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Marion Hingant [1+], Stéphanie Mallarino [2], Egle Conforto [2], Emmanuel Dubillot [1], Pierrick Barbier [4], Arno Bringer [1,3*], Hélène Thomas [1*]

[1] Littoral Environnement et Sociétés (LIENSs), UMRi 7266 CNRS - La Rochelle Université, 2 rue Olympe de Gouges, F-17042 La Rochelle Cedex 01, France.

[2] Laboratoire des Sciences de l'Ingénieur pour l'Environnemen (LaSIE), UMR 7356 CNRS – La Rochelle Université, Avenue Michel Crépeau, 17042 La Rochelle, France.

[3] Qualyse, 5 Allée de l'Océan, 17000 La Rochelle, France.

[4] Centre pour l'Aquaculture, la Pêche et l'Environnement de Nouvelle-Aquitaine (CAPENA), Prise de Terdoux, 17480 Le Château d'Oléron, France.

[+]: Corresponding author: Marion Hingant: Tel: +33 6 59 90 62 15 (FR), marion.hingant@univ-lr.fr

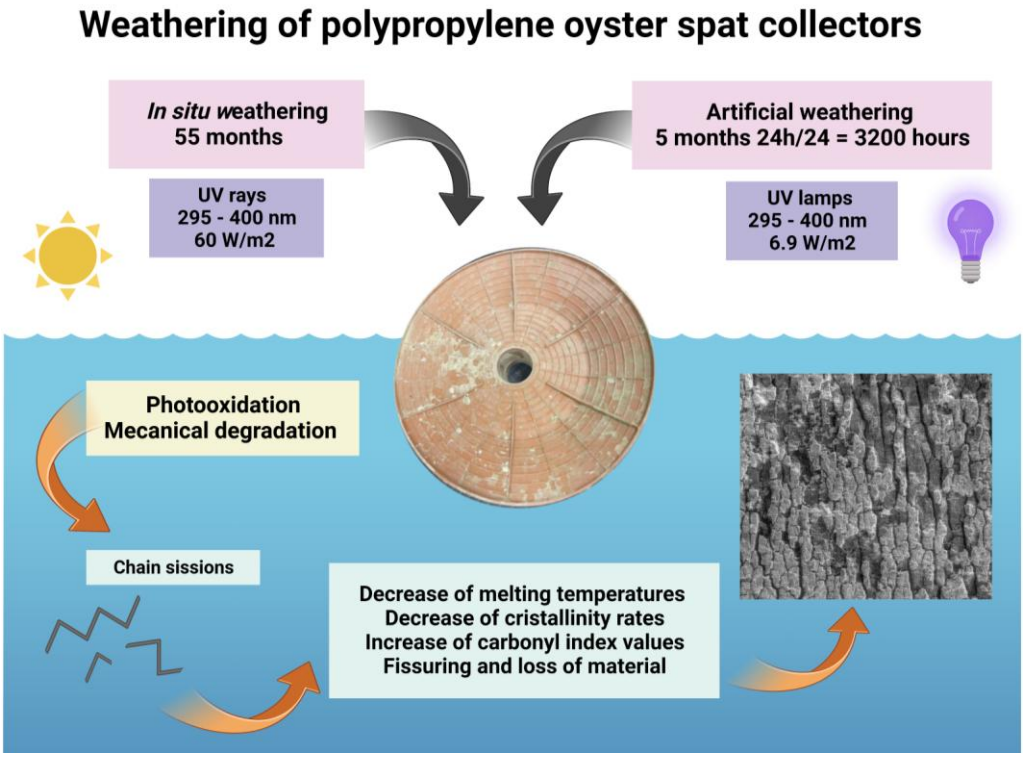
[*]: Equal contribution

ABSTRACT

With the omnipresence of plastic litter from oyster farming in marine coastal areas, the objective of this work was to better understand the weathering of plastics used in this field, focusing on oyster spat collectors. During their use, around fifteen years, collectors made of polypropylene (PP) undergo numerous degradations, alternatively submerged, emerged in seawater, and stored outdoor until the next cycle. They weaken, crack, break, end up fragmenting and disseminated in the environment as microplastics associated to persistant organic pollutants. In this work, a comparison of 55 months of *in situ* weathering with five months of artificial weathering in air or in artificial seawater in a homemade UV chamber was conducted to better understand the mecanisms involved. Chemical, thermal and surface characterizations of virgin and weathered samples were conducted using Fourier Transform Infrared Spectroscopy (FTIR), Differential Scanning Calorimetry (DSC) and Environmental Scanning Electron Microscopy (ESEM). After 55 months of *in situ* weathering, collectors were notably damaged with large fissures and loss of microplastics (MPs) associated with an increase of carbonyl

