Producing fragmented micro- and nano-plastics from expanded polystyrene with an accelerated mechanical abrasion experiment

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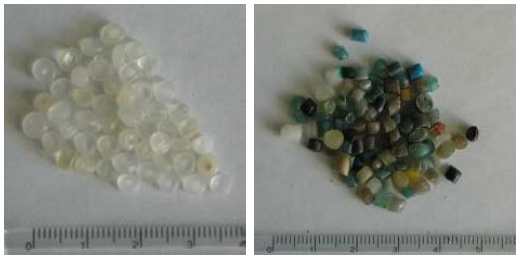
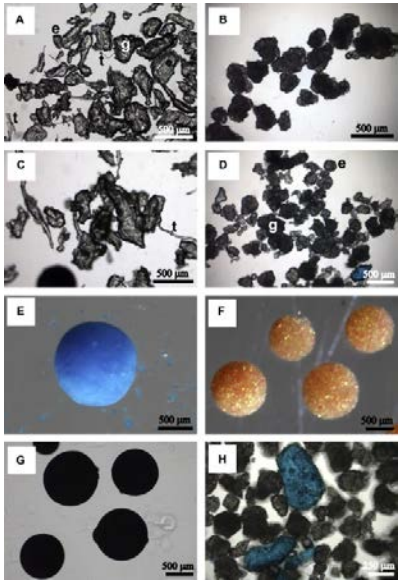
KIOST
한국해양과학기술원

Origin of microplastics

- **Primary microplastics**
  - Pre-production resin pellets
  - Plastic scrubbers in cosmetics
  - Plastic abrasives in blasting
  - Other nano- and micro-polymer composite

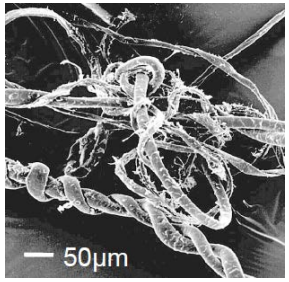


Resin pellets (Geoje, Korea/ KIOST)

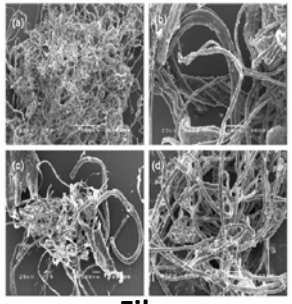


PE scrubs (Fendall and Sewell, 2009)

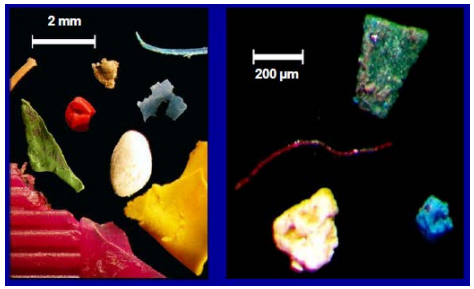
- **Secondary microplastics**
  - Breakdown fragments, fibers, elastomers and coatings of large synthetic polymers



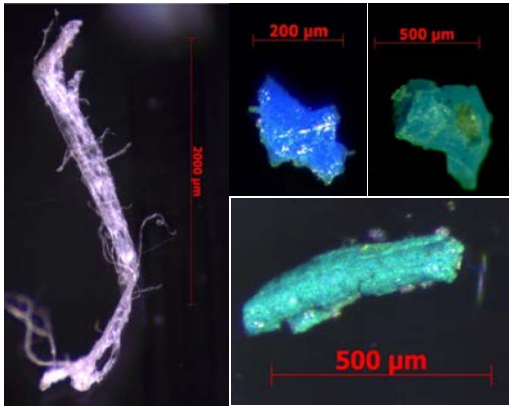
Fiber
(Thompson et al, 2004)



Fiber
(Murray and Cowie, 2011)

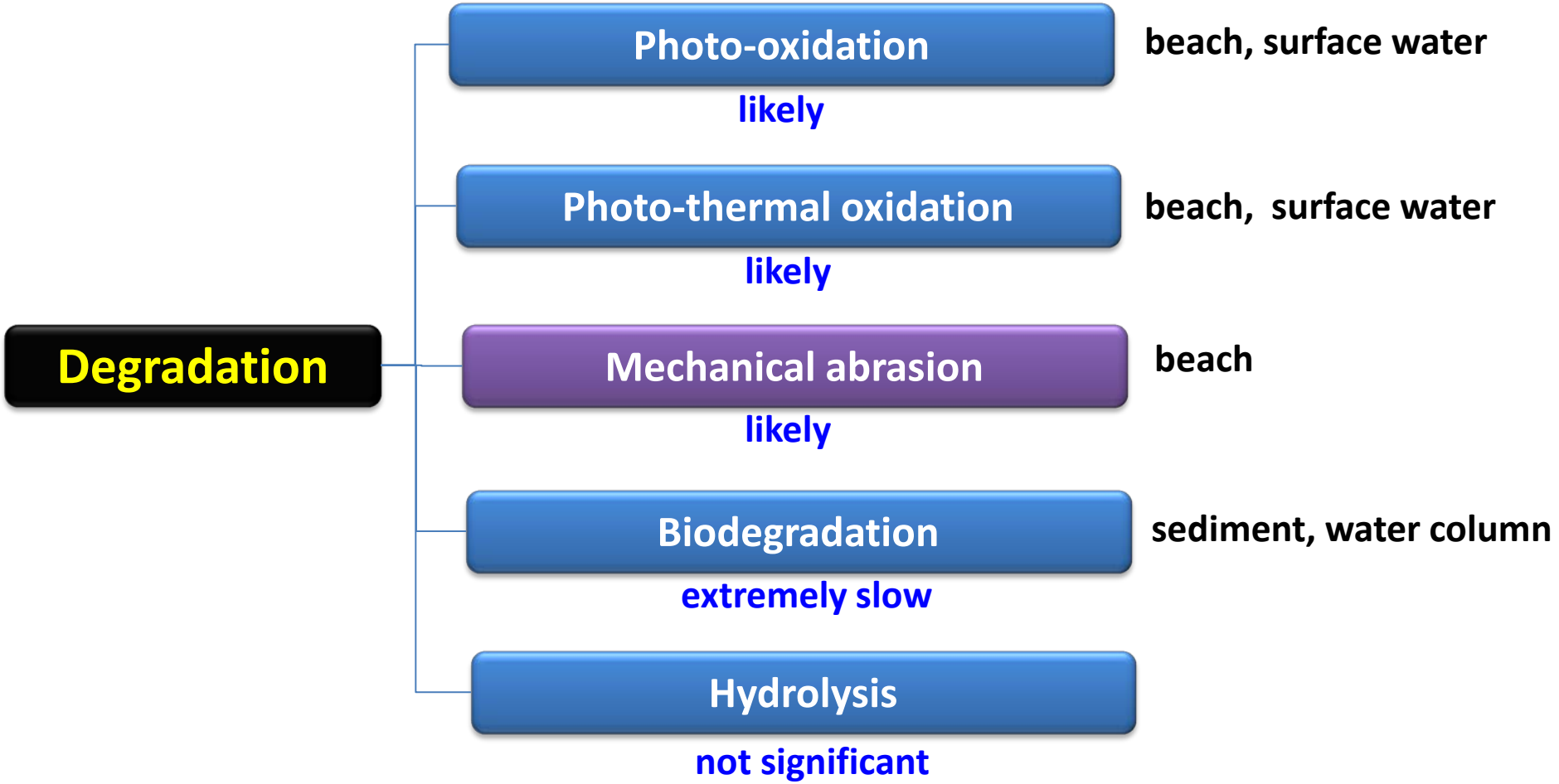


Sewage sludge
(Zubris & Richards, 2005)



