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# New long alkyl side-chain benzo[*a*]phenoxazines as micellisation probes

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ABSTRACT

Several novel fluorescent benzo[*a*]phenoxazinium chlorides possessing a long aliphatic chain substituent at the 5-amino function of the heterocycle were efficiently synthesised. All compounds obtained absorbed and emitted at longer wavelengths with moderate to good fluorescent quantum yields. The photophysics of *N*-[10-methyl-5-(octylamino)-9*H*-benzo[*a*]phenoxazin-9-ylidene]ethanaminium chloride and *N*-[10-methyl-5-(dodecylamino)-9*H*-benzo[*a*]phenoxazin-9-ylidene]ethanaminium chloride was studied in Triton® X-100 and in cetyltrimethylammonium bromide micellar media, demonstrating the capability of these fluorophores in detecting the micellisation process.



## 1. Introduction

Contemporary analytical methodologies based on fluorescent spectroscopy techniques have been well used for biological purposes.[1–3] In this field, suitable probes include fluorophores with absorption and emission at longer wavelengths (600–1000 nm), which showed minimal background interference from biological material as well as high sensitivity.[4,5] Benzo[*a*]phenoxazines, such as Nile Blue and its derivatives possessing a positively charged, oxidised, phenoxazine system, are among the fluorochromophores used in bioapplications as non-covalent and covalent labels.

As is well known, a number of biological macromolecules and structures have hydrophobic and hydrophilic zones. The presence of a long hydrocarbon chain in the fluorescence probe allows it to easily bind to the hydrophobic parts of biomolecules or biomembranes, enabling the fluorophore moiety to probe its environment.[6]

Micelles are a simple model of biomolecules as the hydrophobic effect[7] determines the micellisation process and is also the main driving force for self-association of phospholipids in biological membranes, as well as one of the factors that contributes to protein conformation. In addition, like biological membranes, micelles have a polar surface and a hydrophobic interior. Thus, interaction studies of fluorophores with micelles ascertain their ability as biological fluorescent probes.

Bearing this in mind, in connection with our current research interests,[8–10] and considering the fact that we intended to obtain new benzo[*a*]phenoxazines with aliphatic side chains that would function as anchors in biological structures (membranes, proteins, etc.), as a preliminary study, we decided to synthesise new amphiphatic fluorochromophores possessing octyl or dodecyl substituents at the required amine function of the heterocycle, and used three different combinations of substituents (including H, Me and Et groups) in their 9-amine positions. All benzo[*a*]phenoxazines obtained absorb and fluoresce, in ethanol, from 627 nm to 638 nm and from 654 to 678 nm, respectively.

The interaction of the synthesised *N*-[10-methyl-5-(octylamino)-9*H*-benzo[*a*]phenoxazin-9-ylidene]ethanaminium chloride (**1b**) and *N*-[10-methyl-5-(dodecylamino)-9*H*-benzo[*a*]phenoxazin-9-ylidene]ethanaminium chloride (**1e**) with surfactant micelles was studied by means of fluorescence spectroscopic methods. The results showed that cationic phenoxazine compounds with long alkyl side chains are capable of detecting the critical micellar concentration, even in the case of cationic surfactants, in which there is a repulsive electrostatic interaction between the micelles and the fluorescent probe.

Benzo[*a*]phenoxazinium chlorides **1a–g** were synthesised by condensation of 5-alkylamino-2-nitrosophenol hydrochlorides **2a–c** with *N*-alkyl-naphthylamines **3a–c** in an acidic medium (Scheme 1).[11] The required 5-alkylamino-2-nitrosophenol hydrochlorides **2a–c** were synthesised using a standard procedure[12,8] involving treatment of the corresponding 3-alkylaminophenol with sodium nitrite in an acid solution. Intermediates **3a–c** were prepared by alkylation, in methanol (**3a**) or ethanol (**3b** and **3c**), of 1-naphthylamine with the appropriate bromo-derivative, 1-bromopropane, 1-bromooctane and 1-bromododecane, respectively.[13] After dry chromatography purification, these compounds were

