

The Growth and Shrinking of the Global Plastics Problem

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Sea Education Association
Woods Hole, MA, USA



ANSI-NSP
11 September 2024

Outline

- I. The environmental context
- II. Experimental data on nanoplastics generation
- III. What do we most need to know about nanoplastics?



Ocean plastics in the 1980s



foxhollowcottage.com



rachel syme 
@rachsyme

whoever did the pr in the 90s about cutting open plastic six pack rings so they don't choke animals did an amazing job and they should find that person and put them in charge of the wear a mask campaign

7:29 PM · 27 Jun 20 · [Twitter for iPhone](#)





Plastic in the North Atlantic

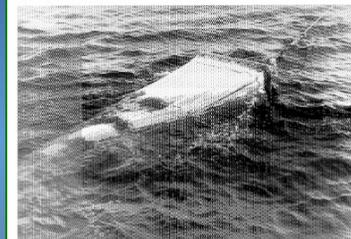
"I just want to say one word to you—just one word."
 "Yes sir."
 "Are you listening?"
 "Yes sir, I am."
 "Plastics."
 "Exactly how do you mean?"
 "There's a great future in plastics. . ."

Mr. McGuire to Ben
The Graduate, 1969



R/V Westward

by R. Jude Wilber



Neuston Net

Epifauna, such as *Membranipora* (a bryozoan—a small group of colonial encrusting animals) and *Lepas* (a barnacle), may use plastic as an "alternative substrate." These animals are commonly found on organic flotsam, such as wood and *Sargassum*. The use of plastic as a substrate by such organisms is at present a noticeable, though relatively rare, phenomenon in the open ocean.

It is virtually impossible to tow a neuston* net through the surface waters of the Sargasso Sea and not catch plastic debris of some sort.

One of the most common items so sampled are small (1 to 5 millimeters) polyethelene pellets known as "nibs" to the plastics industry. Typical beaches in places such as Bermuda, the Bahamas, the Florida Keys, and Cape Cod may contain millions of such pellets mixed with other plastic debris and natural organic flotsam in the upper wrack lines.**

This picture of the current status of plastic in the Atlantic has emerged during the last three years in part from studies conducted by the scientists and students of the Sea Education Association, Woods Hole, Massachusetts, aboard the research vessel *Westward*. In 1984, we began a survey of plastic pollution along *Westward's* routes of operation in the open ocean and along the shorelines of islands

The problem of plastic debris in the marine environment is cause for increasing concern today among the public at large. During the last 20 years, the North Atlantic and other oceans have been polluted with plastic debris through careless handling, accidental loss, and indifferent dumping. Although many of the biological effects of plastic in the ocean are unassessed, the negative effects of this debris on seals, birds, and sea turtles are well documented. Strangulation is often the result of seals and birds trapped in plastic netting. But, marine animals also ingest small plastic pellets. The damage done to certain marine communities from this activity may be serious, although the proof of this awaits further study.

Actually, there may be some positive aspects to the presence of floating plastic in the open ocean.

