Life on a nurdle

the microbial response to plastic vs bioplastic

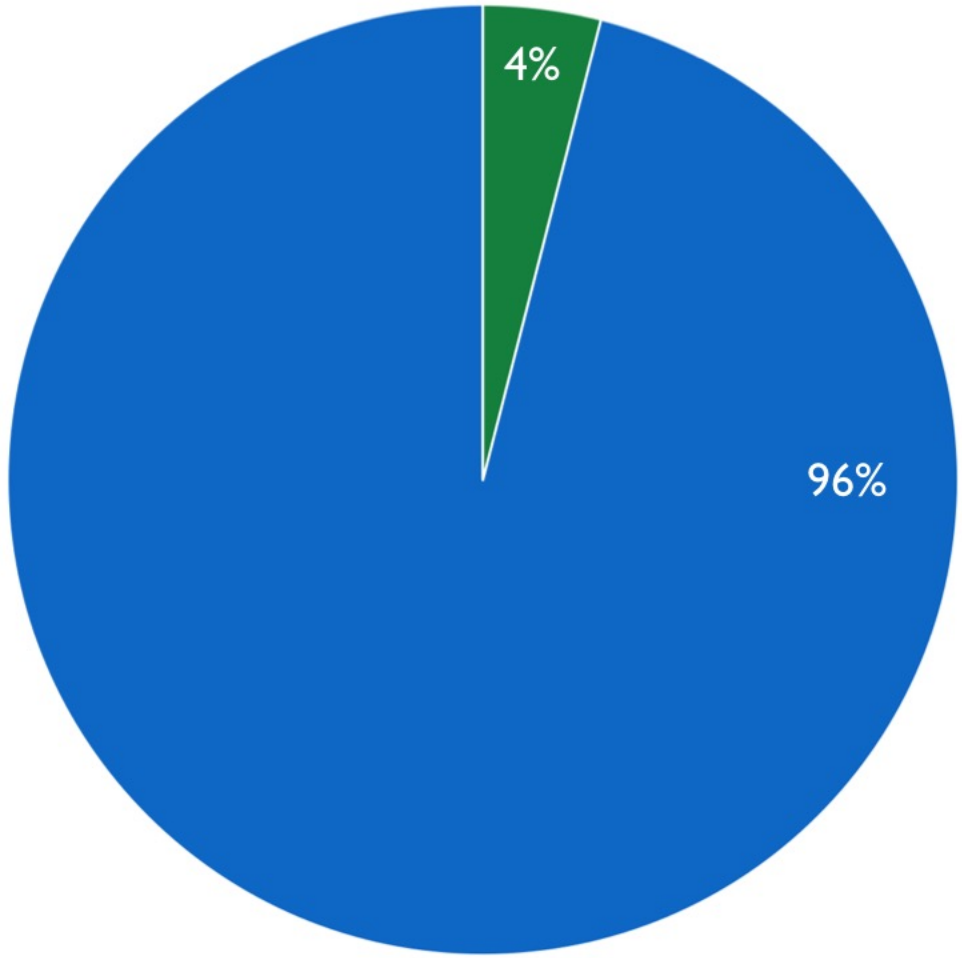
Lee J. Pinnell

PhD Candidate – Marine Biology

Texas Plastic Pollution Symposium
October 30, 2018

TEXAS A&M UNIVERSITY CORPUS CHRISTI | COLLEGE OF SCIENCE AND ENGINEERING

nurdle: small pellet of plastic that serves as raw material in the manufacturing of plastic products



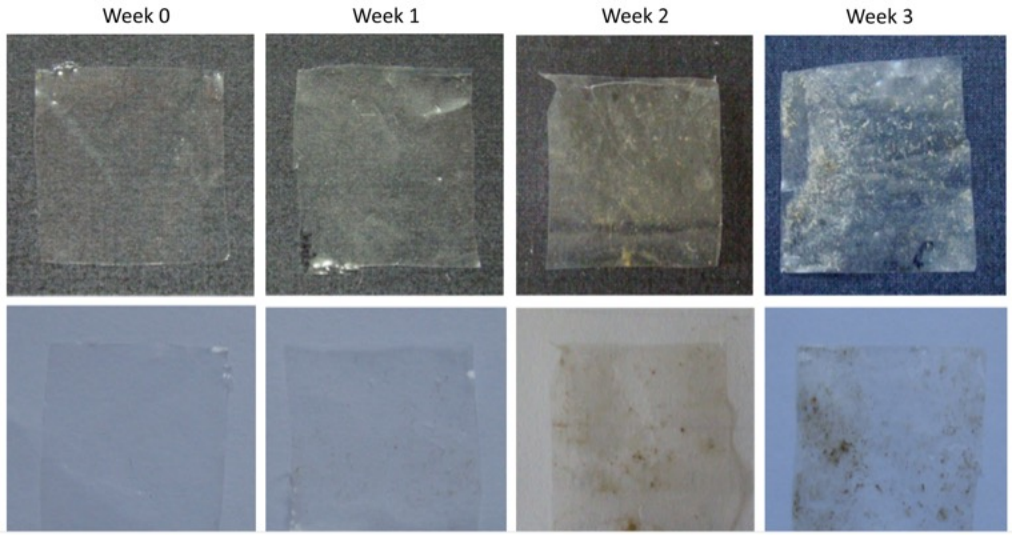
Plastic Manufacturing

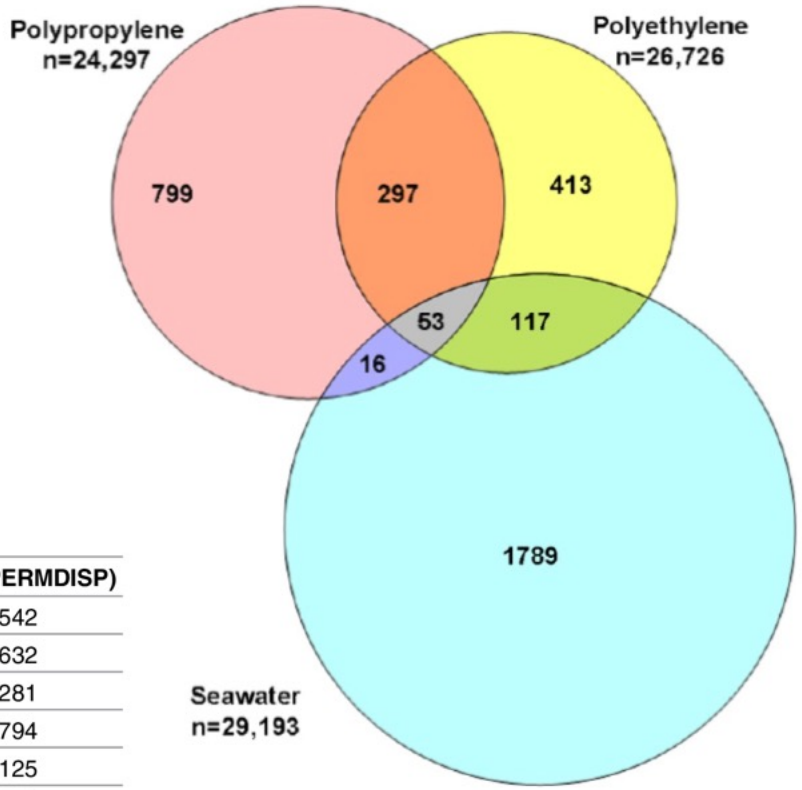
Bioplastic

- Designed to rapidly biodegrade
- Higher cost = low production

Petroleum-based

- Resistant to biodegradation
- cheaper





Zettler et al. 2015

Subset: Factors	marker	df	SS	Pseudo F	p(perm)	Unique perm	p(MC)	p(PERMDISP)
PET: Station	16S	2	10987	2.5436	**0.001** *	999	**0.004** *	0.542
	18S	2	10258	2.8614	**0.001** *	999	**0.001** *	0.632
PET: Season	16S	2	14855	3.7968	**0.001** *	997	**0.001** *	0.281
	18S	2	9542.3	2.5881	**0.002** *	999	**0.004** *	0.794
Summer: Treatment (PET-3-0.2)	16S	2	9435.2	3.0775	**0.003** *	991	**0.011** *	0.125
	18S	2	12006	3.4363	**0.001** *	905	**0.007** *	0.956
Spring: Treatment (PET-glass)	16S	1	3746.9	1.9241	0.058	980	0.057	0.841
	18S	1	1968.7	1.1056	0.29	905	0.344	0.894
Summer: Station (Warp-Gabbard-Dowsing)	16S	2	10097	3.4277	**0.003** *	994	**0.008** *	**0.005** *
	18S	2	9426.7	2.2778	**0.026** *	937	**0.042** *	0.38
Spring: Station (Warp-Gabbard-Dowsing)	16S	2	9373.4	2.7822	**0.002** *	997	**0.001** *	0.848
	18S	2	12674	6.111	**0.001** *	997	**0.002** *	0.573
Summer: “Attached” versus Free-living	16S	1	6692.7	4.0966	**0.003** *	843	**0.013** *	0.124
	18S	1	5358.4	2.3385	**0.025** *	416	0.084	**0.023** *

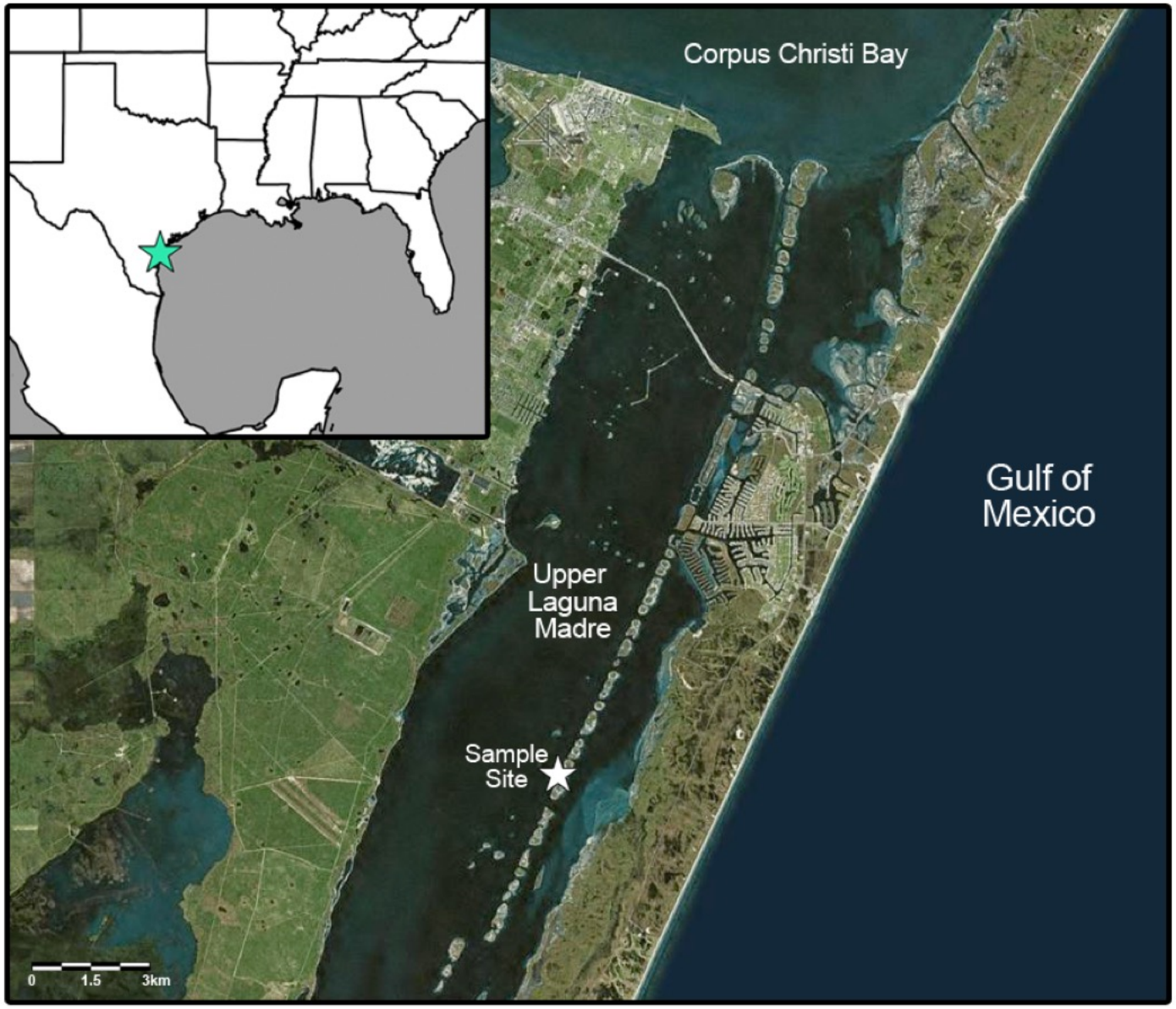
PERMANOVA main tests compare both bacterial/archaeal and eukaryotic (16S and 18S rRNA gene, respectively, denoted by ‘marker’) community structure across seasons, stations, and treatments. Tests are displayed for three data subsets (PET, spring, summer). Significant results ($p < 0.05$) highlighted in bold and marked with *. P-values were obtained using type III sums of squares and 999 permutations [‘p(perm)’] or calculating Monte-Carlo tests [‘p(MC)’]. Pseudo F, PERMANOVA F statistic; d.f., degrees of freedom; SS, sums of squares; Unique perm, unique permutations. p(PERMDISP) are p-values of PERMDISP tests, calculated to centroids.