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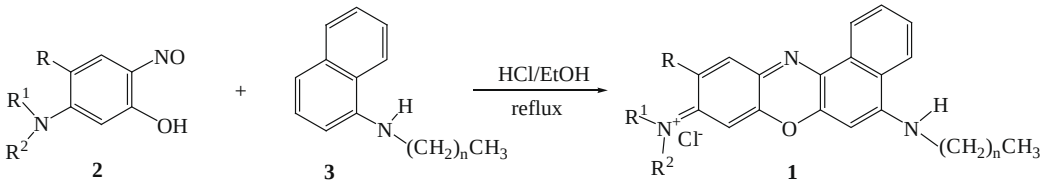


**2**

**a** R = Me, $R^1$ = H, $R^2$ = Et
**b** R = H, $R^1$ = $R^2$ = Et
**c** R = H, $R^1$ = $R^2$ = Me

**3**

**a** n = 2
**b** n = 7
**c** n = 11

**1**

**a** n = 2, R = Me, $R^1$ = H, $R^2$ = Et
**b** n = 7, R = Me, $R^1$ = H, $R^2$ = Et
**c** n = 7, R = H, $R^1$ = $R^2$ = Et
**d** n = 7, R = H, $R^1$ = $R^2$ = Me
**e** n = 11, R = Me, $R^1$ = H, $R^2$ = Et
**f** n = 11, R = H, $R^1$ = $R^2$ = Et
**g** n = 11, R = H, $R^1$ = $R^2$ = Me

**Scheme 1.**

**Table 1**
Yields, UV/visible and fluorescence data in ethanol for compounds **1a–g**

| Compound | Yield (%) | $\lambda_{abs}$ (nm) ($\varepsilon$ [$M^{-1}$ $cm^{-1}$]) | $\lambda_{em}$ (nm) | $\Phi_F$ | Stokes' shift (nm) |
|---|---|---|---|---|---|
| **1a** | 92 | 628 (46,000) | 654 | 0.46 | 26 |
| **1b** | 98 | 627 (67,000) | 655 | 0.49 | 28 |
| **1c** | 88 | 636 (68,000) | 678 | 0.21 | 42 |
| **1d** | 45 | 628 (45,000) | 676 | 0.21 | 48 |
| **1e** | 83 | 627 (63,000) | 655 | 0.48 | 28 |
| **1f** | 69 | 638 (46,000) | 677 | 0.20 | 39 |
| **1g** | 43 | 629 (56,000) | 676 | 0.21 | 47 |

obtained as oils (**3a**, 60%; **3b**, 51%; **3c**, 44%) and were characterised by high resolution mass spectrometry, IR and NMR ($^1$H and $^{13}$C) spectroscopies.

Condensation of 5-ethylamino-4-methyl-2-nitrosophenol hydrochloride **2a** with *N*-propylnaphthalen-1-amine **3a**, in the presence of hydrochloric acid, produced the benzo[*a*]phenoxazinium chloride **1a**. Based on the nitroso compounds **2a**, 5-diethylamino-2-nitrosophenol hydrochloride **2b** and 5-dimethylamino-2-nitrosophenol hydrochloride **2c**, and using *N*-octylnaphthalen-1-amine **3b**, compounds **1b**, **1c** and **1d**, respectively, were obtained. *N*-Dodecylnaphthalen-1-amine **3c** also reacted with nitrosophenol hydrochlorides **2a**, **2b** and **2c**, giving the corresponding benzo[*a*]phenoxazine derivatives **1e–g**.

After purification by dry chromatography on silica gel, cationic dyes **1a–g** were isolated as solid materials in good to excellent yields (Table 1) and were fully characterised by the usual analytical techniques.

Electronic absorption spectra of $10^{-6}$ or $10^{-5}$ M solutions of fluorophores **1a–g** in degassed absolute ethanol were measured. Summarised data of this study are presented in Table 1. These compounds showed maximum absorption ($\lambda_{abs}$) at long wavelengths with molar absorptivities ($\varepsilon$) between 45,000 (**1d**) and 68,000 (**1c**) $M^{-1}$ $cm^{-1}$. Through the comparison of $\lambda_{abs}$ of compounds **1b–d** possessing the same number of methylenic groups ($n$ = 7) and different substituents R, $R^1$ and $R^2$, it was possible to see that compound **1c** (R = H, $R^1$ = $R^2$ = Et) showed maximum absorption at the longest wavelength.

