FACULTEIT
BIO-INGENIEURSWETENSCHAPPEN

DEPARTMENT OF GREEN CHEMISTRY AND TECHNOLOGY

SOLVENT-BASED RECYCLING TOWARDS RECOVERY OF TiO_2 FROM WASTE PLASTICS

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Remove2Reclaim

PLASTICS (WASTE) PRODUCTION

PLASTICS DEMAND IN EU
49.1 Mt

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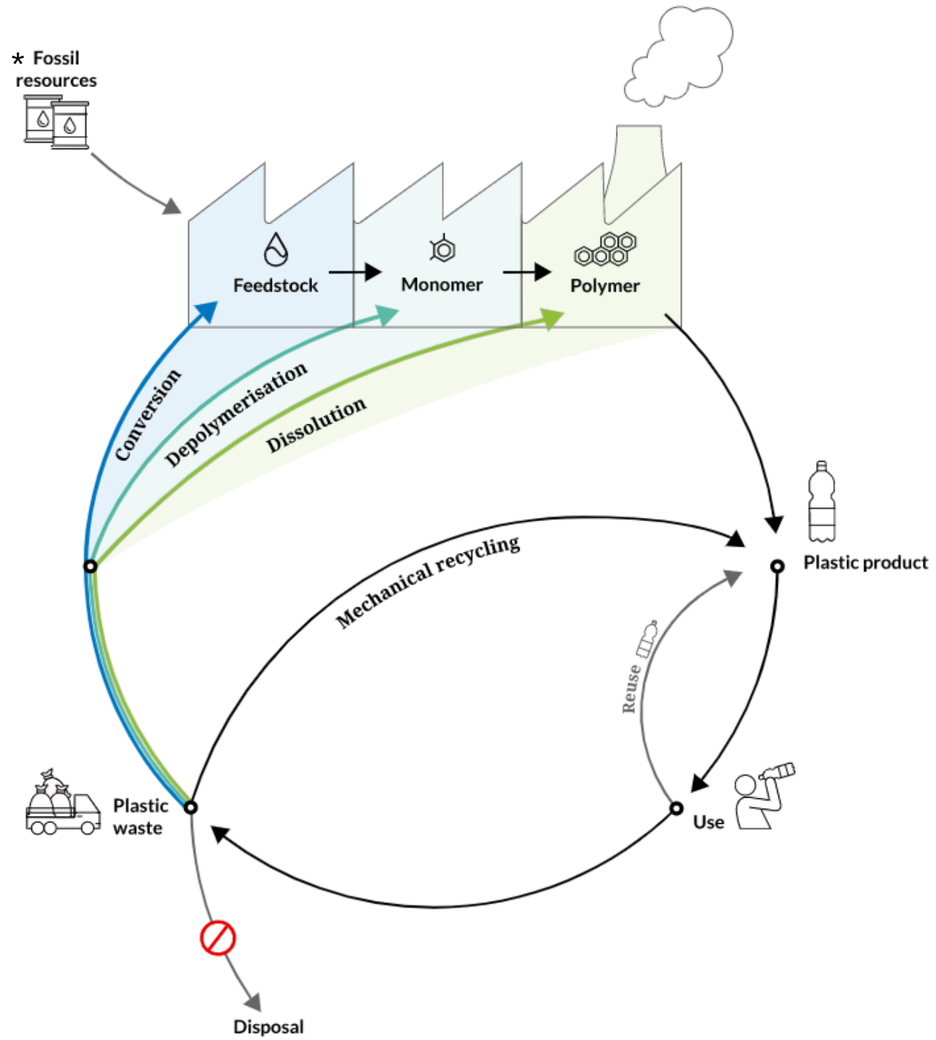
Source: Plastic Europe Market Research Group (PEMRG) and Conversio Market & Strategy GmbH

PLASTICS RECYCLING ROUTES



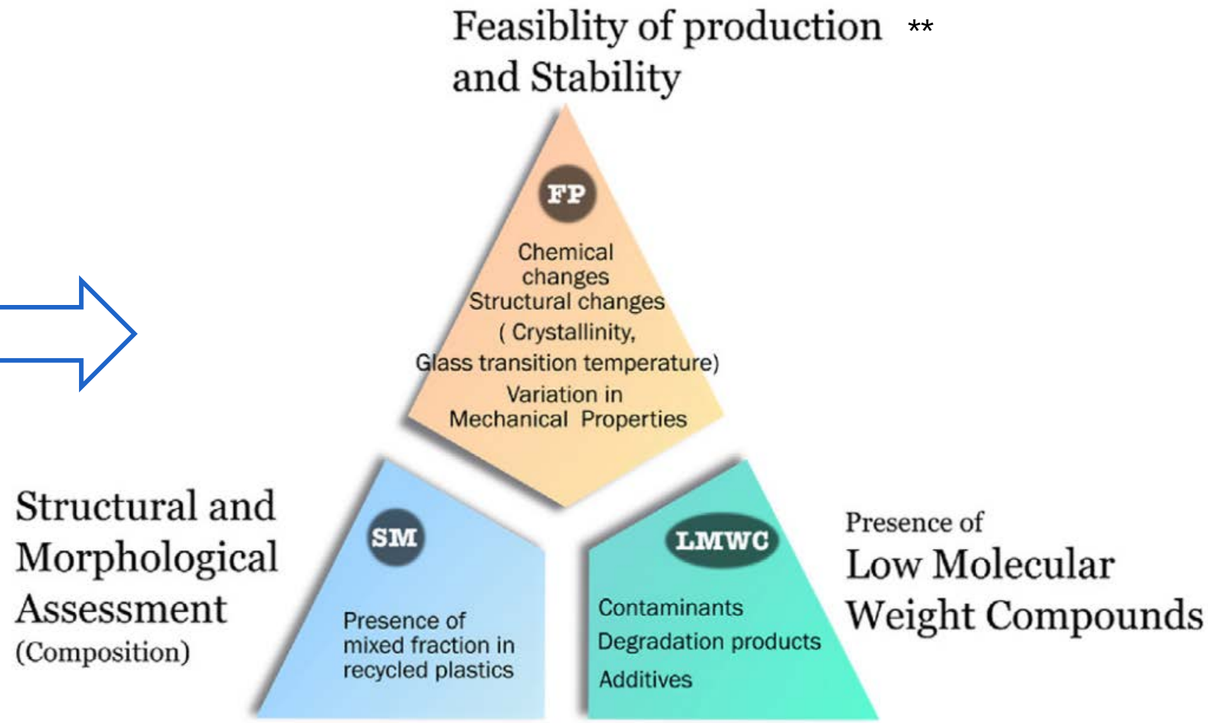


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*Figure from https://cefic.org/a-solution-provider-for-sustainability/chemical-recycling-making-plastics-circular/
**Figure from Cruz Sanchez (2020) Plastic recycling in additive manufacturing: A systematic literature review and opportunities for the circular economy.

