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Cytotoxic investigation of some newly synthesized quinoline-thiazole based azo compounds

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A series of diazotized sulphonamides have undergone azo coupling with the newly synthesized Schiff base ligand (*E*)-N-((2-chloroquinolin-3-yl)methylene)-4-phenylthiazol-2-amine **3a** and (*E*)-4-(4-chlorophenyl)-N-((2-chloroquinolin-3-yl)methylene)-thiazol-2-amine **3b** to give quinoline-thiazole based azo compounds. The solvent effect of the resulting compounds has been studied with different solvents. The structural confirmation of all the synthesized congeners has been carried out by different spectral techniques such as elemental analysis, ^{1}H NMR, FT-IR, UV-Vis and LC-MS. The results of *in vitro* cytotoxic activity of the synthesized compounds has revealed that the compounds N-(4-(((*Z*)-(2-chloroquinolin-3-yl)(4-phenylthiazol-2-ylimino)methyl)diazenyl)phenylsulfonyl)acetamide **5b**, 4-(((*Z*)-(2-chloroquinolin-3-yl)(4-phenylthiazol-2-ylimino) methyl)diazenyl)-benzenesulfonic acid **5d** and 4-(((*Z*)-(4-(4-chlorophenyl) thiazol-2-ylimino) (2-chloroquinolin-3yl)methyl)diazenyl) benzene-sulfonic acid **5h** show excellent cytotoxic action against MCF 7 (human breast cancer cell line) and K562 (CML cell line).

Keywords: Schiff base ligand, spectroscopic, cytotoxic, solvatochromic

Cancer, the emperor of all maladies, is conquering a colossal population globally through decades and it has contextualized itself as the world's second most deadly disease after coronary diseases. It affects the human being due to multiple reasons[1]. Though the researchers have been successful in developing new anticancer molecules by applying various research strategies and drug designing methods in past few years, still a lot many newer and potent molecules are needed for enrichment of the treatment options in chemotherapy.

Most of the reported anticancer drugs are made up of nitrogen based heterocycles. Keeping this in view, Quinoline, one of the nitrogen bearing heterocyclic nucleus can be taken for design of new lead molecules. It occurs in several natural products like the cinchona alkaloids. The first quinoline derivative, quinine is the alkaloid extracted from the cinchona tree used as antimalarial drug[2]. The weak tertiary base, Quinoline was first synthetically extracted in 1834 by Friedlieb Ferdinand Runge from coal tar, the principal source of commercial quinoline. The synthetic feasibility of this aromatic compound makes it a promising nitrogen bearing heterocyclic moiety for designing of newer molecules. Quinoline derivatives have proved their own impact in the field of medicine. They have versatile biological activities including antioxidant, antimalarial, anti-inflammatory, antimicrobial, antifungal, antiprotozoal, analgesic and cardiovascular activity. They have proved their efficacy in cytotoxicity. Some well-known anti-cancer agents like topotecan, irinotecan and camptothecin have the quinoline moiety[3,4].

Thiazole, another nitrogen based heterocycle, which is an azole derivative contains nitrogen and sulphur in its nucleus, has maintained the interest of researchers through decades of historical development of organic synthesis. Their biological activities and unique structures showed several applications in different areas of pharmaceutical and agrochemical research with a significant application in research of material sciences[5,6]. The sulfur and nitrogen based heterocycles are highly stable aromatic compounds which display

physicochemical properties in relevance to the design of newer therapeutic molecules[7]. They have one of their natural origins in thiamine. The potent thiazole nucleus has versatile biological activities such as anti-microbial, anti-viral, anti-fungal, NSAIDs, antibiotics and anti-depressants. Thiazoles also play a vital role in combating cancer. Some major anti-cancer drugs like dasatinib[8], dabrafenib, tiazofurin and bleomycin have proved their potency on the floor of cancer treatment. Also a number of newly synthesized molecules having thiazole nucleus are reported having profound cytotoxic activities.

Schiff bases are nitrogen based organic compounds contain azomethine (-C=N-) group[9]. They are the intermediate synthons, which on cyclization give saturated heterocycles such as azetidinones, thiazolidinones and oxazolidinones. They also exhibit a broad range of biological activities such as antimalarial, antibacterial, antifungal, anticancer and antiviral[10].

The azo groups have -N=N- in its structural framework. Azo compounds are mainly used in the preparation of drugs, dyes and cosmetics. They are synthesized by the azo coupling reaction. Sulpha drugs having versatile therapeutic activities are the primary amines can be taken for azo coupling reaction. These azo compounds have proved their efficacious therapeutic utility as antiseptic[11], antimicrobial[12], antidiabetic[13], antioxidant[14,15], *etc*. Therefore, the development of newer molecules having azo linked heterocyclic scaffolds are a vital sphere of cytotoxic research to-day[16].

This background has encouraged us to synthesize a new series of quinoline-thiazole based azo compounds and to evaluate their cytotoxic activities followed by spectral characterization to project a new horizon in chemotherapeutic treatment.