By comparison of compounds **1e–g**, with a similar alkyl chain ($n$ = 11) at the amine function in the 5-position of benzo[*a*]phenoxazine ring, there is the same trend, that is, a bathochromic shift from the compound with the combination of substituents, R = Me, $R^1$ = H and $R^2$ = Et to compounds with dialkylated amine at the 9-position of the heterocycle, R = H, $R^1$ = $R^2$ = Me (2 nm) and R = H, $R^1$ = $R^2$ = Et (11 nm).

Considering this behaviour, increasing the size of the alkyl chain (change in the values of $n$) of the amine function of 5-position of the benzo[*a*]phenoxazine ring does not seem to influence the values of $\lambda_{abs}$, which are dependent on the amine substituents present in the opposite position. Figure 1 shows the normalised absorbance spectra of compounds **1b–d**, in ethanol.

The evaluation of the fluorescent properties of compounds **1a–g** in ethanol using Oxazine 1 as a standard (fluorescent quantum yield, $\Phi_F$ = 0.11 in ethanol[14]) was performed (Table 1). All compounds were excited at 590 nm and the results showed that these fluorophores have wavelengths of maximum emission ($\lambda_{em}$) superior to 654 nm (**1a**), the highest value being 678 nm (**1c**). Considering compounds **1a–g**, it appears that the values of $\lambda_{em}$ are the same for all fluorophores bearing the same combination of R, $R^1$ and $R^2$ substituents and regardless of the size of the alkyl chain at the amine of the 5-position of the heterocycle. Thus, this occurs when R = Me, $R^1$ = H, $R^2$ = Et, $\lambda_{em}$ is 655 nm (**1b**, **1e**) or 654 nm (**1a**). The higher values of $\lambda_{em}$ arise with the combination R = H, $R^1$ = $R^2$ = Me, where $\lambda_{em}$ is 676 nm (**1d**, **1g**) and R = H, $R^1$ = $R^2$ = Et, where $\lambda_{em}$ is 677 nm (**1f**) or 678 nm (**1c**). Figure 2 shows the normalised fluorescence spectra of compounds **1b**, **1c** and **1d**, in ethanol.

Regarding the Stokes' shift, benzo[*a*]phenoxazines with the diethyl or dimethyl amine at the 9-position (R = H, $R^1$ = $R^2$ = Et or

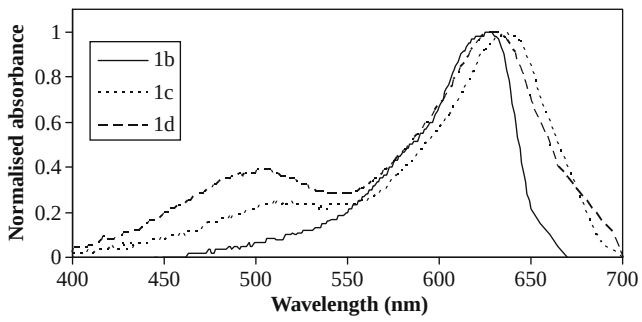


**Figure 1.** Normalised absorbance spectra of compounds **1b**, **1c** and **1d** measured in ethanol ($C$ = 1 × $10^{-6}$ M).

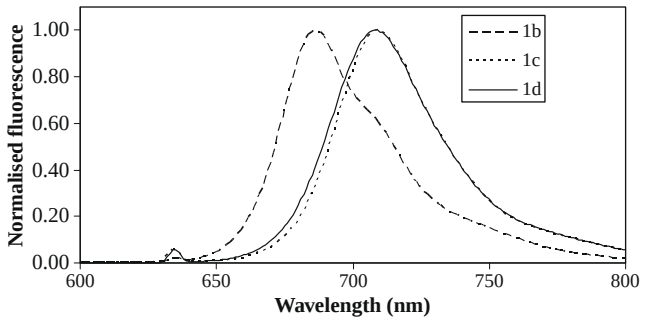


**Figure 2.** Normalised fluorescence spectra of compounds **1b**, **1c** and **1d** measured in ethanol ($C = 1 \times 10^{-6}$ M).