MANY ADDITIVES: WHY TiO_2?

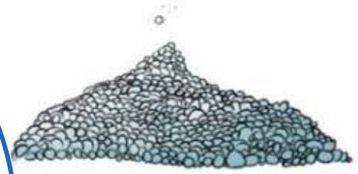
*

Functional

Includes, for example, stabilizers, antistatic agents, flame retardants, plasticizers, lubricants, slip agents, curing agents.

Colourants

Substances such as dyes or pigments added to give colour to plastic. Some of them are added to give a bright transparent colour.



Fillers

Added to change and improve physical properties of plastics. They can be minerals, metals, ceramics, bio-based, gases, liquids, or even other polymers.

Reinforcement

Used to reinforce or improve tensile strength, flexural strength and stiffness of the material. For example: glass fibres, carbon fibres.

NIAS

Non-intentionally added substances. They arrive in products from processes such as reaction by-products or breakdown products.

Dyes
(14%)

Pigments
(86%)

Titanium Dioxide
TiO_2
(59%)

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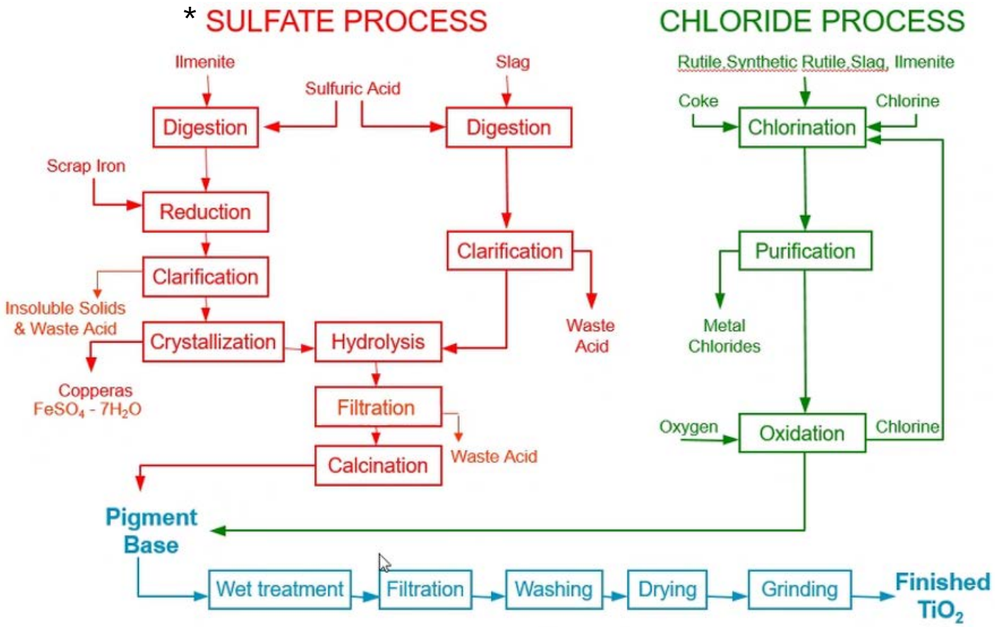
*Source: GRID Arendal.

CIRCULARITY TiO_2 PLASTICS



Compound		Carbon footprint	Price
		$kgCO_2e/kg_{compound}$	€/kg (2021)
TiO_2		4.90	2.6-3.2
Polymer	(LD)PE	1.98	1.2-1.3
	PVC	2.51	~1.2
	PS	3.68	~1.6

SULFATE PROCESS

Concentrated sulfuric acid

Solid and acid waste

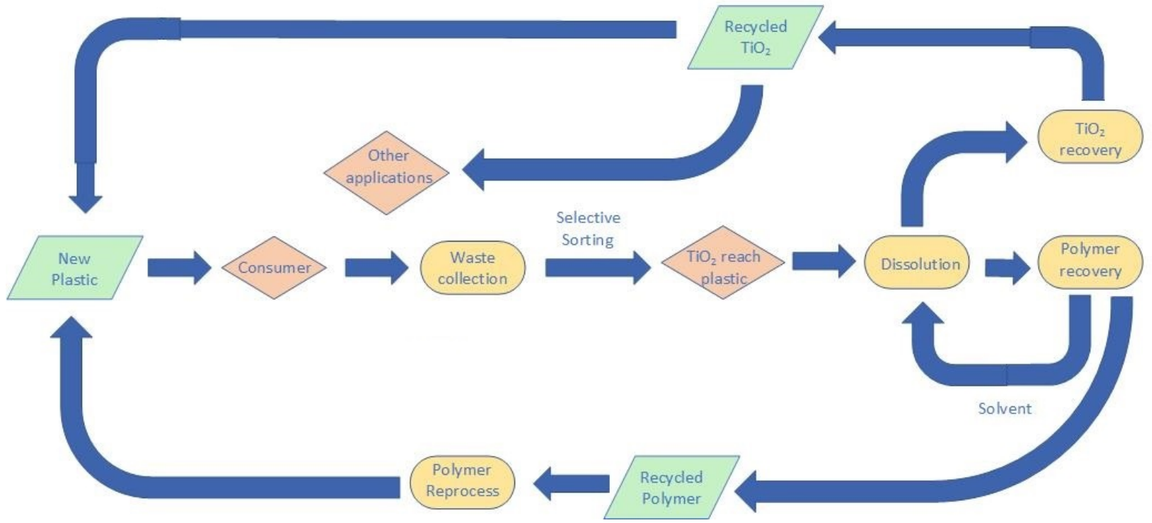
117 $MJ/kgTiO_2$ **

CHLORIDE PROCESS

Petroleum coke chlorine gas

Direct CO_2 emissions

106 $MJ/kgTiO_2$**



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*Source: Chemours

**From Liao (2012), Thermodynamic resource indicators in LCA: a case study on the titania produced in Panzhihua city, southwest China.

