Mikró műanyagok a környezetben

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Tartalom

Definíciók
Globális Műanyag termelés
Rostok a textiliparban
Rostos anyagok forrásai a vizes élőhelyekben
Globális szennyvíz termelés / Szennyvíz kezelés
A mikró műanyagok hatásai a vízi élőlényekre
A természetes és mesterséges rost anyagok biodegradációs hatásai
Esettanulmány a budapesti szennyvíz tisztító kibocsátásáról
Hogyan csökkenthetjük a kommunális szennyvíz tisztítók rost kibocsátását
Esettanulmány a Tevere folyó mikró műanyag és rost anyag terheléséről
Esettanulmány a Tevere folyóról, Rómában
Az embereket terhelő mikró műanyag források
Mikró műanyag toxicitás
Konklúziók

Definíciók

1. Mikró műanyagok (MP): emberi előállítású szintetikus polimer részecskék, 5 mm alatti szemcse nagysággal,
   Elsődleges mikró műanyagok: eredetileg 0.1-100 µm méret tartományban előállítva (kozmetikai ipar, festék pigmentek)
   Másodlagos mikró műanyagok: Műanyag hulladékok degradációjából keletkeznek, UV sugárzás, fizikai hatások kapcsán.

2. Mikrószálak: textilekből származó természetes és szintetikus szálak, a mosási folyamatban keletkezve.
   Átmérő <50 µm; hosszúság 1-5000 µm
   hosszúság/átmérő arány > 100

Globális műanyag termelés (PP)

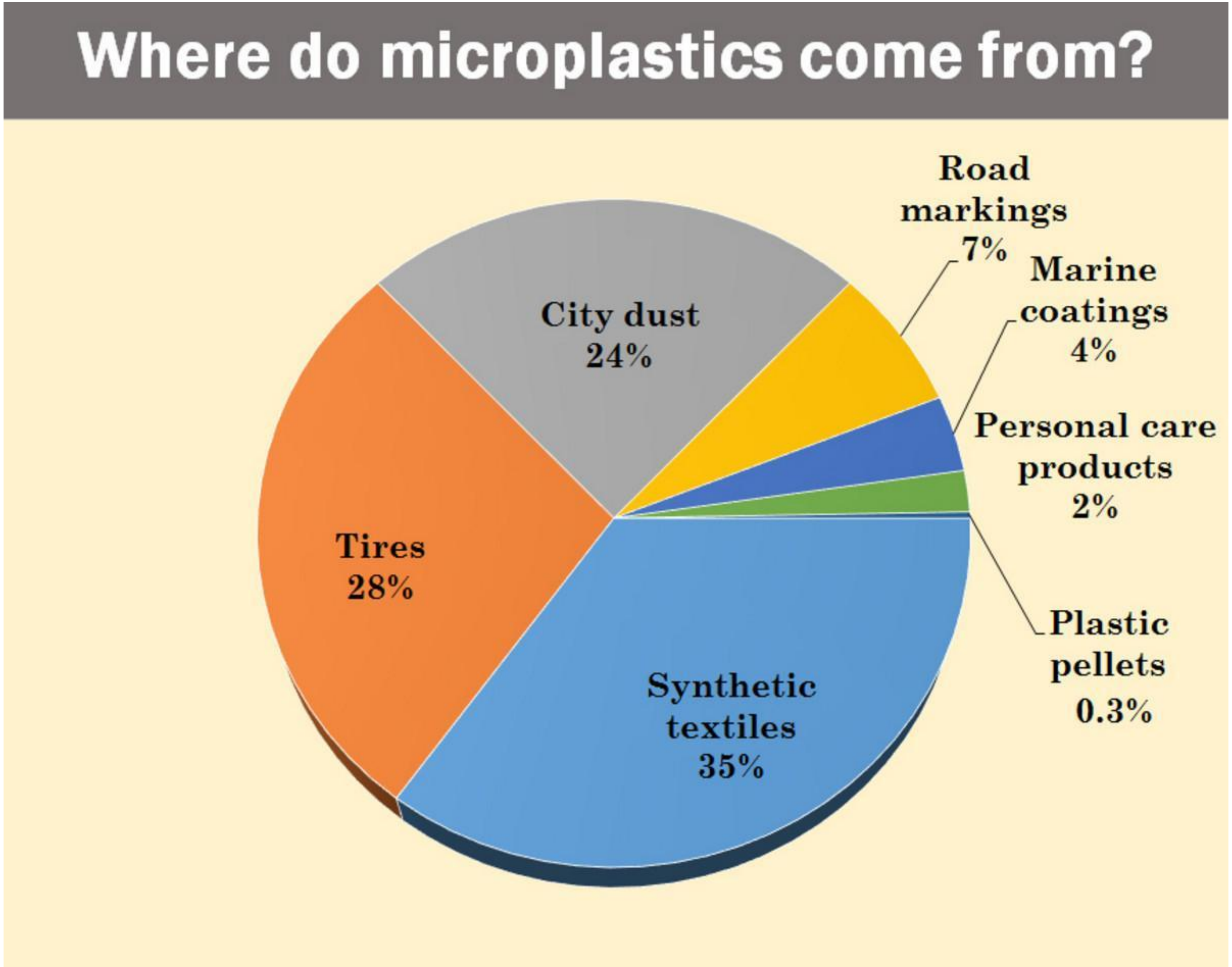
1950 2 millió tonna,

2020 A műanyag termelés exponenciális növekedése kapcsán ez a szám 400 millión tonnára emelkedett,

2040 A műanyag termelés megkétszereződése várható (800 millió tonna) és 2050-re 2.5-szerese lesz.

Az OECD jelentése szerint, a műanyagok kevesebb mint 20%-a kerül újra feldolgozásra, több mint 80% a környezetbe kerül.

2021-ben Kína önmagában 32%-át adta a globális műanyag termelésnek, USA a második 18%-al.



Honnan származnak a mikró műanyagok?

Városi por 24%
Út felfestések 7%
Tengeri hajók burkolata 4%
Szépség ápolás 2%
Műanyag golyócskák 0.3%
Szintetikus textilek 35%
Gumiabroncsok 28%

Műanyagok sűrűsége (g/cm^3)

Polipropilén (PP)	0.90 – 0.92
Kis sűrűségű polietilén (LDPE)	0.92 – 0.94
Nagy sűrűségű polietilén (HDPE)	0.94 – 0.96
Polisztirol (PS)	0.96 – 1.05
Poliamid (Nylon)	1.14 – 1.15
Poliakirilnitril (PAN)	1.18 – 1.19
Polivinilklorid (PVC)	1.16 – 1.45
Polikarbonát (PC)	1.20 – 1.22
Polietilén-tereftalát (PET)	1.38 – 1.39
Politetrafluoretilén (TEFLON)	2.20

Cellulóz és protein-bázisú szálak sűrűsége (g/cm^3)

