

Near-UV molar absorptivities of alachlor, mecoprop-p, pendimethalin, propanil and trifluralin in methanol

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Abstract

An experimental set-up consisting of two parallel absorption cells coupled to a CCD detector was used to determine absolute values of molar absorptivity coefficients ϵ of five herbicides (alachlor, mecoprop-p, pendimethalin, propanil and trifluralin) in methanol. The absorption spectra were measured using a deuterium lamp at room temperature (298 ± 2 K) over the wavelength range 240–340 nm, except for pendimethalin and trifluralin where the wavelength range was extended to 240–550 nm.

Absorbances were also measured at 253.7 nm using an Hg-lamp in different concentrations range depending on the studied compound. Except for mecoprop-p where absorbances were too low at this wavelength, the absolute values of molar absorptivity coefficients at 253.7 nm were determined according to the Beer–Lambert's law: $\epsilon = 381 \pm 28$ for alachlor, $\epsilon = 11,240 \pm 1030$ for pendimethalin, $\epsilon = 22,220 \pm 1850$ for propanil and $\epsilon = 5720 \pm 410$ for trifluralin (in units of $M^{-1} cm^{-1}$). The quoted errors correspond to 2σ obtained from the least square fit analysis and the estimated systematic error of 5% due to the uncertainties in aqueous concentrations. For all the studied compounds, the absorbances measured were lower than two and did not exhibit any deviation from the Beer–Lambert's law.

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1. Introduction

The amount of pesticides routinely applied, mainly for agricultural uses, has dramatically increased in recent years and consequently, there are serious concerns about the increasing risks to human health.

This study has been focused on five herbicides belonging to various chemical families, namely alachlor (chloroacetanilide), mecoprop-p (aryloxyacid), pendimethalin (dinitroaniline), propanil (amide) and trifluralin (dinitroaniline) for which the absolute molar absorptivity has been determined over the wavelength range 240–340 or 240–550 nm.

Propanil is mainly used on the cultures of rice whereas mecoprop-p is a commonly used lawn herbicide. Chloroacetanilides such as alachlor are widely used herbicides, applied as pre-planting, pre-emergent or early post-emergent treatment to control annual grass weeds and broadleaf weeds in soybeans,

corn, sorghum, sweet corns and dry beans [1]. Both trifluralin and pendimethalin are dinitroaniline herbicides. Trifluralin is used primarily as an herbicide on grass, to control broadleaf weeds and on some crops (fruits and vegetables), flowers and shrubs. For example, trifluralin is used on soybeans and cotton. Pendimethalin is used primarily as an herbicide to destroy or prevent the growth of certain plants like weeds. It is also used on crops and residential lawns and ornamentals. Estimated U.S. annual uses of alachlor, pendimethalin, propanil and trifluralin in 1997 were 6.8×10^6 , 12.3×10^6 , 3.6×10^6 and 10.0×10^6 kg, respectively [1].

Alachlor, propanil, mecoprop-p are slightly toxic herbicides as illustrated by their rat oral LD50 values (in units of mg/kg): 930–1350 for alachlor, 930–1210 for mecoprop-p and 1080–2500 for propanil [2]. Pendimethalin is slightly to practically non-toxic by ingestion, with reported oral LD50 values of 1050 mg/kg to greater than 5000 mg/kg in rats while pure trifluralin is practically non-toxic to test animals by oral, dermal, or inhalation routes of exposure. The oral LD50 for technical trifluralin in rats is greater than 10,000 mg/kg. Except mecoprop-p that may be mutagenic at very high

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doses, all the studied herbicides have no mutagenic activity. If propanil and pendimethalin are not carcinogenic, the carcinogenic effects for the three others herbicides are uncertain [2].

Once in the environment, pesticides can contaminate surface water and groundwater depending on their solubilities while the main input mechanisms of pesticides in the atmosphere are dispersion during spraying operations, volatilisation from ground or leaf surfaces and wind erosion [3]. Their resulting atmospheric concentrations are usually relatively low and vary according to the seasons [3]. For example, the maximum concentrations recorded in France in the region centre in 2002 were 17.8, 5.7 and 11.4 ng m⁻³ for alachlor, pendimethalin and trifluralin, respectively [4].

Direct photolysis is a possible pathway for the elimination of pesticides in the environment. The photodissociation rate constants associated to these components depend either on their absorption cross sections $\sigma(\lambda)$ for the molecule in the gas-phase or on their molar absorptivity coefficients $\varepsilon(\lambda)$ for the molecule in the aqueous phase, on the primary quantum yield $\phi(\lambda)$ for photolysis and on the actinic flux of solar radiation $J(\lambda)$. Due to

the low vapor pressures of pesticides, the direct measurements of their absorption cross sections in the gas-phase cannot be performed using a classical absorbance cell [5,6].

