Macro-plastic weathering in a coastal environment: field experiment in Chesapeake Bay, Maryland

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Introduction

Plastic degrades over time into smaller particles, known as microplastics, due to physical, chemical, and biological factors. Little is known about these factors in coastal environments, even though most of the plastic that ends up in the ocean passes through such an environment from land to the ocean.

Methods

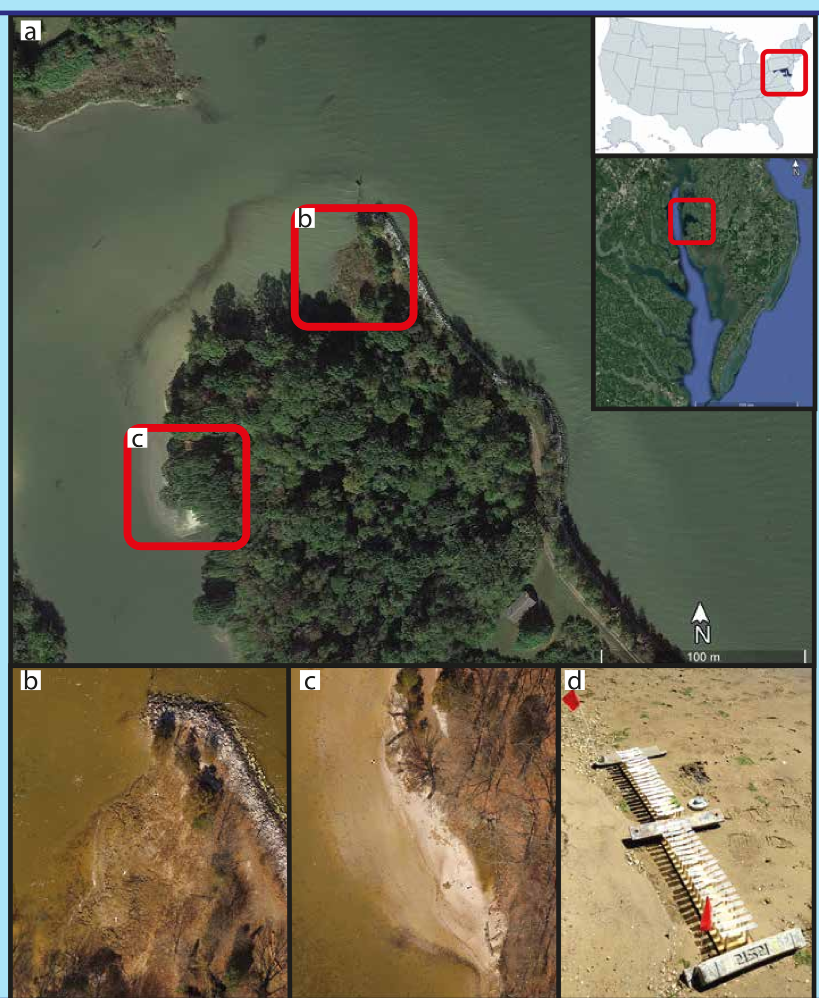
• Study site: shoreline at Lakes Cove at UMCES Horn Point (Cambridge – MD) along the southern shore of the Choptank River, in the Chesapeake Bay (Fig.1a). The site is in erosion on the edge of a salt marsh (Fig.1b), while it is in deposition along a sandy beach (Fig.1c).

• Experimental design (Fig.1d): strips of two different types of plastic, high-density polyethylene (HDPE) and polystyrene (PS), setted to wooden boards. 4 samples apparatus per each type of plastic deployed, one per type, in an intertidal erosion zone (E-IT), in a subtidal erosion zone (E-ST), in an intertidal deposition zone (D-IT), and in a subtidal deposition zone (D-ST).

• Samples collection after 4, 8, and 43 weeks of environmental exposure.

• Analisys of mass variation, chlorophyll *a* concentration, and SEM imaging.

Fig.1



Results

• After 4 weeks: HDPE strips did not show any breakages, PS strips had suffered breakages (Fig.2a).

After 8 weeks: board D-IT-HDPE no longer found, in board E-ST-PS each strip had fully deteriorated. HDPE strips were intact, PS strips showed more and more breaks (Fig.2b).

After 43 weeks: only HDPE strips from the E-IT and E-ST zone were foundhe strips were still intact and completely covered with biofouling (Fig.2c).

