



BIO-/PHOTODEGRADABLE POLYMERS AND BIO-BASED ADDITIVES

WEATHERING TESTING AS A TOOL TO BALANCE DURABILITY AND SUSTAINABILITY

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- Introduction
 - Atlas
 - Weather Factors on Polymers / Ways of Degradation
- Purpose of Weathering
- Lifecycle and Lifetime of Polymer Products
- Example 1: Biodegradable Liquor Bottles
- Example 2: Photodegradable Cigarette Butts
- Example 3: Bio-based Flame Retardants





Weathering Instruments



Weathering Services

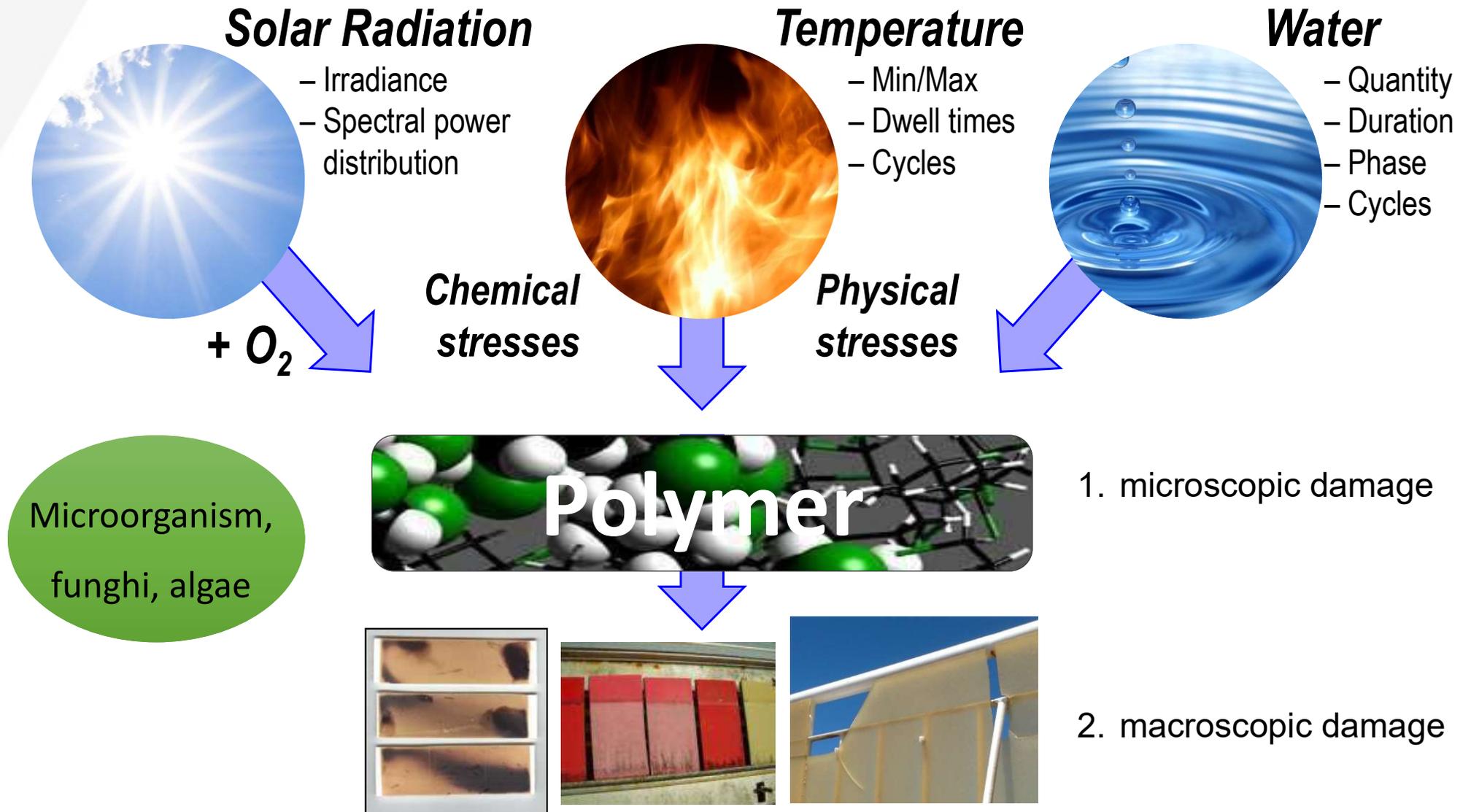


3 Custom Solar Simulators



Training, Consulting, Standards





Polymers undergo degradation in different ways:

■ Thermal degradation

- Non-oxidative
- Oxidative

■ Photodegradation

- Photo-oxidation
- Photolysis
- Photo-induced rearrangements

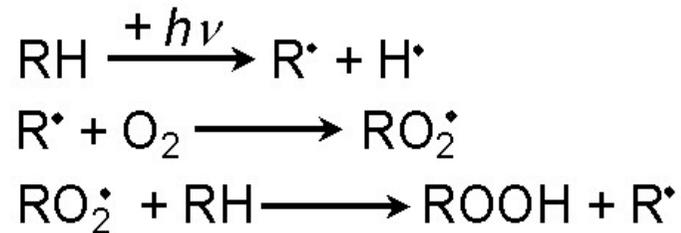
■ Hydrolysis

■ Biodegradation

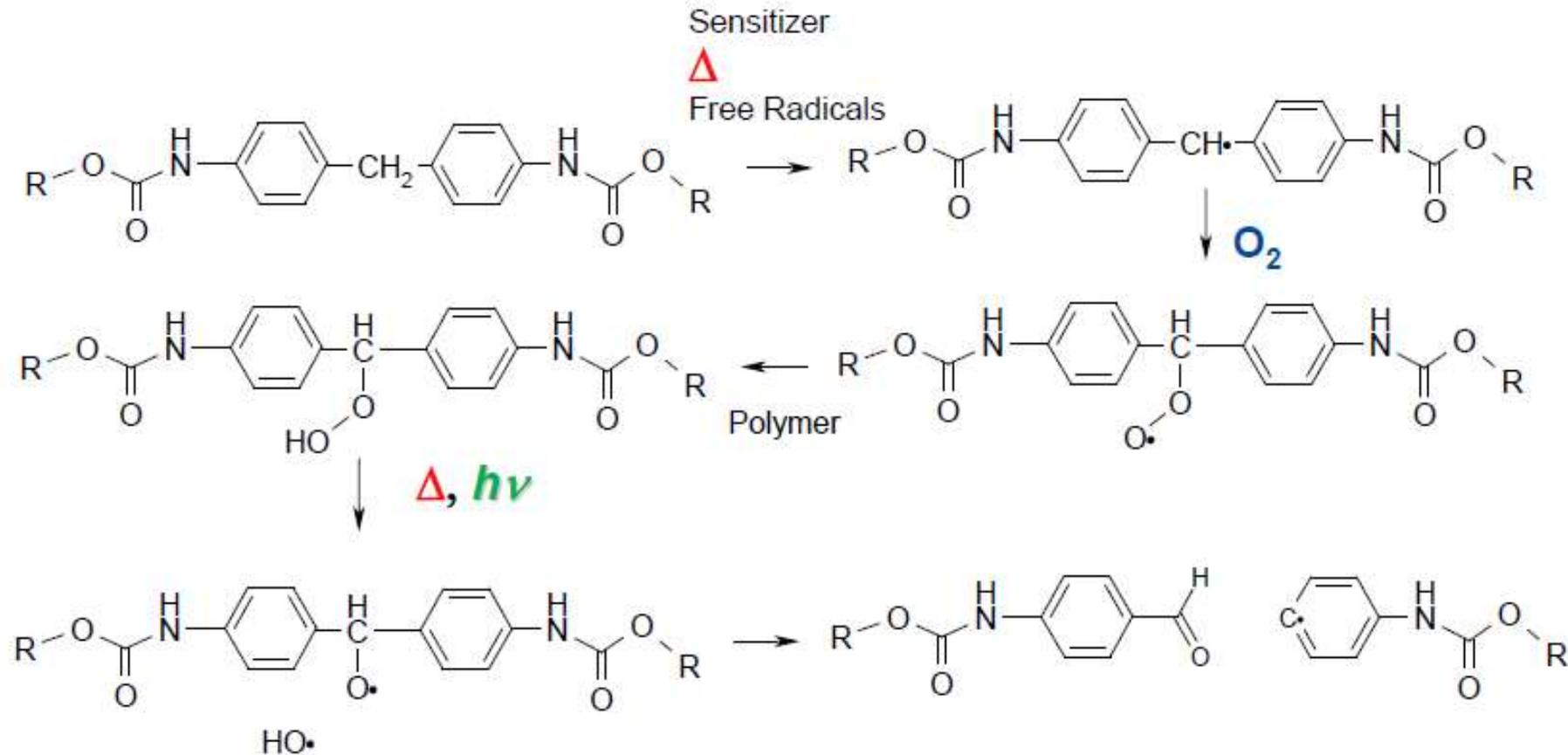
- Microorganism, funghi, algae



PHOTO-OXIDATION OF POLYMERS



Often, only 1 out of 100.000 Photons causes formation of a radical



PURPOSE OF WEATHERING INSTRUMENTS

Weathering instruments are made for determining / achieving desired lifetime of products and materials.



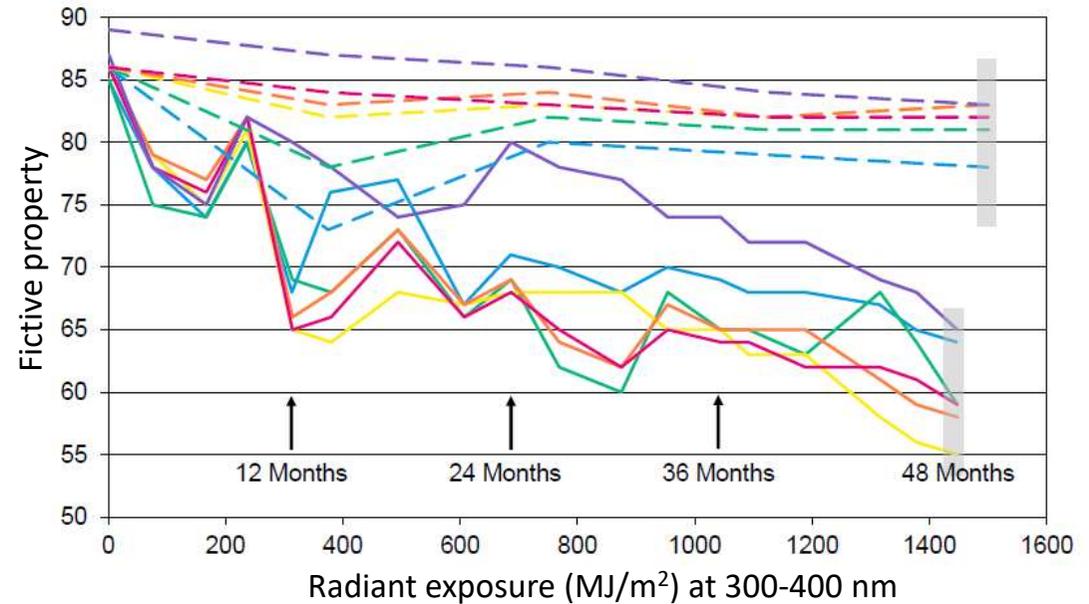
○ *Avoid over-engineering, saving chemical additives, material, and other resources*



○ *Products with desired lifetime reduce waste, crap, and landfill*

PURPOSE OF WEATHERING

- Weathering testing is used to determine durability and lifetime
- Avoiding premature product failure helps to reduce waste, scrap, and landfill, and limits waste of resources. The longer the product service-life the better
- Weathering testing can avoid over-engineering (savings on additives, use of sustainable material) → helps to present the most economical solution



- At the end of service-life, plastics often end up in the environment
 - On the ground
 - In rivers, oceans
- Bio- and photodegradable plastics can be useful in addressing above challenges, especially for packaging. Furthermore, polymer based geotextiles, agricultural foils, etc...
- Of course, bio- and photodegradable plastics must achieve their target service-life - no faster degradation/aging as needed

