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The Investigation of nucleophilic substitution reactions of 2,3-dichloro-1,4-naphthoquinone with various nucleophilic reagents

CEMIL IBIS*, AHMED HASSEN SHNTAIF, HAKAN BAHAR and SIBEL SAHINLER AYLA

Department of Chemistry, Faculty of Engineering, Istanbul University, 34320, Avcilar, Istanbul, Turkey

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Abstract: Novel N- , N,S- and N,O- substituted naphthoquinone compounds were prepared by the reactions of 2,3-dichloro-1,4-naphthoquinone **(1)** and the corresponding nucleophiles in the presence of chloroform and triethylamine or ethanol solution of Na_2CO_3. The structures of the novel naphthoquinone compounds were characterized by micro analysis, FT-IR, ^{1}H NMR, ^{13}C NMR, MS and cyclic voltammetry.

Keywords: 1,4-Naphthoquinone; thioethers; amine; indolylquinones

INTRODUCTION

The synthesis of novel quinone derivatives have been taking great attention because of their bright colors and pharmaceutical properties of quinones. [1-3] Quinone-type drugs systems are also developing and many of the drugs clinically approved are quinone related compounds.[4-7] Antibacterial and antifungal activities of some novel naphthoquinone derivatives have been reported before in literature. [8-10]

2,3-Dichloro-1,4-naphthoquinone **(1)** was selected as starting material because it is reasonably stable, readily available and is known as a key synthetic intermediate in organic, medicinal and industrial chemistry. The aim of this study was the synthesis of the quinone derivatives and characterization them with spectral methods.

RESULTS AND DISCUSSION

Chemistry

The reactions of 2,3-dichloro-1,4-naphthoquinone **(1)** with various N- or S-nucleophilles resulted in a substitution of one or both chlorine atoms. [11-12] The

* Corresponding author. E-mail: ibiscml@istanbul.edu.tr
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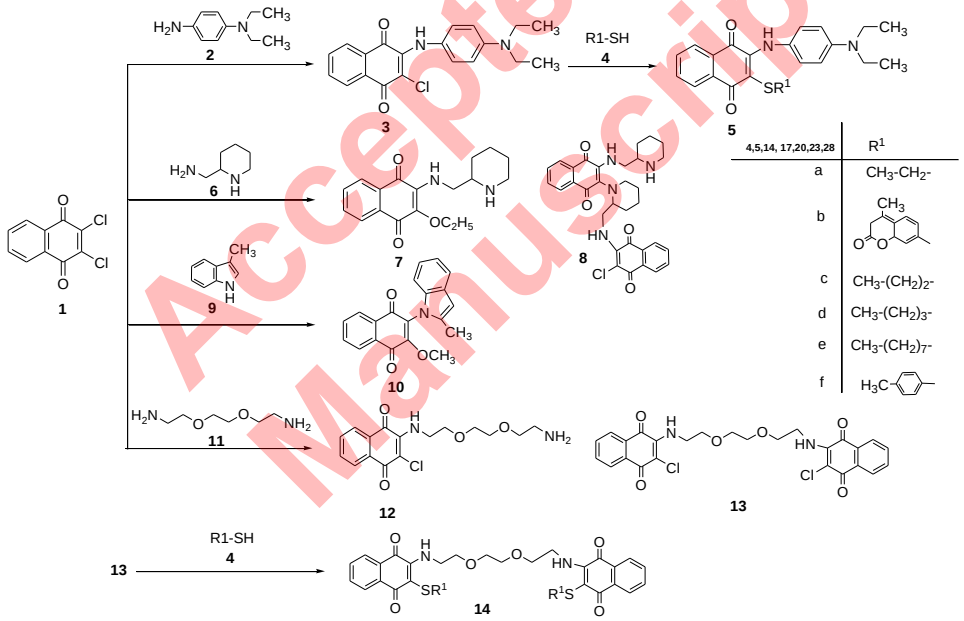
reaction occurs according to addition-elimination mechanism.[13] Some of the novel indolylquinones were also synthesized by using 3-substituated indole derivatives and N- substituted quinonyl derivatives obtained. These substitution reactions of p-chloranile are known from literature. [14-15]

The compound **(3)**[16] was obtained by reaction of **(1)** with (**2)** in chloroform with triethylamine(Et_3N). Novel N-, S- substituted naphthoquinones (**5a-e)** were obtained by the reactions of compound **(3)**[16] and various thiols (**4a-e**). The synthetic strategy for novel compounds was illustrated Scheme 1. The ^{13}C NMR spectrum of compound **(5a)** gave two carbon signals for C=O groups at 179.6 and 179.7 ppm due to the naphthoquinone unit. In the IR spectra of compound **(5b)** lactone carbonyl group was seen at 1734 cm^{-1}while quinone carbonyl group was seen at 1666 cm^{-1}.In the mass spectrum of compounds **(5c)** and **(5d)** the accurate mass measurements of the molecular ion peaks were noticed at m/z 395 and 409 $[M+H]^+$ respectively. The S-CH_2 protons of **(5e)** appeared in the ^1H NMR spectrum as triplets at 2.50 ppm.



Scheme 1. Synthetic pathway for synthesizing novel substitued naphthoquinone derivatives.

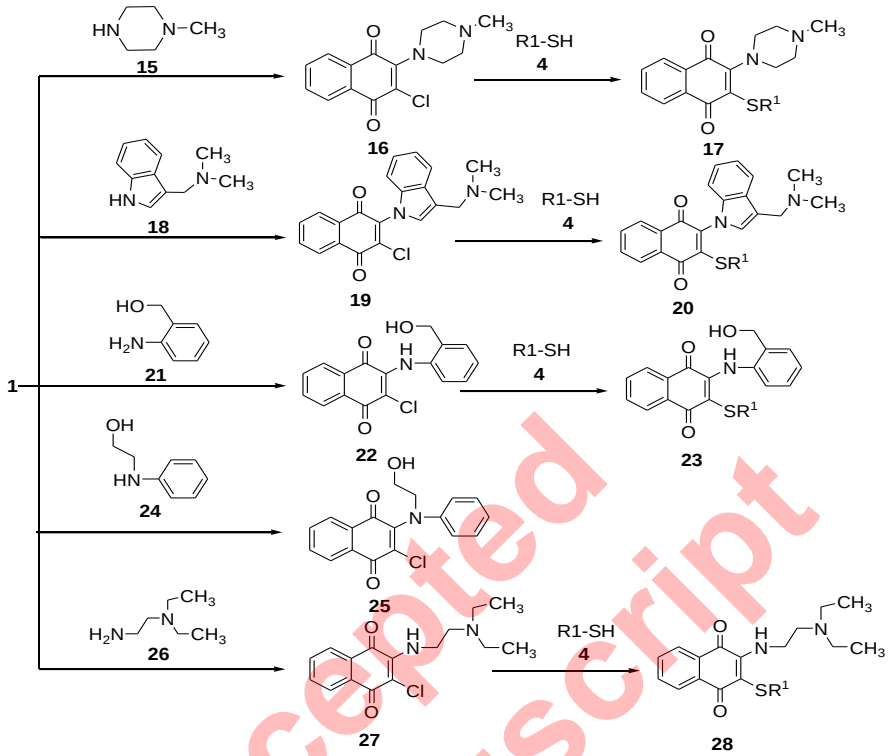
N- and ethoxy substituted naphthoquinone **(7)** was obtained by reaction of **(1)** and equivalent molar of **(6)** in ethanol solution of Na_2CO_3. The -OCH_2 protons of (**7**) appeared in the low-field region of the ^1H-NMR spectrum as multiplets at 4.57- 4.60 ppm ; The interesting *N,N*-substituted dinaphthoquinone derivative **(8)** were synthesized by the reaction of **(1)** and equivalent molar of **(6)** in chloroform with triethylamine. The interesting *N,N*-substituted

dinaphthoquinone derivative **(8)** was obtained as a stable brown solid with a good yield. In the mass spectrum of compound **(8)** the accurate mass of the molecular ion peak with sodium adduct ion was noticed at m/z 595 $[M+Na]^+$.

