Plastic Pellets in the Environment
sources, distribution, effects and solutions

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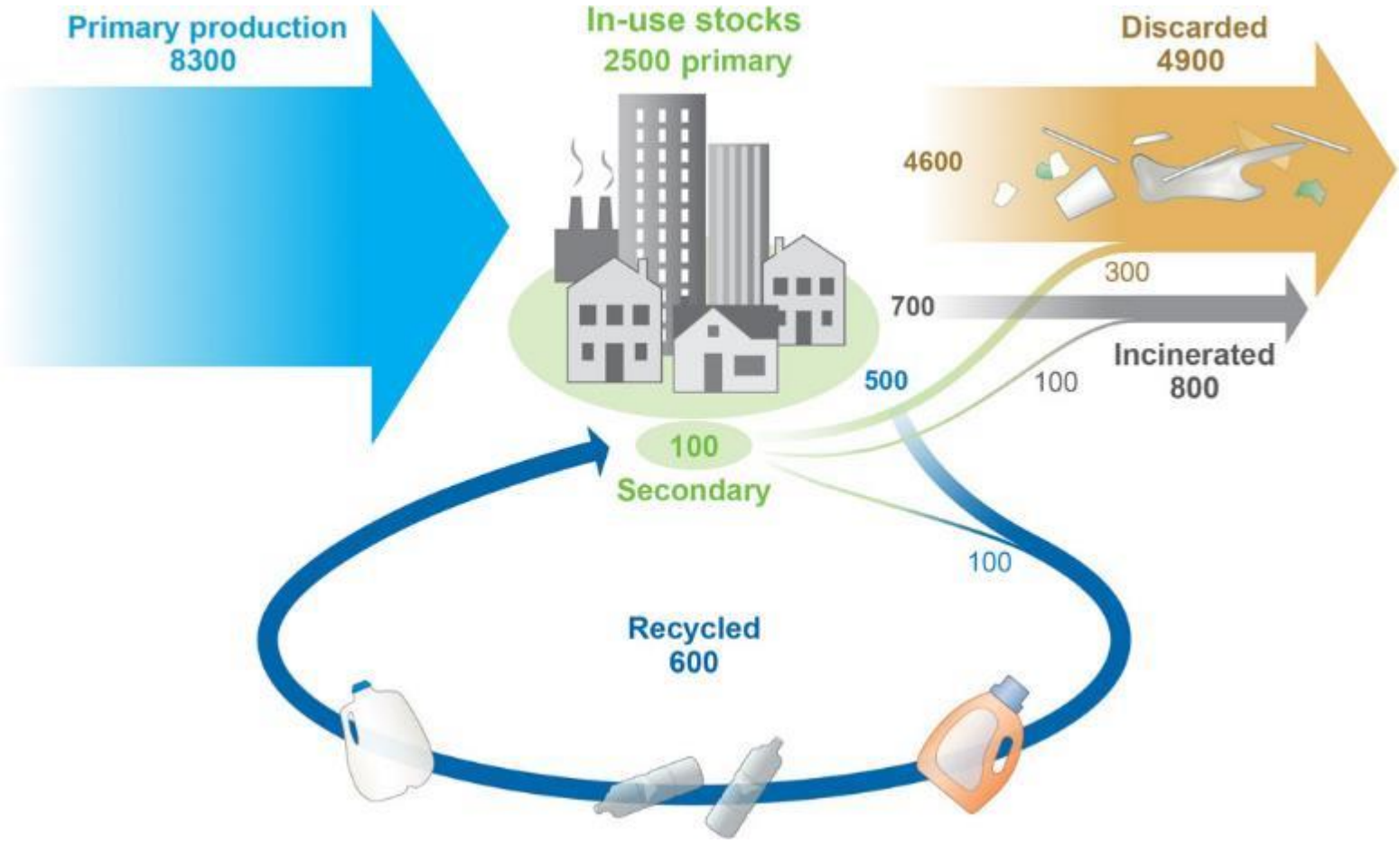
Workshop Microplastic van de Internationale Scheldecommissie
Maastricht, 28 November 2023

Universiteit Antwerpen

ECOSPHERE

Global production, use and fate of polymers, synthetic fibers and additives (1950 to 2015; in million tons)



SCIENCE ADVANCES | RESEARCH ARTICLE

PLASTICS

Production, use, and fate of all plastics ever made

Roland Geyer,[1]* Jenna R. Jambeck,[2] Kara Lavender Law[3]

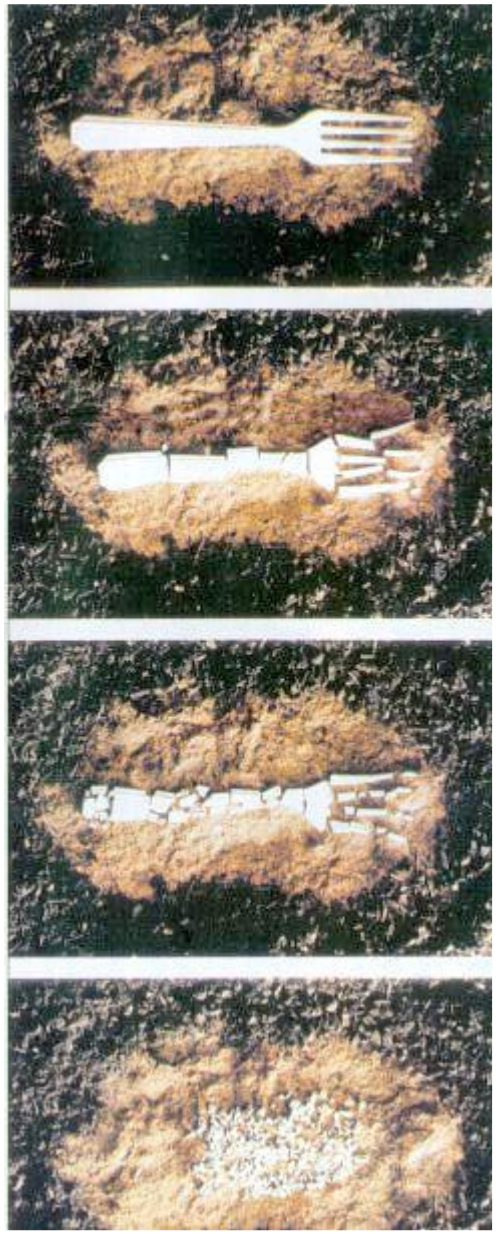
The PBT concept

P=Persistence

B=Bioaccumulation

T=Toxicity

(M=Mobility)



Plastics degradation rates and size classes

Global distribution of plastics

Macro, meso, micro and nanoplastics are omnipresent in marine and freshwater water bodies

Abundancies increase with decreasing size from macro to nano

Qualitative and quantitative analysis remains an analytical challenge but progress is made

PLOS ONE

RESEARCH ARTICLE

Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea

Marcus Eriksen[1*], Laurent C. M. Lebreton[2], Henry S. Carson[3,4], Martin Thiel[5,6,7], Charles J. Moore[8], Jose C. Borerro[9], Francois Galgani[10], Peter G. Ryan[11], Julia Reisser[12]

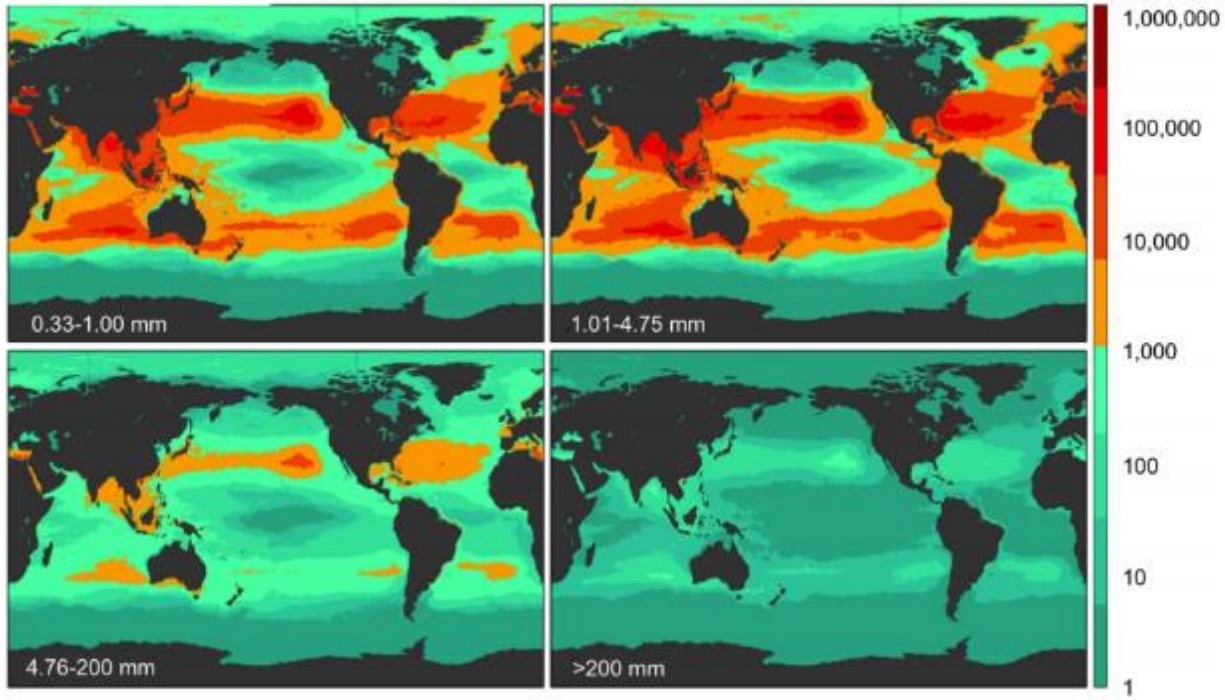


Figure 2. Model results for global count density in four size classes. Model prediction of global count density (pieces km^{-2}; see colorbar) for each of four size classes (0.33–1.00 mm, 1.01–4.75 mm, 4.76–200 mm, and >200 mm).

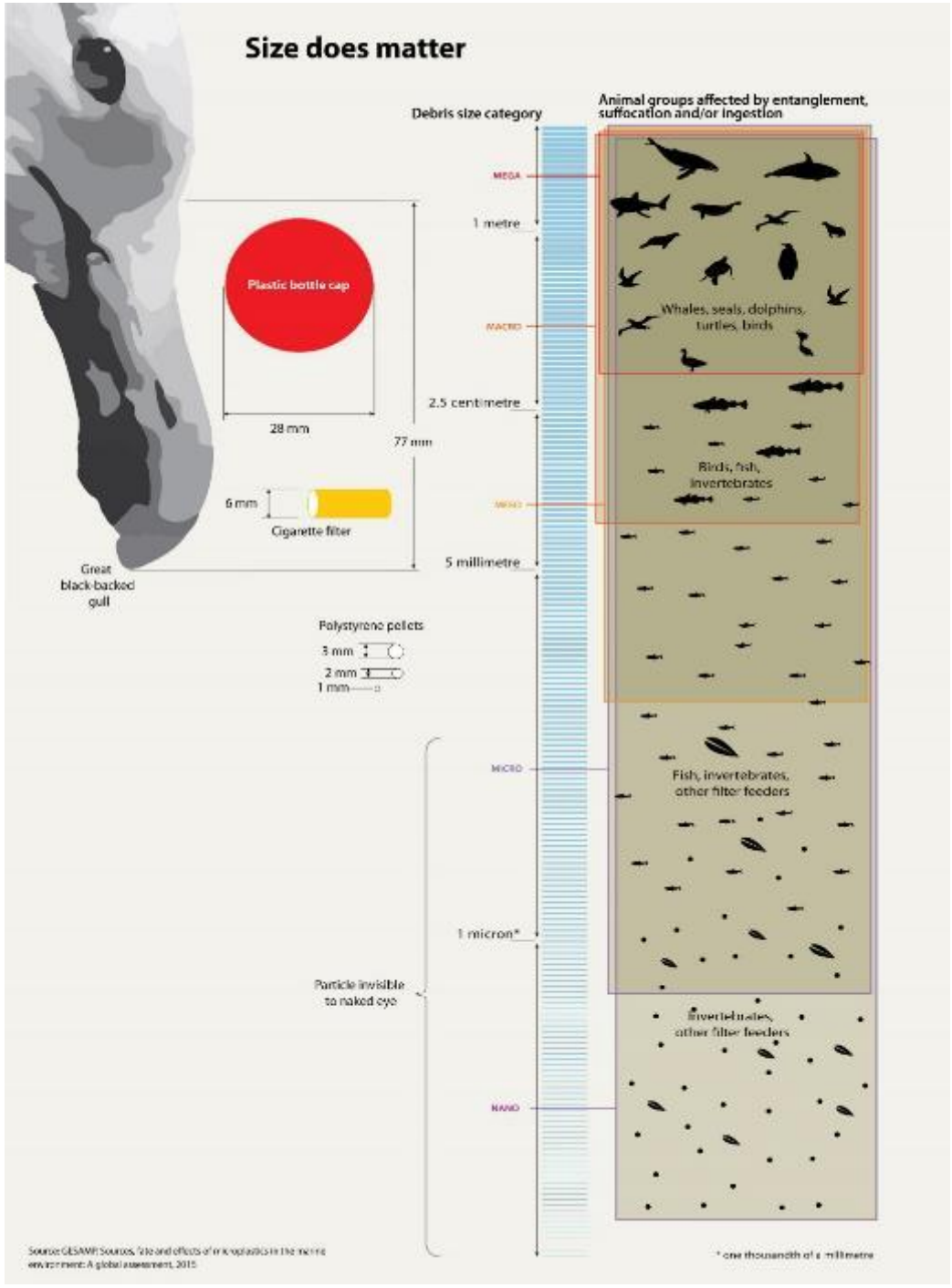
The shape and size of environmental plastics matters