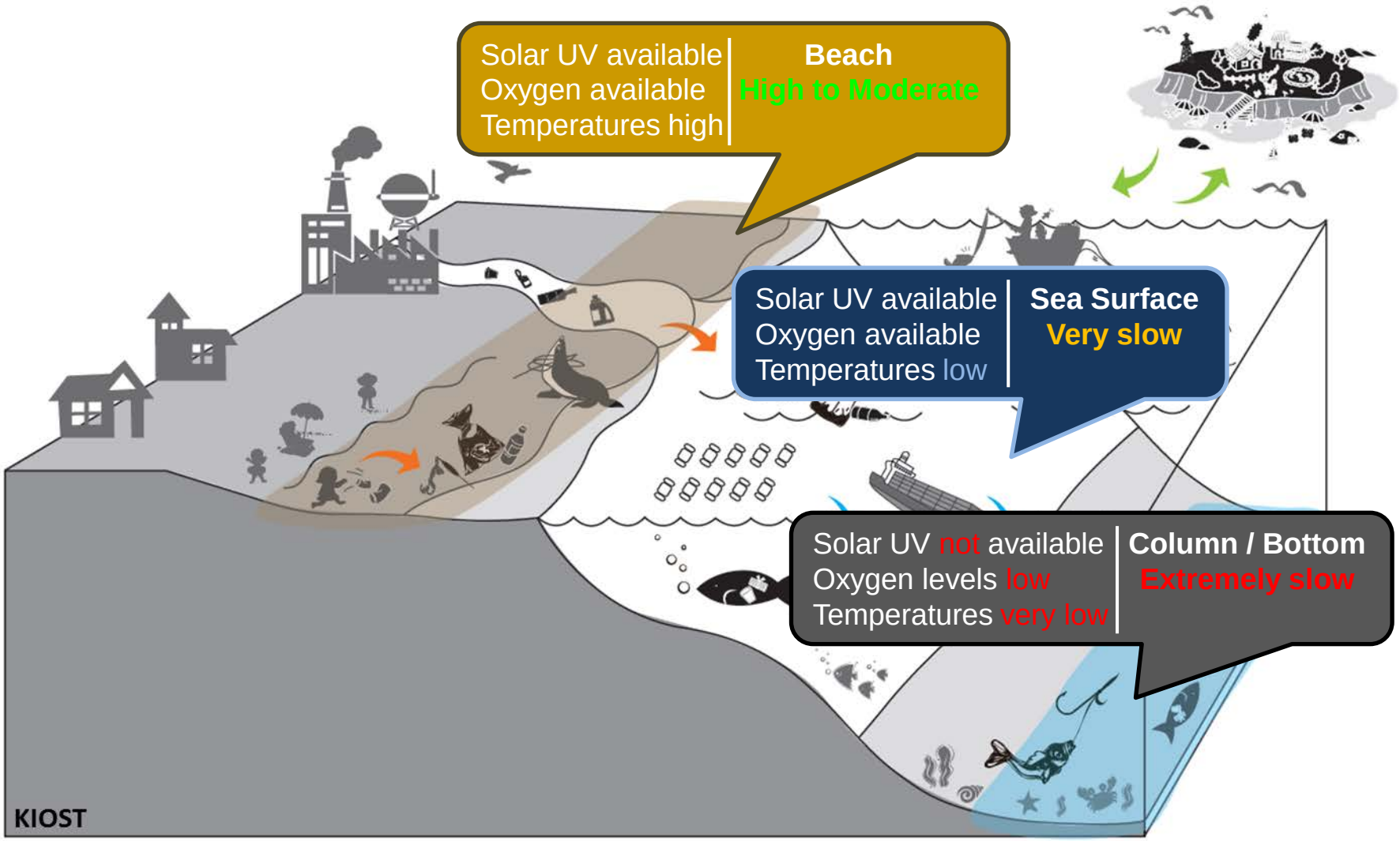
Fragment (Geoje/KIOST)

Polymer degradation/fragmentation mechanism in the Ocean



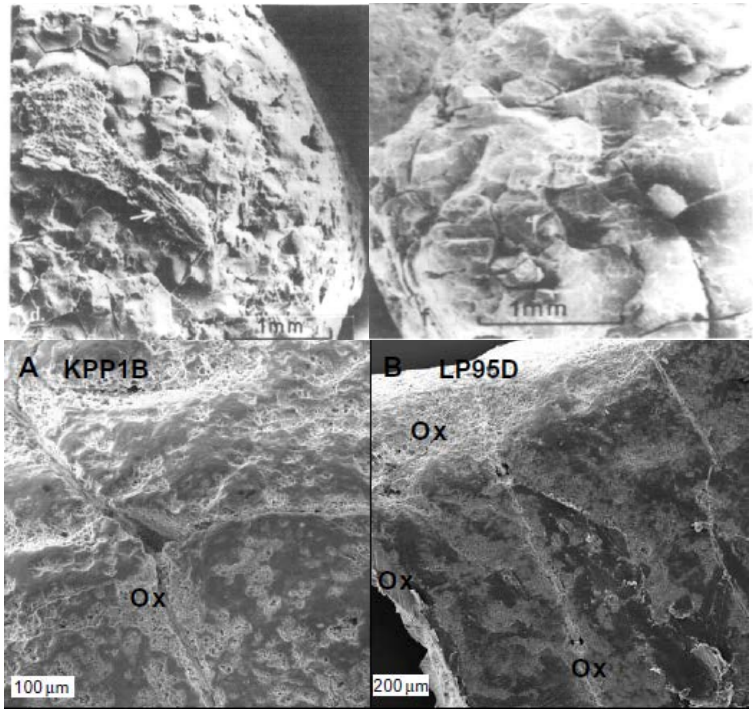
Light-initiated thermal oxidation is the only credible degradation mechanism so far for common plastics found in the marine environment.

Degradation rates in the Ocean



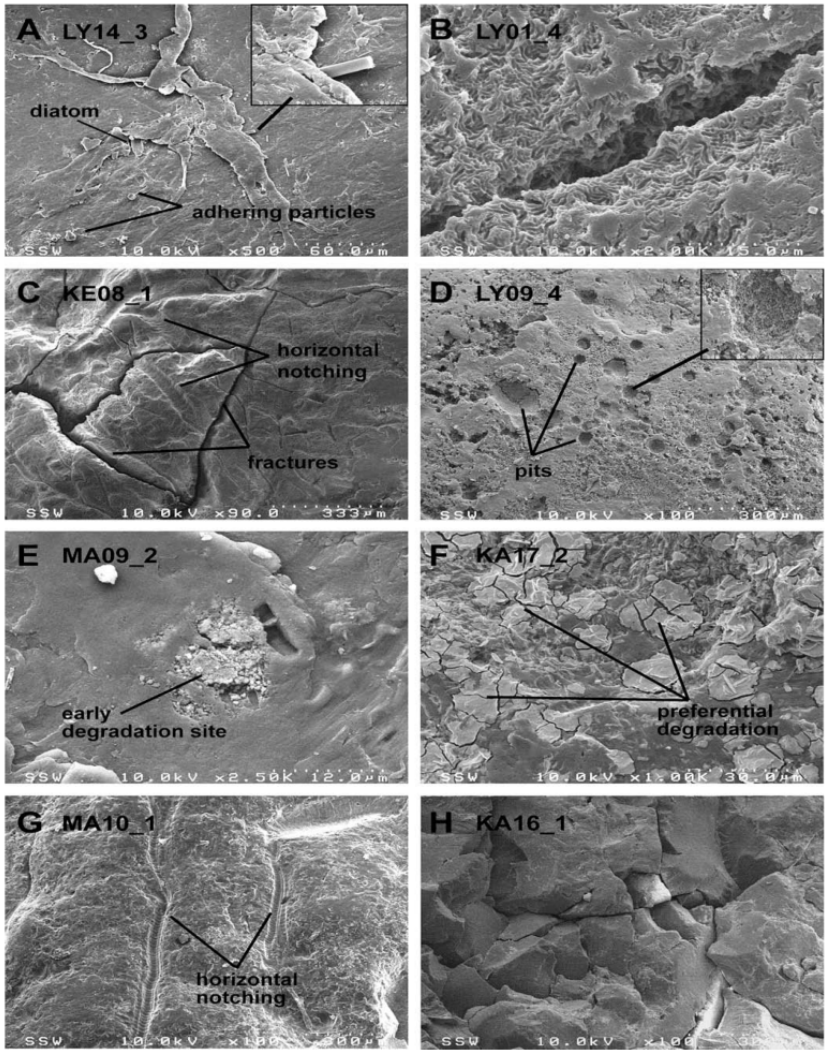
Surface Cracking in UV Degradation

Especially with PE and PP yellowing discoloration and surface cracking are characteristic consequence of UV degradation.