The reaction of **(1)** with indole **(9)** in methanol resulted into the *N*- and methoxy substituted compound **(10)**. The $-OCH_3$ protons of compound **(10)** appeared in the ^1H NMR spectrum as singlet at 4.10 ppm; In this reaction methanol was behaved as nucleophile and attacked the naphthoquinone to give the addition reaction. The indole-substituted quinone derivatives are colored stable compounds.

The known compound **(13)**[17] and novel compound **(12)** was obtained be reaction of **(1)** with diamine **(11)**. The mass spectra of compound **(12)** in the positive ion mode of ESI technique confirmed the proposed structure; the protonated molecular ion peak was identified at m/z (%) 339 $[M+Na]^+$. The reactions of **(13)**[17] with thiols **(4d-e)** gave the interesting *N,S*-substituted dinaphthoquinone derivatives (**14d)** and **(14e)** that was obtained with high yields. The compounds **(14d)** and **(14e)** have interesting N,S- subtituted dinaphthoquinone structures. In the ^{13}C NMR spectra of compound **(14d)** two carbonyl carbon signals were observed at 179.1 and 180.3 ppm. In the mass spectrum of compounds **(14e)** the accurate mass of the molecular ion peak was noticed at m/z 749 $[M+H]^+$. The known compound **(16)**[18] was obtained by reaction of naphthoquinone **(1)** with amine **(15)** in chloroform with Et_3N. The reaction of compound **(16)**[18] with thiols **(4d-f)** gave the novel N,S-naphthoquinone derivatives (**17d-f)**. In the ^1H NMR spectrum of compound **(17d)** the $-SCH_2$ protons gave triplet at 2.96 ppm and $C-CH_3$ for compound **(17f)** gave multiplets at 1.40-1.45 ppm (Scheme 2).

The *N*-substituted naphthoquinone **(19)** was synthesized by reaction of **(1)** with **(18)** in chloroform with Et_3N. The ^1H NMR spectrum of compound **(19)** showed the $-NCH_2$ protons as a singlet at 3.37 ppm. The compound **(20d)** was obtained by the reaction of compound **(19)** with **(4d)** in Ethanol with Na_2CO_3. In the ^{13}C NMR spectra of N,S-substituted compound (**20d)** two carbonyl carbon signals were observed at 179.4 and 180.5 ppm. The novel compound **(22)** was obtained by reaction of **(1)** with amine **(21)**. The IR spectra of compound **(22)** showed characteristic amine band (-NH) at 3365 cm^{-1}.The *N,S*-naphthoquinone substituted **(23c-d)** were obtained by reaction of **(22)** with (**4c-d)** in the ethanol with Na_2CO_3. In the mass spectrum of compounds **(23c)** and **(23d)** the accurate mass measurements of the molecular ion peaks were noticed at m/z 366 $[M+H]^+$ and 354 $[M-H]^-$ respectively. The *N*-substituted naphthoquinone (**25)** was obtained by the reaction of (**1)** with *N*-(2-hydroxy ethyl) aniline (**24)** in chloroform with Et_3N. The $-NCH_2$ protons of (**25)** appeared in the low-field region of the ^1H NMR spectrum as triplets at 3.80 ppm.



Scheme 2. Synthesis of novel N- and N,S- substituted naphthoquinone derivatives.

The reaction of known compound **(27)**[19] with **(4d-e)** gave *N,S*-substituted naphthoquinone **(28d-e)**. The mass spectrum of compounds **(28d)** and **(28e)** gave the molecular ion peaks at m/z 361 $[M]^+$ and 417 $[M+H]^+$ respectively.

Electrochemical assay

Some of the novel naphthoquinone derivatives were studied by cyclic voltammetry in aprotic media (DMF) using tetrabutylammonium perchlorate (0.10 M) as supporting electrolyte at 100 mV / s on Glassy Carbon Electrode. The electrochemical parameters, including cathodic peak potentials (Epc_1 and Epc_2), the half-wave peak potentials ($E_{1,\,½}$) and the difference between the first oxidation and reduction processes (ΔEp) are given at Table I.

The cyclic voltammogram of the 2,3-Dichloro-1,4-naphthoquinone (**1**) gave two monoelectronic waves. The first (Ic) and second (IIc) cathodic peaks correspond to semiquinone ($Q/Q^{\cdot-}$) and dianion ($Q^{\cdot-}/Q^{2-}$) pairs, respectively.

The reduction mechanism has changed when 2,3-dichloro-1,4-naphthoquinone **(1)** substituted with *N*- nucleophilles. Additional cathodic and anodic peaks were detected in voltammograms because of the various type of substituents. [20] During the electrochemical study of *N*-substituted compound **(3)**

and *N*,*S*-substituted compounds **(5a)**, **(5c)**, **(5d)**, **(5e)**, **(14d)** and **(14e)** the CV displayed a different profile which does not follow the typical two monoelectronic reversible charge transfer process occurring for 2,3-dichloro-1,4-naphthoquinone (**1**). The three peaks was observed in both cathodic and anodic region of CV. The potential in the first reduction step for compound **(5a)** was seen at Ep(Ic)=0.2483 V. It can be related the acidity level of proton settled on nitrogen atom.[21]The first cathodic peak was not observed for dinaphthoquinone compound **(8)** in CV. The resulting voltammogram of compound **(19)** showed typical two successive one-electron reduction processes that can be observedfor quinones in aprotic media. It can be related the nonexistence of a proton in the molecule. *N*-substituted compound **(27)** gave three cathodic peaks in CV. The resulting voltammogram of *N*,*S*-substituted compounds **(28d)** and **(28e)** showed a decrement in peak intensities.

TABLE I. Half-wave potentials (for the 1st wave) and electrochemical data for some of the naphthoquinone derivatives (C / 10^{-3} M) in 0.1 M DMF/TBAP; ΔEp_1 = Epa_1-Epc_1; $E_{1,1/2}$ = (Epa_1+ Epc_1)/2

Compound	E_{pIc} / V	E_{pIIc} / V	ΔEp_1[a] / mV	$E_{1,1/2}$[b] / V
2,3-dichloro-1,4-naphthoquinone (**1**)	–0.4038	–1.1620	235	–0.2862
3[16]	0.3133	–0.6661	265	0.4459
5a	0.2483	–0.7499	300	0.3984
5c	–0.3043	–0.7171	252	0.1262
5d	0.2953	–0.7361	133	0.1337
5e	0.2444	–0.7530	303	0.3960
8	–	–0.9873	–	–
14d	–0.2203	–0.7709	102	–0.2712
14e	–0.2774	–0.7980	–	–
19	–0.6961	–1.235	128	–0.6323
20d	–0.7550	–1.3580	88	0.7112
22	–0.5286	–0.7391	–	–
27[19]	–0.4737	–0.7410	–	–
28d	–0.7839	–0.7201	84	–0.7520
28e	–0.7988	–	99	–0.7494

EXPERIMENTAL

Chemistry

Melting points were measured on a Buchi B-540 melting point apparatus. Elemental analyses were performed on a Thermo Finnigan Flash EA 1112 Elemental analyser. Infrared (IR) spectra were recorded in KBr pellets in Nujol mulls on a Perkin Elmer Precisely Spectrum One FTIR spectrometry. ^{1}H and ^{13}C NMR spectra were recorded on Varian UNITYINOVA operating at 500 MHz. Mass spectra were obtained on a Thermo Finnigan LCQ Advantage MAX LC/MS/MS spectrometer according to ESI probe. Products were isolated by column chromatography on Silica gel (Merk Silica gel 60, particle size 63–200 μm). TLC plates silica 60F254 (Merck, Darmstadt), detection with ultraviolet light (254 nm). All chemicals were reagent grade and used without further purification.

