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GEORGIA

New Materials Institute

*Assessing the Biodegradation and Compostability of
Plastics*

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Humans have created about 8.3 billion metric tons of plastics to date, outgrowing all man-made materials other than steel and cement.

HOW HEAVY IS 8.3 BILLION METRIC TONS?

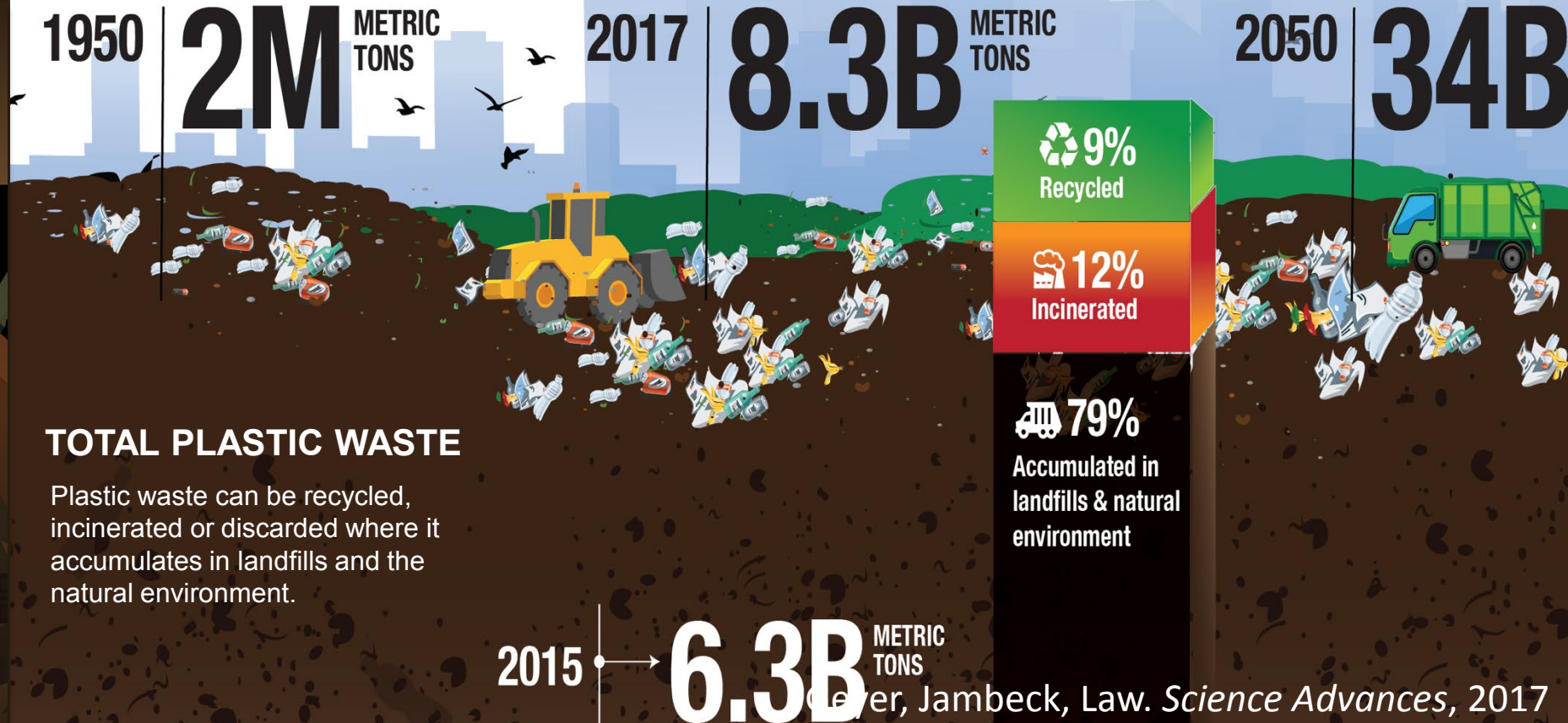


1 million metric tons (Mt) = 1.1 million tons

The rapid rise of plastics

A world without plastics seems unimaginable today, yet their large-scale production and use only dates back to around 1950.