Besides, the pesticides are generally poorly soluble in water so that direct measurements of ε using a classical pathlength of 1 cm is rather limited, except if they exhibit high absorbance. A set-up based on a long pathlength allows the determination of the molar absorptivity coefficients for species with relative low solubility in water [7,8]. In the case of very low soluble species in water like the studied herbicides, absorption measurements can then be performed in an adequate solvent.

In this work, the absolute values of molar absorptivity coefficients ε of alachlor, mecoprop-p, pendimethalin, propanil and trifluralin have been measured in methanol at room temperature (298 ± 2 K), over a wavelength range of either 240–340 nm or 240–550 nm using an absorbance cell coupled to a CCD detector. The chemical formulas of the five studied pesticides are given in Fig. 1. Alachlor measurements performed in methanol in this work were compared to those obtained in water in our previous study [7] in order to validate our new experimental set-up and ensure that results did not depend on the solvent. To our knowl-

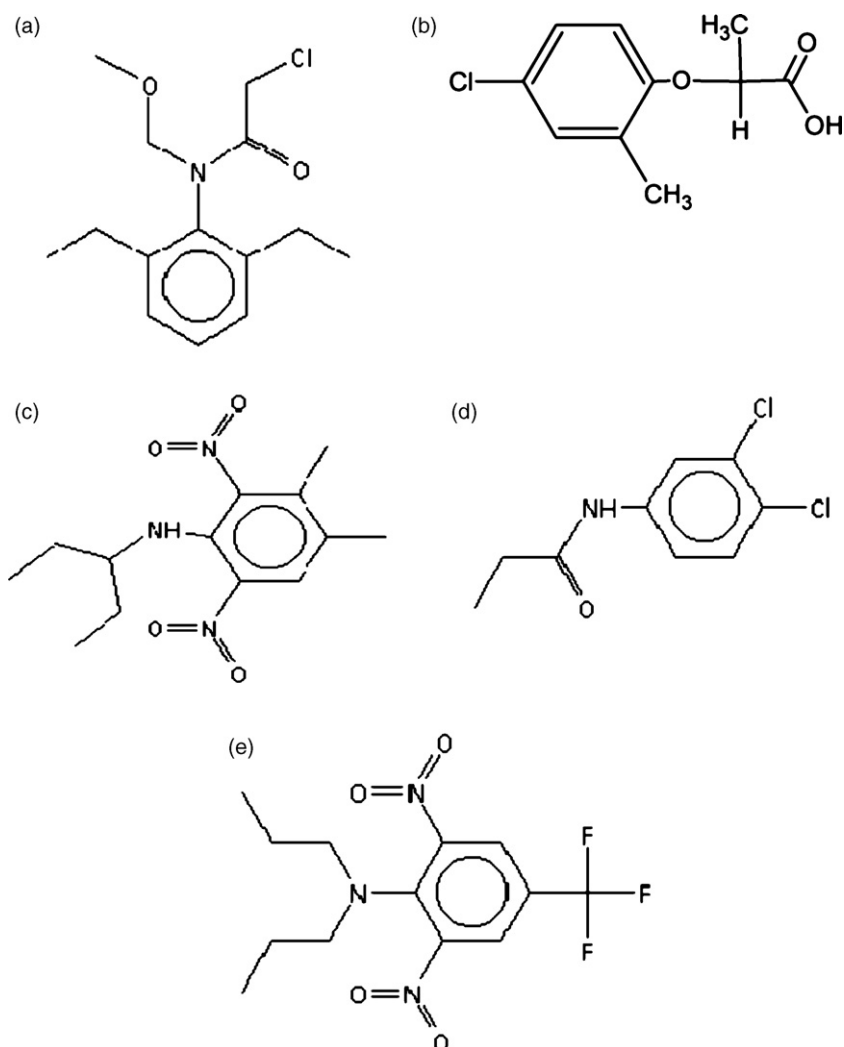


Fig. 1. Chemical formula of the five pesticides: (a) alachlor, (b) mecoprop-p, (c) pendimethalin, (d) propanil and (e) trifluralin.

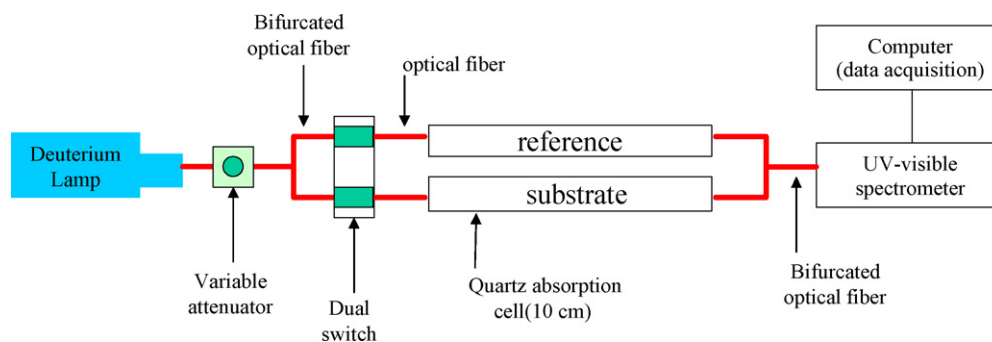


Fig. 2. Scheme of the experimental set-up.

edge, we report here the first absolute UV spectra for the studied herbicides except for alachlor.