Pamut	1.14
Gyapjú	1.32
Selyem	1.33
Viszkóz	1.52 – 1.54

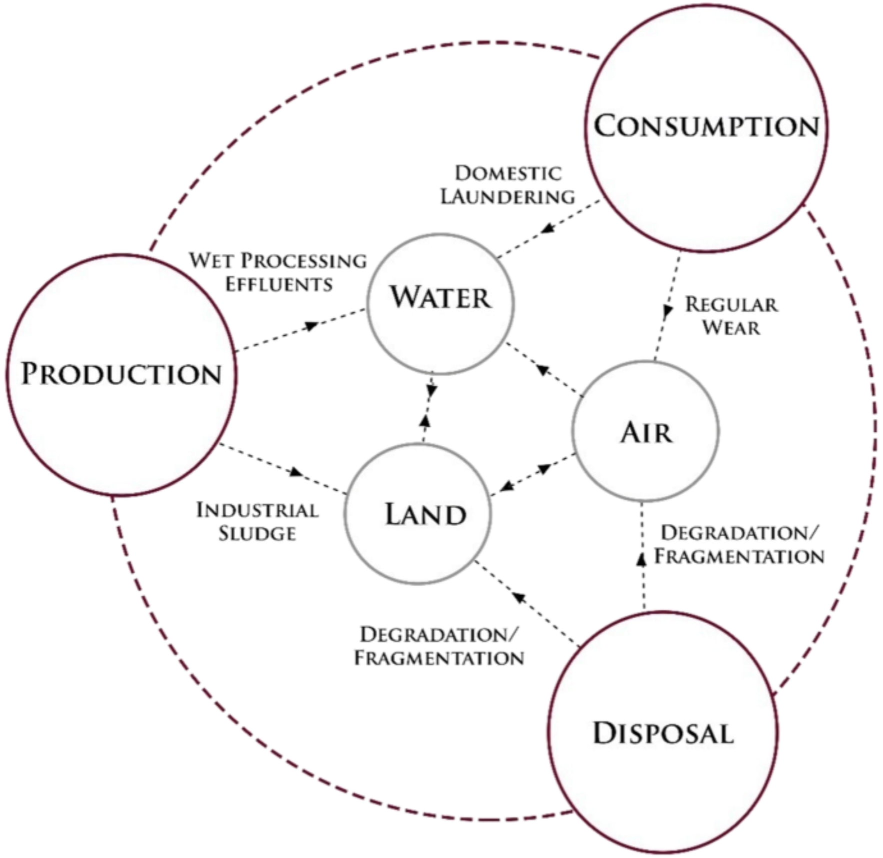
A textil iparban használt szálak

Természetes (29.6%)	Mesterséges (70.4%)
♦ Cellulóz bázisú szálak, pamut háncs szálak, juta, kender, szizál) stb.	♦ Szemiszintetikus polimer alapú, újra feldolgozott cellulóz szálak (viszkóz, modal, lyocell)
28%	**6.4%**
♦ protein-bázisú szálak (gyapjú, selyem, mohair, angora, alpaka)	♦ szintetikus polimer-bázisú szálak (poliészter, poliamid, polipropilén, poliamid, poliakrilnitril stb.)
1.6%	**64%**

Market Report (2022) Fibers and Materials

A vízi öko-szisztémákba kerülő szálak forrásai

1. Kommunális és ipari szennyvíz tisztítók (WWTP) kibocsátásai,
   Textilek mosásából származó finom szálak,
2. Kiülepedés a levegőből (átlagos napi érték 365 MP-szemcse /m^2)
3. Szennyezett talajok szemcséi terjedése árvizek alkalmával. Különösen kritikus szennyvíz iszapokkal kezelt talajok esetében.



Ramasamy and Subramanian (2021), Envrion.Sci. Pollut. Res. 11356-021-14763z

Release of fibers during washing of textiles

Release depends on laundering parameters (temperature, detergents type and concentration, type of wash machine, agitation, washing time) and fabric variables (structure and age of textile, chemical composition and surface properties of fibers)

Generally the microfiber loss ranges from 10-4000 mg/kg per wash.

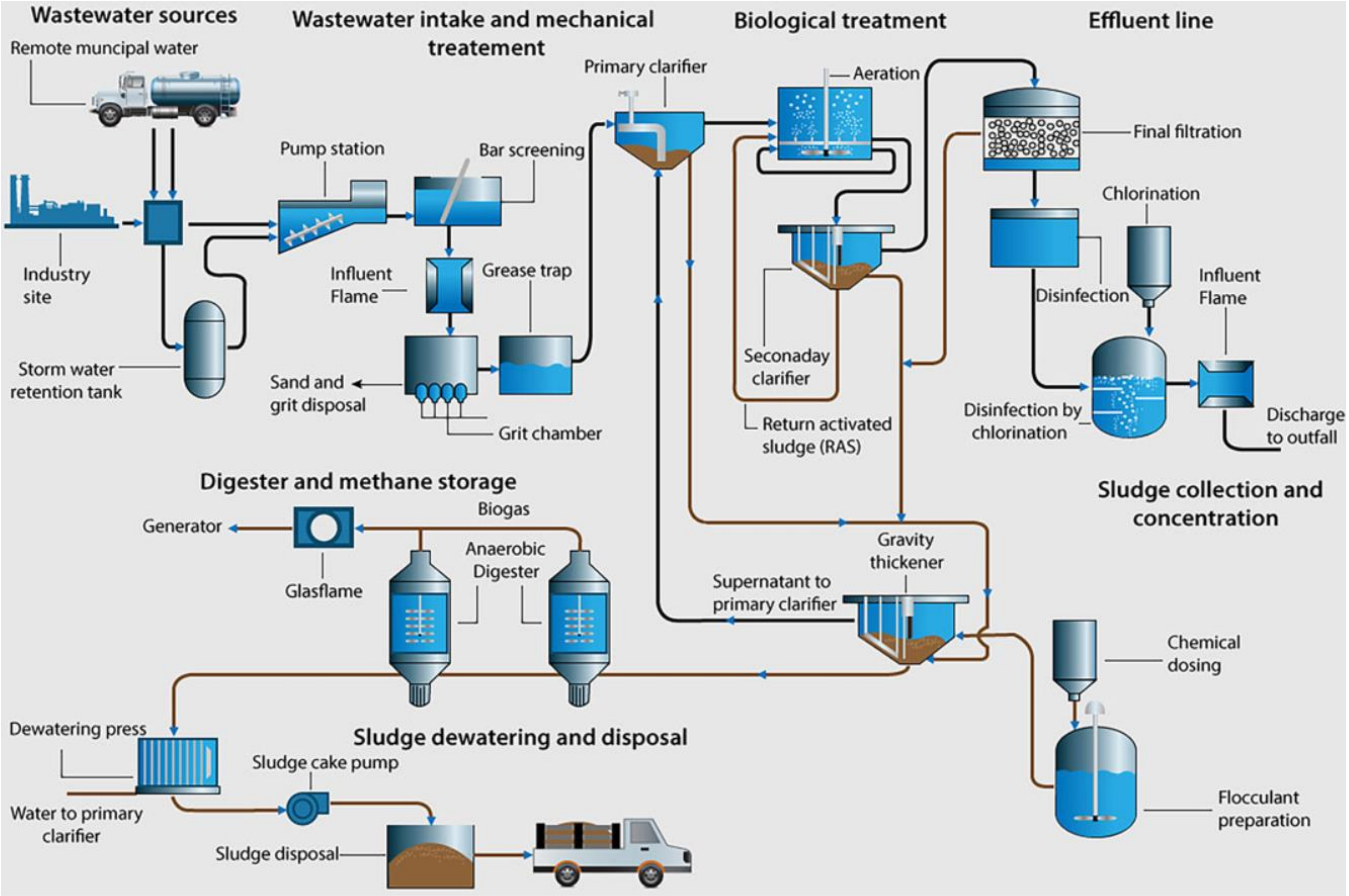
- 700.000 fibers could be released from 6 kg wash load of acrylic fabric (Napper et el. 2016)
- Cellulose-based fabrics released 200-4000 mg/kg fabric and polyester 100-1000 mg/kg at accelerated laundering (Zambrano et al. 2019)

Global Wastewater Production

- 359.4x10^9 m^3/year of which 63% is collected and 52% is treated
- 48% of global wastewater production is released to the environment untreated
- An estimated 40.7x10^9 m^3/year (11.3%) is intentionally reused. This technology is specially important in Middle East and North Africa. For example United Arab Emirates, Kuwait and Qatar reuse more than 80% of their produced wastewater, while in Scandinavia the reuse is only <5%.

Jones et al. (2021) Country-level and gridded estimates of wastewater production, collection, treatment and reuse. Earth Syst. Sci. Data 13.237-254.

Activated sludge technology



Effects of microplastics, microfibers and their additives on aquatic organisms

Ingested particles directly or indirectly resulting in

- Intestinal damage
- Reduced ingestion
- Slow or delayed growth
- Reduced spawning
- Shortened lifespan
- Abnormal or even fatal gen expression

These effects primarily affect species at the bottom of the food chain. It means first of all the zooplanktons are endangered.

Rebelein et al. (2021) Sci. Total Environ. 777: 146045

Biodegradation of natural and artificial fibers

	degradation time
Linen	1 month
Cotton	5 month
Wool	2 years
Silk	4 years
Polyester	200 years
Acrylic	450 years

These degradaton times drastically depends on the physical and chemical conditions of the aquatic envrionment and the properties of fibers

Le et al. (2022) Microfibers in laundry water, Sci. Total Environ. 852, 158412

Study of microplastic and microfiber emission of municipial WWTP Budapest

Capacity 350.000 m^3/day

Hydraulic retention time 16-19 hours

Sewage sludge production 55-60 tonnes/day

Mechanical and biological treatment

Sampling of effluent

Two sampling campaigns in February and April 2023. To receive information on the effect of seasonal changes of technological parameters and domestic activities of the affected population, the effluent samples were collected on Monday, Wendesday and Friday at different time periods.