index values and a decrease of melting temperatures and crystallinity rates. Considering only UV irradiation, five months of artificial weathering at 30°C under continuous irradiation of 6.9 W/m^2 under UV lamps (295 - 400 nm) reproduced approximately 4.4 months of natural sunlight. Artificial weathering confirmed that photooxidation by combined effects of UV rays and oxygen was the main weathering mechanism and was reduced in seawater. These results help to understand the mechanisms involved in the weathering of these collectors in the marine environment and provide valuable informations for industrials and professionals. Our study suggests a better storage away from UV rays and a reduction of the duration of use compared to current pratices.

GRAPHICAL ABSTRACT



KEYWORDS

Oyster farming, Polypropylene, Photooxidation, *In situ* weathering, Artificial weathering

ABBREVIATIONS

PP : Polypropylene, MPs : Microplastics, POPs : Persistent organic pollutants

1. INTRODUCTION

At now, a total of five ocean gyres with high concentrations of plastics debris have been identified (Avio *et al*., 2017; Law *et al*., 2010). 80 % of theses marine debris are land-based sources and 20 % are ocean-based sources like fisheries and maritime activities (Avio *et al*., 2017; Bringer *et al*., 2021b). Since the arrival of plastic from petrochemicals in the 1950s, professionals in aquaculture activities have progressively turned to this new material, which is more resistant, durable, and economical. Due to their stabilility, plastics persist in the environnement for hundreds of years (Cai *et al*., 2018; Gewert *et al*., 2015a). Degradation of plastics can proceed by chemical, physical degradations and biological degradations (Gewert *et al*., 2015; Singh and Sharma, 2008; Song *et al*., 2017). Degradation rates are dependent on the manufacturing process (Han *et al*., 2018), the presence of stabilizers, additives and the weathering conditions including sunlight, temperature, and mechanical stress (Avio *et al*., 2017a; Kalogerakis *et al*., 2017a; Masry *et al*., 2021a; Rajakumar, Sarasvathy, Thamarai Chelvan, *et al*., 2009). In seawater, degradation rates are lower and more uniform compared to landfill due to lower and less variable conditions as UV irradiation, oxygen content and temperatures (Cai et al., 2018; Gewert et al., 2015). But in any cases, degradations finally lead to the release of microplastics (MPs) in the environment which can be accumulated by a wide range of marine organisms from zooplankton (Cole *et al*., 2013), to fishes throught bivalves (Bringer *et al*., 2021a) being transferred along food chains until humans (Avio *et al*., 2017a). Some studies have reported the presence of MPs in human organs (Hermabessiere *et al*., 2017), blood (Leslie *et al*., 2022) and faeces (Zhang *et al*., 2021). MPs exposure by ingestion, inhalation or dermal contact can cause physical damages, with oxidative stress, or inflammatory lesions (Prata *et al*., 2020).

Furthermore, plastics are associated with additives and stabilizers (Zhang *et al*., 2021). Plasticizers as di-n-butyl phtalate, antioxidant agents as bisphenol A, flame retardants as tris-2-chloro-éthyl phosphate, are chemicals added during the manufacturing process to obtain certain desired properties (Avio *et al*., 2017a; Masry *et al*., 2021a). Because they are usually not covalently bonded to the polymers (Gewert *et al*., 2015; Paluselli *et al*., 2019; Wang *et al*., 2020), these chemicals can migrate

from the polymeric matrix towards the surrounding environnement. In seawater, leaching of these chemicals by diffusion is dependent on their solubility, their polarity, and their affinity to the matrix (Paluselli *et al*., 2019). Some of these chemicals are know to be harmful to the marine ecosystems and humans causing dysfunctions of the immune and reproductive systems, cancers and neurodegenerative disorders (Avio *et al.*, 2017; Hermabessiere *et al*., 2017).

