Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 25 | No. 2 | Article ID D1855 | 2026

Original Research Paper

https://doi.org/10.46488/NEPT.2026.v25i02.D1855

Open Access Journal

Potential Pollution by Biodegradable Waste: Assessing the Degradability of Oxo-degradable, Compostable, and Biodegradable Products Under Laboratory Conditions

Dilhara Wijetunge[1], Pathmalal Manage[2] and Kamal Ranatunga[1]†
[1]Centre for Marine Science and Technology, Department of Zoology, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda 10250, Sri Lanka
[2]Centre for Water Quality and Algae Research, Department of Zoology, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda 10250, Sri Lanka
†Corresponding author: Kamal Ranatunga; ranatunga@sci.sjp.ac.lk

Abbreviation: Nat. Env. & Poll. Technol.
Website: www.neptjournal.com

Received: 04-08-2025
Revised: 15-09-2025
Accepted: 17-09-2025

Key Words:

Biodegradable products
Oxo-LDPE
Compostable products
Degradation
Plastic pollution

Citation for the Paper:

Wijetunge, D., Manage, P. and Ranatunga, K., 2026. Potential pollution by biodegradable waste: Assessing the degradability of oxo-degradable, compostable, and biodegradable products under laboratory conditions. *Nature Environment and Pollution Technology*, 25(2), D1855. https://doi.org/10.46488/NEPT.2026.v25i02.D1855

Note: From 2025, the journal has adopted the use of Article IDs in citations instead of traditional consecutive page numbers. Each article is now given individual page ranges starting from page 1.

ABSTRACT

This study evaluated the degradability of three products, namely an oxo-degradable garbage bag (GB), compostable lunch sheet (LS), and biodegradable salad plate (SP), under four controlled laboratory simulations representing natural environmental conditions: freshwater body (FW), riverbank (RS), landfill (COM), and direct ultraviolet (UV) light exposure. Degradation was assessed over time by monitoring the monthly changes in weight. Mechanical and chemical changes were monitored using tensile strength testing and Fourier-transform infrared (FT-IR) spectroscopy, respectively. Among the tested products, SP exhibited the highest mean percentage weight loss (43.76±3.34 to 100%) under RS conditions. Instead of weakening, GB exhibited increased mean tensile strength at break and mean elongation at break under RS (7.25±0.29 and 317.78±9.15, respectively) and COM (4.35±0.88 and 46.16±28.11, respectively), suggesting possible crosslinking or physical aging rather than degradation. No loss of characteristic peaks indicating biodegradation of the polymer material was observed in SP under FW and UV exposure, LS under UV exposure, and GB under FW, RS, or COM exposure. The findings highlight that degradation rates vary substantially across different environmental media and sample types. The potential contribution of certain biodegradable materials, particularly oxo low-density polyethylene (oxo-LDPE), to long-term plastic pollution is emphasized in this study.

INTRODUCTION

Mismanaged domestic plastic waste pollutes the environment and poses a significant challenge to sustainable waste management efforts. Given their persistence, plastics tend to accumulate when they are improperly discarded. Research on biodegradable synthetic polymers began in the early 1980s (Orhan et al. 2004). These materials were designed to remain inert to selected environmental factors during use but to biologically degrade once disposed of (Itävaara et al. 2002). Therefore, these materials are introduced as eco-friendly solutions to mitigate the deleterious impacts of waste plastic accumulation.

Ahmed et al. 2018 classified biodegradable plastics into three categories: fossil-based, bio-based, and biodegradable polymer blends. Fossil-based biodegradable plastics are derived from fossil fuels and are primarily used in the packaging industry, whereas bio-based biodegradable plastics are derived from renewable sources. Biodegradable polymer blends are produced by blending different materials with desirable biodegradation properties.

Polymer degradation is defined as any alteration in the physical or chemical properties of polymers due to environmental factors, including light, moisture, heat, or biological activity. Venkatesh et al. 2021 suggested three types of polymer-degrading mechanisms based on the factors involved: thermo-oxidative degradation, photo-degradation, and biodegradation. Thermo-oxidative degradation involves the degradation of polymers in oxygen-rich environments, initiated by the reaction of free radicals produced via polymerization (Gijsman 2008). Photodegradation is the combined effect of sunlight and air, which causes oxidation and hydrolysis. Photodegradation can be direct or indirect, depending on the compounds involved. Micropollutants undergo direct photolysis when they absorb light under the applied irradiation conditions. Indirect photodegradation occurs in the presence of photosensitizers. Biodegradation is the partial or complete conversion of polymers into CO_2, water, inorganic compounds, and energy by microorganisms. Partial biodegradation can produce micro- to nanosized fragments and other synthetic derivatives (UNEP 2015).