doi:10.1371/journal.pone.0159289.t001

Oberbekmann et al. 2016

Experimental Design

Study Site


Corpus Christi Bay
Gulf of Mexico
Upper Laguna Madre
Sample Site
0
1.5
3km

PET

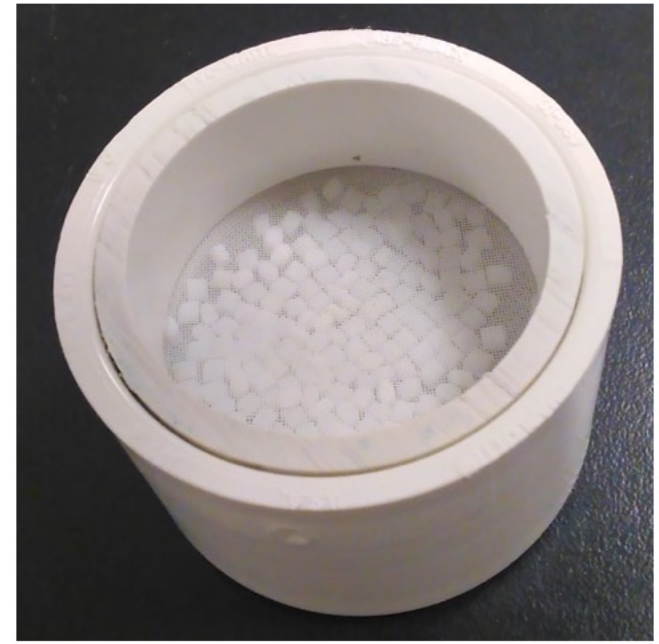
- Designed to resist degradation
- Mainly feedstock for plastic bottles & textile fibers
- 50 million tons produced (2013)

PHA

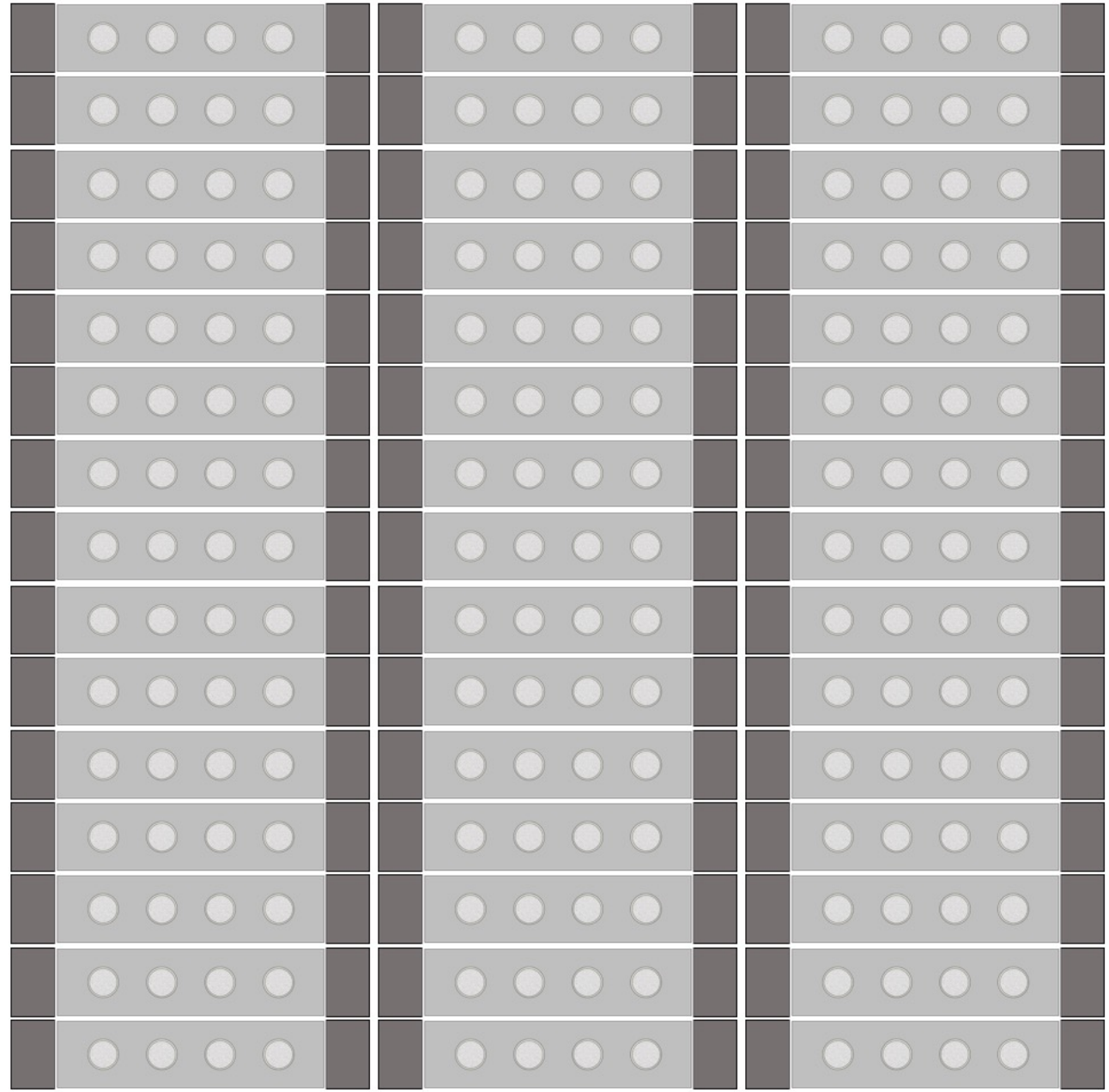
- Designed to rapidly biodegrade
- Synthesized by bacteria
- High cost = low production

~3g:

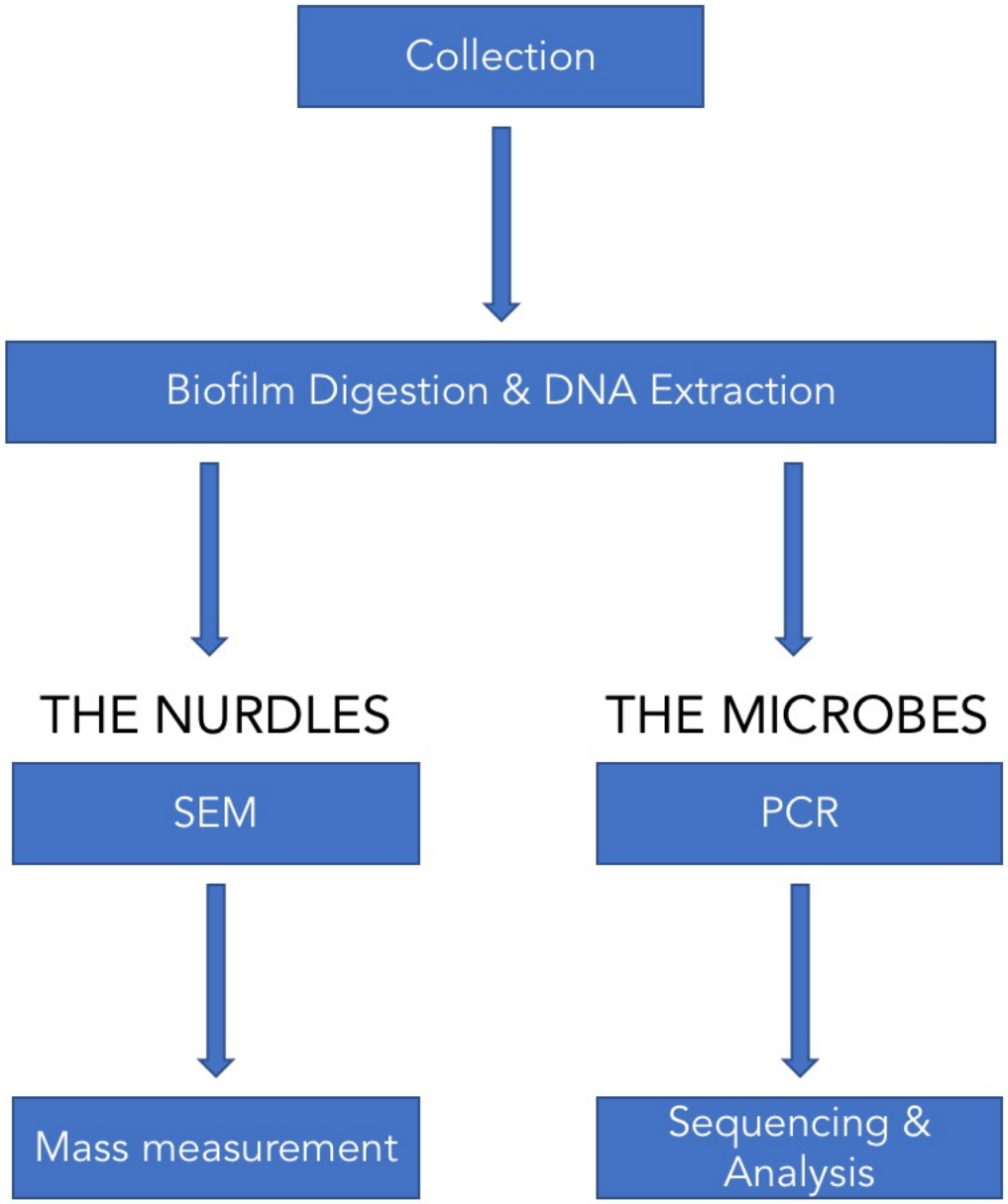
Sample Capsule



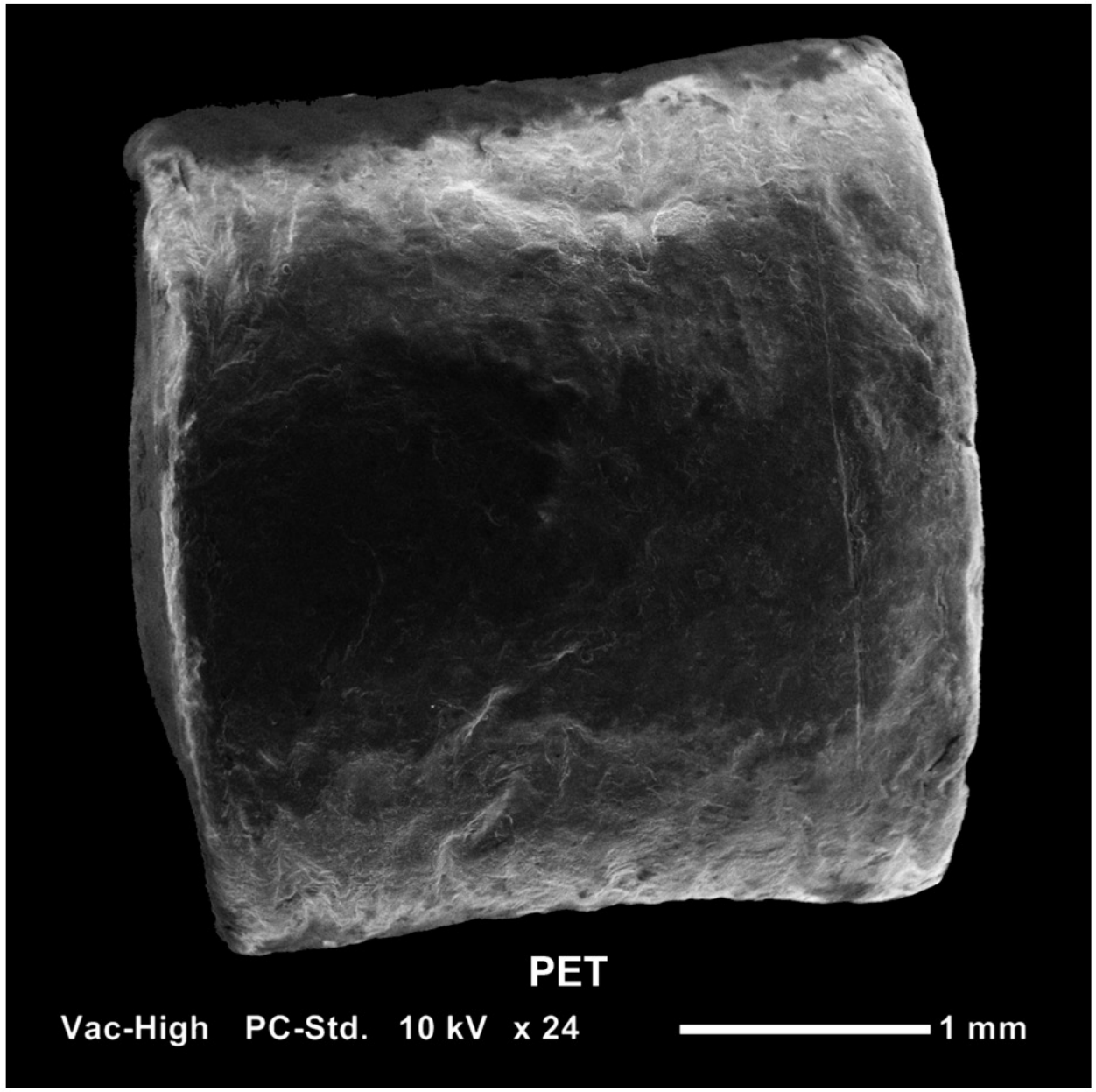
- Water-sediment interface
- 424 days total exposure