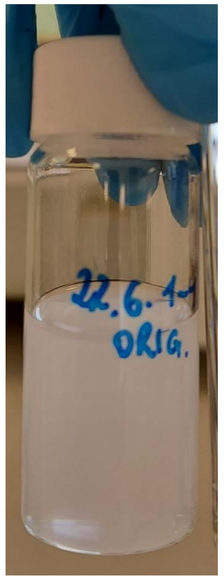
PROCESS

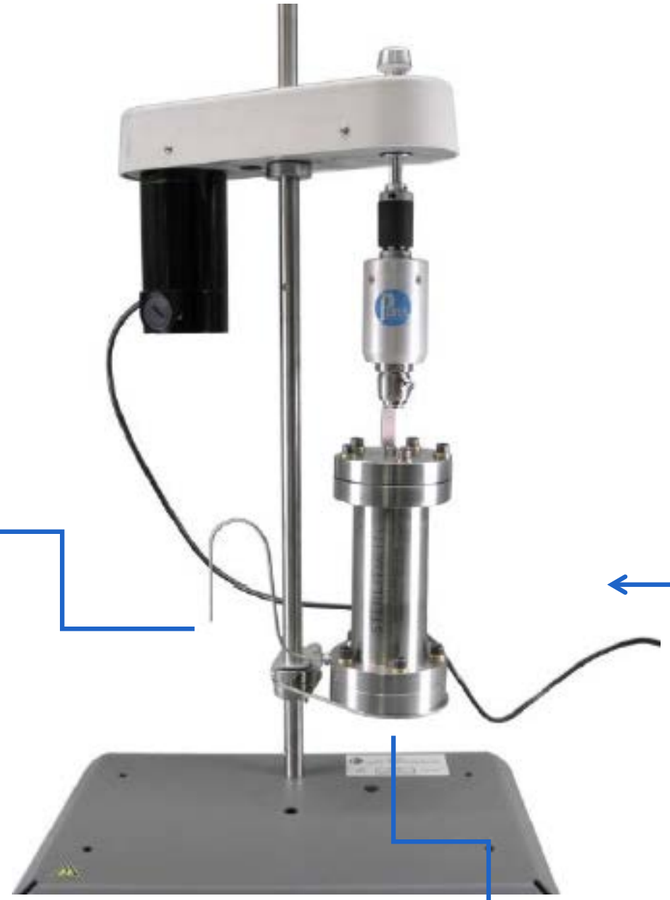
Solvent

Polymer containing TiO_2

+

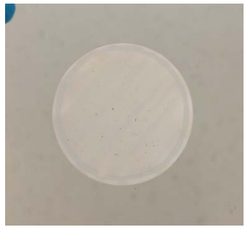
Dissolution





Set-up

(dead-end filtration)



Retentate

Permeate

+

Antisolvent

Precipitation

Recovered polymer

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TiO_2 SEPARATION

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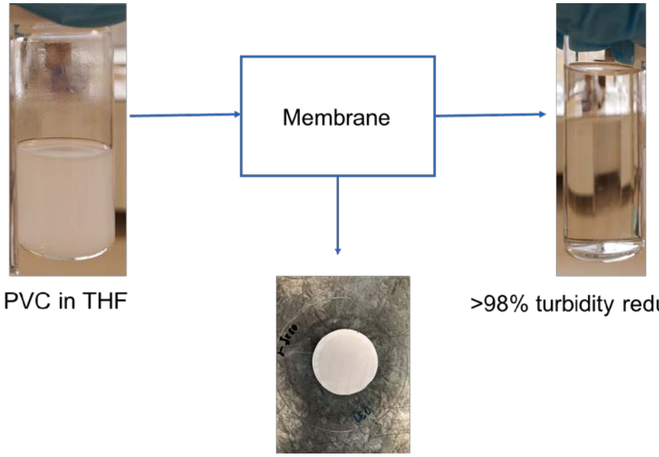
MODEL SAMPLES