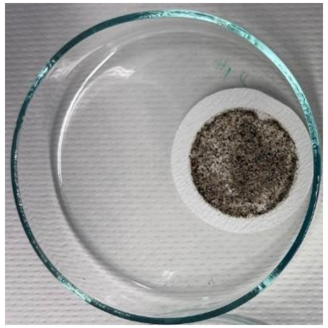
Sampling

1. ~140 L treated wastewater was transported through a 3 stages steel-sieve system with mesh size of 710, 180 and 63 µm
2. From the sieves the particles (fibers) were washed into glass bottles with bidistilled water and transported to laboratories in cool box

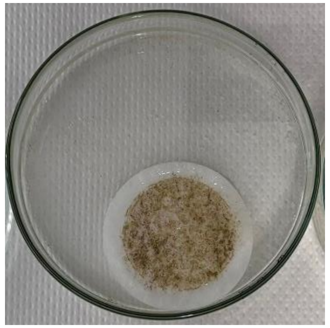
Sample preparation

1. Water samples containing different size fractions were filtered in laminar flow hood applying precombusted glass fiber filter with pore size of 0.7 µm
2. After drying the dry mass of solid particles were determined
3. The dark-brown organic material was removed by H_2O_2 (30%) treatment for 7 days
4. The particles (>5 µm) were individually transferred from the filters by micro tweezer onto a gel layer
5. At the end we have a „fiber bank”!

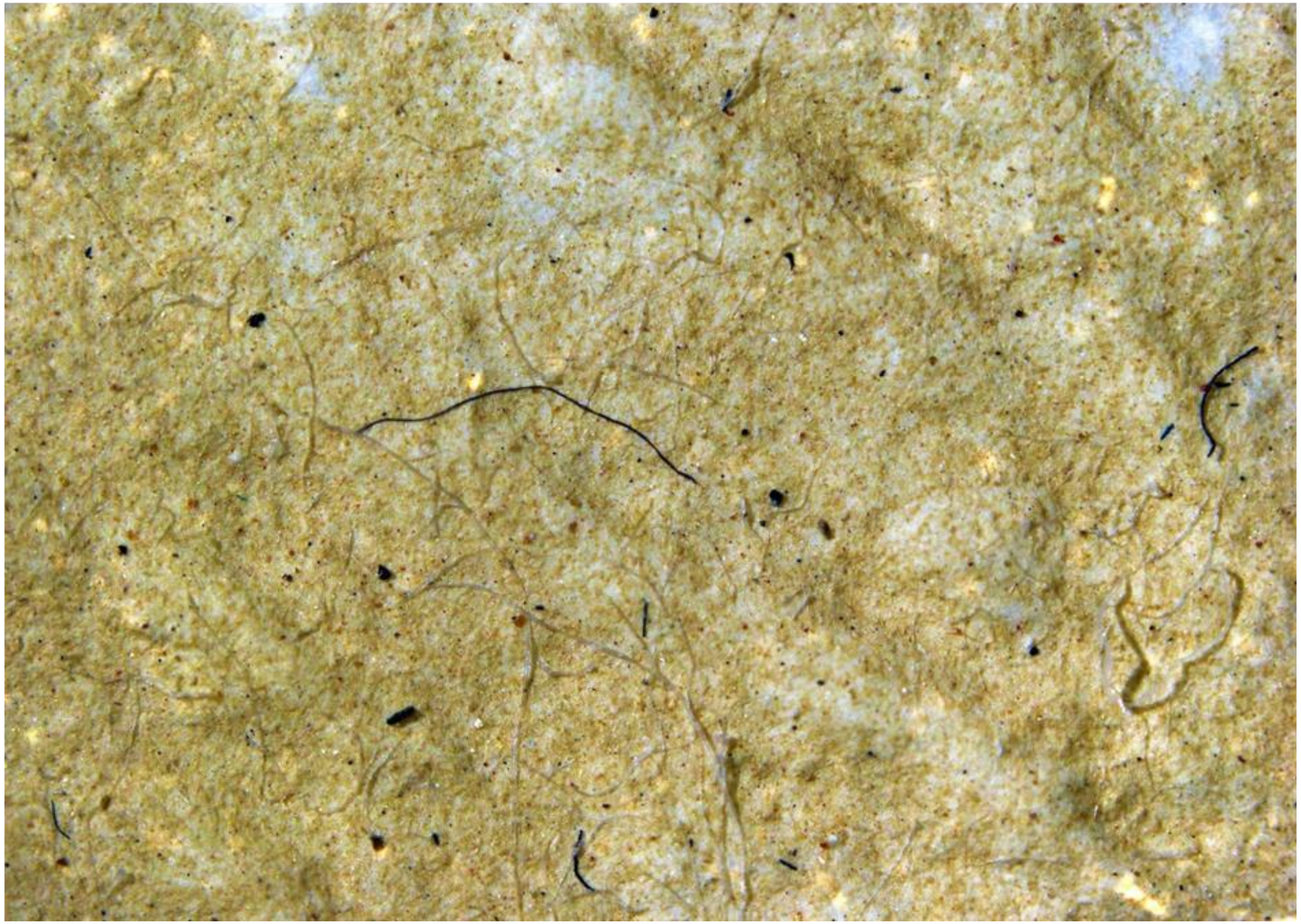
Solids after filtration



Solids after H_2O_2 treatment

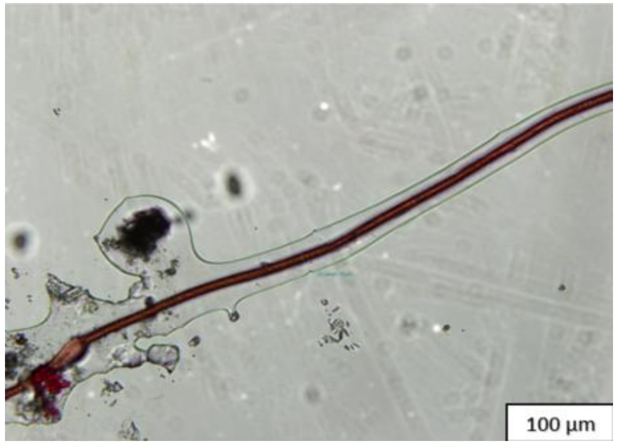


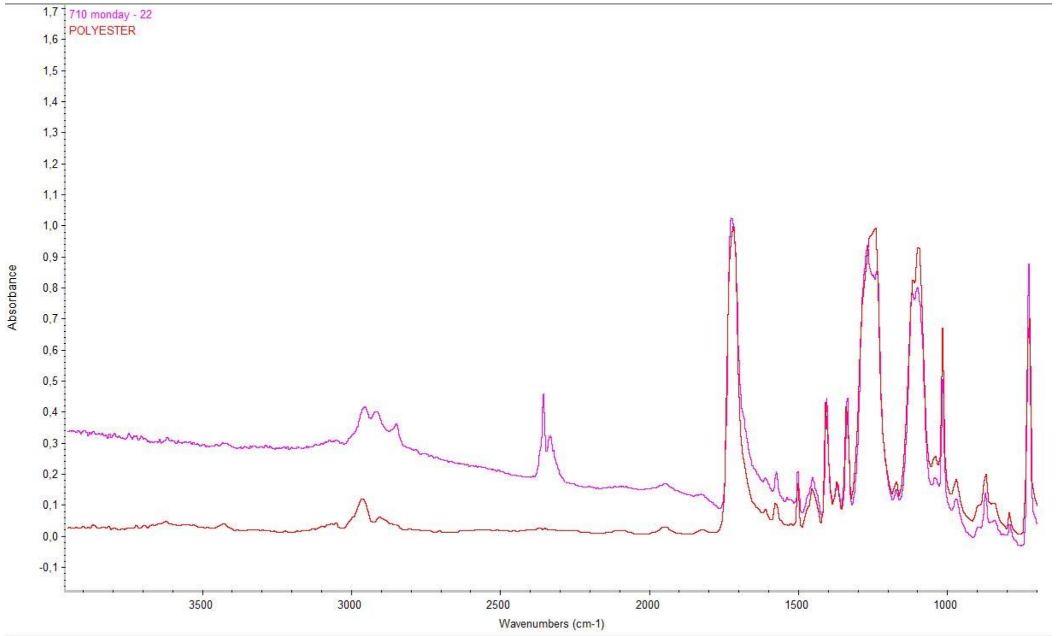
Microfibers on glass fiber filter after H_2O_2 treatment



