarcinoma cell line (MCF-7), liver cancer cell line (HepG-2), and epithelial colorectal adenocarcinoma cells (CaCO-2). They resulted compound (C5) with bis (imidazole) analog that incorporated a 4,5-difuran rings exhibited the highest activity against against HepG-2 cancer cells with high selectivity index (38). A series of new 1Hbenzo [d] imidazoles (BBZs) C6 were designed by Stuti et al. as anticancer agents (39).

Phosphatidylinositol 3-kinase (PI3K) is one of the most attractive therapeutic targets for cancer treatment. A series of 2-arylthio- and 2-arylamino-1H-benzo[d]imidazole derivatives of dehydroabietic acid were synthesized by Yang et al. They investigated some imidazole moiety showed significant inhibitory activities against four cancer cell lines (HCT-116, MCF-7, HeLa and HepG2). Out of these, compound (C7) exhibited the most potent activity against all four cancer cell line, and could be considered as a promising PI3Kα inhibitor(40). Zhang and co-workers employed a facile and significant method to synthesize pyrrole–imidazole via a post-Ugi cascade reaction. They were demonstrated that compound C8 exhibited a high potency of anticancer activity in human pancreatic cancer cell lines PANC and ASPC-1(41).

The employment of privileged scaffolds in medicinal chemistry supplies scientists with a solid start in the search for new and improved therapeutic molecules. A library of 2,4,5-triphenyl imidazole derivatives were synthesized and evaluated in vitro as Xanthine oxidase (XO) inhibitors as well as antiproliferative agents. Compound C11 was the most active XO inhibitor with an IC50 of 85.8 µg/mL. Overall, against the six different evaluated cancerous cell lines, molecule (C9) was the most antiproliferative compounds (42). Screening of the imidazole and oxazolone derivatives on six cancer cell lines: HL60, MDA-MB-321, KAIMRC1, KMIRC2, MCF-10A, and HCT8 using the MTT and CellTiter-Glo assays were performed by Sahar. The imidazole derivative compound C10 is a promising anti-cancer agent that modulates microtubule function (43). Anti-cytokines (like Interleukin-1), related to p38 MAPK families play an important role in the identification of anti-inflammation agent. Zahra et al. were designed 1-hydroxy-2,4,5-triaryl imidazole derivatives as low toxic anti-cytokine agent. Compound C12 were the best inhibitory action and utilized for designing newer anti-cytokine agents and p38α MAP kinase potentially inhibitory action(44).

Table -3-Anticancer activity (C-1 to C-10), Xanthine oxidase inhibitor (C11), p38α MAP kinase inhibitor (C-12)

Structure	Activity	Structure	Activity
 C-1	Anticancer activity	 C-7	Anticancer activity
 C2	Anticancer Activity	 C8	Anticancer Activity
 C3	Anticancer activity	 C9	Anticancer activity
 C4	Anticancer Activity	 C10	Anticancer activity
 C5	Anticancer activity	 C11	Xanthine oxidase inhibitor action
 C6	Anticancer activity	 C12	p38α MAP kinase inhibitory action

Antioxidant activities-

Antar et al. in 2020 synthesized 1,2,4, 5-tetrasubstituted imidazoles through the reaction of equimolar from 1,2- diphenylethane-1,2-dione, ammonium acetate, different aromatic aldehydes, and ethyl glycinate hydrochloride in presence of pyrrolidinium hydrogen sulfate (PHS) ionic liquid catalyst. They were investigated Ethyl 2- (2-(4-chlorophenyl)-4,5-diphenyl-1*H*-imidazol-1-yl) acetate (A1) and 2- (4,5- diphenyl- 2- (thiophen-2-yl)-1*H*-imidazol-1-yl)acetohydrazide (A2) have an in vivo antioxidant activity on experimental animals (rats) (45). New Phenenthro [9,10-d imidazole derivatives (A-6) using Titanium dioxide nanomaterials (TiO2 NPs have been successfully developed by Mahesh et al. which have anti-diabetic and antioxidant activity(46).