Aalytical and spectral data of the synthesized compounds are given in Supplementary material to this paper.

Cyclic Voltammetry measurements were performed in a conventional three-electrode cell using a computer controlled system of a Gamry Reference 600 Model potentiostat/galvanostat. A glassy carbon disc was used as a working electrode. The surface of the working electrode was polished with alumina before each run. A platinum wire served as the counter electrode. The reference electrode was an Ag/AgCl electrode. Electrochemical grade tetrabutylammonium perchlorate (TBAP) in extra pure DMF was employed as the supporting electrolyte at a concentration of 0.10 M. Prior to each run solutions were purged with nitrogen. Measurements were made over a potential range between 1 and -2 V with a step rate of 0.1V s^{-1}.

General procedures

1. 1.0 g (4.43 mmol) 2,3-dichloro-1,4-naphthoquinone **(1)** and corresponding nucleophile were stirred in $CHCl_3$ (30 mL) with triethyl amine (3 mL) solution for 2–3 h at room temperature. The color of the solution quickly changed and the reaction was monitored by TLC. Chloroform (30 mL) was added to the reaction mixture. The organic layer was washed with water (4 × 30 mL), and dried over Na_2SO_4. After evaporation of the solvent the residue was purified by column chromatography on silica gel.

2. 1.0 g (4.43 mmol) 2,3-dichloro-1,4-naphthoquinone **(1)** and corresponding nucleophile were stirred in EtOH (65 mL) solution of Na_2CO_3 (1.52 g) for 2 to 3 h at room temperature. The color of the solution quickly changed and the reaction was monitored by TLC. Chloroform (30 mL) was added to the reaction mixture. The organic layer was washed with water (4×30 mL), and dried over Na2SO4. After evaporation of the solvent the residuewas purified by column chromatography on silica gel.

3. 1.0 g (4.43 mmol) 2,3-dichloro-1,4-naphthoquinone **(1)** and 8.86 mmol nucleophile were stirred in Methanol (65 mL) solution of Na_2CO_3 (1.52 g) for 2 to 3 h at room temperature. The color of the solution quickly changed and the reaction was monitored by TLC. Chloroform (30 mL) was added to the reaction mixture. The organic layer was washed with water (4×30 mL), and dried over Na2SO4. After evaporation of the solvent the residuewas purified by column chromatography on silica gel.

CONCLUSIONS

Novel substituted naphthoquinone compounds were synthesized from the reactions of (1) and related nucleophilles in different reaction media. The structures of novel compounds were characterized by using micro analysis, FT-IR, ^{1}H-NMR, ^{13}C-NMR, MS and cyclic voltammetry.

SUPPLEMENTARY MATERIAL

Aalytical and spectral data of the synthesized compounds are available electronically from http://www.shd.org.rs/ JSCS/, or from the corresponding author on request.

Acknowledgment. We gratefully thank the Research Fund of the University of Istanbul for financial support of this work.

И З В О Д

ИСПИТИВАЊЕ РЕАКЦИЈЕ НУКЛЕОФИЛНЕ СУПСТИТУЦИЈЕ 2,3-ДИХЛОР-1,4-НАФТОХИНОНА СА РАЗЛИЧИТИМ НУКЛЕОФИЛИМА

CEMIL IBIS, AHMED HASSEN SHNTAIF, HAKAN BAHAR и SIBEL SAHINLER AYLA

Department of Chemistry, Faculty of Engineering, Istanbul University, 34320, Avcilar, Istanbul, TURKEY

Синтетисани су нови N- , N,S- и N,O- супституисани деривати нафтохинона реакцијом 2,3-дихлор-1,4-нафтохинона (**1**) са одговарајућим нуклеофилима у хлороформу у присуству триетиламина или у етанолу у присуству Na_2CO_3. Структуре нових једињења одређене су микро-анализом, FT-IR, ^{1}H NMR, ^{13}C NMR, MS и цикличном волтаметријом.

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SUPPLEMENTARY MATERIAL TO

The Investigation of nucleophilic substitution reactions of 2,3-dichloro-1,4-naphthoquinone with various nucleophilic reagents

CEMIL IBIS*, AHMED HASSEN SHNTAIF, HAKAN BAHAR and SIBEL SAHINLER AYLA

[1]*Department of Chemistry, Faculty of Engineering, Istanbul University, 34320, Avcilar, Istanbul, Turkey*

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ANALYTICAL AND SPECTRAL DATA OF THE SYNTHESIZED COMPOUNDS

2-(4-(diethylamino)phenylamino)-3-chloronaphthalene-1,4-dione (3). Compound **3** was synthesized from the reaction of 1 (0.5 g, 2.202 mmol) with **2** (0.36 g, 2.201 mmol) according to general procedure 1.

Blue solid; Yield: 67.53% (0.52 g); m.p. 159-160oC (Lit16 m.p. 159oC); Anal. Calcd. for C20H19ClN2O2 (M, 354.113) C, 67.70; H, 5.40; N, 7.89. Found: C, 67.65; H, 5.32; N, 7.81; Rf (CHCl3): 0.34; IR (KBr, cm-1): 2965-2926 (CHalphatic), 1672-1638 (C=O), 1524-1506 (C=C), 3304 (N-H); 1H-NMR (500 MHz, CDCl3, δ/ppm): 0.98 (t, 3H, CH3), 3.24-3.36 (m, 2H, NCH2), 6.53-6.92 (m, 4H, CHarom), 7.56-8.09 (4H, CHarom); 13C-NMR (125.66 MHz, CDCl3, δ/ppm) 11.5 (CH3), 43.4 (NCH2), 111.4, 133.9, 124.4, 140.8, 125.2, 125.8 125.9, 128.8, 131.5, 131.9, 145.2, (Carom, CHarom), 179.7, 176.2 (C=O); MS (m/z, relative abundance, %): 381 (M+, 100).

2-(4-(diethylamino)phenylamino)-3-(ethylthio)naphthalene-1,4-dione (5a). Compound **5a** was synthesized from the reaction of **3** (0.1 g, 0.282 mmol) with **4a** (0.017 g, 0.273 mmol) according to general procedure 2.