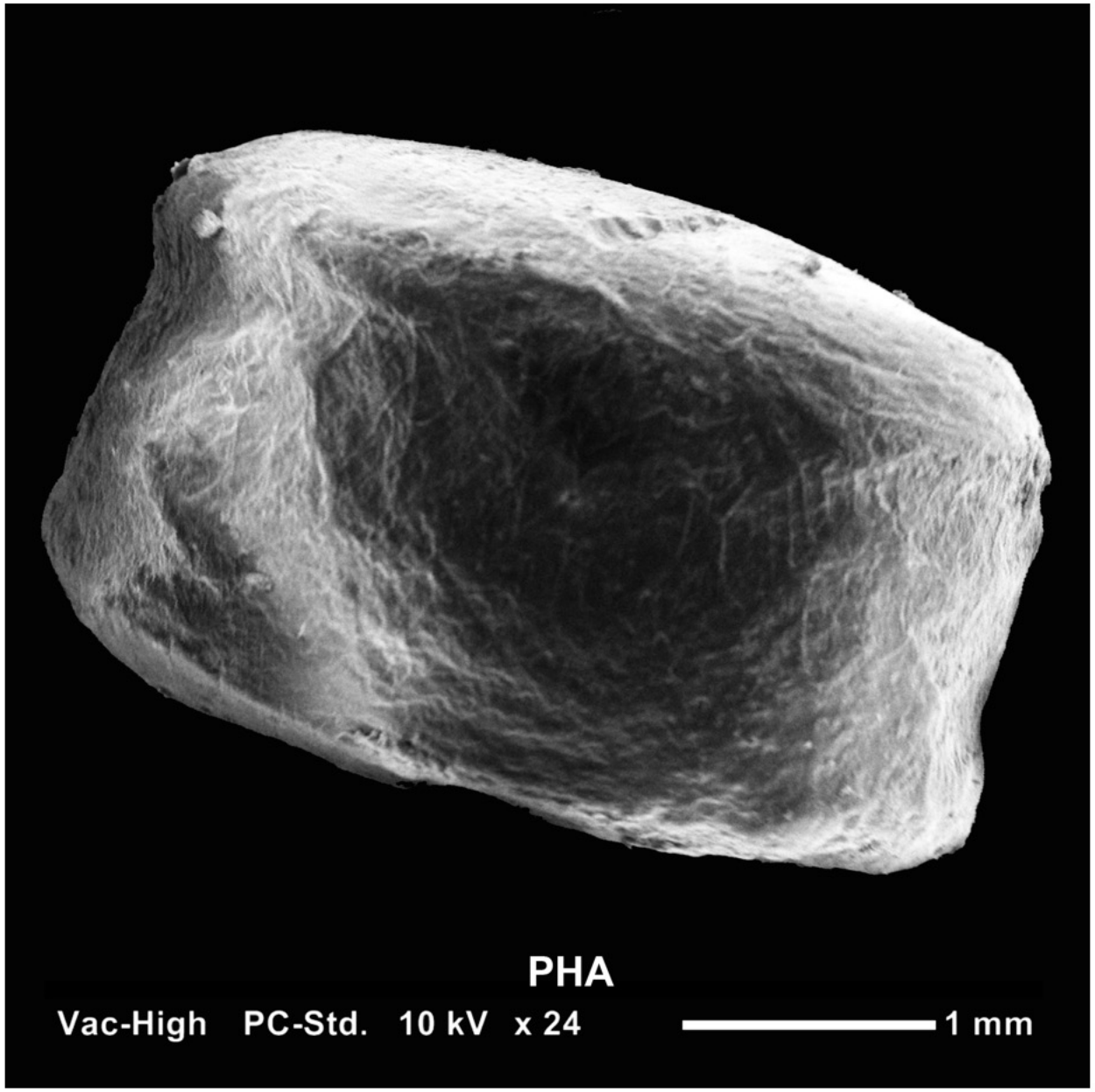


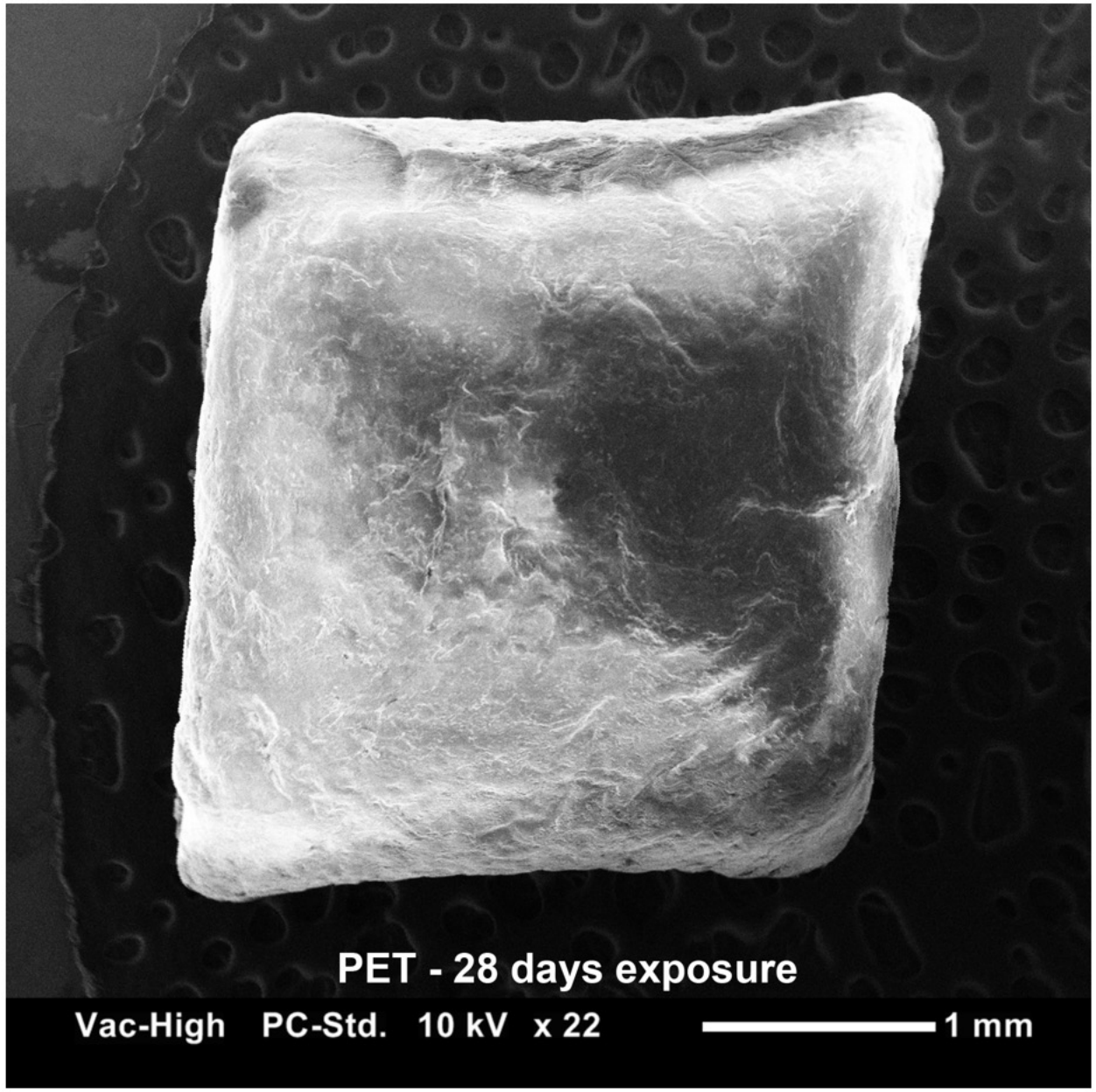
In the Lab

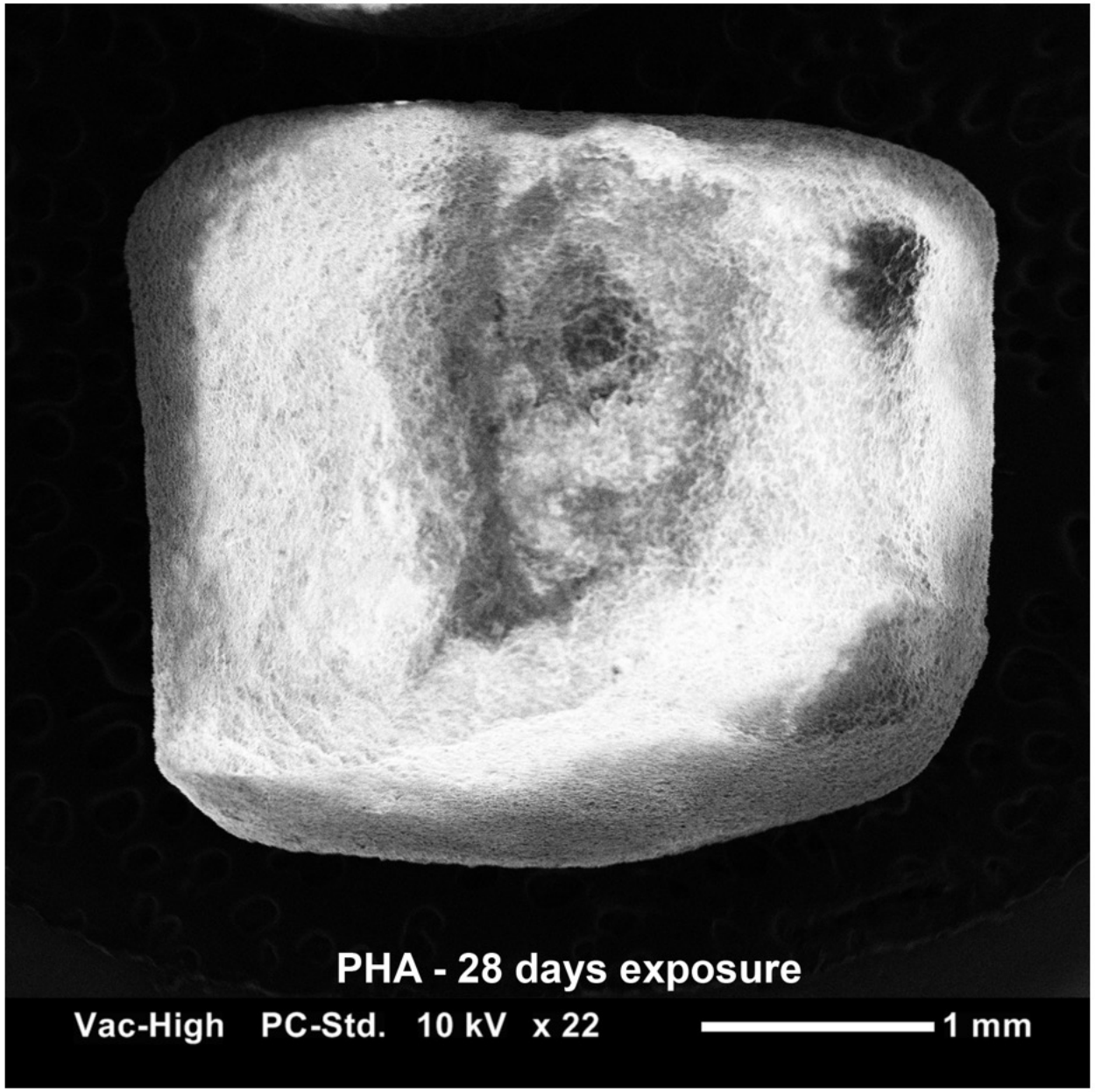

Collection
Biofilm Digestion & DNA Extraction
THE NURDLES
THE MICROBES
SEM
PCR
Mass measurement
Sequencing & Analysis