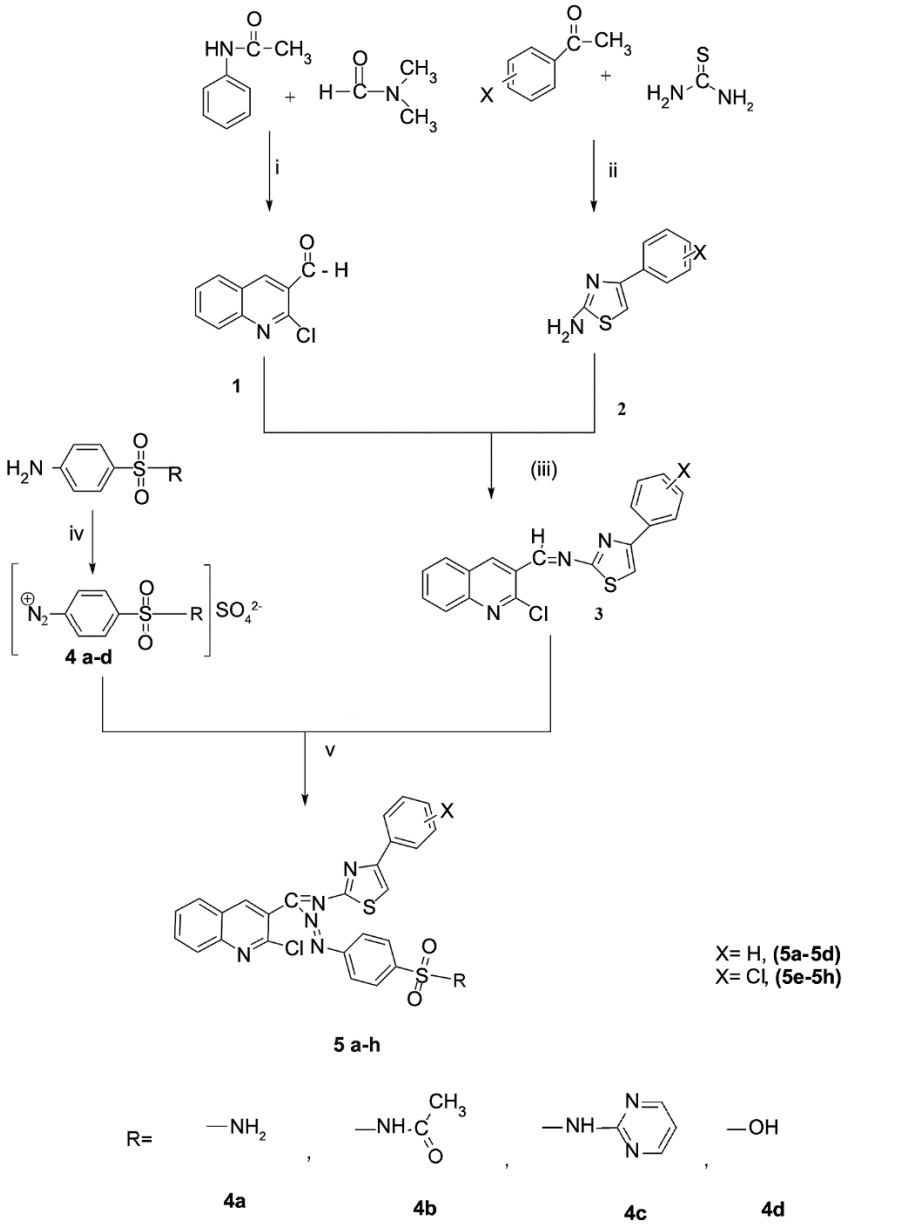
Results and Discussion

Chemistry

The starting precursor CQC (2-choloro quinoline 3-carbaldehyde) **1** was prepared by the mixture of acetanilide and dimethylformamide in phosphorous oxy-trichloride under mild conditions[17]. Another precursor 2-amino-4-substituted phenyl thiazole **2** was prepared according to a reported procedure through the reaction of substituted acetophenone with iodine in presence of thiourea[18]. The compound **1** on further nucleophilic addition with 2-amino-4-substituted phenyl thiazole **2** in the presence of glacial acetic acid in ethanol furnished Schiff bases, (*E*)-N-((2-chloroquinolin-3-yl) methylene)-4-subsituted phenyl thiazol-2-amine **3a-b**. The structures of prepared congeners have been confirmed by FTIR, ^{1}H NMR, UV, LCMS and elemental analysis. In the ^{1}H NMR/FTIR, the board signal of NH_2 and frequency of NH_2 str. present in the spectrum respectively in the compound **2** had disappeared in the Schiff base. These intermediate Schiff base ligands were finally coupled with various diazotised sulphur drugs to give desired azo based quinoline- thiazole molecules (Scheme I). In the final reaction, the diazotised sulphur drugs **4a-d** act as electrophilic species which attack the electron rich species of azomethine group of compounds **3a-b** under mild conditions to give diazenyl based thiazole-quinoline bearing sulphonamides **5a-h**. In the FT-IR spectra of compounds **3a-b**, the aldehydic carbonyl stretching at 1665 cm^{-1} disappeared, which clearly suggested that the formation of Schiff base by condensation of CQC with appropriate amine. The new frequency band appeared at 1612-1617 cm^{-1} which was assigned to azomethine –C=N-str group in the compound **3a-b**. The FT/IR spectral image of compound **3a** is reported in Figure 1. Further, the ^{1}H NMR spectral data of the synthesized Schiff base **3a-b** had appeared sharp singlet protons at δ 9.00 which was assigned to azomethine proton. The significant stretching frequency bands appeared in all synthetic congeners at range of 1339-1327, 1173-1127 and 942-915 cm^{-1} which is attributed to the presence of sulfonyl asymmetrical/symmetrical stretching and S-N str. of sulfonamide respectively. The medium absorption bands appeared at 1493-1457 cm^{-1} which have been assigned to –N=N- group in all the compounds **5a-h**. In all the newly synthesized compounds **5a-h** the azomethine proton disappeared due to an electrophilic substitution at the same position. The ^{1}H NMR spectra of N-[4-{((Z)-(2-chloroquinolin-3-yl) (4-phenylthiazol-2-ylimino) methyl) diazenyl}phenylsulfonyl] acetamide **5b** is illustrated in Figure 2.