2. Experimental section

Because of the poor solubility of the studied pesticides in water, methanol has been chosen as solvent to replace it. Since these two solvents have similar polarity, the UV spectrum obtained in methanol is expected to be very similar than that in water.

The set-up shown in Fig. 2 is similar to the previous used to determine absolute values of molar absorptivity coefficients ϵ of several pesticides in aqueous solution [7,8]. It consists of two cylindrical quartz absorption cells, exposed alternatively to the output of a light source equipped with a variable attenuator and connected to a dual switch with an bifurcated optical fibre. The two cells have pathlength of 10 cm and volume of 28.2 mL and are much smaller than those previously used by Feigenbrugel et al. (2005, 2006), i.e., 100 cm and \sim 900 mL. Since pesticides are much more soluble in methanol than they are in water, smaller absorption cells were then adapted to reduce the amount of solvent.

The light sources are either a deuterium lamp (Ocean Optic, D-2000) or a mercury–argon lamp (Ocean Optics, CAL-2000). After passing through the cell, the UV light, is focused onto another optical fibre connected to the entrance slit of a spectrometer (Jobin Yvon, TRIAX 320) usually equipped with a 1200 grooves/mm grating, which disperses the radiations onto a CCD (Andor Technology, DV420-OE). Experiments were conducted using a 20 μ m entrance slit, providing a spectral resolution of about 0.065 nm. With this configuration, the spectrometer recorded spectra over two 65 nm intervals and the measurements covered two wavelength regions: 233–298 nm and 275–340 nm. Thus there was a 23 nm overlap segment, which made easy to construct the entire spectrum. Since the light produced by the deuterium lamp is temperature dependent, the wavelength scale of the spectrometer was first calibrated with the Hg–Ar lamp using two spectral lines: 253.7 and 296.7 nm for the 233–298 nm range, and 296.7, 302.1 and 334.1 nm for 275–340 nm range. For measurement between 340 and 550 nm, similar procedures were performed using two gratings (600 or 1200 grooves/mm) and at least two spectral lines of calibration given by the Hg–Ar lamp: 365.0 and 404.7 nm for 340–405 nm

range; 404.7, 407.8 and 435.8 nm for 400–465 nm range; 435.8 and 546.1 for 430–560 nm range.

The spectra were measured using the following method. First, the Hg–Ar lamp was used to calibrate the experimental set-up. The light intensities $I_{0,A1}$ and $I_{0,B1}$ transmitted through the two cells A and B were then determined when both cells were filled up with pure methanol in order to determine the ratio $I_{0,B1}/I_{0,A1}$. Cell B was then purged and filled with a diluted solution of pesticide (light intensity I_{B2}) while methanol was maintained in cell A. This allowed the determination of $I_{B2}/I_{0,A2}$. Since during these operations, light intensity from the lamp may have been subject to small variations, the reference intensity $I_{0,B2}$ was calculated from $I_{0,B1}$ according to: $I_{0,B2} = I_{0,B1} \times (I_{0,A2}/I_{0,A1})$. This operation was repeated several times.

The wavelength-dependent molar absorptivity coefficient ϵ ($M^{-1} \text{ cm}^{-1}$) was obtained using the Beer–Lambert's law:

$$A = \log \frac{I_{0,B2}}{I_{B2}} = \epsilon LC \quad (1)$$

where A is the absorbance (dimensionless), L the pathlength of the cell filled with the sample (cm) and C is the concentration of the compound in solution (in mol L^{-1}).

The same operation was repeated by replacing the Hg–Ar lamp with the deuterium lamp in order to explore the entire spectrum either from 240 to 340 nm or from 240 to 550 nm depending on the pesticide and its UV spectrum. Each measurement of I consisted of 200 scans, which required a maximum 4.2 s to be completed.

Alachlor (99.9%), propanil (99.7%), mecoprop-p (99.4%) were from Riedel de Haën while pendimethalin (99.2%) and trifluralin (99.8%) were purchased by the Institute of Organic Industrial Chemistry. Methanol (99.9%) was from Fischer Scientific. All were used without any additional purification.