Inhibitory activity against SARS-Cov 2-

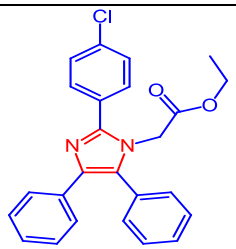
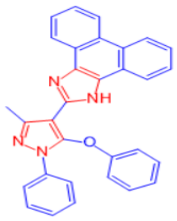
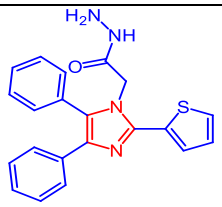
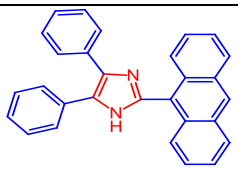
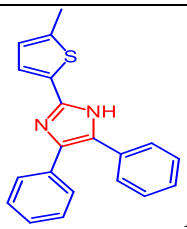
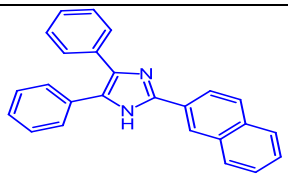
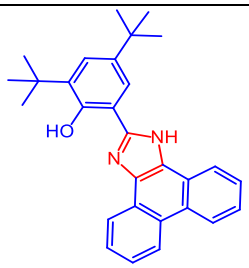
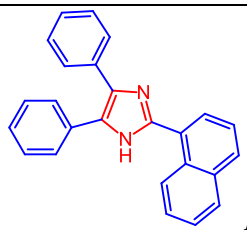
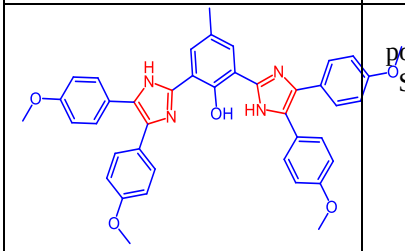
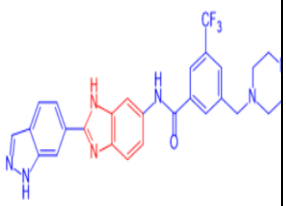
Johson et al. were employed the inhibitory potentials of the newly synthesized imidazoles against SARS-CoV-2 drug targets - main protease (Mpro), spike protein (Spro) and RNA-dependent RNA polymerase (RdRp) through molecular docking analysis.They investigated all these imidazoles showed exciting binding affinities and stability with the target proteins. They reported bisimidazole A5 and phenyl-substituted 1H-imidazoles, A4 scored highest against all targets. A3 scored highest against Mpro and RdRp among the thiophene-imidazoles (47).

Calf thymus- DNA binding affinity-

Gyanendra et al. reported a facile approach to synthesize a new highly versatile heterogeneous catalyst by spontaneous aerial oxidation based on nickel oxide nanocomposites immobilized on surface-functionalized reduced graphene oxide sheets (rGO–NiO-NC) which contributes to the effective and efficient nano-catalyst for the synthesis of imidazole derivatives. Furthermore, the present synthetic methodology was used for the synthesis of highly aromatic imidazole derivatives (A6-A8) whose calf thymus-DNA binding affinities suggest their superior inhibition ability to displace ethidium bromide (EB) (48). Daseul et al. were reported a series of 2-(1H-indazol-6-yl)-1H-benzo[d]imidazol-5-yl benzamide and phenyl urea derivatives as potent FLT3 inhibitors as a therapeutic target for acute myeloid leukaemia (AML). The most potent inhibitor, A-10, demonstrated strong inhibitory

activity against FLT3 and FLT3 mutants with high selectivity profiles over 42 protein kinases (49).

Table-4-Anti-oxidant activity (A-1 to A-2), SARS-Cov-2 inhibitor (A-3 to A-5), Anti-diabetic (A-6), Calf thymus DNA binding affinity (A-7 to A-9), FLT3 inhibitors (A-10).