Fig.2

• At 4 weeks, no detectable differences in Chl*a* concentrations between PS and HDPE. Higher Chl*a* accumulation in ST. At 8 weeks, PS increase in Chla concentration, expecially in D-ST. More variability in Chl*a* accumulation in HDPE by week 8. (Tab.2)

Tab.2

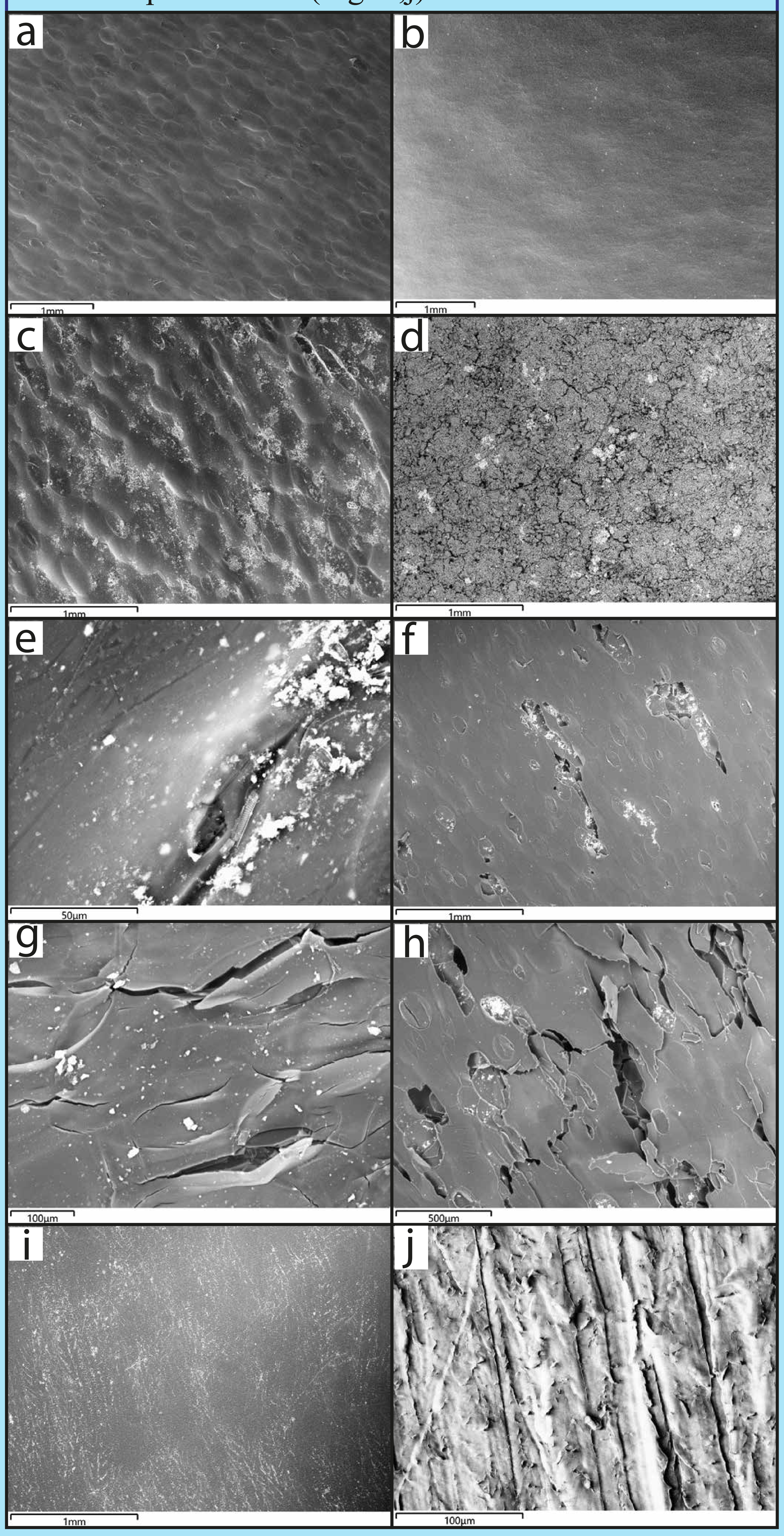
Zone	Chla ($\mu g/cm^2$) at 4 weeks on PS	Chla ($\mu g/cm^2$) at 8 weeks on PS	Chla ($\mu g/cm^2$) at 4 weeks on HDPE	Chla ($\mu g/cm^2$) at 8 weeks on HDPE
E-IT	0.04 ± 0.01	0.17 ± 0.04	0.01 ± 0.00	0.04 ± 0.01
D-IT	0.10 ± 0.01	0.37 ± 0.06	0.04 ± 0.00	
E-ST	0.33 ± 0.03		0.24 ± 0.10	3.25 ± 0.43
D-ST	0.51 ± 0.04	6.66 ± 4.18	0.58 ± 0.07	0.42 ± 0.07
(Mean ± standard error)				