Plastics produced from identical base polymers can exhibit remarkable variability in material characteristics and biodegradation rates owing to differences in additives, manufacturing processes, and environmental exposure conditions. According to GESAMP (2015), biodegradable products of nonbiological origin generally exhibit slow degradation patterns under natural environmental conditions and often require standard industrial composting facilities to achieve complete breakdown.

This assertion remains contentious because the introduction of biodegradable plastics was originally intended to offer an environmentally sustainable alternative that minimizes long-term accumulation in natural ecosystems. Given the increasing prevalence of biodegradable plastics and the potential mismatch between product claims and environmental performance, evaluating their actual degradability in local environmental contexts is essential.

The present study investigated the degradation behavior of three common biodegradable product categories: Oxo-LDPE, compostable, and biodegradable, under simulated laboratory conditions representative of realistic mismanaged waste accumulation sites, including freshwater systems, riverbanks, composting environments, and UV-exposed surfaces. This study also examined the influence of key environmental variables on the degradation process.

MATERIALS AND METHODS

Sample Selection and Preparation

The test materials included a commercially available garbage bag (GB) labeled as oxo-degradable, a lunch sheet (LS) labeled as compostable, and a salad plate (SP) labeled as biodegradable. Product selection was based on market availability, and the samples were standardized according to their date of manufacture to ensure comparability. Whatman No.42 filter paper (FP) served as the positive control due to its known biodegradability. Before testing, the FP, SP, LS, and GB samples were cut into 0.61–0.66 g, 1.10–1.50 g, 2.10–2.60 g, and 1.50–1.90 g pieces, respectively. The samples were cleaned to remove surface contaminants, and their initial dry weights were measured using an analytical balance (OHAUS Pioneer). All experimental treatments were performed in triplicate to ensure statistical reliability.

Exposure Media

Freshwater (FW), River Sediment (RS), Compost (COM), and UV exposure (UV) simulated the natural environmental conditions of a freshwater body, riverbank, landfill, and exposure to direct sunlight, respectively.

Experimental Setups for Freshwater (FW), River Sediment (RS), and Compost (COM) media

Two glass tanks, each measuring 60 × 30 × 30 cm (L × W × H), were used to simulate freshwater (FW) and river sediment (RS) environments. The freshwater tank was filled with unfiltered water from a local lake and continuously aerated to mimic the littoral zone of freshwater bodies. The river sediment tank was filled with moist sediment collected from a riverbank (GPS: 6º 56’57.9” N, 79º 54’28.1” E) to simulate benthic conditions. Test samples were individually enclosed in nylon mesh pockets to prevent the loss of fragments during degradation and then submerged in freshwater (FW) or embedded in river sediment (RS) (Fig. 1 a, b). The compost (COM) was prepared in a 100 L transparent plastic container using layered additions of Gliricidia sepium leaves, other green manure, animal fertilizer, pre-made compost, and rock phosphate. The compost mixture was kept covered with intermittent aeration for four months to allow for stabilization. The test samples were then placed in mesh pockets and embedded in the compost matrix (Fig. 1 c). All experimental setups were maintained indoors near a window to expose the samples to natural day–night light cycles for 12 months. Sampling was conducted on a monthly basis.

Experimental Setup for UV Exposure (UV)

To simulate natural sunlight, a sealed UV exposure chamber was constructed and equipped with UV lamps emitting light in the 280–320 nm range (~15 W). The lamps were positioned 15 cm above the samples to ensure a consistent irradiation intensity. The prepared samples were placed in 70 mL boiling tubes and subjected to continuous UV exposure for 8 months. Light intensity was monitored using a solar power meter (SM206), and samples were collected monthly for analysis (Fig.1 d).

Assessment of Physical Parameters Affecting Degradability

At each sampling, the physicochemical parameters (pH and temperature) of FW, RS, and COM were recorded using a portable pH meter (APERA PH400S), and salinity was measured using a handheld refractometer (ATAGO S/Mill-E).

Assessment of Weight Changes

Samples exposed to FW, RS, and COM were withdrawn from the media, carefully cleaned, and the remaining dry weight was measured. Samples exposed to UV light were directly weighed because of the absence of impurities attached to the medium. Fragmented samples were collected using a 200µm sieve. The Mean Weight Loss (MWL) was calculated using the following equation:

$$\text{Mean Weight Loss} = \frac{[(\text{Initial}_1 - \text{Final}_1) + (\text{Initial}_2 - \text{Final}_2) + (\text{Initial}_3 - \text{Final}_3)]}{\text{No. of replicates (3)}}$$

Assessment of the Loss of Mechanical Properties

The tensile strength of the initial and final samples was tested using a universal testing machine (EKT 2001S), and the thickness of the samples was measured using a micrometer screw gauge. GB samples were cut into 75 × 15 mm strips, and LS samples into 150 × 15 mm strips, where the extension rate was 200 mm.min^{-1} at 25± 2°C (modified method from Kubik & Zeman 2013). FP and SP samples were cut into 55 × 20 mm strips, and the extension rate was 0.5 mm.min^{-1} at 25± 2°C (Artzi et al. 2016).