Structure	Activity	Structure	Activity
 A-1	Antioxidant activity	 A-6	Anti-diabetic and anti-oxidant activity
 A-2	Antioxidant activity	 A-7	calf thymus-DNA binding affinity
 A-3	Inhibitory potential against SARS- cov- 2	 A-8	calf thymus-DNA binding affinity
 A-4	Inhibitory potential against SARS-cov- 2	 A-9	Calf thymus-DNA binding affinity
 A-5	Inhibitory potential against SARS- cov- 2	 A-10	FLT3 inhibitors

Luminescent properties-

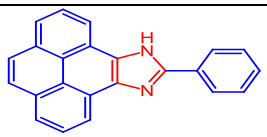
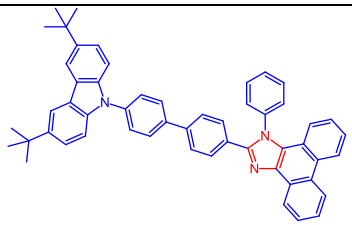
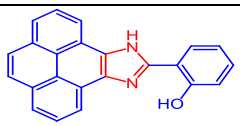
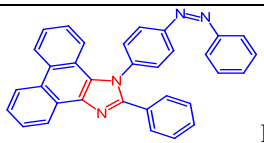
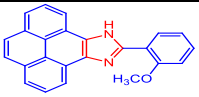
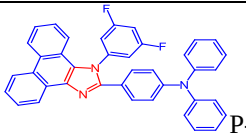
Nichapa et al. in 2021 were successfully synthesized three derivatives of pyreno[4,5-*d*]imidazole (P1-P3) from pyrene-4,5-dione and aromatic aldehydes and evaluated as fluorescent sensors bismuth (III) ion(50). The development of sensors for pH monitoring is of extreme importance in the monitoring of concrete and reinforced concrete structures. Imidazole derivatives are promising probes for pH sensing due to the amphoteric nature of their heterocyclic ring, which can be protonated/deprotonated upon pH changes. Rui et al. synthesized a triarylimidazole (P4) and was used as a dopant in an organic–inorganic hybrid (OIH) sol–gel matrix to obtain a pH-sensitive membrane for further application in optical fibre sensors (OFS) (51).

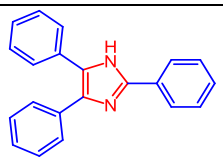
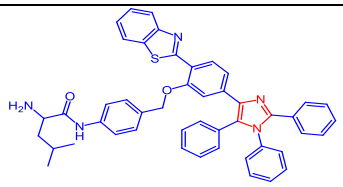
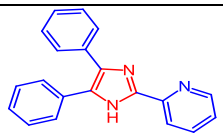
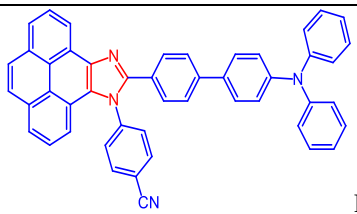
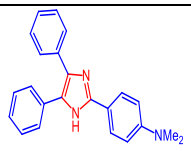
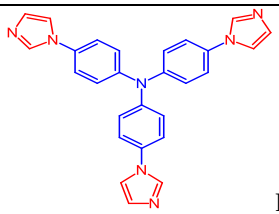
Yu et al. in 2021 designed and synthesized four bipolar blue-emitting materials with carbazole, imidazole, and biphenyl as donor, acceptor, and p bridge, respectively. They investigated among four carbazole-π-imidazole derivatives, 2-(40 -(3,6-di-tert-butyl-9H-carbazol-9- yl)-[1,10 -

biphenyl]-4-yl)-1-phenyl-1H-phenanthro [9,10-d]imidazole (P7),an OLED, affords deep blue electroluminescence (52). An iodine-catalyzed, environmentally benign one pot methodology for the synthesis of diverse substituted imidazoles has been developed by Saswati et al. These imidazole derivatives (P5,P6) show excellent organelle-targetable fluorescent properties both in the solid and solution phase and were modified with lysosome-directing groups (53). Three polycyclic aromatic imidazole derivatives 2-phenyl-1-(4-(phenyldiazenyl) phenyl)-1H-phenanthro[9,10-d]imidazole (PRO,P8), 2-(4-methoxyphenyl)-1-(4-(phenyldiazenyl)phenyl)-1Hphenanthro[9,10-d]imidazole, 2-(2,4-dichlorophenyl)-1- (4-(phenyldiazenyl)phenyl)-1H-phenanthro [9,10-d]imidazole were synthesized with one-pot four component fusion reaction using 1,4-dimethyl pyperazinium dihydrosulfate ([Me2pi][HSO4]2) ionic liquid (IL) catalyst . Yusif et al. were studied the fluorescence properties of (PRO, P8) and the QY was determined as 0.42, which showed it is a good fluorophore (54).