Biodegradable

- capable of being decomposed by bacteria or other living organisms and thereby avoiding pollution; www.oed.com (Oxford English Dictionary)
- Something that is biodegradable breaks down naturally without any special scientific treatment, and can therefore be thrown away without causing pollution; www.collinsdictionary.com

Photodegradable

- capable of being decomposed by the action of light, especially sunlight; www.oed.com (Oxford English Dictionary)
- (plastic) capable of being decomposed by prolonged exposure to light; www.collinsdictionary.com

Photodegradable Plastic

- Photodegradable plastic is usually made of oil-based polymers (Atlas: better bio-based). It either has bonds in its structure that can be weakened and broken by sunlight, or it contains a chemical additive (Atlas: ideally bio-based) which absorbs light and then attacks the polymer and breaks some of the bonds; <https://edu.rsc.org>



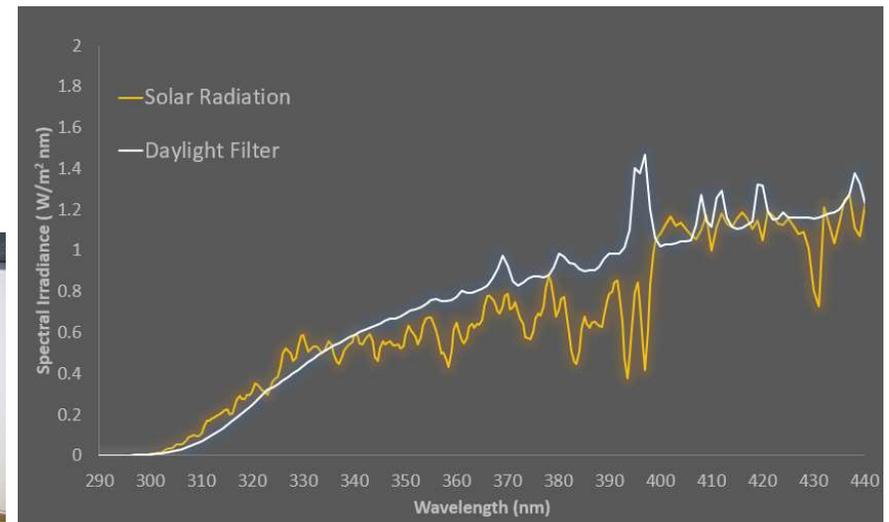
- ISO 14021:2016 Environmental labels and declarations — **Self-declared** environmental claims
 - Referring to relevant weathering testing according to ASTM D5071 (Xenon-arc) and ASTM D5208 (Fluorescent UV)

- EN 13432:2000 Packaging - Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging
 - does not consider weathering
 - photodegradable plastics do not fulfil the requirements