3. Results and discussion

Absorbances were measured at 253.7 nm with the Hg–Ar lamp for different concentration ranges depending on the compound: 8–69.4 mg L^{-1} for alachlor, 0.2–18.0 mg L^{-1} for mecoprop-p, 0.2–2.2 mg L^{-1} for pendimethalin, 0.1–2.0 mg L^{-1} for propanil and 0.8–8.0 mg L^{-1} for trifluralin. The absolute values of molar absorptivity coefficients at this wavelength were determined from the plot of $\log(I_{0,B2}/I_{B2})$

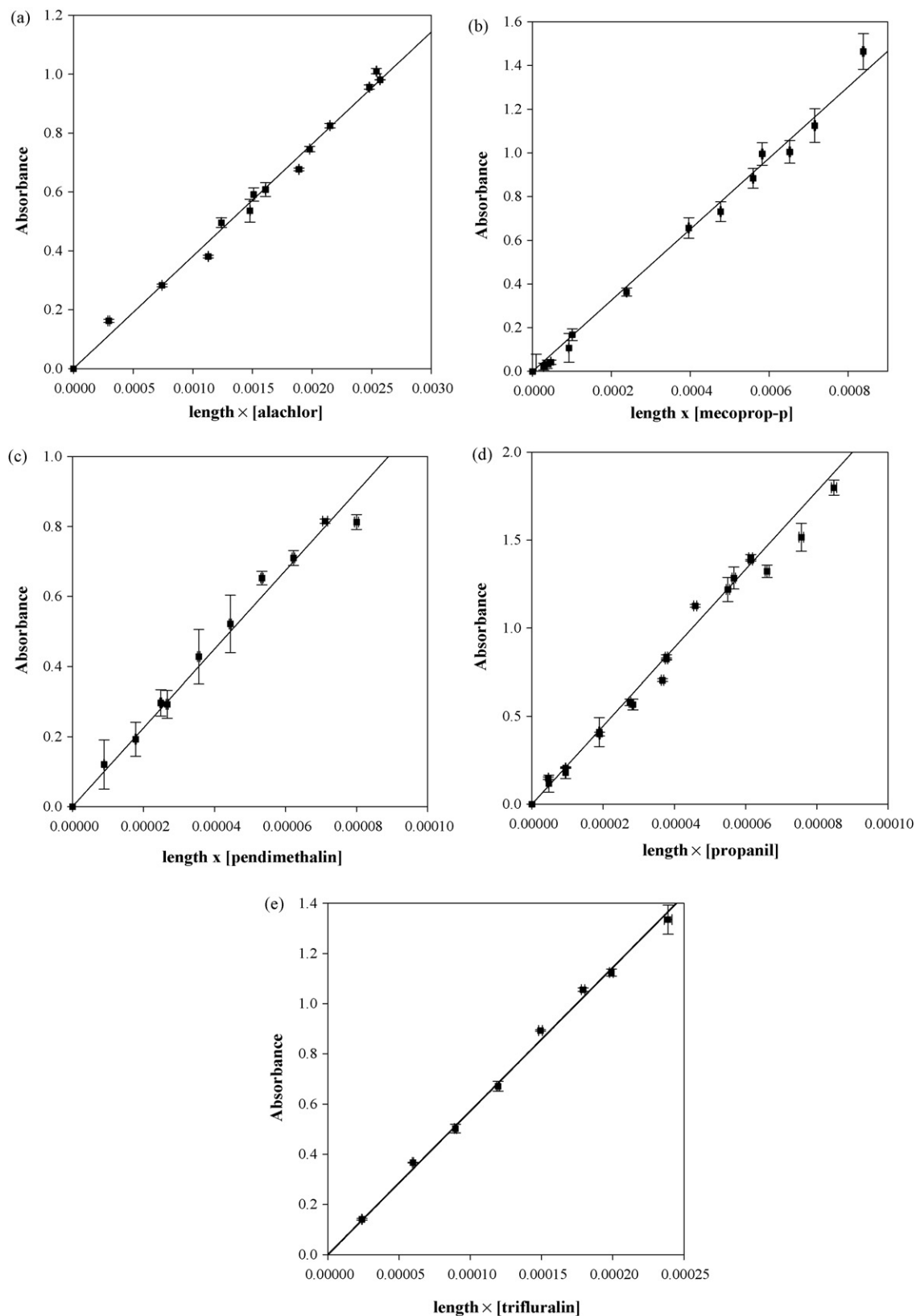


Fig. 3. Absorbance vs. $L \times C$ either at 253.7 nm for (a) alachlor, (c) pendimethalin, (d) propanil and (e) trifluralin, or at 280 nm for (b) mecoprop-p. The slopes of these plots are the corresponding molar extinction coefficients ϵ (in units of $\text{M}^{-1} \text{cm}^{-1}$) according to the Beer–Lambert's law (see Eq. (1)).