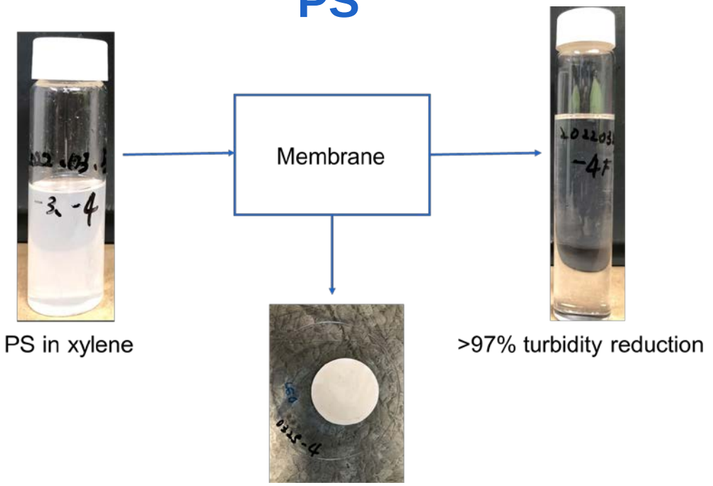
PVC



PVC in THF

>98% turbidity reduction

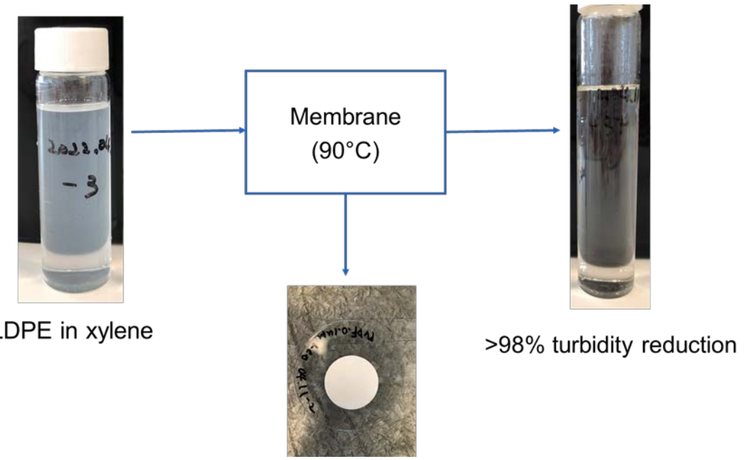
PS



PS in xylene

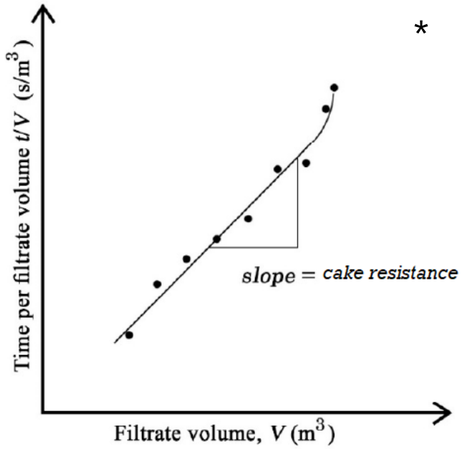
>97% turbidity reduction

LDPE



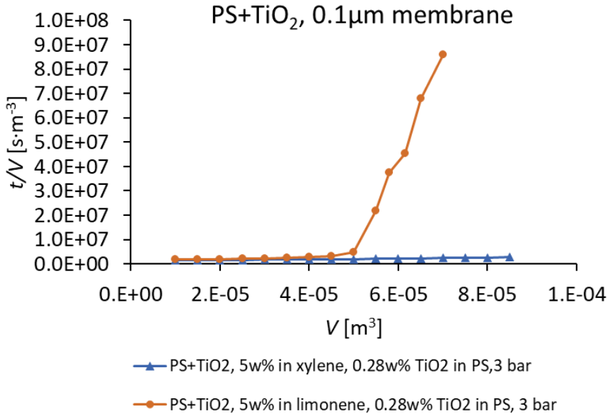
LDPE in xylene

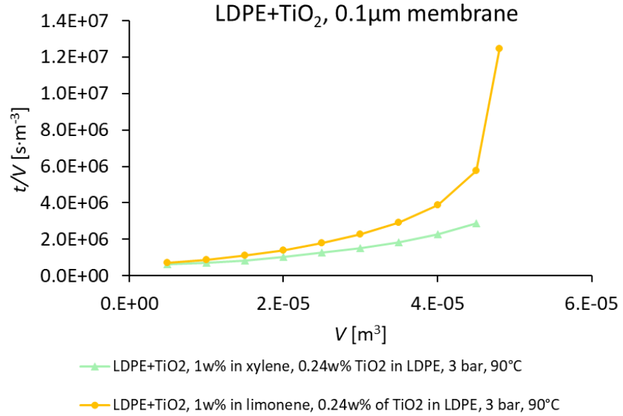
>98% turbidity reduction



*

$$\frac{t}{V} = \frac{\mu_0 \alpha C_m}{2A^2 \Delta P} \cdot V + \frac{\mu_0 R_M}{A \Delta P}$$





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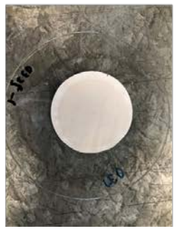
* https://www.researchgate.net/publication/327050728

Solvent influences the flow rate and cake resistance

WASTE SAMPLES

PVC

Membrane



Waste PVC in THF

98.8% turbidity reduction

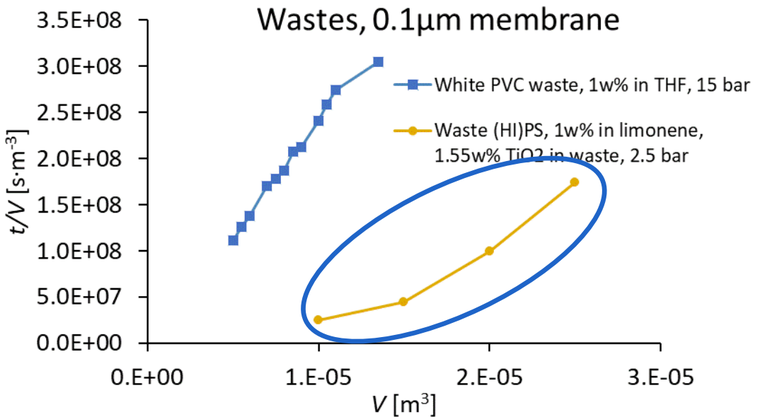
(HI)PS

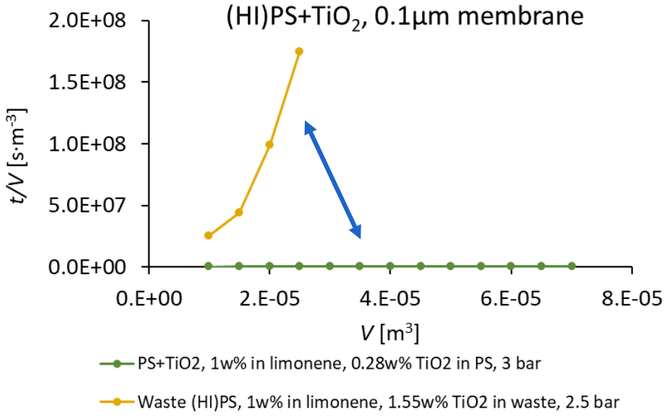
Waste (HI)PS in limonene

Membrane

98% turbidity reduction

Waste samples significantly higher cake resistance





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RECOVERY

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COMPOUNDS RECOVERY

Polymer

Permeate

Precipitation bath (antisolvent)

Recovered polymer

Almost pure polymer sheet is obtained
(4w% (anti)solvent trace)

TiO_2

Carbon black+TiO_2

Oven

TiO_2

TiO_2 can be separated from organic compounds

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CONCLUSIONS & FUTURE PROSPECTIVE

- **Solvent-based** recycling **promising** route for plastic recycling
- **Concurrent recovery** of polymer and TiO_2 is possible
- Filtration efficiency depends on: solvent, concentration, polymer, additives

- Optimization of the process required to treat real waste streams
- Assess recovered polymer properties
- Explore alternative routes for TiO_2 purification

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Thank you for your attention!