The results of electronic absorption spectra are reported in Table I. The compounds **5b**, **5f** and **5g** showed maximum absorption (λ_{max}) at a range of 421-491 nm in all the solvents included, in comparison to other synthesized compounds. The maximum wave length (λ_{max}) observed by the compound 4-[{(*Z*)-(2-chloroquinolin-3-yl) (4-phenylthiazol-2-ylimino) methyl}-diazenyl] benzenesulfonic acid **5d** using DMF is at 280 nm, showed in Figure 3.

The predicted molecular weight of the synthesized compounds was confirmed by LC-MS. The compound



Scheme I — Synthesis of quinoline-thiazole based azo compounds

(*E*)-N-((2-chloroquinolin-3-yl)methylene)-4-phenylthia zol -2-amine **3a** having molecular ion peak at *m/z* 349.13 (M+1) strongly reveals its predicted molecular formula $C_{13}H_9N_3O_4$ reported in Figure 4.

Cytotoxic Screening

The IC_{50} values of the synthesized compounds in cancer cell lines MCF 7 and K562 are presented in Table II. In the cancer cell line MCF 7 the compound **5d** has the lowest IC_{50} value of 15.96 µM. Besides the compounds, **5b** and **5h** have the second and third lowest IC_{50} values of 19.52 µM and 26.71 µM respectively. The performance of compounds in cell line K562 reveals that **5d**, **5b** and **5h** to be most effective with IC_{50} values 13.05 µM, 20.55 µM and 22.12 µM respectively. Figure 5 presents the cytotoxic effects of the synthesized Schiff base compounds **3a-b** and the quinoline-thiazole based azo compound **5d**.

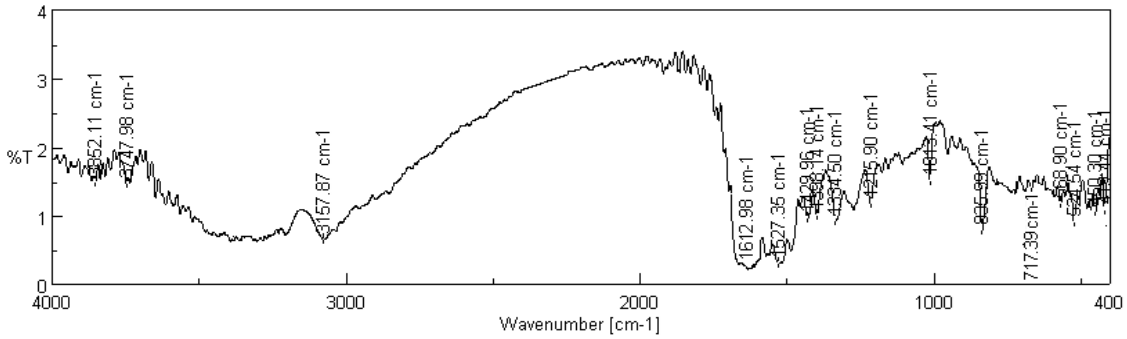


Figure 1 — FT/IR spectra of (*E*)-N-((2-chloroquinolin-3-yl) methylene)-4-phenylthiazol-2-amine **3a**

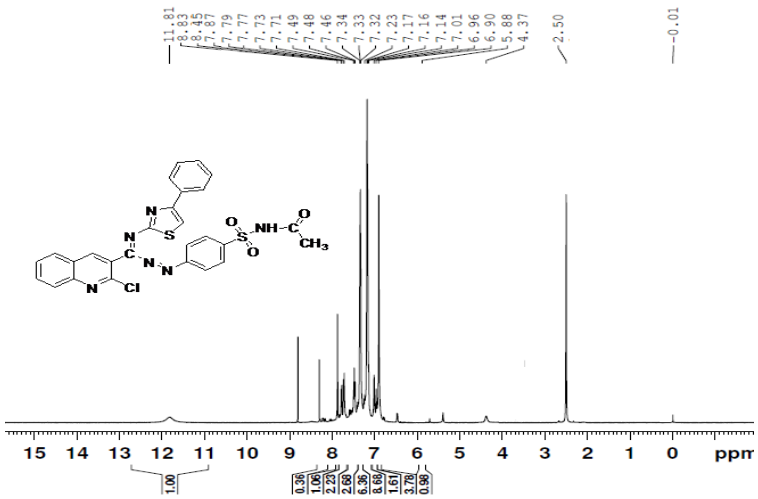


Figure 2 — ^{1}H NMR of N- [4-{ ((*Z*)- (2-chloroquinolin-3-yl) (4-phenylthiazol-2-ylimino) methyl) diazenyl}phenylsulfonyl] acetamide**5b**

Table I — UV-Visible spectral data (λ_{max}) of newly synthesized quinoline-thiazole based Schiff bases(**3a-b**)and quinoline-thiazole based azo compounds (**5a-h**)

Compd	Ethanol	DMF	DMSO	DCM
3a	419	471	476	439
3b	434	439	447	453
5a	286, 294	310	303	380
5b	330, 436	260, 314, 466	482	329, 348, 429
5c	241, 478	267, 278	268	322, 449
5d	271, 331	280, 475	361	328, 347,386
5e	236	252, 293, 480	284	383
5f	421	453	473	431
5g	294, 298, 303, 470	352, 483	491	454
5h	236, 238, 458	243, 314	302	351, 385

The compounds **5d** and **5h** have lower IC_{50} values in K562 than MCF 7. However, the compound **5b** has lower IC_{50} values in MCF 7 than K562. Thus the compounds **5b**, **5d** and **5h** proved to be most effective cytotoxic agents against both the cell lines MCF 7 and K562. The enhancement of cytotoxicity may be due to the attachment of diazotized sulfur molecules with their Schiff base ligands.