GLOBAL PLASTIC PRODUCTION ESTIMATES



TOTAL PLASTIC WASTE

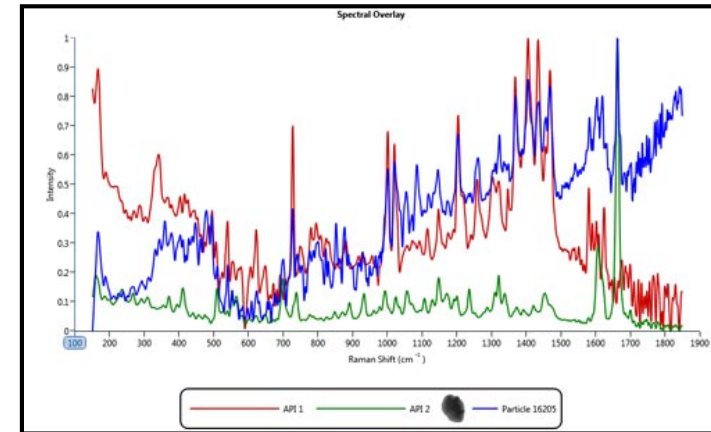
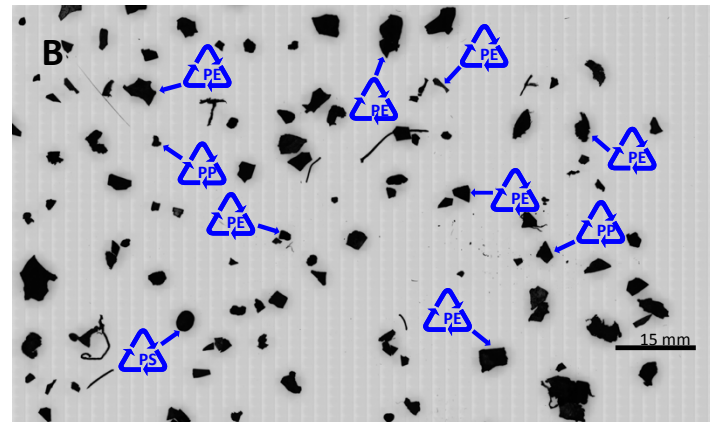
Plastic waste can be recycled, incinerated or discarded where it accumulates in landfills and the natural environment.

Geber, Jambeck, Law. *Science Advances*, 2017

Ingested Micronizing Plastic Particle Compositions and Size Distributions within Stranded Post-Hatchling Sea Turtles



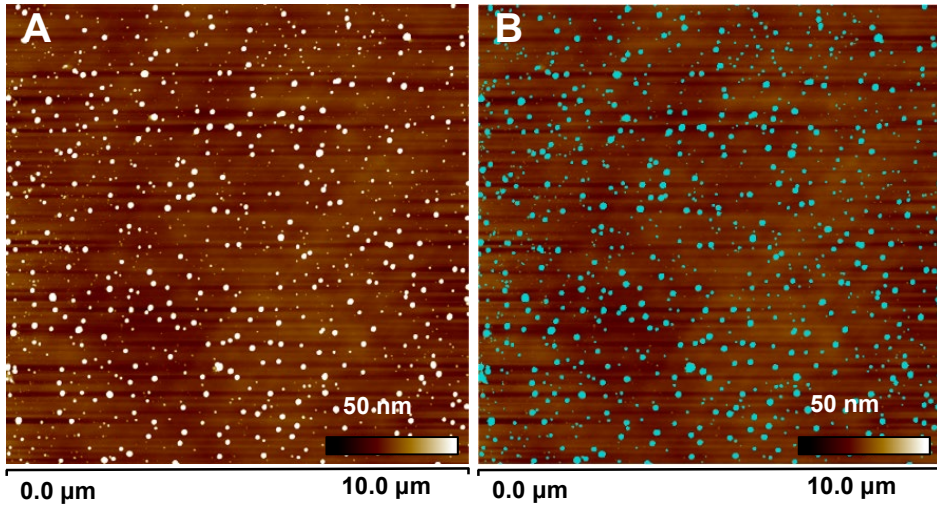
Ingested Plastic in One Baby Sea Turtle



Morphologi G3-ID:
Automated Raman
measurement of
particle size, shape
and chemical identity