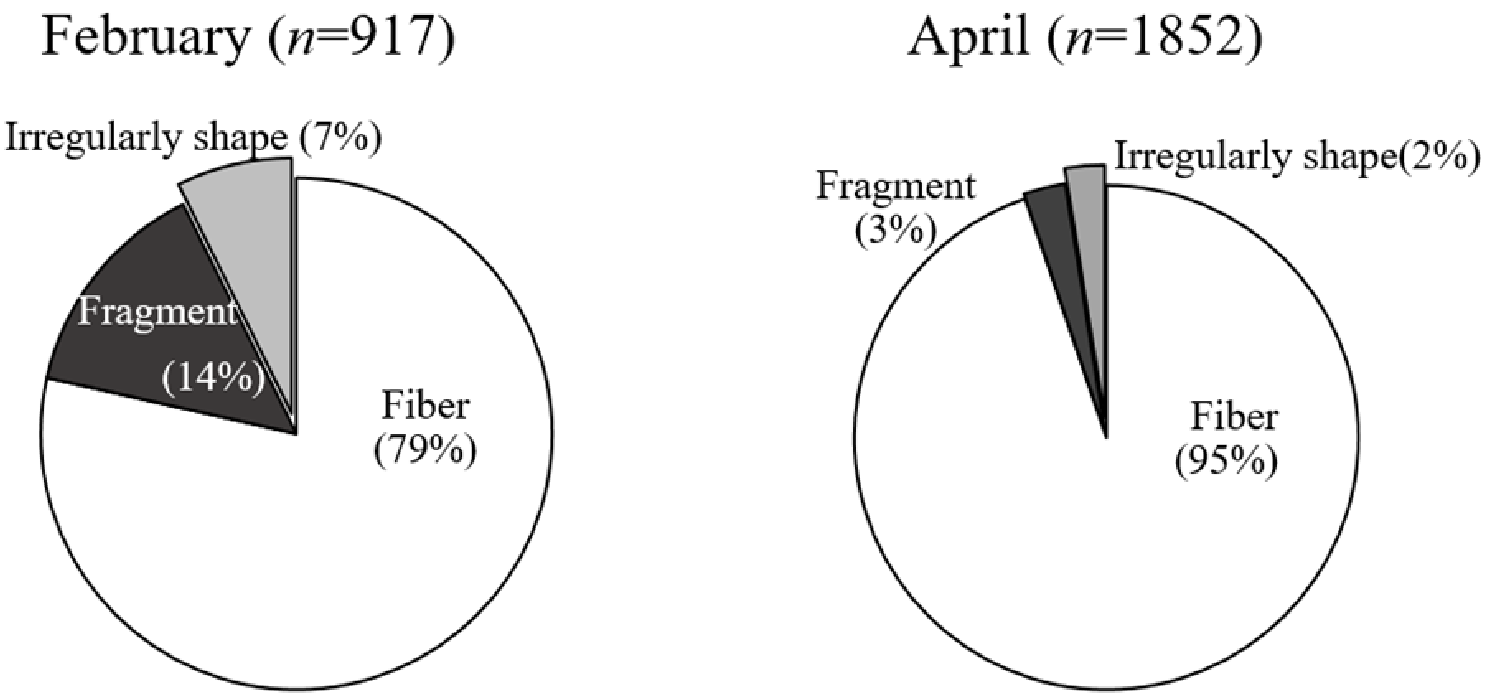
Identification and quantification of particles

- Visual inspections and quantification were performed by using Carl Zeiss-Stemi 508 stereomicroscope and Olympus BX61 fluorescence microscope
- For chemical identification of particles Bruker Vertex 70 FTIR spectrometer was applied

