Aging mechanism of PBS microplastic with UV irradiation and its effects on the adsorption of tetracycline.

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Abstract: Microplastics are generated by the decomposition of plastic debris due to physicochemical processes in the environment. They are emerging as a novel kind of pollution that is garnering worldwide attention. Nevertheless, there is a scarcity of studies about the aging properties and process of microplastics. The study investigated the aging process of biodegradable polybutylene succinate (PBS) microplastics when exposed to UV irradiation in several environments, including canteen wastewater and air. Additionally, the impact of aging on the adsorption of the antibiotic medication tetracycline (TCL) was examined. The findings indicate that PBS exhibits distinct properties when exposed to UV irradiation under varying settings, and the degradation of PBS is particularly evident in an atmospheric environment. The FTIR, XPS, and zeta potential investigation revealed distinct aging mechanisms occurring under different aging settings. The aging sequence of the functional groups in aged PBS was accurately determined for both air and canteen waste water environments. A study using an isothermal adsorption model demonstrates that the process of aging can greatly enhance the adsorption of tetracycline by PBS. The adsorption of Tetracycline is also influenced by various aging techniques. Overall, analysis proved to be an efficient approach for comprehending the aging process of PBS. These findings elucidate the aging process of PBS and establish a theoretical foundation for evaluating the environmental behavior and ecological risk associated with the coexistence of microplastics and antibiotic drugs.

Introduction: A comprehensive investigation is required to examine the impact of microplastics at various stages of aging on the adsorption of pollutants, as well as the distinctive properties of different types of pollutants. Therefore, in order to gain a better understanding of how microplastics age and how they affect the absorption of pollutants, we specifically chose antibiotic drugs commonly found in Chinese wastewater as representative pollutants. Our goal was to investigate the absorption characteristics and mechanisms of tetracycline on biodegradable microplastics at various stages of aging[5]. Consequently, we conducted a comprehensive investigation on the aging characteristics of PBS Biodegradable microplastics in two specific conditions (air and canteen wastewater) while exposing them to UV light for a duration of 2 months. The study elucidated the alterations in chemical bonds, emergence of new functional groups, aging mechanism, and adsorption mechanism of pollutants that occur throughout the aging process of plastics. This study can establish a theoretical foundation for understanding the environmental behavior of biodegradable microplastics and their influence on the migration of antibiotics.

Material and method: Polybutylene succinate Microplastic with size of 50μm, Antibiotic drug: Tetracycline, **Aging Experiment:** The UV aging studies were conducted in an aging chamber using a UVA-340 lamp at ambient temperature.

The experiment consisted of two methods: an aging experiment of PBS in canteen wastewater and air with UV radiation. Table 1 displays the chemical makeup of canteen waste water. The PBS (Phosphate Buffered Saline) of the Wastewater-aged test group were introduced onto a petri dish, followed by the addition of wastewater. The PBS solution was uniformly dispersed, and subsequently a glass lid was positioned within the aging chamber along with a UV lamp to periodically compensate for water evaporation (during a span of 8 days). After undergoing a 2-month age process, the samples were subsequently cleaned many times with Distilled water. The samples underwent dehydration using a freeze dryer and were thereafter gathered for utilization.

Results: Change on surface morphology

The impact of UV irradiation on the surface morphology of PBS was examined using SEM under various conditions. As observed under the scanning electron microscope (SEM), the Fresh PBS has a consistent and smooth flat surface. As the aging time increases, the surface of the material develops pores and becomes rough. Following a one-month aging process, the surface of the PBS exhibits voids. After a period of two months, the presence of voids becomes more pronounced and their size increases. The surface undergoes irregularities and adsorbs debris, which may result from the degradation of the PBS. Typically, the process of PBS aging is more easily noticeable in the air, but the alteration in canteen water is more apparent compared to the air(fig:1). PBS exhibits a higher susceptibility to oxidation in atmospheric conditions compared to its susceptibility in Canteen wastewater. This might be attributed to the fact that the air environment had a larger oxygen content compared to water environments, and the utilization rate of UV light was also higher for the PBS under air conditions due to light reflection . The level of aging in canteen wastewater is more than that in the air, maybe due to the impact of several variables like as proteins, neutrons, salts, and others. Additional research has also documented the presence of fissures and indentations on the exterior of microplastics following the process of aging. When comparing the results of air-aged PBS and wastewater-aged PBS, it is evident that the SSA, zeta potential, SEM, and functional groups undergo more significant changes in wastewater-aged PBS(fig:2). These changes make wastewater-aged PBS more suited for the adsorption of pollutants. In contrast to their approach, this work employs a standardized specification of PBS, facilitating the observation of age-related variations. This facilitates our comprehension of the attributes of deteriorating plastic. An XRD study was conducted on fresh PBS samples and PBS aged for 2 months under various settings to examine the crystal alterations of PBS before and after aging. In descending order of peak value, the substances are UV wastewater, UV air, and fresh PBS. This suggests that the level of crystallinity in PBS is enhanced following UV irradiation, and the maximum level of crystallinity is observed in PBS after UV exposure to canteen wastewater, followed by UV exposure to air. Greater crystallinity results in increased brittleness of the plastics, facilitating the production of smaller particles. This is due to the fact that plastics in the environment are significantly more susceptible to damage.