versus LC, where the slope is equal to ϵ (see Fig. 3a–e). The following values have been found: $\epsilon(253.7 \text{ nm}) = 381 \pm 28$ for alachlor, $\epsilon(253.7 \text{ nm}) = 11240 \pm 1030$ for pendimethalin, $\epsilon(253.7 \text{ nm}) = 22220 \pm 1850$ for propanil, $\epsilon(253.7 \text{ nm}) = 5720 \pm 410$ for trifluralin (in units of $\text{M}^{-1} \text{ cm}^{-1}$). For mecoprop-p, since the absorbance was too low at 253.7 nm, similar measurements were performed at both 240 and 280 nm using the Deuterium lamp: $\epsilon(240 \text{ nm}) = 1521 \pm 144$ and $\epsilon(280 \text{ nm}) = 1628 \pm 132$. The quoted errors correspond to 2σ obtained from the least square fit analysis and the estimated systematic error of 5% due to the uncertainties in concentrations. For all the studied compounds, the absorbances were smaller than two and did not exhibit any deviation from the Beer–Lambert's law as shown in Fig. 3a–e.

Absorbance were also measured between 240 and 340 nm (alachlor, mecoprop-p and propanil) or between 240 and 550 nm (pendimethalin and trifluralin) using the deuterium lamp for the same concentrations ranges. The agreement between our ϵ values obtained for the two lamps at 253.7 nm was always better than 10% for all compounds (Figs. 4–8). Absolute values of molar absorptivity coefficients, with either 2 nm interval in the 240–290 nm range or 5 nm intervals in the 290–340 nm range, are listed in Table 1. For both pendimethalin and trifluralin, absolute values of ϵ are also reported with 10 nm intervals in the 350–550 nm range in Table 2. For all the studied pesticides, the uncertainties on ϵ values between 240 and 550 nm are estimated to be less than 20%.

Our alachlor spectrum in methanol is shown in Fig. 4 together with that obtained in water in our previous study [7]. Our new spectrum in methanol is in good agreement with that previously determined by Feigenbrugel et al. (2005), indicating no significant solvent effect. The maxima of both spectra are particularly well correlated together, highlighting there is neither significant bathochromic nor hypsochromic effects when methanol replaces water. Our new ϵ value of $\epsilon_{\text{methanol}} = 381 \pm 28$

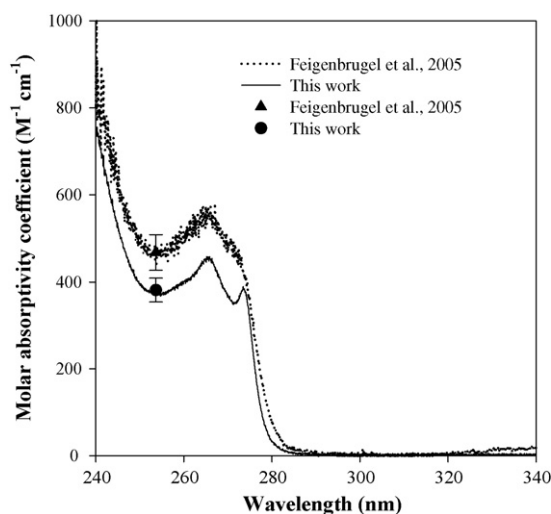


Fig. 4. Comparison of molar extinction coefficients ϵ (in units of $\text{M}^{-1} \text{ cm}^{-1}$) of alachlor between 240 and 340 nm measured in this work at $298 \pm 2 \text{ K}$ and in a previous work in aqueous solution [7]: (—) This work using a deuterium lamp; (●) This work using a Hg–Ar lamp; (···) Feigenbrugel et al. (2005) using a deuterium lamp; (▲) Feigenbrugel et al. (2005) using a Hg-lamp.

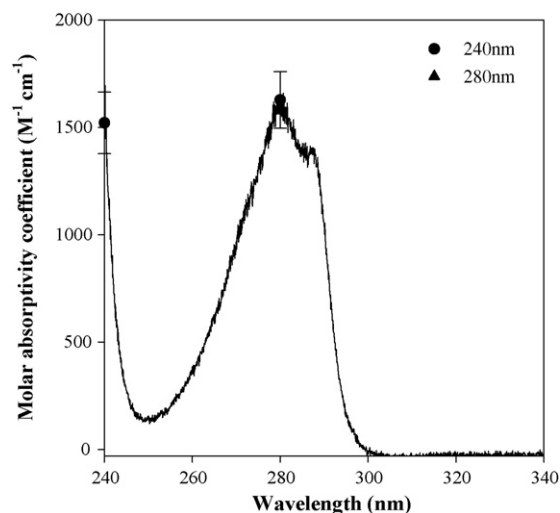


Fig. 5. Molar extinction coefficients ϵ (in units of $\text{M}^{-1} \text{ cm}^{-1}$) of mecoprop-p measured in this work between 240 and 340 nm at $298 \pm 2 \text{ K}$. The solid line corresponds to its UV spectrum obtained with a deuterium lamp while the values of ϵ determined with the same lamp at either 240 or 280 nm are symbolized by (●) and (▲), respectively.