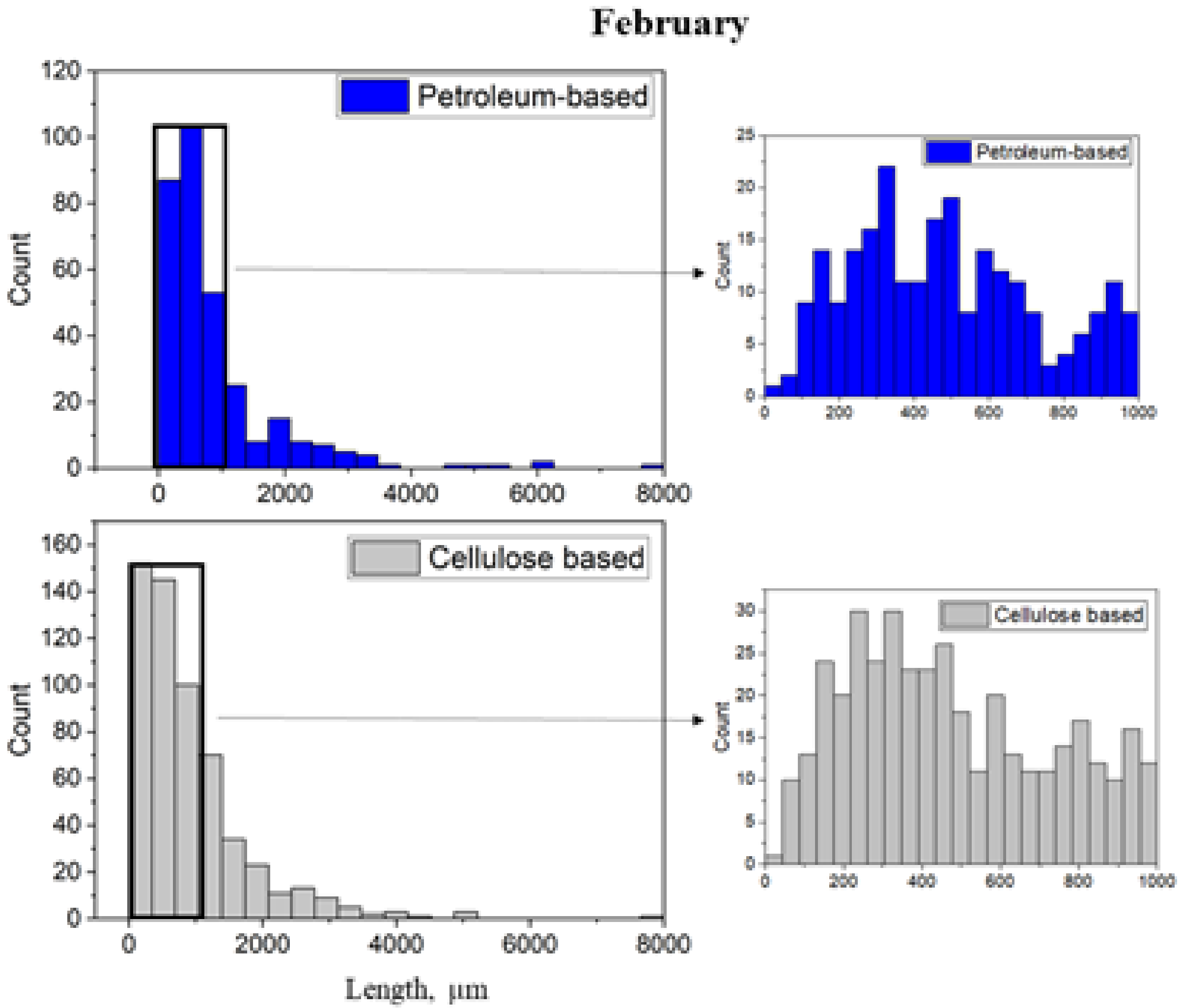




Proportion of particles according to shape



Distribution of microfibers according to length



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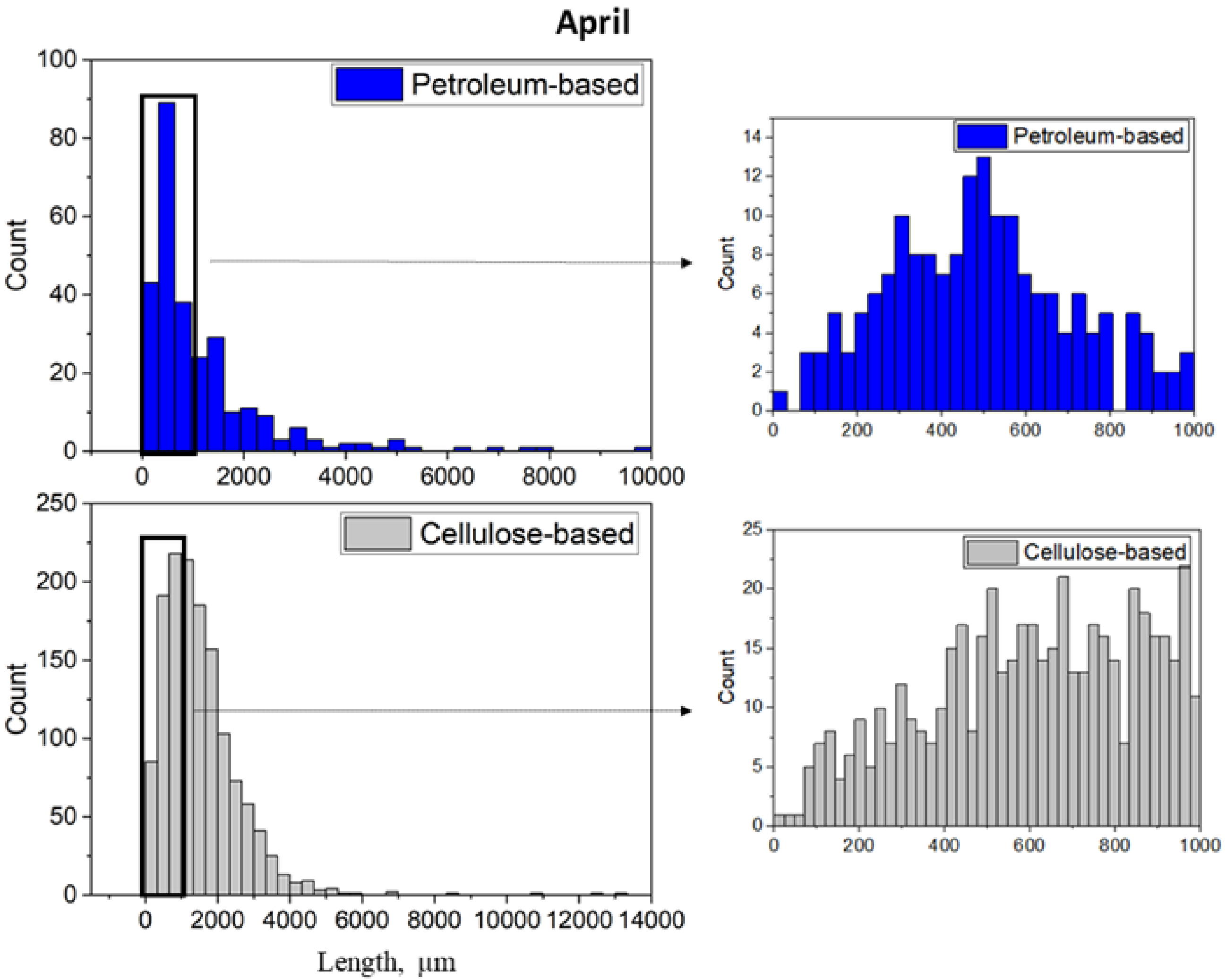
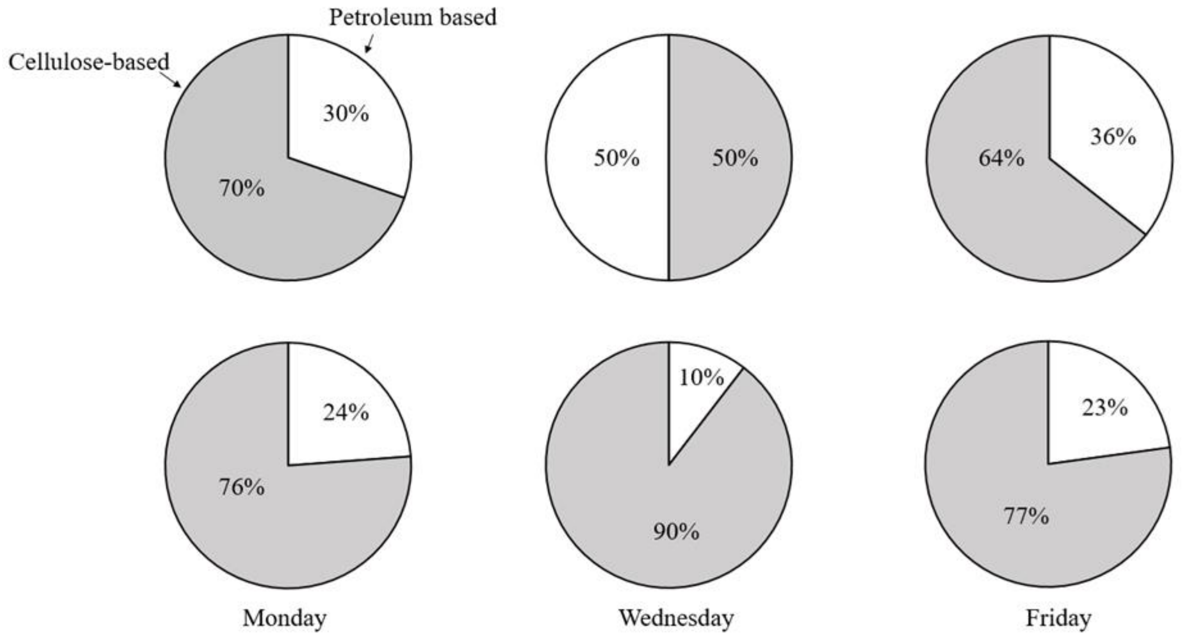
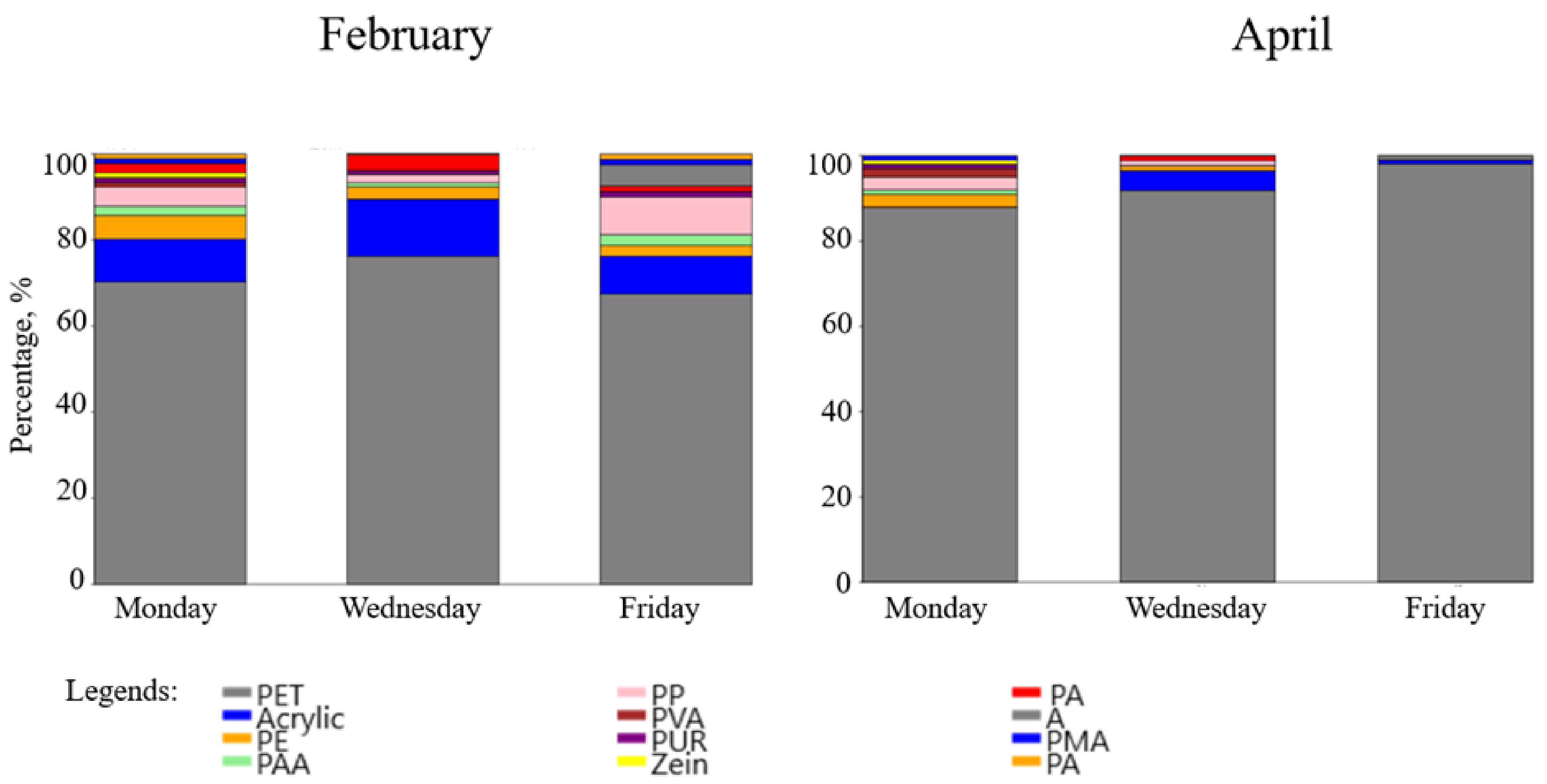