Environmental Science & Technology 2018, 52 (18),
10307-10316. DOI 10.1021/acs.est.8b02776

First observation of plastic nanoparticles in environment



Evidence of an abundance of nanoscopic particles in extracted samples

The z-axis threshold is 5 nm (light blue area, A)

WHAT ARE THE IMPLICATIONS FOR HUMAN HEALTH?

we can reduce the morbidity and mortality of post-hatchling sea turtles, as well as other marine fauna for which the post-hatchlings may serve as an indicator species, by **changing from an economy of non-biodegradable disposable consumer waste in single use products to an economy of only biologically degradable products** and thereby reduce the quantity of environmentally stable micronizing plastics that accumulates in our oceans.

Biologically degradable plastics for single use items and flexible packaging

Conventional Plastics (that are fully recyclable) for durable goods

Appropriate infrastructure to handle both

Bottom line: Complexity Prohibits Recycling

Where else are Dow adhesives used in food applications?

Here are just a few examples:

- Candy wrappers
- Chocolate packaging
- Condiment bottle seals
- Frozen dinners
- Granola bar wrappers
- Ice cream cartons
- Juice cartons
- Milk cartons
- Tuna fish pouches



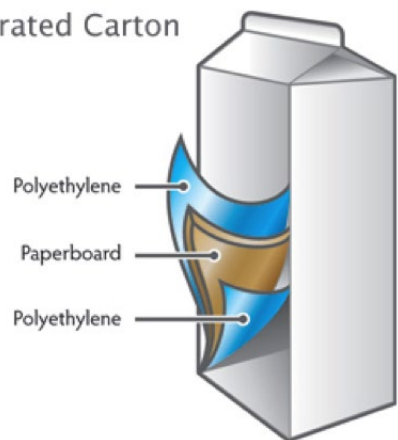
oily, the inner shiny layer— which is usually a metalized film layer — is impermeable. The oil doesn't soak through to the outside of the bag (as it would with a plain paper bag, for instance). The inside of the outer layer — or printing layer — allows brand



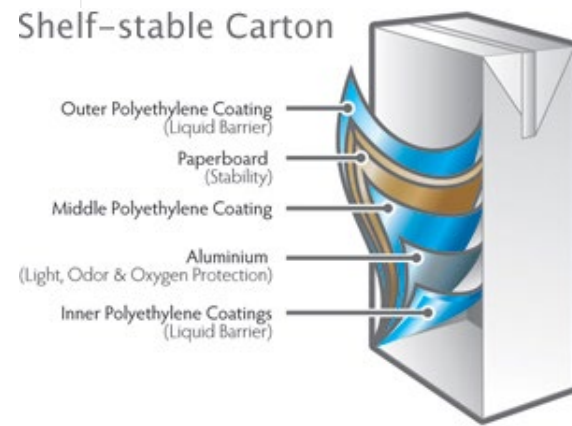
One example:

More than 1 million sari sari stores in Philippines selling sachets

Refrigerated Carton



Shelf-stable Carton



Eco-cycle and Woods End Laboratories, 2011

“Branded Beach” Freedom Island, Philippines (**Brand Audit**)



Nestle, Unilever, P&G, Colgate Palmolive, Monde Nissen, Mayora

Why not compostable packaging?