obtained at 253.7 nm is in reasonably good agreement with that of $\epsilon_{\text{water}} = 466 \pm 18$ reported by Feigenbrugel et al. (2005). Nevertheless, this difference of about 20% suggests a possible small hypochromic effect indicating that the transitions may be less favorable when methanol is used as solvent and consequently the number of absorbed photons decreases. In both studies, its spectrum exhibits two peaks corresponding to $\pi \rightarrow \pi^*$ bands characteristic of aromatic compounds. One of them is rather weak ($\epsilon \sim 500\text{--}700 \text{ M}^{-1} \text{ cm}^{-1}$), centred at 265 nm and corresponds to the 1L_b band while the maximum of the second peak (out of the wavelength range covered in this study) is below 240 nm and corresponds to the 1L_a band. Nevertheless, we can observe in Fig. 4 a third peak centred at 273 nm ($\epsilon \sim 380$

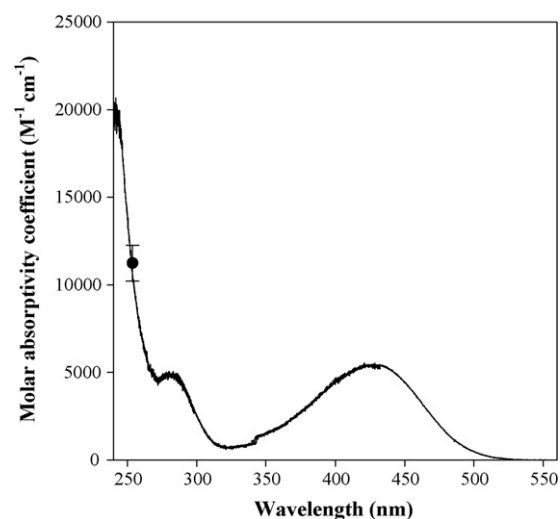


Fig. 6. Molar extinction coefficients ϵ (in units of $\text{M}^{-1} \text{ cm}^{-1}$) of pendimethalin measured in this work between 240 and 550 nm at $298 \pm 2 \text{ K}$. The solid line corresponds to its UV spectrum obtained with a deuterium lamp while the value of ϵ determined at 253.7 nm with an Hg–Ar lamp is symbolized by (●).

$M^{-1} \text{ cm}^{-1}$) with methanol, whereas only a slight shoulder was present when water was used as solvent [7]. Whatever the solvent, absorption of alachlor above 290 nm can be considered as negligible since $\epsilon \leq 5 M^{-1} \text{ cm}^{-1}$ as shown in Table 1.

Similarly to alachlor, the spectrum of mecoprop-p exhibits also two peaks corresponding to $\pi \rightarrow \pi^*$ bands characteristic of aromatic compounds (see Fig. 5). One of them is centred at 280 nm ($\epsilon \sim 1600 M^{-1} \text{ cm}^{-1}$) including a tiny shoulder at 287 nm while the maximum of the second peak (out of the wavelength range covered in this study) is below 240 nm. Its spectrum is quite similar to that obtained for *m*-chlorotoluene [9], from which this pesticide is derived. The substituent group $-\text{OCH}(\text{CH}_3)\text{COOH}$ added on *m*-chlorotoluene, to obtain the mecoprop-p molecule, lead only to a small bathochromic shift of about 5–10 nm. Absorption of mecoprop-p above 295 nm can be considered as negligible (see Table 1).

Below 270 nm, pendimethalin absorbs much more than alachlor and mecoprop-p as shown in Fig. 6. Its UV spectrum exhibits three peaks, which maxima are located at 245 ($\epsilon \sim 16500 M^{-1} \text{ cm}^{-1}$), 280 nm ($\epsilon \sim 4900 M^{-1} \text{ cm}^{-1}$) and 420–430 nm ($\epsilon \sim 5300 M^{-1} \text{ cm}^{-1}$). Its spectrum is partially similar to that obtained for 2,6-dinitroaniline [9], which exhibits three peaks centred at 250 nm, 315 and 420 nm, respectively. The different substituent groups added on 2,6-dinitroaniline molecule, i.e., two methyl groups on the aromatic ring and one $-\text{CH}(\text{C}_2\text{H}_5)_2$ group on the amine function, to obtain the pendimethalin molecule, causes then bathochromic shifts of five and 35 nm, respectively for the two first peaks centred at 250 and 315 nm. As shown in Fig. 6, pendimethalin absorbs relatively strongly between 290 and 500 nm, which corresponds to natural sunlight. It is why it is not surprising that Dureja and Walia [10] report rapid degradation of pendimethalin in methanol under

Table 1
Molar absorptivities ϵ of alachlor, mecoprop-p, pendimethalin, propanil and trifluralin measured between 240 and 340 nm using a deuterium lamp.