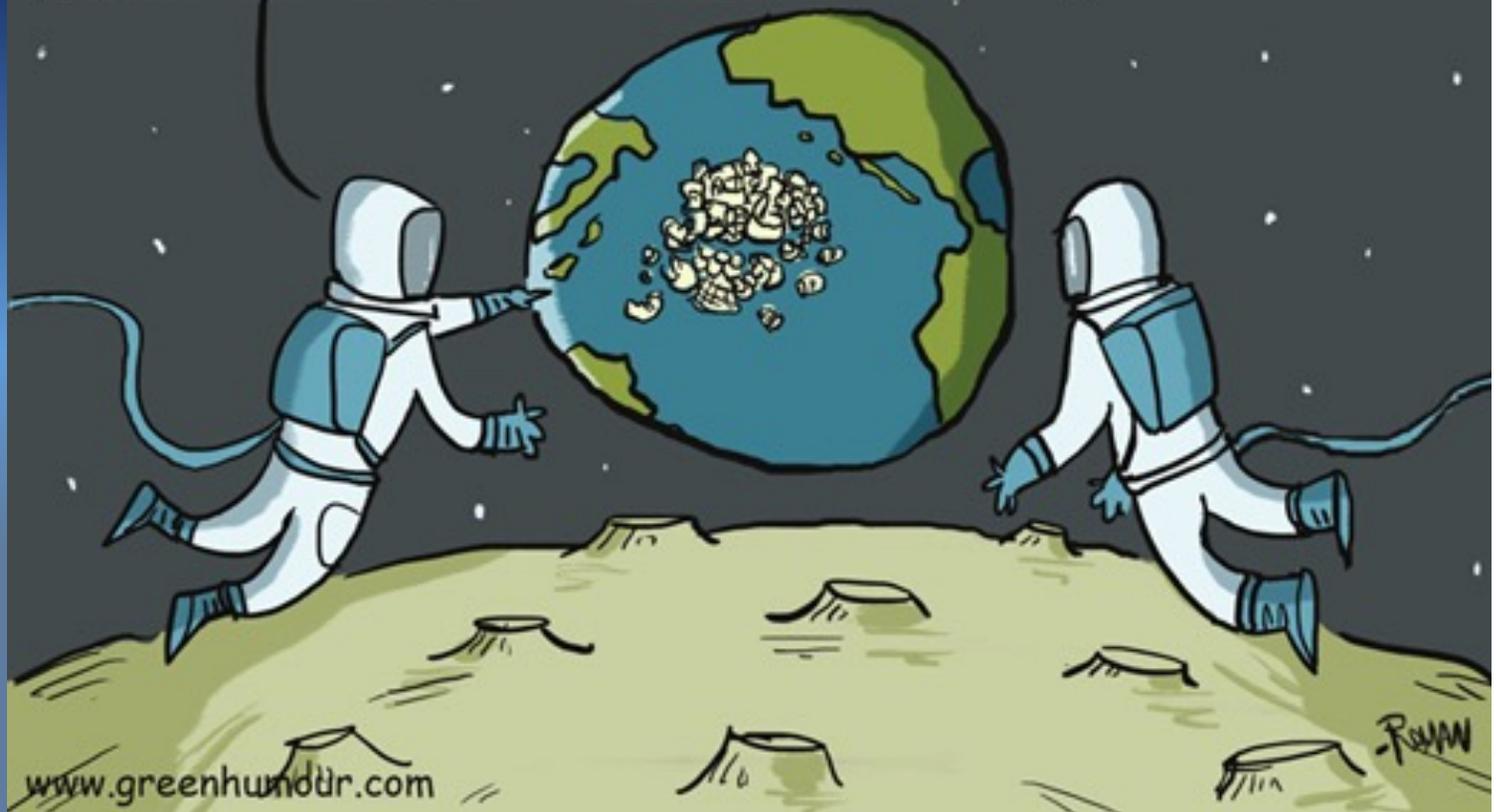
* Neuston refers to both the uppermost surface layer of a body of water as well as that group of organisms that occupy this environment. Neuston nets are designed to sample the air/water interface and down to 25 centimeters below it.

** Wrack refers to marine plant life that is cast up on shores through the action of waves and tides. The uppermost wrack lines are those lines of debris deposited by very high tides and/or storm waves.

“Garbage Patch”

Fact or Fiction?

THE GREAT BARRIER REEF ISN'T VISIBLE FROM SPACE ANYMORE , BUT HEY, THE GREAT PACIFIC GARBAGE PATCH IS!



www.greenhundredr.com

NATURAL HISTORY NEW! MUSEUM GUIDE ARCHIVES FACTOTUM—THE NH BLOG

FEATURED STORY
November 2013

Trashed

Across the Pacific Ocean, plastics, plastics, everywhere.
By Charles Moore



I was on my way home, after finishing the Los Angeles-to-Hawaii sail race known as the Transpac, that my crew and I first caught sight of the trash floating in one of the most remote regions of all the oceans. I had entered my cutter-rigged research vessel, Algalia, an aluminum-hulled catamaran, in the race to test a new mast. Although Algalia was built for research training, she was also a compact sailor, and she fit into the “racing class” of boats that regularly enter the race. We did well, hitting a fair wind of twenty knots under sail and winning a trophy for finishing in third place.

Throughout the race our strategy, like that of every other boat in the race, had been merely to avoid the North Pacific subtropical gyre—the great high-pressure system in the central Pacific Ocean that, most of the time, is centered just north of the Hawaiian and halfway between Hawaii and the mainland. But after our success with the race we were feeling invigorated and confident, and our vessel was equipped with auxiliary twin diesel and carried an extra supply of fuel. So on the way back to our home port in Long Beach, California, we decided to take a shortcut through the gyre, which few sailors ever cross. Fifteenmen stuck it because its report back the nutrients to support an abundant catch. Sailors dodge it because it backs the wind to prevent their sails.

Below caps and other plastic objects are visible from the dismounted remains of this larger debris on beach Algalia, which has no remote and virtually untraveled region of the North Pacific. The best priority research for oceanic trash and regional from aerial imaging.
Photo by Corbin Veenker



The actual view of the “garbage patch” from space

Photo taken August 5, 2021



Images courtesy of M. McArthur and NASA





Microplastics

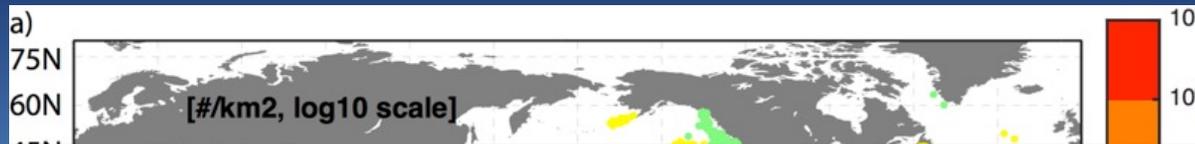


How big is the problem?

