



Coupling Reactions of Aryldiazonium Salt. Part-XI: Review on Coupling of Aryldiazonium Salts of Aminobenzothiazoles with Aromatic and Heterocyclic Components.

Amol N. Dhake¹, Chandrashekhar J. Patil*¹, Ganesh R. Chaudhari²

¹P. G. Research Center, Department of Chemistry, MTES's Smt. G. G. Khadse College, Muktainagar, Tal. - Muktainagar, Dist. - Jalgaon, M. S. India.

²P. G. Research Center, Department of Chemistry, SES's Arts and Science College, Bhalod, Tal. - Yawal, Dist. - Jalgaon, M. S. India.

*Corresponding author's E-mail: drcjpatil@yahoo.com

Received: 09-07-2021; **Revised:** 25-09-2021; **Accepted:** 02-10-2021; **Published on:** 15-10-2021.

ABSTRACT

The azo compounds synthesized from substituted 2-aminobenzothiazoles were scientifically significant for sensor, nano chemistry and pharmaceutically useful applications. Azo-dyes were very important and useful class of synthetic organic compounds, that have a huge variety of applications.

Keywords: 2-Aminobenzothiazole, azo dyes, diazotization, coupling, Biological Activity.

QUICK RESPONSE CODE →

DOI:

10.47583/ijpsrr.2021.v70i02.011



DOI link: <http://dx.doi.org/10.47583/ijpsrr.2021.v70i02.011>

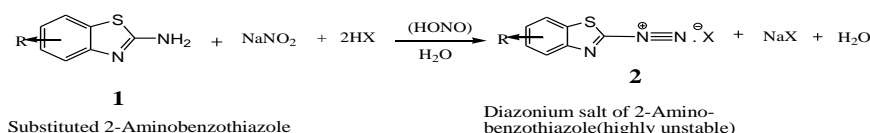
INTRODUCTION

Azo compounds have good fastness and high dyeing properties, also wide applications such as dyeing of textile fibers, cosmetics, plastics, paper, leather and bio-medical studies. Azo compounds were synthesized from aminobenzothiazole and different aromatic or heteroaromatic anilines or phenols. Azo class of compounds or dyes were peculiarly characterized by analysis of the azo group (–N=N–) in their skeleton with aromatic or hetero-aromatic systems. The physio-chemical properties and biological activities makes them useful in variety of applications and in analytical field.

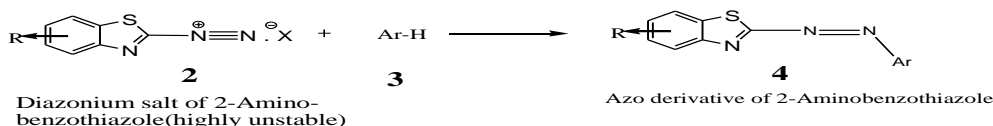
Since, their discovery in 1858¹ many protruding named reactions associated with diazonium salts of arene moiety and have evolved throughout development of one century plus. In 1884, Sandmeyer found out that by treating with

copper chloride, benzene diazonium salt was converted into chlorobenzene². The azo compounds are also valuable in the pharmaceutical and medicinal fields³ and possibly the azo-imine linkage would be accountable for biological activities showed by some Schiff bases as reported⁴. Preparation of most of the azo compounds includes diazotization of a primary (aromatic or heteroaromatic) amine, along with by coupling with coupling agents⁵ viz. pentane-2,4-dione (or acetylacetone)⁶, phenols⁷⁻¹¹.

Literature shows studies on the derivatives in order to explain the newer aptitudes of similar type of compounds. Sometimes azo compounds are frequently described as a chromogen in the literature¹¹. The hydroxy⁷⁻¹¹ or amino-¹² groups are common functional group of organic compounds used as coupling agents¹³. The appearance of various classes of synthetic dyes¹⁴ containing azo dyes occurred due to constant effort. Recently, from our laboratory a review is published¹⁵ pertaining to the reaction of varied diazonium salt with salicylic acid and phenolic compounds, coupling reactions of aryldiazonium salt of various substituted 2-aminobenzothiazoles with Aromatic or Heteroaromatic motifs formed azo dyes¹⁶, the diazotization proceeds with easy processes and ecologically benign situations with high yields of the products¹⁷.



Scheme 1: Typical reaction Mechanism of Diazonium salt synthesis.



Scheme-2: Coupling Reaction of Diazonium salt with aromatic or hetero-aromatic compound.



Literature Survey:

Literature marked that the new azo dyes were synthesized¹⁸ by diazotization of 2-amino benzothiazole and coupling with various aromatic compounds such as naphthol derivatives, N, N-dimethyl aniline and 8-hydroxy quinoline. The structures of the synthesized compound were confirmed by UV-Vis, FT-IR and ¹H NMR spectroscopic methods. Antimicrobial activity by well plate method of these synthesized compounds were studied. Antioxidant studies of the compounds were also accomplished by measuring the DPPH radical scavenging assay and metal chelating method. Some compounds exhibited much better antibacterial activity and having good antioxidant property.

Two series of related donor-acceptor conjugated heterocyclic azo dyes¹⁹ have been prepared by azo coupling reaction. Their electrochemical, optical, and thermal properties have been studied. HRS in dioxane solutions with a fundamental wavelength of 1064 nm was employed to estimate their second-order nonlinear optical properties. These azo dyes exhibited Good to excellent thermal stabilities (235–317 °C). Study showed that modulation of the optical and electronic properties has been accomplished by insertion of the benzothiazole acceptor group in the thienyl pyrrole system to 2 or 6 position of the benzothiazole heterocycle.

New benzothiazole based azo dyes²⁰ and derivatives were prepared by diazotization of 2-amino-6-substituted benzothiazoles and coupled with 4-imino-3,4-dihydro-2H-pyrimido[2,1-b][1,3]benzothiazole-2-one in neutral media. These azo dyes were characterized by various spectroscopic methods like UV-Vis, FTIR, NMR and Mass Spectrometry. Newly synthesized compounds are screened for *in vitro* antimicrobial activities. The few azo compounds exhibited good anti-bacterial activity and anti-fungal activity.

Diazotization of 2-aminobenzothiazole by using sulfuric acid and sodium nitrite to give diazonium salt²¹ which coupled with alkaline salicylaldehyde solution to form azo-aldehyde derivative. The resulting aldehyde was reacted with the various aromatic amines viz. 3-nitroaniline, 4-nitroaniline, 4-methoxyaniline, 4-hydroxyaniline, 4-bromoaniline, 2-methoxyaniline, 4-chloroaniline and 2,4-dichloroaniline using microwave irradiation technique in ethanol to yield eight imines of benzothiazole. The antibacterial activity of these compounds was studied *in vitro* by using two types of bacteria, *Staphylococcus aureus* (Gram-positive) and *Escherichia coli* (Gram-negative). Newly prepared imidazolidines exhibited better activities than gentamycin against *Staphylococcus aureus* while, some compound showed better activities against *Escherichia coli* when compared with that of the control drug.

Diverse diazenyl derivatives were prepared²² by reacting 6-substituted-2-aminobenzothiazole derivatives with 2-naphthol in presence of NaOH. These compounds were

screened for antimicrobial activity against *P. mirabilis*, *S. aureus*, *C. albicans*, *E. coli*, *S. pyrogens* and *A. fumigates* using Amphotericin B and Ciprofloxacin as standard drugs. Few compounds exhibit mild to moderate antimicrobial activity.

Various heteroarylazo disperse dyes were prepared and applied by exhaustion on cellulose acetate were estimated visually and instrumentally²³. A suitable agreement amongst the visual and the instrumental evaluation of these properties was determined. The colour and dyeing properties, temperature range and rate of dyeing of the dyes were studied.

New azo compounds prepared, incorporated with ion of heterocyclic bioactive moiety. Diazo-coupling reaction of the 2-amino benzothiazole with different synthetic phenolic antioxidant²⁴ compounds like phloroglucinol, BHA, 2,4- and 2,6-di-tert-butylphenol. Their structure was confirmed by various spectroscopic techniques, such as UV-Vis, FT-IR, ¹H NMR, ¹³C NMR and LC-(ESI). Their biological effectiveness of the azo compounds was assessed by antioxidant activities like reducing power activity and DPPH radical scavenging activity. Few of them exhibit efficient antioxidant ability. The substantial antibacterial activity showed by the azo compounds against human pathogenic organisms. *In vitro* anticancer and toxicity of some azo compounds were assessed by MTT cytotoxicity assay against lung cancer cell line and normal skin cell line. *In silico* molecular docking study determines the azo compounds owing several crucial interactions with EGFR protein.

Azo-phenol based receptors, having an azo core incorporated with naphthol²⁵ and substituted benzothiazole units were prepared and their complete optical properties have been examined. The nitro derivative displayed, promising optical behaviour in the absence and presence of various transition metal ions in aqueous-acetonitrile solution. It has revealed that greater sensitivity, for the detection of Hg²⁺ ion by greater fluorescence. The characterization of synthesized compounds by emission, absorption, FT-IR, and ¹H NMR spectroscopic methods that showed favourable coordination of Hg²⁺ metal ion with the phenolic oxygen atom, the azo nitrogen atom adjacent to the naphthol ring, and the thiazole nitrogen of benzothiazole ring. Azo-hydrazone type of tautomerism by the photoinduced proton transfer reaction and also metal induced (Hg²⁺ ion) proton transfer reaction from the hydrazone form in the existing organic molecular systems have been examined by photo-irradiation and fluorescence excitation methods, also by ¹H and ¹³C NMR spectra.