Gregory (1983) Mar Environ Res

Corocoran et al. (2009) Mar Pollut Bull



Cooper and Corcoran (2010) Mar Pollut Bull

Sample surface aged under QUV for 800 h (Küpper, et al., 2004)

Very limited information in plastic fragmentation in marine environments

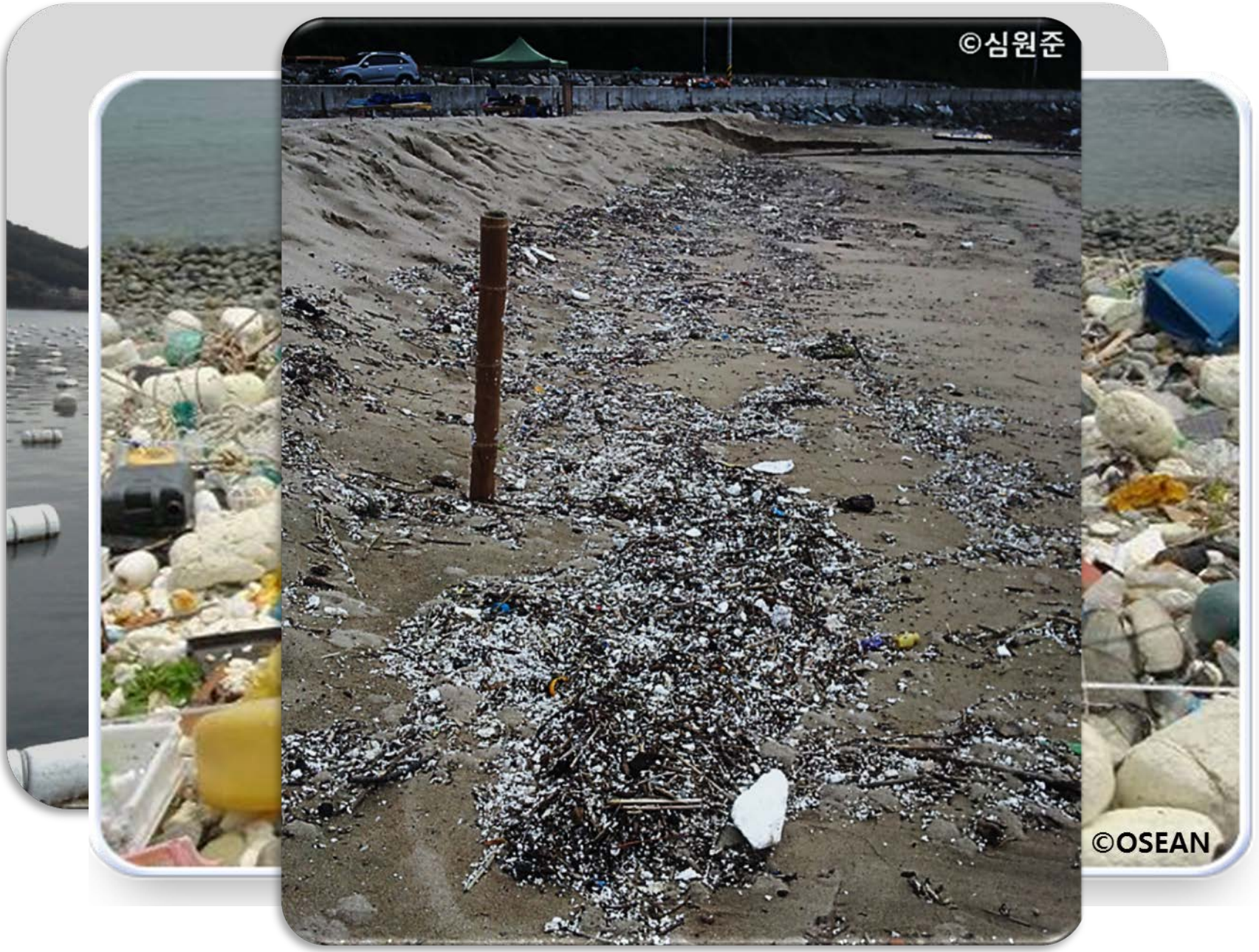
- **Main sources or place of fragmentation?**
  - **Terrestrial *vs* marine environments**
  - **At sea *vs* on shore**
- **How?**
  - **Chemical *vs* Physical weathering**
  - **Rate?**
- **Type of polymers?**
  - **Which polymer types are more labile to chemical or physical weathering?**
- **Size distribution of fragmented polymers?**

Questions in this study

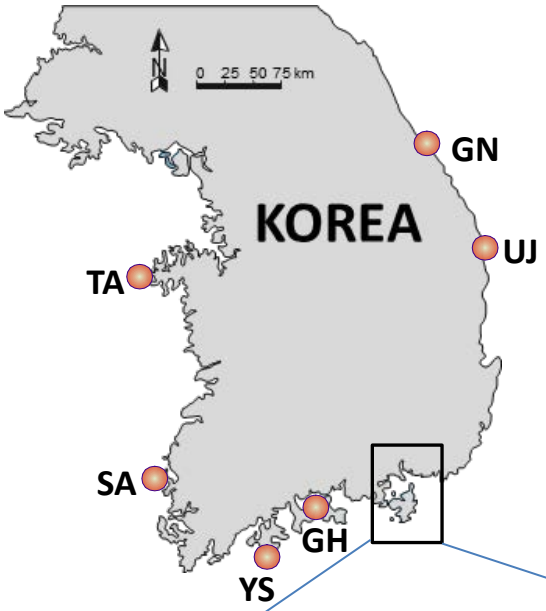
- **Question**

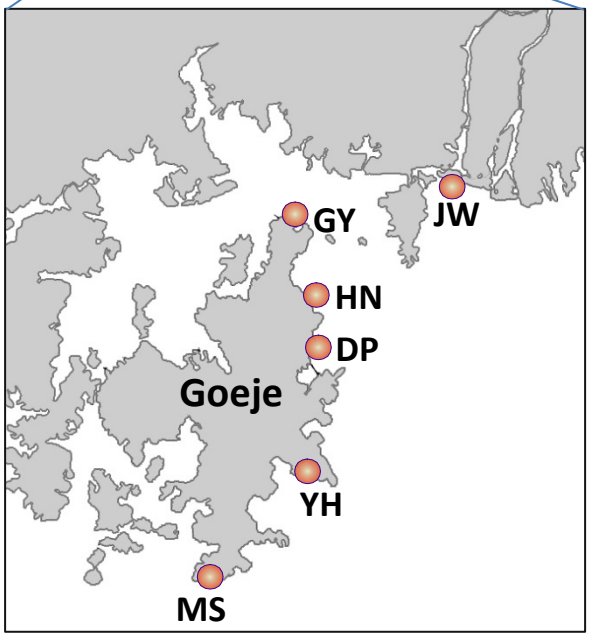
  Accelerated mechanical abrasion of large plastics can produce micro-sized plastics?