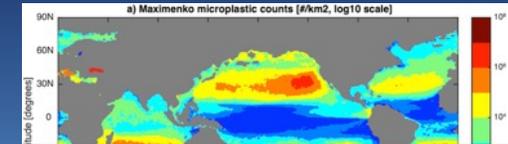


How much plastic is floating in the ocean?

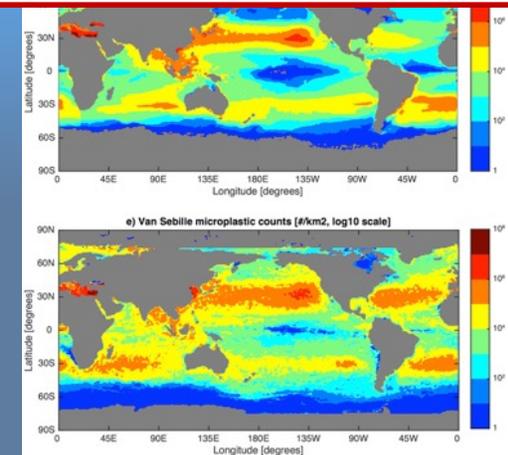
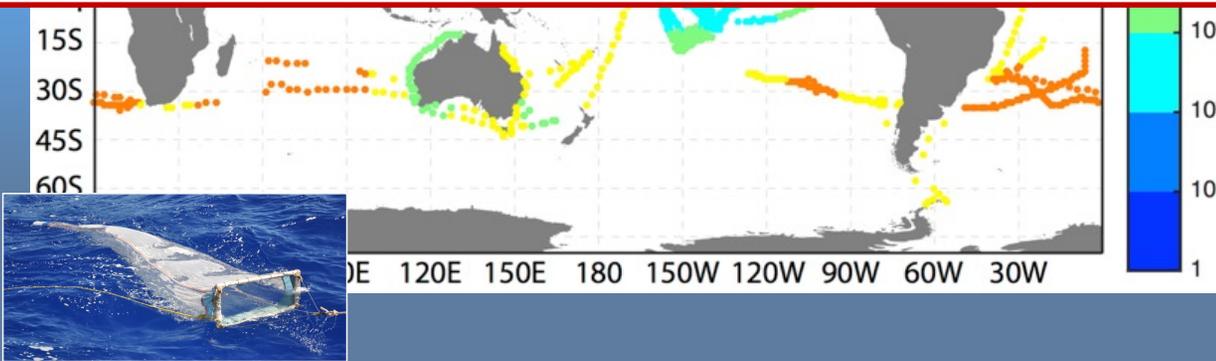
Plankton net data:



Numerical models:



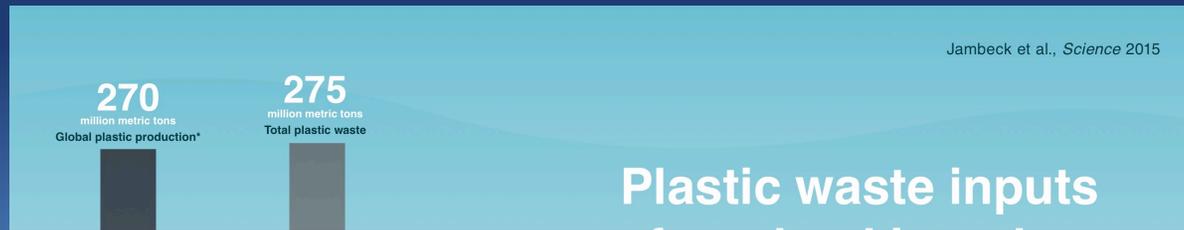
93,000 – 236,000 metric tons



Van Sebille, E., C. Wilcox, L. Lebreton, N. Maximenko, B.D. Hardesty, J.A. van Franeker, M. Eriksen, D. Siegel, F. Galgani, K.L. Law, 2015. A global inventory of small floating plastic debris. *Environ. Res. Lett.* **10**, 124006.



Estimating one source: Plastic waste entering the ocean from land



8 million metric tons in 2010



Dan Janisse/Windsor Star



Jambeck, J.R., R. Geyer, C. Wilcox, T.R. Siegler, M. Perryman, A. Andrady, R. Narayan, K.L. Law, 2015. Plastic waste inputs from land into the ocean. *Science* **347**, 768-771.

How much plastic waste enters the environment?