Dyes with heterocyclic diazo components have received much attention because of their high tinctorial power and excellent brightness because the dyes prepared from 2-aminobenzothiazoles and 2-aminothiazoles have played a significant role in disperse dye²⁶ technology. Various dyes prepared from several heterocyclic amines with 2-amino-1,3,4-thiadiazoles, 5-amino-1,2,4-thiadiazoles, 5-amino-



isothiazoles, 2-aminoimidazoles, 3-amino-2,1-benzisothiazoles, 2-aminothiophenes, and 5-aminopyrazoles have been reported. Introducing newer method of preparation of heterocyclic diazo components, which are being used to prepare acid dyes for polyamide carpet fibres. Few offers excellent brightness of shade and they are commercially competitive with more expensive anthraquinone type. Also, few have the excellent levelling properties.

7-Amino-3-phenylazo-2-methyl-4H-pyrazolo[1,5-*a*]pyrimidine-5-one was synthesized²⁷ by the reaction of 5-amino-3-methyl-4-phenylazo-1H-pyrazole and 2-aminobenzothiazole with ethyl cyanoacetate in acetic acid at 150°C. Four novel heterocyclic azo disperse dyes were prepared by the coupling of heterocyclic amines-based diazonium chloride with 7-Amino-3-phenylazo-2-methyl-4H-pyrazolo[1,5-*a*]pyrimidine-5-one. The solvatochromic behaviours of related dyes were studied in detail by using ultraviolet-visible absorption spectrometer also these were purified and characterized by elemental analysis, FTIR, and ¹H NMR. Experimental data was supported by density functional theory. The detailed analysis of predicted tautomeric structures was also reported.

The PUF grafted²⁸ with the organic compound Me-BTAP was successfully applied to the pre-concentration of cadmium and lead. The sorbent showed characteristics that are desirable for materials used in solid-phase extraction systems, such as resistance to swelling and changes in pH, low resistance to flow passage, and simplicity in preparation. On application to the preconcentration system, the solid phase provided a simple and sensitive method for the determination of cadmium and lead by FAAS. It is a good alternative to estimate these elements. Extractions of other elements were tested using this sorbent.

The isomer mixture of 5,6- and 6,7-dichloro-2-amino-benzothiazole²⁹ was used as the first component in the synthesis of a series of disazo disperse dyes. The influence of structural variations in the end and middle components on the colour of the dyes is evaluated.

The azo aldehyde was obtained by coupling process between 2-aminobenzothiazole diazonium ion³⁰ and 2-hydroxybenzaldehyde and transformed to the corresponding imines by treating with 3-bromoaniline, 2-chloroaniline, 2,4-dichloroaniline, 4-nitroaniline, and 3-nitroaniline to give imine derivatives¹³. These compounds were inserted in reaction with (NaN₃) to produce novel tetrazoles. The structures of tetrazoles were determined based on FT-IR, NMR, and Mass spectral data.

Some new acids benzothiazole azo dyes classified in groups, obtained from 2-aminobenzothiazoles³¹ 6-substituted with -CH₃, -OCH₃, -Cl, -NO₂ groups which are the diazotizable constituent, coupled with 12 coupling constituents at temperatures of 0-5°C and pH of 1.0 – 1.5 are presented. The sulphonic groups in the dye molecules impart these proper solubilities for dyeing the protein

supports such as chrome tanned leather and furs. The acid benzothiazole azo dyes were characterized by melting point, water solubility, and UV-Vis, MS, and FT-IR spectra.

Some benzothiazole azo compounds³² were prepared and studied for their microbial activity. These compounds were prepared by the condensation of substituted phenyl urea with [4-(4,6-Dichloro-[1,3,5]triazin-2-yloxy)-2,6-dimethyl-quinolin-3-yl]-(6-methoxy-benzothiazol-2-yl)-diazene, which was prepared by the reaction between cyanuric chloride and 3-[(6-methoxy-benzothiazol-2-yl)-diazinyl]-2,6-dimethyl-4-hydroxyquinoline. 3-[(6-methoxy-benzothiazol-2-yl)-diazinyl]-2,6-dimethyl-4-hydroxyquinoline prepared by coupling of 2,6-dimethyl-4-hydroxyquinoline and diazotized 2-amino-6-methoxy benzothiazole and were characterized by elemental analysis and spectral methods.

The optical properties of a series of side-chain liquid crystalline polymers containing azo-benzothiazole³³ mesogen with different terminal substituents (-H, -CH₃, and -OCH₂CH₃) in four organic solvents of varying polarity have been examined by absorption and fluorescence spectral analysis. Solvatochromic studies of these compounds don't show any regular difference in the absorption and emission intensities with varying the polarity of the solvent. Theoretical studies were executed based on diverse solvent correlation methods such as Dimroth-Reichardt and Kamlet-Taft methods to examine the solute-solvent interactions. Both emission and absorption maxima of examined polymers were bathochromically shifted with the removal of 6 position hydrogen atom by electron-donating groups in benzothiazole moiety.

Azo dyes derived from 2-amino-6-(2-chloroethoxy) benzothiazole and 2-amino 4-(2-hydroxy ethoxy)-benzothiazole³⁴ were prepared by diazotization and coupling with different N, N-disubstituted anilines. The dyes were then quaternized with some alkylating agents, dimethyl sulphate, acrylamides, benzenesulfonic acid methyl ester, and epoxy compounds. The new benzothiazolic cationic dyes absorb in the region of 606-636 nm and have molar absorptivity of 40000--80000 L mol⁻¹ cm⁻¹.

Several 2-, 4- and 7-substituted benzothiazole derivatives were synthesized³⁵ to inquire into the relationship between the fluorescence of metal chelates and their structures and to investigate their applications as analytical reagents. The color and fluorescence reactions of the metal ions with benzothiazole derivatives were examined by spot tests. When metal complexes are formed there was the color change of 2-substituted derivatives was more notable than that of 4- and 7-substituted. As fluorometric reagents for metal ions, though, 4-aminobenzothiazole derivatives were superior to 2-amino and 7-aminobenzothiazole derivatives.

The series of heterocyclic azo dyes were prepared with 4-hydroxy coumarin by diazo-coupling reaction³⁶. The



structural aspect of the newly synthesized compounds was accomplished by various physicochemical techniques like UV-Vis, FT-IR, NMR, and mass spectrometry. The computational calculations and geometrical optimization of the synthesized azo dyes were examined with Gaussian software through the help of the DFT method using a 6-31G (d,p) basis set at the gaseous phase. Similarly, the quantum chemical parameters were estimated to know the structural activity concept of the dyes. The pharmacological efficiency of the azo dyes was examined by antitubercular, antimicrobial, DNA cleavage. The synthesized compounds exhibited significant inhibitory activity against tested microbes. Further, the in silico molecular docking displayed effective binding properties of the compounds against the RpsA target receptor.

The new azo derivative of 2,5-dihydroxy-3-undecyl-1,4-benzoquinone with 2-aminobenzothiazole was prepared³⁷. The product formed a complex with Mn(III) chloride, nitrate, acetate, and perchlorate. These complexes were found to exhibit enhanced antibacterial, antifungal, and anthelmintic activity than the ligand.

The calamitic liquid crystals involving a benzothiazole ring inside the central core and two various linkage groups have been prepared. Their liquid crystalline properties were studied³⁸ and compared with those of the analogous series of imines. The effect of the linkage group inside the central core has been confirmed to determine the variety of mesomorphism showed by the compounds. The compounds with imine and azo linkages act similarly and show typical nematic and smectic C mesophases. Compounds incorporating an amide linkage show a poorer mesomorphism and mainly present a smectic C mesophase.

Perfluoroalkyls-substituted benzothiazolyl bisazo³⁹ dyes showed higher solubility and greater bathochromicity than the corresponding alkyl derivatives. These dyes exhibited good dichroism (order parameter $S > 0.75$).

Aminothiazoles, benzothiazoles, thiadiazols and thiophenes were diazotised and coupled to N-p-cyanoethyl-N''''-p-hydroxyethylaniline⁴⁰ to give dyes which coloured polyester in orange to blue hues. The colour of the dyes is discussed with respect to the nature of the heterocyclic ring and substituents therein. Solvent effects on the visible absorption maxima of some of the dyes are also reported.

The heterocyclic amines viz. 2-amino-6-methoxy and 2-amino-6-nitrobenzothiazole, 3-amino-5-nitro-[2,1]-benzothiazole, and 2-amino-3,5-dinitrothiophene were diazotized and coupled to substituted N-β-acetoxyethyl anilines to give dyes⁴¹ which colored cellulose acetate in red to deep blue hues. Dyeing and fastness properties of the dyes on cellulose acetate are also reported.

The heteroaryl amines have been prepared from the reaction of aniline derivatives, potassium thiocyanate and bromine in acetic acid. Coupling of diazonium salts of corresponding amines with 2-methylindole led to hetaryl-

azoindole dyes⁴². These dyes have been characterized by UV-Vis, FT-IR and ¹H-NMR spectroscopy. The solvatochromism properties of dyes have been investigated in various solvents. The antimicrobial activity of the synthesized dyes has been estimated against *Bacillus subtilis*, *Escherichia coli*, *Micrococcus leuteus* and *Pseudomonas aeruginosa* bacterial strains. The results exhibited that some of these dyes show good antibacterial activity.