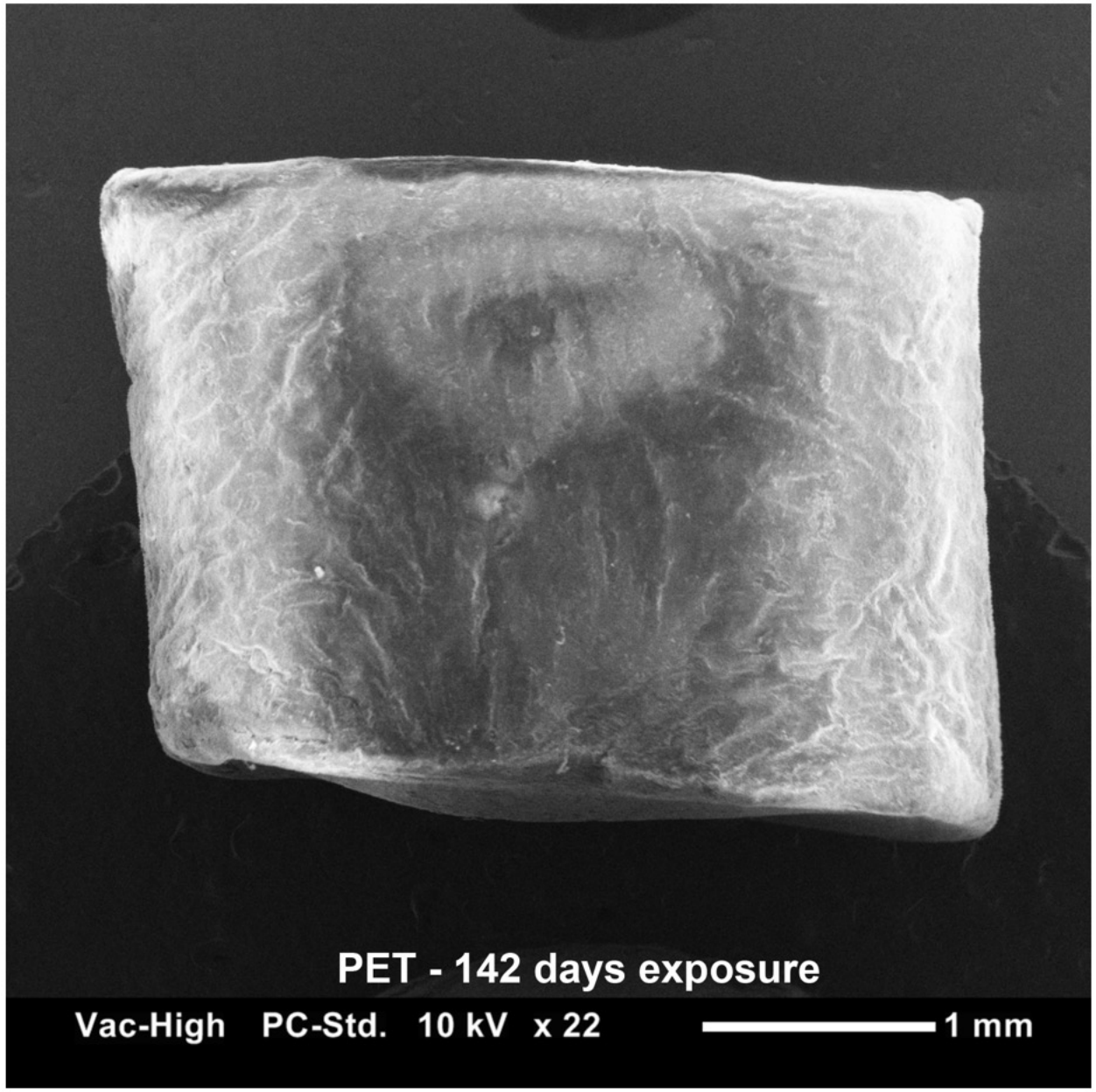

THE NURDLES

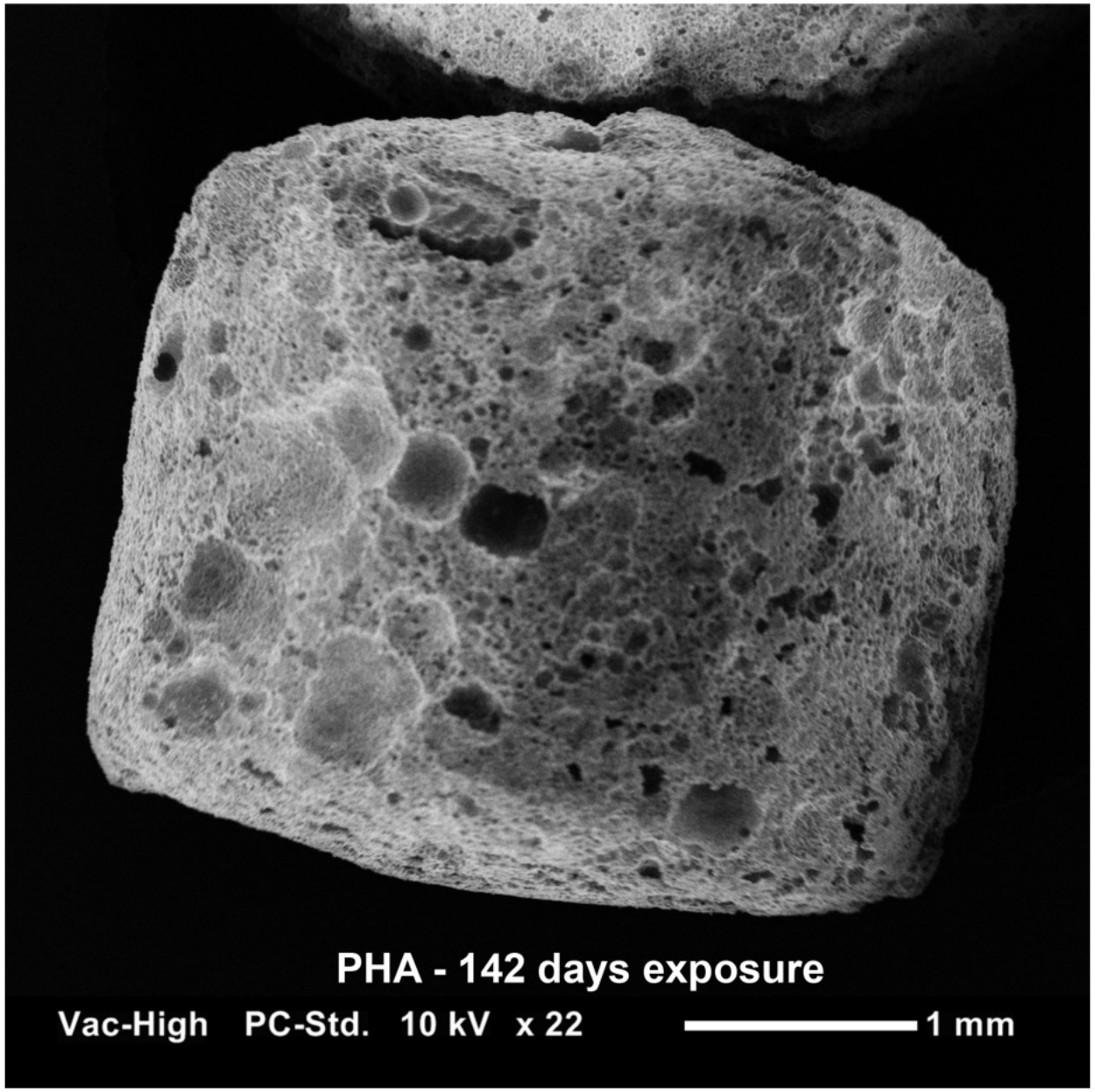

PET
Vac-High PC-Std. 10 kV x 24
1 mm

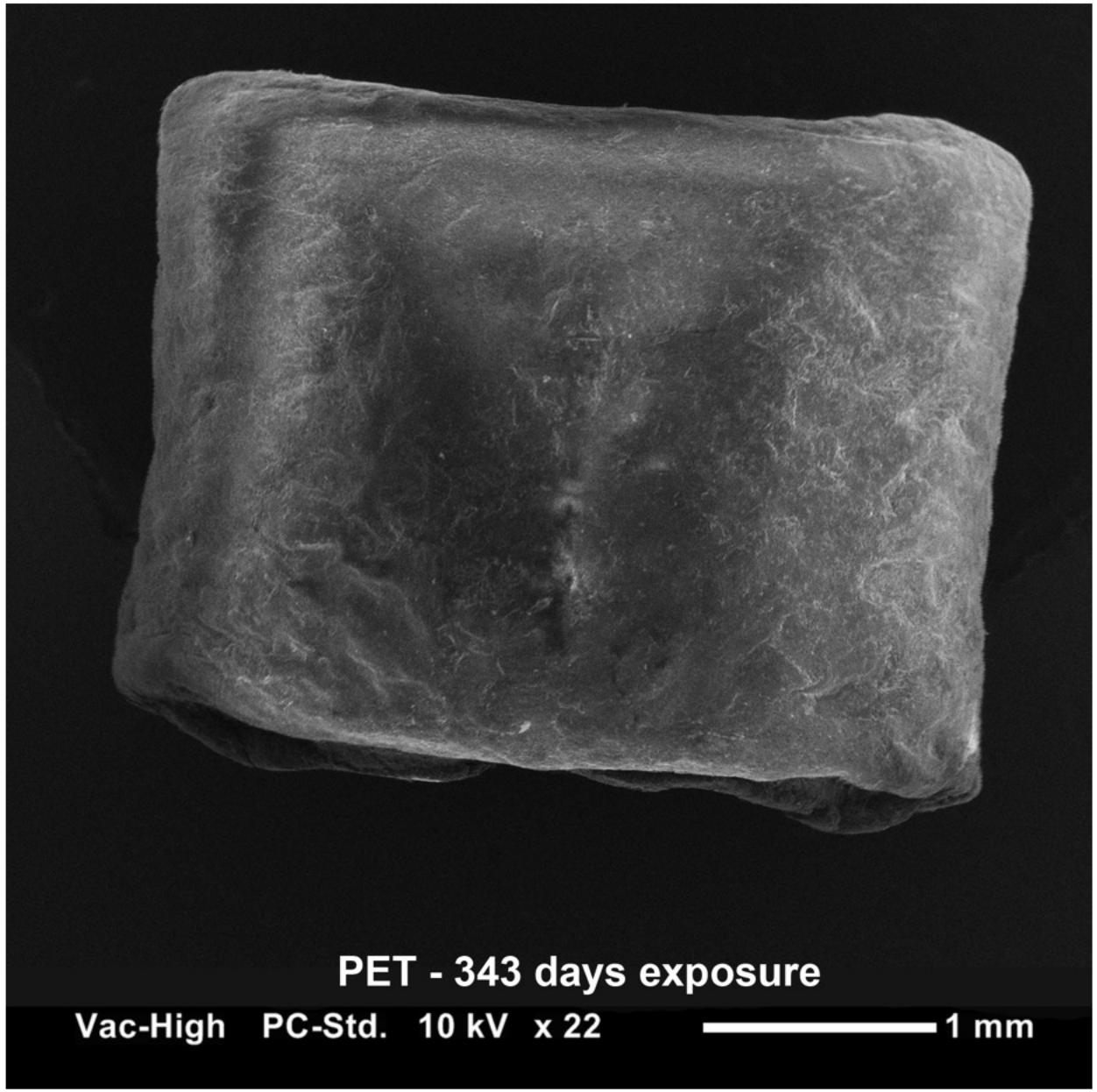

PHA
Vac-High PC-Std. 10 kV x 24
1 mm

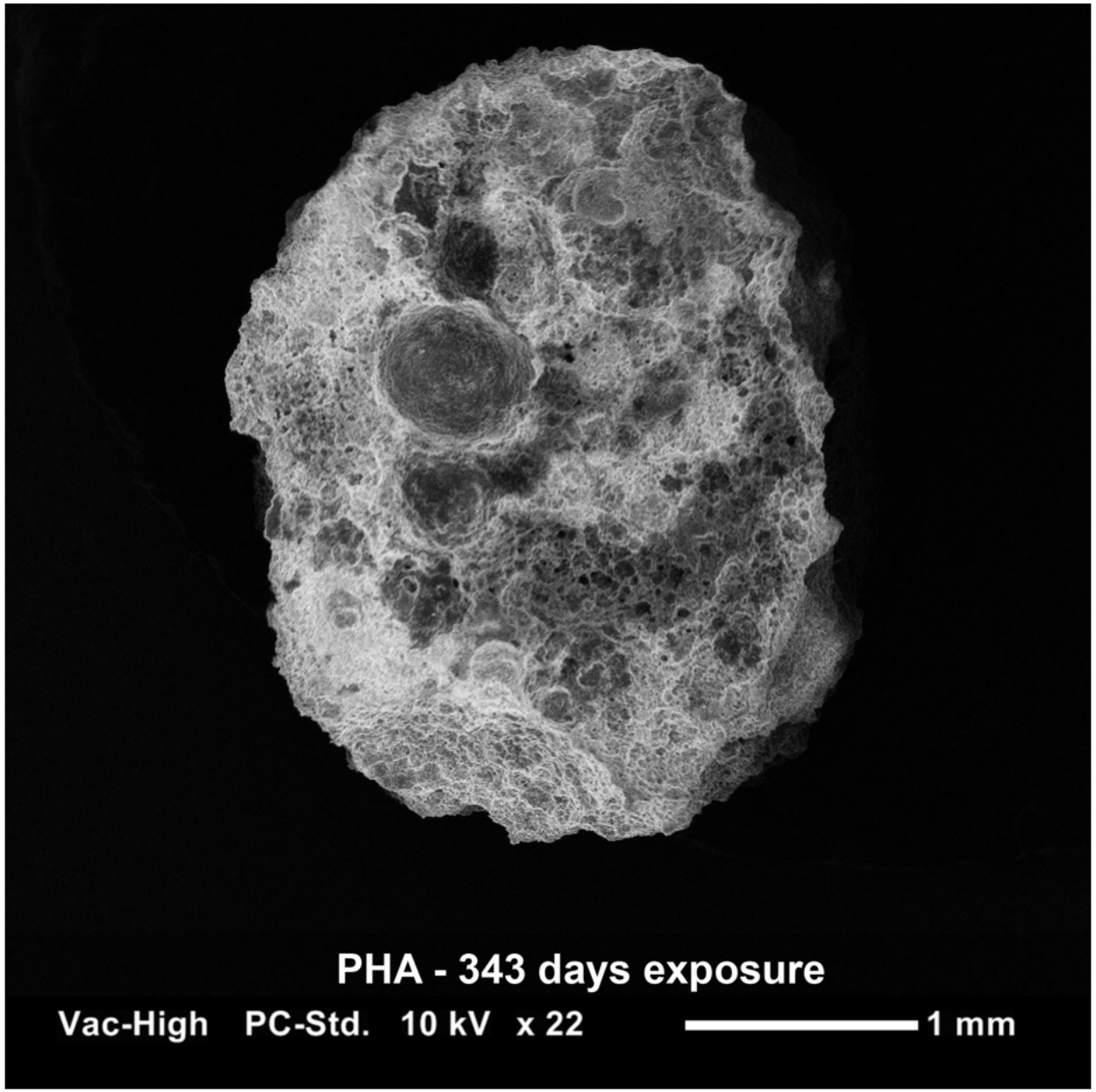

PET - 28 days exposure
Vac-High PC-Std. 10 kV x 22
1 mm

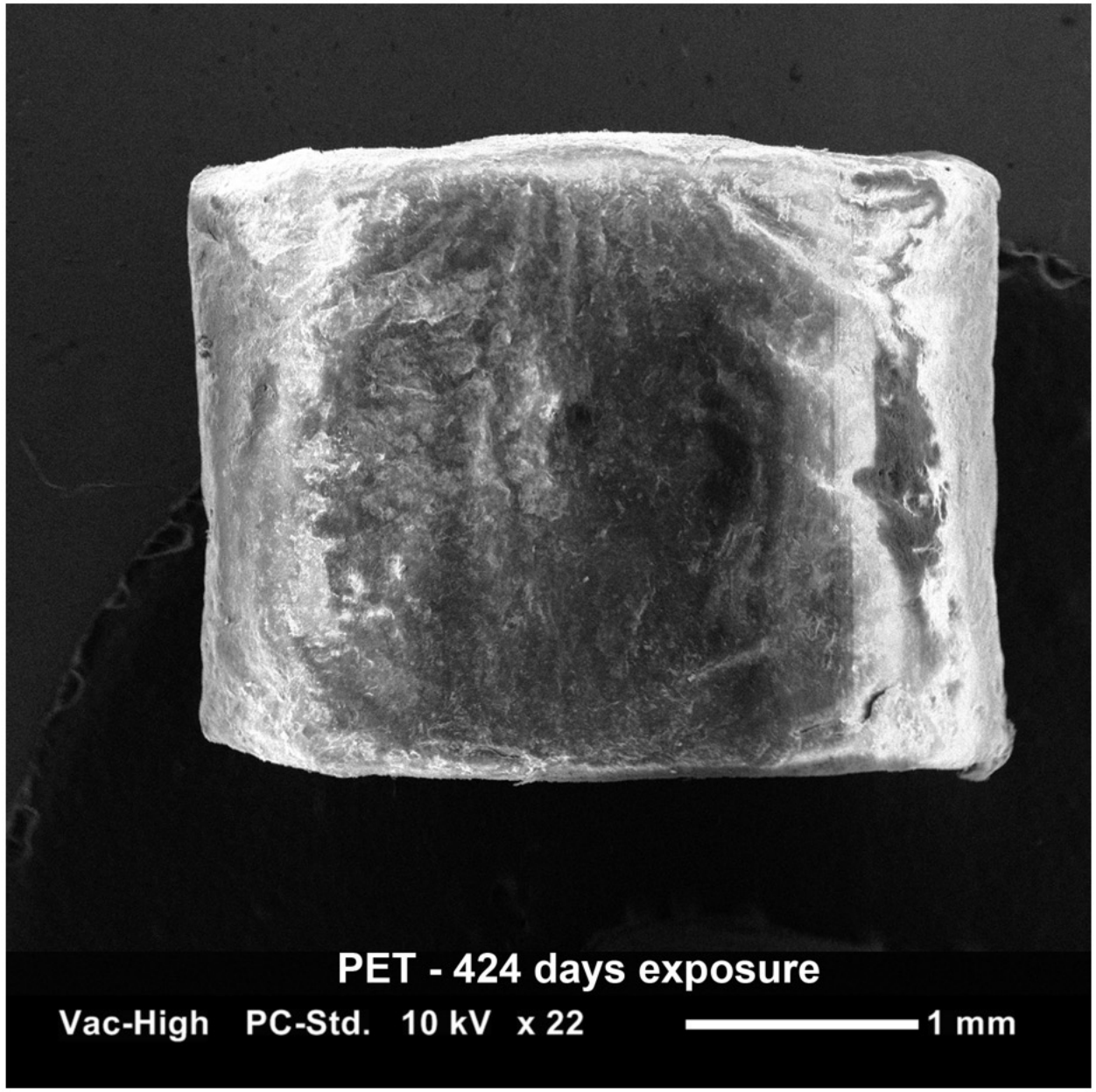

PHA - 28 days exposure
Vac-High PC-Std. 10 kV x 22
1 mm

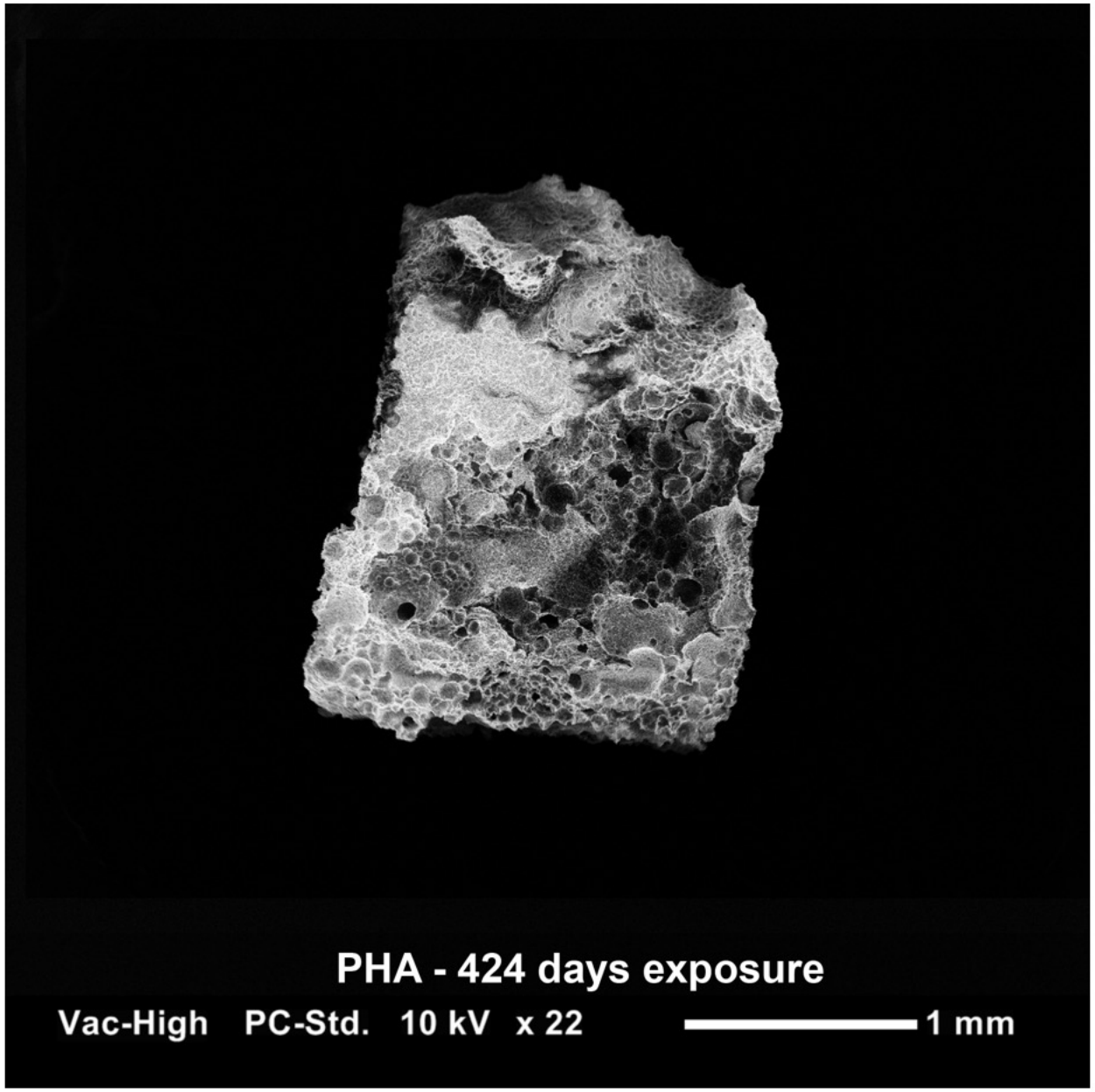