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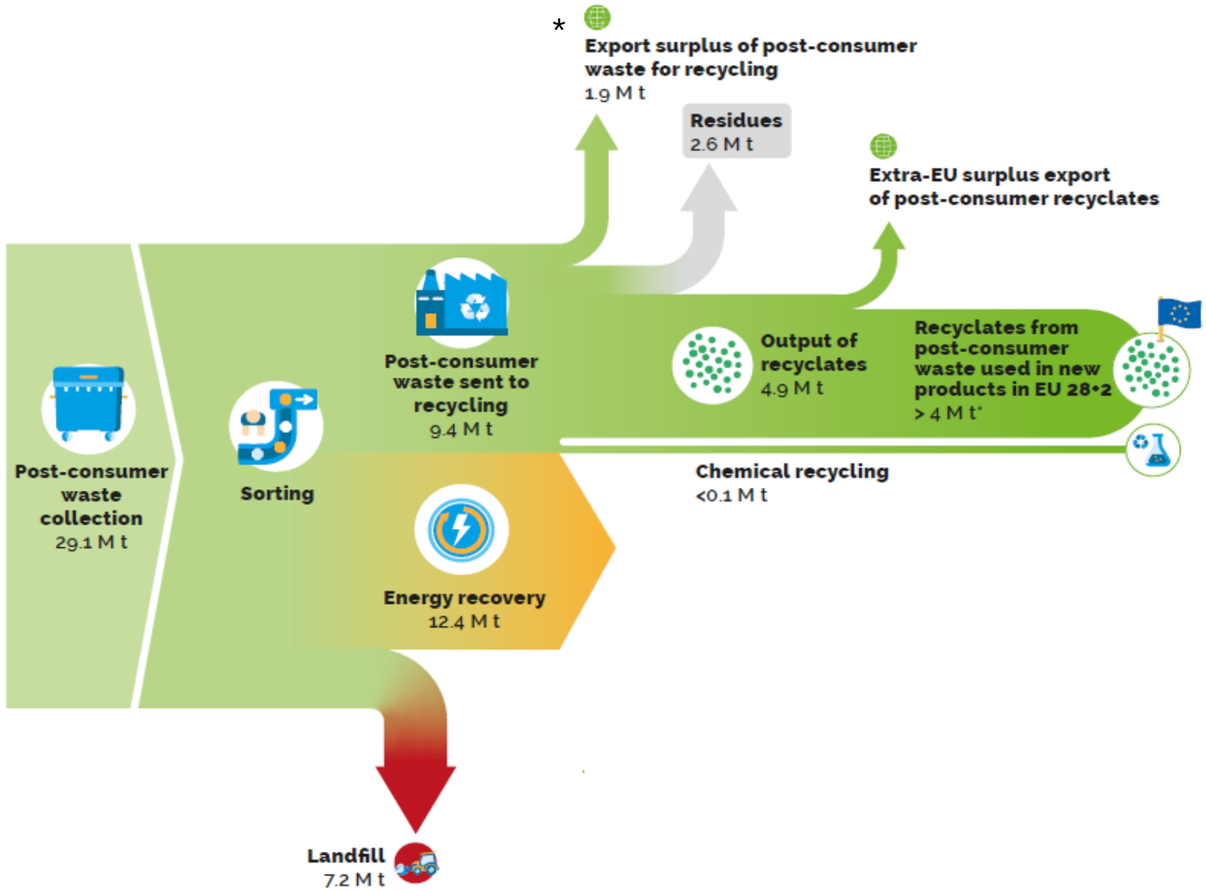
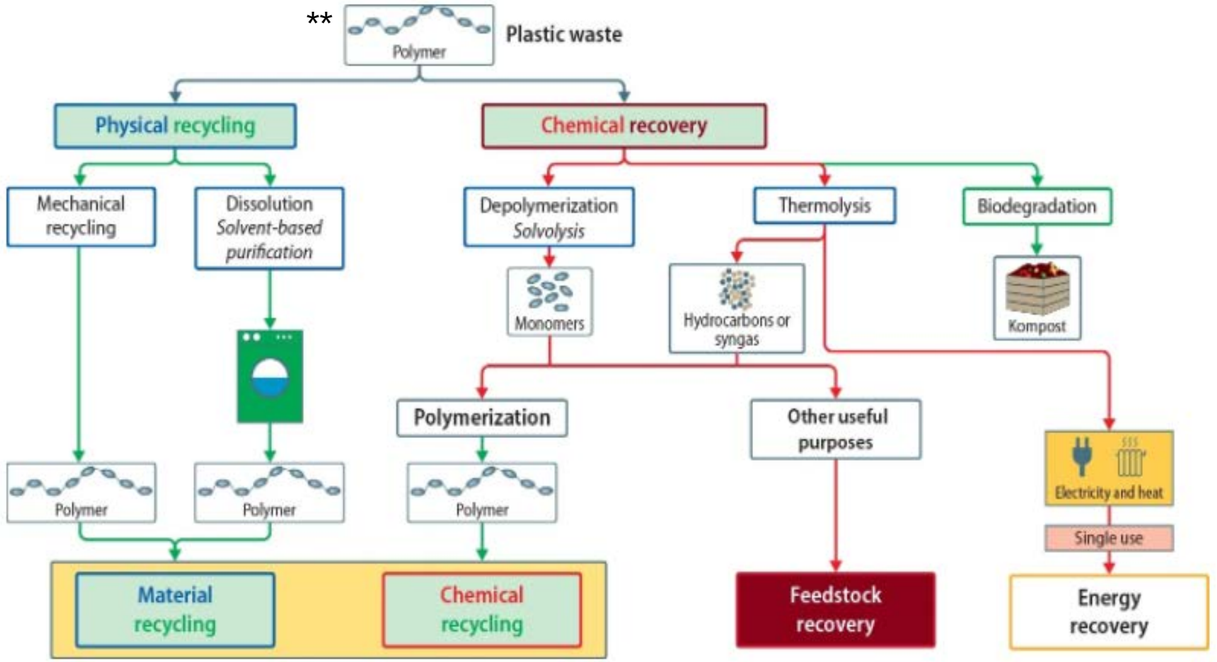
PLASTICS RECYCLING RATES





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*Source: Plastic Europe Market Research Group (PEMRG) and Conversio Market & Strategy GmbH.
**Source: Creacycle