New heterocyclic azo dyes prepared by the diazotization process by using 2-amino-6-ethoxybenzothiazole⁴³ with coupling compounds under suitable experimental conditions. characterization of these compounds has been done by the various analytical methods like UV-Visible absorption spectra, FT-IR, ¹H NMR, ¹³C NMR, elemental analysis and mass spectrometry. Solvatochromism properties of the azo dyes was studied at varied solvents with increasing polarity. The electrochemical properties of the synthesized compounds were examined by using cyclic voltametric method.

Synthesized hydroxyls azo dyes⁴⁴ by diazotization and the proton dissociation constants (pKa) of the dyes in various organic solvent + water mixtures have been determined. The results found were discussed in terms of the solvent characteristic. Effects of H-bonding interactions and solvent basicity on the ionization process have been also examined. In a nutshell, the pKa values of the studied compounds were found to be mostly dependent on both the ratio and the nature of organic co-solvent. In addition, it was very important to identify which structures we are dealing in liquid solutions and how these structures effect physicochemical properties of distinct tautomer and their acidity constants. The theoretical calculations have been done in order to obtain an insight into structure features and physicochemical properties of the compounds under study.

Series of novel dichromophoric dyes based on 2-aminobenzothiazoles⁴⁵ and 3-amino-1,2,4-triazole have been synthesized in high yields. All the dyes were classified as disperse dyes. Also, their electronic spectroscopic properties i.e., high dye-uptakes on polyester, highly extinction coefficients, excellent fastness properties and broad solvatochromic effects have been showed in these new disperse dyes. These synthesized dyes were suitable as pH indicator in the range of 11-13.

Novel azo-benzothiazole dyes⁴⁶ have been synthesized by condensation of 2-nitrosobenzothiazole and 6-nitro-2-nitrosobenzothiazole with aniline, anthranilic acid, 3-hydroxymethylaniline, 2-, 3- and 4-chloroaniline, 4-fluoroaniline, 4-iodoaniline or 4-nitroaniline. The new synthetic method defined is beneficial over the classic diazotization process usually used for the preparation of related disperse dyes, subsequently the existence of an electron-donating group at the para-position of the coupling component is no more a pre-requisite for the completion of the condensation reaction.



Novel azobenzothiazole dyes⁴⁷ obtained by condensation of 2-nitrosobenzothiazoles with several substituted anilines were synthesized and characterized. The effect of solvent polarity on absorption spectra was observed, also the relationship between dye structures and absorption in the UV-visible region examined. These dyes owning an aniline unit which had an o-electron donating group, showed unique absorption properties as exposed by a second, long wavelength absorption band.

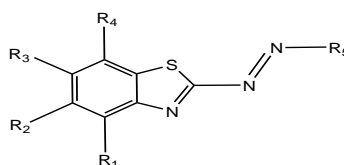
To identify a useful alternative to H₃PO₄, as a medium for diazoting heteroaromatic⁴⁸ amines, a number of organic acids having a similar ionization constant (K_t) were examined. The dichloroacetic acid was an effective solvent for both the diazotization of the synthesized compounds and the synthesis of vital commercial disperse dyes. Disperse Red 177 and Disperse Violet 52 dyes were easily formed in 85-90% yield and very pure form.

The azo compound⁴⁹ was synthesized and characterized by FT-IR, ¹H-NMR, ¹³C-NMR spectral methods. The electrochemical behaviour of the azo compound and its complex with Fe (III) has studied at glassy carbon disk GCE

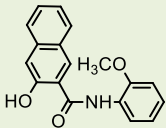
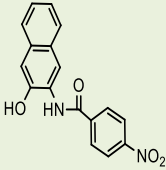
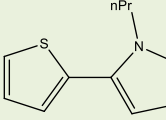
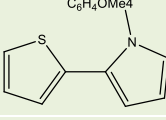
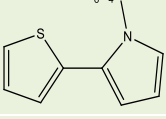
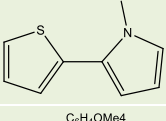
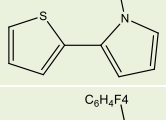
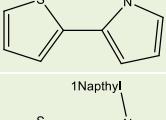
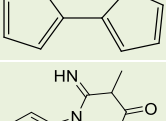
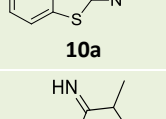
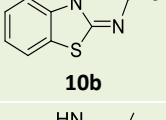
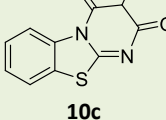
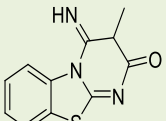
electrode in dissimilar supportive electrolyte at concentration (1M) and scan rate (100mvs⁻¹). A linear correlation (0.1 – 4.0 µg. ml⁻¹) was shown between absorbance at λ_{max} and concentration. The effect of diverse ions on the determination of Iron (III) to explore the selectivity of the process were also studied. The projected scheme was effectively useful to the analysis of blood samples.

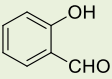
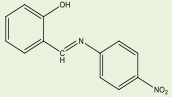
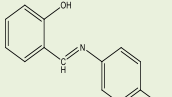
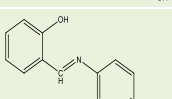
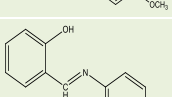
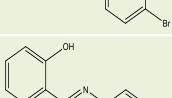
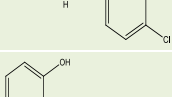
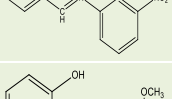
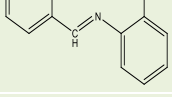
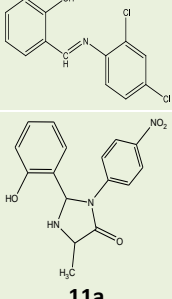
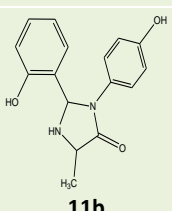
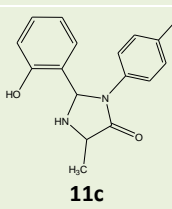
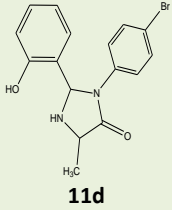
A series of 1-benzothiazolyl-3,5-diphenylformazans with substituents in the 6-position of the benzothiazole⁵⁰ ring were synthesized. The introduction of halogens and methyl and alkoxy groups into this position induces deepening of the color of the corresponding formazans as compared with the unsubstituted benzothiazolyl diphenylformazan. Benzothiazolylazo and 6-methylbenzothiazolylazophenylhydrazones of benzaldehyde were isolated along with formazans in the coupling of benzothiazoline diazonium and 6-methylbenzothiazolinediazonium sulfates with benzaldehyde phenylhydrazone.

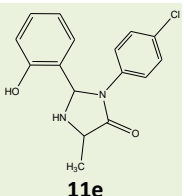
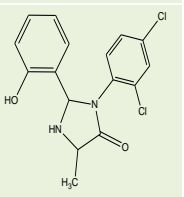
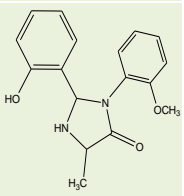
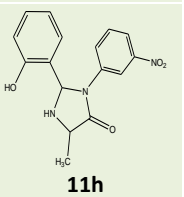
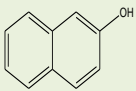
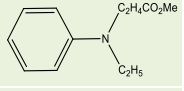
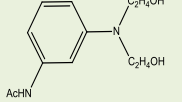
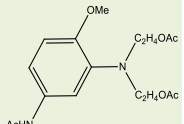
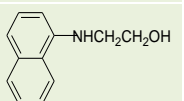
Table 1: Derivatives of aminobenzothiazole-azo compounds, their uses, metal complexes and the applications with references.

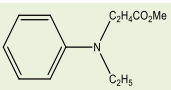
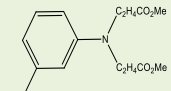
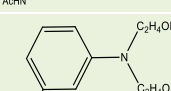
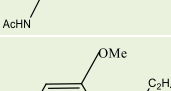
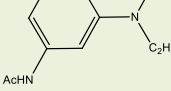
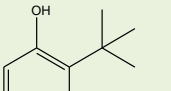
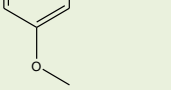
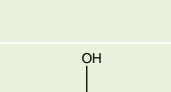
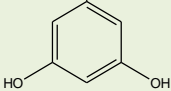
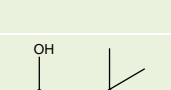


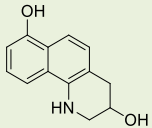
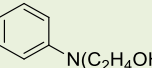
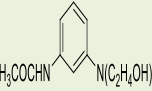
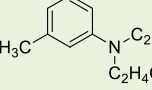
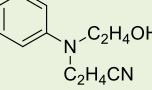
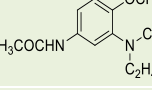
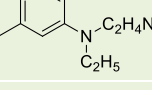
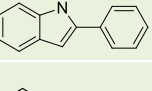
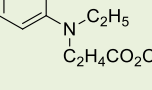
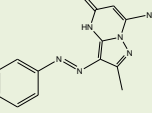
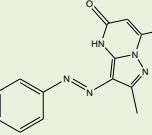
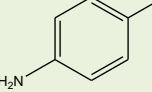
Sr. No.	R ₁	R ₂	R ₃	R ₄	R ₅	Use	Bio	Studies made	Metal	Ref
1	H	H	H	H		Convenient, economical method for synthesis of azo dyes, coupled with naphthol derivatives 8-hydroxy quinolone and N, N-dimethyl aniline to obtain azo dyes.	The synthesized compounds proved to be safer up to upper most dosage and show a significant antimicrobial and in vitro antioxidant activity. Dyes showed a potential antimicrobial activity and antifungal activity against important pathogens like <i>A. Flavus</i> , <i>C. Albicans</i> and <i>C. Keratinophilum</i> , they don't have good activity to the fungus when compare to clinically significant bacteria like <i>P. aeruginosa</i> , <i>E. coli</i> and <i>S. aureus</i> .	UV-Vis FTIR ¹ H-NMR DPPH	-	18
2	H	H	H	H						
3	H	H	H	H						
4	H	H	H	H						
5	H	H	H	H						