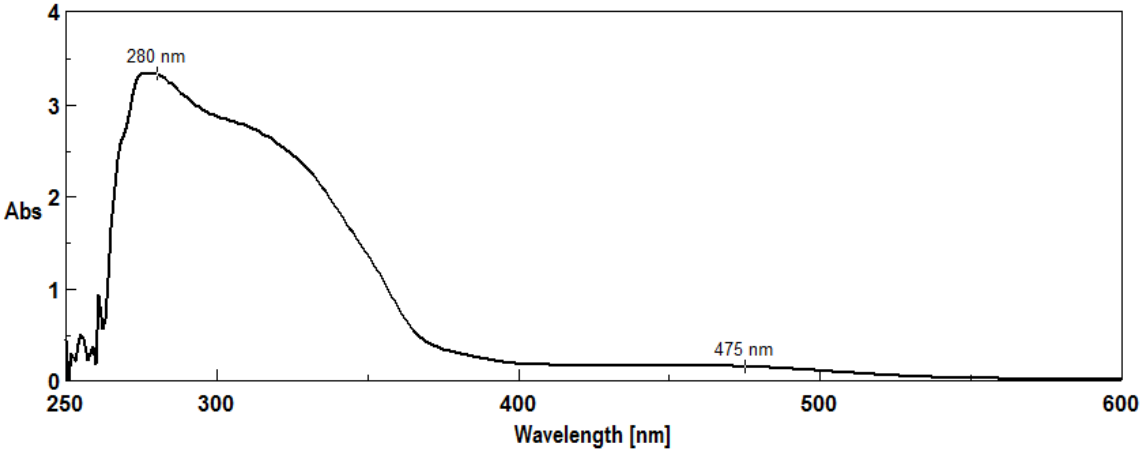


Figure 3 — λ_{max} of 4-[{(*Z*)-(2-chloroquinolin-3-yl) (4-phenylthiazol-2-ylimino)methyl}diazenyl]benzenesulfonic acid**5d**using DMF

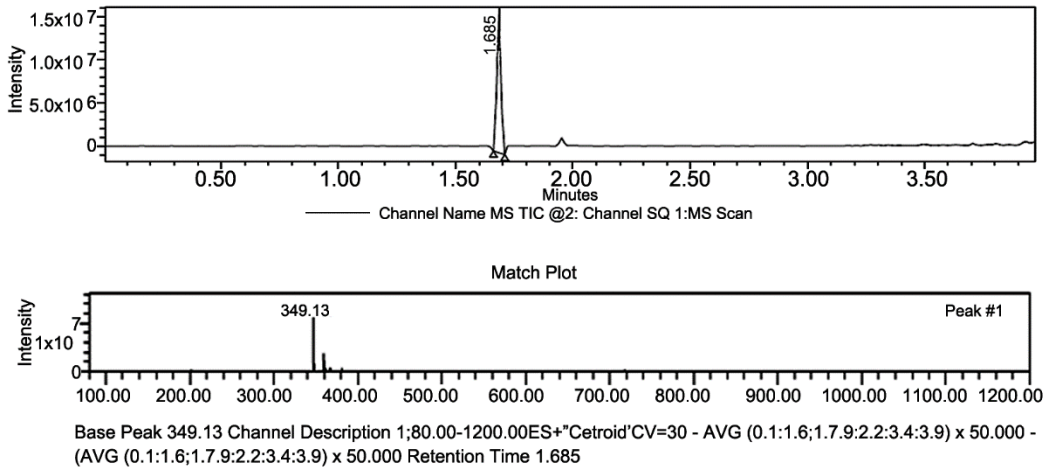


Figure 4 — LC/MS of (*E*)-N-((2-chloroquinolin-3-yl) methylene)-4-phenylthiazol-2-amine **3a**

Experimental Section

The chemicals used in the present experimental work were of synthetic and analytical grade and sourced from Sigma Aldrich and Merck specialties Ltd. (Mumbai, India). The structural analysis of synthesized compounds were done by FT/IR (JASCO FT/IR 4100 Spectrophotometer) using KBr pellets, LC-MS (Shimadzu-Mass spectrophotometer) and ^{1}H NMR (Bruker ^{1}H NMR 400 MHz) using tetramethylsilane as an internal standard.The elemental analysis for C, H, N and S were performed on Perkin-Elmer model 2400 CHNS/O analyzer. The solvatochromic effects of the synthesized compounds were obtained by UV-Vis spectrophotometer (Jasco V-630 Spectrophotometer). The melting points were determined by open capillary method (Elico) and are uncorrected. The *in vitro* cytotoxic activity of the synthesized compounds was investigated by MTT based colorimetric assay method against two human cancer cell lines MCF 7 and K562 using 96-well microtiter plates (Corning, NY, USA). The absorbance was measured at 570 nm using a microtiter plate reader (Synergy HT, BioTek® Instuments Inc. Winooski,VT, USA).

Synthesis of Schiff base ligand 3a-b (Lig)[9]

Equimoles of 2-amino-4-substituted phenylthiazole and 2-chloroquinoline-3-carbaldehyde were taken. Each of the reactant was dissolved in minimum 10 mL of ethanol and mixed together, followed by addition of 2 mL of glacial acetic acid. Then this solution was refluxed for 2 h, cooled to RT and poured into ice cold water. The solid product was collected through filtration and dried. The desired product was purified by recrystallization from ethanol and appeared to be yellow solid crystal.