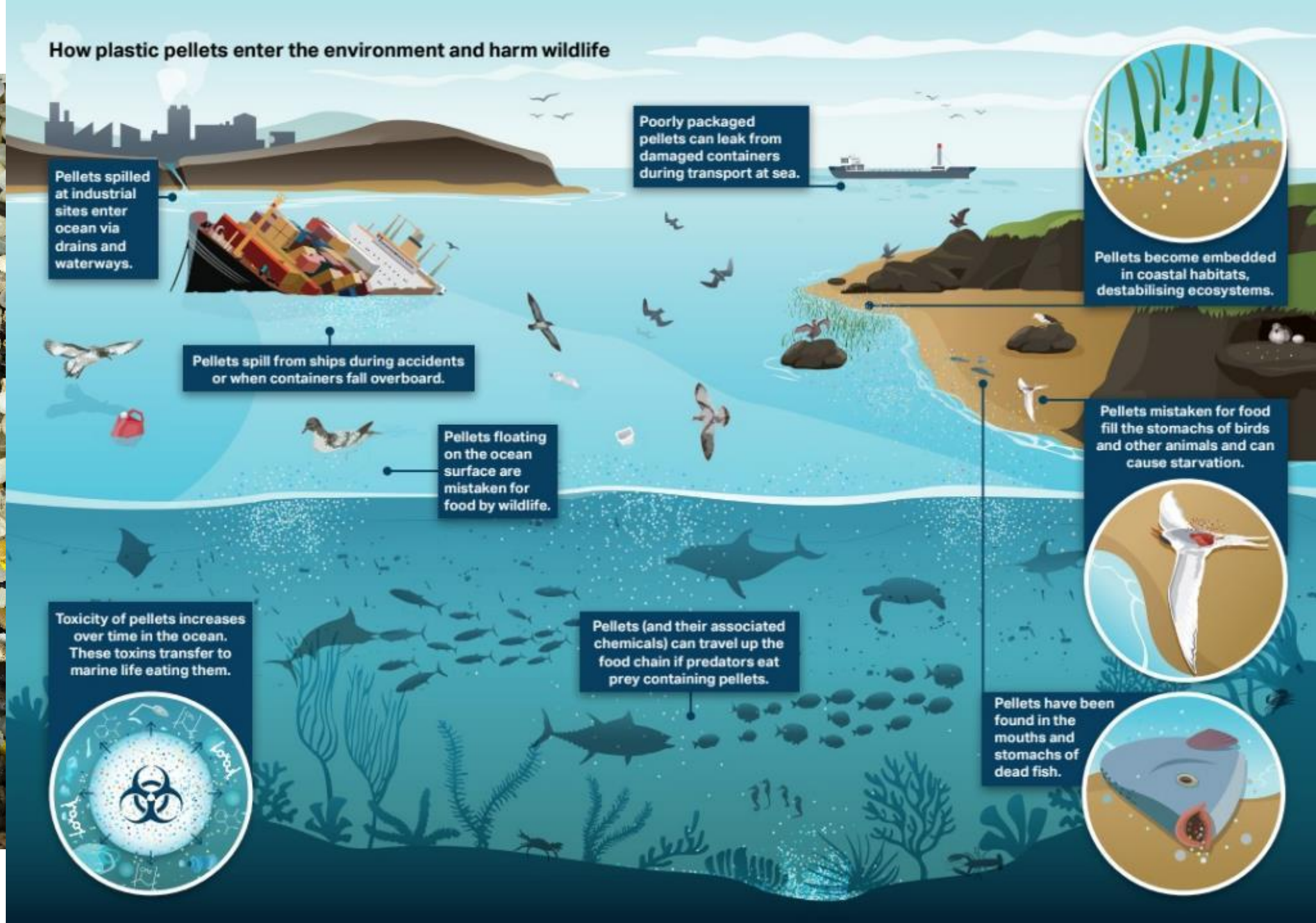
Plastic litter comes in different sizes and the nature, size and shapes determine their distribution and fate,

The availability of the plastics to biota very much depends on their structural and functional organization, this determines the actual exposure.

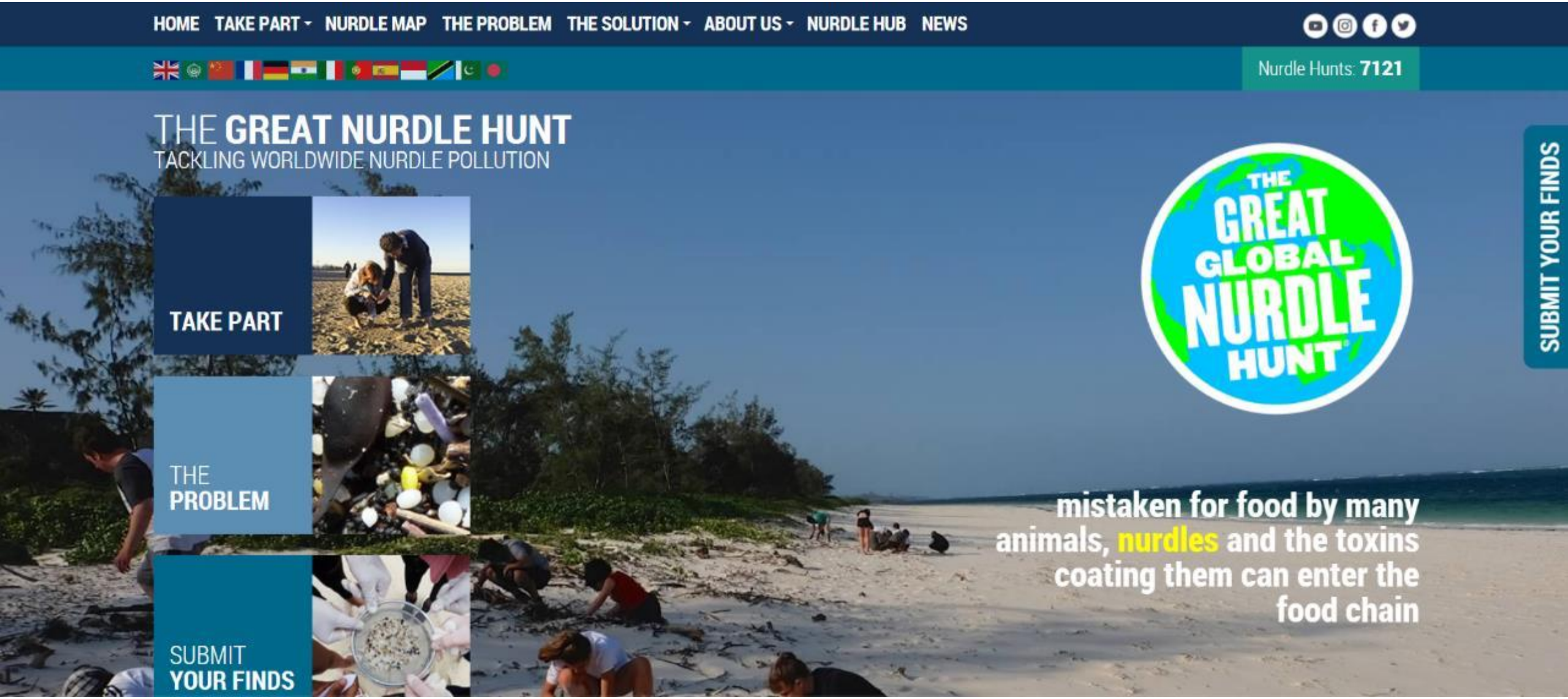
Macro-, meso- and the larger microplastics mainly cause physical (mechanical) damage, the effects of the smaller micro and nanoplastics are more of a cellular (biochemical) nature.

http://www.grida.no/resources/6924




How plastic pellets enter the environment and harm wildlife
Pellets spilled at industrial sites enter ocean via drains and waterways.
Poorly packaged pellets can leak from damaged containers during transport at sea.
Pellets become embedded in coastal habitats, destabilising ecosystems.
Pellets spill from ships during accidents or when containers fall overboard.
Pellets floating on the ocean surface are mistaken for food by wildlife.
Pellets mistaken for food fill the stomachs of birds and other animals and can cause starvation.
Toxicity of pellets increases over time in the ocean. These toxins transfer to marine life eating them.
food
food
Pellets (and their associated chemicals) can travel up the food chain if predators eat prey containing pellets.
Pellets have been found in the mouths and stomachs of dead fish.

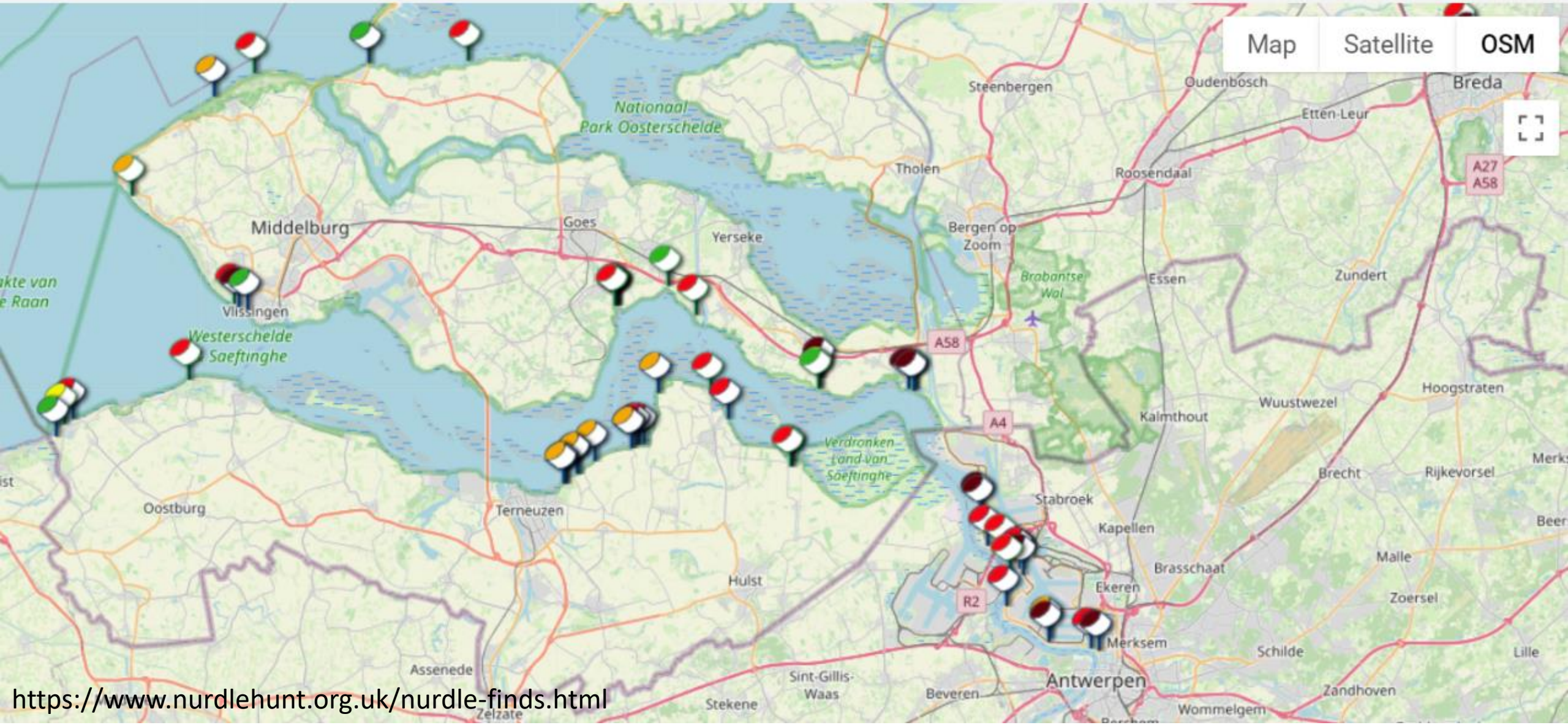
Citizen monitoring projects help to visualize the global distribution of plastic pellets



https://www.nurdlehunt.org.uk/

Key:

= more than 1000 nurdles = 101-1000 nurdles = 31-100 nurdles = 1-30 nurdles = 0 nurdles



https://www.nurdlehunt.org.uk/nurdle-finds.html

Port of Antwerp-Pellet flux project

Goals of the project:

Short term

Mapping of plastic pellet distribution in the harbour public domain.

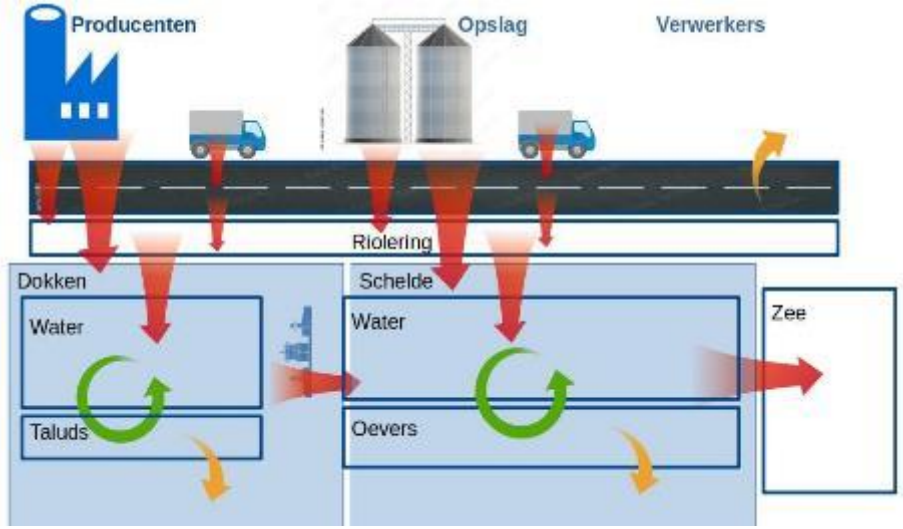
Identification of critical points of pellet loss along transport routes.