R = H, $R^1 = R^2$ = Me) showed higher values (39–48 nm) than fluorophores possessing the monoalkylated amine ($R^1$ = H, $R^2$ = Et) as well as the methyl group at 10-position of the heterocycle (26 or 28 nm).

Considering the fluorescent quantum yields of all compounds (**1a**–**g**), it appears that values are located in two intervals, related to the benzene ring substituents (R, $R^1$ and $R^2$) and regardless of the size of the alkyl side chain of the amine in the naphthalene ring. The values of $\Phi_F$ with the combination R = Me, $R^1$ = H, $R^2$ = Et (**1a**, **1b** and **1e**) were between 0.46 (**1a**) and 0.49 (**1b**) and the other fluorophores (**1c**, **1d**, **1f** and **1g**) occurred at 0.20 and 0.21. This behaviour is consistent with our previous results[8] for other benzo[*a*]phenoxazines with different types of substituents at the 5-amine position of the heterocycle, namely, it was found that electron-donating groups in the R position increased the fluorescence quantum yields (up to 4 times upon changing H to Me). The photophysical properties in organic solvents was the result of the coexistence of acid and basic forms depending on the proton-acceptance nature of the solvent. The basic form occurred in the 500 nm spectral region and the fluorescence quantum yield was almost one magnitude order lower. In aqueous solutions it was influenced by non-fluorescent H-aggregates (~50 nm blue shift), which was dependent on the substituent groups (R, $R^1$ and $R^2$).

The water solubility of benzo[*a*]phenoxazines **1a**–**g** markedly depends on the alkyl side chain length. Compound **1b**, possessing the alkyl substituent with 8 carbons, is easily soluble at least up to 10 μM concentration range, while compound **1e**, with four additional methylenic groups in the same position, is only water-soluble in the sub μM range. This behaviour indicates that there are no micellar aggregates of this type of molecules as they would result in increased solubility. Furthermore, the fluorescence intensity of compound **1b** was found to be linear with concentration in the 0.1–10-μM range (data not shown), which would not be the case if fluorophores were positioned side by side in a micellar arrangement.

As a preliminary evaluation of the suitability of these long-alkyl side-chain benzo[*a*]phenoxazine derivatives as biological probes, we report a fluorescence study of *N*-[10-methyl-5-(octylamino)-9*H*-benzo[*a*]phenoxazin-9-ylidene]ethanaminium chloride (**1b**) and *N*-[10-methyl-5-(dodecylamino)-9*H*-benzo[*a*]phenoxazin-9-ylidene]ethanaminium chloride (**1e**) in aqueous solutions of a neutral (Triton® X-100, TX100) or positive (cetyltrimethylammonium bromide, CTAB) surfactant shown in Figures 3 and 5. TX100 and CTAB form micelles above a critical micellar concentration of 0.25 mM[15] and 0.89 mM,[16] respectively. The photophysical behaviour of compound **1b** depended on the type of surfactant used. Upon micellisation of TX100, 8 nm and 16 nm red shifts were observed in emission and excitation, respectively (Fig. 3). Most fluorescence probes have $\pi\pi^*$ transitions, which show a blue shift[10] as a result of localisation in the more hydrophobic core of the micelle. From results of our previous work,[8] we can conclude that the nature of the transition was indeed $\pi\pi^*$. The observed red shift

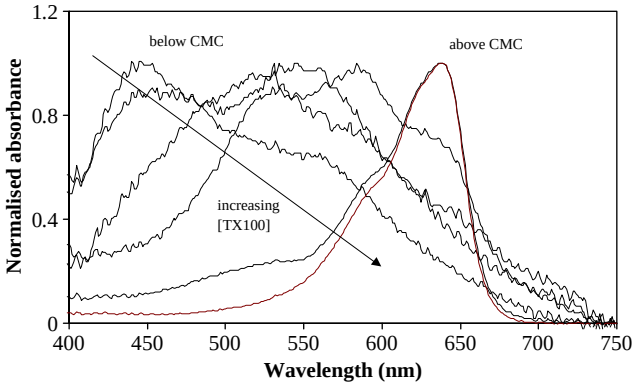


**Figure 4.** Normalised absorption spectra of compound **1e** with TX100. The concentration of compound **1e** was $2 \times 10^{-6}$ M.