Gray oil; Yield: 93.45% (0.1 g); Rf (CH2Cl2): 0.25; Anal. Calcd. for C22H24O2SN2 (M, 380.50): C, 69.44; H, 6.36; N, 7.36; S, 8.43. Found: C, 69.64; H, 6.48; N, 7.12; S, 8.74; IR (KBr, cm-1): 3018 (C-Harom), 2975-2929 (C-Haliphatic), 1664-1631 (C=O), 1593-1549 (C=C), 3330 (N-H); 1H-NMR (500 MHz, CDCl3, δ/ppm): 0.98 (t, 3H, J =7.5, CH3), 1.08 (t, 6H, J =7.5, NCH2CH3), 2.53-2.57 (m, 2H, SCH2), 3.26-3.30 (m, 4H, NCH2), 7.77 (s, 1H, NH), 6.55 (d, 2H, J=7.3, CHarom), 6.86 (d, 2H, J=7.3, CHarom), 7.95-8.07 (m,

* Corresponding author. E-mail: ibiscml@istanbul.edu.tr

4H, CHnaphtho); 13C-NMR (125.66 MHz, CDCl3, δ/ppm) 11.5 (CH3), 13.3 (CH2CH3), 28.6 (SCH2), 43.4 (NCH2),110.3, 112.5, 123.8, 125.4, 125.6, 125.8, 125.9, 129.7, 131.2, 132.8, 133.4, 144.7, 145.4, (CHarom, Carom), 179.6, 179.7 (C=O); MS (m/z, relative abundance, %): 381 ((M+H+), 100).

2-(4-(diethylamino)phenylamino)-3-(4-methyl-2-oxo-2H-chromen-7-ylthio)naphthalene-1,4-dione (5b). Compound **5b** was synthesized from the reaction of **3** (0.1 g, 0.282 mmol) with **4b** (0.05 g, 0.26 mmol) according to general procedure 2.

Blue oil; Yield: 64.28% (0.09 g); Rf (CHCl3): 0.45; Anal. Calcd. for C30H26O4SN2 (M, 510.60): C, 70.57; H, 5.13; N, 5.49; S, 6.28. Found: C, 70.33; H, 4.89; N, 5.26; S, 6.03; IR (KBr, cm-1): 3053(C-Harom), 2962, 2923, 2852 (C-Haliphatic), 1734 (C=Olacton), 1666 (C=Oquinone), 1597, 1537 (C=C), 3253 (N-H); 1H-NMR (500 MHz, CDCl3, δ/ppm): 1.07 (t, 6H, J=5.0, NCH2CH3), 1.48 (s, 3H, CH3), 6.01 (s, 1H, CHvin), 3.24-3.26 (m, 4H, NCH2), 6.26-8.13 (m, 11H, CHarom); 13C-NMR (125.66 MHz, CDCl3, δ/ppm) 11.4, 17.5 (CH3), 43.5 (NCH2), 123.0, 123.2, 124.4, 125.3, 125.9, 126.4, 127.4, 129.2, 131.6, 131.8, 132.8, 134.2, 140.8, 144.7, 145.2, 151.0, 152.5 (CHarom, Carom), 159.6 (C=Ocoumari$_n$) 179.8, 179.2 (C=O); MS (m/z, relative abundance, %): 511 ((M+H$^+$), 100).

2-(4-(diethylamino)phenylamino)-3-(propylthio)naphthalene-1,4-dione (5c). Compound **5c** was synthesized from the reaction of 3 (0.1 g, 0.282 mmol) with **4c** (0.02 g, 0.26 mmol) according to general procedure 2.

Gray oil; Yield: 62.72% (0.06 g); Rf(CHCl3): 0.4; Anal. Calcd. for C23H26N2O2S (M, 394.53): C, 70.02; H, 6.64; N, 7.10; S, 8.13. Found: C, 69.89; H, 6.31; N, 7.05; S, 8.21; IR (KBr, cm-1): 3071 (C-Harom), 2966, 2929, 2870 (C-Haliphatic), 1663 (C=O), 1591, 1562 (C=C), 3311 (N-H); 1H-NMR (500 MHz, CDCl3, δ/ppm): 0.74 (t, 3H, J = 7.5, CH3), 1.08 (t, 6H, J= 7.5, NCH2CH3), 1.30-1.35 (m, 2H, SCH2CH2), 2.50 (t, 2H, J= 7.5, SCH2), 3.25-3.29 (m, 4H, NCH2), 6.54 (bs, 1H, NH), 6.57-6.87 (m, 4H, CHarom), 7.94-8.06 (m, 4H, CHnaphtho); 13C-NMR (125.66 MHz, CDCl3, δ/ppm) 12.3, 13.0 (CH3), 35.1 (CH2), 40.15 (SCH2), 43.5 (NCH2), 112.8, 121.2, 123.2, 123.8 125.4, 125.5, 125.6, 126.0, 129.7, 132.8, 133.3, 144.7, 145.3, (CHarom, Carom), 179.5, 179.7 (C=O); MS (m/z, relative abundance, %): 395 ((M+H+), 100).

2-(4-(diethylamino)phenylamino)-3-(butylthio)naphthalene-1,4-dione (5d). Compound 5d was synthesized from the reaction of 3 (0.1 g, 0.282 mmol) with **4d** (0.025 g, 0.27 mmol) according to general procedure 2.

Gray oil; Yield: 69.52% (0.08 g); Rf (CHCl3): 0.52; Anal. Calcd. for: C24H28N2O2S (M, 408.56): C, 70.55; H, 6.91; N, 6.86; S, 7.85 Found: C, 70.32; H, 6.78; N, 6.61; S, 7.52; IR (KBr, cm-1): 3065 (C-Harom), 2965, 2928, 2870 (C-H aliphatic), 1662, 1610 (C=O), 1591, 1544 (C=C), 3307 (N-H); 1H-NMR (500 MHz, CDCl3, δ/ppm): 0.78 (t, 3H, J=7.5, CH3), 1.10 (t, 6H, J=15.0

NCH2CH3), 1.14-1.18 (m, 2H, CH2CH3), 1.24-1.29 (m, 2H, SCH2CH2), 2.50 (t, 2H, J=7.5, SCH2), 3.25-3.29 (m, 4H, NCH2), 7.77 (bs, 1H, NH), 6.52-6.87 (m, 4H, CHarom), 7.94-8.06 (m, 4H, CHnaphtho); 13C-NMR (125.66 MHz, CDCl3, δ/ppm) 11.5, 12.6 (CH3), 30.4, 32.8 (CH2), 37.8 (SCH2), 43.4 (NCH2), 110.3, 112.9, 123.8, 125.5, 125.6, 125.9, 129.7, 131.2, 132.8, 133.3, 145.2, 144.7 (CHarom, Carom), 179.5, 179.7 (C=O); MS (m/z, relative abundance, %): 409 ((M+H+), 100).

2-(4-(diethylamino)phenylamino)-3-(octylthio)naphthalene-1,4-dione (5e). Compound **5e** was synthesized from the reaction of 3 (0.1 g, 0.282 mmol) with **4e** (0.041 g, 0.28 mmol) according to general procedure 2.