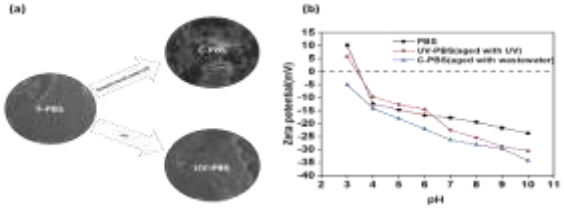

Fig. 1a. SEM images of PBS (treated by UV irradiation 3 months) in Air and wastewater environments.(b) zeta potenial of fresh and aged PBS

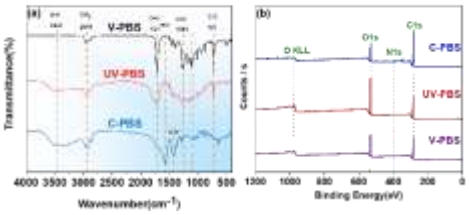

Fig. 2a. FTIR spectra of PS (treated by different UV irradiation times 2 months) and (b) XPS fresh and aged PBS in different environments.

Adsorption of Tetracycline:

The adsorption capacity of tetracycline (TCL) is found to be highest in C-PBS, followed by UV-PBS and F-PBS, showing that C-PBS has superior adsorption capabilities compared to the other materials. The analysis of the material indicates the existence of different functional groups on C-PBS, including amide and hydroxyl groups. The presence of these groups increases the adsorption of TCL, and the examination of the isotherm confirms this fact. The kinetic model proposes that the interaction between C-PBS and TCL involves both physical and chemical mechanisms(fig:3). This thorough investigation offers valuable understanding of the parameters that affect the adsorption of TCL on C-PBS and highlights the importance of particular functional groups in promoting the adsorption process. UV-PBS had more TCL adsorption than F-PBS, which can be attributed to an increase in oxygen functional groups. The observed rise can be attributed to the fracturing of PBS caused by age, which subsequently leads to the creation of smaller particles. As a result, the surface area increased, which improved the ability to adsorb TCL. This explanation elucidates the underlying process responsible for the enhanced adsorption capabilities of UV-PBS as compared to F-PBS. It highlights the significance of oxygen groups and alterations in surface area resulting from PBS degradation.

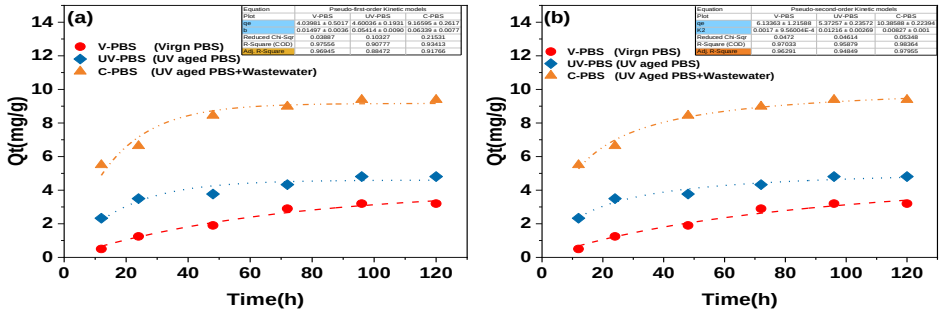

Fig. 3. Isotherm data of tetracyline adsorption on fresh PBS and aged PBS fitted by Pesudu first and second order models.