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Short communication

Degradation of microalgae from freshwater by UV radiation

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ABSTRACT

Algae (*Chlorella*,*Microcystis*, *Oocystis* and *Scenedesmus*) degradation by ultraviolet radiation has been investigated. The radiation source was a low pressure mercury vapor lamp which emits monochromatic radiation at 254 nm. Experiments include initial algae concentration variation. After a period of exposure to UV radiation, algal mass concentration was reduced by more than 80%. The results were interpreted under Line Source Spherical Emission model, so quantum yield was the appropriate target variable for explaining the process. Global quantum yields are determined for *Chlorella*, *Microcystis*, *Oocystis* and *Scenedesmus* being 7.75×10^4, 3.65×10^5, 2.28×10^5, 1.74×10^4 $\mu g\,E^{-1}$, respectively.

Introduction

Eutrophication is the enhancement of the natural process of biological production in rivers, lakes and reservoirs, caused by increases in levels of nutrients, usually phosphorus and nitrogen compounds [1]. Eutrophication was recognized as a pollution problem in many western European and North American lakes and reservoirs in the middle of the twentieth century [2]. At the present, eutrophication causes a number of deleterious effects on drinking water treatment: reduction of coagulation efficiency resulting in a rising coagulant demand [3,4], increased membrane fouling [5], filter clogging, higher yield of sludge as a result of an increased coagulant dose [6] and disinfection by-product formation [7]. In addition, algae organic matters affect the color, taste and odor of drinking water and a number of cyanobacterial species also excrete toxic metabolites which can cause health problems [8].

For these reasons, it is necessary to eliminate algae from drinking waters; suitable techniques are coagulation [9,10], flotation [11], filtration [12], ozonation [13], chlorination [3], oxidation by potassium permanganate [14], electrochemical [15] and ultrasound [16] treatments.

Previous studies have shown that ultraviolet radiation (UV), especially the shortwave ultraviolet (UV-C at 254 nm) is highly effective for the removal of algae [17,18]. UV radiation degrades to the target DNA much more efficiently than chemical agents in water. Moreover, this generates no chemical waste in its germicide effects and produces comparably lower disinfection by products. Studies have bring to light that ultraviolet radiation at 254 nm is an alternative to inhibit blooms of cyanobacterias and green algae in lakes and reservoirs [19].

For these reasons, in this paper is studied the degradation of *Chlorella*, *Microcystis*, *Oocystis* and *Scenedesmus* algae by UV radiation.

Materials and methods

Reagents

The trials were carried out with water from a creek (AEMET) in Badajoz (Southwestern of Spain, Extremadura Community). The basic characteristics [20] of these waters are shown in Table 1.

Algae cultures were incubated at 25 °C under white light photoperiod of 12:12 in a culture medium supplied by Fluka (Algae culture broth). *Chlorella*, *Microcystis*, *Oocystis* and *Scenedesmus* inoculums were provided by the Department of Botany, University of Coimbra (Portugal).

Photochemical trials

The assays were carried out in an installation previously described [21]. Figure drawing thereof is shown in Fig. 1.

Algae inactivation was carried out as follows: 500 mL of a solution of algal mass concentration for each test is prepared. The exact concentration of algae is determined by measuring the

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Table 1
Raw water characterization data.

Parameter	Units	AEMET
pH	–	8.18 ± 0.3
Conductivity	$\mu S\,cm^{-1}$	351 ± 2
Turbidity	NTU	10.75 ± 0.3
Total solids	$g\,L^{-1}$	2.65 ± 0.2
$KMnO_4$ oxidability	$mg\,O_2\,L^{-1}$	6.96 ± 0.3
Hardness	$mg\,CaCO_3\,L^{-1}$	212 ± 3

fluorescence of chlorophyll in a fluorimeter (Aquafluor) previously calibrated [22]. This solution was introduced in the photochemical reactor. The UV lamp was turned on, and samples (5 mL) were collected at regular time. The experiment usually lasted for 30 min.

Actinometric reactions permit to characterize of the lamp emissivity. Uranyl oxalate was extensively considered as a reference according to the general method [23]. Uranyl sulfate ($UO_2SO_4{\cdot}3.5H_2O$) was supplied from Panreac, while oxalic acid ($C_2H_2O_4$) and potassium permanganate ($KMnO_4$) were purchased by Sigma Aldrich.

Results and discussion

Algae degradation tests were performed to obtain information about their efficiency in process of UV radiation. At first, viability of this photodegradation process was confirmed by evaluating the apparent decay in algae content. Finally, kinetic model was utilized to model the process of algae degradation.