PET - 142 days exposure
Vac-High PC-Std. 10 kV x 22
1 mm


PHA - 142 days exposure
Vac-High PC-Std. 10 kV x 22
1 mm


PET - 343 days exposure
Vac-High PC-Std. 10 kV x 22
1 mm


PHA - 343 days exposure
Vac-High PC-Std. 10 kV x 22
1 mm


PET - 424 days exposure
Vac-High PC-Std. 10 kV x 22
1 mm

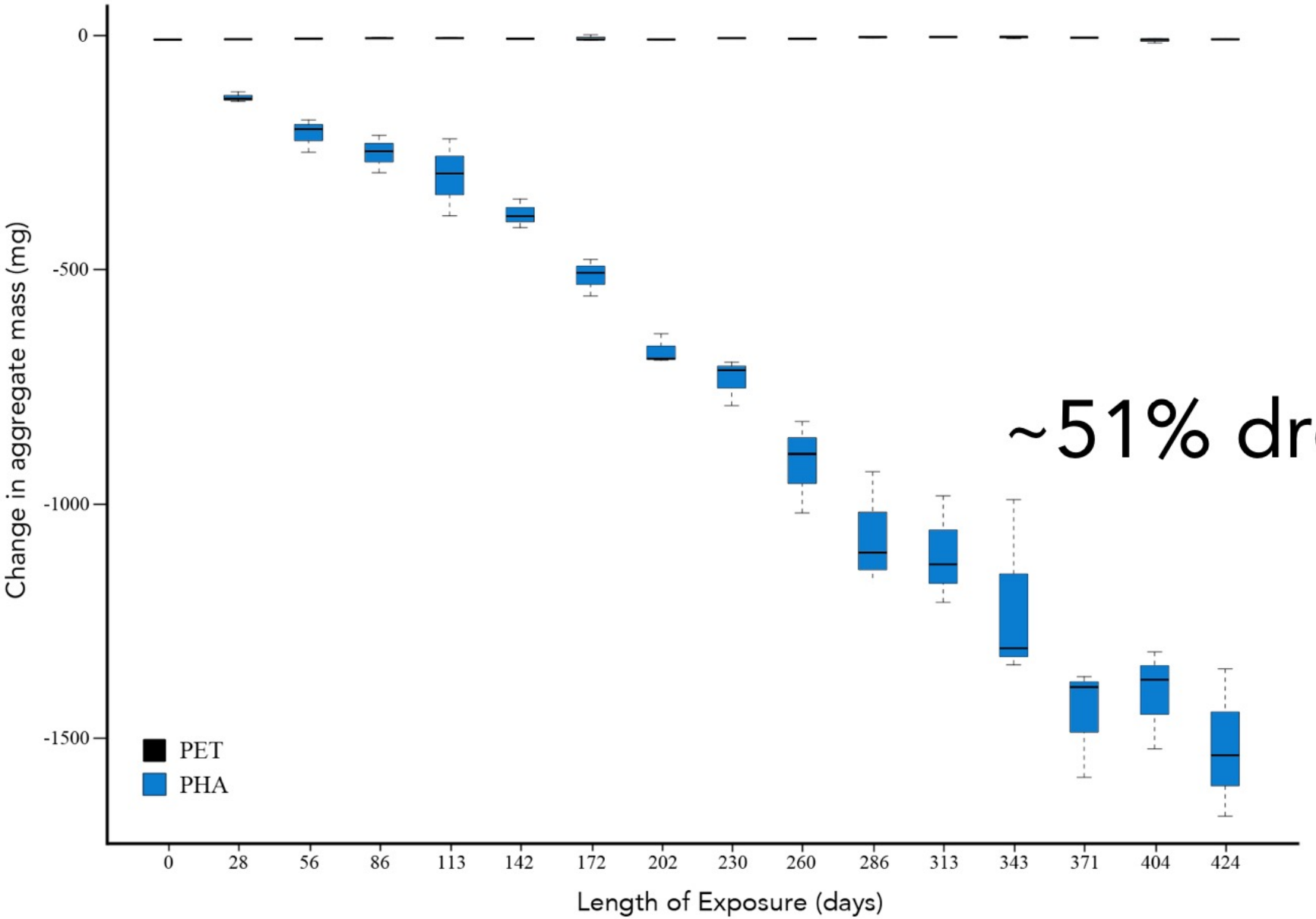

PHA - 424 days exposure
Vac-High PC-Std. 10 kV x 22
1 mm

Avg. pre-exposure masses:

PET = 2.985801 g
PHA = 2.984782 g

Avg. 424 day exposure masses:

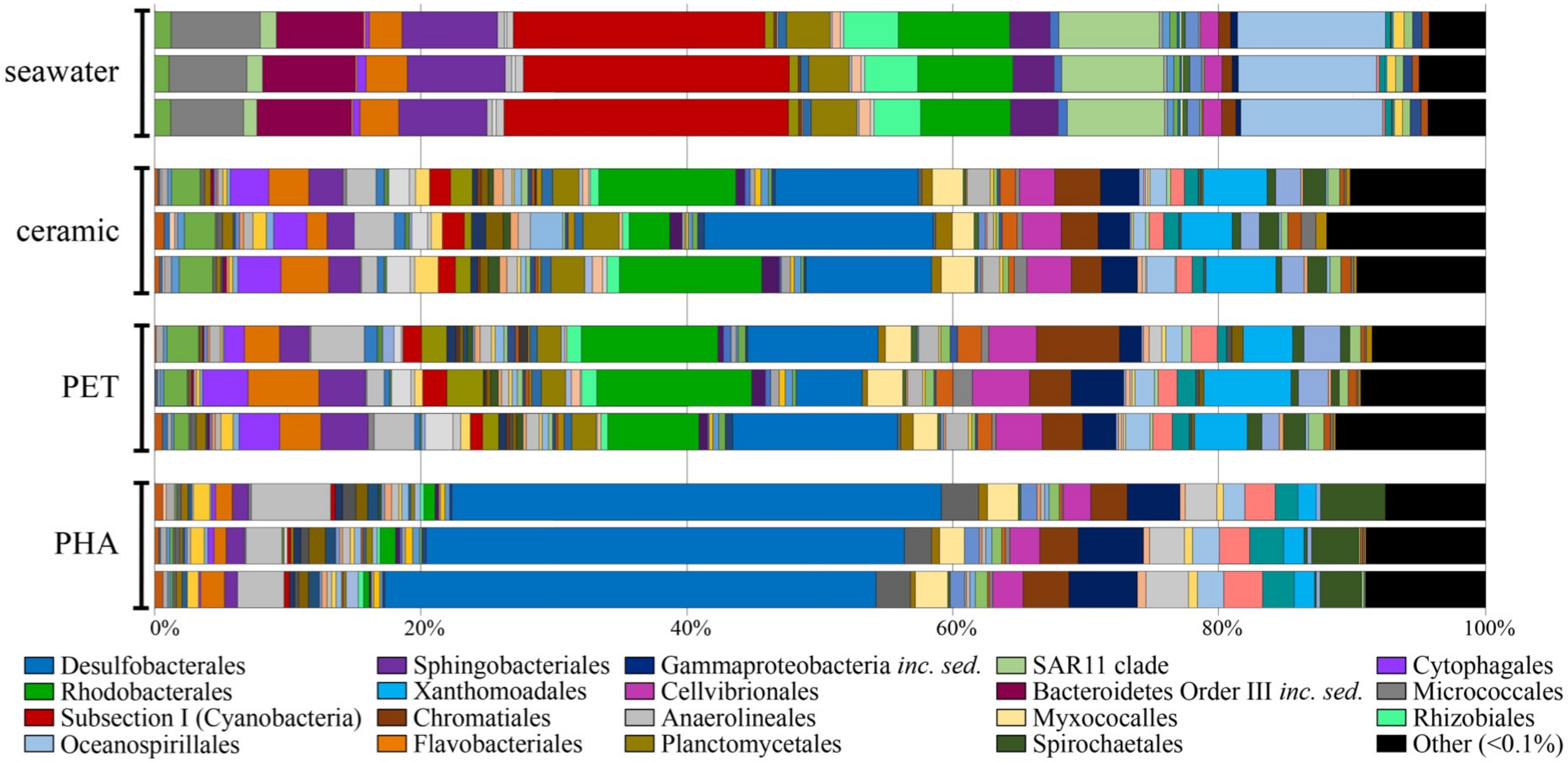
PET = 2.988483 g
PHA = 1.469777 g

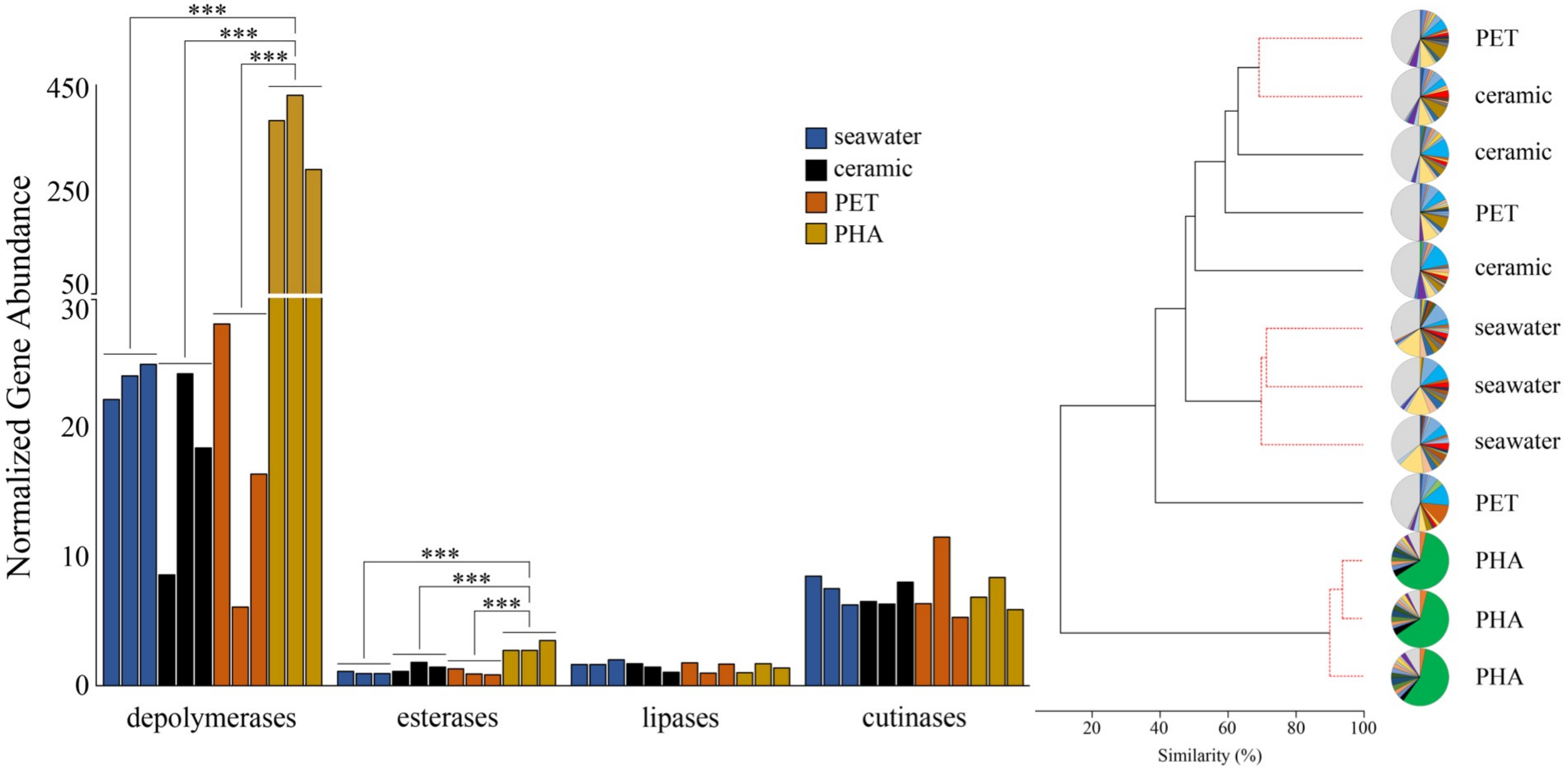


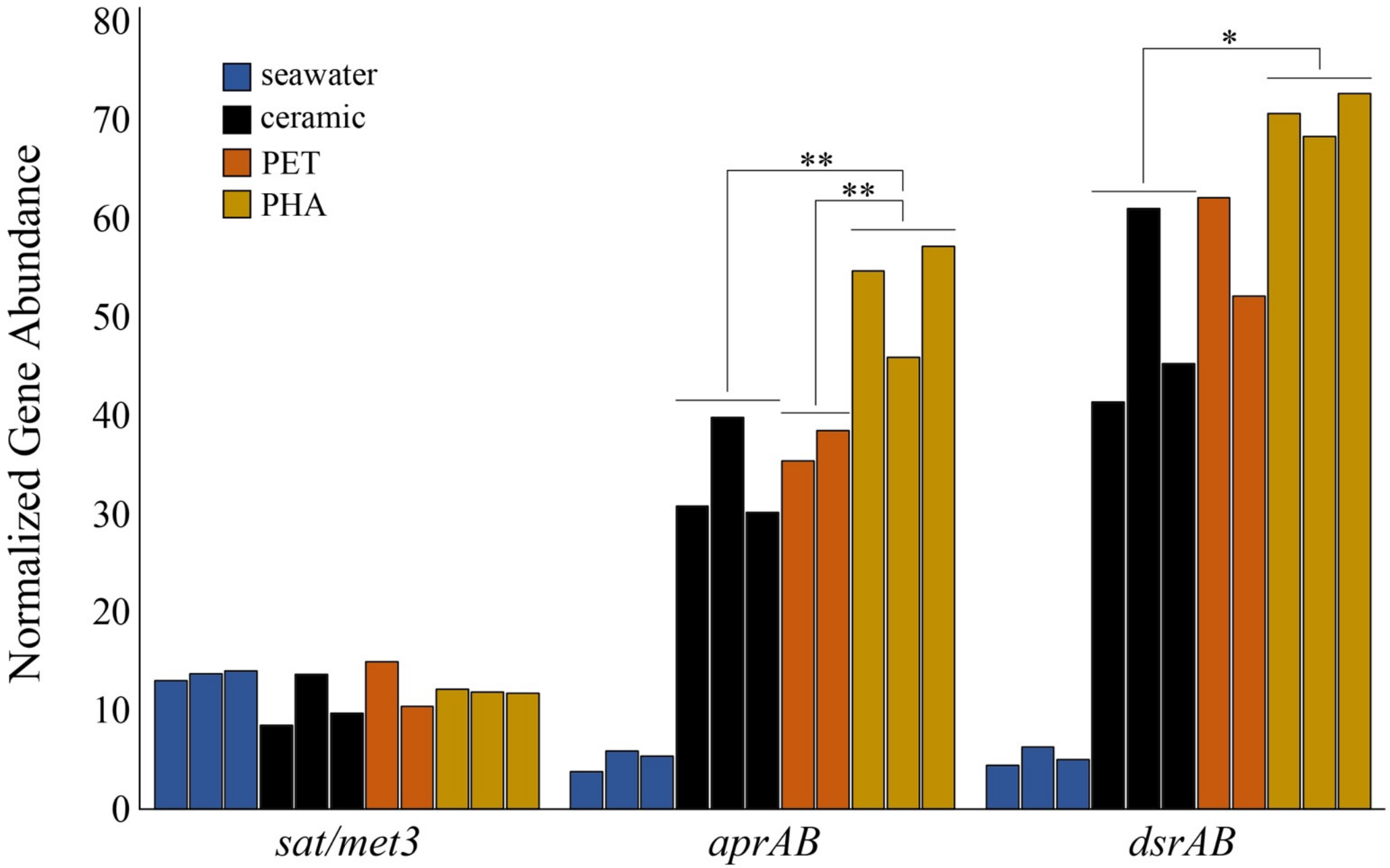
~51% drop in PHA mass

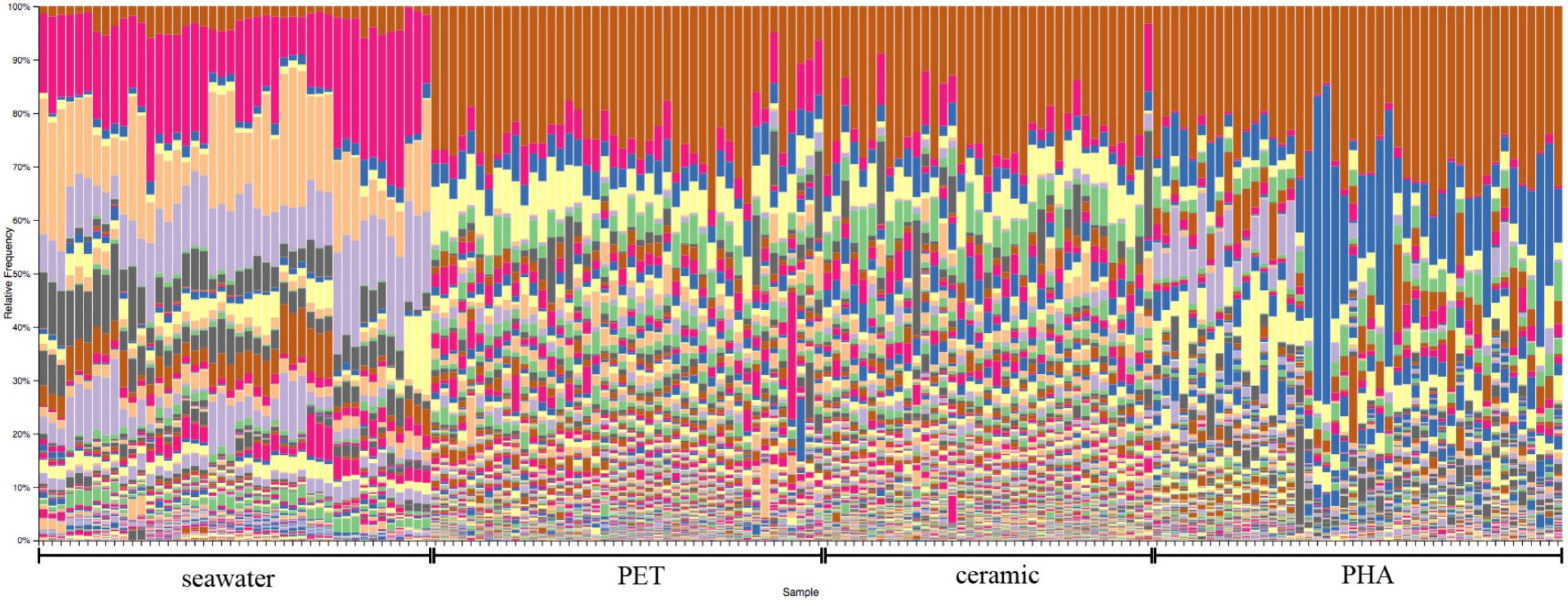
THE MICROBES

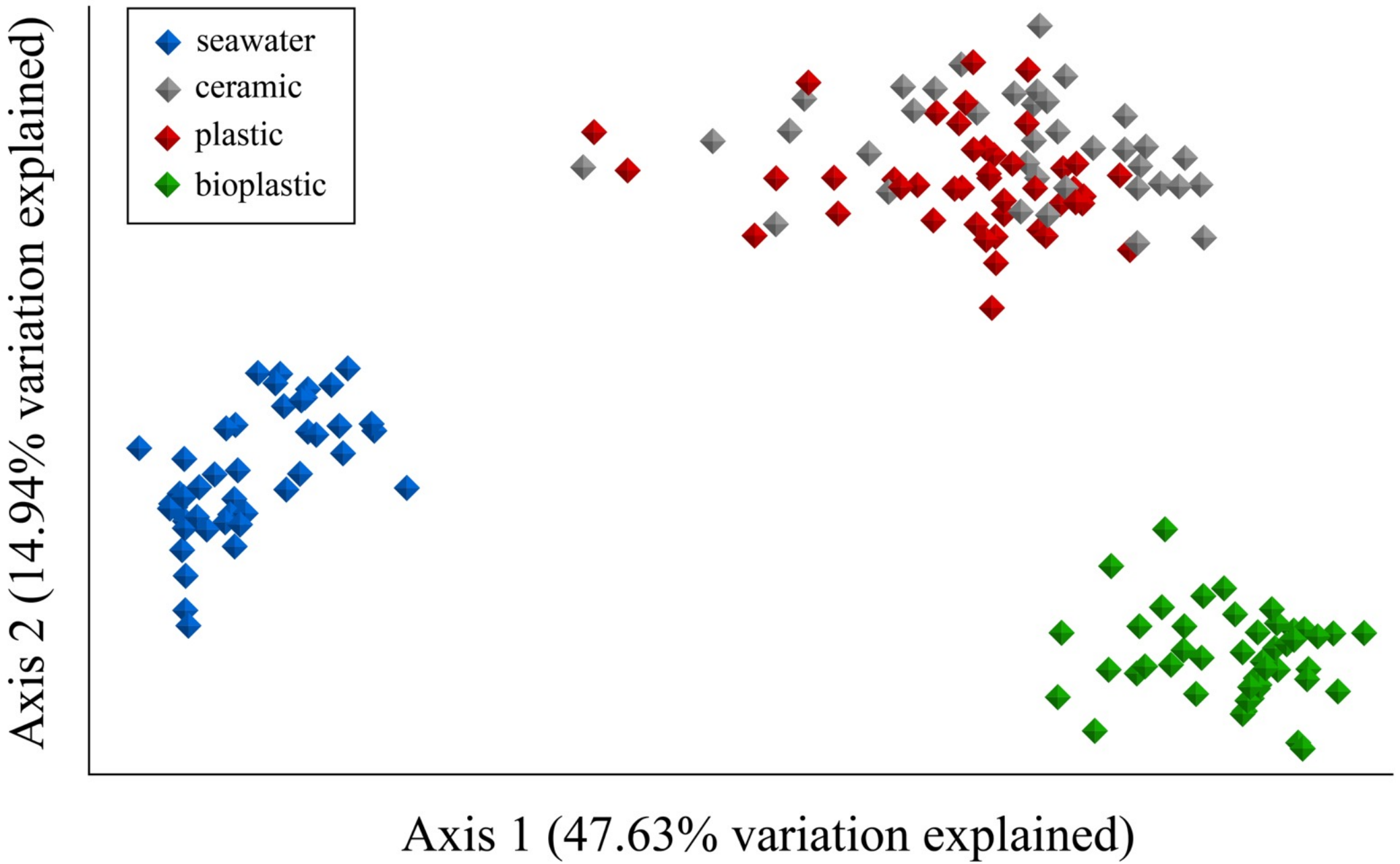
Bacterial community structure at the level of order following 28 days exposure

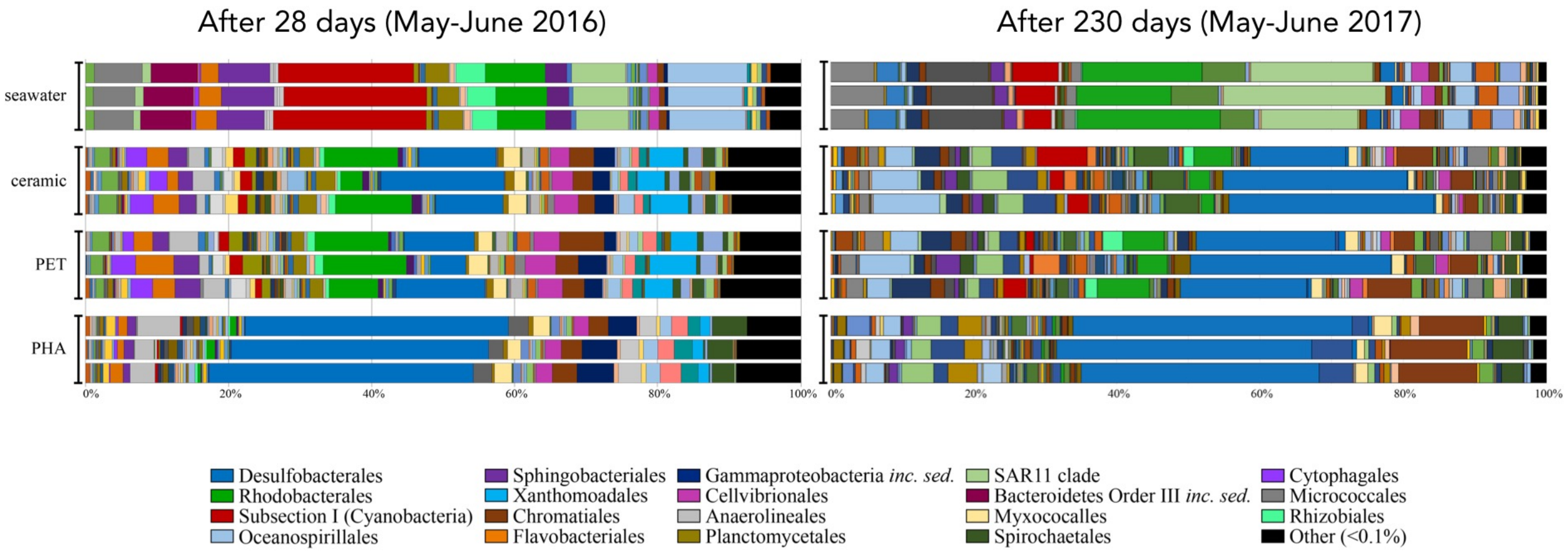



Normalized Gene Abundance
450
250
50
30
20
10
0
***
***
***
***
***
***
seawater
ceramic
PET
PHA
depolymerases
esterases
lipases
cutinases
PET
ceramic
ceramic
PET
ceramic
seawater
seawater
seawater
PET
PHA
PHA
PHA
20
40
60
80
100
Similarity (%)


Normalized Gene Abundance
80
70
60
50
40
30
20
10
0
seawater
ceramic
PET
PHA
**
**
*
sat/met3
aprAB
dsrAB


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Relative Frequency
seawater
PET
ceramic
PHA
Sample


seawater
ceramic
plastic
bioplastic
Axis 2 (14.94% variation explained)
Axis 1 (47.63% variation explained)


After 28 days (May-June 2016)
After 230 days (May-June 2017)
seawater
ceramic
PET
PHA
0%
20%
40%
60%
80%
100%
Desulfobacterales
Rhodobacterales
Subsection I (Cyanobacteria)
Oceanospirillales
Sphingobacteriales
Xanthomoadales
Chromatiales
Flavobacteriales
Gammaproteobacteria inc. sed.
Cellvibrionales
Anaerolineales
Planctomycetales
SAR11 clade
Bacteroidetes Order III inc. sed.
Myxococalles
Spirochaetales
Cytophagales
Micrococcales
Rhizobiales
Other (<0.1%)

- Marine microbes are biodegrading PHA, but not PET
- PHA recruits a specific group of microbes, PET doesn't
- Those microbes have an increased biodegradation and sulfate reduction potential
- An influx of bioplastic may have unintended consequences for biogeochemical cycling

