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A Brief Talk on the Research Progress of Antibiotic Photolysis

Rui Guo[1, a]

[1]Shaanxi Provincial Land Engineering Construction Group Co., Ltd. Xi'an, 710075, China

[2]Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd. Xi'an, 710075, China

Abstract

Antibiotics can migrate and transform in environmental media through a series of biological or non-biological processes such as adsorption, hydrolysis, photolysis and microbial degradation in the water environment. Photolysis is an important way for antibiotics to subtract in natural water environment. The main reaction mechanism is that antibiotic molecules absorb light energy and become excited states to trigger various reactions.

Keywords

Antibiotics; Photolysis; Reactions.

1. Basic Principles of Antibiotic Photolysis

Antibiotics can migrate and transform in environmental media through a series of biological or non-biological processes such as adsorption, hydrolysis, photolysis, and microbial degradation in the water environment [1]. Studies have shown that many antibiotics have stable physical and chemical properties and are not easily hydrolyzed. Glinke [2] found that the degradation rate of gatifloxacin in pure water, fresh water, and seawater was less than 2.9% under 5 days of dark conditions. Pouliquen [3] also found that oxytetracycline, florfenicol, flumequine, etc. are all hydrolytically stable compounds.

Photochemical degradation is an important reduction pathway for antibiotics in natural water environment [4]. Generally, in surface water bodies, there are often direct photolysis, indirect photolysis and self-sensitization photolysis of antibiotic contaminants.

(1) Direct photolysis: The main reaction mechanism is that antibiotic molecules absorb light energy and then become excited states to initiate various reactions [5]. The reaction process includes 2 stages: a. Photo-induced isomerization, the reaction speed is faster. b. Photolysis, the reaction speed is slow. The above two stages all follow the first-order reaction kinetics. It has been proved that antibiotics such as quinolones, sulfonamides, tetracyclines, etc., can undergo direct photolysis under direct irradiation of simulated sunlight and sunlight (λ>290 nm) [6-8].

(2) Indirect photolysis: Oxidants or natural organic matter (such as H2O2, humic acid and Cl-) in the water environment absorb light energy to further induce indirect photolysis of compounds [9].

(3) Self-sensitized photolysis: also known as self-sensitized photooxidation, that is, after absorbing photons, the compound in the excited triplet state transfers energy to other substances (such as 3O2) to generate ROS (such as 1O2), and ROS will make the compound Oxidative degradation [10]. In addition to direct photolysis, chloramphenicols [11] and tetracyclines [12] also undergo self-sensitization photolysis.

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2. The Influence of Water Environmental Factors on the Photolysis Behavior of Antibiotics

When an antibiotic undergoes a photolysis reaction, its reaction speed mainly depends on its molecular structure and environmental conditions. Among them, the molecular structure can determine the quantum yield of the photochemical reaction and the light absorption characteristics of the molecule. Environmental conditions include light wavelength, radiation intensity, presence of environmental media, etc. [13-15]. Various elements in the water environment, such as anions (NO^{3-}, Cl-, HCO^{3-}), ferrous ions (Fe^{2+}), humic acid (HA) and soluble organic matter (DOMs) will undergo energy transfer, electron transfer, and ROS oxidation Such effects affect the photolysis reaction process of antibiotics [16-19].

Studies have shown that Cl-, as the main ion in seawater, often exhibits a dual effect on the photolysis of antibiotics. Gelinke [20] found that under UV-vis, Cl− promotes the generation of $^1O_2$ and accelerates the self-sensitization photolysis of florfenicol and thiamphenicol; under simulated sunlight, the photon energy is limited and can only produce A small amount of $^1O_2$, so the existence of Cl− basically cannot change the reaction rate. In eutrophic water, there are a lot of substances such as NO_3^-, NO_2^{2-} and Fe(III) and Fe(III). These typical photochemically active substances can generate ROS (·OH, etc.) under light conditions to promote the photolysis reaction of antibiotics. [21]. In addition, there are still a large number of other soluble substances in the water body, which can also affect the antibiotic reaction process. For example, HCO3−/CO_3^{2-} can generate ·CO3− under light irradiation, thereby promoting the photolysis of bisphenol A [22]. Because the structure of humic acid contains a large number of carbonyl groups, carboxyl groups, phenolic hydroxyl groups and other groups, it can interact with toxic and harmful organic substances such as oxides and metal ions in water, thus affecting the migration, biological absorption, and light of compounds in nature. Solution and other characteristics [23. 24]. It has been found that Fe(III) and HA will interact with each other, possibly forming Fe(III)-HA colloidal substances, inhibiting photolysis [25]. In environmental waters (especially in the aquaculture water environment), a variety of soluble substances coexist, and the complex interaction between them will seriously affect the photolysis reaction process of antibiotics. Although there have been a large number of literature reports on the effect of a single soluble substance on the photolysis of antibiotics, there are still few studies on the compound effect of multiple dissolved substances on the photolysis of antibiotics.

3. Ecological Risks of Photolytic Antibiotics

At present, there are relatively few studies on the toxicity and toxicology of antibiotics and their photolysis products to aquatic animals at home and abroad. Generally, antibiotics will produce less toxic products or be degraded by microorganisms after photolysis. However, some antibiotics may produce more toxic products after photolysis, or the ROS generated during the photolysis process will cause oxidative damage and damage to organisms. Toxic effects such as apoptosis [26]. Some scholars use artificially simulated sunlight to degrade fluoroquinolone antibiotics in water, and use luminescent bacteria (Vibrio fischeri) to carry out luminescence inhibition toxicity experiments. The toxic effect of enrofloxacin photolysis on Vibrio fischeri is first increased and then decreased. Trend, intermediate products with higher risk of toxicity may be generated during the photolysis process [27]. The photolysis of gatifloxacin and sarafloxacin will also generate intermediate products that have a higher risk of toxicity relative to the parent substance, which exhibits photomodification toxicity to Vibrio fischeri. Gao et al. used UV/$Na_2S_2O_8$ to degrade florfenicol in water, and used the inhibition rate of luminescent bacteria to evaluate the toxicity risk of photolysis products. After 1h of UVC irradiation, florfenicol in water was completely degraded, while the luminescence inhibition rate was only from 17.24% decreased to 11.9%, suggesting the toxicity risk of by-products of florfenicol

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photolysis. At the same time, antibiotics may generate reactive oxygen species such as OH and $^1O_2$ during the photolysis process, triggering lipid peroxidation of cell membranes, and affecting cell structure and function. These free radicals attack biological macromolecules and cause DNA damage. Therefore, it is necessary to evaluate the toxicity risk of antibiotics and their photolysis products in water.

4. Conclusion

Antibiotics are widely used to treat general bacterial infections and promote growth in humans and farmed animals. As a "fake" persistent environmental pollutant, it has been widely detected in the aquatic environment, with concentrations ranging from ng/L to μg/L. Antibiotics continue to migrate and transform in the water environment, which can kill non-target organisms and microorganisms in the environment indiscriminately, and can also induce the production of drug-resistant flora, which will cause harm to the environment. Due to its low pollution, photolysis has been used as one of the effective ways to degrade antibiotics in recent years.

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