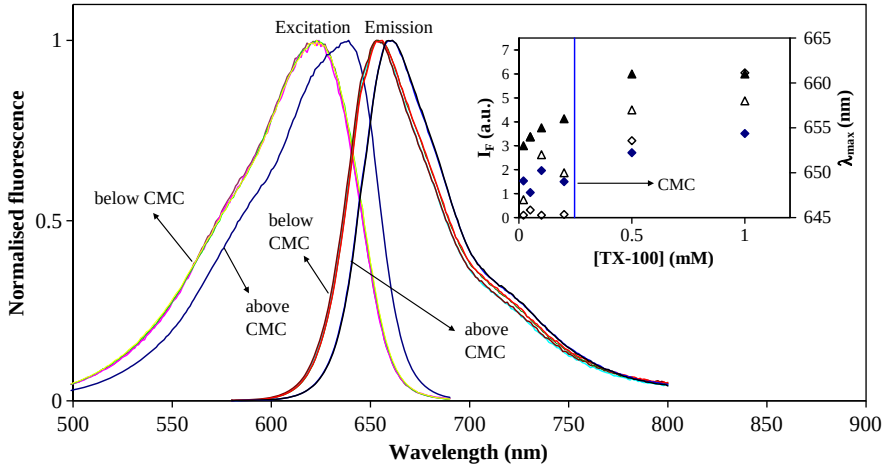


**Figure 3.** Normalised fluorescence emission and excitation spectra of compound **1b** with TX100. The inset shows the plot of the maximum fluorescence intensity, $I_F$, (◆, ◇) and the corresponding fluorescence wavelengths (▲, Δ) as a function of TX100 concentration. The filled and unfilled symbols are used, respectively, for compounds **1b** and **1e**. The concentration of compounds **1b** and **1e** was $2 \times 10^{-6}$ M.

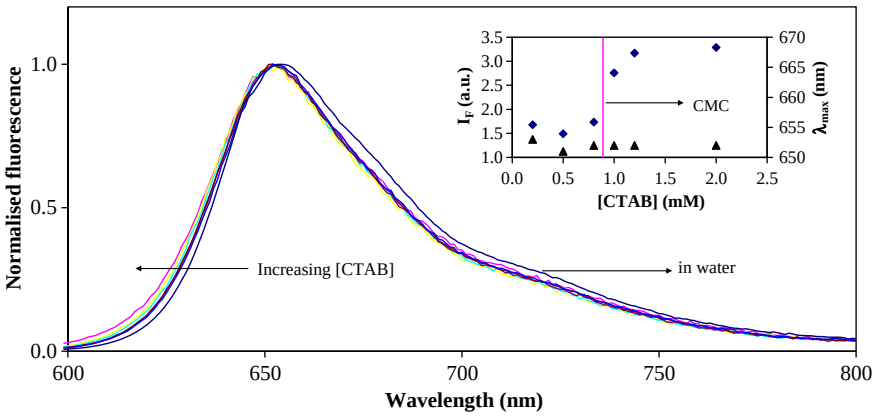


**Figure 5.** Normalised fluorescence spectra of compound **1b** with CTAB. The inset shows the plot of the fluorescence intensity, $I_F$, (◆) and the corresponding fluorescence wavelength (▲) as a function of CTAB concentration. The concentration of compound **1b** was $2 \times 10^{-6}$ M.

was probably due to the formation of ground state complexes between the aromatic moieties of both compound **1b** and TX100, which disappeared upon micellisation. The possibility of variation of the fraction of H-aggregates[8] upon addition of the surfactant cannot explain this result, since no variation would occur in the shape of the excitation spectra. This is due to the fact that H-aggregates do not fluoresce. Concerning the use of this type of probes in proteins, the interaction of compound **1b** with TX100 is interesting, since all fluorescent amino acids (tyrosine, tryptophan and phenylalanine) have aromatic fluorochromes.