Plastics are also able to absorb various pollutants called persistent organic pollutants (POPs) present in the marine environment such as pesticides as dichlorodiphenyltrichloroethane, polycyclic hydrocarbons as naphtalene, and heavy metals as cadmium and lead for examples (Boucher *et al*., 2016; Gewert *et al*., 2015; Hermabessiere *et al*., 2017; Holmes *et al.*, 2012; León *et al*., 2018; Paluselli *et al*., 2019). These pollutants can be ingested and bioaccumulated by marine organisms and humans, often vectorized by MPs (Avio *et al*., 2017; Gewert *et al*., 2015; Guo and Wang, 2019; Prata *et al*., 2020). The risks that MPs and these persistant organic pollutants (POPs) pose to marine life and humans are widely recognized and have been included in national and international marine protection strategies, policies, and legislation (EU Marine Strategy Framework Directive).

With nearly 30,000 tons of Pacific oysters *Crassostrea gigas* produced each year, the department of Charente-Maritime in France represents the first French production area with one third of the national production (AGRESTE 2019). Different types of plastics such as polypropylene (PP), polyethylene (PE) and polyvinyl chloride (PVC) are now used at each stage of production. Oyster spats collection is the first phase of production in traditional oyster farming. Collectors have a specific design of a disc of 160 mm diameter, slightly concave, flexible and ribbed, with a thickness of 0.6 mm, designed in order to collect a maximum of oyster spats in seawater during the reproductive period between July and March. After collecting, collectors are taken out of seawater, oysters are detached and then transferred to oyster bags. The environmental image of the profession is criticized today given the omnipresence of plastic waste from oyster farming in coastal areas. Around 200 tons of plastic waste from oyster farming, including 60 tons of oyster spat collectors, are found each year in the Atlantic south coast

(FEAMP 2020). During their use around fifteen years, collectors made of PP or PE undergo numerous degradations. They weaken, crack, break, end up fragmenting, disseminating MPs and chemicals in the marine environment. The toxicity of weathered MPs and associated chemicals from oyster farming was recently evaluated on early stages of bivalve development (Bringer, Cachot, *et al*., 2021). Diméthylphtalate used as plasticizer and naphthalene as polycyclic hydrocarbons absorbed in the marine environment have been identified on weathered oyster crops, collectors, and pipes (Bringer, Le Floch, *et al*., 2021) . Faced with the growing risk associated to plastics used in oyster farming for marine life and humans, it is necessary understand and reduce their anthropogenic impacts.

In situ and artificial weathering of PP have been described in many studies (Badji *et al*., 2018a; Lv *et al*., 2015; Rajakumar, Sarasvathy, Thamarai Chelvan, *et al*., 2009; Tang *et al*., 2019a) but were never established for PP oyster spat collectors. These collectors are interesting because they have a chemical composition and mechanical properties, with additives and stabilizers designed for aquaculture activities specifications and because, *in fine*, oysters are destined for human consumption. In this work, a comparison of 55 months *in situ* weathering with five months of artificial weathering in a homemade UV chamber was conducted to better understand the mechanisms involved in PP collectors degradations. With the aim of understanding the mechanisms of degradation of these collectors in the marine environment, chemical, thermal, and structural characterizations of virgin and weathered collectors were performed using Environmental Scanning Electron Microscopy (ESEM), Differential Scanning Calorimetry (DSC), and Fourier Transform Infrared Spectroscopy (FTIR).

2. MATERIALS AND METHODS

2.1 Oyster collectors

2.1.1 In situ weathering

In 2017, a project conducted by the Center for Aquaculture, Fisheries, and the Environment of Nouvelle-Aquitaine (CAPENA) had the objective to compare petrosourced and biosourced collectors in terms of oyster spat collection efficiencies. Collectors have a specific design of a disc of 160 mm

diameter, slightly concave, flexible and ribbed, with a thickness of 0.6 mm. These collectors were immerged in the area of the Pertuis Charentais, in the French department Charente-Maritime (45°51'41.7"N 1°12'19.0"W) during three cycles of eight months collecting oyster spats in seawater between 2017 and 2020. These collectors were alternatively submerged and emerged in seawater during collection and were stored outdoors until the next collection cycle. Each cycle started in July and stopped in March. In total, these collectors spent 24 months in seawater, and 31 months stored outdoors until the start of this work in January 2022. A continuous environnemental monitoring during *in situ* weathering measured seawater temperature from 6 to 21 °C, salinitity from 26 to 34 g/L, outdoor temperature from 5 °C to 23 °C and a mean solar irradiance of 1200 kW/h/m^2/year. Virgin collectors, as references, were stored indoors and protected from humidity and UV rays. Virgin and *in situ* weathered collectors were characterized by FTIR, DSC, and ESEM as described below.