Selection test polymer types

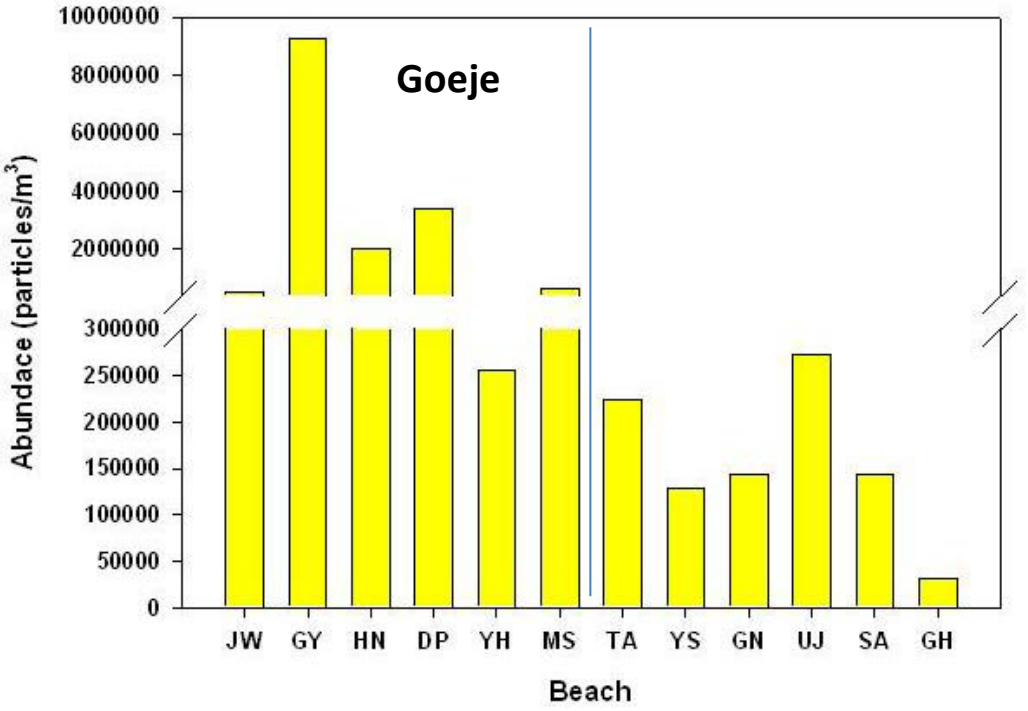



cm
inch

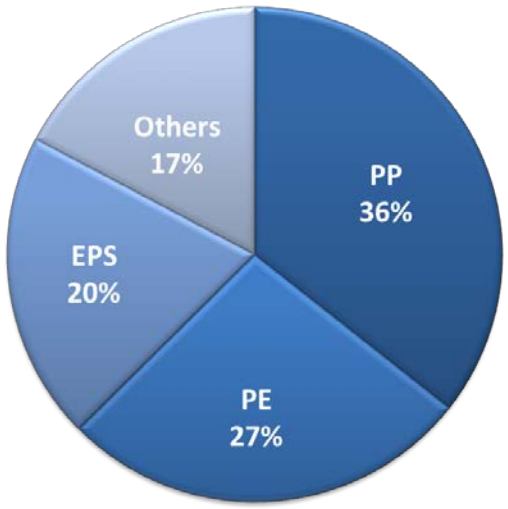




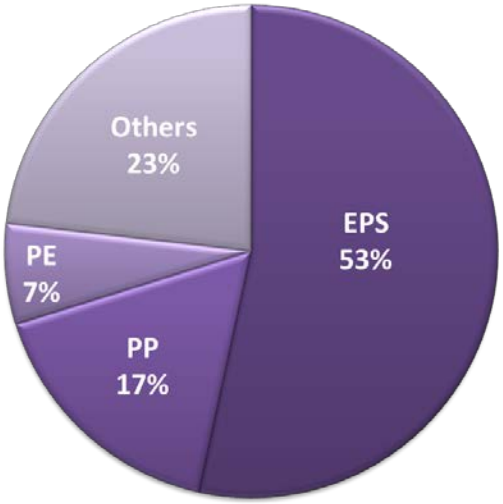
Microplastic (< 1 mm) abundance on Korean beach



Mean composition



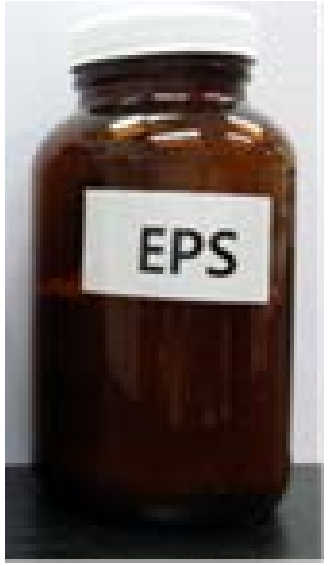
Total composition



Materials and Methods

1. Experimental condition

- Tumbler RPM: 113
- Duration: 30 day
- Bottle: 500 ml amber glass
- Glass bead: ϕ 3 mm
- Sand: Natural / ϕ 300-500 μm
- Expanded polystyrene (EPS): 40 spherules



2. Surface analysis of EPS particles using a SEM

- Field Emission-Scanning Electron Microscope
  - Jeol JSM-7600F: Surface analysis
- Samples: Experimental samples
  - EPS spherules and fragmented particles
  - Field samples (weathered EPS spherules on a beach)
- Energy Dispersive Spectroscopy (EDS) :
  - Analysis of elemental composition

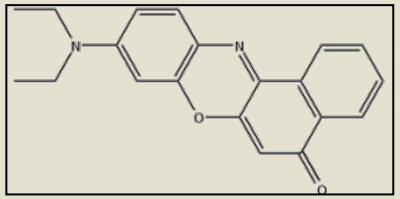
3. Density separation of EPS particles

- Separated with deionized water for three times
- Filtered using GF/F (0.75 μm pore size / 47 mm ϕ)

3. Identification of EPS particles using a FT-IR

- Fourier Transform Infra-Red (FT-IR) microscope
  - Thermo Nicolet6700-Continuμm
- 128 scans in the spectral range of 600 – 4,000 cm^{-1} at a resolution of 8 cm^{-1}.

5. Nile Red staining & fluorescence microscope counting

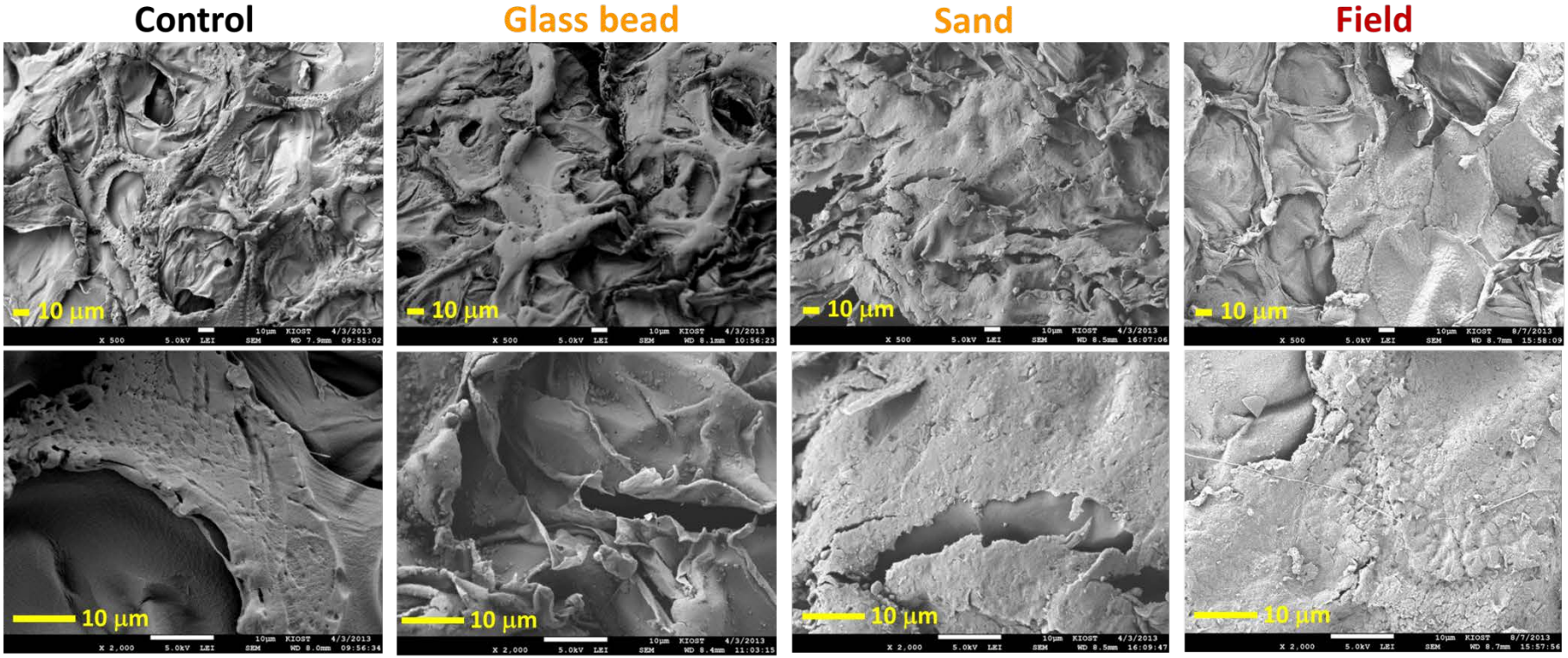


- Fluorescence dye: Nile Red (NR)
- Working solution: 50 mg /L NR in *n*-hexane
- Staining: One drop of the NR working solution on a filter paper
- Washing: Two drops of n-hexane
- Excitation / Emission wavelength: 450-490 nm / 515-565 nm
- Counting: Fluorescent microscope (Carl Zeiss Axio Imager 2)