Long term

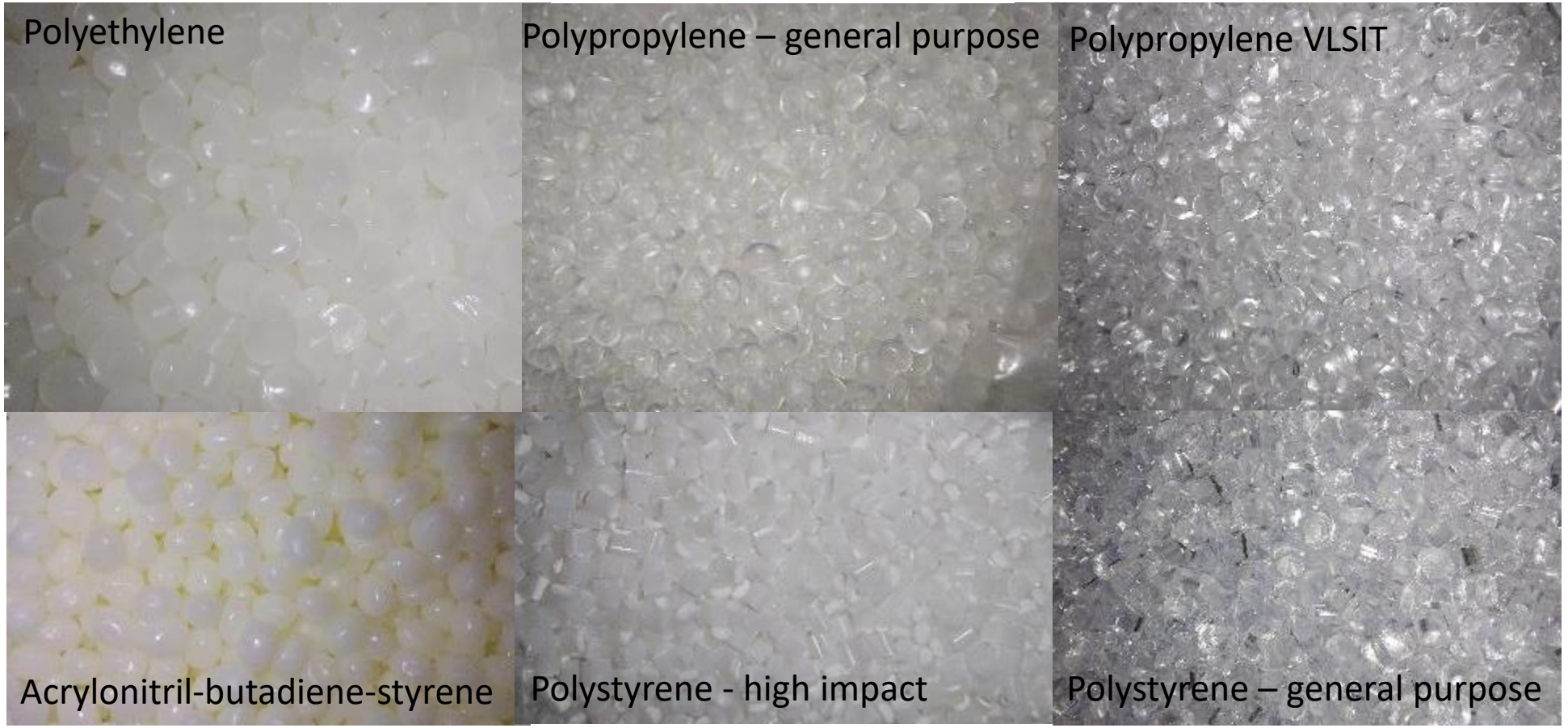
Dynamics of pellet concentrations following clean-up and other measures.

Distribution and loss of pellets to the docks and Scheldt estuary.

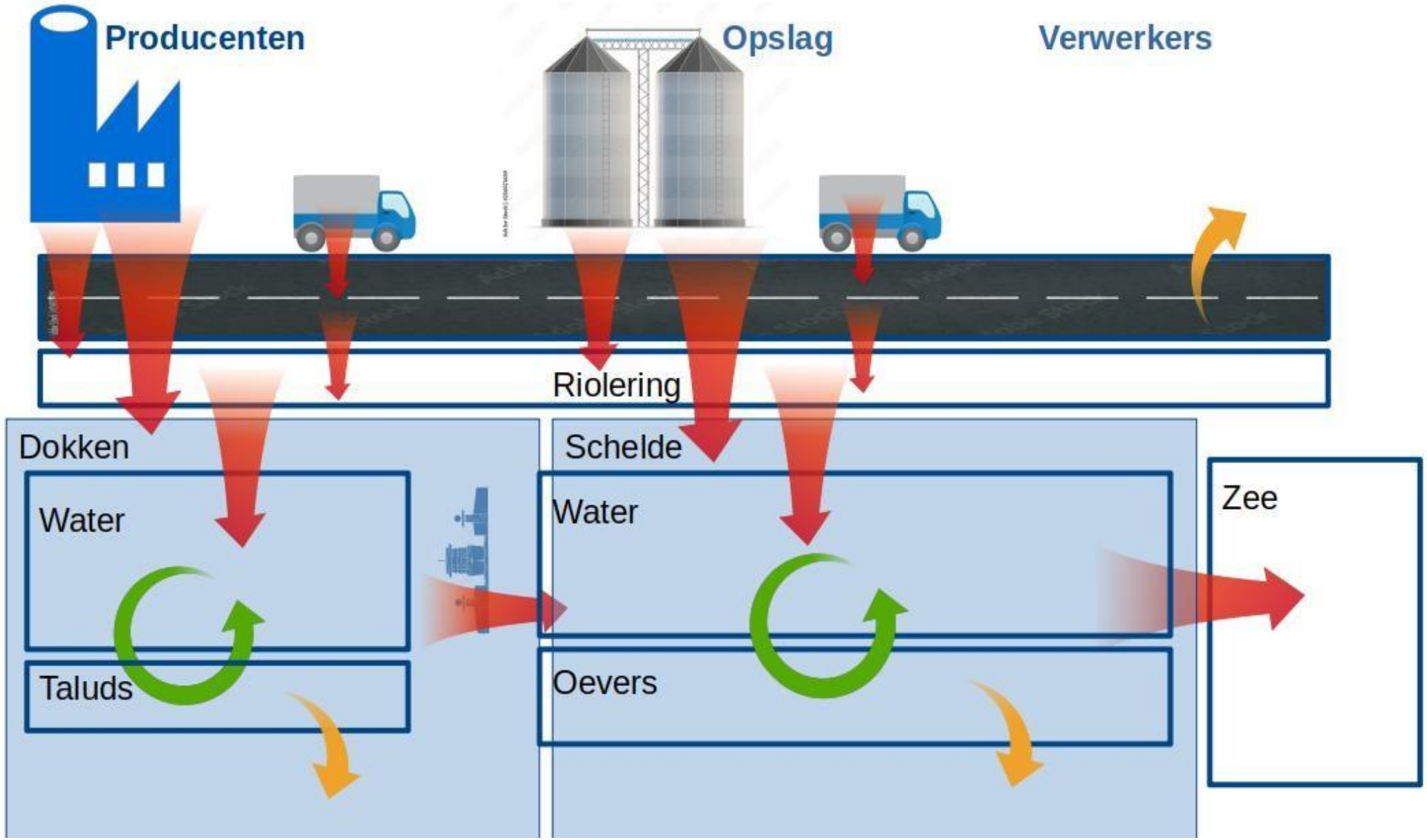
Exposure of wildlife and effects.

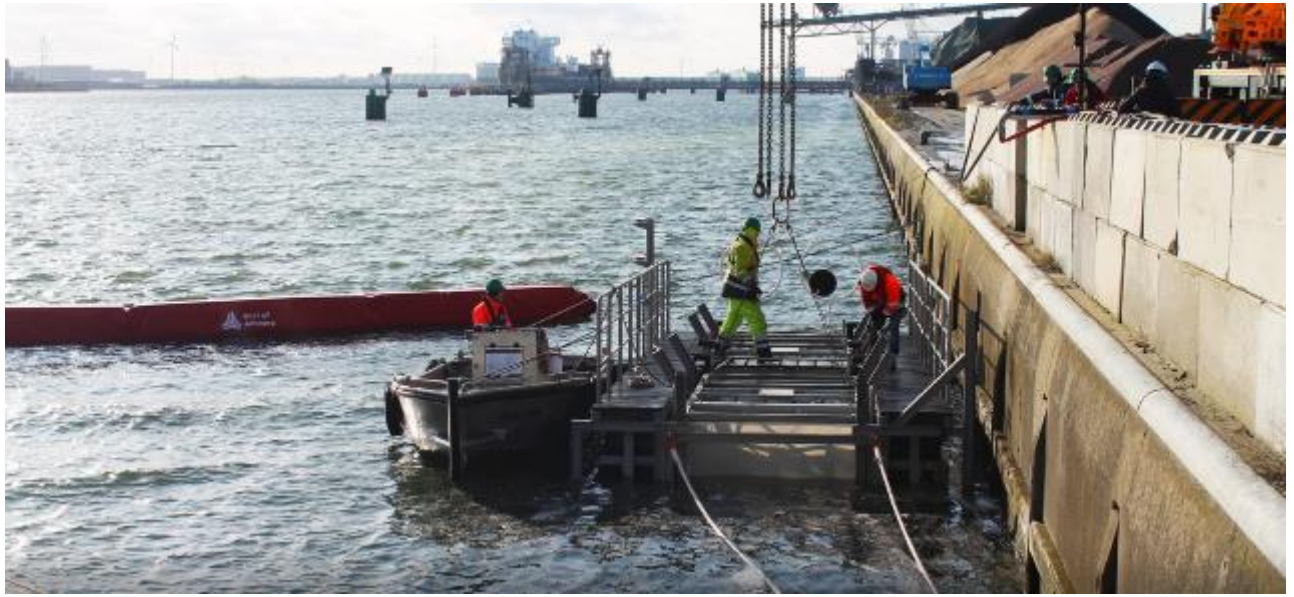


In the Port of Antwerp different types of pellets are produced, packed and transported

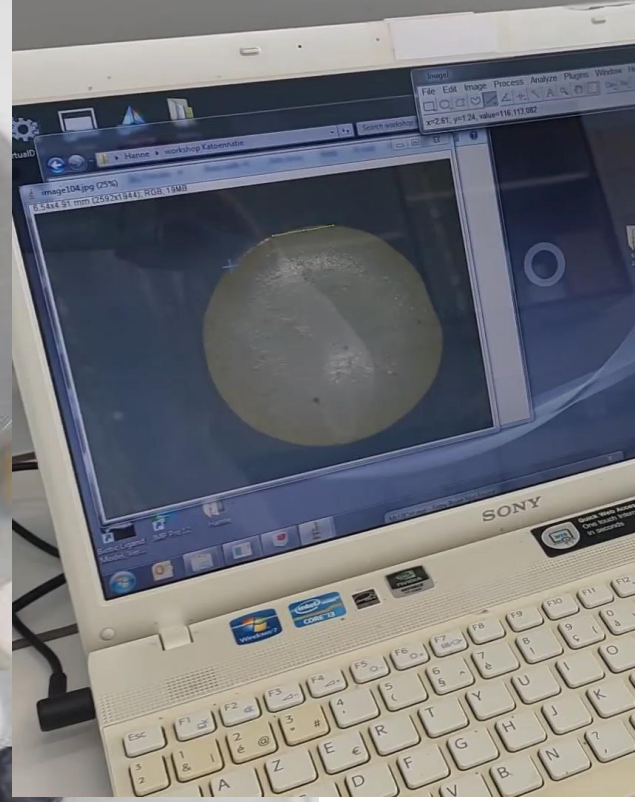


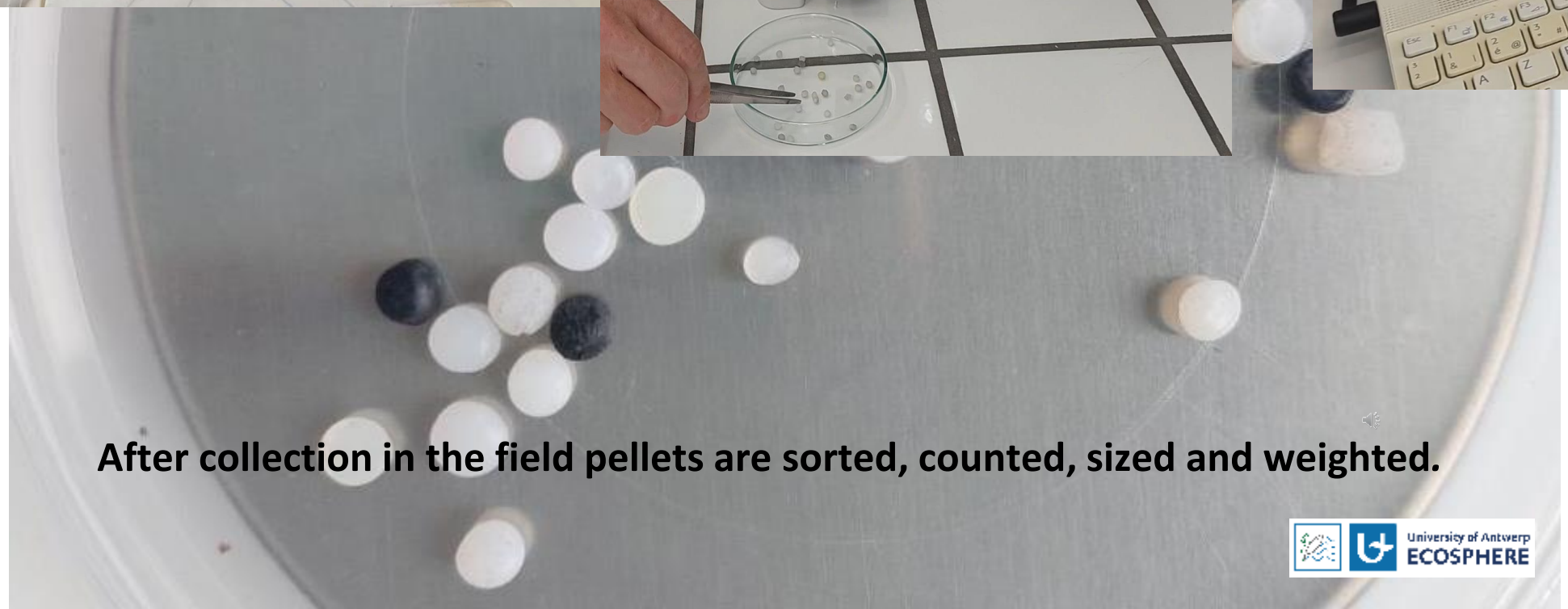
During the production and handling a small but significant part of the pellets are lost and enter the sewage system, are lost on the route during transport or shipping and finally end up in the docks and estuary


Producenten
Opslag
Verwerkers
Riolering
Dokken
Water
Taluds
Schelde
Water
Oevers
Zee




NUL-O-PLASTIC
JAWDEVIL.COM





After collection in the field pellets are sorted, counted, sized and weighted.