In order to further confirm the ground state complexation, we obtained the absorption spectra of compound **1b** in TX100 water solutions and found a similar red shift to that observed in excitation spectra upon micellisation (data not shown). Compound **1e** showed a similar photophysical behaviour, but the variations in absorption spectra were much more complex (Fig. 4) indicating that various types of surfactant-dye aggregates existed and possibly with the presence of the neutral basic form of **1e**, which showed an absorption maximum near 500 nm.[8] In addition, a much higher increase in fluorescence intensity upon micellisation was observed for compound **1e** than for compound **1b** (60 times instead of three times). The more pronounced increase could be due to a sudden change in the amount of the basic form of **1e** which should have a ~10 times lower fluorescence quantum yield than the acid form. In the case of compound **1b**, no basic form was detected in the absorption spectra (data not shown) and we conclude that the quantum yields of **1b** in water and in TX100 micelles are similar with the increase in fluorescence intensity originating mainly from a ~4 times increase in absorbance.

Regarding the positive surfactant, CTAB, no spectral shifts were observed from the fluorescence measurements obtained but the micellisation process was still detected (Fig. 5) through a sudden increase in fluorescence intensity. From the absorption measurements (data not shown), it was observed that compound **1e** again had a very distinct behaviour when compared to compound **1b**. In the latter, there were no significant spectral variations while, for the former, there were complicated spectral features involving mainly the neutral basic form (bands from 450 to 550 nm in the spectral region) with very little contribution from the usual acid form near 600 nm. As a result, there was no trend in fluorescence measurements, which allowed for the detection of the micellisation process of CTAB using compound **1e**. Both the dependence of fluorescence intensity and maximum emission wavelength showed an oscillating behaviour (data not shown). Further studies will be undertaken to better understand the behaviour of benzo[*a*]phenoxazine derivatives with long alkyl (>8 carbons) side chains.

In the case of compound **1b**, there was obviously no ground state association with CTAB molecules and the photophysical behaviour can be interpreted by a rapid decrease in the amount of H-aggregate fraction upon association of compound **1b** with CTAB micelles, which appear above the critical micellar concentration. This association occurred even though there was a charge repulsion as a consequence of the effect of the octylamino substituent as an anchor in the hydrophobic core of the micelle. Due to the hydrophobic effect[7] the energetic expenditure would be far higher if one octylamino substituent of the side chain was solvated by water molecules.

## 2. Conclusion

In this work, 5,9-diaminobenzo[*a*]phenoxazinium dyes **1a**–**g**, containing long-alkylamino side chains at 5-position of the fluorochromophores were efficiently synthesised.

These cationic dyes, with absorption in ethanol in the 627–638 nm range, were highly fluorescent and revealed a maximum wavelength between 654 and 678 nm. Preliminary results of the study of *N*-[10-methyl-5-(octylamino)-9*H*-benzo[*a*]phenoxazin-9-ylidene]ethanaminium chloride (**1b**), with Triton® X-100 and cetyltrimethylammonium bromide showed the potential of this fluorophore in sensing the micellisation process of neutral and cationic surfactants. The longer side chain derivative, *N*-[10-methyl-5-(dodecylamino)-9*H*-benzo[*a*]phenoxazin-9-ylidene]ethanaminium chloride (**1e**) showed a distinct photophysical behaviour and is better in the detection of the micellisation of Triton® X-100, but is unable to detect the self-organisation of the CTAB surfactant. The results obtained in this investigation suggested that this type of 5,9-diaminobenzo[*a*]phenoxazines presents great potential as biological fluorescent probes in the near-infrared spectral region.