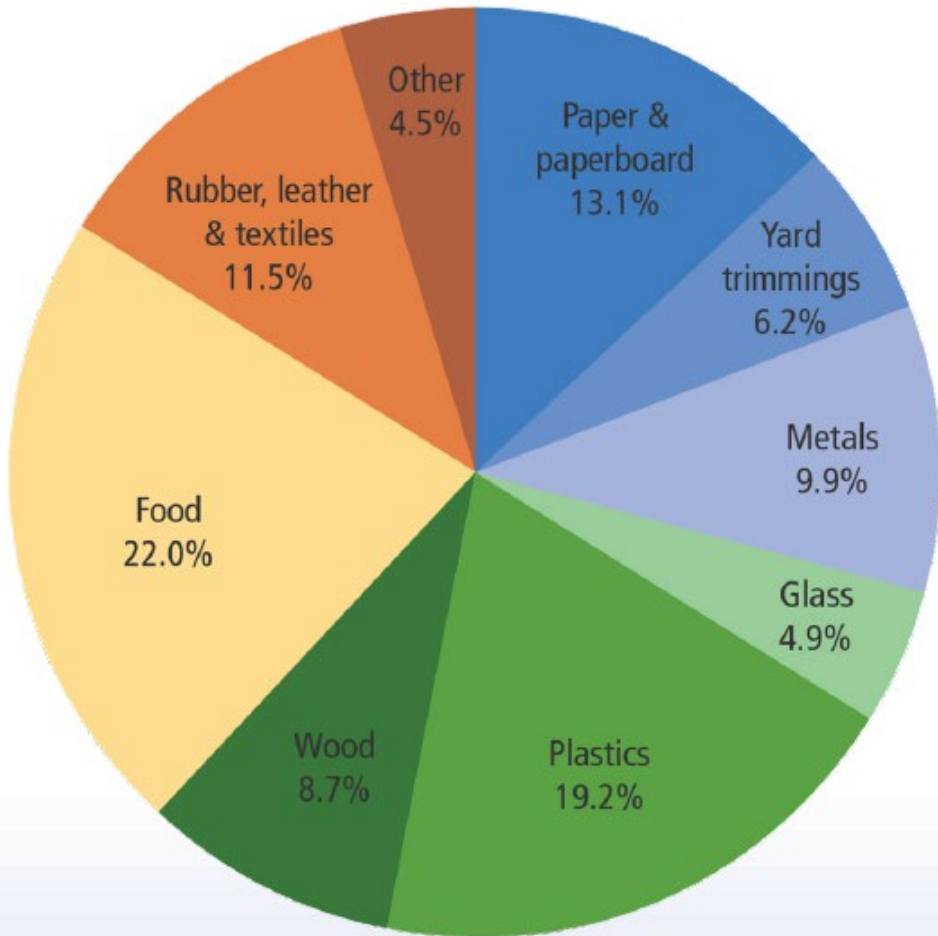
COMPOST: Impacts More Than You Think

Composting is the aerobic decomposition of organic materials by microorganisms. It transforms raw materials—such as leaves, grass clippings, garden trimmings, food scraps, animal manure, and agricultural residues—into compost, a valuable earthy-smelling soil conditioner, teeming with life.

One Person's Trash is...

...another's black gold.