Assessment of Visual Changes During Degradation

Visual signs of degradation, including changes in the shape, size, and color of the initial and final test samples, were compared, and microscopic changes were analyzed via Scanning Electron Microscopy (SEM).

Assessment of Chemical Degradation

Initial and final test samples were scanned via Fourier Transform Infrared (FT-IR) spectroscopy in ATR mode at room temperature, covering 4000–400 cm-1 wavelength to examine changes in the polymer structure during the experiment time. FT-IR spectra of the initial samples were compared with those of the inbuilt library to confirm the significant polymer composition.

RESULTS AND DISCUSSION

According to UNEP (2015), if a product is marketed as biodegradable, a recognized standard such as EN 13432 (European), ASTM 6400 (USA), or ISO 17088 (international), which defines compostability, should be stated; however, none of the products contained such information available to the consumer.

Assessment of Weight Changes

In the freshwater exposure (FW) setup, the biodegradable salad plate (SP) exhibited the highest mean weight loss (MWL), ranging from 4.42% to 44.42% relative to the positive control (FP). The maximum MWL observed for the oxo-degradable garbage bag (GB) was 6.82% over time (Fig. 2). Complete degradation was not observed for any test sample in FW; however, visual assessments indicated discoloration and slight deformation of the samples. These findings are consistent with those of Kliem et al. (2020), who reported that aquatic environments typically support lower microbial activity because of the dilutive nature of water, which limits biodegradation. In contrast, in the river sediment (RS) and compost (COM) setups, SP underwent complete degradation within 120 d. GB exhibited minimal degradation in these media, with MWL values of 1.96% in

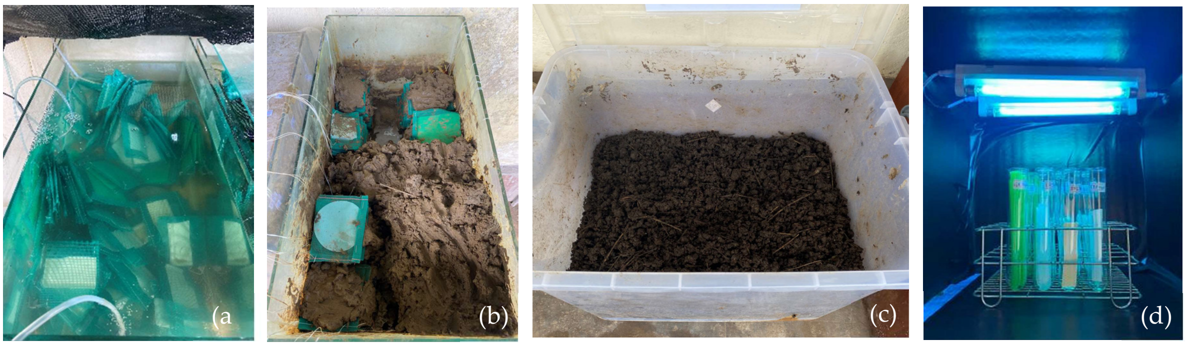

Fig. 1: Exposure media (a) Freshwater (b) River Sediment (c) Compost (d) UV chamber.