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## References and notes

1. Neuhaus, W.; Trzeciak, J.; Lauer, R.; Lachmann, B.; Noe, C. R. *J. Pharm. Biomed. Anal.* **2006**, *40*, 1035–1039.
2. Sevestre, A.; Charmantray, F.; Hélaine, V.; Lásiková, A.; Hecquet, L. *Tetrahedron* **2006**, *62*, 3969–3976.
3. Gonçalves, M. S. T. *Chem. Rev.* **2009**, *109*, 190–212.
4. Frangioni, J. V.; Onishi, S. U.S. Patent 082423A2, 2005.

5. Jose, J.; Burgess, K. *Tetrahedron* **2006**, *62*, 11021–11037.
6. Pozharski, E. V.; Macdonald, R. C. *Anal. Biochem.* **2005**, *341*, 230–400.
7. Tanford, C. In *The Hydrophobic Effect: Formation of Micelles and Biological Membranes*; John Wiley & Sons: New York, 1980.
8. Frade, V. H. J.; Gonçalves, M. S. T.; Coutinho, P. J. G.; Moura, J. C. V. P. *J. Photochem. Photobiol. A.* **2007**, *185*, 220–230.
9. Frade, V. H. J.; Barros, S. A.; Moura, J. C. V. P.; Coutinho, P. J. G.; Gonçalves, M. S. T. *Tetrahedron* **2007**, *63*, 12405–12418.
10. Coutinho, P. J. G.; Castanheira, E. M. S.; Rei, M. C.; Oliveira, M. E. C. D. R. *J. Phys. Chem. B* **2002**, *106*, 12841–12846.
11. Typical procedure for the synthesis of compounds **1a–g** (described for **1b**): To a cold solution (ice bath) of 5-ethylamino-4-methyl-2-nitrosophenol hydrochloride **2a** (0.087 g; $4.82 \times 10^{-4}$ mol) in ethanol (2 mL), *N*-octylnaphthalen-1-amine (**3b**) (0.307 g; $1.20 \times 10^{-3}$ mol) and concentrated hydrochloride acid ($5.0 \times 10^{-2}$ mL) were added. The mixture was refluxed for 4 h and monitored by TLC (silica: dichloromethane/methanol 59:1). The solvent was removed under reduced pressure and the crude mixture was purified by dry chromatography on silica gel using dichloromethane/ *n*-hexane and dichloromethane/methanol, mixtures of increasing polarity as the eluent. *N*-[10-methyl-5-(octylamino)-9*H*-benzo[*a*]phenoxazin-9-ylidene]ethanaminium chloride (**1b**) was obtained as a blue solid (0.49 g, 98%). Mp 147.5–149.0 °C. $R_f$ = 0.45 (silica: dichloromethane/methanol, 5:1). FTIR (KBr): $\nu_{max}$ 3195, 2925, 2853, 1642, 1592, 1561, 1544, 1519, 1498, 1451, 1435, 1315, 1295, 1259, 1232, 1185, 1163, 1129, 1085, 1054, 1010, 881, 817, 773, 733, 708, 666 $cm^{-1}$. $^1$H NMR ($CDCl_3$, 300 MHz): $\delta$ 0.86 (3H, t *J* 6.6 Hz, $NH(CH_2)_7CH_3$), 1.20–1.50 (13 H, 2 × m, 5 × $CH_2$ and $NHCH_2CH_3$), 1.85 (2H, br s, $NHCH_2CH_2$), 2.45 (3H, s, $CH_3$), 3.20–3.30 (2H, m, $NHCH_2CH_2$), 3.57 (2H, br s, $NHCH_2CH_3$), 6.30 (2H, br s, 8-H and 6-H), 7.49 (1H, s, 11-H), 7.87 (2H, br s, 2-H and 3-H), 8.80–8.90 (1H, m, 1-H), 9.18 (1H, br s, 4-H), 10.81 (1H, br s, NH) ppm. $^{13}$C