ECO59: **FRAGMENT-MNP**

Developing a mechanistic model of Micro and NanoPlastic FRAGMentation in the ENvironmenT

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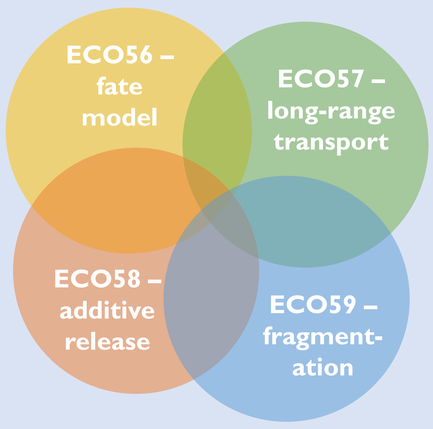
Objective

To develop and deliver a pragmatic open-source mechanistic **model of how environmental factors affect plastic fragmentation and degradation rates**

LRI Microplastics Cluster

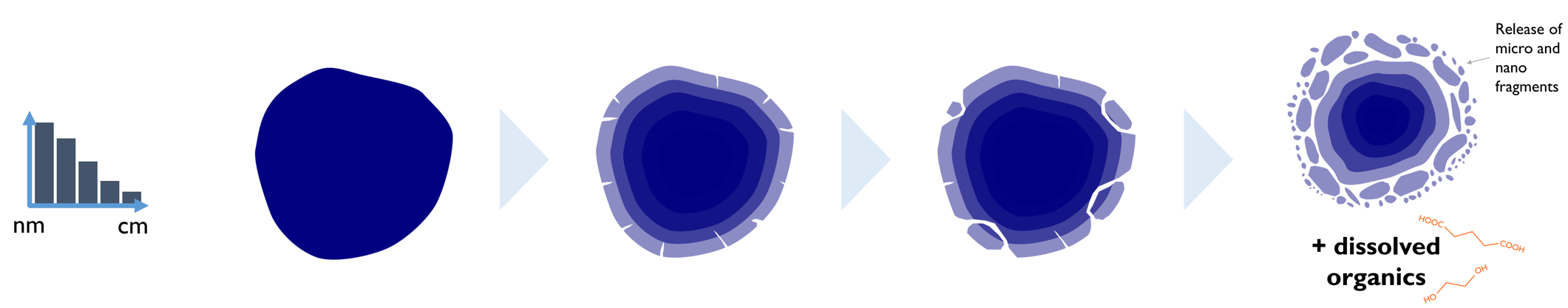
To maximise synergies between parallel projects ECO56-59, we will create an **LRI Microplastics Cluster** to enable the sharing of knowledge, data and ensure interoperability between our models.



Compartment 1: Soil — UV: Low — Biodegradation: High — Hydrolysis: Medium — *P* Power: Medium

Compartment 2: Ocean surface — UV: High — Biodegradation: Low — Hydrolysis: High — *P* Power: Medium

Compartment *N: XXX* — UV: ? — Biodegradation: ? — Hydrolysis: ? — *P* Power: ?



Chemical degradation

Degradation by environmental factors such as UV light, biodegradation and hydrolysis, makes polymer more susceptible to mechanical fragmentation. This is a function of intensity of these factors in different compartments and the polymer properties.

Mechanical fragmentation

$k_{\mathrm{frag}} \propto P$

Mechanical stress causes fragmentation of the polymer. This is a function of degradation state, polymer, and power input from fragmentation process (e.g. abrasion against sand particles), which varies amongst environmental compartments.