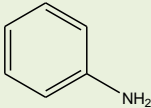
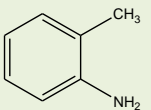
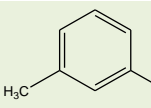
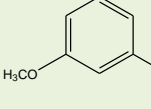
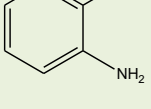
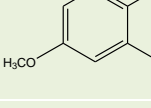
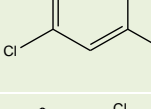
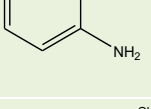
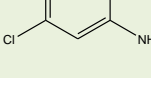
6	H	H	H	H							
7	H	H	H	H							
8	H	H	H	H							
9	H	H	H	H		Series of new azo dyes with normal or reverse polarities are synthesised. By changing position of linkage of benzothiazole heterocycle (2 / 6) to azo bridge, the electrochemical properties and linear, nonlinear optical properties of this well-defined asymmetric push-pull π -conjugated systems can be readily tuned.					
10	H	H	H	H							
11	H	H	CH ₃	H				-	¹ H NMR Electro-chemical Thermal properties	-	19
12	H	H	CH ₃	H							
13	H	H	CH ₃	H							
14	H	H	CH ₃	H							
15	H	H	H	H		Due to interaction of polar solvents and hetero or H atom present in compounds, very strong solvatochromic performance, which was studied in different polar solvents. H bond formation mainly affects chromotropic phenomenon.					
16	H	H	NO ₂	H							
17	H	H	H ₃ CH ₂ C O	H							
18	H	H	H ₃ CO	H							
							Compound 10b and 10d showed better antibacterial activities than others. MIC of synthesized compounds 10c against <i>A. flavus</i> , extremely inhibited organisms were reported in compound 10b showed good MIC 100 μ g/mL against <i>C. albicans</i> .	UV-Vis IR ¹ H-NMR Mass Spectrometry	-	20	

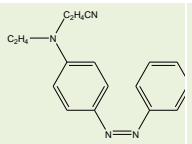
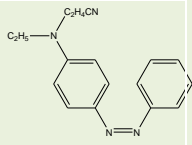
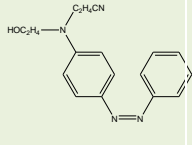
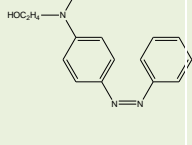
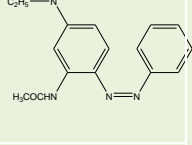
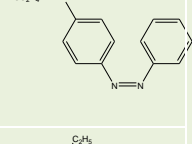
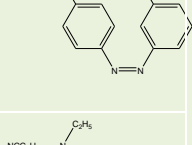
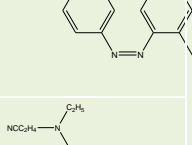
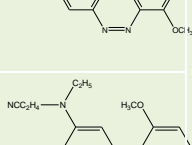
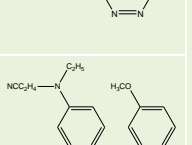
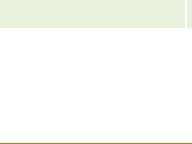
19	H	H	H	H		<p>Imidazolidines also known as tetrahydroimidazoles are biologically active N containing heterocyclic moiety which have been described to shown wide display of significant biological activities.</p>	<p>Newly prepared imidazolidines showed greater activities than gentamycin against Gram-positive bacteria and some compounds also showed better activities against Gram-negative bacteria when compared with that of the control drug (Gentamycin).</p>	<p>FTIR, ¹H-NMR UV-Vis</p>	<p>-</p>	<p>21</p>
20	H	H	H	H						
21	H	H	H	H						
22	H	H	H	H						
23	H	H	H	H						
24	H	H	H	H						
25	H	H	H	H						
26	H	H	H	H						
27	H	H	H	H						
28	H	H	H	H						
29	H	H	H	H						
30	H	H	H	H						
31	H	H	H	H						

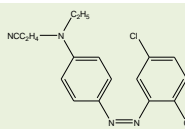
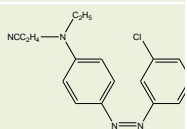
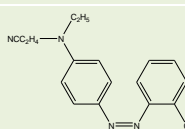
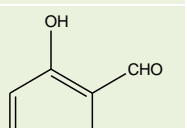
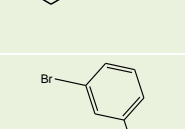
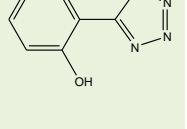
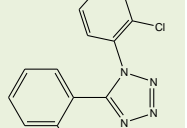
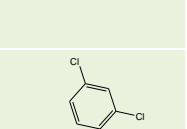
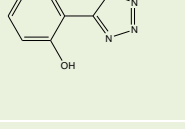
32	H	H	H	H	 11e					
33	H	H	H	H	 11f					
34	H	H	H	H	 11g					
35	H	H	H	H	 11h					
36	H	H	H	H		6-Substituted-2-aminobenzothiazol e can be a lead and strong molecule targeted to introduce new antimicrobials	These compounds were screened for <i>in vitro</i> antimicrobial activity against four pathogenic bacteria viz. <i>S. aureus</i> , <i>S. pyrogens</i> , <i>E. coli</i> and <i>P. mirabilis</i> using Ciprofloxacin as standard drug. <i>In vitro</i> antifungal activity of these compounds was screened against pathogenic fungi <i>C. albicans</i> , and <i>A. fumigatus</i> using Amphotericin B as standard drug.	TLC FT-IR NMR M.P.	22	
37	H	H	CH ₃	H						
38	H	H	OCH ₃	H						
39	H	H	Cl	H						
41	H	H	CH ₃ O	H		Relation between the hues of dyeing (h _o) values and absorption maxima (λ _{max}) of methanol solutions of dyes.	-	UV-Vis ε _{max} ΔE	-	23
42	H	H	CH ₃ O	H						
43	H	H	CH ₃ O	H						
44	H	H	CH ₃ O	H						

45	H	H	NO ₂	H						
46	H	H	NO ₂	H						
47	H	H	NO ₂	H						
48	H	H	NO ₂	H						
49	H	H	H	H		<p>In silico molecular docking study has described that new azo compound bearing variability of tight interactions with effective binding sites of EGFR protein in lung cancer tissues, which supports to design the potent chemotherapy agent. The anticancer effectiveness of new bio effective azo compounds was explored by cytotoxicity activity against lung cancer cell line and observed that both are anticancer active.</p>	<p>Antioxidant activity such as DPPH radical scavenging and reducing power activities showed the new azo compounds includes considerable antiradical property, especially 2-(benzo[d]thiazol-2-ylidiazanyl)-6-(tertbutyl)-4-methoxyphenol and 2-(benzo[d]thiazol-2-ylidiazanyl)benzene-1,3,5-triol azo compounds showed significant antioxidant efficiency. As same in antibacterial evaluation, azo compounds 2-(benzo[d]thiazol-2-ylidiazanyl)-6-(tertbutyl)-4-methoxyphenol and 2-(benzo[d]thiazol-2-ylidiazanyl)benzene-1,3,5-triol shows notable bacterial resistant effect on human pathogens.</p>	<p>UV-Vis FT-IR ¹H-NMR ¹³C-NMR LC-MS</p>	-	24
50	H	H	H	H						
51	H	H	H	H						
52	H	H	H	H						
53	H	H	H	H		<p>An efficient and cost-effective chemo sensor was developed that able to detect Hg²⁺ ion selectively, in aq. medium and on a test paper strip. The chemo sensor was acted as a real time, sensitive, and naked-eye visible colorimetric sensor for Hg²⁺ ion.</p>	-	<p>UV-Vis FT-IR, ¹H-NMR ¹³C-NMR</p>	-	25
54	H	NO ₂	H	H						
55	H	CH ₃	H	H						
56	H	OCH ₃	H	H						
57	H	NO ₂	H	H						

58	H	H	CH ₃ O	H		Azo dyes seem to offer no advantages over the Z-amino isomers. Blue dyes are reported, 3-amino-2-nitro-4-cyano-5-Methyl mercapto thiophene when diazotized and coupled to N,N-diethyl-Inmino acetanilide 3-Aminobenzo thiophenes and 3-amino-pyridines. which are 3-aminothiophenes containing respectively fused benzo and pyridino rings, give orange to red dyes with common aniline-type couplers.	-	-	-	26
59	H	H	CH ₃ O	H						
60	H	H	NO ₂	H						
61	H	H	CH ₃ SO ₂	H						
62	H	H	CH ₃ NH O ₂ S	H						
63	H	H	NO ₂	H						
64	H	H	CH ₃	H						
65	H	H	CH ₃ O	H						
66	H	H	NO ₂	H						
67	H	H	H	H		New heterocyclic azo dyes were Prepared and solvatochromic behaviours of dyes were studied by using ultraviolet-visible absorption spectrometer. The experimental data were supported by density functional theory using b3lyp/cc-pvtz level calculations, and a detailed analysis of predicted tautomeric structures was made	-	UV-Vis Elemental analysis FTIR ¹ H NMR	-	27
68	H	H	OMe	H						
69	H	H	Me	H		The sorbent showed characteristics that are desirable for materials used in solid phase extraction systems, such as resistance to swelling and	-	FT-IR Differential thermal analysis (DTA) Thermogravimetric analysis (TGA)	Zn(II) Hg(II) Cd(II) U(VI) Ag(I)	28