Blue oil; Yield: 83.20% (0.109 g); Rf ($CHCl_3$: Ethylacetate 3:1): 0.85; Anal. Calcd. for: $C_{28}H_{36}N_2O_2S$ (M, 464.66): C, 72.38; H, 7.81; N, 6.03; S, 6.90. Found: C, 72.19; H, 7.61; N, 5.81; S, 6.68; IR (KBr, cm^{-1}): 3071 (C-H_{arom}), 2964, 2926, 2853 ($CH_{alliphatic}$), 1663, 1633 (C=O), 1592, 1548 (C=C), 3318 (N-H); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 0.77 (t, 3H, *J*= 5.0, CH_2CH_3), 1.08-1.11 (m, 6H, NCH_2CH_3), 1.14-1.18 (m, 10H, $(CH_2)_5$), 1.26-1.31 (m, 2H, SCH_2CH_2), 2.50 (t, 2H, *J*= 7.5, SCH_2), 3.26-3.31 (m, 4H, -NCH_2), 7.77 (s, H, NH), 6.53 (d, 2H, *J* =5.0, CH_{arom}), 6.87 (d, 2H, *J* =5.0, CH_{arom}), 8.02 (dd, 2H, *J*=5.0, $CH_{naphtho}$) 7.59 (t, 2H, *J*=7.5, $CH_{naphtho}$); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 11.5 (CH_3), 13.0 (CH_3)$_{thio}$, 30.7, 28.6, 28.4, 28.1, 28.0, 27.7 (CH_2), 33.1 (SCH_2), 43.5 (NCH_2), 110.3, 113.0, 123.8, 125.4, 125.7, 125.9, 129.7, 131.2, 132.8, 133.4, 144.7, 145.2 (CH_{arom}, C_{arom}), 179.6, 179.8 (C=O); MS (m/z, relative abundance, %): 465 ((M+H^+), 100).

2-((piperidin-2-yl)methylamino)-3-ethoxynaphthalene-1,4-dione (7). Compound **7** was synthesized from the reaction of **1** (0.5g, 2.202mmol) with **6** (0.25g, 2.192 mmol) according to general procedure 2.

Blue oil; Yield: 34.73% (0.33 g); Rf ($CHCl_3$): 0.31; Anal. Calcd. for: $C_{18}H_{22}N_2O_{43}$ (M, 414.38): C, 68.77; H, 7.05; N, 8.91. Found: C, 68.52; H, 6.88; N, 8.58; IR (KBr, cm^{-1}): 3010 (C-H_{arom}), 2926, 2850 (C-$H_{aliphatic}$), 1703, 1613 (C=O), 1594, 1505 (C=C), 3385 (N-H); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 0.76-0.82 (m, 3H, CH_3), 1.17-1.26 (m, 6H, $CH_{2piper.}$), 1.50 (bs, 2H, NH), 2.20-2.25 (m, 4H, NCH_2), 2.78-2.81 (m, H, NCH), 4.57-4.60 (m, 2H, OCH_2), 7.69-8.71 (m, 4H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 20.7 (CH_3), 28.3, 28.6, 28.9 (CH_2), 30.9, 35.2 (NCH_2), 52.3 (OCH_2), 124.6, 124.7, 127.3, 128.9, 130.1, 131.5, 131.7, 136.2 (CH_{arom}, C_{arom}), 174.7, 178.8 (C=O); MS (m/z, relative abundance, %): 314 ((M+H^+), 100).

2-((piperidin-2-yl)methylamino)-3-[2-((piperidin-2-yl)methylamino)-3-choloronaphthalene -1,4-dione]-naphthalene-1,4-dione (8). Compound **8** was synthesized from the reaction of **1** (0.5g, 2.202mmol) with **6** (0.25g, 2.192 mmol) according to general procedure 1.

Brown solid; Yield: 50.79% (0.64 g). m.p. 155-156°C; R_f (CH_2Cl_2:Petroleum eter 2:1): 0.41; Anal. Calcd. for: $C_{32}H_{33}ClN_4O_4$ (M, 573.08): C, 67.07; H, 5.80; N, 9.78. Found: C, 66.85; H, 5.56; N, 9.63; IR (KBr, cm^{-1}): 3048 (C-H_{arom}), 2938-2855 (C-$H_{aliphatic}$), 1633-1614 (C=O), 1593 (C=C), 3400 (N-H); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 1.37-1.90 (m, 12H, $CH_{2piper.}$), 3.49 (t, 4H, *J*=7.3, NCH_2), 4.18 (t, 4H, *J*=7.3, NCH_2), 2.60-3.10 (m, 2H, NCH), 7.77 (m, 3H, NH), 7.45-8.06 (m, 8H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 28.6, 24.2, 22.5 (CH_2), 52.68, 52.74 (NCH_2), 108.9, 122.7, 125.2, 129.9, 130.9, 130.06, 131.8, 144.7, 157.5 (CH_{arom}, C_{arom}), 176.9 (C=O); MS (m/z, relative abundance, %): 595 ((M+Na^+), 100).

2-ethoxy-3-(2-methyl-1H-indol-1-yl)naphthalene-1,4-dione (10). Compound **10** was synthesized from the reaction of **1** (0.5g, 2.202mmol) with **9** (0.288 g, 2.19 mmol) according to general procedure 3.

Blue oil; Yield: 9.66% (0.14 g); R_f ($CHCl_3$): 0.72; Anal. Calcd. for: $C_{20}H_{15}NO_3$ (M, 317.34): C, 75.70; H, 4.74; N, 4.41. Found: C, 75.51; H, 4.85; N, 4.12; IR (KBr, cm^{-1}): 3018 (C-H_{arom}), 2926, 2854 (C-$H_{aliphatic}$), 1717, 1664 (C=O), 1596, 1459 (C=C); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 2.27 (s, 3H, CH_3), 4.10 (s, 3H, OCH_3), 7.01-8.18 (m, 8H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 12.8 (*C*H_3), 61.0 (O*C*H_3), 104.8, 126.1, 126.2, 126.3, 125.7, 129.8, 130.6, 131.1, 132.7, 132.9, 133.6, 134.3, 140.8 141.8, 146.5 (CH_{arom}, C_{arom}), 177.3 180.9 (C=O); MS (m/z, relative abundance, %): 318 ((M+H^+), 100).

2-(2-(2-(2-aminoethoxy)ethoxy)ethylamino)-3-chloronaphthalene-1,4-dione (12). Compound **12** was synthesized from the reaction of **1** (0.5 g, 2.202 mmol) with **11** (0.652 g, 4.39 mmol) according to general procedure 1.

Brown oil; Yield: 3.22% (0.048 g); R_f (CH_3OH): 0.93; Anal. Calcd. for: $C_{16}H_{19}ClN_2O_4$ (M, 338.79): C, 56.72; H, 5.65; N, 8.27. Found: C, 56.63; H, 5.77; N, 8.36; IR (KBr, cm^{-1}): 3012 (C-H_{arom}), 2872 (C-$H_{aliphatic}$), 1678, 1644 (C=O), 1574, 1515 (C=C), 3334 (N-H); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 3.97–4.04 (m, 8H, OCH_2), 3.60-3.70 (m, 4H, NCH_2), 7.47-7.99 (m, 4H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 43.4 (NCH_2), 68.9 (OCH_2), 69.4 (O*C*H_2CH_2NH), 76.2 (C*H*$_2CH_2NH_2$), 125.7, 131.4, 133.8 (CH_{arom}, C_{arom}), 179.3, 181.3 (C=O); MS (m/z, relative abundance, %): 339((M+H^+), 100).

2,2'-[1,2-ethanediylbis(oxy-2,1-ethanediylimino)]bis(3-chloronaphthalene-1,4-dione) (13). Compound **13** was synthesized from the reaction of **1** (0.5 g, 2.202 mmol) with **11** (0.652 g, 4.39 mmol) according to general procedure 1.