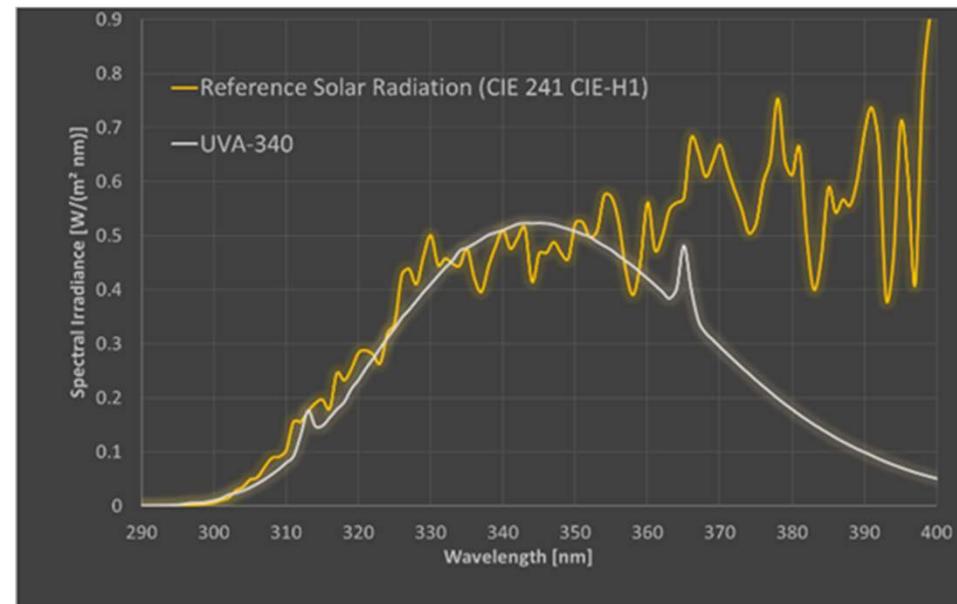
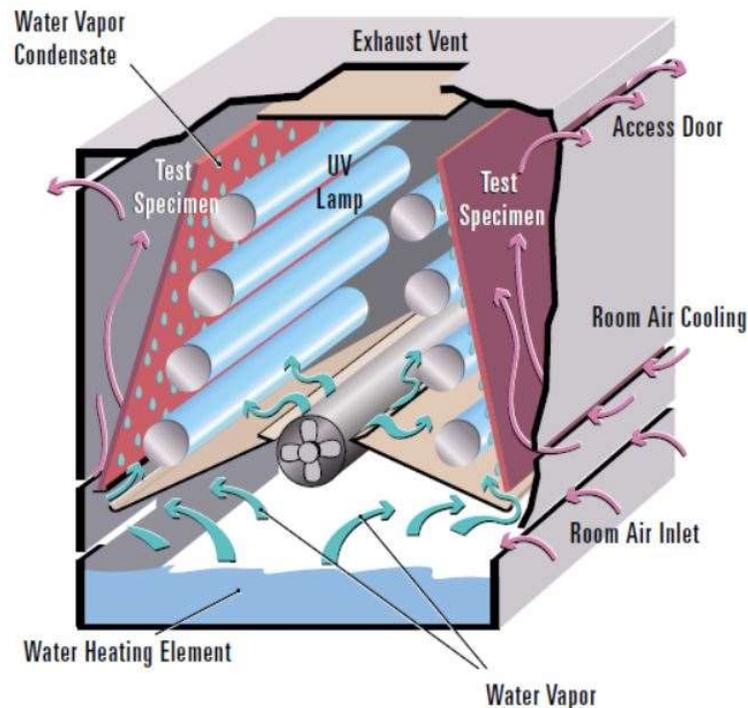
ASTM D5071– 08 (REAPPROVED 2021)

- Standard Practice for Exposure of Photodegradable Plastics in a Xenon Arc Apparatus
- 3 full-spectrum xenon weathering cycles (Daylight filter) for degradation testing
 - Continuous light phase dry
 - Continuous light phases dry / wet
 - Continuous light phases dry / wet followed by humid dark phase