DISSOLUTION-PRECIPITATION PROCESS

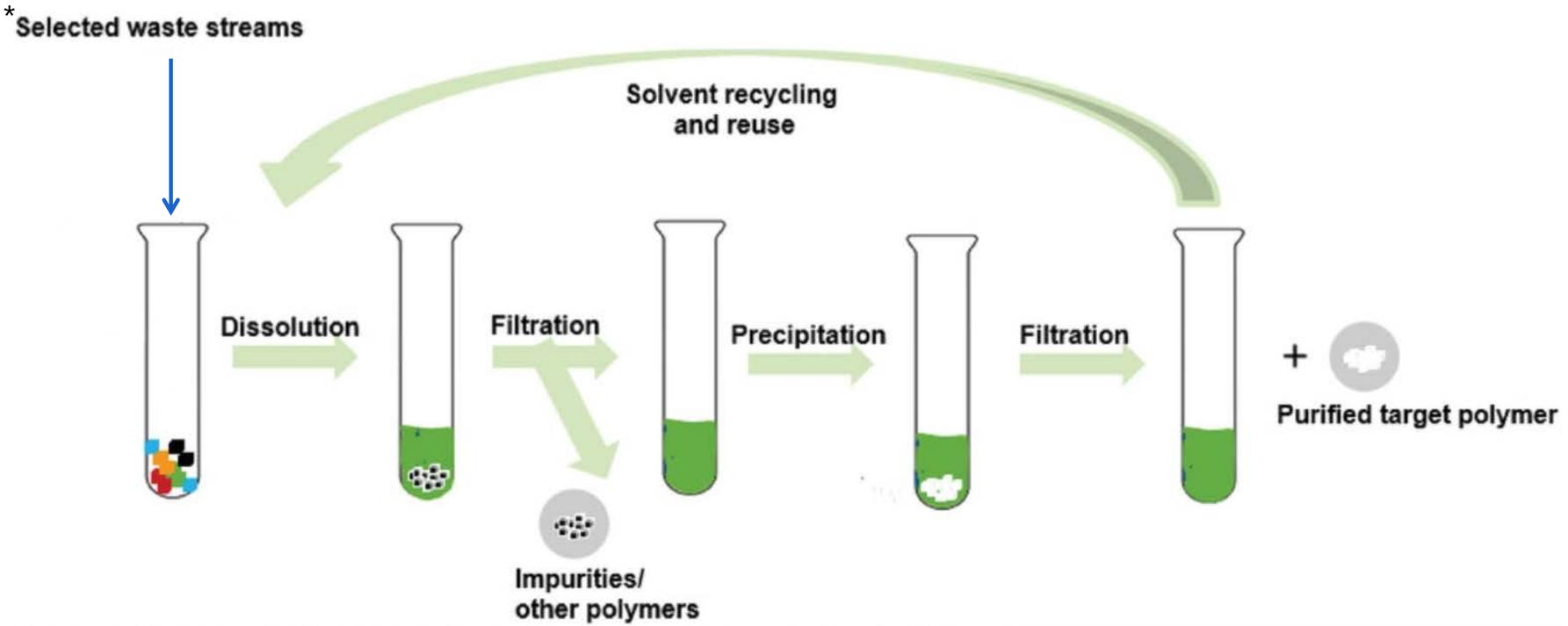

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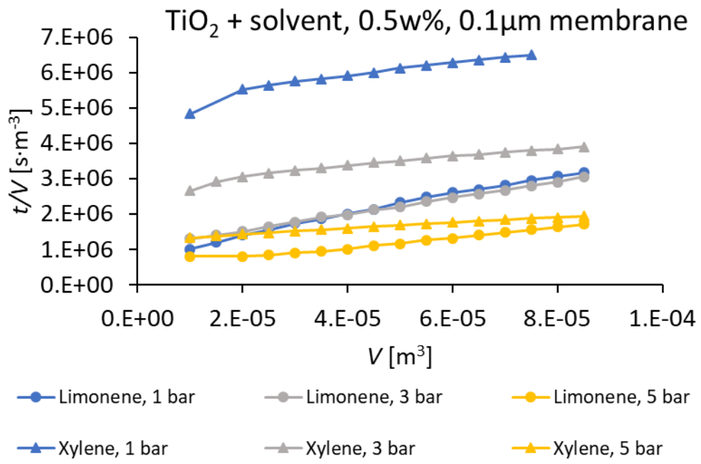
*Figure adapted from Mangold (2022), The Frontier of Plastics Recycling: Rethinking Waste as a Resource for High-Value Applications.

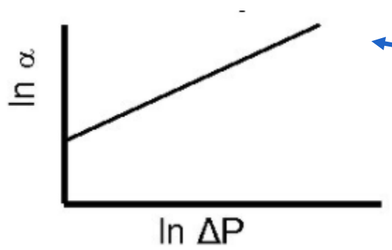
FILTRATION CURVES

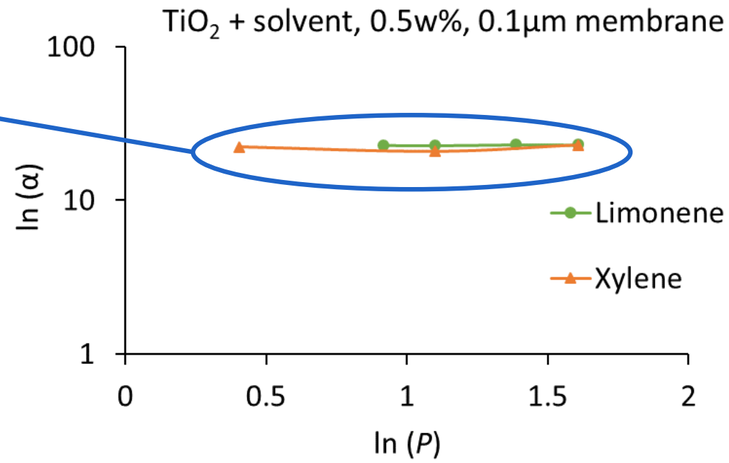
Pure TiO_2 filtration (R-350)

Sample	Solvent	Pressure (bar)	Turbidity reduction (%)
TiO_2 0.5wt%	Xylene	1	100
		3	100
		5	100
	Limonene	1	100
		3	100
		5	100



No significant compressibility





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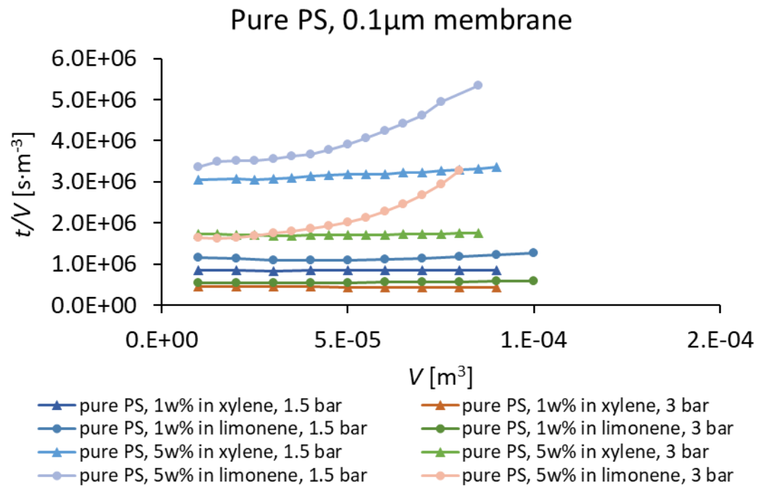
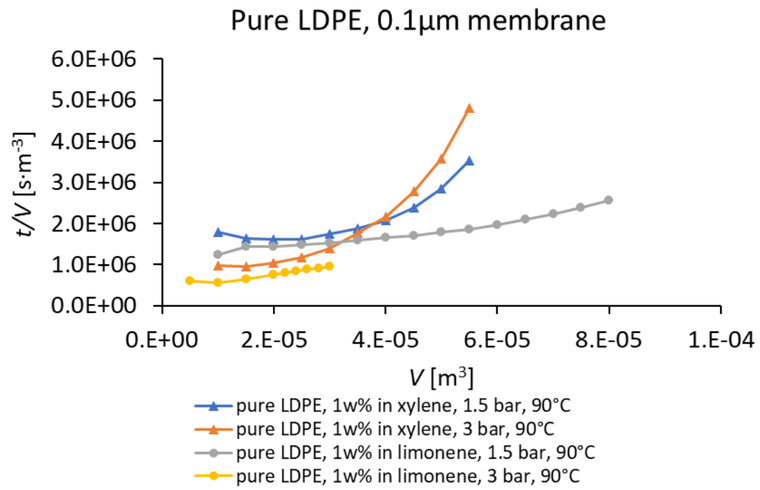
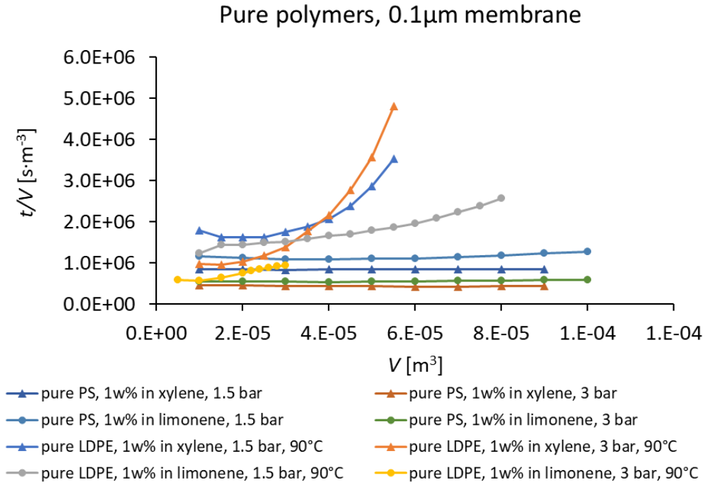
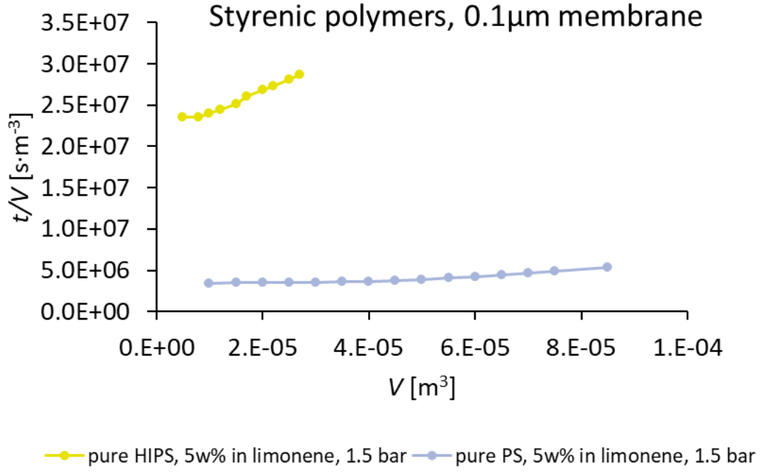
PURE POLYMER FILTRATIONS