Red solid; Yield: 64.49% (0.75 g). m.p. 150-152°C (Lit[17] for **13** m.p. 150-152°C); R_f ($CHCl_3$: Ethylacetate 1:1): 0.48; Anal. Calcd. for: $C_{26}H_{22}ClN_2O_6$ (M, 528.09) C, 58.99; H, 4.19; N, 5.29. Found: C, 58.78; H, 4.27; N, 5.16; IR (KBr, cm^{-1}): 3053 (C-H_{arom}), 2900-2863 (C-$H_{aliphatic}$), 1679-1636 (C=O), 1579-

1513 (C=C), 3334 (N-H); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 3.72 (t, 4H, NCH_2), 4.0-4.04 (m, 8H, OCH_2), 7.60-7.98 (m, 8H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 43.41 (NCH_2), 68.9, 69.4 (OCH_2), 125.7, 128.6, 131.5, 131.4, 133.8, 143.1, (CH_{arom}, C_{arom}), 179.3, 175.7 (C=O); MS (m/z, relative abundance, %): 529 (($M+H^+$), 38).

2,2'-[1,2-ethanediylbis(oxy-2,1-ethanediylimino)]-3,3'(butanthio)-naphthalene-1,4-dione (14d). Compound **14d** was synthesized from the reaction of **13** (0.25 g, 0.47 mmol) with **4d** (0.061 g, 0.67 mmol) according to general procedure 2.

Red oil; Yield: 57.76% (0.17 g); Rf ($CHCl_3$): 0.35; Anal. Calcd. for: $C_{34}H_{40}N_2O_6S_2$ (M, 636.82): C, 64.13; H, 6.33; N, 4.40; S, 10.07, Found: C, 64.22; H, 6.46; N, 4.72; S, 10.25; IR (KBr, cm^{-1}): 3066 (C-H_{arom}), 2956, 2927, 2870 (C-$H_{aliphatic}$), 1674, 1629 (C=O), 1592, 1550 (C=C); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 0.80 (t, 6H, *J*= 7.5, CH_3), 1.29-1.34 (m, 4H, CH_2), 1.45-1.51 (m, 4H, SCH_2CH_2), 2.72 (t, 4H, *J*=7.5, SCH_2), 3.69 (t, 2H, *J* = 7.5, NCH_2), 4.08 (t, 8H, OCH_2), 7.47-8.02 (m, 8H, C-H_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 12.6 (CH_2CH_3), 21.0 (CH_2CH_3), 30.9 (CH_2S), 33.7 (CH_2CH_2-S), 44.4 ($NHCH_2$), 69.0 (O-CH_2CH_2NH), 69.5 (OCH_2), 125.5, 125.7, 130.9, 132.7, 133.4 (CH_{arom}, C_{arom}), 179.1, 180.3 (C=O); MS (m/z, relative abundance, %): 659 (($M+Na^+$), 100).

2,2'-[1,2-ethanediylbis(oxy-2,1-ethanediylimino)]-3,3'(octanethio)-naphthalene-1,4-dione (14e). Compound **14e** was synthesized from the reaction of **13** (0.3 g, 0.56 mmol) with **4e** (0.082 g, 0.56 mmol) according to general procedure 2.

Red oil; Yield: 58.80% (0.25 g); Rf ($CHCl_3$:Ethylacetate 2:3): 0.82; Anal. Calcd. for: $C_{42}H_{56}N_2O_6S_2$ (M, 749.03): C, 67.35; H, 7.54; N, 3.74; S, 8.56. Found: C, 66.98; H, 7.76; N, 3.45; S, 8.23; IR (KBr, cm^{-1}): 3066 (C-H_{arom}), 2956, 2927, 2870 (C-$H_{aliphatic}$), 1674, 1629 (C=O), 1592, 1550 (C=C); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 0.80 (t, 6H, CH_3), 1.15-1.19 (m, 12H, CH_2), 1.46-1.51 (m, 12H, CH_2), 2.72 (t, 4H, SCH_2), 3.69 (t, 4H, NCH_2), 4.08 (t, 8H, OCH_2), 7.46-8.02 (m, 8H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 13.0 (CH_3), 34.0, 30.7, 28.9, 28.6, 28.1, 28.1 (CH_2), 38.2 (SCH_2), 44.4 ($NHCH_2$), 69.0 (O-CH_2CH_2NH), 69.5 (OCH_2), 125.3, 125.5, 130.9, 132.7, 133.4 (CH_{arom}, C_{arom}), 179.0, 180.3 (C=O); MS (m/z, relative abundance, %): 749 (($M+H^+$), 100).

2-chloro-3-(4-methylpiperazin-1-yl)naphthalene-1,4-dione (16). Compound **16** was synthesized from the reaction of **1** (0.5 g, 2.202 mmol) with **15** (0.22 g, 2.19 mmol) according to general procedure 1.

Brown solid; Yield: 65% (0.33 g). m.p. 105-106°C (Lit[18] for **16**.HCl m.p. 220-225°C); Rf(Ethylacetate): 0.73; Anal. Calcd. for: $C_{15}H_{15}ClN_2O_2$ (M, 290.74): C, 61.97; H, 5.20; N, 9.64. Found: C, 61.73; H, 5.11; N, 9.56; IR (KBr, cm^{-1}): 3072 (C-H_{arom}), 2929, 2855 (C-$H_{aliphatic}$), 1682, 1614 (C=O), 1592, 1562

(C=C); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 1.18 (s, 3H, NCH_3), 2.89-3.02 (m, 8H, NCH_2), 7.99-8.88 (m, 4H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 28.6 (NCH_3), 44.7, 44.02 (NCH_2), 125.6, 125.9, 127.7, 127.9, 128.5, 128.8, 140.4 (CH_{arom}, C_{arom}), 177.5, 175.4 (C=O); MS (m/z, relative abundance, %): 291(($M+H^+$), 100).

2-(butylthio)-3-(4-methylpiperazin-1-yl)naphthalene-1,4-dione (17d). Compound **17d** was synthesized from the reaction of **16** (0.5 g, 1.72 mmol) with **4d** (0.15 g, 1.66 mmol) according to general procedure 2.

Violet oil; Yield: 18.15% (0.071 g); Rf (Ethylacetate): 0.73; Anal. Calcd. for: $C_{19}H_{24}N_2O_2S$ (M, 344.47): C, 66.25; H, 7.02; N, 8.13; S, 9.31, Found: C, 65.96; H, 7.20; N, 7.82; S, 9.21; IR (KBr, cm^{-1}): 3005 ($C\text{-}H_{arom}$), 2928, 2793 ($C\text{-}H_{aliphatic}$), 1667, 1640 (C=O), 1591, 1563 (C=C); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 0.84 (t, 3H, CH_3), 1.21-1.24 (m, 4H, NCH_2), 1.32-1.36 (m, 4H, NCH_2), 2.96 (t, 2H, SCH_2), 7.63–7.97 (m, 4H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 17.39 (CH_3), 27.52-29.84 (CH_2), 39.39 (SCH_2), 43.53 (NCH_3), 49.61 (NCH_2), 122.16, 127.25, 128.24, 128.9, 129.40, 146.51 (CH_{arom}, C_{arom}), 176.5, 177.5 (C=O); MS (m/z, relative abundance, %): 345 (($M+H^+$), 100).

2-(p-tolylthio)-3-(4-methylpiperazin-1-yl)naphthalene-1,4-dione (17f). Compound **17f** was synthesized from the reaction of **16** (0.5 g, 1.72 mmol) with **4f** (0.15 g, 0.39 mmol) according to general procedure 2.