Algae degradation

Algae degradation was tackled through three trial series in which initial algae concentration was 25, 50 and 75 $\mu g\,L^{-1}$. As it can be appraised in Fig. 2 *Scenedesmus* is less responsive than the other algae to UV radiation because *Chlorella*, *Microcystis* and *Oocystis* concentration are negligible after being subjected to 30 min of light exposure. This may be due to the size and structure of microalgae; *Scenedesmus* is larger and more robust than the other algae.

This is to verify the feasibility of this procedure in degrading this type of microalgae although it does not provide valuable information in terms of reaction rate; therefore does not allow the comparison under different experimental conditions.

Kinetic studies

It is labeled to identify a target variable that represents the reaction rate and effectiveness of the degradation process in a numerical way. For this purpose, classical studies implement the Line Source Spherical Emission (LSSE) model [24] and they are still in force [25].

In short, the basis of LSSE model is shown in previous publications [21]. Following the model described is obtained the value of total radiation flow emitted by the lamp, W_L, for the current system was $2.80 \times 10^{-6}\,E\,s^{-1}$.

Molar extinction coefficients values were determined for each alga: *Chlorella*: 2.50×10^{-3}; *Microcystis*: 3.77×10^{-4}; *Oocystis*: 3.18×10^{-4}; *Scenedesmus*: 4.52×10^{-3} ($\mu g^{-1}\,cm^{-1}\,L$).

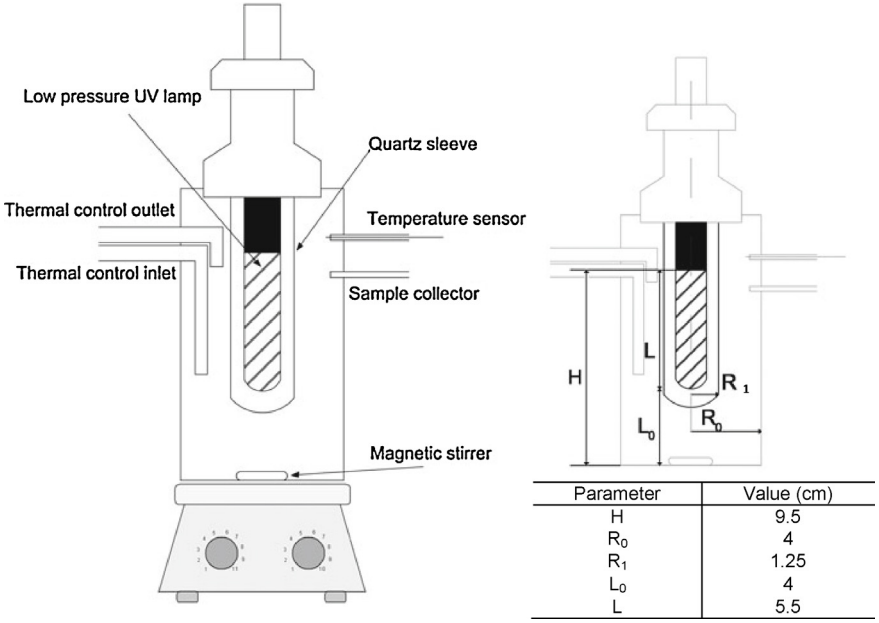
According to the model algae degradation can be represented by Eq. (1).

$$C_B = C_{B0} - \frac{\phi}{V}\int_0^t W_{abs}\,dt \quad (1)$$

Where C_{B0} and C_B are the concentration of chlorophyll at the start and at any one time. V is the total volume of the liquid phase (L) and W_{abs} is the flow of radiant energy absorbed by the reaction medium ($Eins\,s^{-1}$).

Therefore it is possible to determine, for each operation time, the corresponding μ, W_{abs} and integral term in Eq. (1). The linear adjustment of this expression will lead to a constant slope that is representative of ϕ. This ϕ (chlorophyll degraded by photons absorbed) is the kinetic parameter (called quantum yield) which allows us to compare different efficiencies at various operating conditions, hence, it can determine how the system responds to operational changes and, finally, to propose a theoretical or empirical model.

In Fig. 3 it can be observed the graphical representations of these linear adjustments. Values quantum yields obtained are shown in Table 2. It can be seen that the quantum yields for each



Parameter	Value (cm)
H	9.5
R_0	4
R_1	1.25
L_0	4
L	5.5

Fig. 1. UV installation.