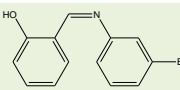
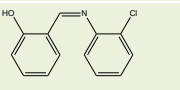
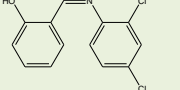
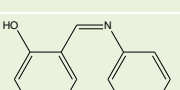
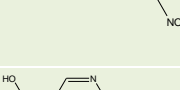
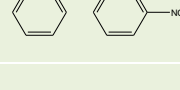
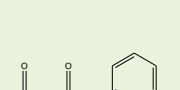

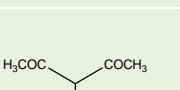
						variations in pH, low resistance to flow passage and simplicity in preparation. Also, when applied to preconcentration system, solid phase providing a simple and sensitive method for determination of cadmium and lead by FAAS. The synthesized material is a good alternative for the determination of these elements.				
70	H	Cl	Cl	H		Estimation of substituent effects on colour of dyes. Diazotisation - coupling process of mono azo intermediates retaining essentially aqueous phase systems suitable for 4-aminoazobenzene based dis azo some dyes were unsatisfactory,	-	UV-Vis, Mass Spectra, Column Chromatography	-	29
71	H	Cl	Cl	H						
72	H	Cl	Cl	H						
73	H	Cl	Cl	H						
74	H	Cl	Cl	H						
75	H	Cl	Cl	H						
76	H	Cl	Cl	H						
77	H	Cl	Cl	H						
78	H	Cl	Cl	H						

79	H	Cl	Cl	H					
80	H	Cl	Cl	H					
81	H	Cl	Cl	H					
82	H	Cl	Cl	H					
83	H	Cl	Cl	H					
84	H	Cl	Cl	H					
85	H	Cl	Cl	H					
86	H	Cl	Cl	H					
87	H	Cl	Cl	H					
88	H	Cl	Cl	H					
89	H	Cl	Cl	H					

90	H	Cl	Cl	H							
91	H	Cl	Cl	H							
92	H	Cl	Cl	H							
93	H	H	H	H							
94	H	H	H	H		<p>The azo dyes were synthesized by coupling of diazonium ion with salicylaldehyde, then imines were prepared by reaction with various aniline. These imines were inserted in reaction with NaN_3 to form tetrazoles. Reactions rates of these tetrazoles were increased with decreasing the electron withdrawal caused by substituent in benzene.</p>					
95	H	H	H	H							
96	H	H	H	H							
97	H	H	H	H							
98	H	H	H	H							

$^1\text{H-NMR}$
Mass
spectra
FT-IR

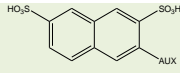
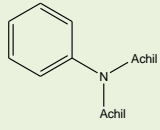
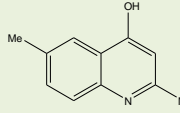
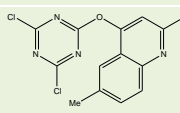
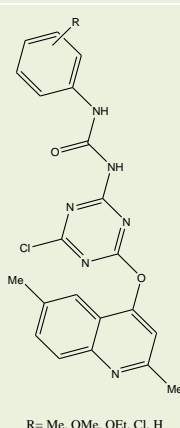
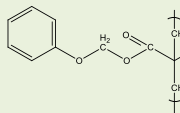
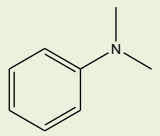
30

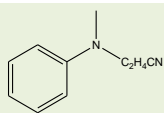
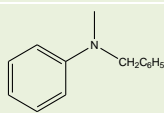
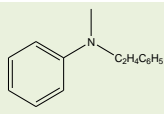
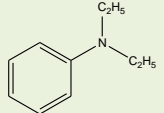
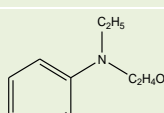
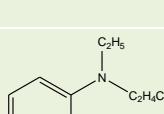
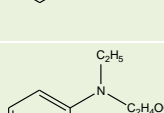
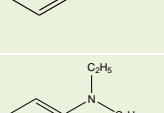
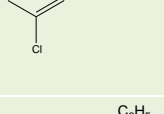
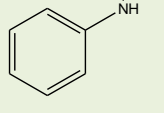
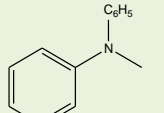
99	H	H	H	H						
100	H	H	H	H						
101	H	H	H	H						
102	H	H	H	H						
103	H	H	H	H						
104	H	SO ₃ H	Me	H						
105	H	SO ₃ H	OMe	H						
106	H	SO ₃ H	Cl	H						
107	H	SO ₃ H	NO ₂	H						
108	H	SO ₃ H	Me	H						
109	H	SO ₃ H	OMe	H						
110	H	SO ₃ H	Cl	H						
111	H	SO ₃ H	NO ₂	H						
112	H	SO ₃ H	Me	H						
113	H	SO ₃ H	OMe	H						
114	H	SO ₃ H	Cl	H						
115	H	SO ₃ H	NO ₂	H						
116	H	SO ₃ H	Me	H						
117	H	SO ₃ H	OMe	H						
118	H	SO ₃ H	Cl	H						
119	H	SO ₃ H	NO ₂	H						
120	H	SO ₃ H	Me	H						
121	H	SO ₃ H	OMe	H						

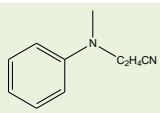
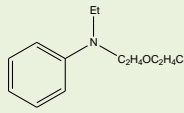
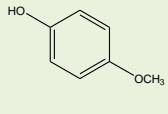
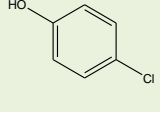
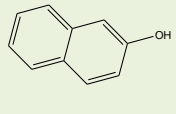
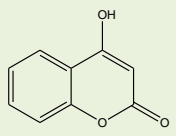
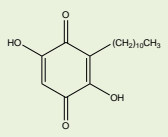
Number of new acids benzothiazole azo dyes were prepared. The sulphonic groups in dyes impart these proper solubilities for dyeing protein supports such as chrome tanned leather and furs.

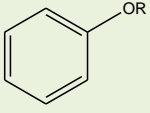
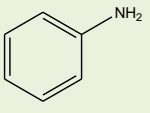
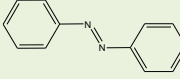
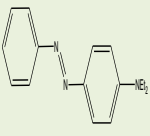
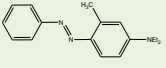
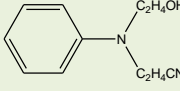
M.P.
UV-Vis
Mass
spectra
FTIR

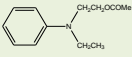
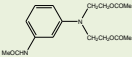
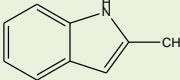
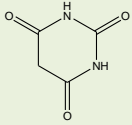
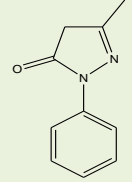
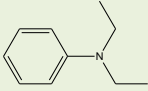
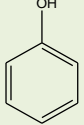
31

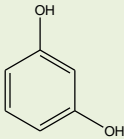
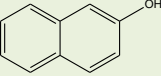
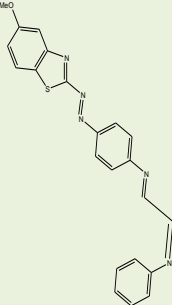
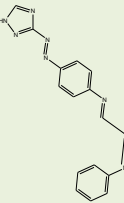
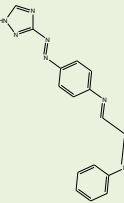
122	H	SO ₃ H	Cl	H							
123	H	SO ₃ H	NO ₂	H	AUX=OH, NH ₂						
124	H	SO ₃ H	Me	H							
125	H	SO ₃ H	OMe	H							
126	H	SO ₃ H	Cl	H	Achil = Me, Et						
127	H	SO ₃ H	NO ₂	H							
128	H	H	OMe	H		Synthesized molecules were toxic against the bacteria. The comparison of antibacterial and antifungal activity of these molecules with standard drugs shows that the presence of methoxy and halogen (-Cl) groups in the phenyl ring increases the antimicrobial activity. Their potency has been found to be lower than that of standard drugs, but their acute toxicity is significantly lower.	Synthesized compounds were screened for antifungal activity against <i>C. albicans</i> , <i>A. Niger</i> by plate diffusion method and antibacterial activities of compounds were studied against Gram-negative bacteria <i>E. coli</i> & <i>S. typhi</i> and Gram-positive bacteria <i>S. pyogenes</i> & <i>S. aureus</i>	FT-IR, ¹ H NMR Mass spectra	-	32	
129	H	H	OMe	H							
130	H	H	OMe	H	 R= Me, OMe, OEt, Cl, H						
131	H	H	H	H		Solvatochromic studies were made of these compounds and they did not show any regular variation on the absorption and emission intensities with varying the polarity of solvent.					
132	H	H	CH ₃	H							
133	H	H	OCH ₂ C H ₃	H				¹ H NMR ¹³ C NMR UV-Vis and Fluorescence	-	33	
134	H	H	ClC ₂ H ₄ O	H		The synthesised dyes were quaternized with various alkylating agents and molar			UV-Vis NMR FTIR Elemental		34