Brown solid; Yield: 18.15% (0.071 g). m.p. 278-279 ^{o}C, R_f ($CHCl_3$: Ethylacetate 2:1): 0.73; Anal. Calcd. for: $C_{22}H_{22}N_2O_2S$ (M, 378.49): C, 69.81; H, 5.86; N, 7.40; S, 8.47, Found: C, 69.29; H, 5.03; N, 7.26; S, 7.36; IR (KBr, cm^{-1}): 3000 ($C\text{-}H_{arom}$), 2927, 2855 ($C\text{-}H_{aliphatic}$), 1718, 1654 (C=O), 1593, 1491 (C=C); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 1.40-1.45 (m, 3H, CH_3), 1.18-2.26 (m, 8H, NCH_2), 7.04–8.01 (m, 4H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 27.91 ($C_{arom}\text{-}CH_3$), 42.8 (CH_3), 52.9, 53.21 (NCH_2), (C_{arom}-S), 125.78, 126.17, 127.78, 128.24, 128.7, 128.76, 129.1, 129.8, 130.6, 131.2, 132.5, 133.3, 136.8 (CH_{arom}, C_{arom}), 175.3, 176.5 (C=O); MS (m/z, relative abundance, %): 379 (($M+H^+$), 100).

2-chloro-3-(3-((dimethylamino)methyl)-1H-indol-1-yl)naphthalene-1,4-dione (19). Compound **19** was synthesized from the reaction of **1** (0.5 g, 2.202 mmol) with **18** (0.38 g, 2.23 mmol) according to general procedure 1.

Red solid; Yield: 54.82% (0. 44 g). m.p. 67-68^{o}C. R_f ($CHCl_3$:Petroleum ether 1:1): 0.35; Anal. Calcd. for: $C_{21}H_{17}N_2O_2$ (M, 364.82): C, 69.14; H, 4.70; N, 8.77, Found: C, 68.84; H, 4.62; N, 8.49; IR (KBr, cm^{-1}): 3020 ($C\text{-}H_{arom}$), 2961, 2926 ($C\text{-}H_{aliphatic}$), 1676, 1643 (C=O), 1593, 1519 (C=C); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 3.17 (s, 6H, NCH_3), 3.37 (s, 2H, NCH_2), 7.18 (s, H, CH_{vin}), 7.52-8.07 (m, 8H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 44.6 (NCH_3), 47.05 (NCH_2), 120.4, 126.7, 127.8, 129.3, 129.9 131.6, 131.9, 133.1,

133.9, 134.1, 134.4, 135.1, 135.6, 151.1, (CH_{arom}, C_{arom}), 178.1, 182.4 (C=O); MS (m/z, relative abundance, %): 366 (($M+H^+$), 100).

2-(butylthio)-3-(3-((dimethylamino)methyl)-1H-indol-1-yl)naphthalene-1,4-dione (20d). Compound **20d** was synthesized from the reaction of **19** (0.05 g, 0.13 mmol) with **4d** (0.012 g, 0.013 mmol) according to general procedure 2.

Red solid; Yield: 52.24% (0.03 g). m.p. 134-135 ºC. R_f ($CHCl_3$): 0.43; Anal. Calcd. for: $C_{25}H_{26}N_2O_2S$ (M, 418.55): C, 71.74; H, 6.26; N, 6.69; S, 7.66, Found: C,71.58; H, 6.13; N, 6.48; S, 7.46; IR (KBr, cm^{-1}): 3015 (C-H_{arom}), 2961, 2926, 2871 (C-$H_{aliphatic}$), 1655, 1592 (C=O), 1459, 1377 (C=C); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 0.89 (t, 3H, C*H*$_3$), 1.18-1.55 (m, 4H, CH_2), 2.70 (t, 2H, SC*H*$_2$), 3.37 (s, 6H, NCH_3), 3.40 (s, 2H, NCH_2), 7.19 (s, H, CH_{vin}), 7.51-8.08 (m, 8H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 12.4 (CH_3), 22.2 (CH_2CH_3), 30.9 (SCH_2CH_2), 31.5 (SCH_2), 32.8 (NCH_3), 36.1 (NCH_2), 125.3, 125.5, 125.7, 125.8, 125.9, 128.7, 129.6, 130.9, 131.3, 131.7, 132.8, 133.5, 133.9, 143.8, (CH_{arom}, C_{arom}), 179.4, 180.5 (C=O); MS (m/z, relative abundance, %): 441(($M+H^+$), 12).

22-(2-(hydroxymethyl)phenylamino)-3-chloronaphthalene-1,4-dione (22). Compound **22** was synthesized from the reaction of **1** (0.5 g, 2.202 mmol) with **21** (0.27 g, 2.19 mmol) according to general procedure 1.

Red oil; Yield: 58% (0.4 g); Rf ($CHCl_3$): 0.32; Anal. Calcd. for: $C_{17}H_{12}ClNO_3$ (M, 313.74):C, 65.08; H, 3.86; N, 4.46; Found: C, 65.25; H, 4.08; N, 4.29; I IR (KBr, cm^{-1}): 3010 (C-H_{arom}), 2910-2871 (C-$H_{aliphatic}$), 1674-1606 (C=O), 1568-1505 (C=C), 3365 (N-H); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 3.81-3.87 (m, 2H, OC*H*$_2$), 4.20 (m, 1H, OH), 7.01 (s, 1H, NH), 7.46-8.09 (m, 8H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 68.4 (C*H*$_2$O), 108.5, 110, 127, 127.1, 129.1, 132.1, 135.2, 138.5, 143.2, 167.3, (CH_{arom}, C_{arom}), 175.2 180.8, (C=O); MS (m/z, relative abundance, %): 314 (($M+H^+$), 100).

2-(2-(hydroxymethyl)phenylamino)-3-(propylthio)naphthalene-1,4-dione (23c). Compound **23c** was synthesized from the reaction of **22** (0.1 g, 0.31 mmol) with **4c** (0.02 g, 0.026 mmol) according to general procedure 2.

Pink oil; Yield: 81.80% (0.09 g); Rf ($CHCl_3$:Ethyl acetate 3:1): 0.66; Anal. Calcd. for: $C_{20}H_{19}NO_3S$ (M, 353.43):C, 67.97; H, 5.42; N, 3.96; S, 9.07. Found: C, 67.74; H, 5.28; N, 3.84; S, 8.77; IR (KBr, cm^{-1}): 3010 (C-H_{arom}), 2962, 2929, 2871 (C-$H_{aliphatic}$), 1667, 1636 (C=O), 1585, 1548 (C=C), 3289 (N-H) , 3439 (O-H); ^{1}H-NMR 500 MHz, $CDCl_3$, δ/ppm): 0.70 (t, 3H, CH_3), 1.44 (bs, 1H, OH), 1.12-1.28 (m, 2H, CH_2), 2.50 (t, 2H, SCH_2), 4.73 (s, 2H, OCH_2), 6.80 (s, 1H, NH), 7.57-8.08 (m, 8H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 21.9 (CH_3), 28.6 (SCH_2CH_2), 34.5 (SCH_2), 63.0 (CH_2O), 121.8, 123.3, 125.6, 125.8, 126.5, 127.1, 127.8, 129.8, 130.5, 131.7, 132.5, 133.4, 137.4, 144.8

(CH_{arom}, C_{arom}), 179.4, 180 (C=O); MS (m/z, relative abundance, %): 354 ($(M+H^+)$, 100).

2-(2-(hydroxymethyl)phenylamino)-3-(butylthio)naphthalene-1,4-dione (23d). Compound **23d** was synthesized from the reaction of **22** (0.1 g, 0.31 mmol) with **4d** (0.02 g, 0.022 mmol) according to general procedure 2.