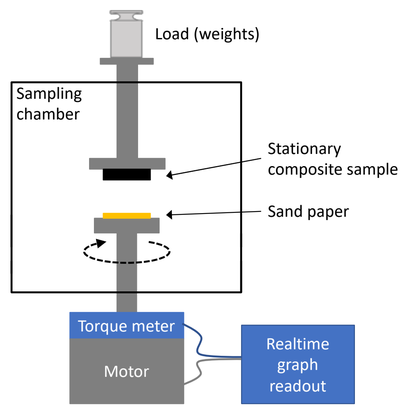
experimentally determined by

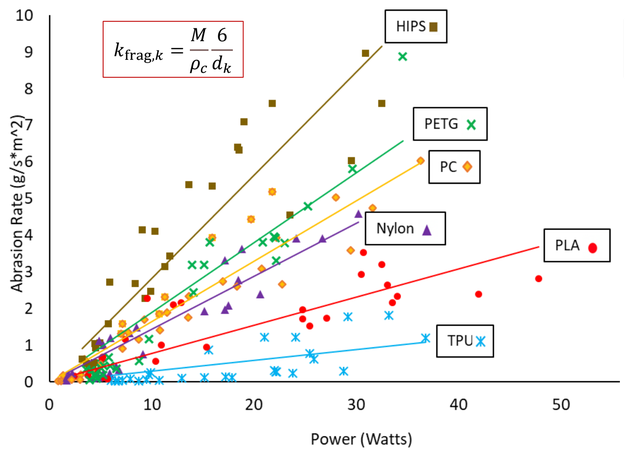
We will measure fragmentation rates of a variety of polymers that have undergone degradation by a variety of factors, covering a broad range of susceptibilities. For example:

Stress	Low susceptibility		Mid susceptibility		High susceptibility
Mechanical disruption	TPU	PLA	PA-66	PC	HIPS
Fragmentation rate [g/s/m²/W] (Duke)	0.05	0.07	0.16	0.17	0.30
Elongation at break [%] ISO 527	> 400	> 50	> 50	10	3
Hydrolysis	LDPE	PP	PET	TPU	PA
Water uptake [%] ASTM D570 // ISO 62	0.01	0.05	0.15	0.35	0.7-1.9
Photolysis	PE	PP	PA		(T)PU aromatic
Change of Yellowness index [YI] by irradiation ASTM E313, ISO4892	-1.1	6.51	8-9		10-30
MNP release by ISO irradiation [mg/MJ]	0.002	tbd	0.3		1.5
Biodegradation	PP	HDPE	TPU		PLA
Biodegradability testing, ISO 14855	< 1%	< 1%	10-60 %		> 90 %
Other properties that e.g. have been linked to nanoplastics generation	PP	HDPE	PET		PLA
Crystallinity [%]	70-80	70-80	30-40		< 10
Glass transition [°C]	-10	-120	70-80		50-80
More stresses, as requested by the literature review or stakeholders	(ideally with reference materials, e.g. from the ACC projects, or from BAM.)				

experimentally determined by

We can relate input power to mechanical abrasion M and thereby fragmentation rates and size distributions. This will be applied to polymers of varying degradation states so we can build a **database of the dependence of fragmentation on polymeric properties, degradation state and environment factors**, which will drive our model.





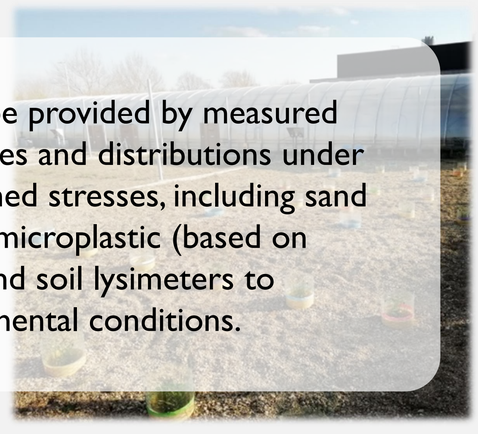
Constants vary with aging

$$k_{\mathrm{frag}} = \Phi_1 \sigma^{-\theta_1} \Phi_2 \varepsilon^{\theta_2}$$

Surface energy, dependent on degradation state, polymer and particle size

Energy dissipation rate, proportional to mechanical abrasion rates

Validation will be provided by measured fragmentation rates and distributions under single and combined stresses, including sand abrasion of aged microplastic (based on ISO/TR 22293) and soil lysimeters to simulate environmental conditions.



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