Article

A local-to-global emissions inventory of macroplastic pollution

57 million metric tons per year

Accepted: 26 June 2024

Published online: 4 September 2024

Open access

 Check for updates

Negotiations for a global treaty on plastic pollution¹ will shape future policies on plastics production, use and waste management. Its parties will benefit from a high-resolution baseline of waste flows and plastic emission sources to enable identification of pollution hotspots and their causes². Nationally aggregated waste management data can be distributed to smaller scales to identify generalized point of plastic accumulation and source phenomena^{3–11}. However, it is challenging to use this type of spatial allocation to assess the conditions under which emissions take place^{12,13}. Here we develop a global macroplastic pollution emissions inventory by combining conceptual modelling of emission mechanisms with measurable activity data. We define emissions as materials that have moved from the managed or mismanaged system (controlled or contained state) to the unmanaged system (uncontrolled or uncontained state—the environment). Using machine learning and probabilistic material flow analysis, we identify emission hotspots across 50,702



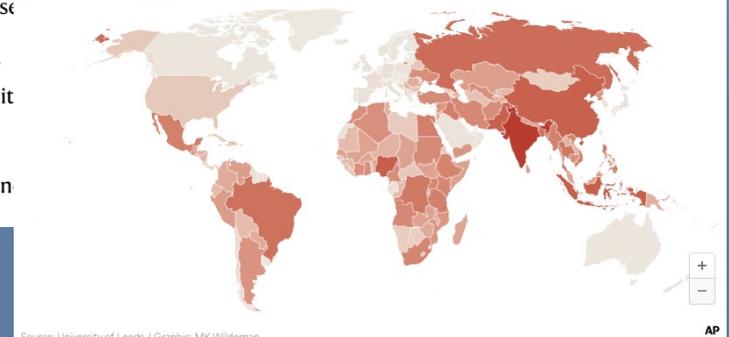
Dan Janisse/Windsor Star

Global plastic pollution reaches 57 million tons annually

India is the world's biggest plastics polluter, according to a study in the journal Nature.

Tons of plastic waste

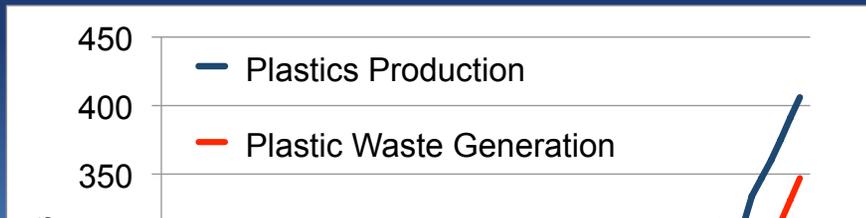
2.2 10.2M



Source: University of Leeds / Graphic: MKWildeman

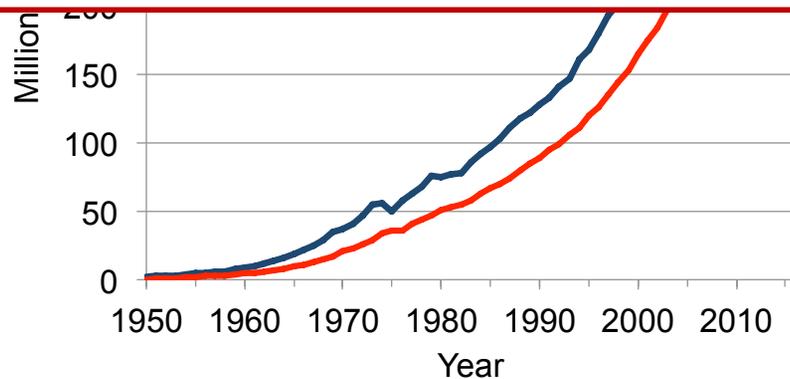
AP

How much plastic exists on the planet?



➤ 8.3 B metric tons produced

7.5 BILLION metric tons



➤ 90% are still in existence

The “Plastics Problem” in 2024



Feb. 2022

Historic day in the campaign to beat plastic pollution ›

Heads of State, Ministers of environment and other representatives from UN Member States endorsed a historic resolution at the UN Environment Assembly (UNEA-5) in Nairobi.

Intergovernmental negotiating committee (INC) on plastic pollution

Intergovernmental negotiating committee (INC) to develop an international legally binding instrument on plastic pollution, including in the marine environment.

In February 2022, at the resumed fifth session of the United Nations Environment Assembly (UNEA-5.2), a historic resolution (5/14) was adopted to develop an international legally binding instrument on plastic pollution, including in the marine environment with the ambition to complete the negotiations by end of 2024.

The instrument is to be based on a comprehensive approach that addresses the full life cycle of plastic. The INC will consider how to promote sustainable production and consumption of plastics from product design to environmentally sound waste management through resource efficiency and circular economy approaches.