Figure 8. Total MSW Landfilled (by material), 2017
139.6 Million Tons



US EPA Fact Sheet, 2017 numbers

50% of this garbage sent to landfill could be composted

22% food scraps alone

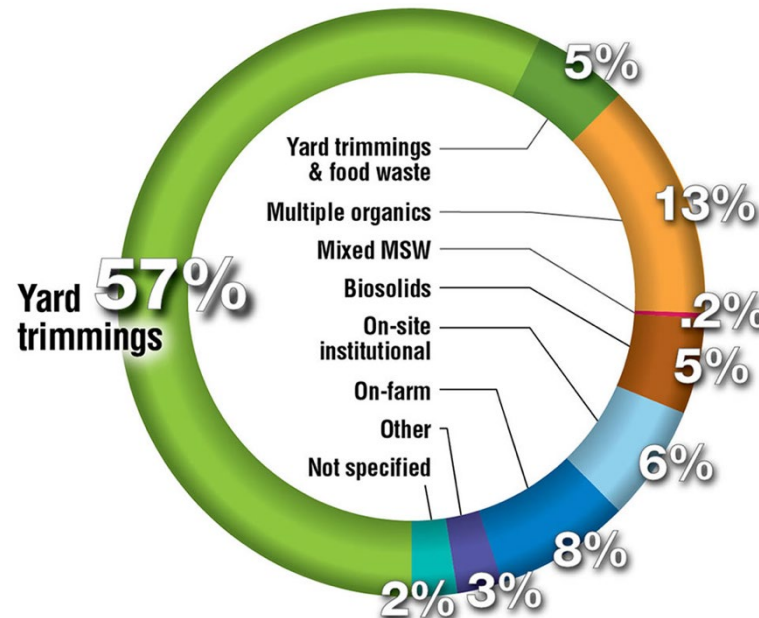
8.7% wood waste

6.2% yard trimmings

13.1% paper/paperboard

**Total
composting facilities**
4,713

Composting facilities by type



Colorado
33 facilities
15 of which are
“on farm” or
institutional

Biocycle “State of Organics”

When added to soil, compost can filter out urban stormwater pollutants by an astounding **60-95%**



IT'S ALL ABOUT THE SOIL

COMPOST improves biological, chemical, and physical characteristics of soil.

Protects against soil desertification and soil erosion

Enhances plant disease suppression

Increases resilience to floods and droughts

Increases soil fertility

Reduces need for chemicals

Converts nitrogen into a more stable and less mobile form and phosphorous into a less soluble form

Increases microbial activity

Improves water retention

Improves soil structure

Improves ability to store nutrients (such as cation exchange capacity)

Adds humus, keeping soil particles stuck together

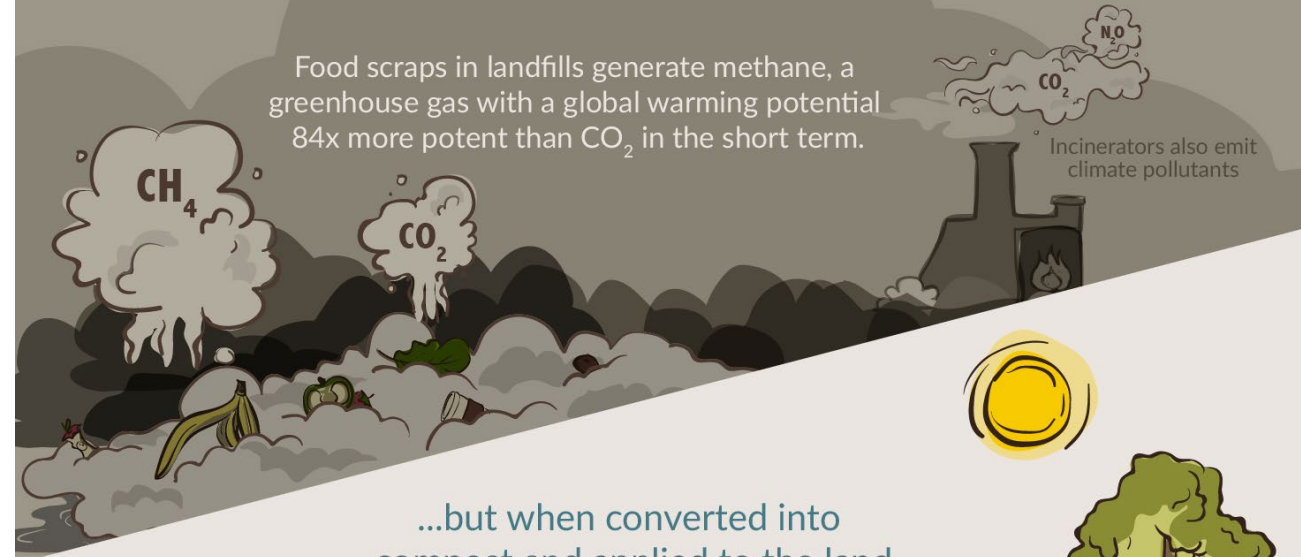
Compost serves as a filter and sponge. It immobilizes and degrades pollutants, improving water quality.

Compost helps reduce stormwater runoff because it can hold **~5x its weight** in water.