NMR ($CDCl_3$, 75.4 MHz): $\delta$ 13.95 ($NHCH_2CH_3$), 14.03 ($NH(CH_2)_7CH_3$), 18.60 ($CH_3$), 22.55 ($CH_2$), 27.12 ($CH_2$), 28.65 ($NHCH_2CH_2$), 29.14 ($CH_2$), 29.24 ($CH_2$), 31.71 ($CH_2$), 38.72 ($NHCH_2CH_2$), 44.40 ($NHCH_2CH_3$), 92.44 (C-6), 93.22 (C-8), 123.46 (Ar-C), 123.99 (C-1), 125.54 (C-4), 127.06 (C-10), 129.66 (Ar-C), 129.94 (C-3), 130.57 (Ar-C), 130.98 (C-11), 131.61 (C-2), 133.48 (Ar-C), 146.72 (Ar-C), 150.57 (Ar-C), 154.03 (C-9), 156.71 (C-5) ppm. The assignments were supported by HMBC and HMQC techniques. HRMS: *m/z* (FAB): calcd for $C_{27}H_{34}N_3O$ [$M^+$] 416.2702; found 416.2708.
12. Crossley, M. L.; Turner, R. J.; Hofmann, C. M.; Dreisbach, P. F.; Parker, R. P. *J. Am. Chem. Soc.* **1952**, *74*, 578–584.
13. Typical procedure for the synthesis of compounds **3a–c** (described for **3b**): To a solution of 1-naphthylamine (1.0 g; $6.98 \times 10^{-3}$ mol) in ethanol (2 mL), 1-bromooctane (1.97 mL; $9.81 \times 10^{-3}$ mol) was added and the resulting mixture was refluxed for 33 h 30 min., and monitored by TLC (silica: chloroform). The solvent was removed under reduced pressure and the crude mixture was purified by dry chromatography on silica gel using chloroform/*n*-hexane, 1:1). *N*-Octylnaphthalen-1-amine **3b** was obtained as a brown oil (0.455 g, 51%). $R_f$ = 0.61 (silica: chloroform/*n*-hexane, 1:2). FTIR (neat): $\nu_{max}$ 3389, 3058, 2956, 2925, 2855, 2469, 1625, 1605, 1582, 1531, 1465, 1410, 1377, 1344, 1282, 1254, 1216, 1173, 1142, 1081, 1016, 953, 861, 800, 770, 724, 666 $cm^{-1}$. $^1$H NMR ($CDCl_3$, 300 MHz): $\delta$ 0.97 (3H, t *J* 7.2 Hz, $CH_3$), 1.30–1.60 (10 H, m, 5 × $CH_2$), 1.78–1.90 (2H, m, $NHCH_2CH_2$), 3.33 (2H, t *J* 7.5 Hz, $NHCH_2CH_2$), 6.85 (1H, d *J* 7.2 Hz, 4-H), 7.35 (1H, d *J* 8.1 Hz, 2-H), 7.45 (1H, t *J* 8.1 Hz, 3-H), 7.38–7.56 (2H, m, 6-H and 7-H), 7.80–7.88 (1H, m, 8-H), 7.90–7.98 (1H, m, 5-H) ppm. $^{13}$C NMR ($CDCl_3$, 75.4 MHz): $\delta$ 13.99 ($CH_3$), 22.50 (2 × $CH_2$), 26.86 ($CH_2$), 27.13 ($CH_2$), 29.03 ($CH_2$), 31.62 ($CH_2$), 49.08 ($NHCH_2CH_2$), 114.57 (C-4), 120.81 (C-5), 124.75 (C-7), 125.65 (C-2), 126.17 (C-4a), 126.47 (C-3), 126.57 (C-6), 128.73 (C-8), 134.33 (C-8a), 136.21 (C-1) ppm. The assignments were supported by HMBC and HMQC techniques. HRMS: *m/z* (EI): calcd. for $C_{18}H_{25}N$ [$M^+$] 255.1987; found 255.1985.
14. Sens, R.; Drexhage, K. H. *J. Lumin.* **1981**, *24*, 709–712.
15. Gharibi, H.; Razavizadeh, B. M.; Hashemianzaheh, M. *Colloid Surf. A-Physicochem. Eng. Asp.* **2000**, *174*, 375–386.
16. Paredes, S.; Sepulveda, L.; Tribout, M. *J. Phys. Chem.* **1984**, *88*, 1871–1875.