

# Aqueous Ranitidine Elimination in Photolytic Processes

Javier Rivas\*, Olga Gimeno, Maria Carbajo, Teresa Borralho

**Abstract**—The elimination of ranitidine (a pharmaceutical compound) has been carried out in the presence of UV-C radiation. After some preliminary experiments, it has been experienced the no influence of the gas nature (air or oxygen) bubbled in photolytic experiments. From simple photolysis experiments the quantum yield of this compound has been determined. Two photolytic approximation has been used, the linear source emission in parallel planes and the point source emission in spherical planes. The quantum yield obtained was in the proximity of  $0.05 \text{ mol Einstein}^{-1}$  regardless of the method used. Addition of free radical promoters (hydrogen peroxide) increases the ranitidine removal rate while the use of photocatalysts ( $\text{TiO}_2$ ) negatively affects the process.

**Keywords**—Quantum yield, photolysis, ranitidine, water treatment.

## I. INTRODUCTION

RECENTLY, a great concern has been raised about the presence of some chemicals, catalogued as endocrine disruptors, in water matrixes [1]. Endocrine disruptor compounds (EDC's) are characterized by acting like hormones in the endocrine system and disrupt the physiologic function of endogenous hormones. They are sometimes also referred to as hormonally active agents or endocrine disrupting chemicals/compounds [2]. Studies have linked endocrine disruptors to adverse biological effects in animals, giving rise to concerns that low-level exposure might cause similar effects in human beings. An extensive bibliography has been documented on the presence of EDC's and their presence after conventional water treatment facilities [3-6].

Amongst endocrine disruptors, personal care products, pharmaceuticals, pesticides, etc. can be listed. Ranitidine is a histamine  $\text{H}_2$ -receptor antagonist that inhibits stomach acid production. It is commonly used in treatment of peptic ulcer disease and gastroesophageal reflux disease. There is scarce literature about oxidation of this environmentally relevant pharmaceutical. The processes applied for elimination of ranitidine from water are electrochemical (heterogeneous catalytic reaction between a semiconductor and water under a superimposed electric field) [7], photochemical oxidation (under sunlight and oxygen) [8] and ozonation [9]. In this manuscript, the UV-C irradiation of ranitidine has been investigated. The influence of promoters and photo-catalysts

has also been assessed in terms of mineralization level achieved.

## II. MATERIALS AND PROCEDURE

Ranitidine was purchased from Aldrich and used as received. Titanium dioxide ( $\text{TiO}_2$ ) P-25 from Degussa was used as photocatalyst with no previous treatment. According to manufacturers Degussa P-25 is a non porous solid formed by the combination of the anatase (70%) and rutile (30%) forms of titanium dioxide.

Experiments were carried out in a 1 L glass annular jacketed photochemical reactor (see Fig. 1). Water pumped from a thermostatic bath circulated through the reactor jacket to ensure a constant temperature inside the reactor. The reactor walls were insulated to avoid release of radiation and/or heat outside. Prior to the photocatalytic experiments in the presence of titanium dioxide, the suspension was stirred for 60 min in the dark to achieve the adsorption equilibrium.

A 15 W Heraeus low pressure mercury vapor lamp introduced in a quartz well was used for experiments carried out by using UV-C radiation (254 nm). Actinometry experiments led to the determination of the incident radiation flux ( $q_0 = 2.5 \times 10^{-8} \text{ Einstein cm}^{-2} \text{ s}^{-1}$ ) and radiant power ( $E_0 = 3.3 \times 10^{-6} \text{ Einstein s}^{-1}$ ).

Total organic carbon (TOC) was determined by a Shimadzu TOC 5000A analyser by directly injecting the aqueous solution. Peroxides were monitored by iodometric titration. Ranitidine concentration was quantified by high-performance liquid chromatography (Agilent Technologies, series 1100) equipped with a Chromasil C-18 column was used.

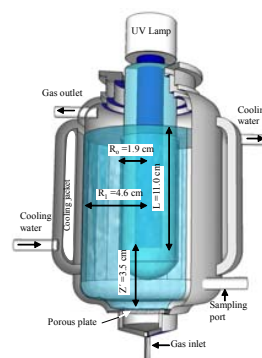


Fig. 1. Dimensions of the photochemical reactor used

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## III. RESULTS AND DISCUSSION

## A. Photolysis of ranitidine

An initial series of ranitidine photolysis experiments was conducted in the absence of promoters or photocatalysts. Fig. 2 shows the results obtained in terms of normalized ranitidine evolution with time. As observed, ranitidine is completely eliminated from water in just 60 min, indicating the high photo-reactivity of this compound. The efficiency of the photolytic process was corroborated after the calculation of the molar extinction coefficient (absortivity) which was in the proximity of  $5000 \text{ M}^{-1}\text{cm}^{-1}$  at  $\text{pH} > 2$  (a lower value of  $4000 \text{ M}^{-1}\text{cm}^{-1}$  was obtained at  $\text{pH} = 2$ ). Nevertheless, in spite of the fast ranitidine elimination, the mineralization level achieved after the photolytic process was negligible, indicating that photo-transformation products do accumulate in the aqueous medium.