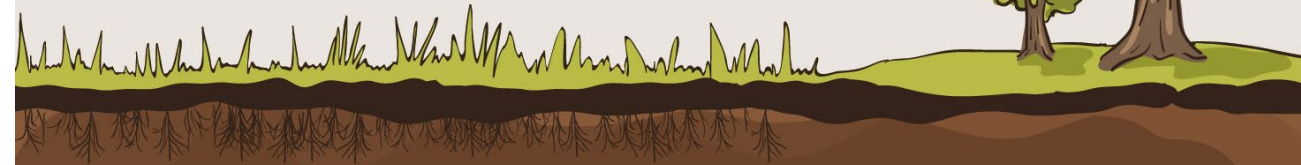
Composting Protects the Climate

Food scraps in landfills generate methane, a greenhouse gas with a global warming potential 84x more potent than CO₂ in the short term.

Incinerators also emit climate pollutants



...but when converted into compost and applied to the land, compost sequesters carbon.



One research project found that ½ inch of compost applied to rangeland sequestered the equivalent of **1 metric ton of CO₂e/hectare over three years.**

This level of sequestration on half of California's rangeland would offset **42 million metric tons of CO₂e**, which is equal to the annual greenhouse emissions from California's commercial and residential energy sectors.



A Message from Composters Serving Oregon:

Why We Don't Want Compostable Packaging and Serviceware

1. It does not always compost
2. It introduces contamination
3. It hurts re-sale quality
4. The composters cannot sell to organic farmers
5. It may impact human and environmental health
6. It increases compost operators' costs and makes our jobs harder
7. Just because something can be composted does not mean that is necessarily better for the environment
8. In some cases, the benefits of recycling surpass those of composting
9. Good intentions are not being realized

Questions to address the disconnect:

How do we bring certifications and testing closer to reality?

What about multilayer packaging?

How do we design packaging to compost faster?

What (if any) new standards need to be created?

How do we account for climate/regional variations?

What organisms/thermophiles accelerate degradation?

How can science guide policy?

END-OF-LIFE CRITERIA FOR Biobased, Biodegradable, & Compostable Plastics

- Sourcing of microbial communities
- Screening Candidate Materials



Characteristics of raw activated sludge inoculum

Total solids (g L ⁻¹)	959±19
Volatile solids (g L ⁻¹)	753±15
MLSS ^a (g L ⁻¹)	800±15
MLVSS ^a (g L ⁻¹)	687±15
pH	6.11

Minerals (ppm)

Aluminum (Al)	46.4
Boron (B)	0.819
Cadmium (Cd)	<0.1
Calcium (Ca)	166
Chromium (Cr)	0.249
Copper (Cu)	2.12
Iron (Fe)	131
Lead (Pb)	<0.04
Magnesium (Mg)	77.1
Manganese (Mn)	6.87
Molybdenum (Mo)	<0.1
Nickel (Ni)	0.301
Phosphorus (P)	332
Potassium (K)	125
Silicon (Si)	32.4
Sodium (Na)	54.4
Sulfur (S)	79.2
Zinc (Zn)	5

^a MLSS and MLVSS are Mixed liquor suspended solids and Mixed liquor volatile suspended solids, respectively.

Biodegradable Testing

Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials

ASTM D6691: In the Marine Environment by Natural Sea Water Inoculum

ASTM D5271: In Municipal Sewage Sludge

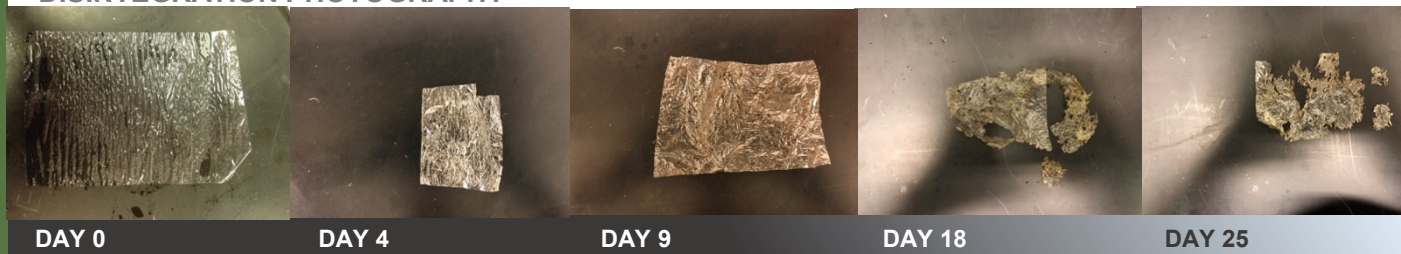
ASTM D5338: Under Controlled Composting Conditions