• SEM: control, original surface of the strips (Fig.3a,b); unwashed: presence of sediment, biofouling and biomass (Fig.3c,d).

SEM PS washed: after 4 weeks fractures and holes, adherent particles of sediment and biomass inside the cavities (Fig.3e); after 8 weeks, many holes of more irregular size (Fig.3f,g), many more fractures of larger dimensions (Fig.3g,h), and flakes (Fig.3g,h).

SEM HDPE washed: after 4 weeks, grooves on the surface; after 8 weeks grooves more marked; after 43 weeks, ruts more pronounced (Fig.3i,j).

Fig.3



• Unwashed: after 4 weeks of exposure, mass increase from less than 1% (in E-IT-HDPE) up to more than 75% (in D-ST-PS); after 8 weeks, mass change from almost -1% (for E-IT-PS) to almost 270% (in D-ST-PS); after 43 weeks, E-IT-HDPE increase by 21.6%.

Washed: 4 weeks of exposure, mass change from 0.01% (E-ST-HDPE) to -1.67% (E-IT-PS); after 8 weeks, the greatest loss in PS strips of the E-ST zone (100%), E-IT-PS loss -10.7%, HDPE decrease by less than 1%. (Tab.1)

Tab.1

Samples	percentage change in mass **before** cleaning			percentage change in mass **after** cleaning		
	4 weeks	8 weeks	43 weeks	4 weeks	8 weeks	43 weeks
E-IT-HDPE	0.95	1.15	21.60	-0.01	0.06	0.06
E-IT-PS	2.27	-0.92	/	-1.67	-10.74	/
E-ST-HDPE	8.14	71.55	/	0.01	0.00	/
E-ST-PS	16.36	/	/	-0.74	-100	/
D-IT-HDPE	5.56	/	/	-0.04	/	/
D-IT-PS	14.47	25.53	/	-0.31	-1.36	/
D-ST-HDPE	35.34	9.43	/	-0.01	-0.40	/
D-ST-PS	77.31	269.59	/	-0.37	2.61	/

Discussion

Increased mass of the strips in an unaltered state can be caused by biomass and of sediment deposition. Only two types of sample showed decreased mass after 8 weeks. The mass of PS samples increased much more than the one of HDPE samples, as if biomass and sediment were more attracted to PS than to HDPE, probably due to the contact angle that is a marker of hydrophobicity [1].

After cleaning the strips, HDPE samples basically maintained constant mass, while a decrease was noticed in the PS strips. Constant mass in HDPE can be attributed to the long degradation time of this material and therefore, being in the initial phase of degradation, there is little mass loss [2]. Only 8-week-exposed PS samples from the deposition subtidal zone showed gained mass, probably due to the entrapment of sediment and organisms into the structure, as shown by the SEM images and reported by other authors [1, 3, 4].

SEM analyses showed increasing signs of physical degradation (fractures, holes, scratches, flakes and grooves) over time, in particular in PS strips. 4-week-exposed PS strips deployed in the intertidal zones resulted more weathered than those in the subtidal zones. The two put in the deposition zones were more degraded than those in the erosion zones presumably because of . Analogue observations can be done for PS 8-week-exposed samples, even if E-ST strips had been completely dispersed in the environment. Moreover, the SEM images show different kind of fragmentation, with fractures, with holes or with desquamations. The presence of pits probably indicates chemical weathering, as reported by [5].

The HDPE strips got slightly marked scratches on their surfaces, probably caused by sand grains dragging across plastic surfaces [5], but the degree of erosion has not been established.

Conclusion

The degree of plastic degradation with time depends on the type of plastic and the environment. The degradation of the PS macroscopically occurred just after 4 weeks, while HDPE samples showed no macroscopic weathering even after 43 weeks. Furthermore, the degradation in the studied environments is much more evident in the erosion zone rather than in the depositional one, above all for the PS strips.

References

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