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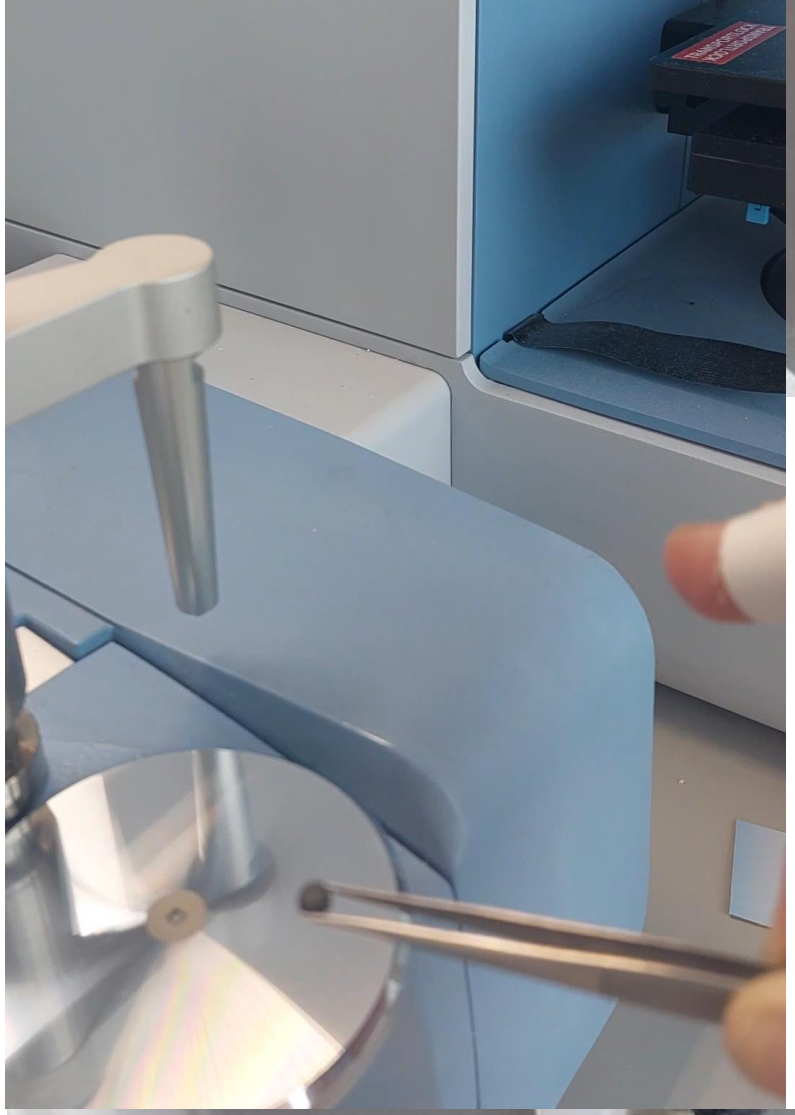

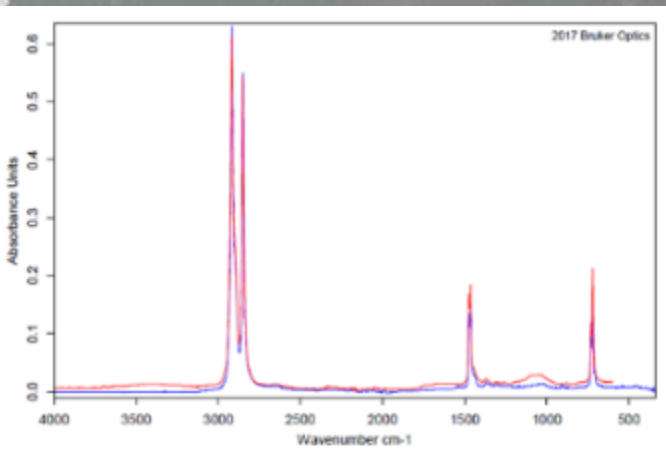

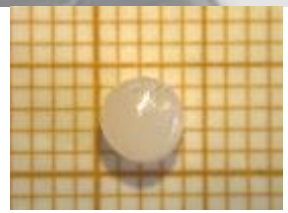

Polymer	PE-HD
CAS Registry Number	9002-88-4
Substance	polyethylene, high density
Trade Name	Alcudia 49070-UV
Supplier	Repsol
Filler	unfilled
Color	natural
Applications	container, tanks
MVR/MFR	9 g/ 10 min (21.6 kg/ 190 °C)
Density	0.949

Color	Hit Quality	Compound name	CAS Number	Molecular formula	Molecular weight
	960	PE-HD	9002-88-4		

Color	File	Path	Spectrum Type
	H.0	C:\Users\Administrator\Documents\Hanne Diels	Query Spectrum

The type of polymer is determined using Fourier Transform Infra Red spectrometry

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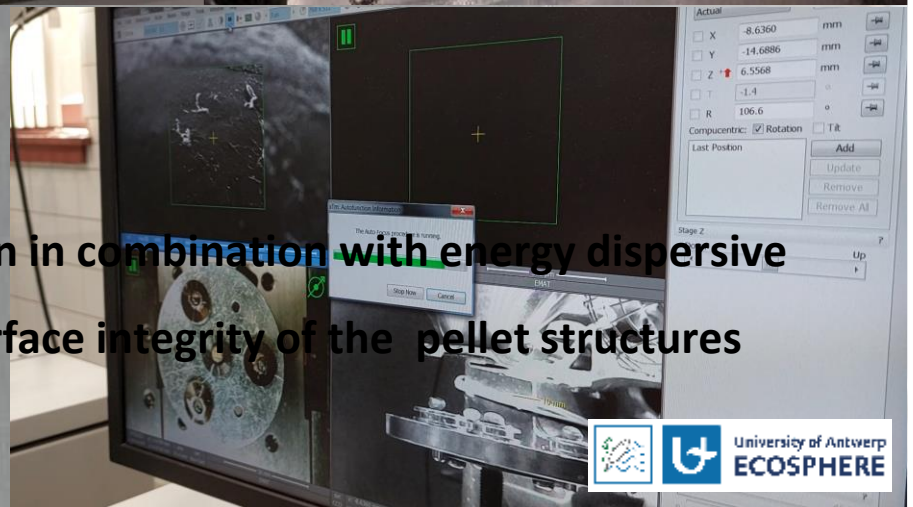

Scanning electron microscopy in combination in combination with energy dispersive spectroscopy are used to investigate the surface integrity of the pellet structures

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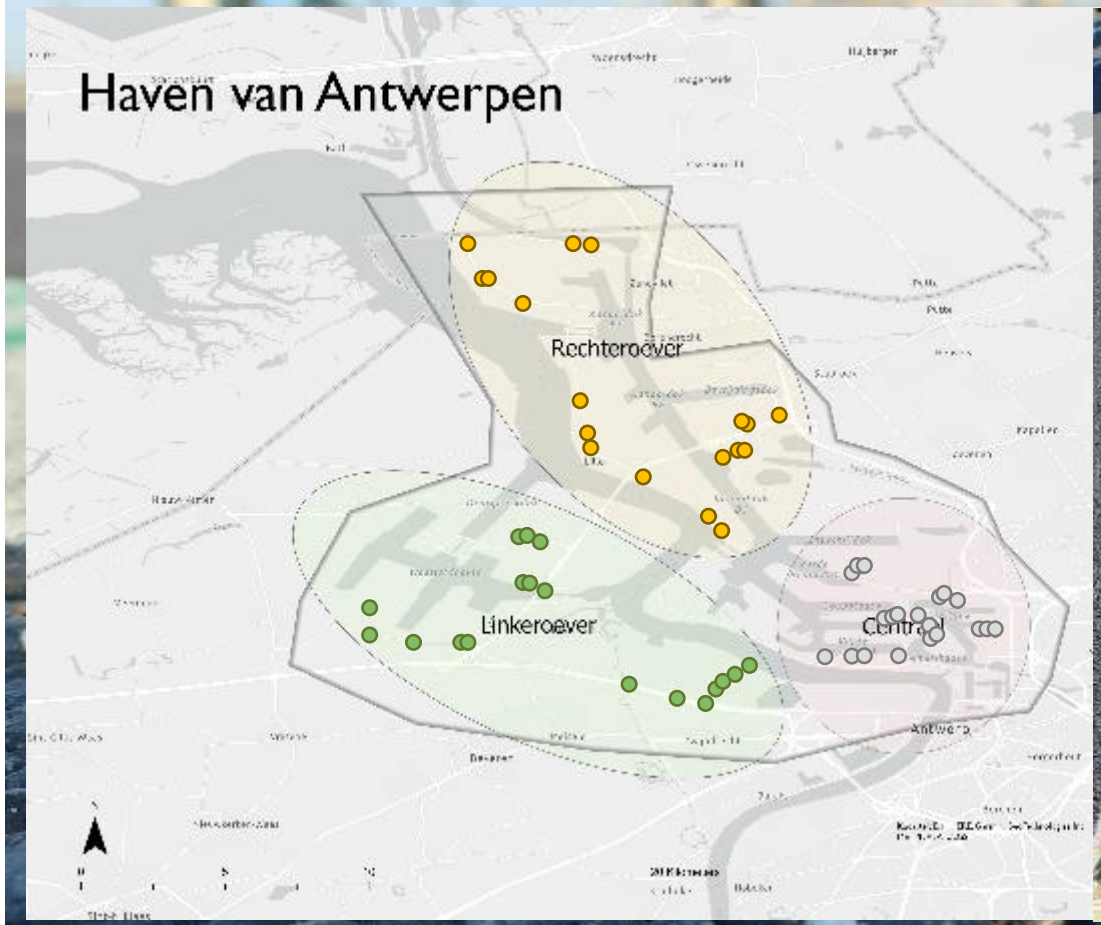
Methodology

Port is divided in zones, plots, subplots, replicates



3 zones

17 plots

57 subplots

171 frames

! Critical points of pellet loss
(close to a company or transportation route, in a turn, entrance, exit, roundabout, traffic light)

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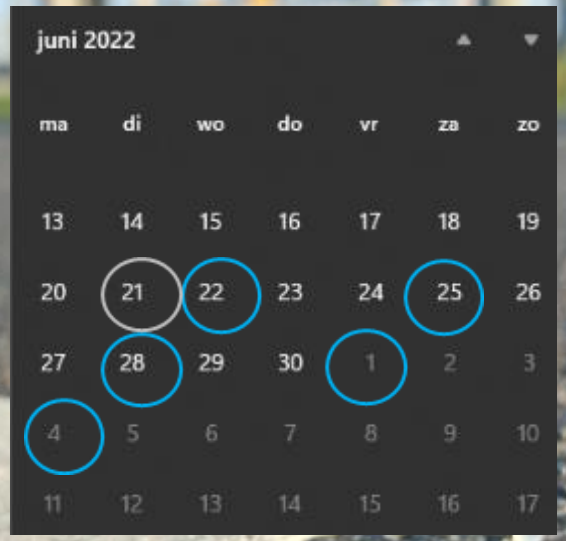
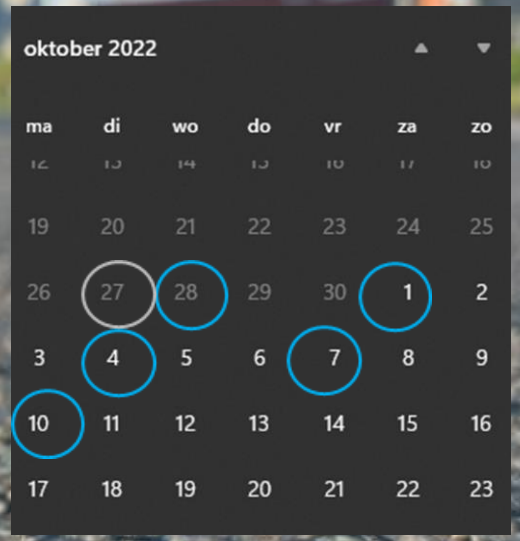
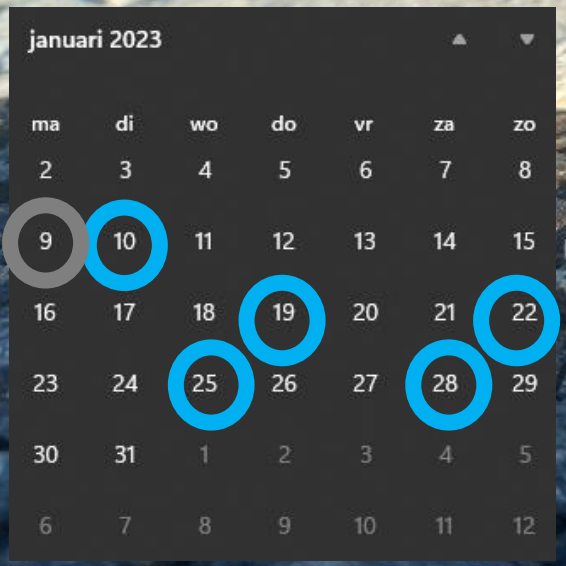
Methodology

Spring, summer, autumn 2022 and winter 2023







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Results

Spring, summer, autumn 2022 and winter 2023

Raw data: total number of pellets sampled on all subplots (42.75 m²)								
Season	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**	**Day 15**	**Day 18**	**Sum**
Spring 2022	5564	1031	886	720	548			8749
Summer 2022	724	598	459	483	277			2541
Autumn 2022	530	267	261	420	182			1660
Winter 2023	616			984	501	338	293	2732
Sum								**15682**

15.682 plastic pellets (492 gram)

4 sampling campaigns

each 5 sampling days

total area 42.75 m²

- Although the road was swept, most pellets were found on day 0 in spring, summer and autumn
- Wintersampling differed; more pellets could accumulate between day 0 and day 9, resulting in a larger number of pellets on day 9.