2.1.2 Artificial weathering

Inspired by ISO 4892:2016 part 3 and ATSM G154:06, a homemade UV chamber was equipped with five UV lamps with wavelength between 295 and 400 nm (KFMS reference PH710932 15W). These UV lamps were selected because they can give a good reproduction of natural sunlight in the UV range (Andrade *et al*., 2019; Cai *et al*., 2018) and because this medium energy is particularly efficient in facilitating photodegradation of PP (Andrady, 2015). Virgin PP collectors were weathered under UV rays in two different conditions: in air (UV+) or immerged in artificial seawater at 30 g/L (UV+/SW). Negative controls, not exposed to UV rays, were installed in a box in the chamber (UV- and UV-/SW). Artificial seawater was made by mixing milliQ water and commercial salt. Virgin PP collectors were installed directly under UV lamps at 15 cm (UV+) or in borosilicate crystallizers filled with 500 mL of 30 g/L of artificial seawater (SW) and closed with a borosilicate lid to limit evaporation but letting pass UV rays through. This experiment was conducted for five months, at 30°C, under 24h/24 continuous UV irradiation. Temperature was monitored weekly with a mercury thermometer. Intensity was monitored weekly with a radiometer (RS Pro reference IM-213) placed at 15 cm from the lamps and was approximately equal to 6.9 W/m^2 in a empty crystallizer and 3 W/m^2 in

152 artificial seawater. Salinity was monitored weekly with a multiparameter (WMW reference Multi3430
153 with Tetracon 925 probe) and was adjusted to 30 g/L by adding milliQ water if necessary. Each
154 month, one triplicate for each condition was removed and stored in glass petri dishes at 4 °C, in the
155 dark, to stop weathering.
156
157 ## *2.2 Charaterization*
158 ### *2.2.1 Environmental Scanning Electron Microscopy (ESEM)*
159 The scanning electron microscope used in this work is an Environmental FEI Quanta 200 –
160 ESEM/FEG (LaSIE, La Rochelle University) working at 9 KV of electron beam accelerating voltage
161 and 0.1 nA of beam current under 200 Pa of water vapor pressure in the specimen chamber (Conforto
162 *et al*., 2015). Secondary electron-type images, providing topographical information from the surfaces,
163 were obtained in environmental mode using a “Gaseous Large-Field" detector. The low-energy beam
164 and environmental conditions used are necessary to observe plastic materials, which are thermally
165 sensitive and poor electrical and thermal conductors, without any preparation. In fact, if a surface
166 metallization (which is part of the sample preparation procedure) was performed, it could partially or
167 totally mask cracks. The latter are an important parameter used to evaluate the weathering of plastic.
168 Surface topography of different parts of virgin and weathered collectors was observed. We made sure
169 that the results were coherent, homogenenous, reproducible. Ten fissures lengths were measured on
170 random fissures and averaged with FIJI software.
171
172 ### *2.2.2 Fourier Transform Infrared Spectroscopy (FTIR)*
173 In order to identify the different types of chemical bonds, FTIR was used. Infrared frequency identical
174 to the vibrational frequency of a bond results in absorption, creating a spectrum acting as a molecular
175 “fingerprint” of the sample. The position, shape, and intensity of peaks in the spectrum reveal details
176 about the molecular structure of the sample. Different parts of virgin and weathered collectors were
177 analyzed using a thermoscientific Nicolet iS50 FITR spectrophotometer equipped with an attenuated
178 total reflectance mode (ATR). We made sure that the results were coherent, homogenenous,

reproducible. Each spectrum was recorded as the average of 32 scans in the spectral range of 500 to 4000 cm^{-1}, with a spectral resolution at 4.0 cm^{-1}. Ten spectras were done randomly at the surface of each sample averaged with a corrected baseline, and analyzed with Spectragryph 1.2 software.

2.2.3 Differential Scanning Calorimetry (DSC)

Specific temperatures of the samples such as melting temperature and crystallization, as well as the enthalpy values associated with these phenomena were examined on a differential scanning calorimeter TA Instrument Q100. Samples were cut, weighed, and heated from -60 °C to 210 °C in an aluminum pan, then cooled to 40 °C. All experiments were performed at a rate of 20 °C/min under nitrogen flow (50 ml/min) to avoid thermal degradation. For the sake of repeatability, at least two samples for each type of collector were used for the DSC measurements. The analysis of DSC thermograms was carried out with TA Universal Analysis software.