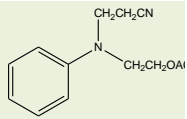
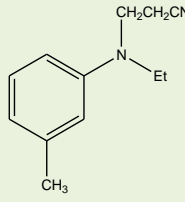
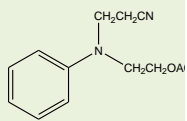
135	H	H	ClC_2H_4 O	H		absorptivity of these dyes were evaluated.			Analysis s
136	H	H	ClC_2H_4 O	H					
137	H	H	ClC_2H_4 O	H					
138	H	H	ClC_2H_4 O	H					
139	H	H	ClC_2H_4 O	H					
140	H	H	ClC_2H_4 O	H					
141	H	H	ClC_2H_4 O	H					
142	H	H	ClC_2H_4 O	H					
143	H	H	ClC_2H_4 O	H					
144	H	H	ClC_2H_4 O	H					
145	HO C2 H4 O	H	H	H					

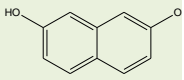
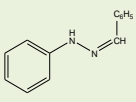
146	HO C ₂ H ₄ O	H	H	H						
147	HO C ₂ H ₄ O	H	H	H						
148	H	H	H	H		The colour and fluorescence reactions of metal ions with benzothiazole derivatives were studied through spot tests. On formation of metal complexes in solution, colour change of 2-substituted derivatives was more notable than that of 4- and 7-substituted. As fluorometric reagents for metal ions, though, 4-aminobenzothiazole derivatives were superior to 2-amino and 7-aminobenzothiazole derivatives.	-	-	Co II Mn II Cu II Zn II Ni II Hg II Cd II Bi III Ag I Pb II	35
149	H	H	H	H						
150	H	H	H	H						
151	H	H	OC ₂ H ₅	H		The computational calculations and geometrical optimization of the newly synthesized azo dyes were studied. Also, the quantum chemical parameters were evaluated to understand the structural activity concept of the dyes.	Newly prepared compounds were able to show significant inhibitory activity against tested microbes. In silico molecular docking showed effective binding properties of the compounds against RpsA target receptor	UV-Vis FT-IR NMR Mass spectra DFT	-	36
152	H	H	H	H		new azo compounds of embelin with 2-aminobenzothiazole was synthesised. The prepared compound 6-(2'-benzothiazolylazo) embelin (H2ABTE) (I) was complexed with Mn(III) by using chloride, nitrate, acetate	The synthesized complexes were screened for antibacterial, antifungal and anthelmintic activities and the complexes were found to exhibit enhanced activity than the ligand.	-	Mn (III)	37

						and perchlorate as counter anions.					
153	H	H	n-C ₁₀ H ₂₁	H	 R=n-Cn-H _{2n+1} n=3-10	Mesomorphic properties of the dyes were studied and a comparative studied of the influence of the linkage group on the mesomorphism of the materials.	-	¹³ C-NMR ¹ H-NMR Elemental analysis	-	38	
154	H	H	C ₄ H ₉	H							
155	H	H	C ₄ H ₉	H		Synthesised dyes showed higher solubility and greater bathochromicity than corresponding alkyl derivatives, also these dyes showed good dichroism.	-	UV-Vis ¹ H NMR Mass spectra Elemental analysis	-	39	
156	H	H	H	H							
157	H	H	C ₄ H ₉	H							
158	H	H	C ₄ F ₉	H							
159	H	H	C ₆ F ₁₃	H							
160	H	H	C ₄ F ₉ CH ₂ CH ₂ S	H							
161	H	H	C ₄ F ₉ S	H							
162	H	H	C ₄ H ₉	H							
163	H	H	C ₄ F ₉	H							
164	H	H	H	H							
165	Cl	H	H	H							
166	H	H	Cl	H							
167	Br	H	H	H							
168	H	H	Br	H							
169	F	H	H	H							
170	H	H	F	H							
171	SO ₂ Me	H	H	H							
172	H	H	SO ₂ Me	H		The synthesized dyes provide good coloration of polyester and maximum light fastness was apparent in dyes prepared from diazo components involving nitro substituents.	-	M.P. FT-IR ¹ H NMR Elemental analysis	-	40	
173	H	H	CN	H							
174	CF ₃	H	H	H							
175	H	H	CF ₃	H							
176	NO ₂	H	H	H							
177	H	H	NO ₂	H							
178	H	H	SCN	H							
179	H	H	OMe	H							
180	H	H	Me	H							
181	H	H	NHAc	H							
182	NO ₂	H	NO ₂	H							

183	N O ₂	H	SO ₂ Me	H						
184	CF ₃	H	NO ₂	H						
185	H	H	OMe	H		Dyeing and light fastness properties of these dyes were discussed and estimated. These dyes were medium to high uptake on cellulose acetate, excellent wash fastness, and moderate to high light fastness depends on heterocyclic moiety and depth of dyeing.	-	UV-Vis ¹ H NMR Elemental analysis	-	41
186	H	H	NO ₂	H						
187	H	H	OMe	H						
188	H	H	NO ₂	H						
189	H	H	H	H						
190	H	H	Me	H		Solvatochromic properties of synthesized dyes were examined in different solvents, also the antimicrobial activity of these dyes was studied.	The antimicrobial activity of prepared dyes was evaluated against <i>M. leuteus</i> , <i>B. subtilis</i> , <i>E. coli</i> and <i>P. aeruginosa</i> bacterial strains. The results exhibited that some of these dyes are potential antibacterial compounds.	UV-Vis FT-IR ¹ H NMR	-	42
191	H	H	OMe	H						
192	H	H	Cl	H						
193	H	H	Br	H						
194	H	C ₂ H ₄		H						
195	H	H	EtO	H		Synthesized dye shows excellent colouring properties due to presence of chromophores in their skeleton and acts as good electron exchange mediators in redox reactions. Electrochemical behaviour of azo dyes was studied at glassy carbon electrode by using cyclic voltametric method.	-	UV-Vis FT-IR ¹ H NMR ¹³ C NMR Elemental analysis	-	43
196	H	H	EtO	H						
197	H	H	EtO	H						
198	H	H	H	H		The pKa (Proton dissociation constants) values of synthesized compounds were	-	Dihedral angle Dipole moment (D)	-	44

199	H	H	H	H		determine in aqueous buffer solutions containing changing proportions of organic		Electronic absorption spectra		
200	H	H	H	H		solvents of various polarities. Effects of H-bonding interactions and solvent basicity on ionization process were also discussed.				
201	H	H	OMe	H		Solvatochromic effects of various solvents were studied and dyes were excited at 279-355 nm and showed fluorescence emission at a broad range i.e., 428–573 nm with low and medium intensities.	-	UV-Vis FT-IR ¹ H-NMR Elemental analyses	-	45
202	H	H	H	H		Fastness properties of these dyes are good to excellent and three derivatives of 3-azo-1,2,4-triazoles are used as pH indicators in the pH range of 11-13.				
203	H	H	OMe	H						
204	H	H	H	H	C ₆ H ₆	New synthetic method was helpful				
205	H	H	H	H	2-Cl-C ₆ H ₅					
206	H	H	NO ₂	H	3-CH ₂ OH-C ₆ H ₅	for classic diazotization process used for preparation of disperse azo				
207	H	H	NO ₂	H	C ₆ H ₆					
208	H	H	NO ₂	H	2-CO ₂ H-C ₆ H ₅					
209	H	H	NO ₂	H	2-Cl-C ₆ H ₅					
210	H	H	NO ₂	H	3-Cl-C ₆ H ₅	dyes, the presence of an electron-releasing group at para-position, or equivalent, of the coupling				
211	H	H	NO ₂	H	3-CH ₂ OH-C ₆ H ₅	compound is no more a pre-requisite for completion of condensation reaction.		M.P. UV-Vis	-	46
212	H	H	NO ₂	H	4-F-C ₆ H ₅					
213	H	H	NO ₂	H	4-Cl-C ₆ H ₅					
214	H	H	NO ₂	H	4-I-C ₆ H ₅					
215	H	H	NO ₂	H	4-NO ₂ -C ₆ H ₅					
216	H	H	NO ₂	H	4-NO ₂ -C ₆ H ₅	New 2-nitrosobenzothiazole	The effect of solvent polarity on absorption	¹ H NMR ¹³ C NMR	-	47
217	H	H	H	H	2-Cl-C ₆ H ₅					