***[Please, visit POSTER #S8-P4 for method developing in detail]**

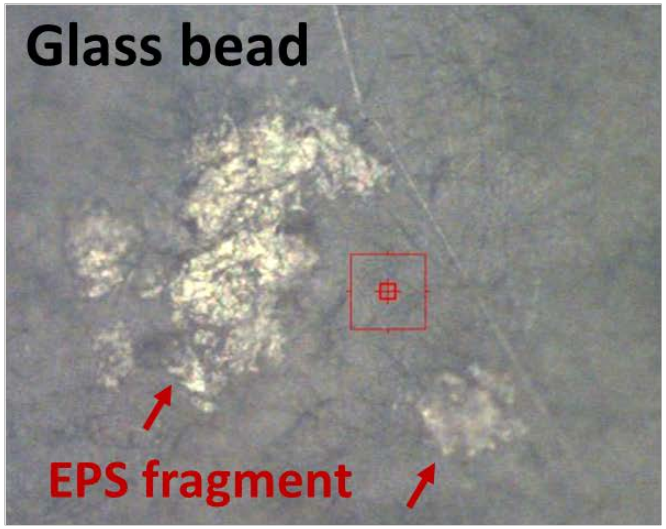
Accelerated mechanical abrasion of plastics: EPS spherule

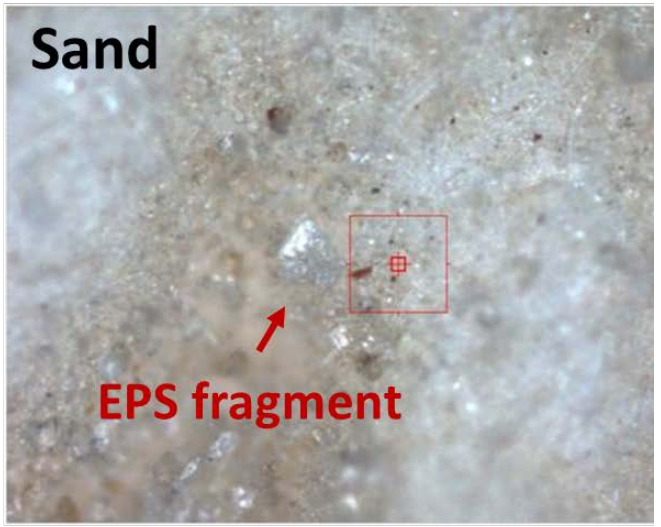
1. Surface analysis

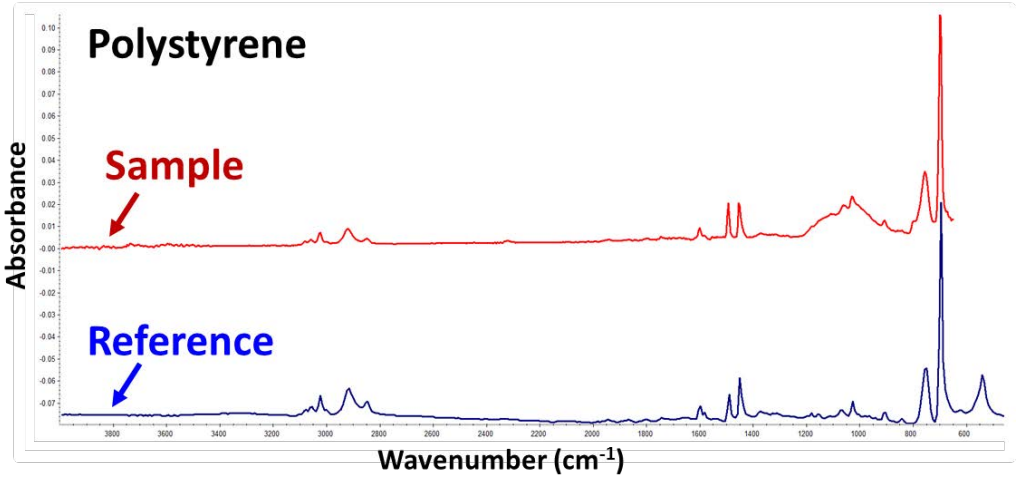


- Fragmented particles were observed on the damaged surface of the experimental (glass bead and sand treated) and field collected EPS spherules

2. Spectroscopic identification

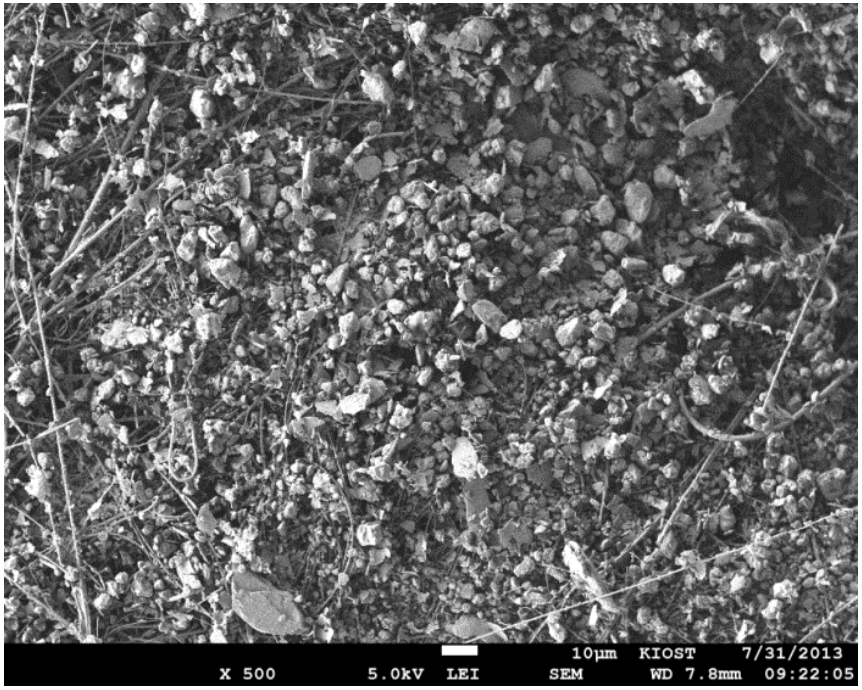


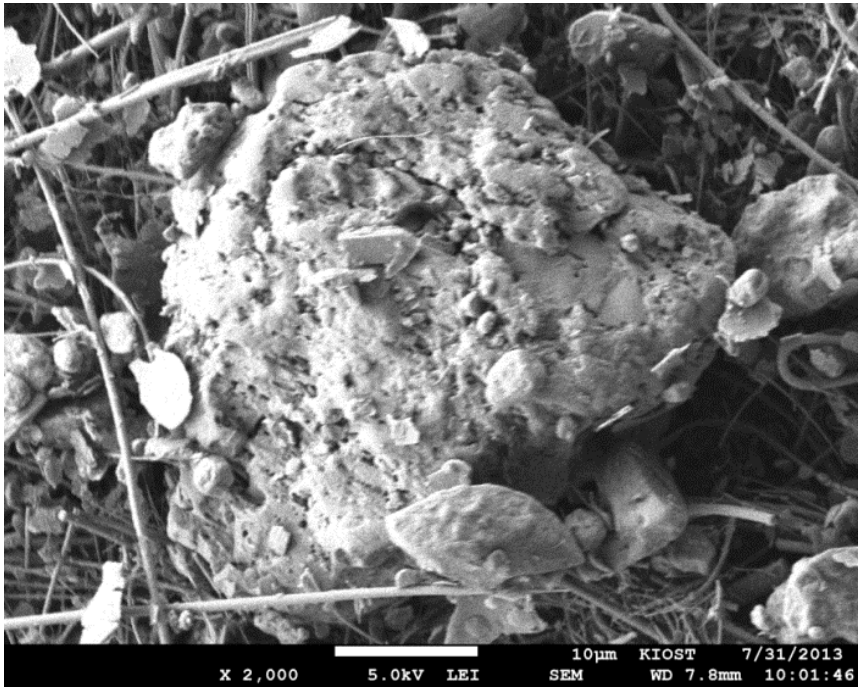




- The fragmented EPS particles on the density separated filter paper were identified and confirmed with a FT-IR microscope.