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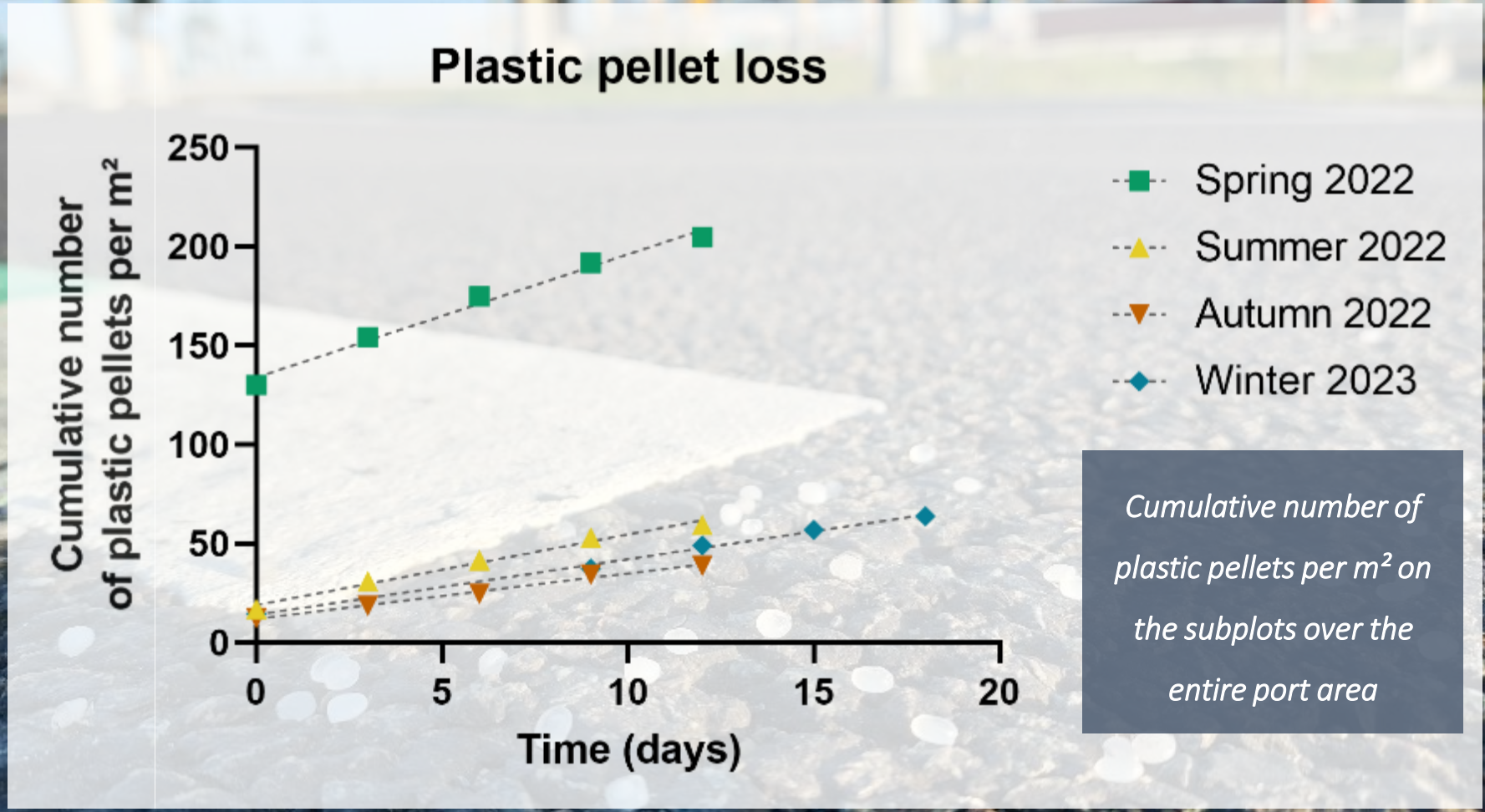
Results

Spring, summer, autumn 2022 and winter 2023



Cumulative number of plastic pellets per m² on the subplots over the entire port area

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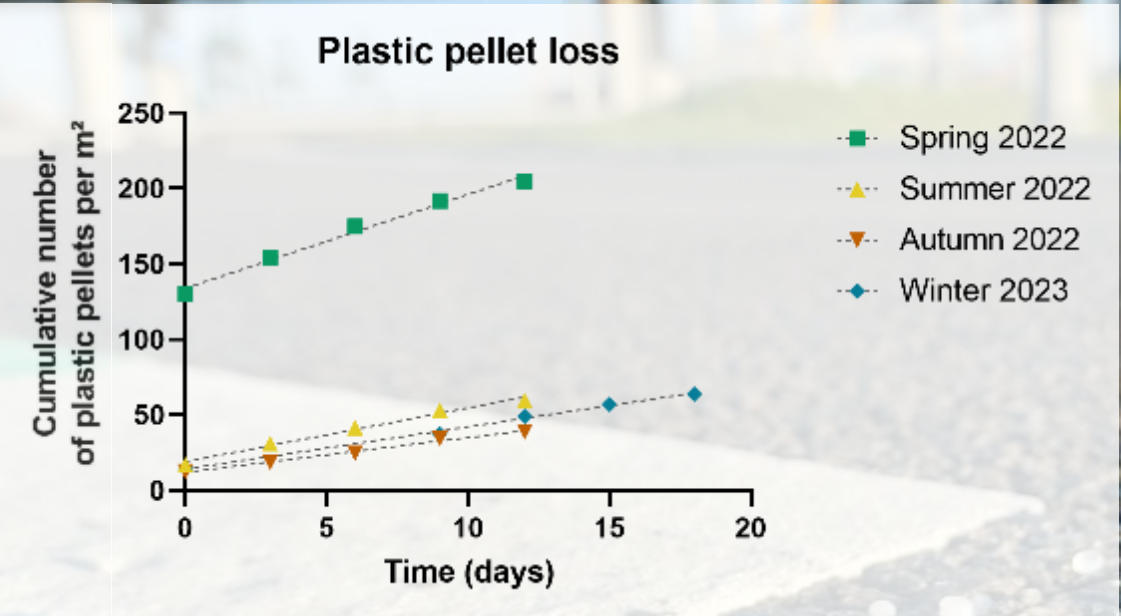
Results

Spring, summer, autumn 2022 and winter 2023



*Y = a*X + b*

a = slope

Plastic pellet loss per m²

b = Y-intercept

Number of pellets on day 0

Season	Function (Y = a*X + b)	95% slope interval (a) Plastic pellet loss per m²	R^2	N
Spring 2022	Y = 6.219*X + 133.9	4.8 to 7.6	0.9858	5
Summer 2022	Y = 3.568*X + 18.98	2.8 to 4.3	0.9859	5
Autumn 2022	Y = 2.293*X + 12.08	1.8 to 2.7	0.9887	5
Winter 2023	Y = 2.808*X + 14.06	2.5 to 3.2	0.9954	5

Average plastic pellet loss : 3.0 to 4.5 plastic pellets per day and per m²

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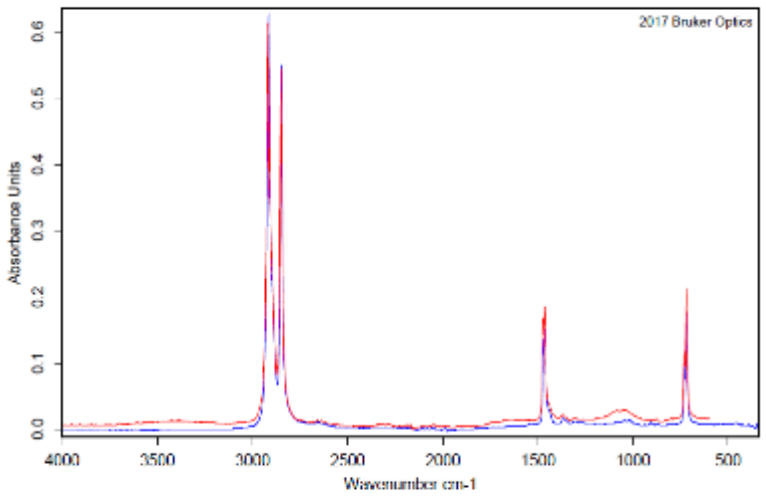
Results

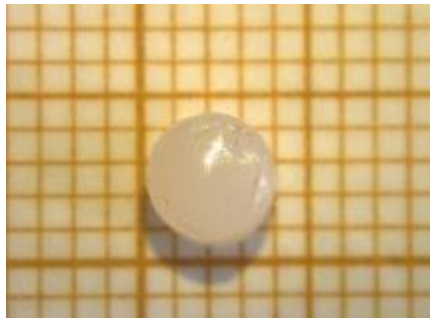
Polymertypes

50 types of plastic pellets were identified, based on physical properties (color, shape, size, density)

7 polymer types were identified using Fourier Transform Infrared Spectroscopy

Library Search





Polymer	PE-HD
CAS Registry Number	9002-88-4
Substance	polyethylene, high density
Trade Name	Alcudia 49070-UV
Supplier	Repsol
Filler	unfilled
Color	natural
Applications	container, tanks
MVR/MFR	9 g/ 10 min (21,6 kg/ 190 °C)
Density	0,949

Color	Hit Quality	Compound name	CAS Number	Molecular formula	Molecular weight
	960	PE-HD	9002-88-4		

Color	File	Path	Spectrum Type
	H.0	C:\Users\Administrator\Documents\Hanne Diels	Query Spectrum

Page 1 of 1

Example spectrumanalysis of PE: Red = own spectrum; Blue = spectrum from library

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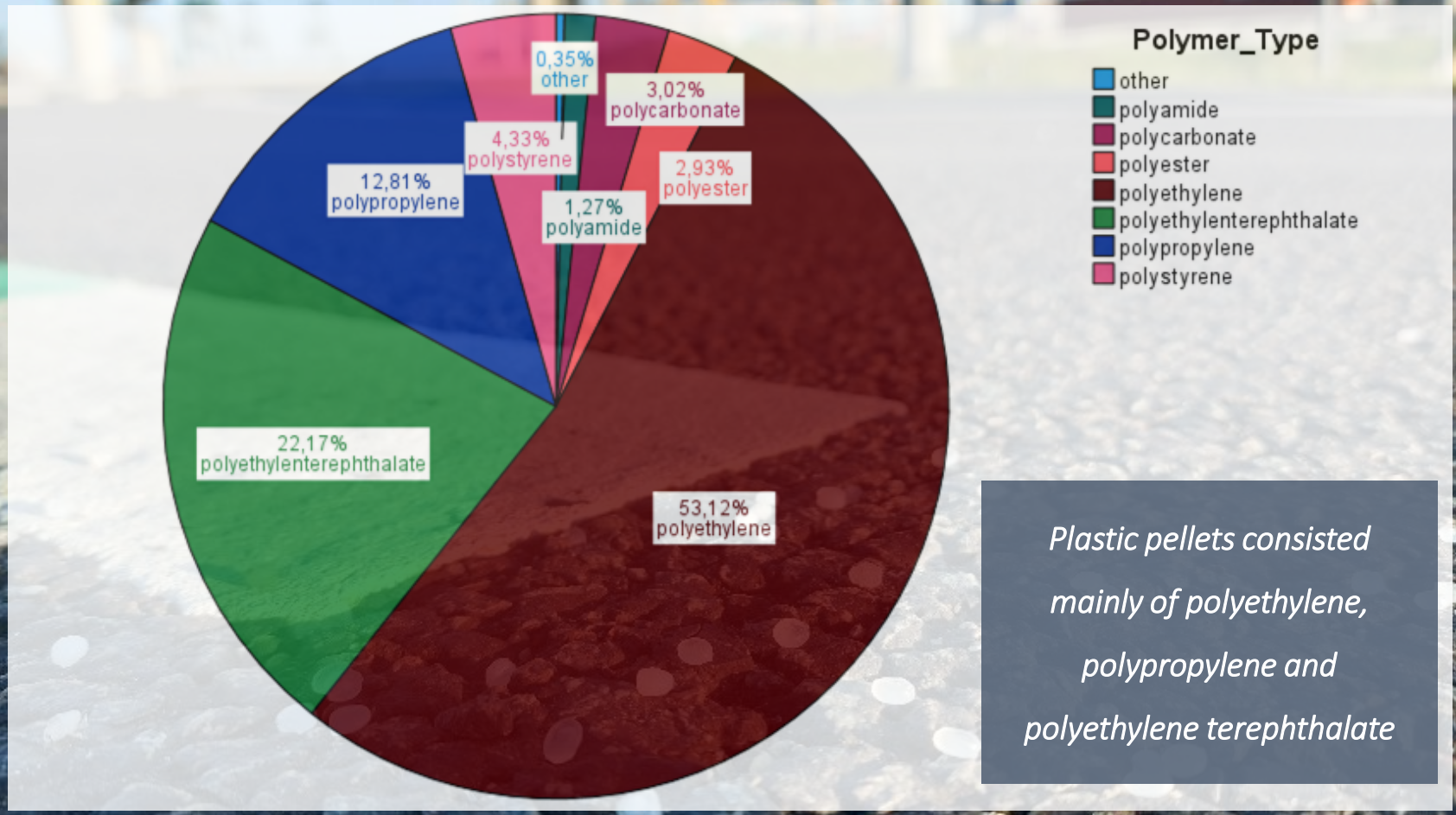
Results

Polymertypes



Plastic pellets consisted mainly of polyethylene, polypropylene and polyethylene terephthalate

Intermediate Conclusion

Plastic pellet loss is still going on

Average plastic pellet loss of 3 to 4.5 plastic pellets per day and per m²

= 1,095 to 1,643 plastic pellets (34 to 52 gram) per year per m²

On the critical points (42.75 m²)

Representing only 0,000037 % of the total area of the port (11,467 ha = 114,670,000 m²)

Overestimation

We search on places where there are likely to be pellets

Old pellets might migrate to the sampling points

Underestimation

Still 99,99 % of the port area left where we might have overlooked places where plastic pellet loss is also going on

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Research continues

Factors that may affect the distribution:

- Weather (wind speed, wind direction, rainfall)
- Intensity of (pellet)transport near the sampling sites
- Speed of the transport
- Surfaces of the sampling sites
- Redistribution of plastic pellets on the road

Methodologies are evaluated and adjusted

We continue to communicate, inform, build knowledge

Important to try to address the problem as close to the source as possible to achieve zero loss of plastic pellets together

Key solution:

Prevention of plastic pellet loss

⇩

Zero loss has not yet been achieved

⇩

Cleaning, sweeping the road thoroughly

⇩

Implementing further measures and training

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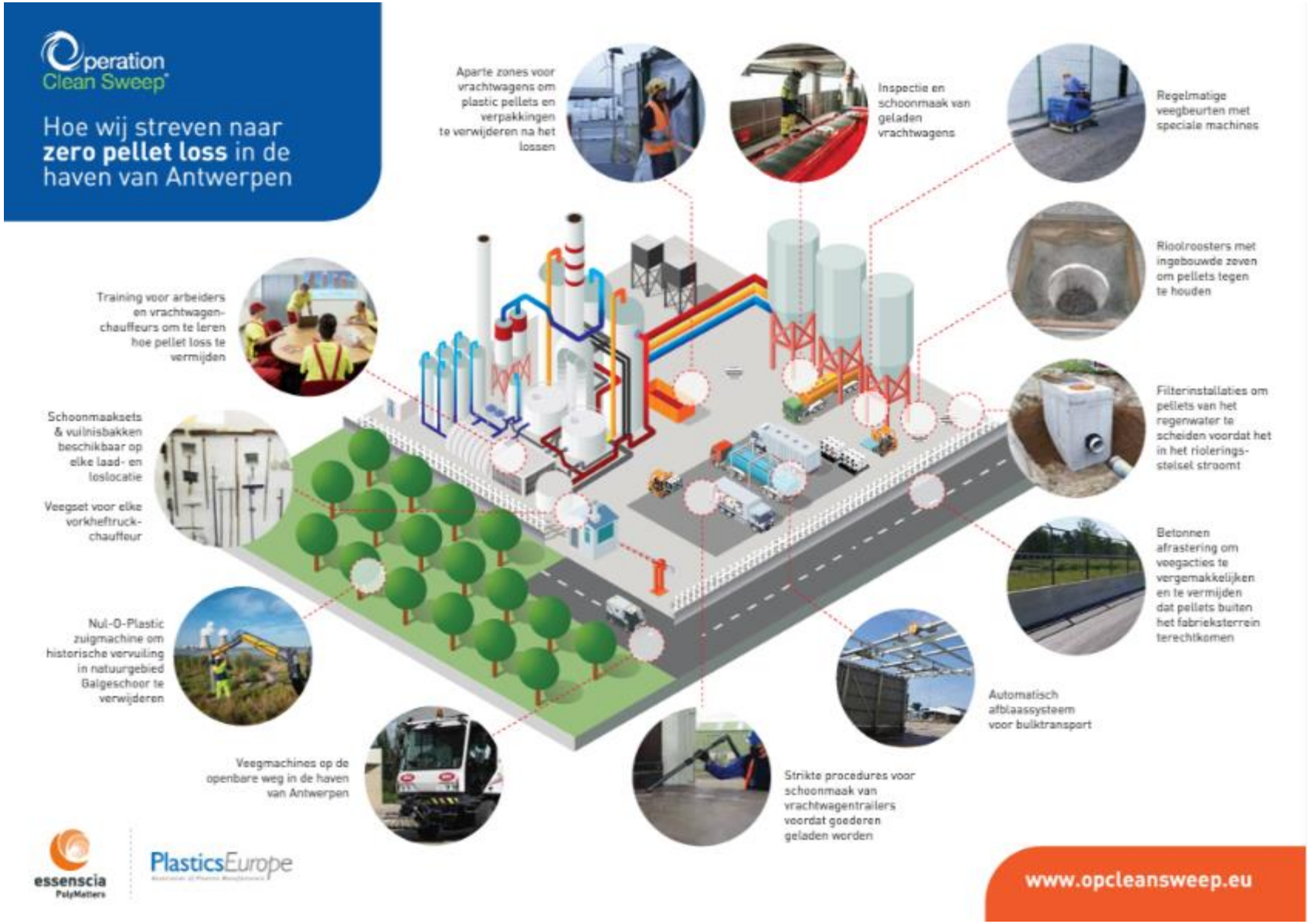


https://www.essenscia.be/van-opruimacties-tot-mobiele-app-actieplan-in-haven-van-antwerpen-voert-strijd-tegen-kunststofkorrels-in-de-natuur-verder-op/

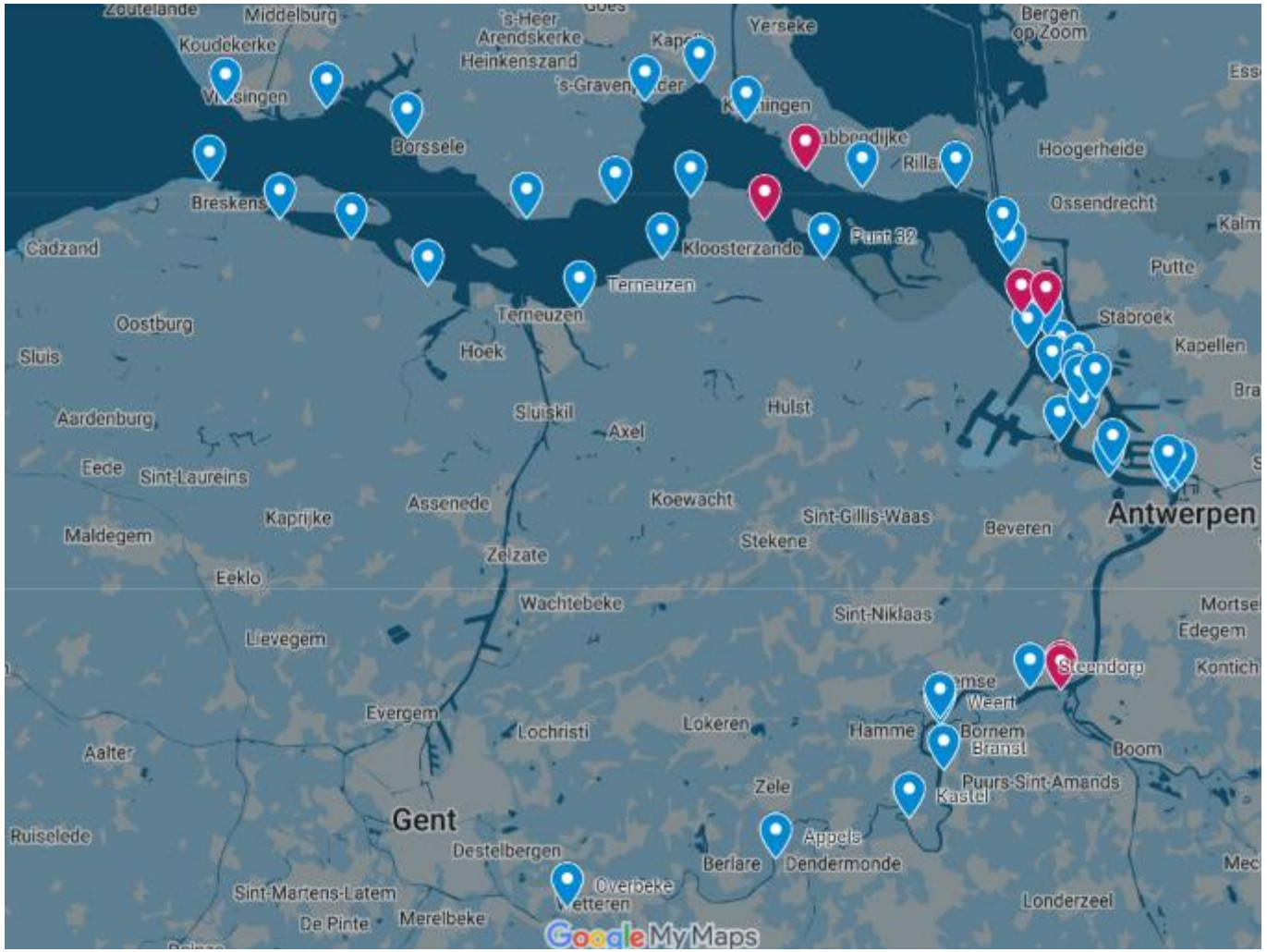
Pellet presence on the Scheldt riverbank

Done

- **6 red places**
  - **Downstream**
    - **Walsoorden (left bank)**
    - **Waarden (right bank)**
  - **Port**
    - **Doel (left bank)**
    - **Galgenschoor (right bank)**
  - **Upstream**
    - **Rupelmonde(left bank)**
    - **Wintam (right bank)**

To Do

- **44 blue places? No, perhaps less places, indicated by model of sediment? => see Waterbouwkundig labo**
- **Planned to do in February-March**
- **Places can still change, depending on the accessibility of the riverbank. Between Antwerpen and Steendorp we have to figure out if the Scheldt riverbank is accessible over there or not.**



Masterproef

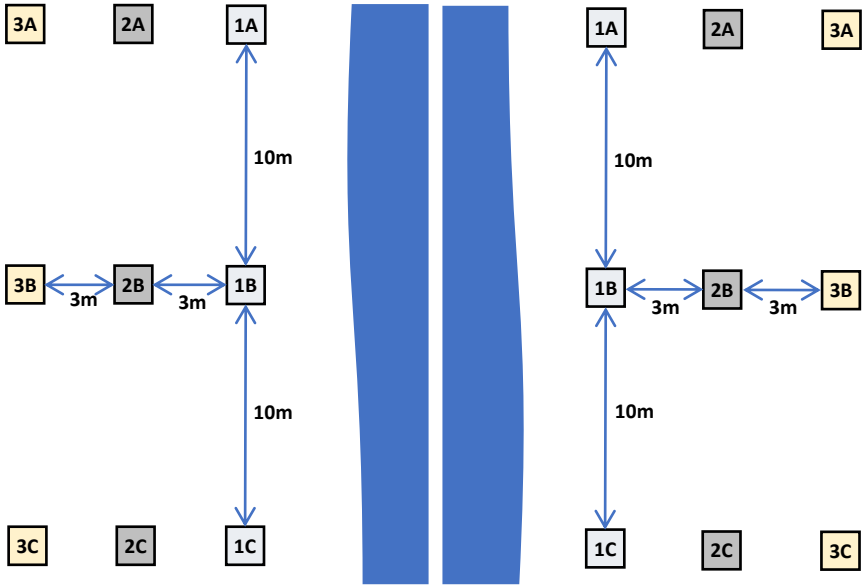
- ‘Plastic korrels in het milieu: bronnen, verspreiding en milieueffecten’

Pellet presence on the Scheldt riverbank - Methodology

DOWN-STREAM

Walsoorden
9 samples

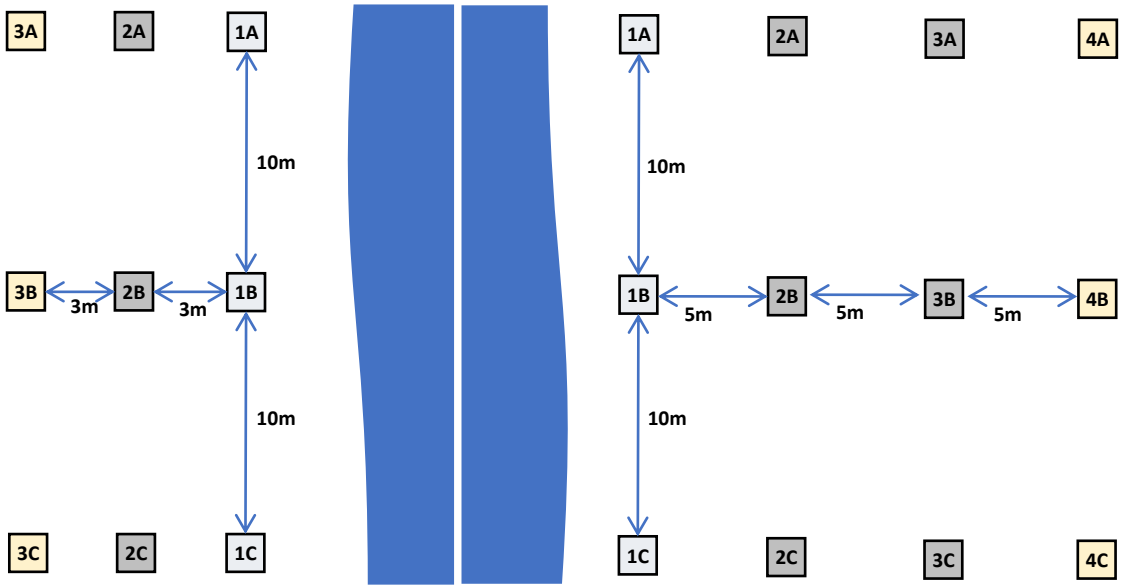
Waarde
9 samples



PORT

Doel
9 samples

Galgenschoor
12 samples



Distance depended on the area, vegetation or rocks

'High tide line'

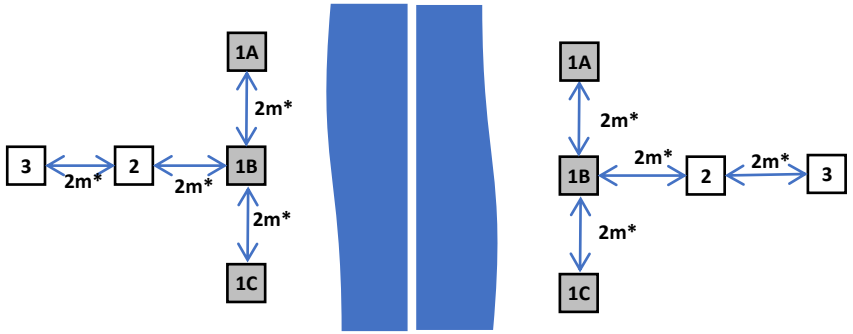
'Closer to the river

Further away from the river

UP-STREAM

Rupelmonde
5 samples

Wintam
5 samples



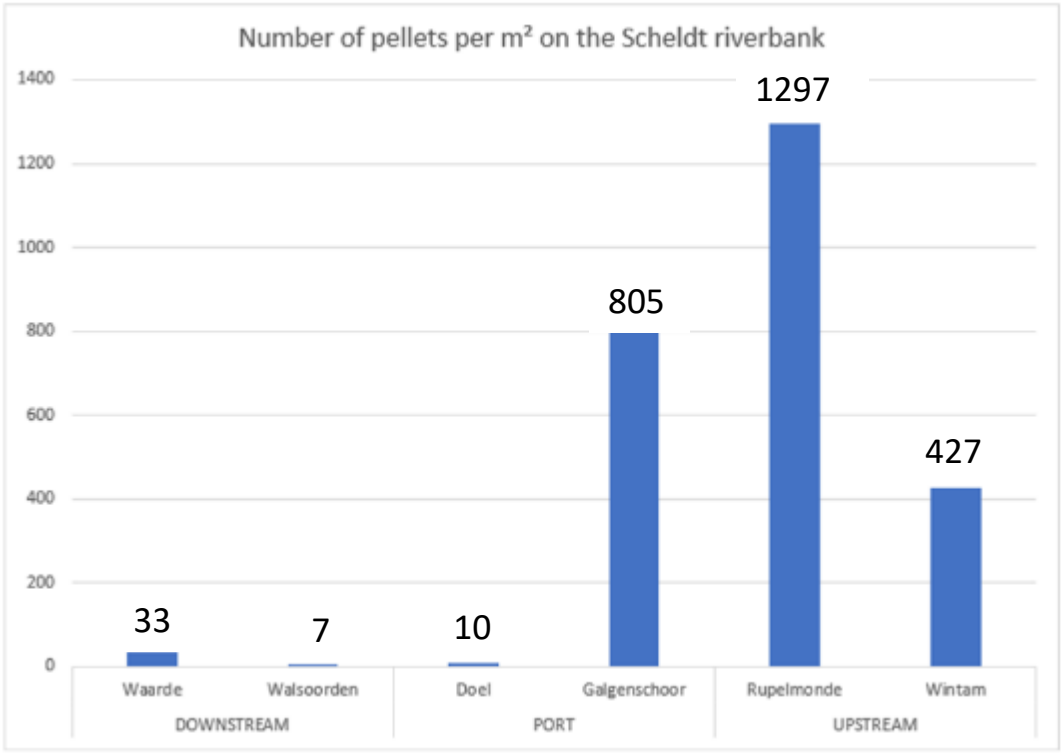
1.3 Pellet presence on the Scheldt riverbank - Methodology