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FILTRATION EXPERIMENTS

Original solution

Filtrate

$PS+TiO_2$ (R-350)

Sample	Solvent	Pressure (bar)	Turbidity reduction (%)	Polymer retention (%)
$PS+TiO_2$, 5w% solution (0.28w% TiO_2 in PS)	Xylene	1.5	98.6	5.2
		3	99.5	2.6
	Limonene	1.5	97.5	1.2
		3	98.7	3.4
$PS+TiO_2$, 1w% solution (0.28w% TiO_2 in PS)	Xylene	1.5	96.7	6.2
		3	96.8	7.7
	Limonene	1.5	96.7	1.1
		3	96.6	0.0
$PS+TiO_2$, 7w% solution (10w% TiO_2 in PS)	Xylene	9	98.9	5.4

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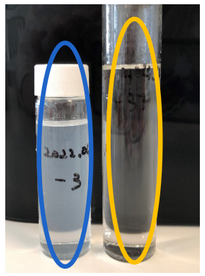
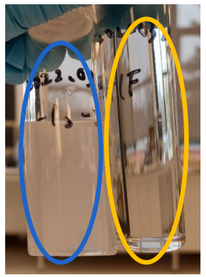
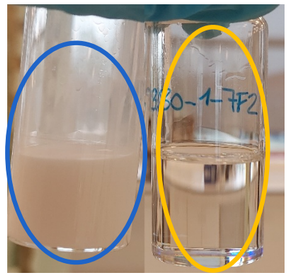
TiO_2 can be easily separated from pure PS by filtration