3. RESULTS

3.1 Surface analysis

Surface images were obtained by using environmental scanning electron microscopy (ESEM). Virgin PP collectors exhibited relatively homogeneous, smooth and compact textures without any fissures (Fig 1a). *In situ* weathered PP collectors (Fig 1c and 1d) exhibited heterogeneous surfaces, with large and deep averaged fissures up to 24 µm. Loss of material was observed at lower magnification (Fig 1d) caused by mechanical stress as tides, currents during submersion, wind and rain during emersion but also handling. This loss of material suggests a release of MPs in the environment. Crystals of sodium chloride salts and algae and diatom residues were also observed and confirmed that the collectors stayed in seawater. Artificially weathered collectors under UV rays (UV+) start fissuring after five months with the observation of 2 µm length fissures (Fig 1b). No fissures were observed for the other conditions as negative control (UV-) and immersion in artificial seawater for five months (UV-/SW and UV+/SW) (Results not presented). Artificial weathering confirmed that fissuring started after five months exposed to UV rays.

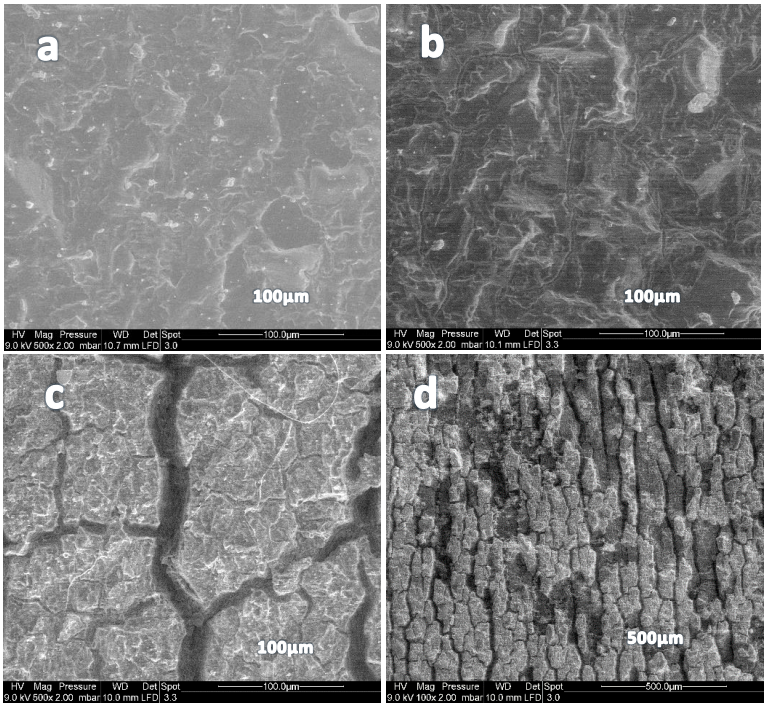


Figure 1. ESEM pictures of (a) virgin PP collector x 500; (b) five months artificially weathered PP collector under UV rays x 500; (c) and (d) 55 months *in situ* weathered PP collector (x 500 and x 100 respectively). Arrow point to a small fissure of 2 µm.

3.2 Chemical analysis

The averaged infrared spectra of a virgin PP collector, used as reference, is presented in the Figure 2 (blue). The spectra showed absorption peaks located at wavenumbers of 971, 995, 1167, 1375, 1454, 2838, 2865, 2918, and 2953 cm^{-1} corresponding to specific vibrations of rocking, bending and stretching and identified as the native hydrocarbon bonds of virgin PP $(C_3H_6)_n$ (Badji *et al*., 2018b; Tang *et al*., 2019b). Photooxidation, by combined effects of UV rays and oxygen, is known to be the main weathering process for thermoplastics such as PP (Andrady, 2015; Gewert, 2015; Kalogerakis *et al*., 2017b; Masry *et al*., 2021b). UV radiation has sufficient energy to break the C─C and C─H bonds (Singh & Sharma, 2008). Diminution of C─C and C─H bonds on the *in situ* weathered collector (Fig 2 – orange) were observed at wavenumbers between 2800 - 3000 cm^{-1} confirming their break. The free radicals produced during photooxidation reacted freely with atmospheric oxygen to form hydroxyl groups (O─H) peaking at wavenumbers between 3000 - 3700 cm^{-1} and carbonyl groups (C═O)

including carboxylic acids and ketones peaking at wavenumber 1711 cm^{-1}, esters and aldehydes peaking at wavenumber 1740 cm^{-1} and lactones peaking at wavenumber 1780 cm^{-1} (Badji *et al.*, 2018a; Lv *et al.*, 2015; Masry *et al.*, 2021b). These new significant peaks at around wavenumbers 3000 - 3700 cm^{-1} and 1500 - 1800 cm^{-1} were identifiable on *in situ* and artificially weathered collector infrared spectra (Fig 2) and their areas were a function of weathering conditions (Cai *et al.*, 2018; Rajakumar, Sarasvathy, Thamarai Chelvan, *et al.*, 2009; Tang *et al.*, 2019b).