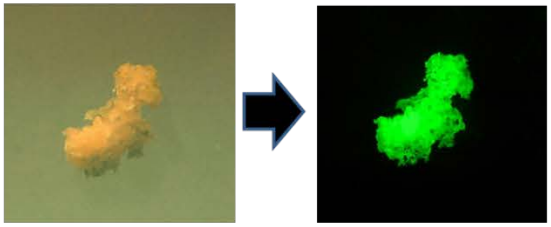
3. SEM identification



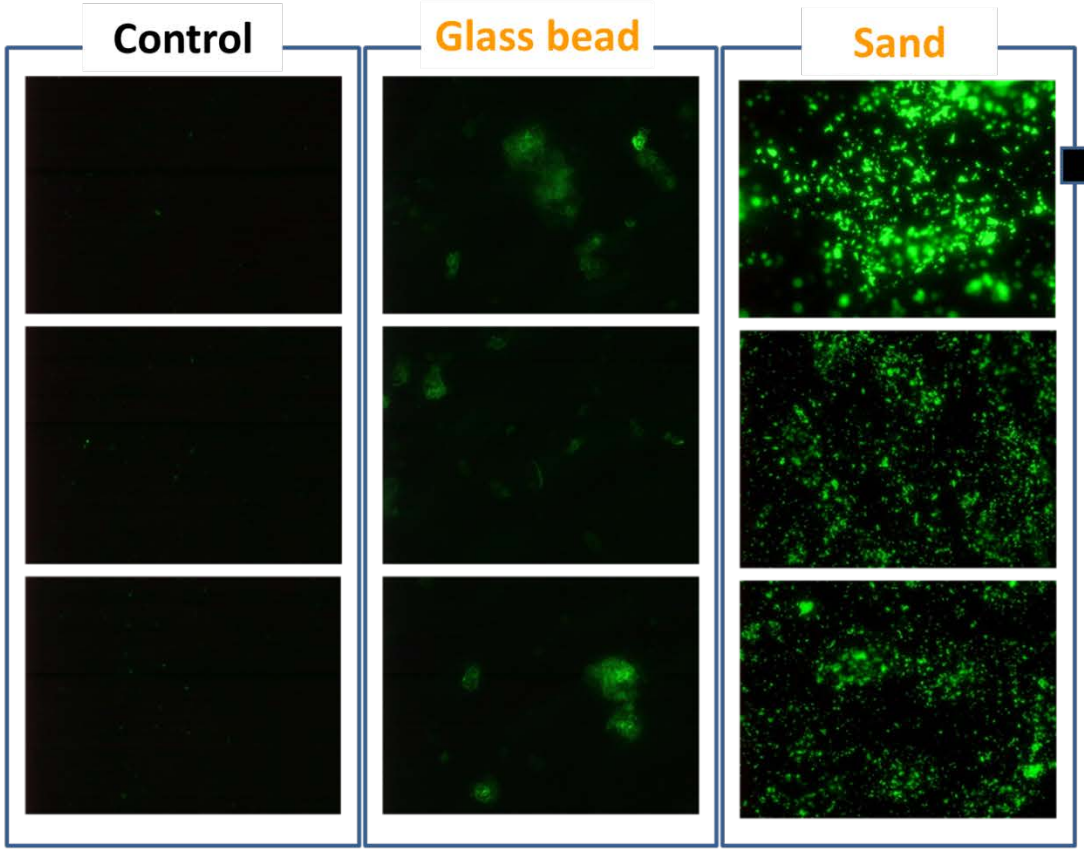


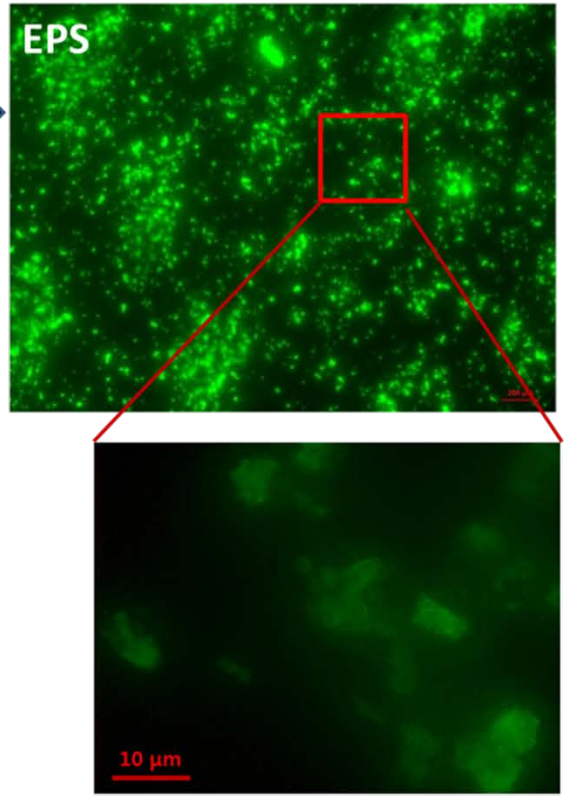
- The EPS particles can not be identified with a SEM due to a number of concurrently density separated inorganic particles

4. Nile Red staining



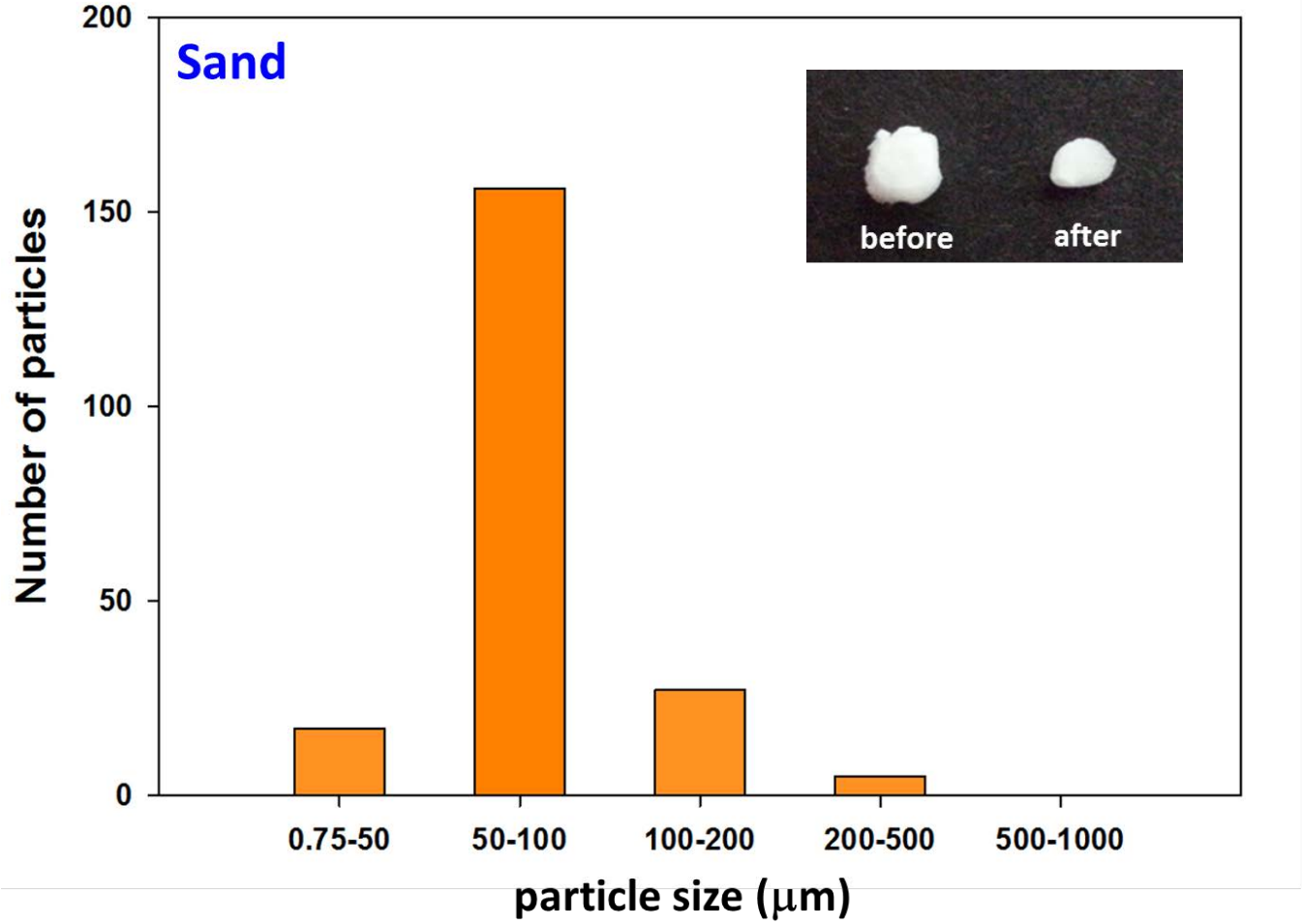
- The EPS particles were successfully stained with Nile Red under the condition developed.
- The fragmented EPS particles were stained with Nile Red and counted using a fluorescence microscope.