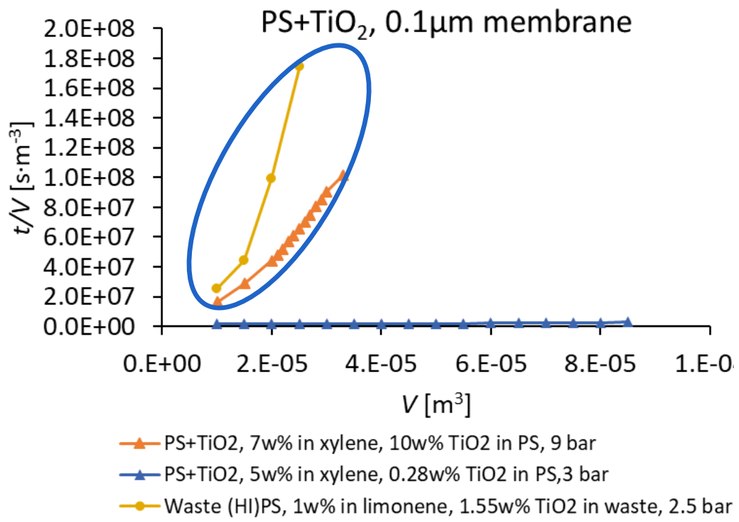


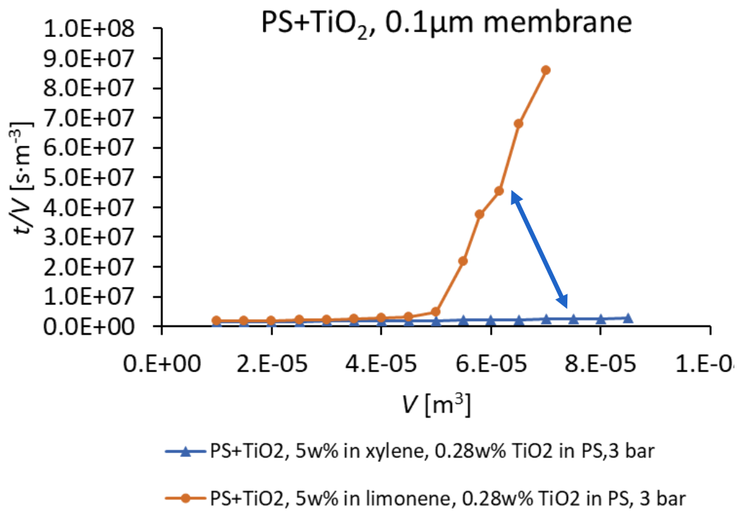


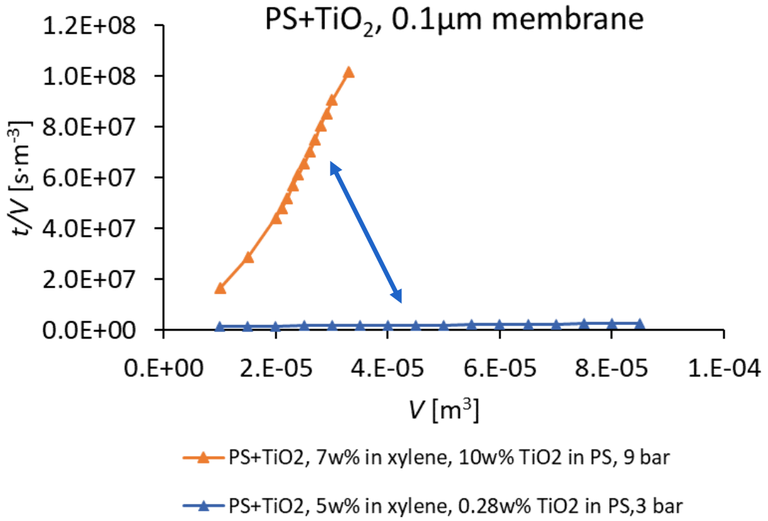


FILTRATION CURVES

Styrenic polymers







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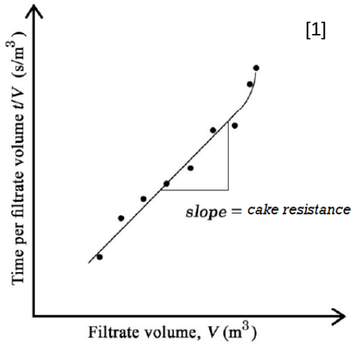

- Waste sample behaves similar to high concentration of pure PS+TiO_2 solution
- Solvent influences cake resistance
- Increasing concentration, cake resistance increases significantly

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[1] https://www.researchgate.net/publication/327050728

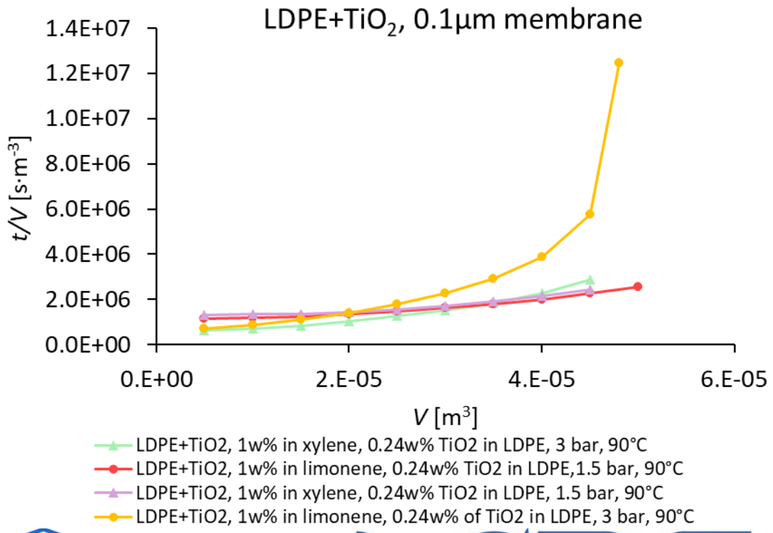
FILTRATION EXPERIMENTS

LDPE+TiO_2 (R-350)

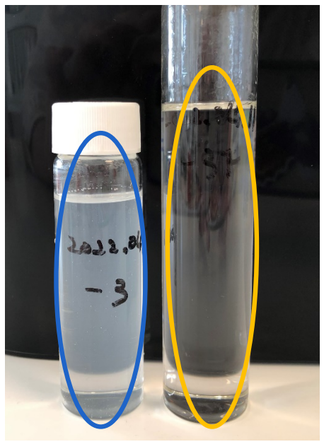
Original solution

Filtrate

Sample	Solvent	Pressure (bar)	Turbidity reduction (%)	Polymer retention (%)
LDPE+TiO_2, 1w% solution (0.24w% TiO_2 in LDPE)	Xylene	1.5	98.6	1.3
		3	99.5	0.9
	Limonene	1.5	97.5	0.8
		3	98.7	0.3



TiO_2 can be easily separated from pure LDPE by filtration



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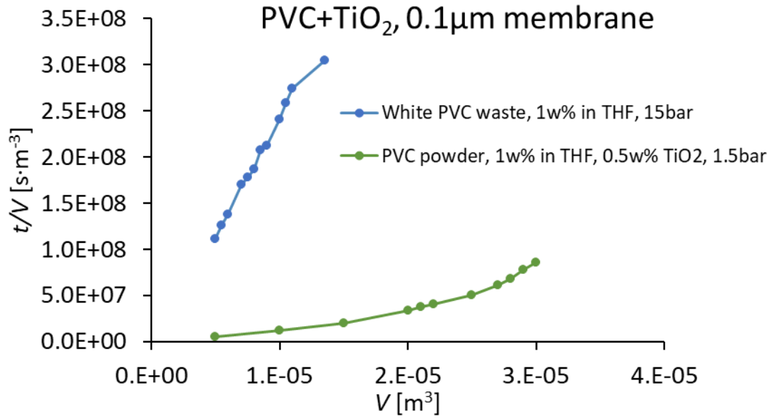
FILTRATION EXPERIMENTS

Original solution

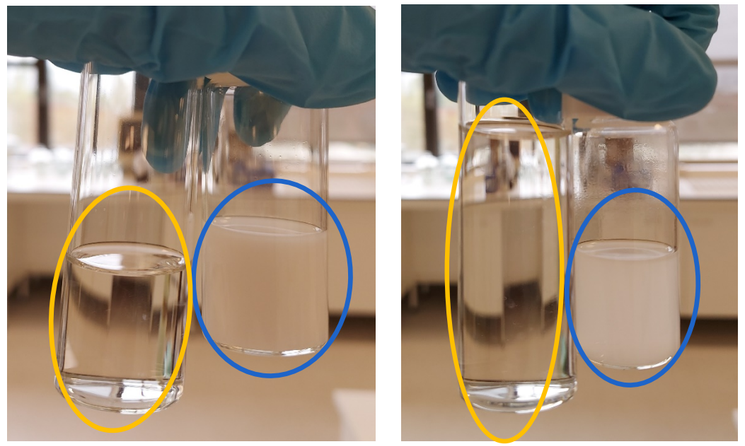
Filtrate

PVC (Deceuninck)

Sample	Solvent	Pressure (bar)	Turbidity reduction (%)	Polymer retention (%)
PVC, 1w% (0.5w% TiO_2 in PVC+additives)	THF	1.5	98.8	7.9
Waste PVC, 1w%		15	99.9	76.3



TiO_2 can be separated from PVC by filtration (**also** for **waste** sample*)



Waste PVC **PVC+additives**

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* = optimization needed