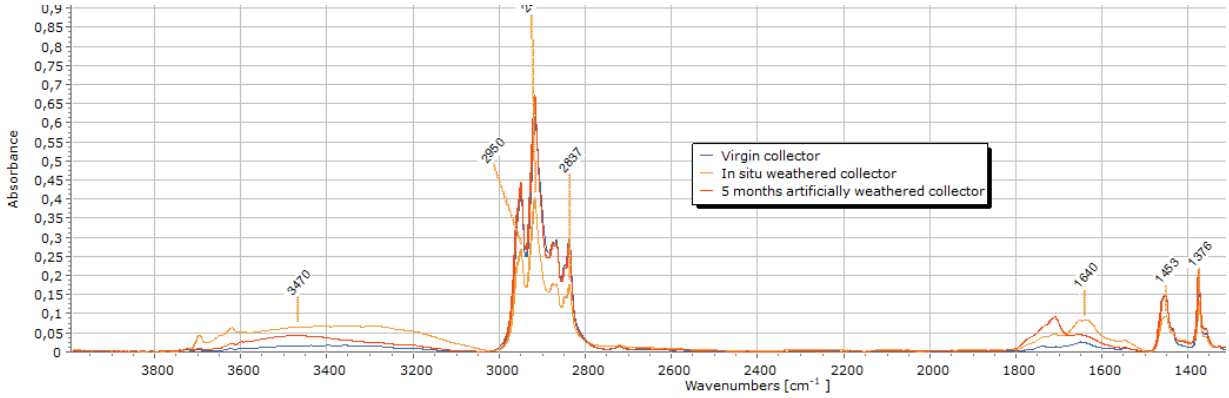


Figure 2. FTIR spectra of a virgin PP collector (blue), *in situ* weathered PP collector (orange) and a 5 months artificially weathered collector (UV+) (yellow)

The carbonyl index (CI) has been used to quantify the degree of weathering of various samples (Almond *et al.*, 2020; Badji *et al.*, 2018a; Julienne *et al.*, 2019; Rajakumar, Sarasvathy, Chelvan, *et al.*, 2009; Song *et al.*, 2017b; Tang *et al.*, 2019a). This index is defined as the ratio of the integrated area of the carbonyl group peak at around wavenumbers 1700 cm^{-1} to an internal constant peak. In this work, boundaries between wavenumbers 1390 and 1340 cm^{-1} were chosen for the constant peak because it remained unchanged during weathering. Consequently, boundaries between wavenumbers 1820 and 1570 cm^{-1} were chosen for the carbonyl peak. Carbonyl index of *in situ* and artificially weathered samples calculated on the average of ten spectra for each sample and after baseline correction are resumed in Table 1. Carbonyl index values for the virgin collector and negative control (UV-), as references, were similar and equal to 0.7 and 0.5 respectively. These values were not equal to zero probably due to thermal degradation of the material during injection. Negative control (UV-)

also confirmed that no additional degradation occurred during the five months of artificial weathering. Consequently, only UV ray exposure and immersion in seawater can be considered in this experiment. After five months of artificial weathering in seawater (UV-/SW), the carbonyl index value reached 1.9. Additionally immerged and exposed to UV rays (UV+/SW), this value increased to 2.1. Finally, upon exposure to UV rays only during five months (UV+), the carbonyl index reached the value of 3. In this experiment, the highest value for carbonyl index was therefore found after five months artificially exposed to UV rays only (UV+). After 55 months of *in situ* weathering, the carbonyl index value reached 4.2.