5. Number of fragmented EPS particles

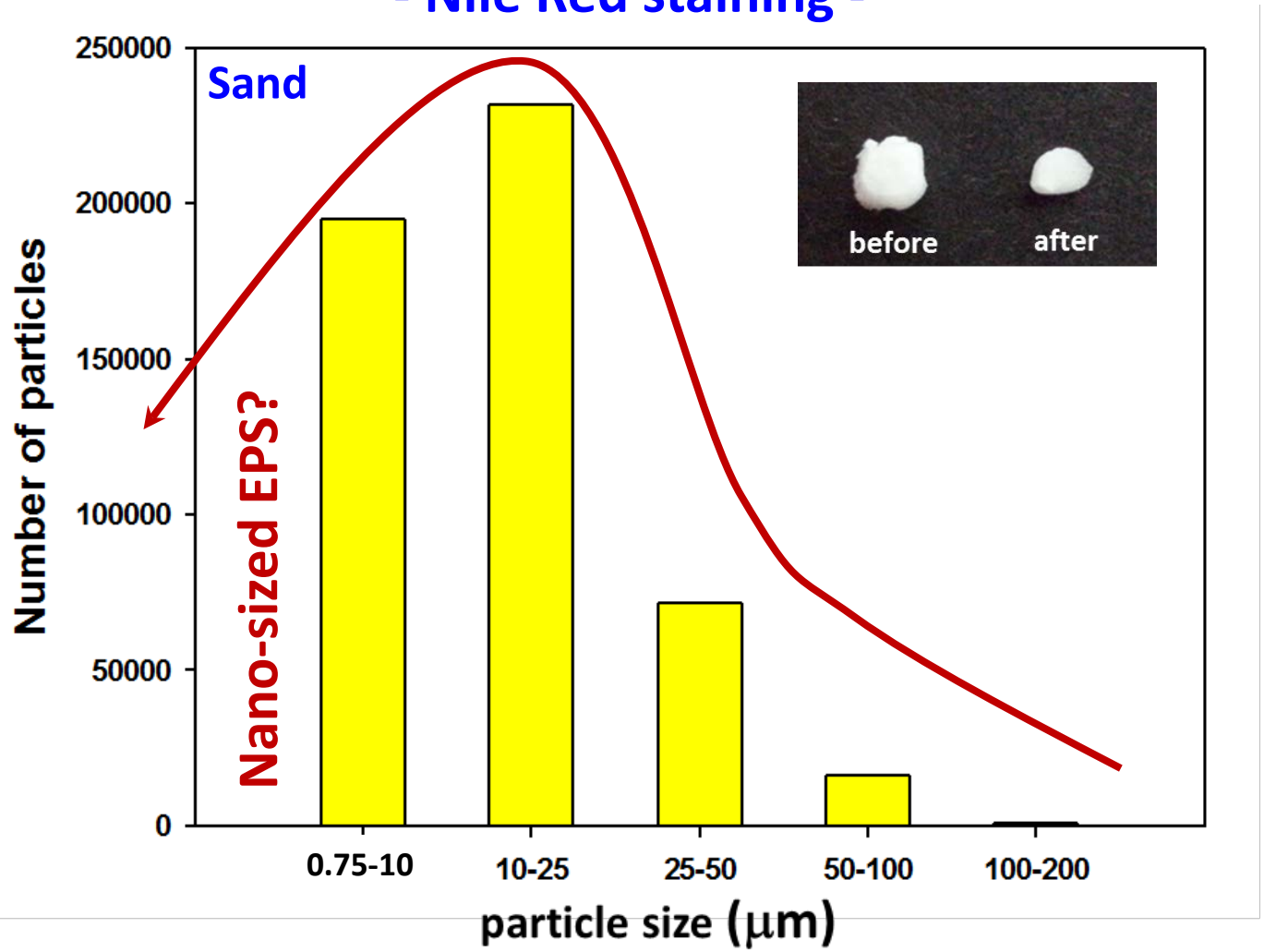
- FT-IR counting -



- Total of **820 EPS particles** were identified in the sand treated group.
- Particle size of **50-100 μm was dominant**.

5. Number of fragmented EPS particles

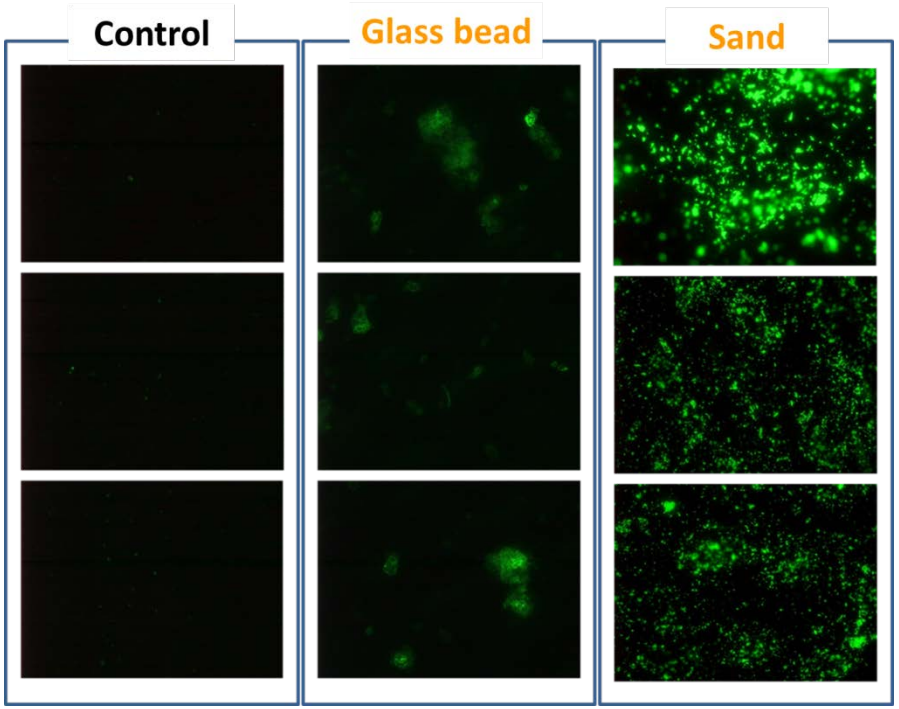
- Nile Red staining -



- Total of **515,282 EPS particles** were identified in the sand treated group.
- Smaller particles in size range of **10-25 μm and 1-10 μm were dominant**.