218	H	H	H	H	2-Cl-C ₆ H ₅	<p>les use as synthons to access New azo benzothiazole dyes through condensation with various aromatic amines, mostly those that containing electron withdrawing groups at the coupling component was extended successfully. Hence, six new azo benzothiazole dyes having electron releasing groups at aniline coupler were synthesized in moderate to good yields.</p>	spectra were studied.	Mass spectra FTIR UV-Vis		
219	H	H	H	H	3-Cl-C ₆ H ₅					
220	H	H	H	H	4-Cl-C ₆ H ₅					
221	H	H	H	H	3-Cl-C ₆ H ₅					
222	H	H	H	H	4-I-C ₆ H ₅					
223	H	H	H	H	3-CH ₂ OH-C ₆ H ₅					
224	H	H	H	H	4-F-C ₆ H ₅					
225	H	H	H	H	4-NO ₂ -C ₆ H ₅					
226	H	H	H	H	4-NHCOCH ₃ -C ₆ H ₅					
227	H	H	H	H	2-NHCOCH ₃ -C ₆ H ₅					
228	H	H	H	H	2-OCH ₃ -C ₆ H ₅					
229	H	H	H	H	4-OCH ₃ -C ₆ H ₅					
230	H	H	H	H	2-SCH ₃ -C ₆ H ₅					
231	H	H	H	H	4-SCH ₃ -C ₆ H ₅					
232	H	H	NO ₂	H	2-Cl-C ₆ H ₅					
233	H	H	NO ₂	H	2-Cl-C ₆ H ₅					
234	H	H	NO ₂	H	3-Cl-C ₆ H ₅					
235	H	H	NO ₂	H	4-Cl-C ₆ H ₅					
236	H	H	NO ₂	H	3-Cl-C ₆ H ₅					
237	H	H	NO ₂	H	4-I-C ₆ H ₅					
238	H	H	NO ₂	H	3-CH ₂ OH-C ₆ H ₅					
239	H	H	NO ₂	H	4-F-C ₆ H ₅					
240	H	H	NO ₂	H	4-NO ₂ -C ₆ H ₅					
241	H	H	NO ₂	H	4-NHCOCH ₃ -C ₆ H ₅					
242	H	H	NO ₂	H	2-NHCOCH ₃ -C ₆ H ₅					
243	H	H	NO ₂	H	2-OCH ₃ -C ₆ H ₅					
244	H	H	NO ₂	H	4-OCH ₃ -C ₆ H ₅					
245	H	H	NO ₂	H	2-SCH ₃ -C ₆ H ₅					
246	H	H	NO ₂	H	4-SCH ₃ -C ₆ H ₅					
247	H	H	NO ₂	H		<p>The 2-amino-6-nitrobenzothiazole was diazotized in a medium having 85% aq. Halo acetic acid and conc. Sulphuric acid followed by coupling with different amines to form azo dyes. To find a beneficial alternate to Phosphoric acid, as a medium for diazotising heteroaromatic amines, a number of organic acids</p>	-	¹ H NMR Mass spectra M.P.	-	48
248	H	H	NO ₂	H						
249	H	H	H	H						

						having a similar ionization constant (Kt) were studied				
250	H	H	H	H		Electrochemical properties of azo reagent and complex with Fe (III) was studied. The azo reagent was a maximum absorption at 440 nm reacts with FeCl ₃ .6H ₂ O at room temperature to give a colored complex at pH 6. The effect of pH on absorption of complex formed by reaction of reagent with Fe(III) was studied at various pH.	-	FT-IR ¹ H-NMR ¹³ C NMR	Fe (III)	49
251	H	H	H	H		Benzothiazolyl azo and 6-methyl benzothiazolyl azo phenylhydrazones of benzaldehyde were prepared with formazans in the coupling of benzothiazoline and 6-methyl benzothiazoline diazonium sulfates with benzaldehyde phenylhydrazone. The synthesized compound form stable complexes with different metals.				
252	H	H	Me	H			-	M.P. Elemental Analysis	Cu Ni Zn Co	50

Abbreviations:*B. subtilis* : *Bacillus subtilis**E. coli* : *Escherichia coli**P. aeruginosa* : *Pseudomonas aeruginosa**S. aureus* : *Staphylococcus aureus**S. pyogenes* : *Streptococcus pyogenes**C. albicans* : *Candida albicans*

FTIR : Fourier Transform Infrared Spectroscopy

UV-Vis : Ultra Violet Visible

NMR : Nuclear Magnetic Resonance

TGA : Thermogravimetric Analysis

SAR : Structural Activity Relationship

SmC : Smectic C

N : Nematic

SmA : Smectic A

DFT : Density Functional Theory

TD-DFT : Time Dependent Density Functional Theory



CONCLUSION

The synthesized azo compounds from the 2-aminobenzothiazole are beneficial for many applications. The colours of dyes of azo compounds have different shades and hence used for dyeing of animal textile fibres, for the chelation. Pharmaceutically acceptable and readily soluble salts, polymeric biodegradable prodrug, antifungal, anthelmintic activities and their dyeing ability, for antioxidant activities. In basic solution azo compounds formed normally from easily dissolvable salts with strong color. Azo derivatives also used as prodrugs. Similarly, these compounds also served as building block for many other applicable final products, now-a-days in pharmaceutical field. The present review paper gives an overview or detailed account of azo-benzothiazole synthesized and its use in various reactions.

The compounds synthesized from the azo derivatives of azo- benzothiazole were valuable for many applications dyeing industry, for the ion-exchanging properties of polymers. The antibacterial, antifungal and antioxidant activities.

Thus, this review may be beneficial for many researchers for further developments of azo- benzothiazole and their different reactions to give various applied derivatives in near future.

Acknowledgement: Authors are thankful to the Principal, MTES's Smt. G. G. Khadse College, Muktainagar and the Management, also to the Principal, SES's Art and Science College, Bhalod and the Management, for the facility given for the present work.

REFERENCES

- Griess J. P. Vorläufige Notiz über die Einwirkung von salpetriger Säure auf Amidinitro- und Aminotrophenylsäure. *Annalen Der Chemie Und Pharmacie* 1858; 106(1): 123-125. doi:10.1002/jlac.18581060114.
- Griess J. P., *Philos. Trans. R. Soc. London* 1864; 164: 693.
- Park C., Lim J., Lee Y., Lee B., Kim S., Lee J., Kim S. Optimization and morphology for decolorization of reactive black 5 by *Funalia troglia*. *Enzy. Microb. Tech.* 2007; 40: 1758-1764. doi: 10.1016/j.enzmictec.2006.12.005.
- Chandravadeivelu G., Senniappan P. In-vitro antimicrobial activity of novel derivative of azo dye from cyano ester. *Int. J. Res. Pharm. Chem.* 2011; 1(4): 1082-1086.
- Swati G., Karnawat R., Sharma I. K., Verma P. S. Synthesis, Characterisation and Antimicrobial Screening of Some Azo Compounds. *Int J. Appl. Biol Pharma. Techn.* 2011; 2(2): 332-338.
- Patil C. J., Patil P. A., Patil P. B., Patil M. C. Coupling Reactions Involving Aryldiazonium Salt: Part-I. Chemoselective Synthesis of 3-Oxo-(substituted-2-phenylazo)-butyricacid ethyl ester derivatives and their Antibacterial Activity. *Der. Chemica. Sinica.* 2015; 6(5): 108-114.
- Patil C. J., Talele D. S., Talele S. P., Pohekar P. R., Patil A. S. Coupling Reactions Involving Reactions of Aryldiazonium Salt: Part-IV. Chemoselective Synthesize and Antibacterial Activity of 3-(Substituted-phenylazo)-pentane-2,4-dione. *Int. J. Pharm. Sci. Rev. Res.* 2017; 45(1): 64-73.
- Patil C. J., Talele D. S., Talele S. P., Pohekar P. R., Kolhe D. S. Coupling Reactions Involving Reactions of Aryldiazonium Salt: Part-VII. Product of reaction of aryl diazonium chloride with active methylene group containing moiety. *J. Pharm. Sci. Res.* 2019; 11 (6); 2213-2219.
- Patil C. J., Patil M. C., Rane V., Mahajan K., Nehete C. A. Coupling Reactions Involving Reactions of Aryldiazonium Salts: Part-III. Chemoselective condensation with β -naphthol to Synthesize Sudan-I, its Nitro Derivatives and Antibacterial Potential. *Int. J. Chem. Biol. Phy. Envir. Sci.* 2015; 5(4): 3860-3867.
- Patil C. J., Waghulade G. P., Patil M. C., Patil Mru. C. Coupling Reactions Involving Reactions of Aryldiazonium Salt: Part-V. Chemoselective Synthesis of 1-(Substituted-phenyl)-azo-naphthalene-2-ol. *Int. J. Pharm. Res. Rev.* 2017; 45(2): 21-28.
- Patil C. J., Waghulade G. P., Patil M. C. Coupling Reactions Involving Reactions of Aryldiazonium Salt: Part-VI. Chemoselective Condensation with Resorcinol. *Int. J. Green Herbal Chem.* 2017; 6(2): 5-14. doi: 10.24214/IJGHC/GC/6/2/0514.
- Shridhar A. H., Keshavayya H., Hoskeri H. J., Ras A. Synthesis of some novel bis 1,3,4-oxadiazole fused azo dye derivatives as potent antimicrobial agents. *Int. Res. J. Pure Appl. Chem.* 2011; 1(3): 119-129. doi: 10.9734/IRJPAC/2011/493.
- Nehete C. A., Patil C. J. Coupling Reactions Involving Reactions of Aryldiazonium Salt: Part-IV. Synthesis of Novel Azo-Aniline from Different Substituted Anilines and study of their Biological Activity. *Int. J. Pharma Biol. Arch.* 2017; 8 (1): 20-26.
- Heinrich Z., *Color Chemistry: Syntheses, Properties and Applications of Organic Dyes and Pigments.* VCH, *Angew. Chem. Int. Ed.* 2004; 43: 5290 – 5292, ISBN: 3906390233, 9783906390239.
- Patil, C. J., Nehete C. A. The Azo Derivatives of Salicylic Acid. *Int. J. Pharm. Sci. Rev. Res.* 2015; 33(2): 248-256.
- Patil C. J., Dhake A. N., Chaudhary G. R. The Coupling Reactions of Aryldiazonium salt: Part-X. Review on Coupling of Aryldiazonium Salt of Aminobenzothiazoles with Aromatic or Heteroaromatic motifs, *Orient. J. Chem.* 2021.
- Kyriaki G., Ioannis E., Tsatsaroni, E. Colour and dyeing properties of hetarylazo disperse dyes, Visual and instrumental evaluation. *Am. J. Appl. Chem.* 2014; 2(2): 33-37.
- Keerthi Kumar C. T., Keshavayya J., Rajesh. T and Peethambar S. K., Synthesis, Characterization and Biological Activity of Heterocyclic Azo Dyes Derived from 2-Aminobenzothiazole. *Int. J. Pharma. Sci.* 2013; 5(1): 296-301.
- Raposo M. Manuela M. , Castro R. Cidália M., Fonseca C. Maurício A., Schellenberg P., Belsley M., Design, synthesis, and characterization of the electrochemical, nonlinear optical properties, and theoretical studies of novel thienylpyrrole azo dyes bearing benzothiazole acceptor