3.3 Thermal analysis

Semi-crystalline PP has a heterogeneous structure, consisting of crystalline and amorphous phases (Masry *et al*., 2021b). The crystallinity rate and the melting temperature are impacted by weathering (Badji *et al*., 2018b). Monitoring the evolution of these parameters using Differential Scanning Calorimetry (DSC) gave a global indication of weathering degree of the samples. On the DSC thermograms (Fig 3), the heat flow exhibited endothermic peaks related to the melting of PP allowing the measure of melting temperatures and melting enthalpies (ΔH_m) corresponding to the energy needed to melt the sample. Crystallinity rates can be calculated as this relation: Crystallinity rate (%) = ΔH_m / (ΔH_{inf}) x 100 (equation 1) with ΔH_{inf} equal to 209 J/g for PP corresponding to the theoretical melting enthalpy of a fully crystalline PP (Badji *et al*., 2018; Han *et al*., 2018) ΔH_m can be calculated with TA analysis software. Melting temperatures and crystallinity rates and of virgin, *in situ* and artificially weathered PP collectors are summarized in Table 1. For the virgin collector, as reference, melting temperature was equal to 169 °C, melting enthalpy was equal to 59 J/g and crystallinity rate was equal to 29 % (equation 1). These values were equivalent for the negative control after five months of artificial weathering without UV rays (UV-). After *in situ* weathering, significant decreases of the melting temperature from 169 to 164 °C, and crystallinity rates from 29 to 25 % were observed. Changes in melting temperature and crystallinity rate were observed on samples exposed to UV rays (UV+). No differences were observed for the other conditions in seawater (UV+/SW, UV-/SW).

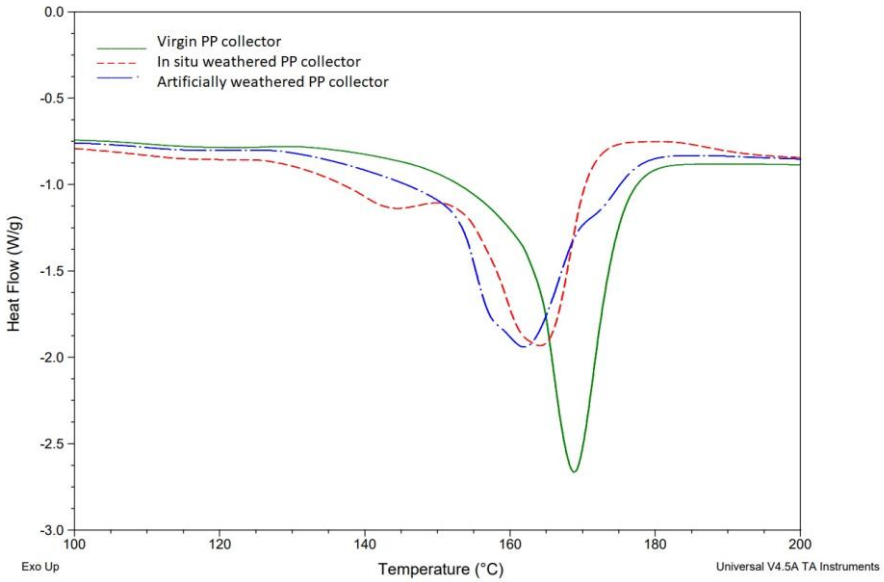


Figure 3. DSC thermograms of a virgin PP collector (green line), *in situ* weathered PP collector (red line) and artificially weathered PP collector (blue line) with endothermic peak indicating the melting of the material.

Virgin PP collector	*55 months in situ weathered PP collector*	*5 month artificially weathered PP collectors*			
		UV-	UV+	UV-/SW	UV+/SW
0.7	4.2	0.5	3.0	1.9	2.1
169	164	169	164	169	169
29	25	31	26	30	30
0	24	0	2	0	0

Table 1: Carbonyl index values, melting temperatures, crystallinity rates, and fissure lengths for virgin PP collectors, 55 months *in situ* weathered PP collectors, and five months artificially weathered PP collectors.

4. DISCUSSION

During their use, PP oyster spat collectors undergo various degradations as the result of photooxidation, thermal degradation, mechanical degradation, and biodegradation, all based on free-