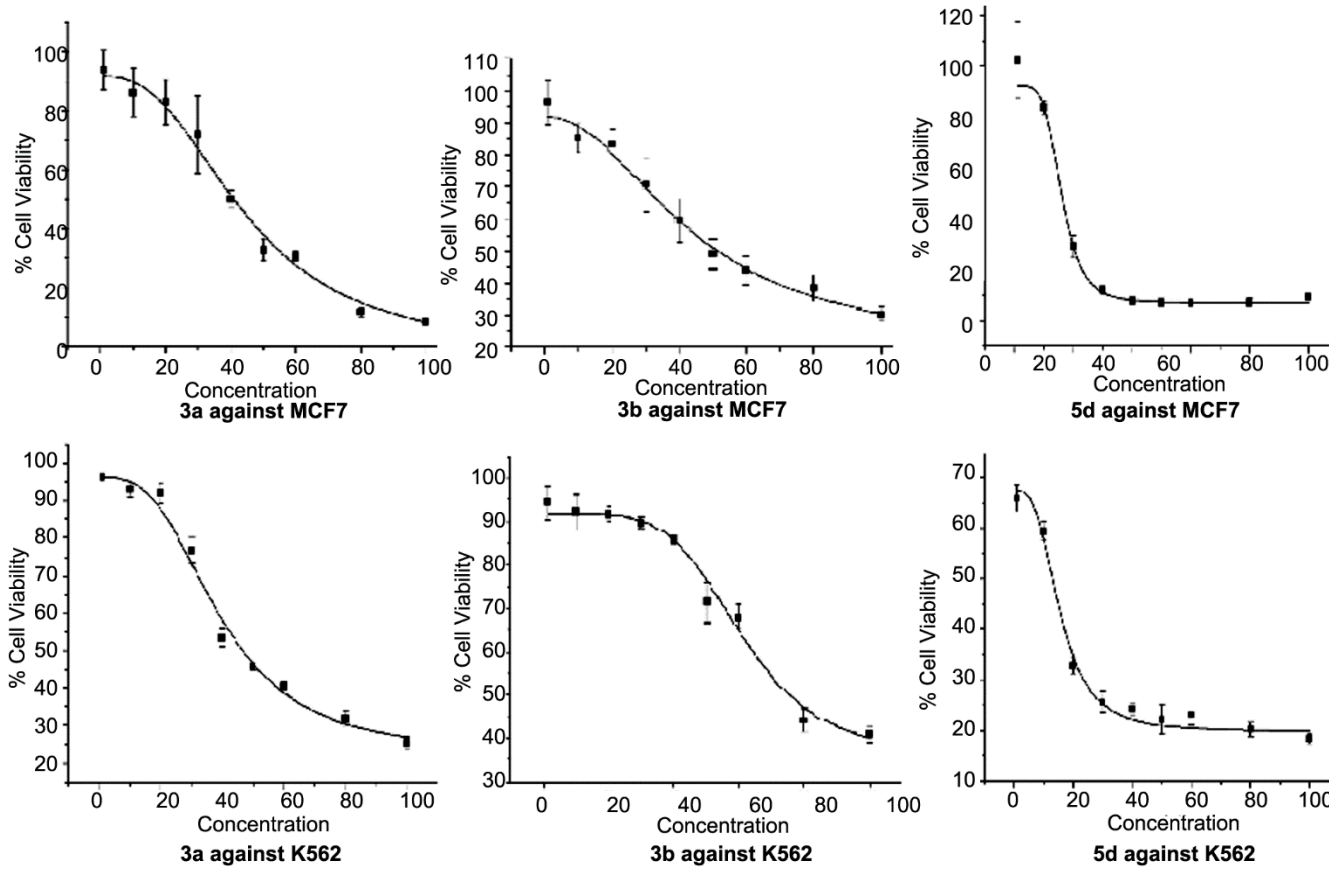


Figure 5 — Cytotoxic effects of the synthesized Schiff base compounds **3a-b** and the quinolinethiazole based azo compound **5d**

Table II — *In vitro* cytotoxicity of compounds **3a-b** and **5a-h**

Compd	IC_{50} values (in μM)	
	MCF 7	K562
3a	39.40	46.68
3b	51.60	75.35
5a	30.09	37.32
5b	19.52	20.55
5c	52.78	35.13
5d	15.96	13.05
5e	33.42	25.26
5f	34.68	32.17
5g	39.50	28.48
5h	26.71	22.12

IC_{50} is defined as the concentration at which there is 50% decrease in cell numbers as compared with that of control culture without an inhibitor.

General method of synthesis ofquinoline-thiazole based azo compounds, 5a-h[19]

Two to three drops of conc. H_2SO_4 (8-9 mmol) was added to a solution of sulpha drug (3 mmol) and water (5 mL) and kept on an ice bath. A cold solution of $NaNO_2$ (0.207 g, 3 mmol) was added drop-wise to it by maintaining the temperature of the reaction up to 5°C. After completion of addition, the solution was kept for 15 min with occasional stirring to complete the diazotization reaction. To the ice cold solution of a above prepared Schiff's base (3 mmol) with ethanol and 10% of 20 mL of aqueous NaOH, individual diazotised sulpha drugs was poured. The resultant mixture was stirred and allowed to stand in an ice bath for 1 h and the *p*H was maintained at 5-6 by occasional and controlled addition of dilute HCl. Then the coloured products obtained were filtered, washed repeatedly with water and dried. The progress of reaction was monitored by TLC using suitable solvent system ethyl acetate and cyclohexanol. Finally the products were purified by recrystallization from ethanol.

(*E*)-N-[(2-Chloroquinolin-3-yl)methylene]-4-phenyl-thiazol-2-amine, 3a:Pale yellow colored powder. Yield 82%. m.p. 207-10°C. R_f: 0.6; UV-Vis (λ max, ethanol): 419 nm; IR (KBr): 1612 (C=N str.), 1527 (C=C str.), 1013 (C-S str.), 717 (C-Cl str.), 3157 cm^{-1} (C-H str. of azomethine); ^1H NMR (DMSO-d_6, 400 MHz): δ 7.43-7.79 (m, 5H, Ar H), 9.33 (s, 1H, Quinolinyl H-4), 8.07 (d, 1H, Quinolinyl H-5), 7.59 (m, 1H, Quinolinyl H-6), 7.78 (m, 1H, Quinolinyl

H-7), 8.00 (d, 1H, Quinolinyl H-8), 8.13 (s, 1H, thiazolyl H-5), 9.005 (-CH=N-); LC-MS (RT, % area): 1.685, 93.62; *m/z*: 349.13 (M+1). Anal. Calcd for $C_{19}H_{12}ClN_3S$: C, 65.23; H, 3.46; N, 12.01; S, 9.17. Found: C, 65.28; H, 3.43; N, 12.09; S, 9.16%.