ASTM D5988: In Soil

RESPIROMETRY



DISINTEGRATION PHOTOGRAPHY



12
Chambers

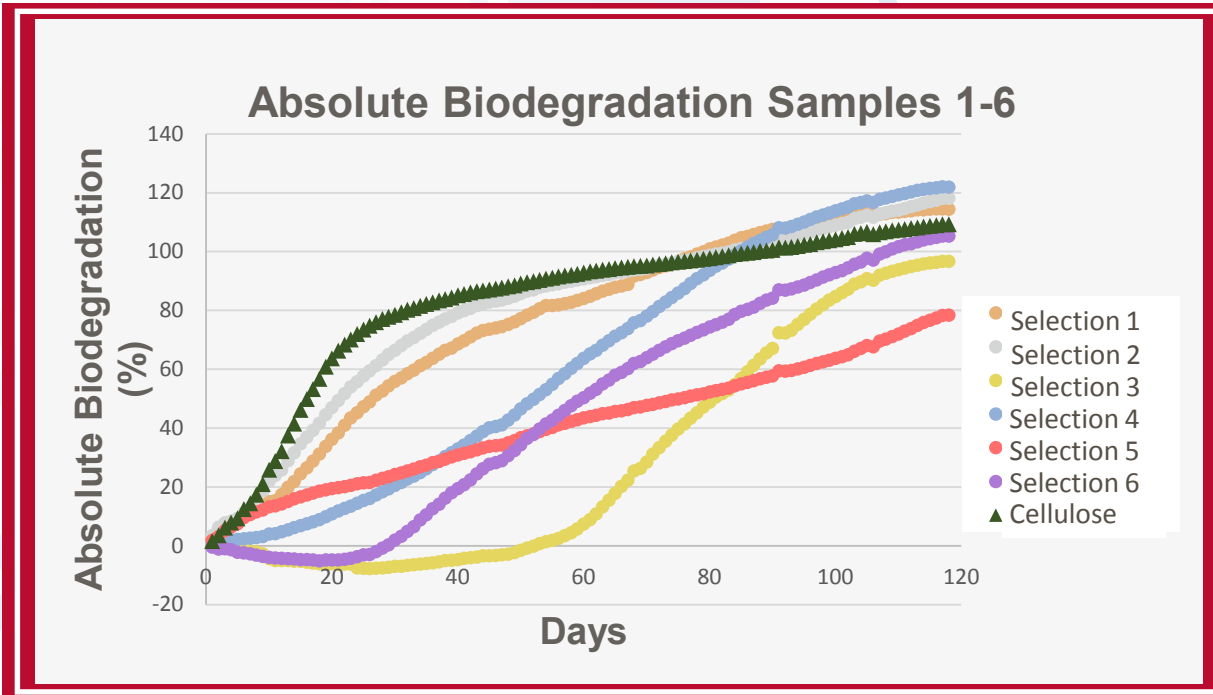
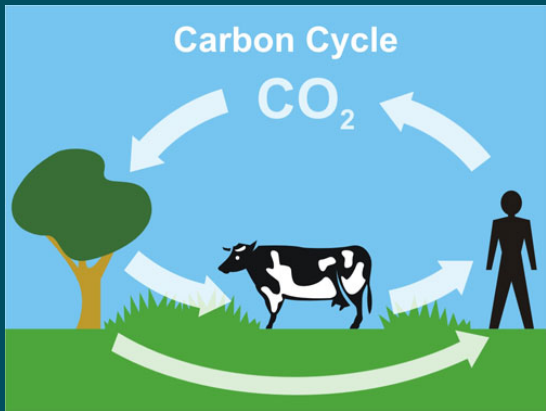
Another 60
chambers Feb
2020



Multiple incubators allows for testing at different temperatures industrial, "home", soil, marine, wastewater, freshwater

Compostable Flexible Packaging

Multilayer films are complex and not easily recycled



Realize Carbon Recycling

For packaging that is too lightweight and too complex to recycle, we can engage the carbon cycle to naturally recycle carbon back to ecosystems and protect our wildlife.