Proportion of cellulose- and petroleum-based microfibers in the WWTP effluent



Proportion of petroleum based microfibers in the WWTP effluent



Toilet papers

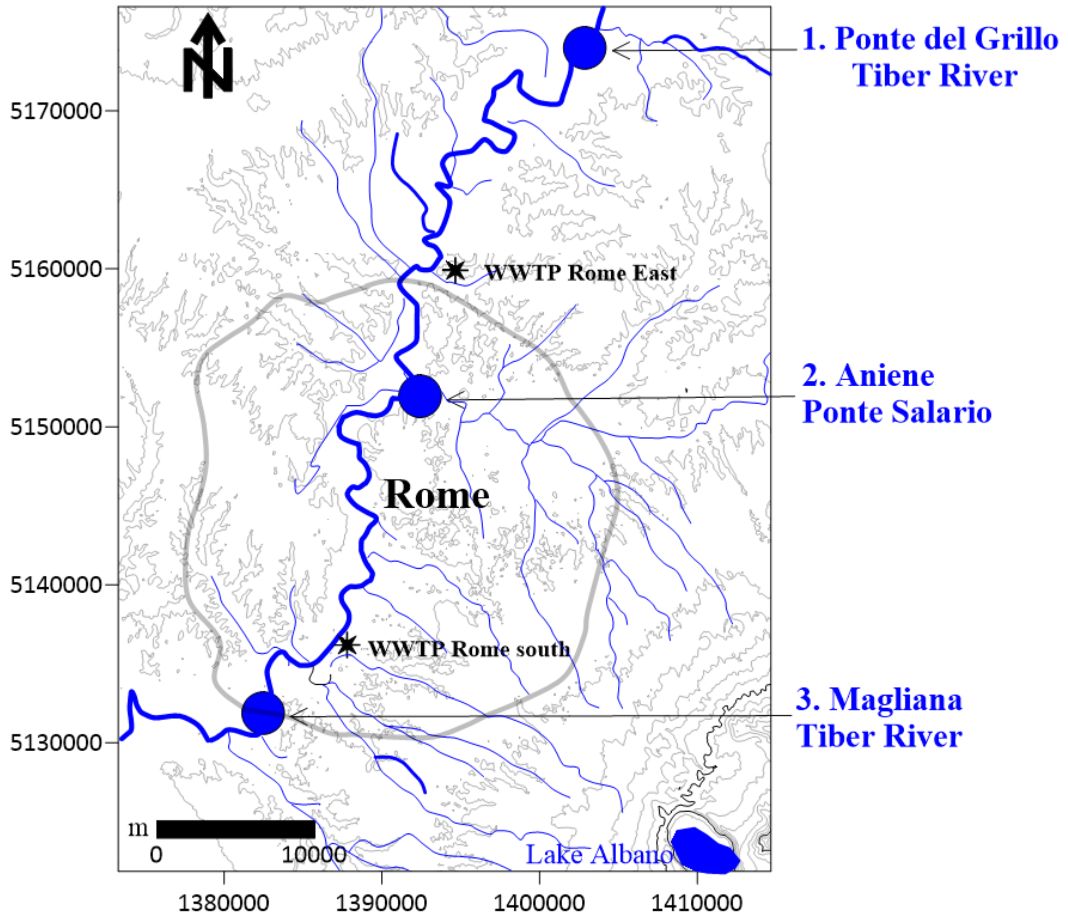
- Cellulose fibers of toilet papers became a primary insoluble substrate entering WWTPs
- These fibers compose 30-50% of the total solids in the sewage
- Large fraction of this cellulosic matter (cellulose, hemicellulose, lignin) is recalcitrant to current physicochemical and biological treatment technologies, resulting in extra surplus sludge production
- Cellulose fiber removal by mesh sieving (0.35 mm) in the pretreating significantly (~90%) reduces the organic loading and aeration demand. High economic advantage and low environmental impact. Disadventage is the clogging!
- Wastewater derived cellulose fibers are excellent source for production of cellulose nanocrystals.
- Redesign of TPs is necessary to change their structure

Li et al. (2020) J. Cleaner Prod. 261, 121138

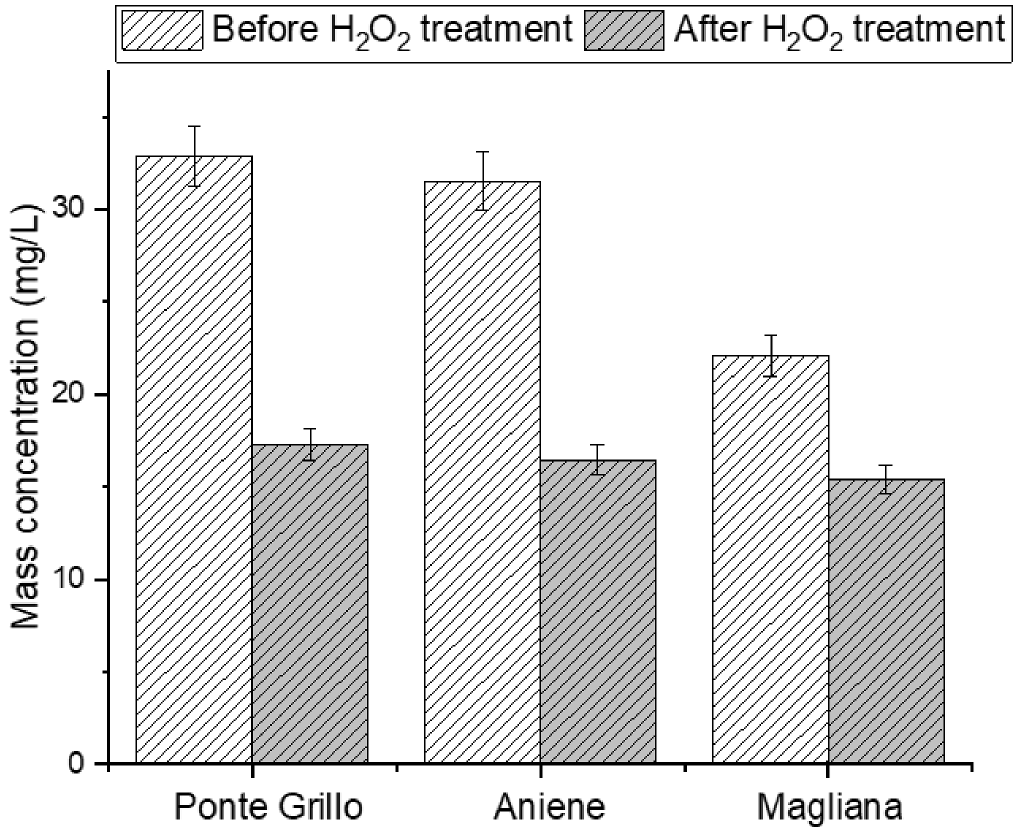
Summary for effluent of WWTP

1. Fiber emission is dominant in case of municipal WWTPs
2. The Central WWTP in Budapest emitts 2,5-5 particles/L into the Danube River. At daily capacity of 250.000 m^3 about 10^9 particles are transported to the river. The proportion of cellulose-based and fossil-based fibers amounts to 79-94%
3. Polyester, acrilnitril and polypropylene have the highest occurence among the fossil-based fibers (5-50%)
4. For the high proportion (50-95%) of cellulose-based fibers beside the natural textile fibers pressumably the toilet papers (TP) are responsible. Li et al. (2020) had similar observations and suggested to redesign the strucure of TPs.
5. Reduction of fiber concentration in effluents results in lower risk for microorganisms in the aquatic environment