(*E*)-4-(4-Chlorophenyl)-N-((2-chloroquinolin-3-yl)methylene)thiazol-2-amine, 3b: Pale yellow color powder. Yield 79 %. m.p.197-00°C. R_f: 0.5; UV-Vis (λ max, ethanol): 434 nm; IR (KBr): 1617 (C=N str.), 1512 (C=C str.), 1013 (C-S str.), 739 (C-Cl str.), 835,780 (1,4-disubst. aromatic ring), 3177 cm^{-1} (C-H str. of azomethine); ^{1}H NMR (DMSO-d_6, 400 MHz): δ 7.52-8.00 (m, 4H, Ar H), 9.31 (s, 1H, Quinolinyl H-4), 8.07 (d, 1H, Quinolinyl H-5), 7.59 (m, 1H, Quinolinyl H-6), 7.78 (m, 1H, Quinolinyl H-7), 8.02 (d, 1H, Quinolinyl H-8), 8.13 (s, 1H, thiazolyl H-5), 9.005 (-CH=N-); LC-MS (RT, area %): 1.907, 87.62; *m/z*: 382.2 (M-1). Anal. Calcd for $C_{19}H_{11}Cl_2N_3S$: C, 59.38; H, 2.89; N, 10.93; S, 8.34. Found: C, 59.41; H, 2.91; N, 10.94; S, 8.31%.

4-[{(*Z*)-(2-Chloroquinolin-3-yl)(4-phenylthiazol-2-ylimino)methyl}diazenyl]benzenesulfonamide, 5a: Dark red color powder. Yield 83%. m.p.195-00°C. R_f: 0.6; UV-Vis (λ max, DCM): 380 nm; IR (KBr): 3441 (NH $_{str.}$), 1618 (C=N $_{str.}$/C=C $_{str.}$), 1486 (-N=N-), 1335, 1136 ($SO_{2str.}$ SO_2NH_2), 922 cm^{-1} (S-N $_{str.}$); ^{1}H NMR (DMSO-d_6, 400 MHz): δ 7.18 (d, 1H, Quinolinyl H-8), 7.34 (s, 2H, SO_2NH_2), 7.45- 7.61(m, 5H, Ar H), 7.61 (m, 1H, Quinolinyl H-6), 7.78 (m, 1H, Quinolinyl H-7), 7.78 (m, 1H, Quinolinyl H-7), 7.83-7.86 (m, 4H, diazenyl Ar H), 8.06 (d, 1H, Quinolinyl H-5), 8.19 (s, 1H, thiazolyl H-5), 9.27 (s, 1H, Quinolinyl H-4); LC-MS (RT, area %): 1.954, 83.62; *m/z*: 534.13 (M+1). Anal. Calcd for $C_{25}H_{17}ClN_6O_2S_2$: C, 56.33; H, 3.21; N, 15.77; S, 12.03. Found: C, 56. 36; H, 3.19; N, 15.83; S, 12.15%.

N- [4-{ ((Z)- (2-Chloroquinolin-3-yl) (4-phenyl-thiazol-2-ylimino) methyl) diazenyl} phenylsulfonyl] acetamide, 5b: Dark red color powder. Yield 91%. m.p.123-25°C; UV-Vis (λ $_{max}$, ethanol): 436 nm; R_f: 0.6; IR (KBr): 3309 (NH $_{str.}$), 1650 (C=O $_{str.}$), 1614 (C=N $_{str.}$), 1518 (C=C $_{str.}$), 1473 (-N=N-), 1333, 1148 ($SO_{2str.}$ SO_2NH_2), 922 cm^{-1} (S-N $_{str.}$); ^{1}H NMR (DMSO-d_6, 400 MHz): δ 2.50 (s, 3H, CH_3), 6.90-7.33 (m, 5H, Ar H), 7.14 (d, 1H, Quinolinyl H-8), 7.34- 7.71 (m, 4H, diazenyl Ar H), 7.71 (m, 1H, Quinolinyl H-6), 7.79 (m, 1H, Quinolinyl H-7), 7.87 (d, 1H, Quinolinyl H-5), 8.13 (s, 1H, thiazolyl H-5), 8.83 (s, 1H, Quinolinyl H-4), 11.81 (s, 1H, SO_2NH); LC-MS (RT, area %); 2.236, 84.72; *m/z*: 576.13 (M+1). Anal. Calcd for $C_{27}H_{19}ClN_6O_3S_2$: C, 56.39; H, 3.33; N, 14.61; S, 11.15. Found: C, 56.23; H, 3.27; N, 14.43; S, 11.21%.