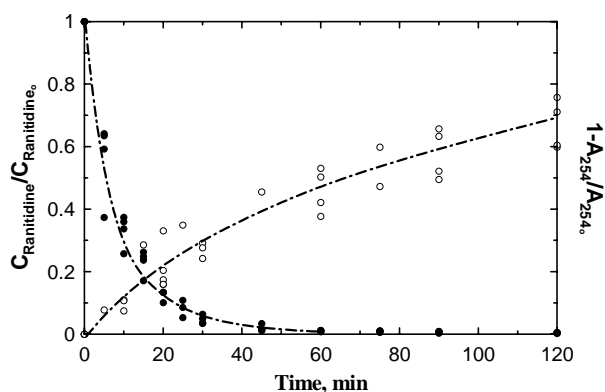


Fig. 2. Photolysis of ranitidine ( $10^{-4} \text{ M}$ ). (Open symbols: absorbance evolution).

Another crucial parameter in photolytic processes is the quantum yield, which is a measure of the fraction of absorbed photons leading to photo-transformation. Two different approaches were used in this work:

- The linear source with emission in parallel planes model (LSPP). Being the equation describing the photo-transformation of ranitidine ( $C_R$ ):

$$-\frac{dC_R}{dt} = \phi \frac{q_0 2\pi R_0 L \varepsilon C}{A_{254} V} \left[ 1 - 10^{(-A_{254}(R_1 - R_0))} \right] \quad (1)$$

where  $\phi$  is the metoprolol quantum yield,  $q_0$  is the incident radiation flux ( $\text{Einstein cm}^{-2} \text{ s}^{-1}$ ),  $R_i$  is defined in Fig. 1,  $V$  is the reaction volume,  $\varepsilon$  the molar absorption coefficient of metoprolol and  $A_{254}$  is the absorbance of the photolysed solution.

- The point source with spherical emission model (PSSE). Now the expression used to calculate the ranitidine quantum yield is:

$$-\frac{dC_R}{dt} = \phi \frac{E_0 A_{254}}{V 2L} \int_0^L \int_{R_0}^{R_1} \int_{z'}^{z'+L} r \frac{e^{(-A_{254}\omega)}}{r^2 + (z-z')^2} dr dz dz' \quad (2)$$

where  $E_0$  is the radiant power ( $\text{Einstein s}^{-1}$ ) and  $\omega$  is

$$\text{defined as: } \omega = \frac{\sqrt{r^2 + (z-z')^2}}{r} \quad (3)$$

After applying the previous models, by numerical integration the ranitidine quantum yield obtained was  $0.049 \pm 0.004 \text{ mol Einstein}^{-1}$ . This results again confirms the high photoreactivity of this pharmaceutical if compared to reported values for other compounds (i.e.  $0.02$ ,  $3.4 \times 10^{-3}$ ,  $1.1 \times 10^{-3}$ , or  $4.7 \times 10^{-3} \text{ mol Einstein}^{-1}$ , for metoprolol, norfloxacin, doxycycline and mefenamic acid, respectively, [10, 11]).

B.  $\text{H}_2\text{O}_2$  promoted photolysis of ranitidine

In an attempt to increase the mineralization of ranitidine, a free radical promoter was initially added. Hydrogen peroxide decomposes into two hydroxyl radicals in the presence of UV-C radiation:



Hydroxyl radicals can effectively degrade the organic material into  $\text{CO}_2$  and water. Results are shown in Fig. 3.

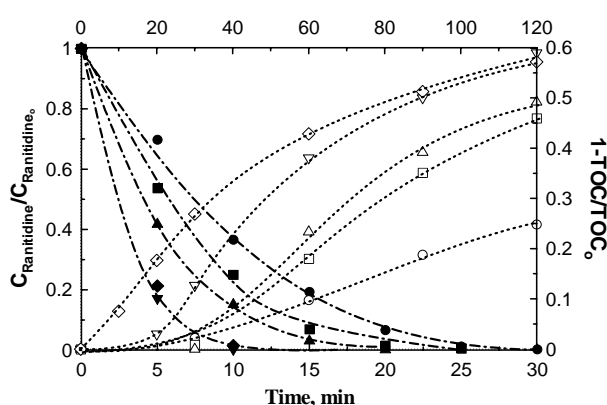


Fig. 3. Photolysis of ranitidine ( $10^{-4} \text{ M}$ ) in the presence of  $\text{H}_2\text{O}_2$ .  $\bullet$ ,  $5 \times 10^{-4} \text{ M}$ ;  $\blacksquare$ ,  $1.0 \times 10^{-3} \text{ M}$ ;  $\blacktriangle$ ,  $2.0 \times 10^{-3} \text{ M}$ ;  $\blacktriangledown$ ,  $5.0 \times 10^{-3} \text{ M}$ ;  $\blacklozenge$ ,  $1.0 \times 10^{-2} \text{ M}$ . (open symbols: TOC conversion).