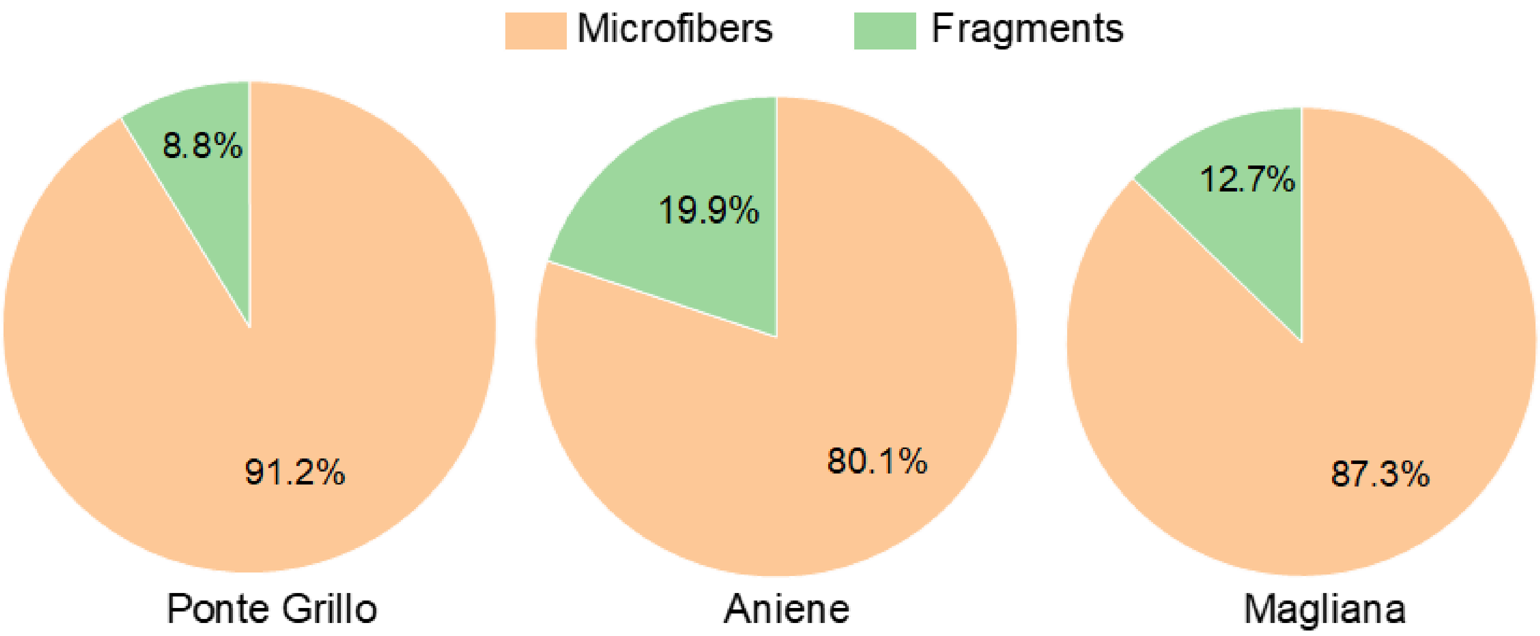
Location of sampling sites (blue circles) along the Tiber river; including WWTPs in East and South (black stars). Local creeks and rivers are indicated in blue



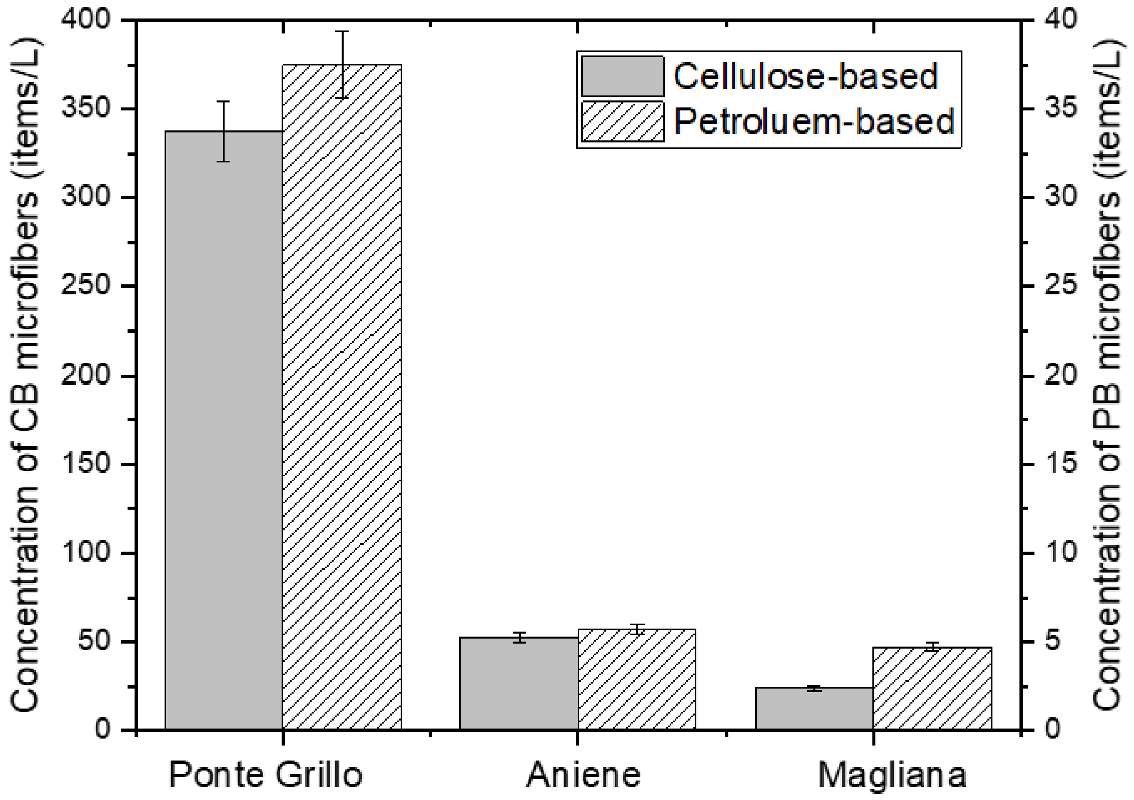
Mass concentration of total suspended solids (TSS) (mg/L) before and after treatment with H_2O_2 at the sampling points



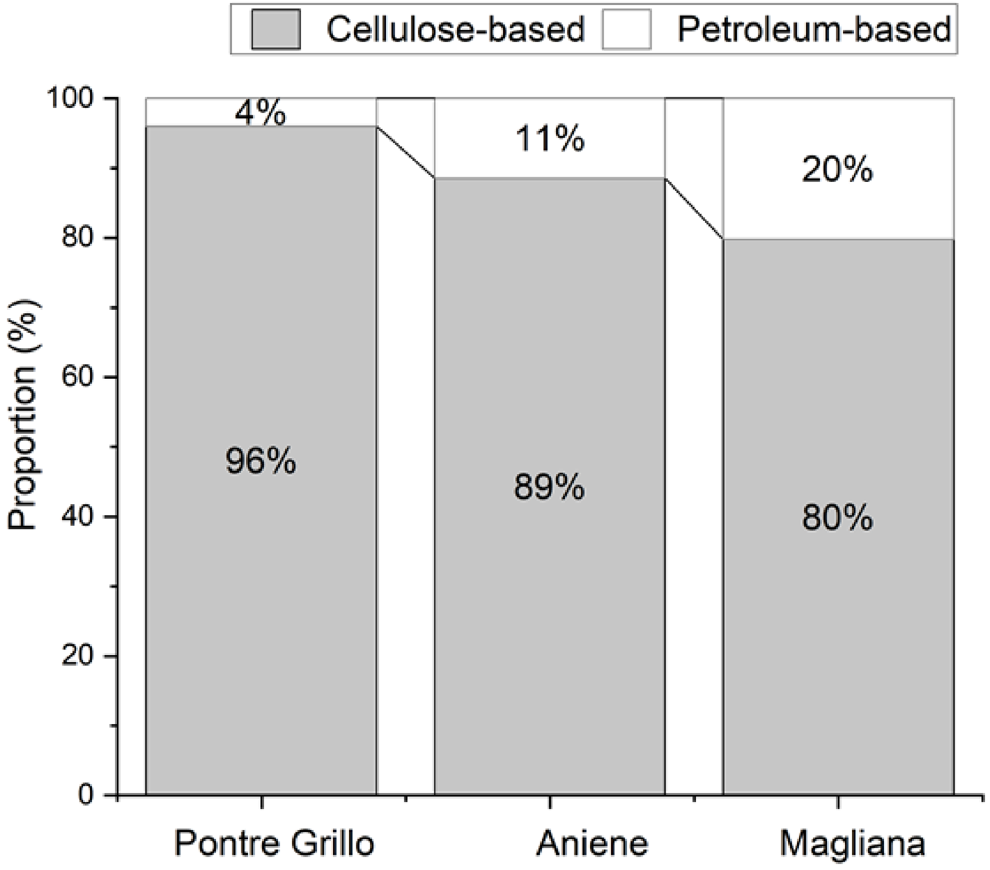
Proportion of microfibers and fragments according to shape