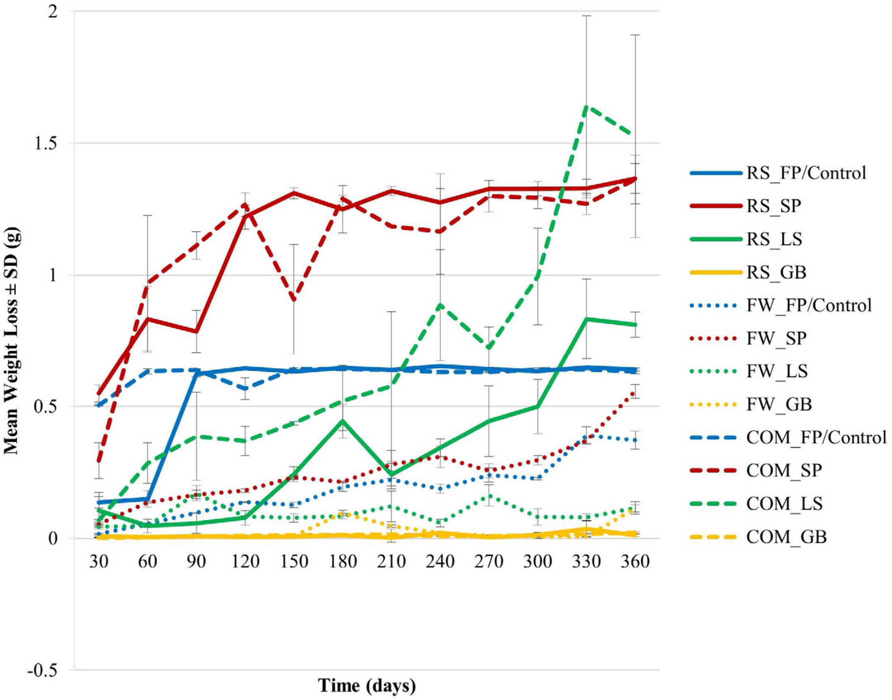

Fig. 2: Mean weight loss ± SD of test samples in RS, FW, and COM during the experiment period.

RS and 1.16% in COM (Fig. 2). The enhanced degradation observed in RS and COM compared to FW is attributed to the higher microbial activity promoted by moist, oxygen-rich conditions in wet sediment media, which favor aerobic microbial processes. These environments provide favorable conditions for microbial colonization and enzymatic breakdown of biodegradable materials.

Statistical analysis using one-way ANOVA and Kruskal–Wallis tests indicated significant differences (p=0.000; p<0.05) in MWLs for FP, SP, and the compostable lunch sheet (LS) across the three environments, FW, RS, and COM. In contrast, the MWLs for GB were not statistically significant (p=0.759; p>0.05), suggesting limited environmental degradation across all tested conditions.

Under UV exposure, SP recorded a maximum MWL of 2.43%, indicating limited photodegradation (Fig. 3). Although GB exhibited slight increases in weight, physical cracking, and fragmentation were observed indicating that photo-oxidative processes initiated polymer breakdown.

Assessment of the Loss of Mechanical Properties

The methodology for assessing the mechanical property degradation was adapted from Kubik and Zeman (2013) to account for the unexpected elasticity of the oxo-degradable garbage bag (GB) and the limited dimensions of the test samples. A reduction in mechanical properties, specifically tensile strength at break (F_b) and elongation at break ($\boldsymbol{\varepsilon}_b$), is generally considered indicative of material degradation. However, in this study, GB samples exhibited increased mechanical performance over time under both river sediment (RS) and compost (COM) exposures. In RS, GB recorded a F_b of 7.25±0.29 N and εb of 317.78±9.15%, while in COM, values were 4.35±0.88 N and 46.16±28.11%, respectively, suggesting a counterintuitive increase in elasticity, potentially due to environmental plasticization or sample variability during the early stages of degradation. In contrast, the biodegradable salad plate (SP) exhibited the lowest mechanical integrity under compost exposure, with a F_b of 26.72±2.77 N and εb of 0.57±0.22%, indicating a considerable weakening of the material. The compostable lunch sheet (LS) exhibited the highest initial ε_b value (54.81±7.29%), indicating a greater ability to undergo deformation without fracturing. However, LS samples became brittle across all exposure media by the first month of exposure, indicating rapid degradation. All tested materials demonstrated a measurable decrease in thickness over the exposure period, further supporting progressive degradation (Table 1).

Assessment of Visual Changes During Degradation

Visual changes in RS, FW, and COM included discoloration, deformation, loss of smoothness, fading, thinning, and weight loss. SE micrographs revealed microscopic surface alterations, such as surface erosion, tiny cracks, pits, holes,