Pink oil; Yield: 81.80% (0.09 g); Rf ($CHCl_3$: Ethylacetate 3:1): 0.36; Anal. Calcd. for: $C_{21}H_{21}NO_3S$ (M, 367.46):C, 68.64; H, 5.76; N, 3.81, S, 8.73. Found: C, 68.52; H, 5.94; N, 3.97, S, 8.52; IR (KBr, cm^{-1}): 3011 (C-H_{arom}), 2958, 2929, 2872 (C-$H_{aliphatic}$), 1667, 1636 (C=O), 1586, 1548 (C=C), 3293 (N-H); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 0.74 (t, 3H, CH_3), 1.44 (bs, 1H, OH), 1.18-1.24 (m, 4H, CH_2), 2.49 (t, 2H, SCH_2), 4.74 (s, 2H, OCH_2), 6.85 (s, 1H, NH), 7.57-8.08 (m, 8H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 20.7 (CH_3), 28.6 ($SCH_2CH_2CH_2$), 30.6 (SCH_2CH_2), 32.2 (SCH_2), 63.0 (CH_2O), 117.7 121.8, 123.2, 125.6, 125.8, 127, 127.7, 128.7, 129.8, 130.5, 132.5, 133.3, 144.7, (CH_{arom}, C_{arom}), 179.4, 180.0 (C=O); MS (m/z, relative abundance, %): 366 ($(M+H^+)$, 100).

2-(N-(2-hydroxyethyl)-N-phenylamino)-3-chloronaphthalene-1,4-dione (25). Compound **25** was synthesized from the reaction of **1** (1 g, 4.404 mmol) with **24** (0.64 g, 4.40 mmol) according to general procedure 1.

Violet oil; Yield: 45.18% (0.65 g); Rf ($CHCl_3$): 0.45; Anal. Calcd. for: $C_{18}H_{14}ClNO_3$ (M, 327.76): C, 65.96; H, 4.31; N, 4.27. Found: C, 65.68; H, 4.62; N, 4.44; IR (KBr, cm^{-1}): 3067 (C-H_{arom}), 2940, 2880 (C-$H_{aliphatic}$), 1731, 1674 (C=O), 1593, 1557 (C=C), 3330 (OH); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 1.20 (s, 1H, OH), 3.80 (t, 2H, NCH_2), 4.01(t, 2H, OCH_2), 7.25 -8.14 (m, 9H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 52.5 (NCH_2), 60.1 (CH_2O), 116.8, 126.6, 127.9, 128, 128.1, 128.3, 130.6, 132.7, 133, 133.1, 133.4, 144.8, 147.2 (CH_{arom}, C_{arom}), 177, 181.1 (C=O); MS (m/z, relative abundance, %): 327 ((M^+), 100).

2-(2-(diethylamino)ethylamino)-3-chloronaphthalene-1,4-dione (27). Compound **27** was synthesized from the reaction of **1** (1 g, 4.404 mmol) with **26** (0.51 g, 4.38 mmol) according to general procedure 1.

Yellow solid; Yield: 70% (0.95 g). m.p. 86-87 °C (Lit[19] for **27**.HCl m.p. 242 °C); Rf($CHCl_3$): 0.44; Anal. Calcd. for: $C_{16}H_{19}ClN_2O_2$ (M, 306.11): C, 62.64; H, 6.24; N, 9.13. Found: C, 62.82; H, 6.36; N, 9.23; IR (KBr, cm^{-1}): 3002 (C-H_{arom}), 2966,2931,2887 (C-$H_{alifatik}$), 1682,1639 (C=O), 1594,1576 (C=C), 3267 (N-H); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 81-0.84 (m, 6H, CH_3), 3.75-3.79 (m, 8H, $NHCH_2$), 7.53-8.09 (m, 4H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 10.9 (CH_3), 40.8 (NH-CH_2), 50.5 (NCH_2CH_3), 65.9 (NCH_2), 108.7, 158.4 125.6, 131.2, 133.6 (CH_{arom}, C_{arom}), 183.6, 179.8 (C=O); MS (m/z, relative abundance, %): 309 ($(M+H^+)$, 100).

2-(2-(Diethylamino)ethylamino)-3-(butylthio)naphthalene-1,4-dione (28d). Compound **28d** was synthesized from the reaction of **27** (0.1 g, 0.24 mmol) with **4d** (0.021 g, 0.058 mmol) according to general procedure 1.

Red oil; Yield: 75% (0.06 g); Rf (metanol): 0.56; Anal. Calcd. for: $C_{20}H_{28}N_2O_2S$ (M, 360.51): C, 66.63; H, 7.83; N, 7.77; S, 8.89. Found: C, 66.87; H, 7.92; N, 7.69; S, 8.76; IR (KBr, cm^{-1}): 3096 (C-H_{arom}), 2959, 2927, 2871 (C-$H_{aliphatic}$), 1673, 1628 (C=O), 1592, 1557 (C=C), 3266 (N-H); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 0.80 (t, 3H, CH_3), 0.86 (t, 6H, CH_3), 1.00-1.29 (m, 4H, CH_2), 1.30-1.37 (m, 1H, NH), 22.64 (t, 2H,SCH_2), 2.72 (t, 6H, NCH_2), 3.90 (bs, 1H, NH), 7.64-8.07 (m, 4H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 12.6, 13.1 (CH_3), 31.0, 21.6 (CH_2), 37.8 (SCH_2), 42.0 ($NHCH_2$), 45.4, 50.6 (NCH_2), 125.2, 125.5, 130.8, 132.9, 133 (CH_{arom}, C_{arom}), 179.2, 180.7 (C=O); MS (m/z, relative abundance, %): 361 (($M+H^+$), 100).

2-(2-(Diethylamino)ethylamino)-3-(octylthio)naphthalene-1,4-dione (28e). Compound **28e** was synthesized from the reaction of **27** (0.5 g, 1.62 mmol) with **4e** (0.23 g, 1.57 mmol) according to general procedure 1.

Red oil; Yield: 65% (0.44 g); Rf ($CHCl_3$): 0.87; Anal. Calcd. for: $C_{24}H_{36}N_2O_2S$ (M, 416.62): C, 69.19; H, 8.71; N, 6.72; S, 7.70. Found: C, 68.98; H, 9.02; N, 6.51; S, 7.54; IR (KBr, cm^{-1}): 3065 (C-H_{arom}), 2956, 2925, 2853 (C-$H_{aliphatic}$), 1673, 1630 (C=O), 1592, 1552 (C=C), 3258 (N-H); ^{1}H-NMR (500 MHz, $CDCl_3$, δ/ppm): 0.77-0.87 (m, 9H, CH_3), 1.01-1.20 (m, 12H, (CH_2), 2.61 (t, 2H, SCH_2), 2.72 (t, 6H, NCH_2), 3.90 (bs, 1H, NH), 7.63-8.07 (m, 4H, CH_{arom}); ^{13}C-NMR (125.66 MHz, $CDCl_3$, δ/ppm) 13.05, 13.07 (CH_3), 21.6, 28.2, 28.6, 28.9, 30.3, 30.7 (CH_2), 38.2 (SCH_2), 42.0 ($NHCH_2$), 45.4, 50.6, (NCH_2), 125.2, 125.5, 129.8, 130.8, 132.2, 132.9, 133.3, 137.1 (CH_{arom}, C_{arom}), 179.1, 180.6 (C=O); MS (m/z, relative abundance, %): 417 (($M+H^+$), 100).