4-[{(Z)-(2-Chloroquinolin-3-yl)(4-phenylthiazol-2-ylimino)methyl}diazenyl]-N-(pyrimidin-2-yl) benzenesulfonamide, 5c: Dark red color powder. Yield 93%. m.p.143-45°C. R_f: 0.5; UV-Vis (λ $_{max}$, ethanol): 478 nm; IR (KBr): 3453 (NH $_{str.}$), 1521 (C=C $_{str.}$), 1473 (-N=N-), 1338, 1127 ($SO_{2str.}$ SO_2NH_2), 924 cm^{-1} (S-N $_{str.}$); ^{1}H NMR (DMSO-d_6, 400 MHz): δ 6.93 (m, 1H, pyrimidinyl H-5), 7.15 (d, 1H, Quinolinyl H-8), 7.41-7.69 (m, 5H, Ar H), 7.55 (m, 1H, Quinolinyl H-6), 7.72 (m, 1H, Quinolinyl H-7), 7.81-7.91 (m, 4H, diazenyl Ar H), 7.95 (d, 1H, Quinolinyl H-5), 8.15 (s, 1H, thiazolyl H-5), 8.41 (d, 1H, pyrimidinyl H-4& H-6), 9.21 (s, 1H, Quinolinyl H-4), 11.36 (s, 1H, SO_2NH); LC-MS (RT, area %); 2.138, 83.62; *m/z*: 611.2 (M). Anal. Calcd for $C_{29}H_{19}ClN_8O_2S_2$: C, 57.00; H, 3.13; N, 18.34; S, 10.49. Found: C, 56. 93; H, 3.17; N, 18.44; S, 10.53%.

4-[{(Z)-(2-Chloroquinolin-3-yl)(4-phenylthiazol-2-ylimino)methyl}diazenyl]benzenesulfonic acid, 5d: Brick red color powder. Yield 87%. m.p.237-40°C. R_f: 0.7; UV-Vis (λ $_{max}$, ethanol): 331 nm; IR (KBr): 3320 (OH $_{str.}$), 3185 (intramolecular hydrogen OH $_{str.}$), 1610 (C=C $_{str.}$), 1485 (-N=N-), 1336, 1173 ($SO_{2str.}$ SO_2NH_2), 1037 cm^{-1} (S-O $_{str.}$); ^{1}H NMR (DMSO-d_6, 400 MHz): δ 7.41- 7.79 (m, 5H, Ar H), 7.59 (m, 1H, Quinolinyl H-6), 7.78 (m, 1H, Quinolinyl H-7), 7.83-7.86 (m, 4H, diazenyl Ar H), 7.97 (d, 1H, Quinolinyl H-8), 8.13 (s, 1H, thiazolyl H-5), 8.16 (d, 1H, Quinolinyl H-5), 8.85 (s, 1H, Quinolinyl H-4); LC-MS (RT, area %); 1.878, 84.72; *m/z*: 533.00 (M-1). Anal. Calcd for $C_{25}H_{16}ClN_5O_3S_2$: C, 56.23; H, 3.02; N, 13.11; S, 12.01. Found: C, 56. 19; H, 3.13; N, 13.09; S, 12.12%.

4-[{(Z)-(4-(4-Chlorophenyl)thiazol-2-ylimino)(2-chloroquinolin-3-yl)methyl}diazenyl] benzene-sulfonamide, 5e: Brown color powder. Yield 86%. m.p.120-25°C. R_f: 0.6; UV-Vis (λ $_{max}$, DCM): 383 nm; IR (KBr): 3427 ($NH_{2str.}$), 1520 (C=C $_{str.}$), 1465 (-N=N-), 1339, 1129 ($SO_{2str.}$), 917 cm^{-1} (S-N $_{str.}$); ^{1}H NMR (DMSO-d_6, 400 MHz): δ 7.08 (d, 1H, Quinolinyl H-8), 7.37 (s, 2H, SO_2NH_2), 7.43- 7.91(m, 4H, Ar H), 7.58 (m, 1H, Quinolinyl H-6), 7.82 (m, 1H, Quinolinyl H-7), 7.87-7.89 (m, 4H, diazenyl Ar H), 7.95 (d, 1H, Quinolinyl H-5), 8.15 (s, 1H, thiazolyl H-5), 9.25 (s, 1H, Quinolinyl H-4); LC-MS (RT, area %); 2.826, 87.72; *m/z*: 568.21 (M+1). Anal. Calcd for $C_{25}H_{16}Cl_2N_6O_2S_2$: C, 52.91; H, 2.84; N, 14.81; S, 11.30. Found: C, 52.73; H, 2.69; N, 14.94; S, 11.37%.

N-[4-{ ((Z)-(4- (4-Chlorophenyl) thiazol-2-ylimino) (2-chloroquinolin-3-yl) methyl) diazenyl} phenylsulfonyl] acetamide, 5f: Brick red color powder. Yield 93%. m.p. 137-40°C. R_f: 0.7; UV-Vis (λ_{max}, DCM): 431 nm; IR (KBr): 33310 (NH $_{str.}$), 2922 ($CH_{2str.}$), 1648 (C=O $_{str.}$), 1457 (-N=N-), 1338, 1147 ($SO_{2str.}$ SO_2NH_2), 915 cm^{-1} (S-N $_{str.}$); ^{1}H NMR (DMSO-d_6, 400 MHz): δ 2.51 (s, 3H, CH_3), 6.91-7.41 (m, 4H, Ar H), 7.17 (d, 1H, Quinolinyl H-8), 7.44-7.98 (m, 4H, diazenyl Ar H), 7.73 (m, 1H, Quinolinyl H-6), 7.81 (m, 1H, Quinolinyl H-7), 7.89 (d, 1H, Quinolinyl H-5), 8.16 (s, 1H, thiazolyl H-5), 8.85 (s, 1H, Quinolinyl H-4), 11.83 (s, 1H, SO_2NH); LC-MS (RT, area %); 2.138, 83.62; *m/z*: 607.3 (M-2). Anal. Calcd for $C_{27}H1_8Cl_2N_6O_3S_2$: C, 53.21; H, 2.98; N, 13.79; S, 10.52. Found: C, 53.19; H, 2.99; N, 14.73; S, 10.67%.