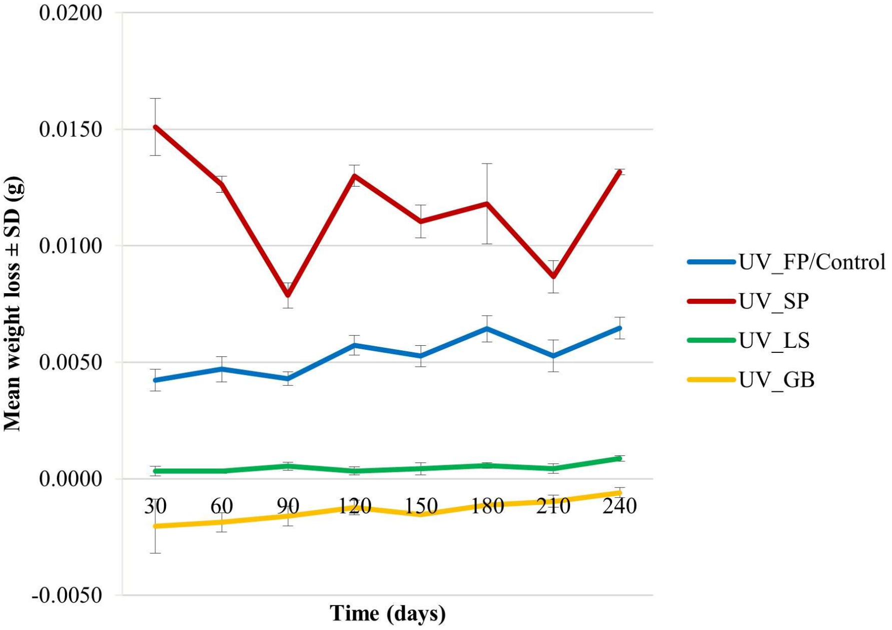

Fig. 3: Mean weight loss ± SD of test samples under UV exposure during the experiment period.

Table 1: Changes in Mean Tensile Strength at Break and Mean Elongation at Break of the test samples in FW, RS, and COM media, compared to the initial values. Samples in the UV region were omitted because of unavoidable size adjustments of the test samples.

Sample	Medium	Mean Thickness ± SD [mm]	Exposure time [months]	Mean Tensile strength at break (F_b) ± SD (N)	Mean elongation at break (ε_b) ± SD [%]	ΔFb [%]	Δεb [%]
SP	Initial	1.35 ± 0.01	0	248.35 ± 23.52	5.52 ± 0.30	-	-
	FW	0.54 ± 0.05	11	156.85 ± 4.96	4.50 ± 0.29	-36.84	-18.37
	RS	0.35 ± 0.05	1	52.17 ± 3.42	1.40 ± 0.08	-78.99	-74.57
	COM	0.62 ± 0.00	1	26.72 ± 2.77	0.57 ± 0.22	-89.24	-89.74
LS	Initial	0.01 ± 0.00	0	1.93 ± 0.06	54.81 ± 7.29	-	-
	FW	Too brittle to test at the first sampling					
	RS	Too brittle to test at the first sampling					
	COM	Too brittle to test at the first sampling					
GB	Initial	0.02 ± 0.00	0	3.87 ± 0.46	10.37 ± 1.15	-	-
	FW	0.02 ± 0.00	11	2.82 ± 0.67	9.53 ± 1.76	-27.16	-8.10
	RS	0.02 ± 0.00	11	7.25 ± 0.29	317.78 ± 9.15	87.50	2965.95
	COM	0.02 ± 0.00	11	4.35 ± 0.88	46.16 ± 28.11	12.5	345.34
FP/ Control	Initial	0.19 ± 0.00	0	25.85 ± 1.75	3.31 ± 0.40	-	-
	FW	0.15 ± 0.00	9	14.98 ± 2.37	1.45 ± 0.14	-42.07	-56.21
	RS	0.14 ± 0.01	1	0.63 ± 0.03	0.13 ± 0.00	-97.58	-96.12
	COM	Too brittle to test at the first sampling					

and coagulated fibers formed during degradation. Fig.4 shows representative images comparing the changes in the surfaces of LS samples in experimental media, highlighting the least changes under UV exposure.

Analysis of FT-IR Spectra (ATR Mode)

Changes in chemical composition are considered vital transformations in polymer degradation, resulting in environmentally friendly and simple compounds. According to the initial FT-IR spectra (ATR mode), the chemical composition of the biodegradable salad plate (SP) was similar to that of cellophane (~42%), the compostable lunch sheet (LS) was similar to that of polyester (~ 60%), the oxo-degradable garbage bag (GB) was similar to that of