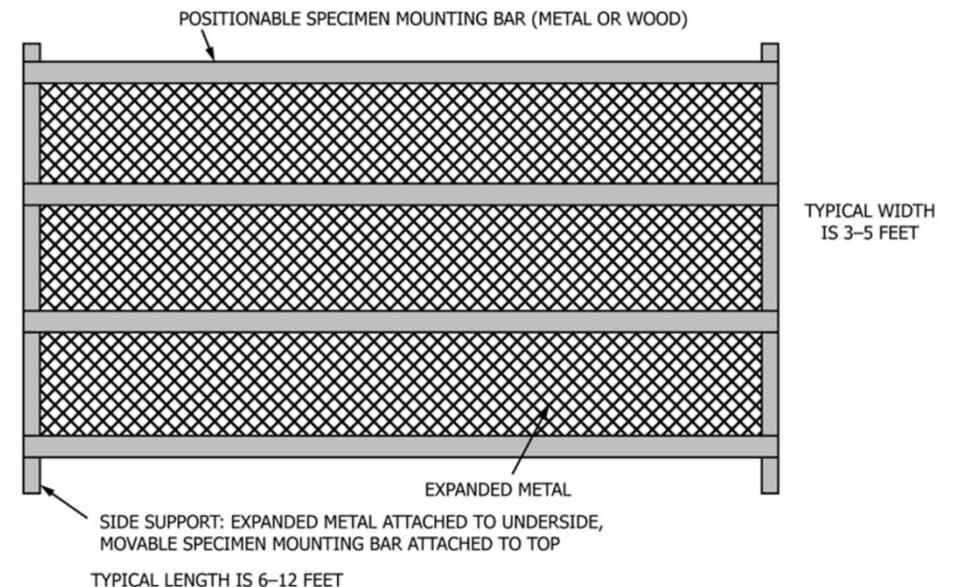
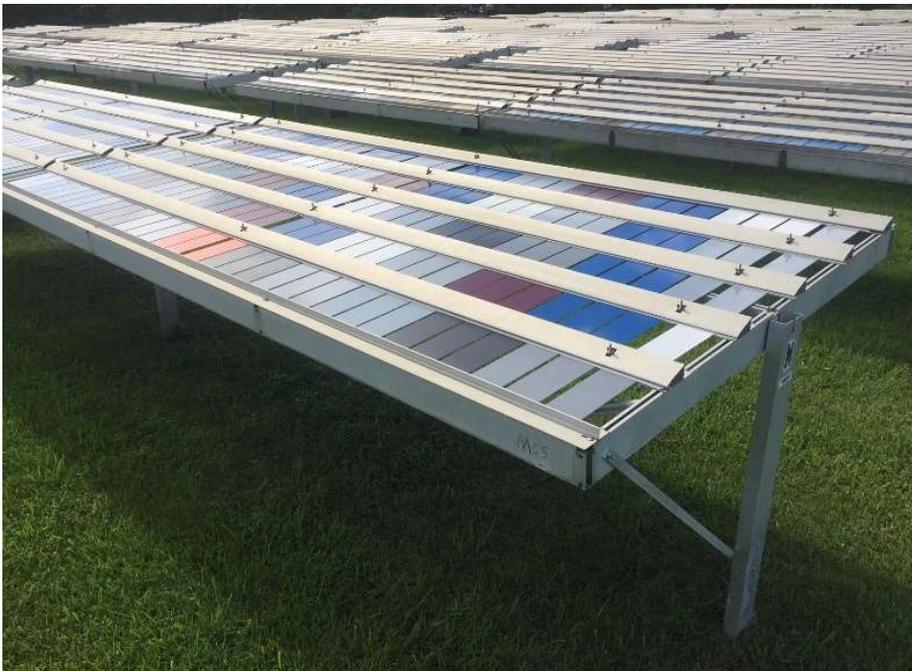
ASTM D5208- 14 (REAPPROVED 2022)

- Standard Practice for Exposure of Photodegradable Plastics in a Fluorescent UV Apparatus
- 3 UV-Fluorescent/condensation cycles (UVA-340) for degradation testing
 - 20 h continuous light phase dry followed by 4 h dark/condensation
 - 4 h continuous light phase dry followed by 4 h dark/condensation
 - Continuous light phases dry



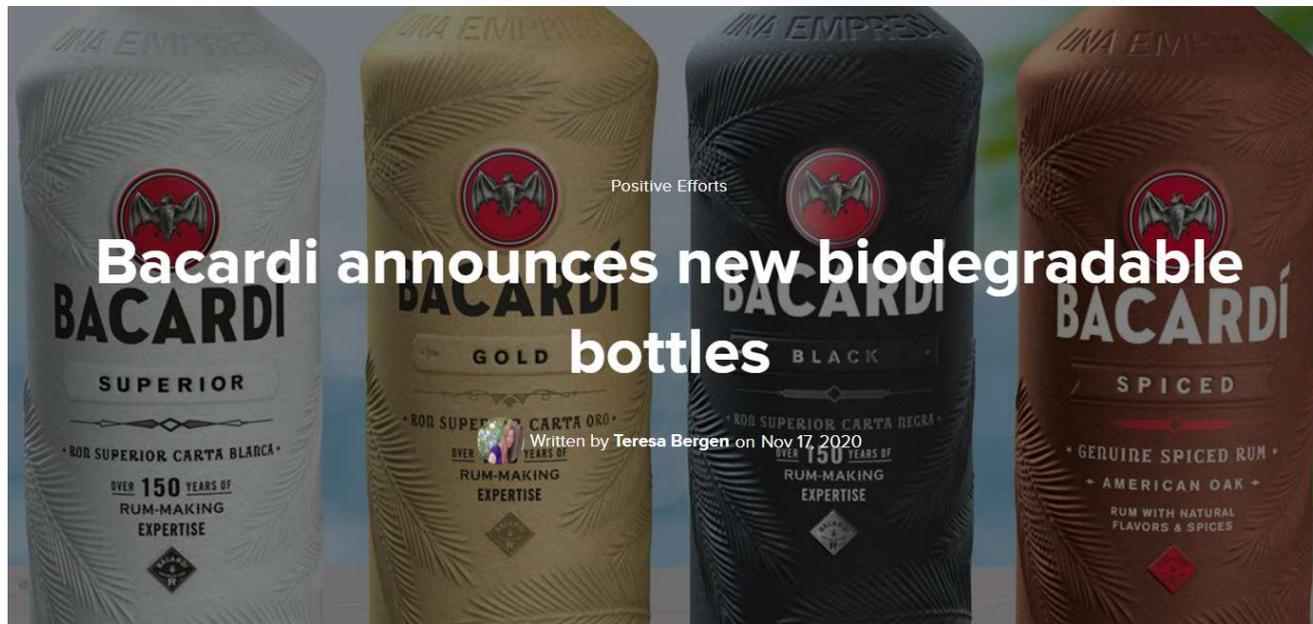
Standard Practice for Outdoor Exposure Testing of Photodegradable Plastics