- groups. *Tetrahedron* 2011; 67(29): 5189-5198. doi: 10.1016/j.tet.2011.05.053.
20. Maliyappa M.R., J Keshavayya, Shoukat Ali R.A, Harisha S, Synthesis, Characterization, Solvatochromic and Biological studies of novel Benzothiazole based azo dyes, *J. Chem. and Pharm. Sci.*, 2017.
 21. Abood Z. H., Qabel H. A. and Ali H. R., Microwave Synthesis of 2,3-Disubstituted-5-methyl-1,3-imidazolidines-4-one Bearing Benzothiazole Moiety and Elementarily Assessment of Their Antibacterial Action. *J. Phy. Conf. Series*.2018; 1032: 012058. doi :10.1088/1742-6596/1032/1/012058.
 22. Bele D. S., Kothari H. and Singhvi I., Synthesis and antimicrobial activity of some Benzothiazole derivatives. *Int. J. Pharma. Chem. Sci.* 2012; 1(4): 1238-1242.
 23. Chakraborty A., Saha P. K. and Datta C., Synthesis and application of azo-naphthol dyes on wool, silk and nylon fabric, 7th Int. Conf. TEXSCI, 6-8, Liberec, Czech. Rep. 2010.
 24. Prakash S., Somiya G., Elavarasan N., Subashini K., Kanaga S., Dhandapani R., Sivanandam M., Kumaradhas P., Thirunavukkarasu C., Sujatha V., Synthesis and characterization of novel bioactive azo compounds fused with benzothiazole and their versatile biological applications. *J. Mol. Struct.* 2020; 1224: 129016.
 25. Misra A. and Shahid M., Chromo and Fluorogenic Properties of Some Azo-Phenol Derivatives and Recognition of Hg²⁺ Ion in Aqueous Medium by Enhanced Fluorescence. *J. Phys. Chem.* 2010; 114: 16726-16739.
 26. Weaver M. A. and Shuttleworth L., Heterocyclic diazo components. *Dyes and Pigments* 1982; 3(2): 81-121. doi: 10.1016/0143-7208(82)80016-8.
 27. Şener N., Gür M., Çavuş M. S., Zurnaci M., and Şener İ., Synthesis, Characterization, and Theoretical Calculation of New Azo Dyes Derived from [1,5-*a*]Pyrimidine-5-one Having Solvatochromic Properties *J. Heterocyclic Chem.* 2019. DOI 10.1002/jhet.3497.
 28. Rafael Vasconcelos Oliveira and Valfredo Azevedo Lemos, Chapter 12, Synthesis of a New Sorbent Based on Grafted PUF for the Application in the Solid Phase Extraction of Cadmium and Lead. <http://dx.doi.org/10.5772/36501>
 29. Peters A.T., Chisowa E., Disazo disperse dyes derived from 5,6(6,7)-dichloro-2-aminobenzothiazole. *Dyes and pigments* 1996; 31(2): 131–139. doi:10.1016/0143-7208(95)00097-6.
 30. Abood Z. H. , Hussain N. M. A. , Suhail H. A. and Khalaf S. D., Synthesis of some new 1,5-disubstituted tetrazoles from 2-aminobenzothiazole. *AIP Conference Proceedings* 2020; 2290: 030033. <https://doi.org/10.1063/5.0027663>.
 31. Maria-Marcela P., Corneliu C., George M., Tefan T., Luigi S., Coloranþivbenzotiazolici acizi pentru vopsirea suporturilor proteice. *Rev. Chim.*2007; 58(10): 972-9777.
 32. Mistry M. H., Parmar S. J., Desai G. C., Synthesis of some heterocyclic compounds and studies of their antimicrobial efficacy. *J. Chem. Pharm. Res.* 2011; 3 (4): 831-837.
 33. Dzultharnien N.S.F., Karim Md. R., Zahid N. I., Rahman N.M.M.A., Abdullah I. and Salleh N. M., Optical properties of azo aminobenzo thiazole side chain liquid crystalline polymers effects of solvents, substituents & taps. *J. Fluoro.* 2019. doi:10.1007/s10895.
 34. Todor G. D., Dimitar S., Preparation of cationic azo dyes derived from 2-amino-6-(2-chloroethoxy) benzothiazole and 2-amino-4-(2-hydroxyethoxy) benzothiazole. *Dyes and pigments*.1998; 38(1-3): 115–125.doi:10.1016/s0143-7208(97)00091-0.
 35. Naoki S. and Toyozo U., Studies on Benzothiazole Derivatives as Chelating Agents, Syntheses of Benzothiazole Derivatives and Their Reactions with Metal Ions. *Chem. Pharm. Bull.* 1973; 21 (1): 184-190.
 36. Nagaraja O., Bodke Y. D., Pushpavathi I., Kumar S. R., Synthesis, characterization and biological investigations of potentially bioactive heterocyclic compounds containing 4-hydroxy coumarin. *heliyon* 2020; 6: e04245.
 37. Sushama P. G., Dorothy A. M. and Alaudeen M., Antimicrobial and Antifungal Activity of Mn (III) Complexes of 2,5-Dihydroxy-3-undecyl-1,4-benzoquinone Derivative. *Asian J. Chem.* 2007; 19(5): 3403-3406.
 38. Belmar J., Parra M., Zuã Nã Iga C., Peã Rez C., Munã Oz C., New liquid crystals containing the benzothiazol unit: amides and azo compounds. *Liquid Crystals* 2010; 26(3): 389-396. doi:-10.1080/026782999205164.
 39. Matsui M., Kamino Y., Hayashi M., Funabiki K., Shibata K., Muramatsu H., Abe Y. and Kaneko M., Fluorine-containing benzothiazolyl bisazo dyes-their application to guest-host liquid crystal displays. *Liq. Cryst.* 1998; 25(2): 235-240, 1998, doi: 10.1080/026782998206380.
 40. Peters A. T. & G. Adam, Disperse Dyes: 4-Hetarylazo Derivatives from N-P-Cyanoethyl-N-P-Hydroxyethylaniline. *J. Chem. Tech. Biotechnol.* 1992; 53: 301-308.
 41. Georgiadou K. L., Tsatsaroni E. G., Kehayoglou A. H., Synthesis and Characterization of Hetarylazo Disperse Dyes Derived from Substituted N-β-Acetoxyethylanilines— Application on Cellulose Acetate. *J. Appl. Polym. Sci* 2004; 92: 3479–3483.
 42. Yahyazadeh A., Yousefi H., Nezhadmehdipour Z., Synthesis, Spectral Characterization and Antimicrobial Activity of Novel Hetarylazoindole Dyes from Some 2-Aminobenzothiazole Derivatives. *J. Color Sci. Tech.* 2015; 9: 125-133.
 43. Kumar V., Keshavayya J., Pandurangappab M., Ravi B. N., Synthesis, Characterization and Electrochemical investigations of Azo dyes derived from 2-amino-6-ethoxybenzothiazole, *Chem. Data Coll.* 2018; doi: 10.1016/j.cdc.2018.07.002.
 44. Ebead Y. H., Salman H. M. A., Khodari M., Ahmed A. A., Spectrophotometric investigations of the role of the organic solvent on the acid dissociation constants of some azo dyes derived from 2-aminobenzothiazole. *J. Mol. Liq.* 2010; 154: 52–57.
 45. Nourmohammadian F., Novel Aza-Substituted Benzothiazol and 1,2,4-Triazol Dyes: Synthesis, Characterization and Properties. *Prog. Color Colorants Coat.* 2013; 6: 37-49.
 46. Faustino H., El-Shishtawy R. M., Reis L. V., Santos P. F., Almeida P., 2-Nitrosobenzothiazoles: useful synthons for



- new azobenzothiazole dyes. *Tetrahedron Letters* 2008; 49(48): 6907–6909. doi: 10.1016/j.tetlet.2008.09.096.
47. Faustino H., Brannigan C. R., Reis L. V., P. Santos F., Almeida P., Novel azobenzothiazole dyes from 2-nitrosobenzothiazoles. *dyes and pigments* 2009; 83(1): 88–94. doi: 10.1016/j.dyepig.2009.03.018.
48. Jolanta S. G., Harold S. F., A new medium for the diazotization of 2-amino-6-nitrobenzothiazole and 2-aminobenzothiazole. *dyes and pigments* 1992; 20(2): 137–145. doi:10.1016/0143-7208(92)85006-8.
49. Khazal F. A., Hussain J. M. and Khazal H., Novel Cyclic Voltammetry Behavior of 3-Benzothiazol-2-Diazenyl naphthalene-2,7-Diol and Use It for Spectrophotometric Determination of Iron (III) In Blood Sample. *J. Phys. Conf. Ser.*; 2019: 1294 052005. doi:10.1088/1742-6596/1294/5/052005.
50. Shegal L. M., Shegal I. L., and Bednyagina N. P., Research in the Benzazole and Naphthazole Series XXXIII. Unsymmetrical Formazans Containing Substituted Benzothiazole Rings. Plenum Publishing Corporation. 1972; UDC 547.789.6.

Source of Support: The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

For any question relates to this article, please reach us at: editor@globalresearchonline.net

New manuscripts for publication can be submitted at: submit@globalresearchonline.net and submit_ijpsrr@rediffmail.com