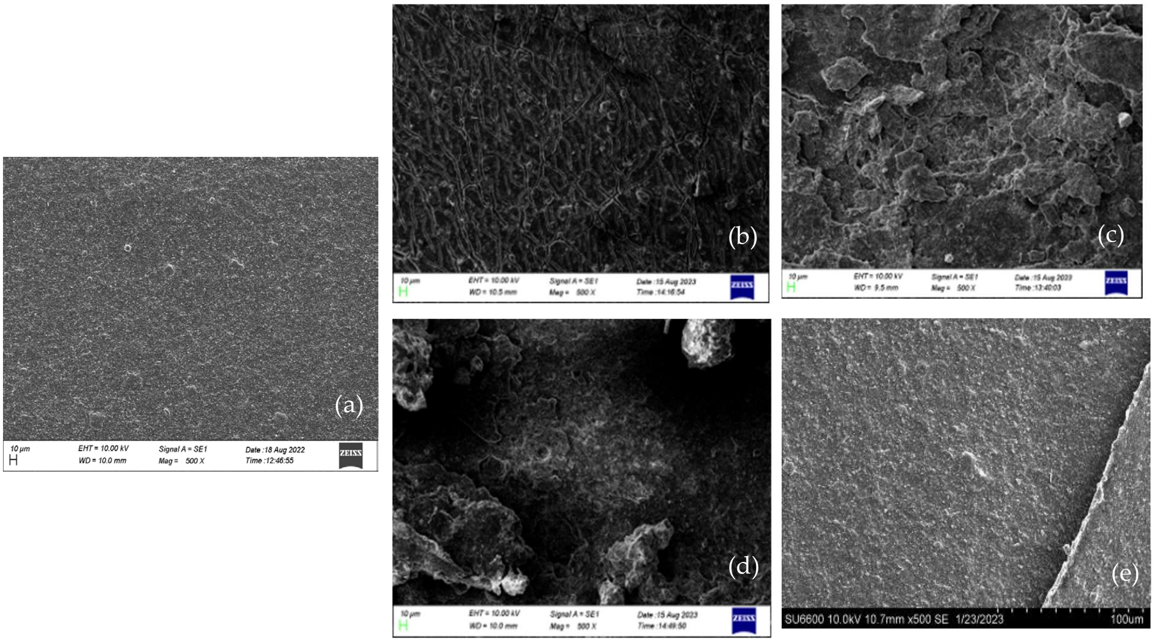

Fig. 4: Microscopic changes on the surface topography of LS samples during the experiment period (500×) (a) Initial (b) in FW (c) in RS (d) in COM (e) in UV.

Low-Density Polyethylene (LDPE) (~ 63%), and the control, filter paper (FP) was similar to that of dextrose anhydrous (~ 32%). In addition to the chemicals revealed via FT-IR, the label of SP included natural sugarcane bagasse, a complex mixture of hemicellulose, cellulose, and lignin (Nunes et al. 2020). The LS label mentioned the presence of cornstarch ($C_{27}H_{48}O_{20}$), and the control and Whatman filter papers were manufactured from treated cotton liners.

All final samples exhibited lower intensities than the initial samples (Figs 5, 6, and 7). Final SP samples in the river sediment (RS) and compost (COM) exposures displayed loss of characteristic peaks of cellophane at wave numbers 3200-3550 cm-1 (O-H stretching) and 2850–2950 cm-1 (C-H stretching) (Da Costa et al. 2018) (Fig. 5).

The Final LS samples exposed to RS and COM revealed the loss of characteristic peaks associated with polyester-derived components, specifically the C–O–C stretching vibrations at 1050–1150 cm^{-1} and C–H stretching vibrations at 2850–2950 cm^{-1}, indicating chemical degradation (Fig.6). In contrast, the final garbage bag (GB) samples did not exhibit any notable changes in the characteristic LDPE spectral features. Peaks corresponding to C–H stretching (2850–2950 cm^{-1}), C–H bending (~1460 cm^{-1}), C–C stretching (1470–1500 cm^{-1}), and symmetric C–H stretching or in-plane C–C stretching (~720–730 cm^{-1}) remained intact, suggesting minimal or no polymer backbone degradation (Ranjan & Goel 2019). However, a new absorption peak emerged at ~ 1700 cm-1 under UV exposure, indicative of carbonyl group (C=O) formation, marking photo-oxidative degradation (Ranjan & Goel, 2019) (Fig.7). Although GB was marketed as oxo-degradable, the final FT-IR spectra remained largely similar to the initial profiles, reflecting incomplete biodegradation under all tested environmental conditions. This observation is consistent with previous findings that LDPE is inherently resistant to microbial degradation (Balasubramanian et al. 2010, Da Costa et al. 2018, Yoezer et al. 2023) and is commonly used as a negative control in biodegradability studies (Carteny & Blust 2021). Therefore, such misleading labels promote littering behavior and eventually encourage consumers to purchase non-biodegradable products.

Relationship Between Physicochemical Parameters and Mean Weight Loss (MWL)

The relationship between the measured physicochemical parameters and the mean weight loss (MWL) of the test samples was analyzed using linear regression and locally estimated scatterplot smoothing (Loess) regression. In freshwater (FW), a statistically significant (p=0.003; p<0.05) negative correlation (R^2=60.2%) was observed between the MW losses of garbage bags (GB) and pH in FW, where the pH ranged between 6.82-8.65, temperature 25.4-31.6ºC, and salinity ~0 ppt. However, Loess Regression indicated a weaker non-linear relationship with pH. In the compost (COM) medium, significant negative correlations were observed between MW losses and pH for both lunch sheet