- Samples on 5° exposure racks
- real-world data that can be used as a baseline for comparison with accelerated laboratory testing results (correlation / acceleration of laboratory test)



NO 1: BIODEGRADABLE BOTTLES

- 2020 Bacardi / Martini developed fully biodegradable bottles
 - Weathering Test for service lifetime determination
 - Complete bottle test: xenon rotating rack with Daylight filter and water sprays



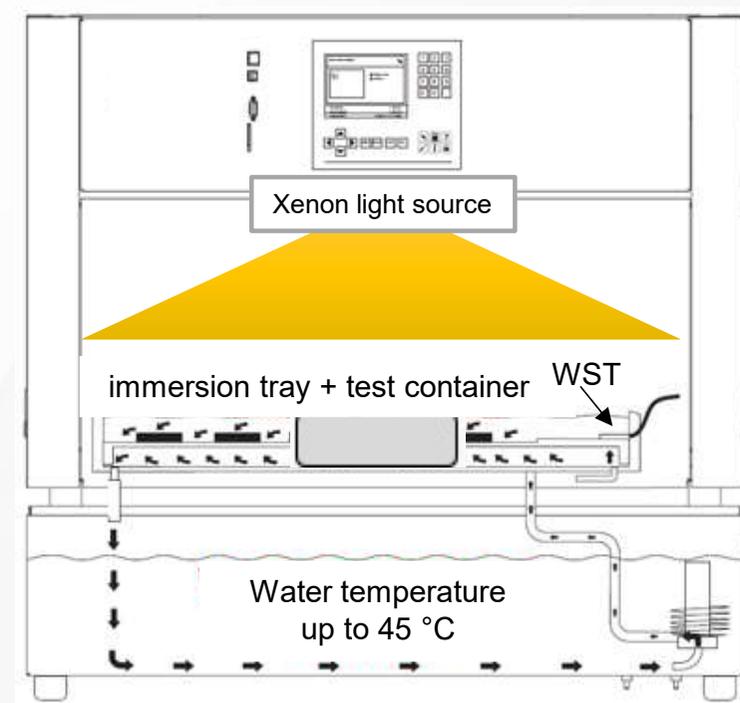
<https://www.businessinsider.com/bacardi-launches-first-fully-biodegradable-spirits-bottle-2020-11>

Xenotest Beta+ FD (bottle rack):

- Daylight Filter XENOCROME 300
- 65 W/m² (300-400 nm)
- BST: 65°C; CHT: 38 °C
- RH: 50 ±10 %; water sprays 102/18 min
- Test duration: unknown