Micro-omics Lab

Dr. Jeff Turner
Nicole Elledge
Paxton Bachand

Center for Coastal Studies

Dr. Paul Zimba
Brien Nicolau
Erin Hill
Bobby Duke
Jay Tarkington

M&G Chemicals

Jeff Shea

TEXAS A&M UNIVERSITY CORPUS CHRISTI

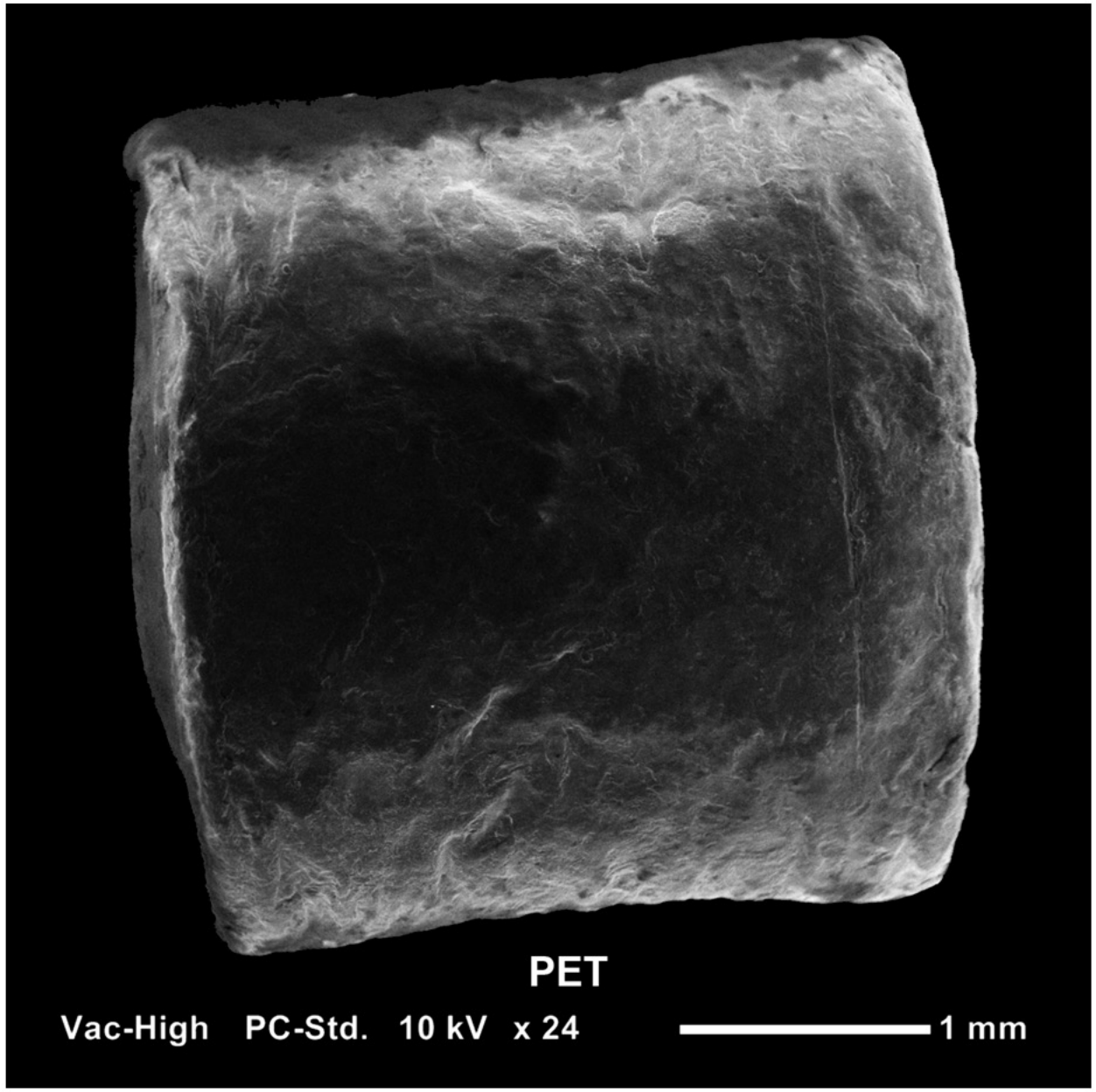
Texas Research & Development Fund

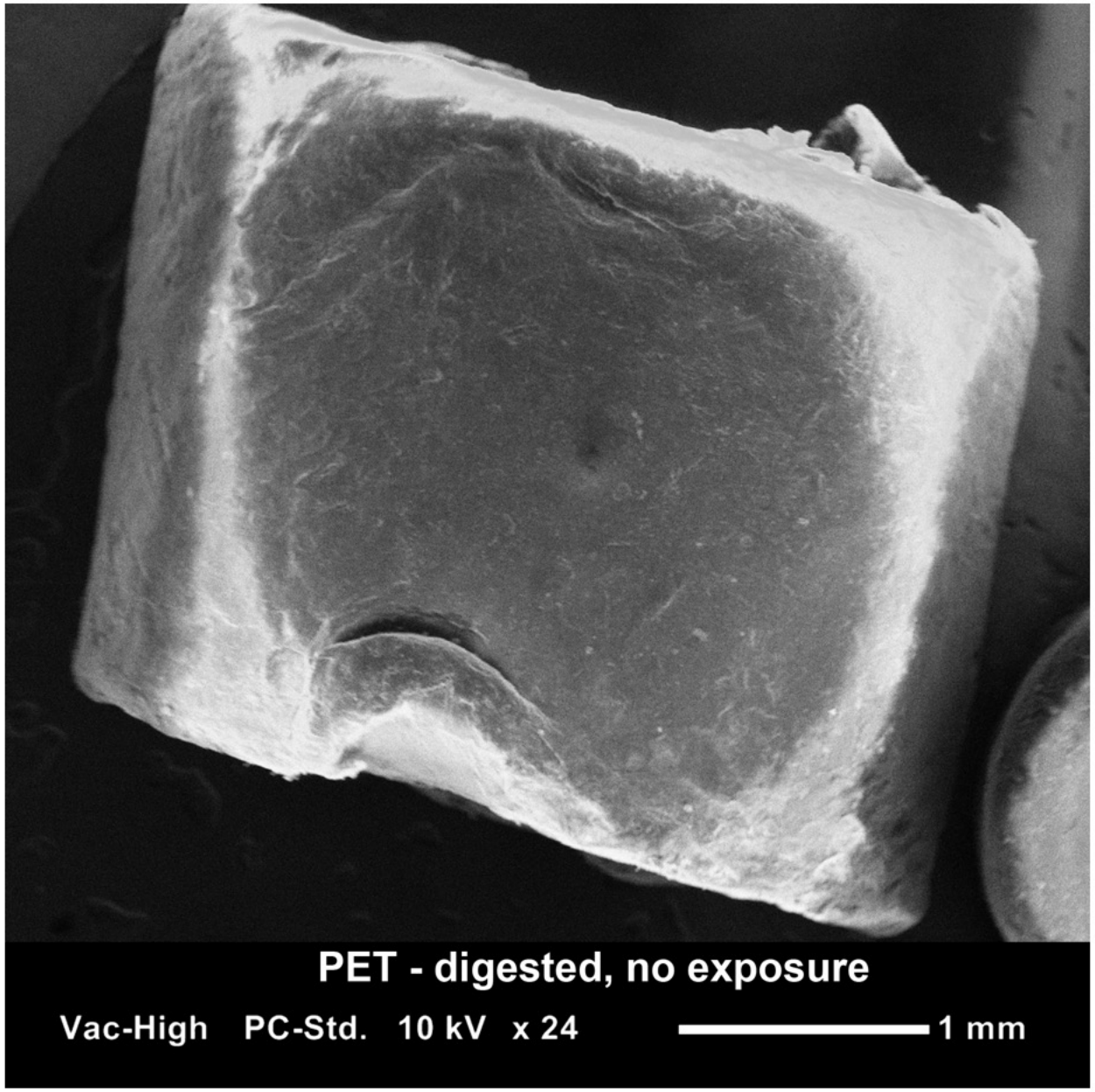
NSERC CRSNG

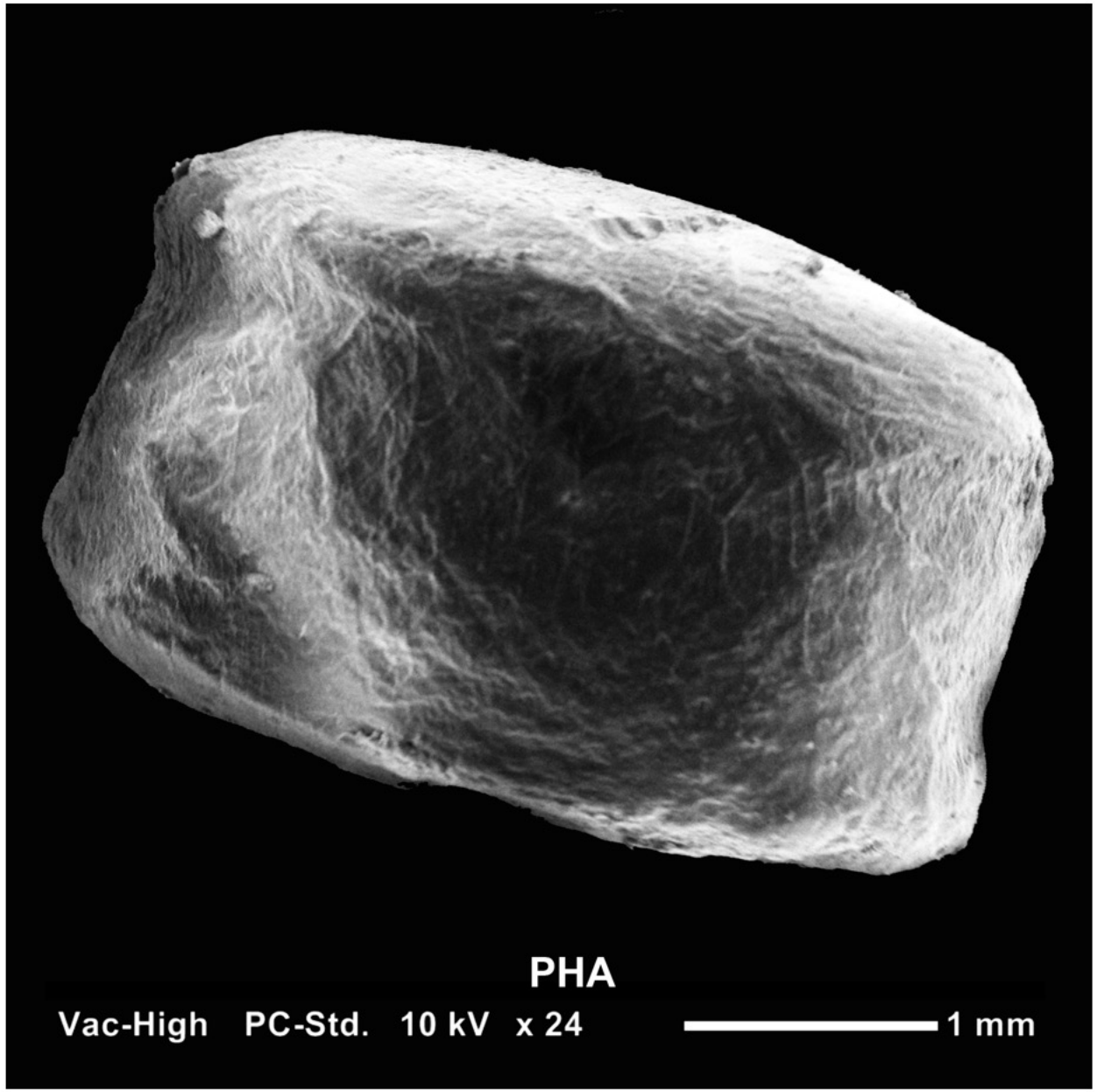
Sea Grant Texas

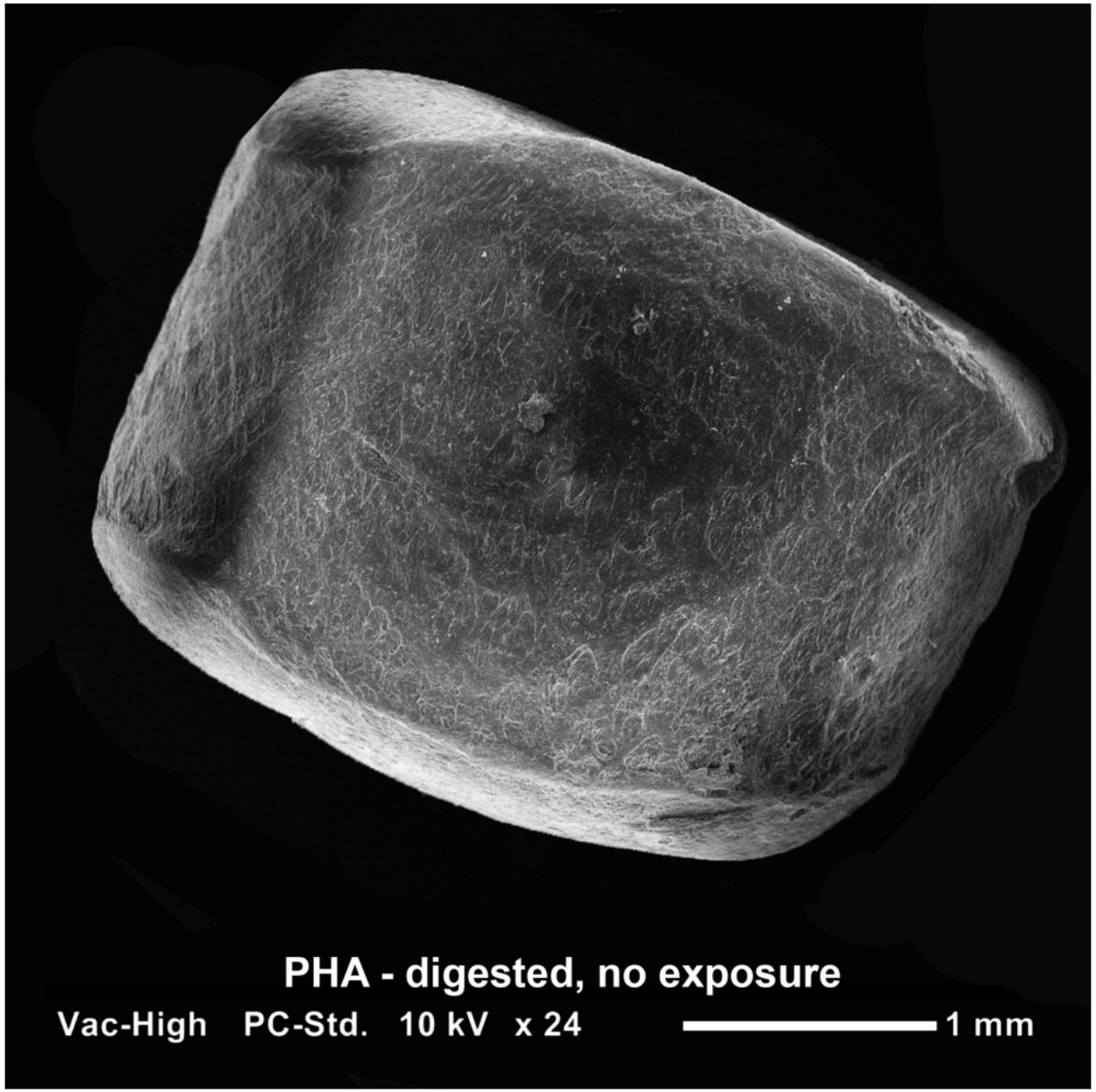
Questions?

lpinnell@tamucc.edu


PET
Vac-High PC-Std. 10 kV x 24
1 mm


PET - digested, no exposure
Vac-High PC-Std. 10 kV x 24
1 mm


PHA
Vac-High PC-Std. 10 kV x 24
1 mm


PHA - digested, no exposure
Vac-High PC-Std. 10 kV x 24
1 mm