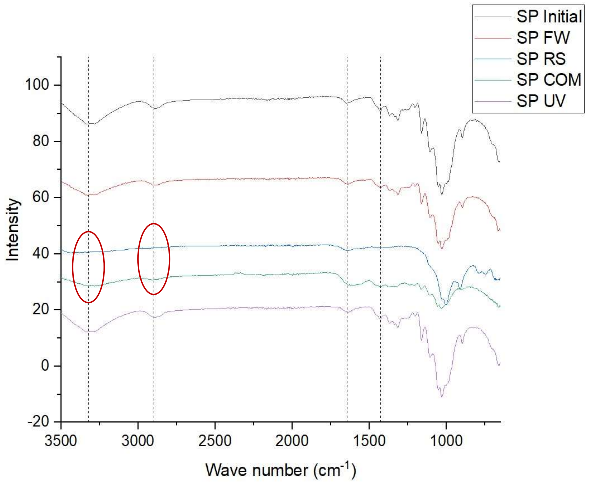

Fig. 5: Initial FTIR vs final FTIR of SP samples under different exposures.

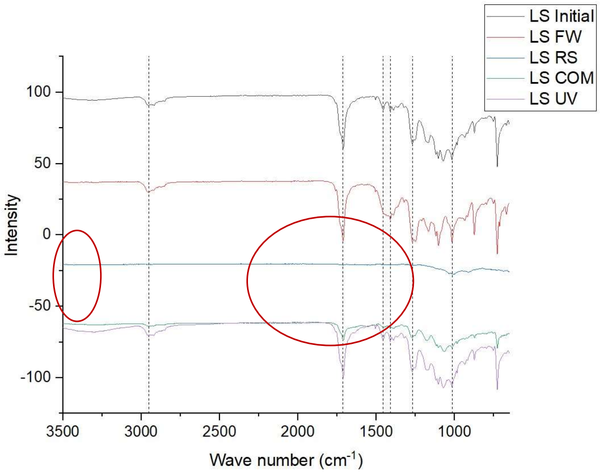

Fig. 6: Initial FTIR vs final FTIR of LS samples under different exposures.

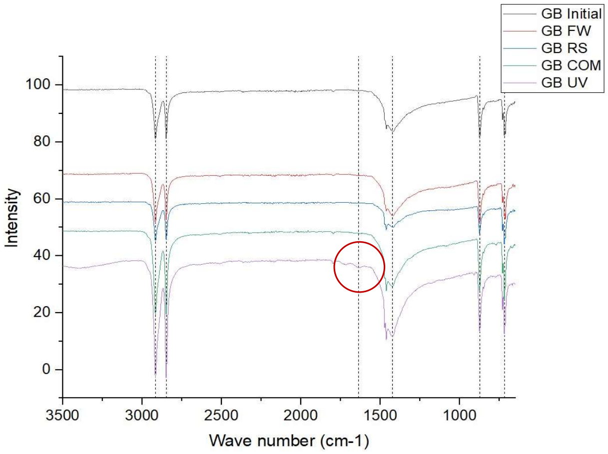

Fig. 7: Initial FTIR vs final FTIR of GB samples under different exposures.

(LS) (p=0.044; p<0.05: R^2=44.80%) and garbage bag (GB) (p=0.021; p<0.05: R^2=53.23%) samples. Here, the pH ranged between 6.26 and 7.21, the temperature was 26.8-31.5°C, and the salinity was 0-5.6 ppt. Despite statistical significance, Loess regression suggested weak relationships, highlighting the complexity of environmental degradation dynamics. Given the limitations of periodic parameter measurements, continuous monitoring of physicochemical parameters is recommended in future studies to better elucidate their influence on the degradation of polymers.

CONCLUSIONS

The degradability of commercial biodegradable products under natural environmental conditions is highly dependent on both the chemical composition of the material and the characteristics of the medium to which it is exposed. This study demonstrated that degradation rates vary substantially across media types and sample materials. Sediment-rich environments (RS and COM) supported higher degradation of biodegradable polymers than fully aqueous conditions (FW), likely due to enhanced microbial activity and higher organic content. These findings suggest that waste accumulating in sediment-laden environments, such as landfills and riverbanks, may exhibit greater degradation potential than plastic waste suspended in water columns or exposed only to sunlight. The salad plate (SP) labeled as biodegradable showed complete degradation (100% MWL) within 120 days under both RS and COM conditions. The lunch sheet (LS), labeled as compostable, recorded the highest MWL in COM after 330 days. In contrast, the garbage bag (GB), labeled oxo-LDPE/biodegradable, showed a maximum MWL of only 6.82% after 360 days. Although Whatman No. 42 filter paper (FP) was used as a positive control, its rapid disappearance across all media suggests that a chemically stable negative control may be more appropriate for future studies. Nevertheless, the complete degradation of FP confirmed that the environmental conditions in all test media were conducive to degradation processes. FT-IR analysis indicated chemical alterations in some samples, including the loss of characteristic polymer peaks, which is consistent with biological degradation. However, further research is needed to confirm whether the observed changes lead to complete mineralization into non-toxic inorganic compounds.