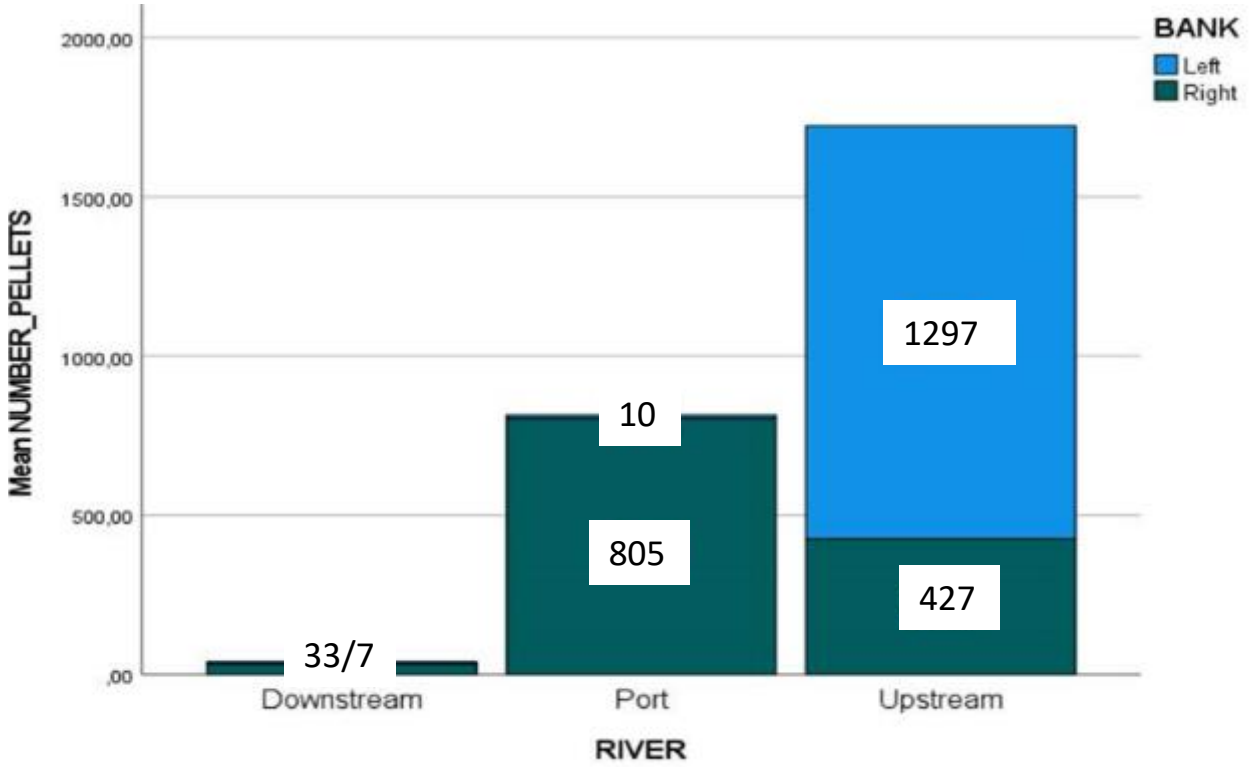
Upstream | Port | Downstream

Leftbank

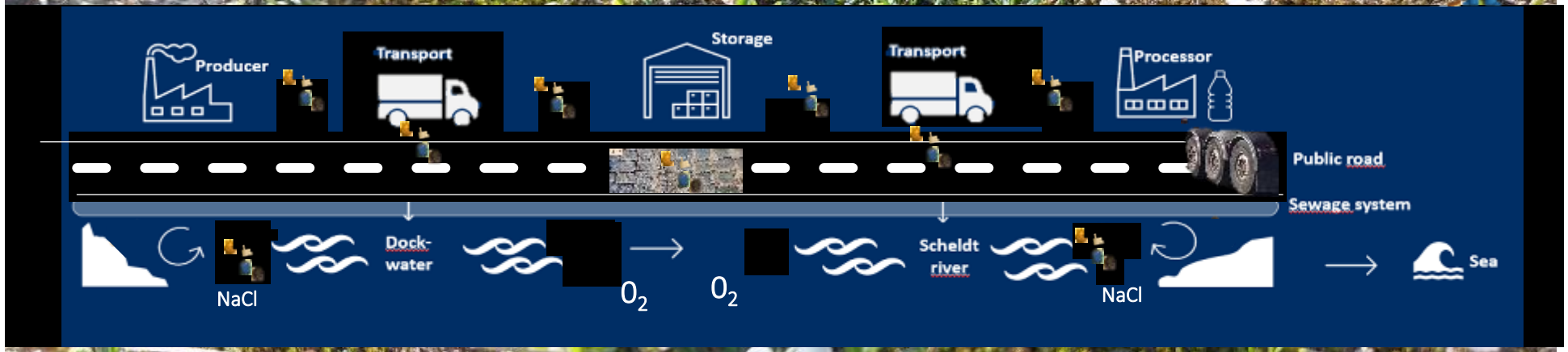
Right bank

Number of plastic pellets per m2 on the Scheldt riverbanks





Many more pellets found upstream compared to downstream, distribution is heterogeneous in terms of sites and location per site.



During their journey through the environment, pellets are exposed to a variety of stressors; UV light, salt, oxygen, temperature, moisture, rocks, sand,....

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Rupelmonde
Scheldeoever *riverbank*
Mei May 2023
Haven *Port*
Kanaaldok
Oktober *Octobre* 2022
Wintam
Scheldeoever *riverbank*
Mei May 2023
Haven *Port*
Noordelijk insteekdok
Juni *June* 2022
Nieuw
New
Beschadigd
Damaged
?
?
?
?
Pellets become more brittle and very small plastic particles, micro- or nanoplastics, can be released from the pellet.
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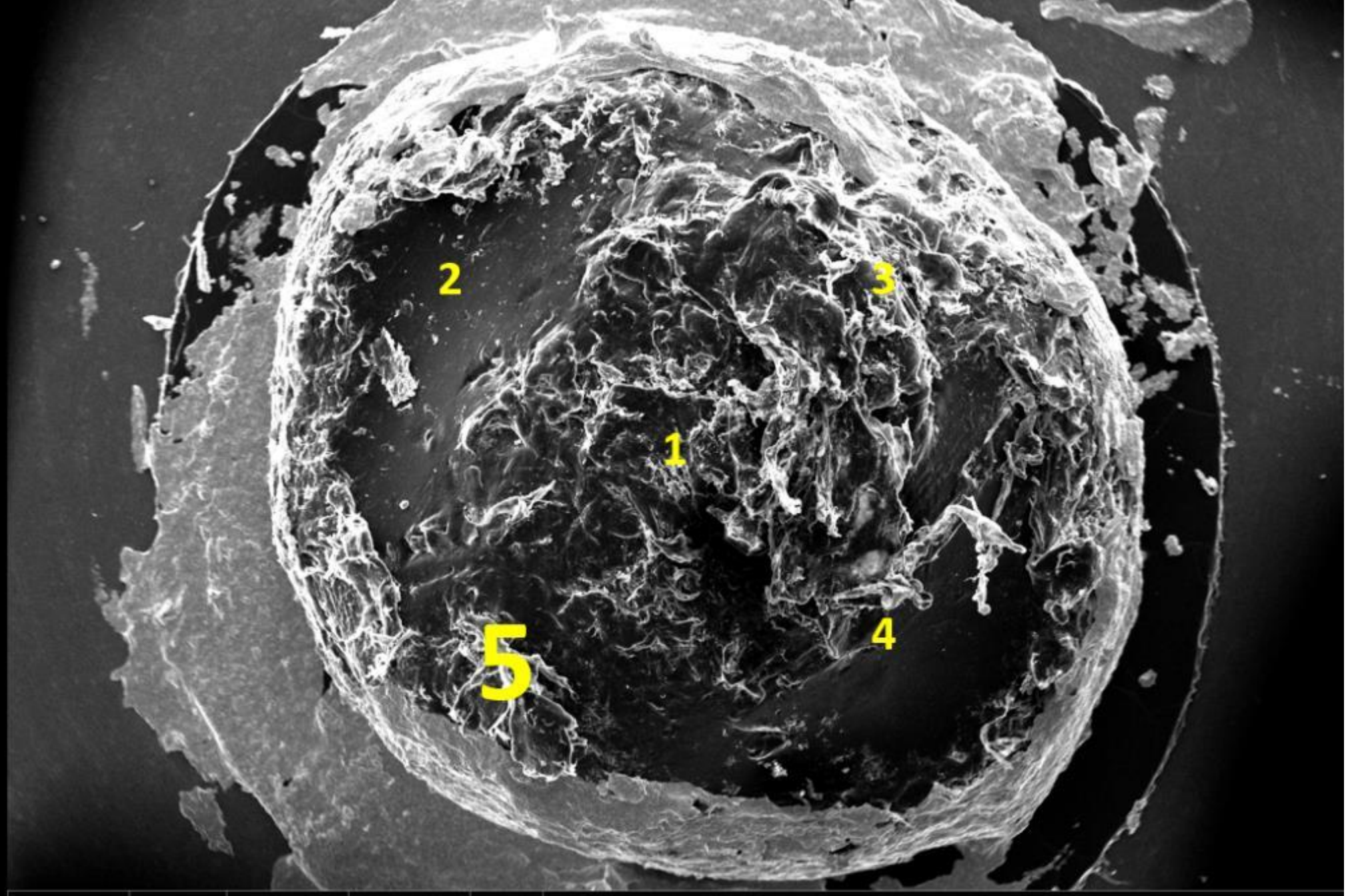
Plastic pellet found on the Scheldt riverbank 30/05/2023

Mag: 30x

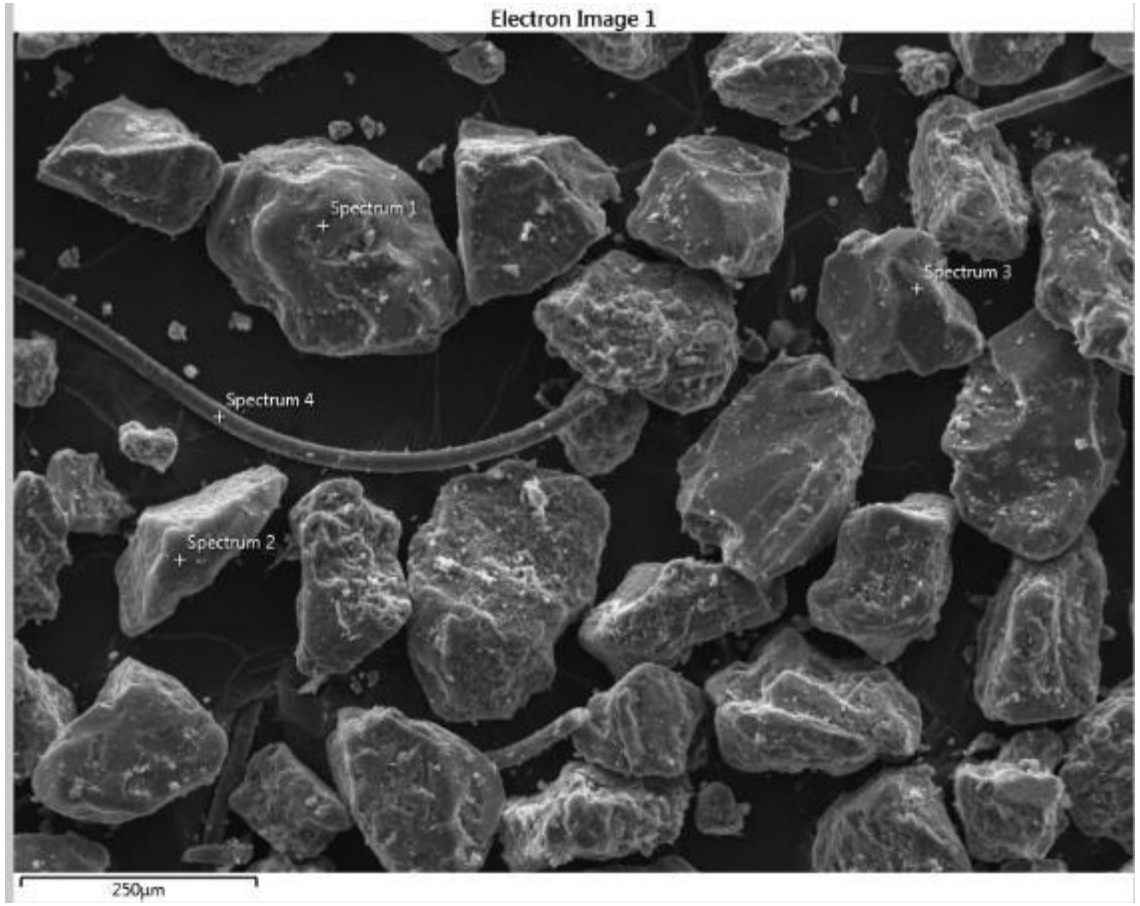
Hereafter 5 pictures of the same pellet, on the indicated places