Everyone is involved: Raw material suppliers, compounders, converters, form/fill/seal, brands



SELECTION	LAYERS
1	FILM A
2	FILM B
3	FILM C
4	FILM D
5	FILM E
6	FILM F
7	FILM C GLUE A FILM A
8	FILM D GLUE A FILM A
9	FILM E GLUE A FILM A
10	FILM F GLUE A FILM A

Disintegration Particle Analysis

Disintegration varies from site to site

Disintegration

Examine materials according to ISO 20200

5 – 20 grams of test samples per 1000 grams of synthetic compost


Less than 10% of the original sample mass may remain from the particles collected

Understand the nature of chemical transformations as plastics are microbially degraded



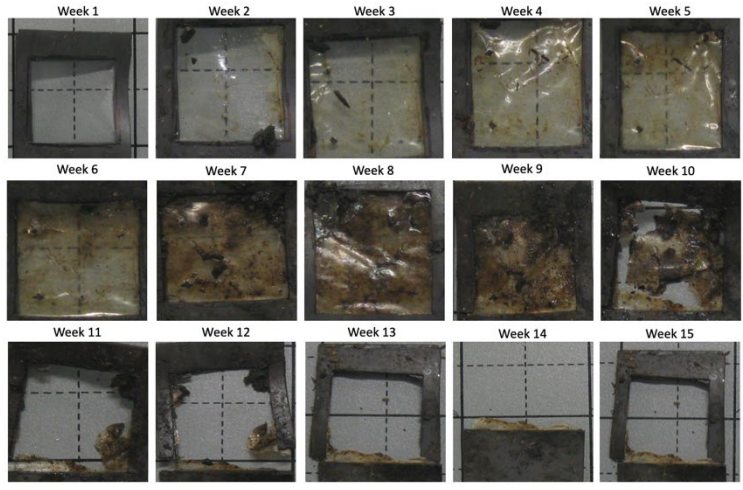
AFM-IR

Probe the nanoscopic organization of mixed materials



Raman Microscopy

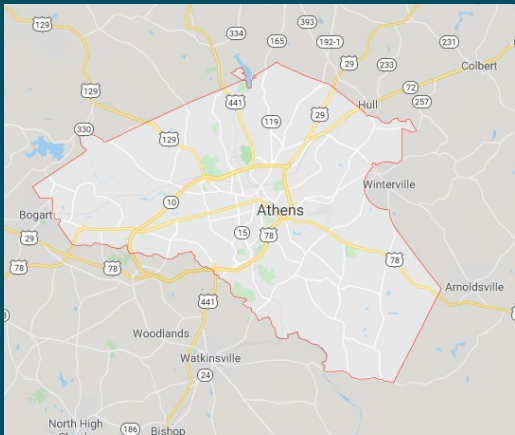
Automated particle imaging coupled with Raman spectroscopy for high throughput screening of complex particle blends



Week 1	Week 2	Week 3	Week 4	Week 5
Week 6	Week 7	Week 8	Week 9	Week 10
Week 11	Week 12	Week 13	Week 14	Week 15

Local Partners

Engaging local businesses and infrastructure in Athens



letuscompost.com



Let Us Compost

Let Us Compost has been starving landfills, sharing compost culture and creating soil since 2012. To date, LUC has composted 5,000,000 lbs of food scrap that would have gone to landfill.

- 324,723** Athens residents
- 300** residential curbside clients
- 40** businesses for curb side pick up
- 4** full time positions



Distant Partners

Engaging
communities abroad

NMI Center for Circular
Materials Management
Jambeck Research Group



Identify solution proactively
and technically