Intergovernmental Negotiating Committee - Second session

Intergovernmental Negotiating Committee - first session

Ad hoc open-ended working group

Secretariat

Bureau

National Focal Points Directory

INC-1: 28 Nov – 2 Dec, 2022
Punta del Este, Uruguay

INC-2: 29 May – 2 Jun, 2023
Paris, France

INC-3: 13 – 19 November 2023
Nairobi, Kenya

INC-4: 23 – 29 April 2024
Ottawa, Canada

INC-5:
25 Nov – 1 Dec, 2024
Busan, Rep. of Korea

<https://www.unep.org/about-un-environment/inc-plastic-pollution>

Microplastics: abundant & widespread

Beaches



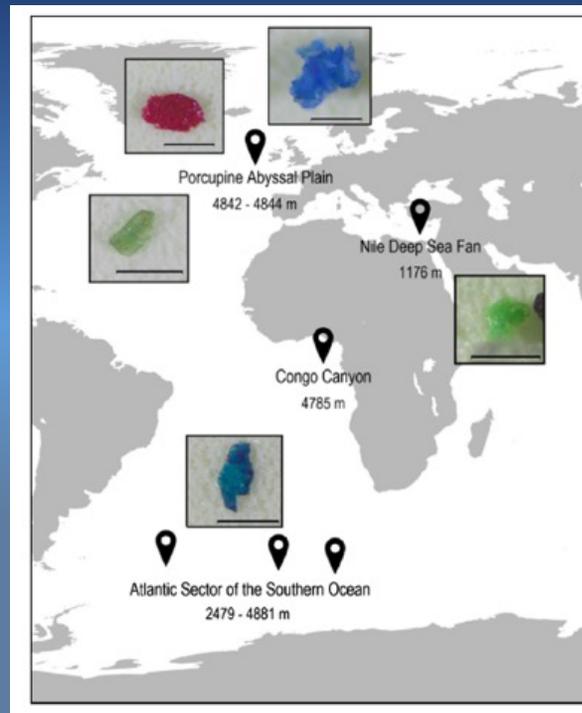
Nicholas Mallos/Ocean Conservancy

Water column



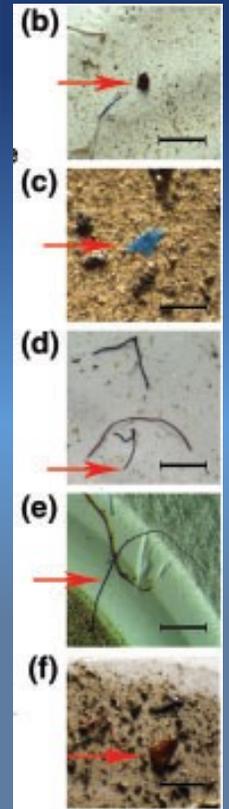
Giora Proskurowski/SEA

Deep-sea sediments



Van Cauwenberghe *et al.*, 2013

Arctic sea ice



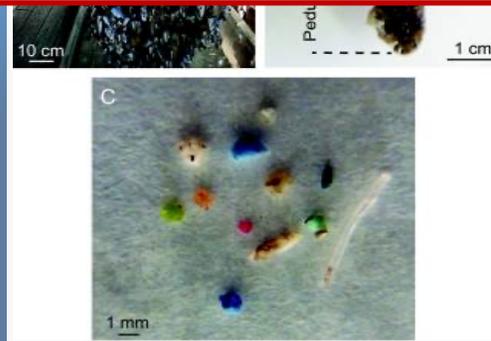
Obbard *et al.*, 2014

What are the impacts of microplastics?