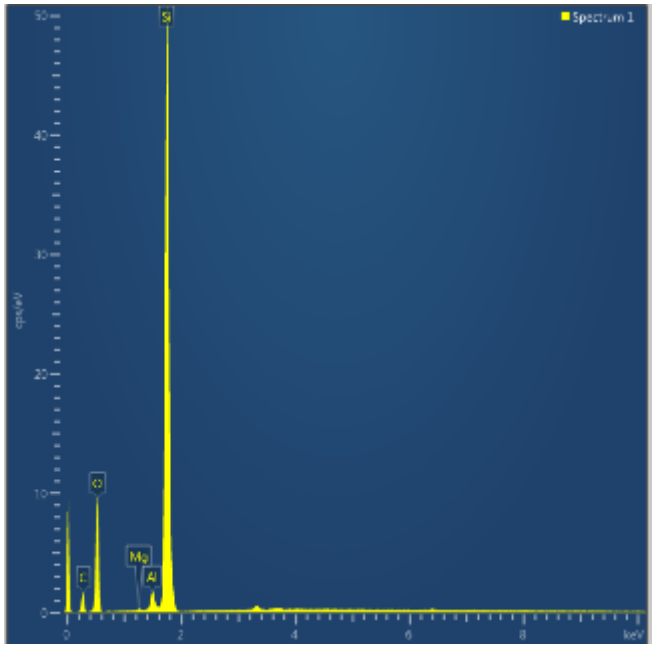
HV	mag	HFW	WD	det	3 mm
30.00 kV	30 x	6.92 mm	16.4 mm	ETD	EMAT

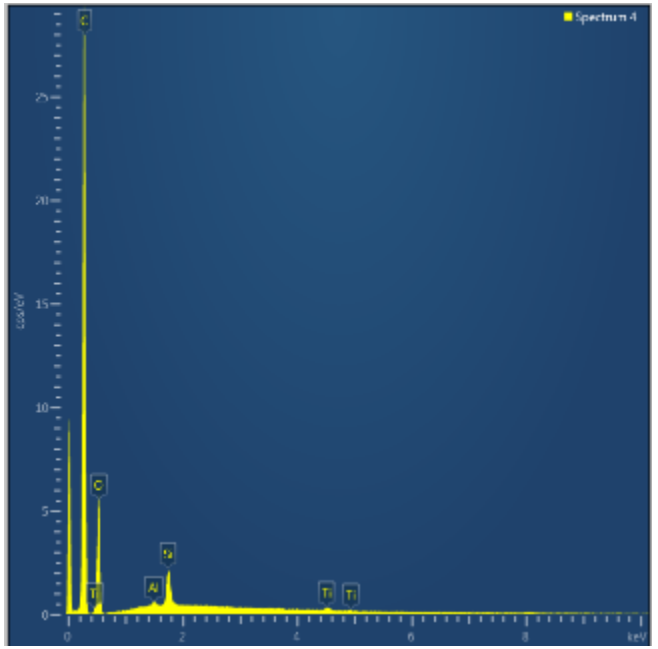
HANNE DIELS - ECOSPHERE

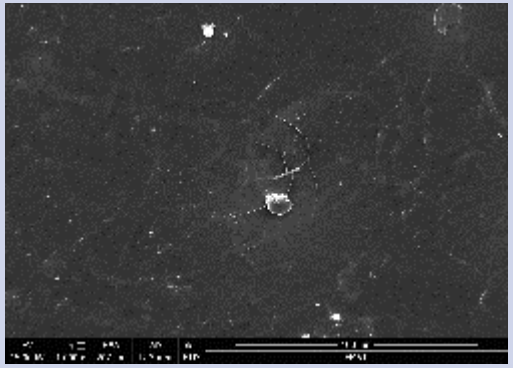
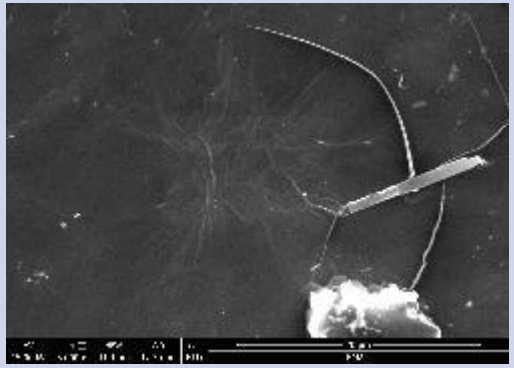
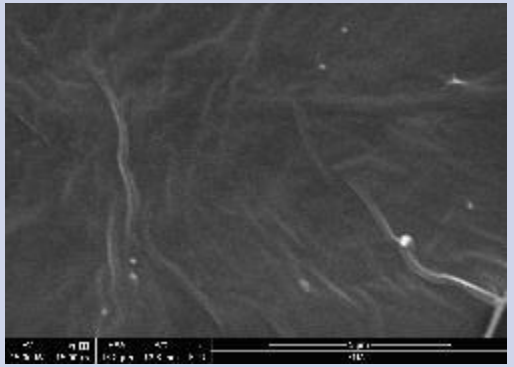
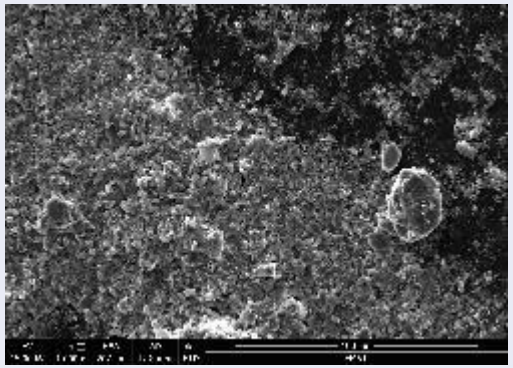
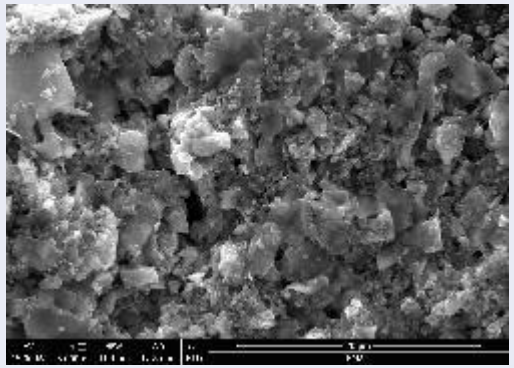
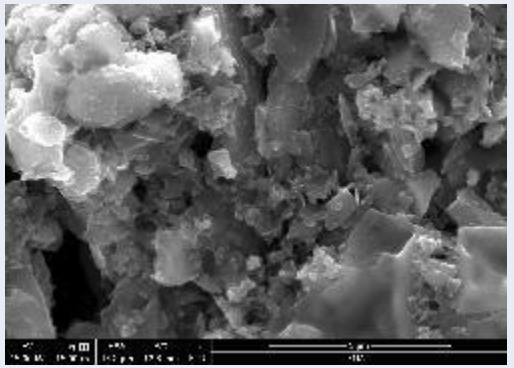
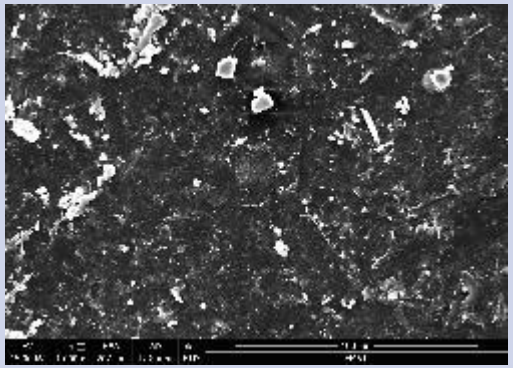
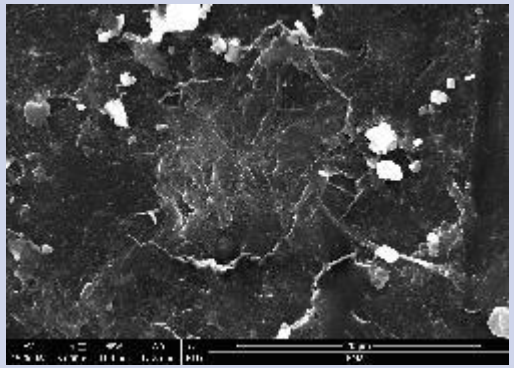
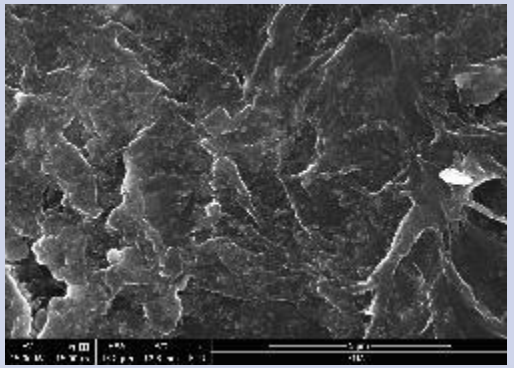
Scanning Electron Microscopy of sediment sample with textile fiber



EDX





SEM 19-04-23	1000x enlarged	5000x enlarged	15000x enlarged
PE pristine	 1	 2	 3
PE 28 days thumbling in artificial seawater and gravel	 4	 5	 6
PE 28 days thumbling in artificial seawater and sand	 7	 8	 9

Plastic pellets in birds of the harbour area

13 pellets were found in the gizzard of 4 of 12 birds (3 juvenile)
2, 3, 4 and 4 pellets per bird (B0010, B0002, B0003, PW bird 11)

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Seabirds, gyres and global trends in plastic pollution

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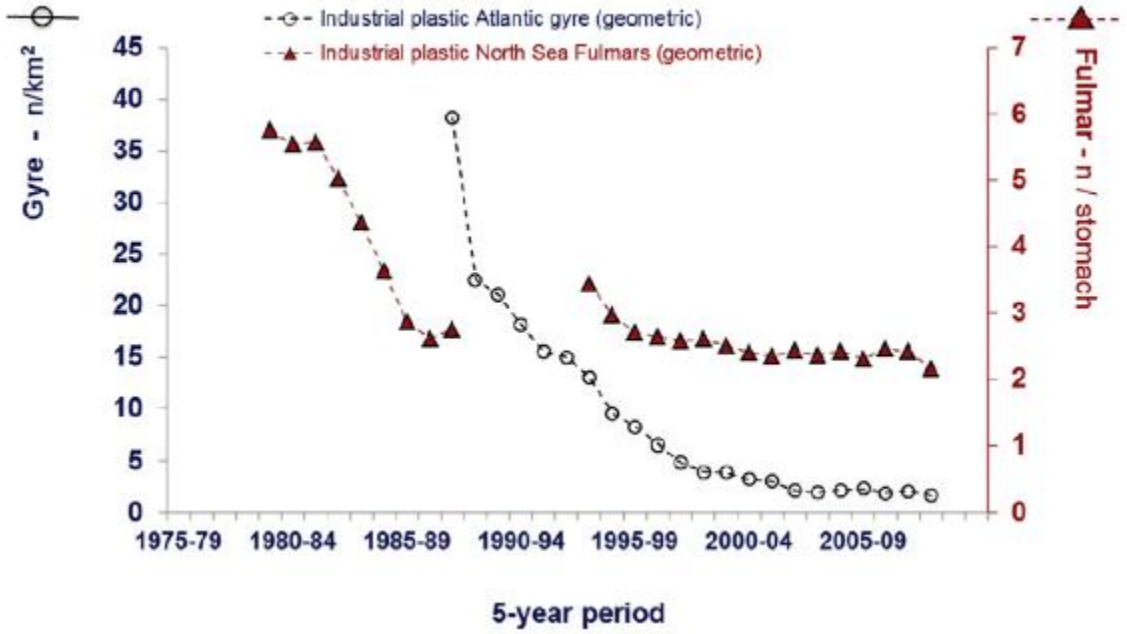

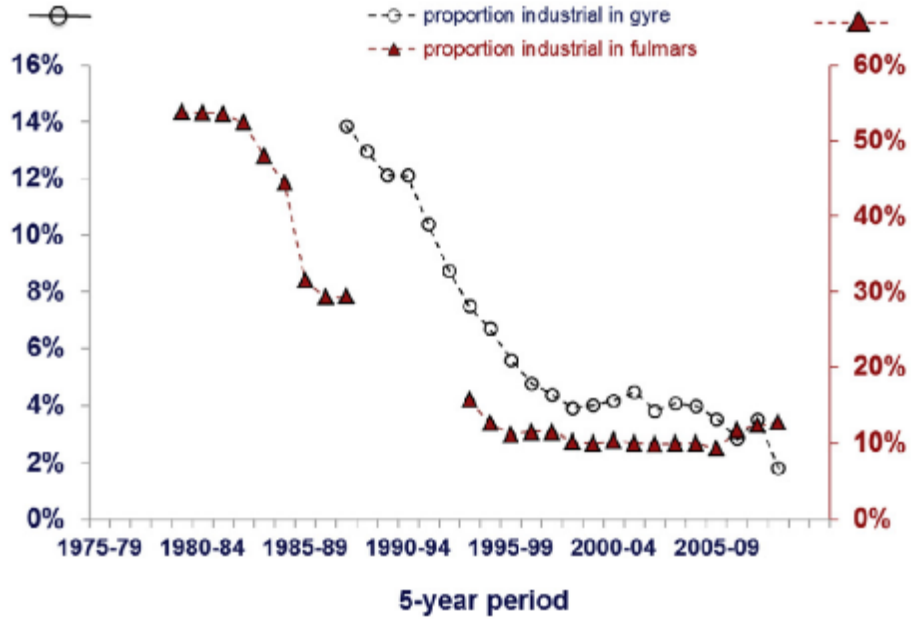

Comparative trends in numerical (left panel) and percentage (right panel) abundance of industrial plastics in stomachs of North Sea fulmars and surface densities in the North Atlantic subtropical gyre by running geometric means over 5-year periods.

Take home messages:

Plastic pellets are lost at production sites and every other step of handling and processing.

Harbours are a major source of pellet loss entering the estuaries, seas and oceans.

Prevention of pellet loss is the only solution to the problem, regular clean up helps but does not suffice.

Awareness is building and compagnies are making efforts to reduce the losses, but further progress needs to be made.

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Take home messages:

Once in the environment it is difficult or impossible to recover the lost pellets.

The pellets slowly change structure and eventually fragment but this may take years, decades or even longer.

One pellet can fragment into thousands or millions of smaller micro or nanoplastics.

Fish and birds take up plastic pellets, dissection of death animals shows that a fraction of exposed organisms contain pellets in the gut.

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