NO 2: PHOTODEGRADABLE CIGARETTE BUTTS

- 1993 „Cigarette Butt Degradability Task Force“
- Aug 2000: Final report submitted to CORESTA Scientific Commission
 - CORESTA = Cooperation Centre for Scientific Research Relative to Tobacco
 - Atlas participated
- APPENDIX : ACCELERATED CIGARETTE BUTT DISINTEGRATION TEST
 - SUNTEST with water immersion unit
 - Ten cigarette butts in a stainless steel test container with holes in the bottom
 - Daylight Filter, 0.35 W/(m²nm) at 340 nm
 - WST = 55 °C (White Standard Temperature)
 - Continuous light 702 min dry, 18 min wet



Excerpt from Final Report – Aug 2000

... The Task Force was chartered in 1993 by the CORESTA Technology Study Group to develop a method to predict the degradability of cigarette butts outdoors ... butts will degrade over time due to the action of weathering elements such as sun, wind, rain, and mechanical action; ... can take ... months or ... years ... The objective of the Task Force was to develop an accelerated test that could provide consistent results in a matter of days or weeks.

... Cigarette butts that are improperly disposed of ... experience an extremely wide range of conditions ... There is no “standard” set of temperature, humidity, sunlight, rainfall, etc., which could be used to model the disintegration process in the laboratory. The best ... was to specify a laboratory protocol that was defensible in terms of one selected environment ... to be extended to be representative of other environments as well. ...

Ultimately it was decided to use a type of weathering test commercially available benchtop weatherometer that combines water, heat and ultraviolet radiation to mimic the effects of sunlight and rain. An additional procedure whereby the samples are gently agitated in the presence of metal spheres provides a minimal amount of mechanical degradation and also serves to expose fresh surfaces to the action of the weatherometer. ... the test has its roots ... in ASTM weathering protocols ...

.... The result is the method attached to this report. **The procedure works. It will rank cigarette butts in the order in which they are likely to disintegrate outdoors under at least one specific set of conditions. ... Task Force achieved its primary goal.**

... two issues remained. Length of the test. ...time ranged from 12 to 20 weeks. The second issue involved the statistical treatment of the data. ...

The Scientific Commission ... directed the Task Force to discontinue its experimental efforts and generate a final report.



- Typically, focus of bio-based products is the polymer itself
- Additives often out of the focus
 - required to adjust polymer properties and durability:
UV stabilizers, heat stabilizers, antioxidants, plasticizers, flame retardants ...(properties need to last during polymer lifetime)
 - Additive can be **harmful** to the environment and may be released during degradation → need for renewable types / uncritical vs pollution



PROJECT INNFLA (INDOOR APPLICATION)

- Funding: German Federal **Ministry of Food and Agriculture** (BMEL)
- Project execution: **Agency for Renewable Resources e. V** (FNR)
- Coordination: **Fraunhofer WKI** and **LBF** together with industry partners
- Scope: **Flame-retardant wood coating using bio-based binders**
 - Development of bio-based acrylates and polyurethanes
 - Development of bio-based flame retardants (alkoxyamines and –imides)
 - Goal: Permanent flame-retardant effect
 - Fulfillment of the requirements for furniture and interior wood designs
 - Formaldehyde sources are avoided → no negative impact on indoor air quality
- Project Time Frame: 3 years (01.06.2021 - 31.05.2024)
- Status: Formulation of Coatings (Acrylates) with different amounts of “sugar”-monomers and biobased flame-retardant agents (almost finalized)



- **Atlas MTT GmbH:** coordination/execution of weathering testing.
- **Proposed Weathering Methods:**
 - **ISO 4892-2 Method B**
(Xenon-arc with window glass filters)
 - **ISO 4892-3 Method B**
(UVA-351 lamps)
- **Testing of flame-retardant properties**
prior and after lightfastness testing
- **Test start: Q4/2022**



Source: Project report 2021; Claudia Schirp; Fraunhofer WKI; Flammability examples of non-weathered specimens

- Biodegradable / Photodegradable plastics are needed to support the world to manage parts of plastic waste
- Standard weathering testing of photodegradable plastics is well defined in ASTM standards (Xenon, UV-Fluorescent, Natural)
- Weathering testing is a tool to balance durability and sustainability.
 - required product service-life
 - Environmental degradation
- Shown examples: biodegradable bottles, photodegradable cigarettes, and ongoing bio-based additive study



THANK YOU VERY MUCH !