The development of high-efficiency deep-blue emitters is of great importance for full-color organic light-emitting diodes (OLEDs). In this contribution, three difluorine-substituted phenanthro[9,10-d]imidazole derivatives with optimized charge-transfer character and deep-blue emission have been developed by Lia et al. Through fine-tuning of molecular structures, 4'-(1-(3,5-difluorophenyl)-1H-phenanthro[9,10-d]imidazol-2-yl)-N,N-diphenyl-[1,1'-biphenyl]-4-amine (P9) achieved an external quantum efficiency of 8.47% in multilayer OLEDs (55). Huang et al. reported a rational strategy to deliberately construct the first asymmetric tetraarylimidazole-based AIE probe, integrating AIE behavior in synergy with ESIPT character to image endogenous LAP for the first time. It offered good sensitivity and selectivity, and concomitantly, was applied successfully for real-time tracking of LAP in the cisplatin-induced liver injury zebrafish model (56). Library of pyrene[4,5-d]imidazole derivatives, N,N-Diphenyl-4-(9-phenyl-9H-pyreno(4,5-d)-imidazole-10-yl)aniline (PyPA), N,N-Diphenyl-4′-(9-phenyl-9H-pyreno(4,5-d) imidazole-10-yl)-(1,1′-biphenyl)-4-amine (PyPPA), 4-(10-(4′-(Diphenylamino)-(1,1′-biphenyl)-4-yl)-9H-pyreno(4,5-d)imidazole-9-yl)benzonitrile (PyPPAC), and 4-(10-(4-(Diphenylamino) phenyl)-9H pyreno(4,5-d)imidazole-9-yl) benzonitrile (PyPAC), with Hybridized Local and Charge-Transfer State (HLCT) for Highly Efficient Blue and White Organic Light-Emitting Diodes were successfully developed by Liu et al. Among them, the nondoped organic light-emitting diode (OLED) based on PyPPA (P9) displayed maximum external quantum efficiency (EQE) for nondoped blue and white HLCT OLEDs (57). The intermarriage of neutral and tripodal imidazole ligand, tris (4-(1*H*-imidazol-1-yl) phenyl) amine (TIPA), with zinc phosphite yields two hybrid phosphites, $[Zn_2(HPO_3)_2(TIPA)]\cdot 2H_2O$ (1) and $[Zn_3(HPO_3)_3(TIPA)]\cdot 6H_2O$ (2) have been investigated by Jiang et al. It was a new electron-acceptors (EAs), the tri(imidazole)-derivative moiety, used for the design of crystalline hybrid photochromic material (58).

Table-5-Flourescent property (P-1 to P-10)

Structure	Activity	Structure	Activity
 P-1	Flourescent property	 P-7	an OLED, affords deep blue electroluminescence
 P-2	Fluorescent property	 P-8	fluorescence properties
 P-3	Flourescent property	 P-9	Deep blue emitter

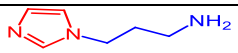
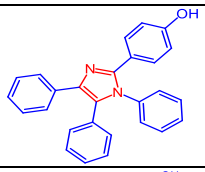
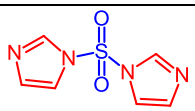
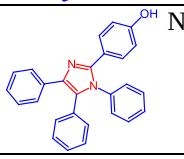
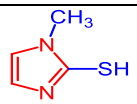
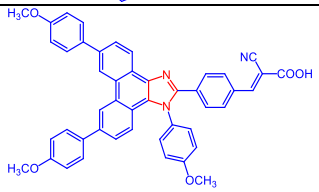
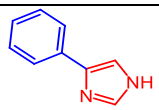
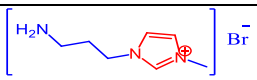
 P-4	Optical fibre sensor	 P-10	Active Flourescent probe
 P-5	fluorescent properties	 P-11	Used as white and blue OLED
 P-6	fluorescent properties	 P-12	Photochromic material