λ (nm)	ϵ (alachlor) ($M^{-1} \text{ cm}^{-1}$) ^a	ϵ (mecoprop-p) ($M^{-1} \text{ cm}^{-1}$) ^a	ϵ (pendimethalin) ($M^{-1} \text{ cm}^{-1}$) ^a	ϵ (propanil) ($M^{-1} \text{ cm}^{-1}$) ^a	ϵ (trifluralin) ($M^{-1} \text{ cm}^{-1}$) ^a
240	754	1521 ± 144 ^b	15,468	17,364	7778
242	661	812	16,515	18,898	7710
244	567	389	16,564	20,401	7494
246	491	213	16,133	21,403	7129
248	433	150	14,684	22,273	6661
250	396	140	12,971	22,600	6269
252	379	151	11,414	22,617	5947
253.7	381 ± 28 ^c	166	11,240 ± 1030 ^c	22,220 ± 1850 ^c	5720 ± 410 ^c
254	372	176	10,014	22,170	5728
256	376	229	8795	2161	5621
258	387	286	7733	19,902	5616
260	400	360	6936	18,165	5757
262	414	447	6213	16,049	5963
264	439	559	5558	13,694	6197
266	448	667	5106	11,115	6414
268	410	810	4798	8624	6591
270	369	956	4579	6446	6734
272	357	1099	4357	4629	6815
274	364	1225	4478	3367	6840
276	217	1369	4689	2529	6793
278	88	1514	4906	2054	6670
280	35	1628 ± 132 ^b	4926	1407	6483
282	16	1522	4904	1121	6222
284	8	1423	4795	1143	5858
286	5	1377	4661	1125	5453
288	3	1346	4465	1042	5003
290	3	1037	4207	891	4557
295	1	236	3338	808	3599
300	1	0	2464	307	2802
305	2	0	1659	0	2280
310	2	0	936	0	1917
315	3	0	583	0	1765
320	3	0	377	0	1665
325	3	0	285	0	1644
330	3	0	355	0	1677
335	3	0	367	0	1726
340	2	0	403	0	1791

The quoted errors correspond to 2σ obtained from the least square fit analysis.

^a The reported values are averaged over 2 nm intervals in the range 240–290 nm and over 5 nm intervals in the range 290–340 nm.

^b The values are obtained according to the Beer–Lambert's law using a deuterium lamp.

^c The values are obtained according to the Beer–Lambert's law using an Hg–Ar lamp.

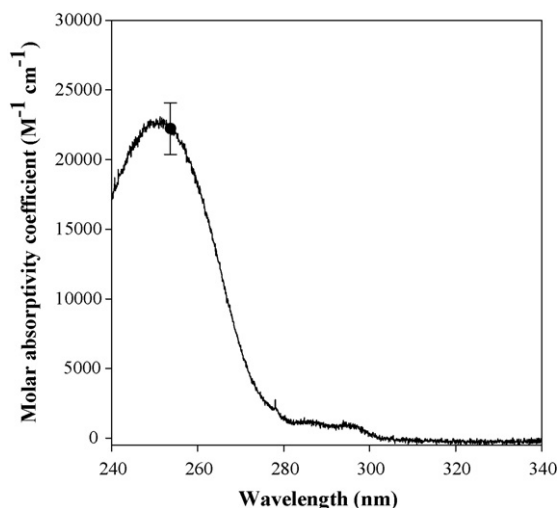


Fig. 7. Molar extinction coefficients ϵ (in units of $M^{-1} \text{cm}^{-1}$) of propanil measured in this work between 240 and 340 nm at 298 ± 2 K. The solid line corresponds to its UV spectrum obtained with a deuterium lamp while the value of ϵ determined at 253.7 nm with an Hg–Ar lamp is symbolized by (●).

ultraviolet light and sunlight, yielding to the major products, i.e. 2-amino-6-nitro-*N*-(1-ethylpropyl)-3,4-xylylidine and 2-nitroso-6-nitro-3,4-xylylidine [10].

Pronanil exhibits a large intensive absorption band centred at 250 nm ($\epsilon \sim 23,000 M^{-1} \text{cm}^{-1}$) while a meticulous glance enables us to foresee two tiny shoulders at 285 and 295 nm, respectively (see Fig. 7). Its spectrum is very similar to that of acetanilide [9] from which propanil is derived, that shows also a large band centred at 240–245 nm and two shoulders at 275 and 283 nm, respectively. The addition of two chlorine atoms on the aromatic ring and the replacement of the methyl group located near the amide function by an ethyl group, does not modify much the UV–vis spectrum and causes only a small bathochromic shift of about 10 nm of the entire spectrum. The UV spectrum of