As inferred from this figure, the presence of hydrogen

TABLE I  
CONTRIBUTIONS TO RANITIDINE REMOVAL

$\text{H}_2\text{O}_2 \text{ (M)}$	Direct photolysis	Free radical oxidation
$1.0 \times 10^{-3}$	83.5%	16.5%
$5.0 \times 10^{-3}$	54.5%	45.5%
$10.0 \times 10^{-3}$	60.0%	40%

peroxide not only enhances significantly the photodegradation rate of ranitidine but is also capable of removing a 60% of the total organic content (TOC) initially present in solution. A rough estimation of the two contributions for ranitidine removal can be accomplished at time zero. Table 1 indicates a higher contribution of the radical pathway as the hydrogen peroxide concentration is raised.

Evolution profiles of the absorbance at 254 nm decrease from roughly 0.5 to almost zero, i.e., it is suggested that remaining TOC in solution has no aromatic rings nor double

bonds, typical structures contributing to absorption in the UV region.

Moreover, hydrogen peroxide conversion can also be related to TOC conversion in a rough way by a simple linear relationship. Figure 4 shows a slope of  $1.14 \pm 0.20$  which could be a useful tool to determine the  $\text{H}_2\text{O}_2$  requirements for a pre-specified TOC conversion.

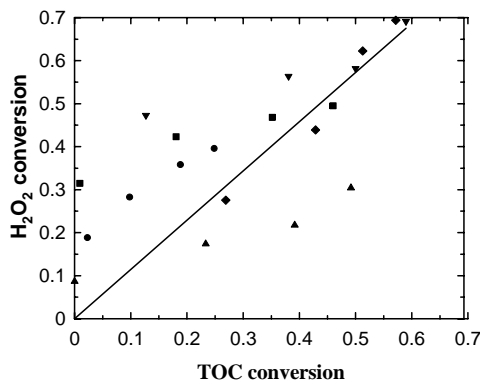


Fig. 4. Photolysis of ranitidine ( $10^{-4}$  M) in the presence of  $\text{H}_2\text{O}_2$ . TOC versus  $\text{H}_2\text{O}_2$  conversions. Symbols as in Fig. 3.

#### C. $\text{H}_2\text{O}_2$ promoted photocatalysis of ranitidine in the presence of $\text{TiO}_2$

Experiments carried out in the presence of titanium dioxide led to a slight negative effect in ranitidine conversion rate if compared to results obtained in the absence of the semiconductor. This effect could be attributed to a potential shielding effect of the solid, avoiding the absorption of radiation by ranitidine. Nevertheless some TOC conversion (roughly 20%) could be achieved when the solid was added to the aqueous ranitidine solution. In an attempt to improve the mineralization level achieved, the photocatalytic process was conducted in the presence of hydrogen peroxide.

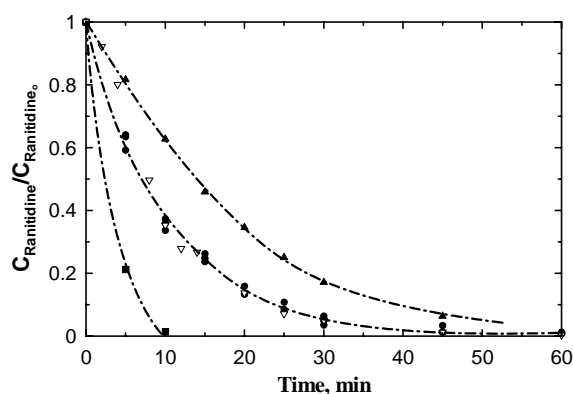


Fig. 5. Photocatalysis of ranitidine ( $10^{-4}$  M). ●, photolysis; ▲, photocatalysis ( $\text{TiO}_2 = 0.0125$  M); ■, promoted photocatalysis ( $\text{H}_2\text{O}_2 = 0.01$  M); ▽, promoted photocatalysis ( $\text{TiO}_2 = 0.0125$  M,  $\text{H}_2\text{O}_2 = 0.01$  M)

Results were somehow disappointing since the combination of titanium dioxide and hydrogen peroxide did not bring appreciable differences to experimental data obtained by simple photolysis experiments (Fig. 5). Thus, it is hypothesised that the positive effect exerted by  $\text{H}_2\text{O}_2$  is compensated by the negative influence of  $\text{TiO}_2$ .

#### ACKNOWLEDGMENT

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