ACKNOWLEDGMENTS

The authors would like to acknowledge the Instrument Center of the Faculty of Applied Sciences, University of Sri Jayewardenepura, Sri Lanka, for the support in FT-IR (ATR mode) Spectroscopy.

REFERENCES

Ahmed, T., Shahid, M., Azeem, F., Rasil, I., Ali Shah, A., Noman, M., Hameed, A., Manzoor, N., Manzoor, I. and Muhammad, S., 2018. Biodegradation of plastics: Current scenario and future prospects for environmental safety. *Environmental Science and Pollution Research*, 25, pp.7287–7298. [DOI]

Artzi, L., Morag, E., Shamshoum, M. and Bayer, E.A., 2016. Cellulosomal expansin: Functionality and incorporation into the complex. *Biotechnology for Biofuels*, 9, p.61. [DOI]

Balasubramanian, V., Natarajan, K., Hemambika, B., Ramesh, N., Sumathi, C.S., Kottaimuthu, R. and Rajesh Kannan, V., 2010. High-density polyethylene (HDPE)-degrading potential bacteria from the marine ecosystem of the Gulf of Mannar, India. *Letters in Applied Microbiology*, 51, pp.205-211. [DOI]

Carteny, C.C. and Blust, R., 2021. Not only are diamonds forever: Degradation of plastic films in a simulated marine environment. *Frontiers in Environmental Science*, 9, p.662844. [DOI]

Da Costa, J.P., Nunes, A.R., Santos, P.S.M., Girao, A.V., Duarte, A.C. and Rocha-Santos, T., 2018. Degradation of polyethylene microplastics in seawater: Insights into the environmental degradation of polymers. *Journal of Environmental Science and Health, Part A*, pp.1-10. [DOI]

GESAMP, 2015. Sources, Fate and Effects of Microplastics in the Marine Environment: A Global Assessment (Kershaw P.J. ed.). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 90, p.96. Retrieved June 8, 2021, from http://www.gesamp.org/publications/reports-and-studies-no-90

Gijsman, P., 2008. Review on the thermo-oxidative degradation of polymers during processing and in service. *E-Polymers*, 8(1), p.065. [DOI]

Itävaara, M., Karjomaa, S. and Selin, J-F., 2002. Biodegradation of polylactide in aerobic and anaerobic thermophilic conditions. *Chemosphere*, 46, pp.879-885. [DOI]

Kliem, S., Kreutzbruck, M. and Bonten, C., 2020. Review on the biological degradation of polymers in various environments. *Materials*, 13, p.4586. [DOI]

Kubik, L. and Zeman, S., 2013. Tensile properties of polyethylene films and paper. In: *Trends in Agricultural Engineering 2013*. Prague: Faculty of Engineering, Czech University of Life Sciences Prague, pp.707-711.

Nunes, L.J.R., Loureiro, L.M.E.F., Sá, L.C.R. and Silva, H.F.C., 2020. Sugarcane industry waste recovery: A case study using thermochemical conversion technologies to increase sustainability. *Applied Sciences*, 10, p.6481. [DOI]

Orhan, Y., Hrenović, J. and Büyükgüngör, H., 2004. Biodegradation of plastic compost bags under controlled soil conditions. *Acta Chimica Slovenica*, 51, pp.579-588.

Ranjan, V.P. and Goel, S., 2019. Degradation of low-density polyethylene film exposed to UV radiation in four environments. *Journal of Hazardous, Toxic, and Radioactive Waste*, 23(4), p.04019015-1-11. [DOI]

UNEP, 2015. Biodegradable Plastics and Marine Litter: Misconceptions, Concerns and Impacts on Marine Environments. United Nations Environment Programme (UNEP), Nairobi. Retrieved June 10, 2024, from https://www.unep.org/resources/report/biodegradable-plastics-and-marine-litter-misconceptions-concerns-and-impacts

Venkatesh, S., Mahboob, S., Govindarajan, M., A.Al-Ghanim, K., Ahmed, Z., Al-Mulhm, N., Gayathri, R. and Vijayalakshmi, S., 2021. Microbial degradation of plastics: Sustainable approach to tackling environmental threats facing big cities of the future. *Journal of King Saud University – Science*, 33, p.101362. [DOI]

Yoezer, N., Gurung, D.B. and Wangchuk, K., 2023. Environmental toxicity, human hazards and bacterial degradation of polyethylene. *Nature Environment & Pollution Technology*, 22(3). [DOI]