Plastic ingestion reported for > 1,200 marine species

Santos *et al.* *Science* 2021



Goldstein & Goodwin, 2013

Elise Virginia Pullen
Coastal Carolina University



Sharks in Brazil test positive for cocaine, say scientists

By Jack Guy, CNN
© 3 minute read · Published 12:06 PM EDT, Tue July 23, 2024

Nanoplastics: the next frontier

Chapter 12

In: *Marine Anthropogenic Litter* 2015

Nanop
Critica

Environmental Science: Nano

Environ. Sci: Nano 2016

COMM

ENVIRONMENTAL
Sci

ES&T 2017

Article

Albert A. J

Nanop

ENVIRONMENTAL
Science & Technology

ES&T 2021

SCIENCE ADVANCES | RESEARCH ARTICLE

Sci. Adv. 2024

Alexandra
Laurent B

Mi
Ch
Ra
Duš
Erik

APPLIED :
Direct
ocean

comment

Nat. Nanotechnol. 2019

Seunghyun
Wei Xu^{2*}, T

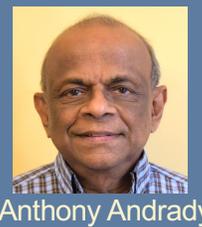
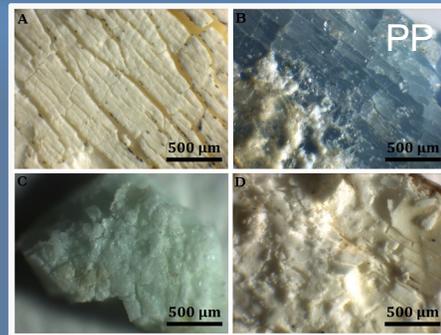
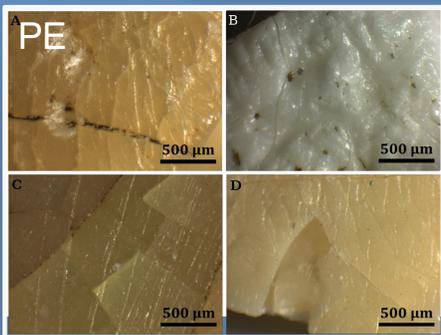
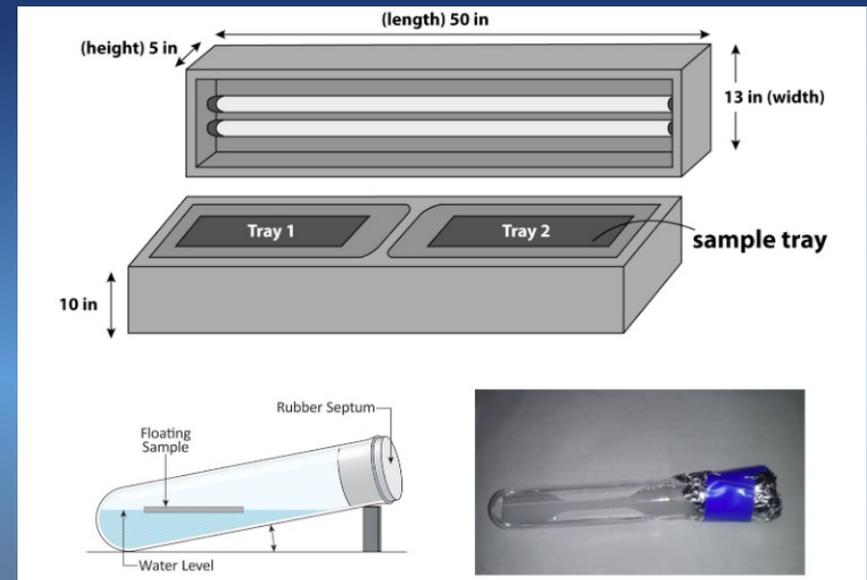
Things we know and don't know about nanoplastic in the environment

Fragments of plastic smaller than 1 μm have raised concerns about the potential risks they pose to the environment. Research will have to answer a number of questions to establish what the realistic risks are.

Stephan Wagner and Thorsten Reemtsma

Photochemical degradation and NP formation

Life history: past and future?

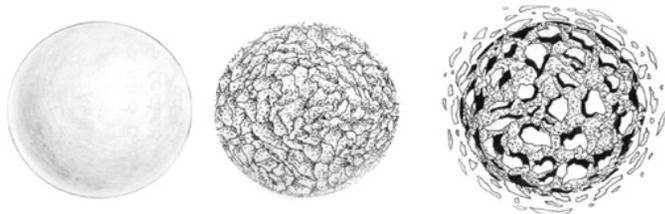


Anthony Andrady

Photochemical degradation and NP formation

Hypothesis:

Surface fragmentation



Andrady 2017

Lower NP counts in seawater exposures compared to air

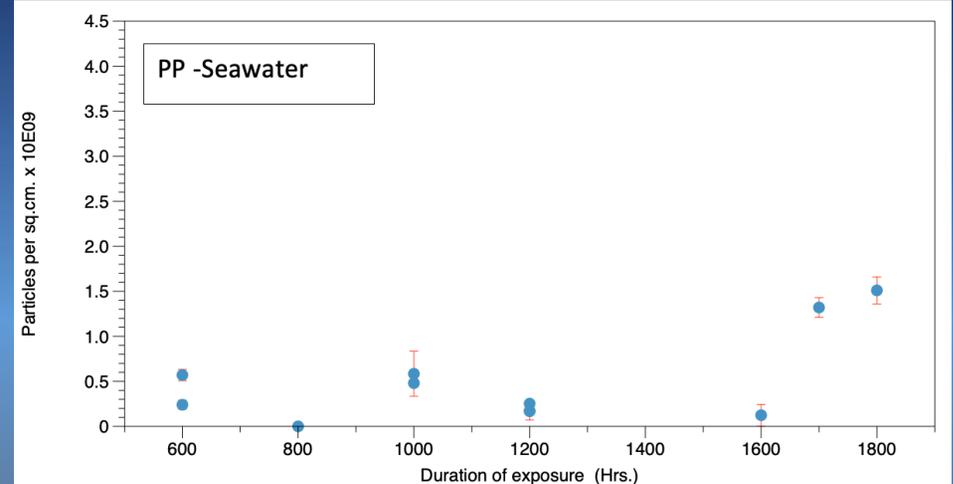
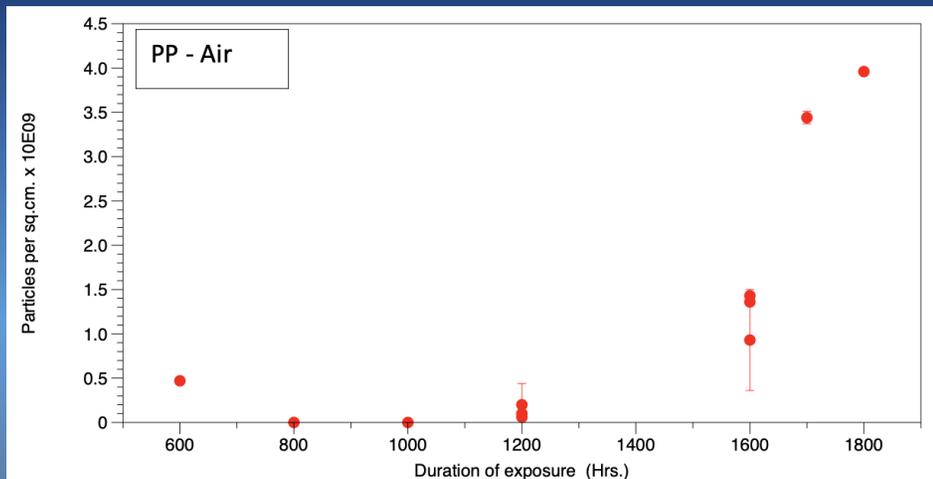
Experimental design:

- < 1 mm thick films: PE, PP, PS, PLA, ECO
- In quartz vials in air or synthetic seawater
- Four Q-lab UV 340 fluorescent lamps
- Up to 1800 hours exposure on light/dark cycle
- Sonication after exposure: 15 min
- Nanoparticle Tracking Analysis (NTA): < 2,000 nm
- 11 replicates/sample (#/unit area)

Collaboration with Tony Andrady

Photochemical degradation and NP formation

Polypropylene (PP)

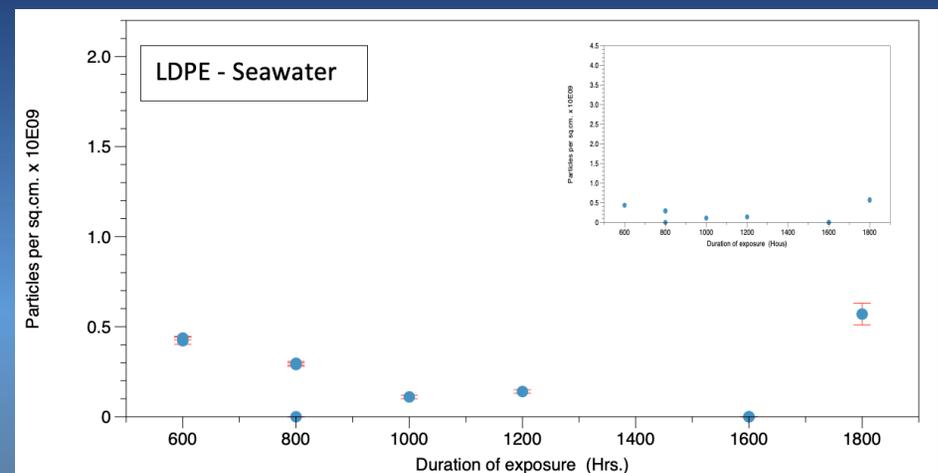
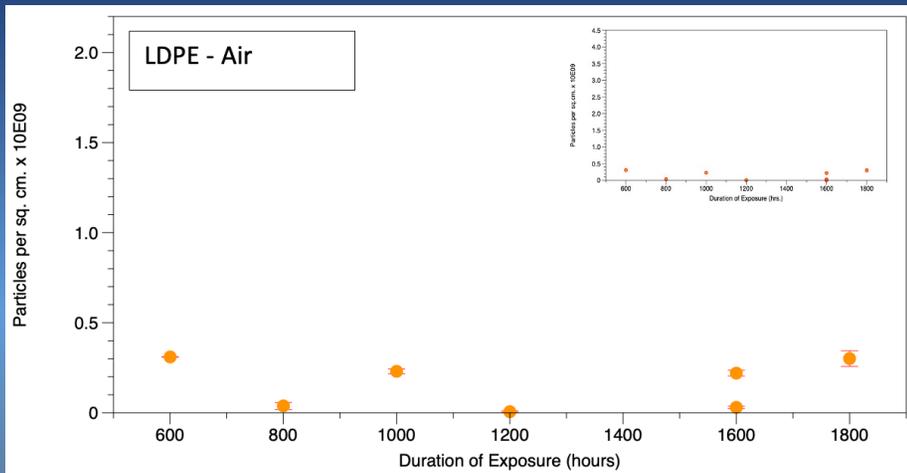


- Little NP generation up to 1600 hours exposure
- Higher NPs per sq. cm in air than in seawater at 1800 hrs
- Average particle size: 120-140 nm

Collaboration with Tony Andradý

Photochemical degradation and NP formation

Polyethylene (LDPE)



- Much lower NP generation than PP at all exposure times
- Average particle size: 114-150 nm

Collaboration with Tony Andradý

Photochemical dissolution

Dissolved Organic Carbon (DOC)



Romera-Castillo *et al.* 2018

Ward *et al.* 2019

Zhu *et al.* 2020

Driving questions in nanoplastics research

1. How are nanoplastics formed?

- understanding chemical degradation & fragmentation processes
- dependence upon environmental conditions



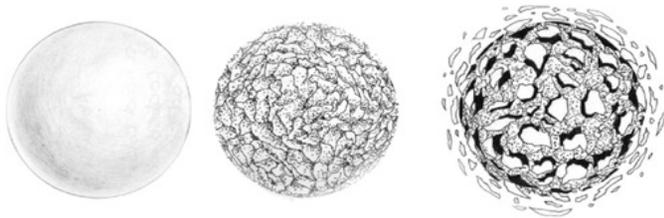
Driving questions in nanoplastics research

2. How does particle size evolve?

- Are fragmentation processes progressive & monotonic?