4-[{(Z)-(4-(4-Chlorophenyl) thiazol-2-ylimino) (2-chloroquinolin-3-yl) methyl} diazenyl]-N-(pyrimidin-2-yl)benzenesulfonamide, 5g: Dark red color powder. Yield 86%. m.p.145-50°C. R_f: 0.5; UV-Vis (λ_{max}, ethanol): 470 nm; IR (KBr): 3353 (NH $_{str.}$), 1493 (-N=N-), 1327, 1152 ($SO_{2str.}$ SO_2NH_2), 942 (S-N $_{str.}$), 825 cm^{-1} (1,4 disubstitution); ^{1}H NMR (DMSO-d_6, 400 MHz): δ 6.94 (m, 1H, pyrimidinyl H-5), 7.13(d, 1H, Quinolinyl H-8), 7.42-7.89 (m, 4H, Ar H), 7.52 (m, 1H, Quinolinyl H-6), 7.62 (m, 1H, Quinolinyl H-7), 7.81- 7.93 (m, 4H, diazenyl Ar H), 8.01(d, 1H, Quinolinyl H-5), 8.17 (s, 1H, thiazolyl H-5), 8.31 (d, 1H, pyrimidinyl H-4 & H-6), 9.18 (s, 1H, Quinolinyl H-4), 11.26 (s, 1H, SO_2NH); LC-MS (RT, area %); 2.844, 84.72; *m/z*: 646.5 (M+1). Anal. Calcd for $C_{29}H_{18}Cl_2N_8O_2S_2$: C, 53.96; H, 2.81; N, 17.36; S, 9.93. Found: C, 53.77; H, 2.93; N, 17.19; S, 9.79%.

4-[{(Z)- (4-(4-Chlorophenyl) thiazol-2-ylimino) (2-chloroquinolin-3- yl) methyl} diazenyl] benzene-sulfonic acid, 5h: Brown color powder. Yield 89%. m.p.147-50°C. R_f: 0.8; UV-Vis (λ_{max}, ethanol): 458 nm; IR (KBr): 3306 (OH $_{str.}$), 3181 (intramolecular hydrogen OH $_{str.}$), 1617 (C=N, C=C $_{str.}$), 1482 (-N=N-), 1329, 1168 (SO_2 str. SO_2NH_2), 1029 cm^{-1} (S-O $_{str.}$); ^{1}H NMR (DMSO-d_6, 400 MHz): δ 7.43- 7.79 (m, 4H, Ar H), 7.57 (m, 1H, Quinolinyl H-6), 7.81 (m, 1H, Quinolinyl H-7), 7.85-7.88 (m, 4H, diazenyl Ar H), 7.93 (d, 1H, Quinolinyl H-8), 8.14 (s, 1H, thiazolyl H-5), 8.19 (d, 1H, Quinolinyl H-5), 8.84 (s, 1H, Quinolinyl H-4); LC-MS (RT, area %); 1.801, 84.72; *m/z*: 567.9 (M-1). Anal. Calcd for $C_{25}H_{15}Cl_2N_5O_3S_2$: C, 52.82; H, 2.66; N, 12.32; S, 11.28. Found: C, 52.57; H, 2.77; N, 12.44; S, 11.27%.

Cytotoxic investigation[20]

The synthesized compounds were evaluated for their cytotoxic activity by MTT based colorimetric assay against the human breast cancer cell line MCF 7 and the chronic myelogenous leukemia cell line K562. The cells were seeded in 96-well plates at density 2000 cells per well. After the overnight incubation at 37°C, cells were treated with varying concentrations of drugs ranging from 1 µM to 100 µM. The cell viability was determined on second day, following drug treatment using MTT assay. A 100 µL/well MTT solution (5 mg/mL) was added, plates were incubated at 37°C for 3 h and then the media was replaced with 100 µL of DMSO to dissolve the formazan crystals. The absorbance was measured at 570 nm using a microtiter plate reader. The effect of each treatment was calculated as a percentage inhibitionagainst the respective untreated controls.The IC_{50} values were determined by nonlinear regression analysis using the equation for a sigmoid plot through Origin Pro 8 software.

Conclusion

This work comprises of a series of newly synthesized quinoline-thiazole based azo compounds followed by their spectral characterization and cytotoxic evaluation. The Schiff base having unsubstituted 2-amino-4-phenyl thiazole [(*E*)-N-((2-chloroquinolin-3-yl)methylene)-4-phenylthiazol-2-amine] **3a** has major impact on cytotoxic activity than the Schiff base having chloro-substitution at the C4-position of the phenyl ring of 2-amino-4-phenyl thiazole moiety [(*E*)-4-(4-chlorophenyl)-N-((2-chloroquinolin-3-yl)-methylene)thiazol-2-amine] **3b** against both the human cancer cell lines of MCF 7 and K562. A good structure activity relationship (SAR) is found to be observed in the cytotoxic study of the synthesized azo coupled diazotized sulfonamides **5a-h** and their respective Schiff base ligands **3a-b**, which shows that the IC_{50} values are markedly decreased in all of the azo coupled diazotized sulfonamides against K562 in respect to the Schiff based ligands. But in case of MCF 7, all the synthesized azo coupled diazotized sulfonamides showed significant lowering of IC_{50} values except **5c** and **5g** in comparison to the Schiff bases. However the compounds **5b**, **5d** and **5h** are proved to be most effective cytotoxic agents in comparison to the remaining compounds against both the cell lines. But it can be concluded that the compound 4-[{(*Z*)-(2-chloroquinolin-3-yl)(4-phenyl-thiazol-2-ylimino) methyl}

diazenyl]benzenesulfonic acid **5d** is the most promising, having excellent cytotoxic activity against both the tested cell lines MCF 7 and K562 with IC_{50} values 15.96 µM and 13.05 µM respectively. Corroborating the findings of the above discussion it can be concluded that a more structural exploitation of these quinoline-thiazole based azo analogues may provide some challenging anticancer compounds in future.

Supplementary Information

Supplementary information is available in the website http://nopr.niscair.res.in/handle/123456789/60.

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