5. Number of fragmented EPS particles

- Nile Red staining -

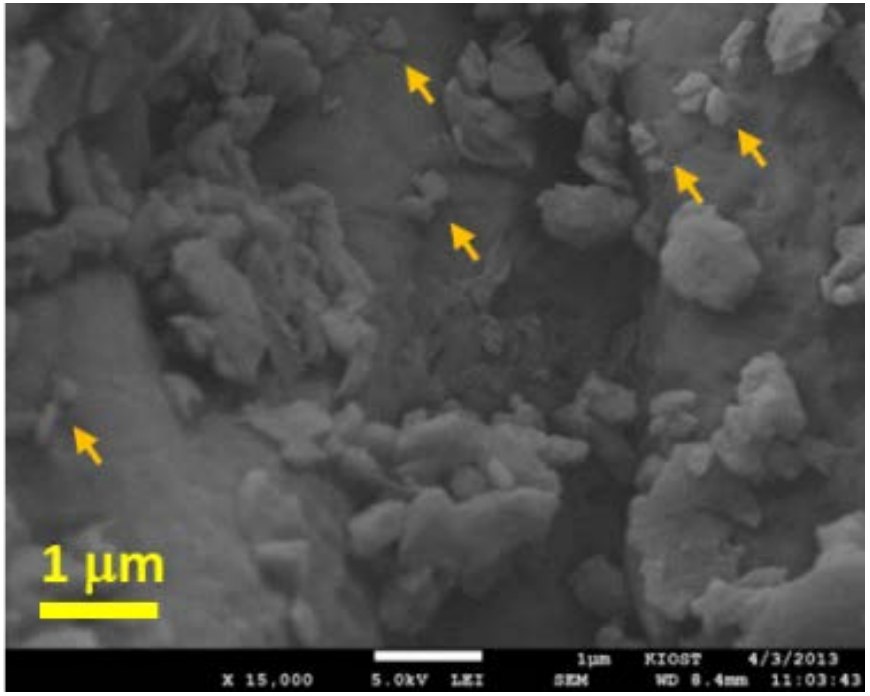


	Glass bead	Sand
Control	4,753±716	2,717±769
EPS	4,572	515,282

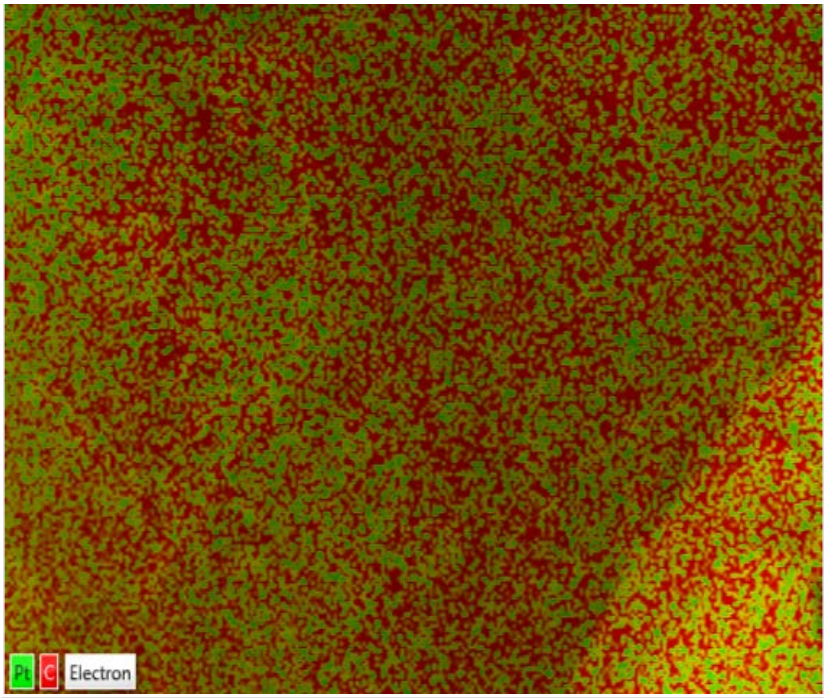
- The particles less than 1 μm in size can not be counted with a fluorescence microscope.
- The control group (glass bead or sand only) contained the NR stainable organic particles of which numbers are comparable to those in the glass bead treated group.

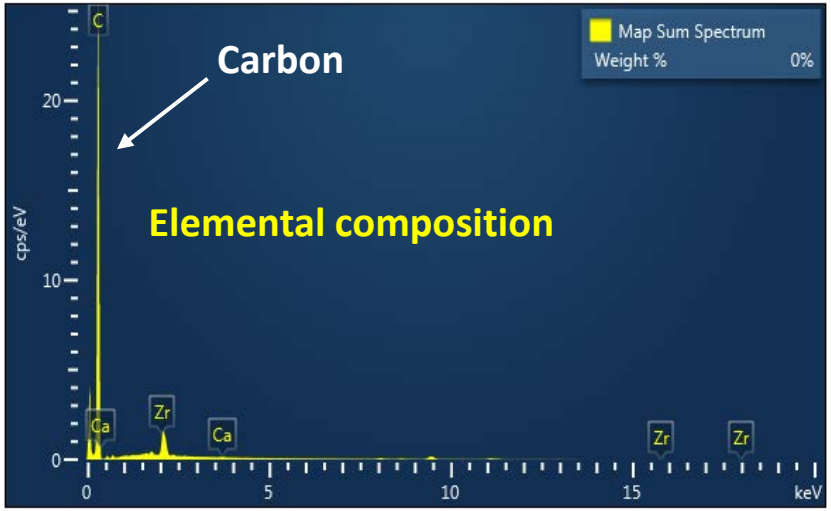
6. SEM and EDS confirmation of nano-sized EPS particles

SEM



SEM-EDS

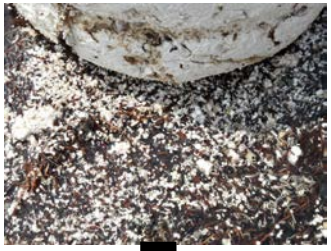




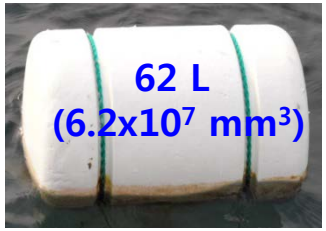
- **Question:**
  Accelerated mechanical abrasion of large plastics can produce micro-sized plastics?

- **Answer:**
  Yes and even produce nano-sized fragments

Fragmentation of standard EPS buoys used for aquaculture



Mean diameter



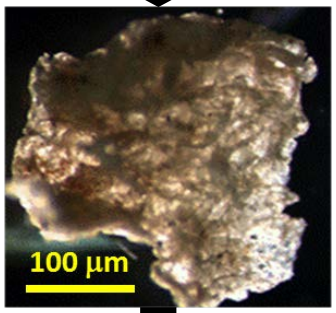
Ant

2.5 mm

7,600,000

X 10^6

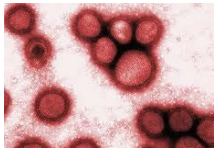
Dust mite



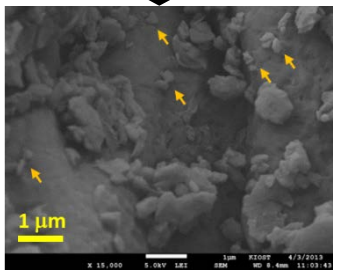
250 µm

7,600,000,000

X 10^6



Virus



250 nm

7,600,000,000,000,000,000,000

X 10^6

On-going / Further studies

- Development of method to remove micro-sized less dense inorganic mineral particles as well as biogenic materials in sand

  > 4,700 -> 70 particles

- More realistic experimental condition

  - mild mechanical abrasion at 30 rpm (PE, PP, & EPS)
  - combined effects of UV + mechanical abrasion for 60 days

  > EPS (↓), PE (↓), PP (↑)

- Development of identification method for nano-sized polymers and confirmation of them in field samples

Thank you!

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