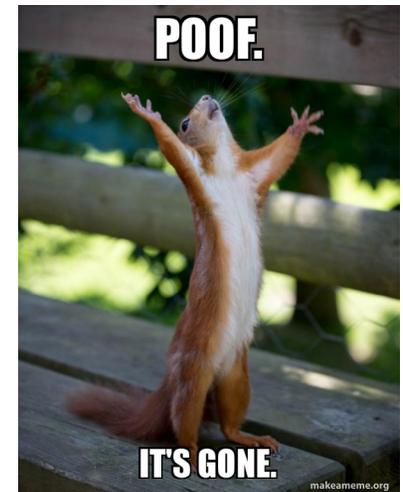
Macro- → Meso- → Micro- → Nano-

- Photodissolution: rate and products

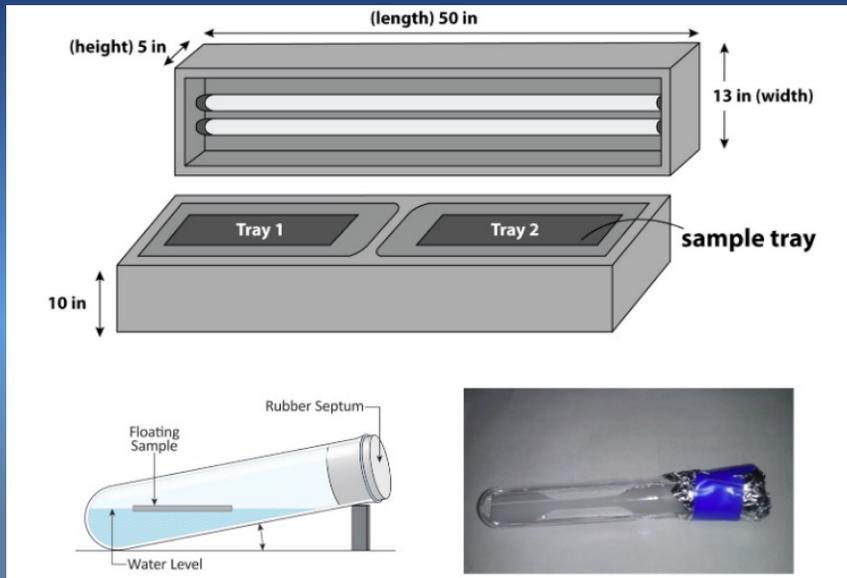


Driving questions in nanoplastics research

1. How are nanoplastics formed?
2. How does particle size evolve?
3. What is the time scale of mineralization?



Weathering and “Age” Laboratory ↔ Environmental

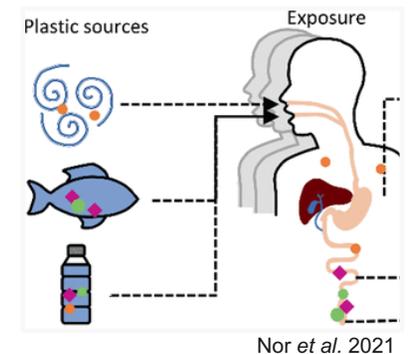


Mitimiti coast in Northland (NZ), Moerewa Point in the foreground (Credit: Raewyn Peart)

THE QUEST: A metric to quantify environmental age, lifetime

Driving questions in nanoplastics research

1. How are nanoplastics formed?
2. How does particle size evolve?
3. What is the time scale of mineralization?
4. What are the risks of NPs to organisms and to human health?



Contamination → Impact?



“Blonde Bomber”
The Marine Mammal Center, Sausalito, CA



The “Plastics Problem”



Driving questions in nanoplastics research

e) When is a plastic particle no longer a particle?



nature water



Article

<https://doi.org/10.1038/s44221-023-00191-5>

Oligomers are a major fraction of the submicrometre particles released during washing of polyester textiles

Received: 11 May 2023

Tong Yang^{1,4}, Yanghui Xu^{2,3}, Gang Liu² & Bernd Nowack¹✉

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> 10,000 SEA students

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Deb Goodwin

Skye Morét-Ferguson

Giora Proskurowski

Erik Zettler

Anthony Andrady

NC State University



NCEAS Marine Debris Working Group



SCOR FLOTSAM Working Group



2020-2021 U.S. NASEM Committee



Ocean Conservancy

March Marine Initiative