Corrosion inhibition efficiency and antifouling properties-

Ana et al. were investigated the effect of the imidazole derivatives on corrosion behavior of copper in acid rain solution. Result showed that inhibition efficiency of 1,1′-sulfonylimidazole (N2) and 2-mercapto-1-methylimidazole (N3) improves with the increase of inhibitors concentration. SEM–EDS analysis of the copper electrode surface confirmed adsorption of inhibitor on active sites on electrode surface. Adsorption of inhibitors in acid rain solution follows the Langmuir adsorption isotherm (59). Ouakki et al. were interested in studying the effect of the addition of three heterocyclic organic compound derived from imidazole, namely 2-(1,4,5-triphenyl-1H-imidazol-2-yl)phenol (IM-OH), 1,4,5-triphenyl-2-(4-metyoxyphenyl)-1H-imidazole (IM-OCH_3), and 3-methoxy-4-(1,4,5-triphenyl-1H-imidazol-2-yl)phenol (IM-H) on the corrosion inhibition of mild steel in acidic medium H_2SO_4 0.5 M. The obtained results indicate that IM-OH(N4) act as excellent inhibitors for mild steel in H_2SO_4 0.5 M. Levamisole (LMS, N5) and 4-phenylimidazole (PIZ, N6), used as corrosion inhibitors of copper in sulfuric acid solution were explored by electrochemical tests, morphology analysis and theoretical calculation investigated by ting et al. At the concentration of 8 mM, the maximum corrosion inhibition efficiencies of LMS and PIZ are 99.03% and 95.84%, respectively. LMS is a cathodic corrosion inhibitor, while PIZ belongs to a mixed-type corrosion inhibitor(60-61). Implementing new methods to prepare magnetite nanoparticles with a covered or uncovered surface has been, and still is, a significant challenge. 1-(3-aminopropyl) imidazole(N1) with sodium hydroxide was used for the preparation of magnetite nanoparticles have been reported by Nan et al. (62).

Sivanadanam et al. were synthesized a novel series of systematically tailored aryl acyclic (biphenyl dye) and cyclic (phenanthrene dye) and methyl-substituted imidazole derivatives for dye-sensitized solar cells (DSSCs) application. Among the synthesized dyes, dye (N7) having phenanthrene donor and anisole ancillary donor showed highest power conversion efficiency (PCE) of 7.16% (*JSC* = 13.07 mA/cm2, *VOC* = 0.831 V, FF = 0.659) among imidazole-based dyes reported so far. Guo et al. were synthesized neutral membrane 1-(3-Aminopropyl)-imidazole (IM-NH2), 1-(3-Aminopropyl)-3-methylimidazolium bromide (IL-NH2) imidazole derivatives to chemically functionalize membranes. With distinct properties, these imidazole grafts could tailor membrane physicochemical properties and structures to benefit forward osmosis (FO) processes for the removal of 20–100 ppm of Safranin O dye—a common dye employed in the textile industry. Regardless of the dye concentration, the IL-NH_2 (N8) modified membrane exhibited steadily higher permeation performance demonstrating the good antifouling properties and renewability of the newly developed membrane (63-64).

Table -6-Magnetite nanoparticle (N-1), Corrosion inhibition efficiency (N-2 to N-6), Dye sensitizer solar cell (N-7), Antifouling property (N-8).

Structure	Activity	Structure	Activity
 N-1	magnetite nanoparticles	 N-4	Corrosion inhibiton efficiency
 N-2	Corrosion inhibition efficiency	 N-5	Corrosion inhibition efficiency
 N-3	Corrosion inhibition efficiency	 N-7	Dye sensitiser solar cell
 N-6	Corrosion inhibition efficiency	 N-8	Antifouling properties

Conclusion-

Imidazole moiety have wide range of applications in pharmaceutical field and it is used in the treatment of various type of diseases. It also act as corrosion inhibitor for copper moiety and have also found application in OLEDs. On the basis of various literature surveys imidazole molecules show various activities like, anti-bacterial, anti-fungal, anti-inflammatory, anti-parasitic, anti-cancer, anti-viral and anti-tubercular. It have been also found that it shows inhibitory potential against Severe acute respiratory syndrome (SARS) cov-2. So from the above summarised discussion it can be concluded that imidazole is a therapeutically active versatile compound, having diverse pharmacological activities, and still can be further utilized for the future prospective against various diseases or disorders.

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