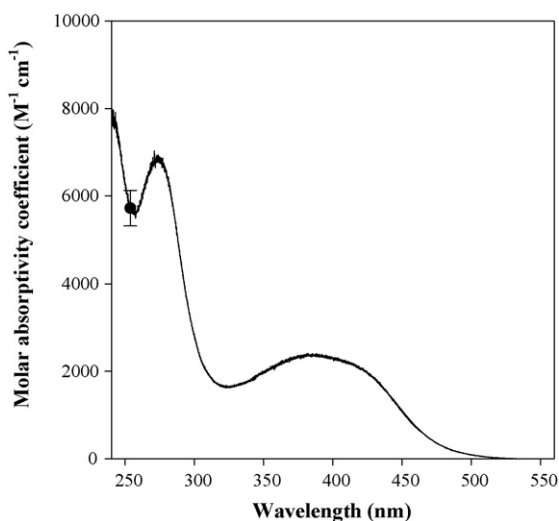


Fig. 8. Molar extinction coefficients ϵ (in units of $M^{-1} \text{cm}^{-1}$) of trifluralin measured in this work between 240 and 550 nm at 298 ± 2 K. The solid line corresponds to its UV spectrum obtained with a deuterium lamp while the value of ϵ determined at 253.7 nm with an Hg–Ar lamp is symbolized by (●).

Table 2

Molar absorptivities ϵ of pendimethalin of trifluralin measured between 350 and 550 nm using a deuterium lamp.

λ (nm)	ϵ (pendimethalin) ($M^{-1} \text{cm}^{-1}$) ^a	ϵ (trifluralin) ($M^{-1} \text{cm}^{-1}$) ^a
350	1511	1978
360	1869	2135
370	2403	2277
380	3039	2359
390	3762	2353
400	4490	2293
410	4975	2206
420	5354	2060
430	5335	1833
440	5125	1485
450	4430	1103
460	3492	737
470	2463	459
480	1545	275
490	900	158
500	476	89
510	218	44
520	91	16
530	14	1
540	0	0
550	0	0

^a The reported values are averaged over 10 nm intervals in the range 350–550 nm.

propanil exhibits non negligible absorbance between 290 and 300 nm, so that its photolysis cannot be excluded.

As pendimethalin, trifluralin is derived from 2,6-dinitroaniline. Consequently, we observe three peaks (see Fig. 8) in the studied wavelength range, with maxima located at 240 ($\epsilon \sim 8000 M^{-1} \text{cm}^{-1}$), 270–275 nm ($\epsilon \sim 7000 M^{-1} \text{cm}^{-1}$) and 380–390 nm ($\epsilon \sim 2300 M^{-1} \text{cm}^{-1}$). In opposite to pendimethalin, the two first bands appear to have similar intensities. Trifluralin absorbs significantly for wavelength higher than 290 nm ($\epsilon \sim 2000 M^{-1} \text{cm}^{-1}$ for $295 < \lambda < 430$ nm). The strong absorbance of trifluralin observed for $\lambda > 290$ nm is consistent with the recent results reported by Le Person et al. [11] who have investigated its atmospheric gas-phase photolysis under natural sunlight [11]. The authors measured a high photolysis rate of $J_{\text{trifluralin}} = (1.2 \pm 0.5) \times 10^{-3} \text{ s}^{-1}$ and derived a lifetime towards the photolysis of about 15 min at ground level. They concluded that the tropospheric degradation of trifluralin is mainly controlled by photolysis with a non negligible contribution of OH reaction. As both trifluralin and pendimethalin present similar UV spectra, pendimethalin is expected to have also a large photolysis rate and consequently a short photolysis lifetime in the atmosphere.

4. Conclusion

The new set up developed in this work was based on a relative long pathlength (~ 10 cm) allowing the use of lower concentrations of organic species and/or the determination of lower molar absorptivity coefficients ϵ . It was validated by measuring the UV spectrum of alachlor in methanol between 240 and 340 nm which was compared with that obtained in water.

Using the same methodology than that previously used in our recent works, we have highlighted that water can be satisfactory substituted by methanol where the poorly water soluble organic species such as pesticides are much more soluble. Afterwards, the UV spectra of mecoprop-p, pendimethalin, propanil and trifluralin have been determined in the same experimental conditions either in the wavelength ranges of 240–340 nm or of 240–550 nm. At tropospheric wavelength of 295 nm, $\epsilon(\text{trifluralin}) \sim 3600 \geq \epsilon(\text{pendimethalin}) \sim 3300 > \epsilon(\text{propanil}) \sim 800 > \epsilon(\text{mecoprop-p}) \sim 200 > \epsilon(\text{alachlor}) \sim 0$ (in units of $\text{M}^{-1} \text{cm}^{-1}$).

Such data have many interesting applications. Our experimental determinations provide useful information to estimate the potential fate of these pesticides by sunlight photolysis in both aqueous and gas phases. They can also be considered for chemical remediation of wastewaters to eliminate such pesticides or for analytical measurements by HPLC coupled to UV detection.

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