radicals mechanisms. (Avio *et al*., 2017a; Singh & Sharma, 2008). After *in situ* weathering, increase of carbonyl index values, and decrease of crystallinity rates, melting temperatures and apparition of fissures were observed (Table 1). Artificial weathering was conducted to better understand the mechanisms involved. Because the temperature in the UV chamber was fixed, homogenous and relatively low, and because no additional mechanical stress was applied, only UV irradiation was considerated in this experiment. The highest degradation rate obtained after UV irradiation in air (UV+) and negative control confirmed that no additional degradation than photooxidation occurred. Abiotic degradations precede biotic degradations. Photooxydation by combined effect of oxygen and UV rays is known to be the main weathering mecanisms for PP. Initiated by UV rays absorbed by structural abnormalities or impurities, photooxidation cause chain scissions and produce shorter and more mobile chains with free radicals reacting freely with atmospheric oxygen (Gewert *et al*., 2015). This mechanism usually starts in the amorphous phase (Andrady, 2015; Julienne *et al*., 2019a; Masry *et al*., 2021, Han *et al*., 2018) but results of this work obtained after artificial weathering showed a decrease of crystallinity rate indicating that photooxidation already caused damage in the amorphous phase and then occurred in the crystalline phase. This mechanism, already described by (Badji *et al*., 2018; Lv *et al*., 2015; Tang *et al*., 2019), finally lead to a decrease of the hydrophobicity and the molecular weigh of the polymer. However, the molecular weight remaining high, biodegradation of the long chains stays limited (Gewert *et al*., 2015; Singh and Sharma, 2008). In fact, PP is often used as a negative control in biodegradation experiments (Kalogerakis *et al*., 2017; Lott *et al*., 2020).

At the location of the *in situ* weathering, a mean solar irradiance of 1200 kWh/m^2/year was monitored (https://re.jrc.ec.europa.eu/pvg_tools/fr/#DR) which corresponds to an irradiance of 60 kWh/m^2/year in the total UV range (295 and 400 nm). During artificial weathering, the intensity of the UV lamps in this same range was averaged at 6.9 W/m^2 and was maintained for 3200 hours which correspond to a total cumulated irradiance of 22 kWh/m^2 (= 6.9 x 3200). Consequently, artificial weathering reproduced approximately 134 days (22 / 60 x 365) corresponding to 4.4 months (Gewert *et al*., 2018).

This calculation of solar simulation equivalent is theoretical because it is dependant of numerous environnemental factors, which varies throughout the seasons.

After five months of artificial weathering in seawater, an increase of carbonyl index values was observed whereas the crystallinity rates and melting temperatures were little impacted (Table 1). Absorption of seawater in PP can allow the entrance of dissolved oxygen into the matrix favoring chain oxidation and hydrolysis (Kalogerakis *et al*., 2017a) but the kinetics of these degradation mechanisms are slower than those for photooxidation. Moreover, intensity of UV irradiance in artificial seawater (3 W/m^2) was lower than for direct exposure to a UV lamp (6.9 W/m^2), reducing the photooxidation mechanism in seawater, wich it is expected to occur in the marine environment. No fissures were observed for these conditions (UV+/SW and UV-/SW).

Collectors artificially weathered during five months gave approximately the same results than after 55 months weathered *in situ* except for the fissure lengths due to additional degradations involved *in situ*. It is important to consider that *in situ*, degradation of PP collectors was influenced by alternations of tides, day and night cycles, weather and seasonal conditions, presence of spats, biofooling and crystal salts. In conclusion, *in situ* weathering of these PP collectors was mainly caused by photooxidation during emersion and outdoor storage and was enhanced with additional effects of mechanical stresses such as tides, currents, wind and rain but also professional handling. Comparing *in situ* and artificial weathering must be done with caution since there is still not an adequate simulation of the combined effects and synergies of various environnemental factors (Andrade *et al*., 2019; Rajakumar, Sarasvathy, Thamarai Chelvan, *et al*., 2009; Yang & Ding, 2006).

5. CONCLUSIONS

This is the first study comparing *in situ* and artificial weathering of PP oyster spat collectors. This work shows that after only 55 months *in situ*, alternatively submerged and emerged, the collectors were notably damaged, with large fissures and loss of material such as MPs. These damages were

mainly due to photooxidation during exposure to UV rays, enhanced by mechanical stress as tides, current, wind, rain and handling all along their use and storage. Considering only irradiation in the UV range, five months of artificial weathering reproduced approximately 4.4 months of natural sunlight *in situ* and confirmed that photooxidation by combined effect of UV rays and oxygen was the main weathering mechanism and was higher in air than in seawater. Degradations as the apparition of the first fissures were observed relatively soon under UV irradiation. This first comparative study gave preliminary results on this topic and help to better understand the mechanisms involved in the degradation of these collectors. This work allows to make recommendations to industrials and professionals including a better storage protected from UV rays and a reduction of the duration of use. It is important to note that there is still a lack of information on the toxicity and the potential environmental hazard of these altered plastics in the marine environment, as vectors of MPs, POPs and microorganisms (Avio *et al*., 2017b; Gewert *et al*., 2015b). Consequently, a future work will be focused on the relationship between weathering, fragmentation and toxicity including promising alternatives such as biosourced materials.

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