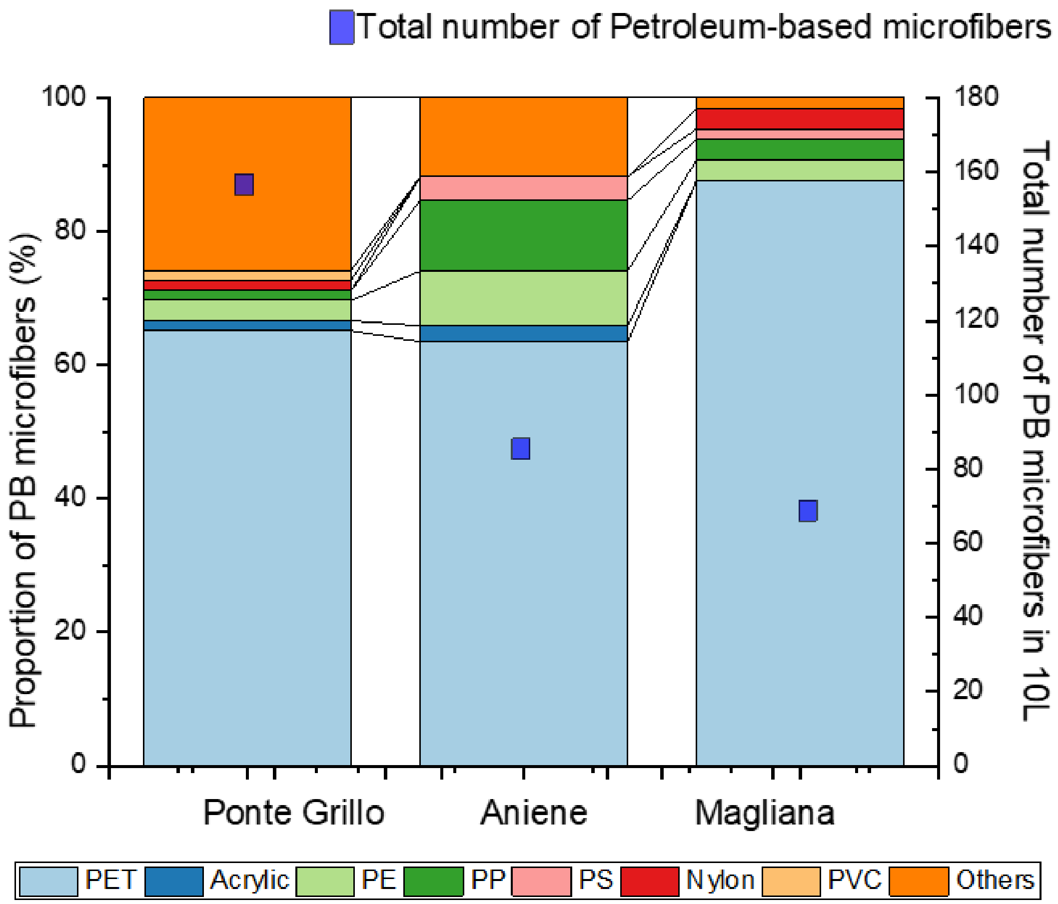
Concentration of cellulose-based (CB) and petroleum-based (PB) microfibers/L at Ponte Grillo, Aniene, and Magliana



Proportion of cellulose-based (CB) and petroleum-based (PB) microfibers at different sampling sites



Proportion of different petroleum-based (PB) microfibers at the sampling sites according to chemical composition



How can we reduce the fiber emission?

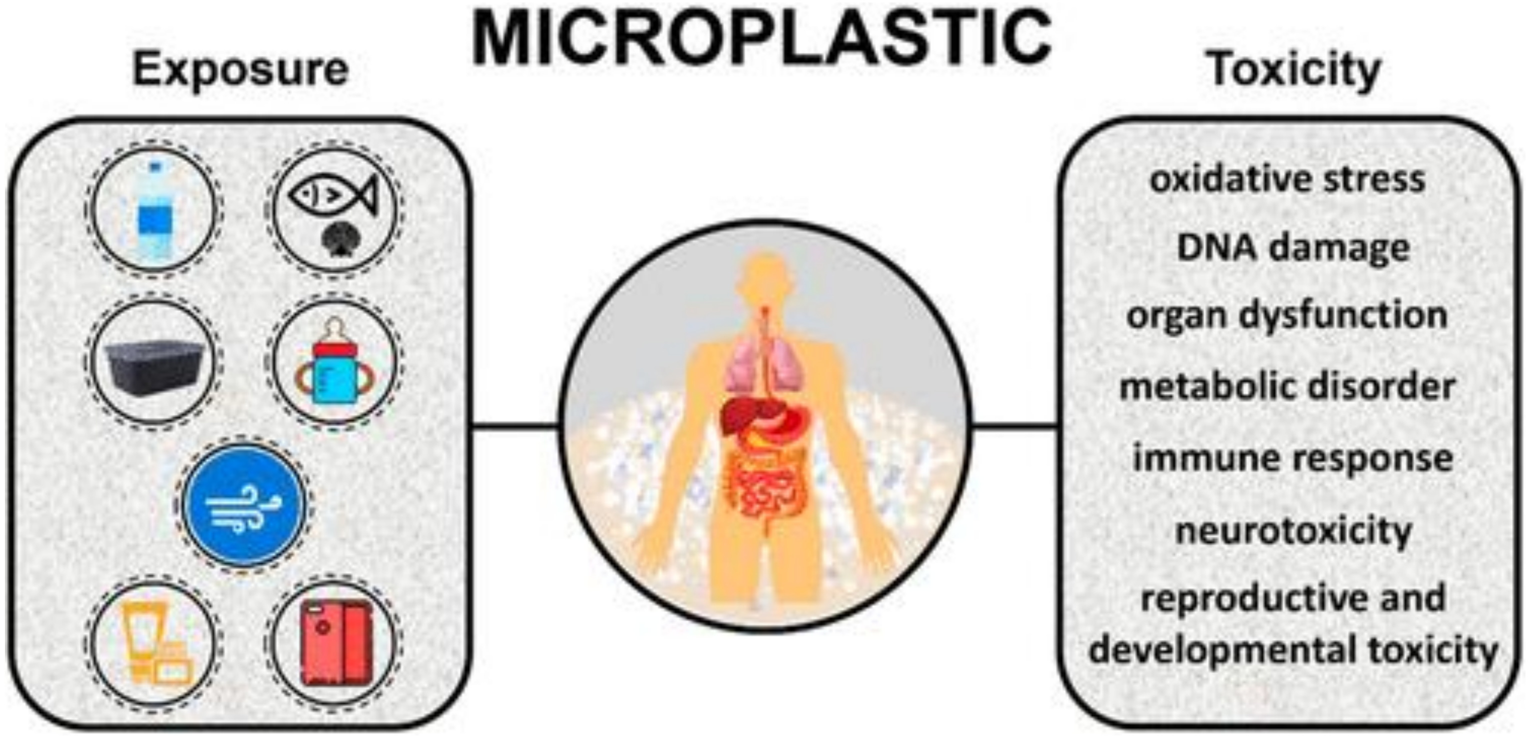
1. The textile industry has to develop new technologies e.g. use of finer yarns with filaments and compact structures reducing microfiber shedding or application of chemical (coating) finishing processes
2. The wash machine producers have to develop more efficient laundry filters and to optimize the agitation processes
3. The wash machine producers have to give information for the users on the suggested washing time, temperature, detergent concentration for different textile materials
4. The WWTPs have to modify their technology increasing the efficiency of pretreatment step
5. The structure of toilet paper should be changed to increase the removal efficiency of pretreatment

Remark: France will be the first country to introduce mandatory filters on washing machines for trapping MFs in 2025.

Pathways of human exposure to microplastics

Li et al. (2023) Potential Health Impact of Microplastics, Environ. Health, 1, 4, 249-257.

Toxicity of microplastics



Microplastics (mostly PE, PP, PET, PS) were found in spleen, liver (4.6 items/g) colon (28,1 items/g) lung, faces, placenta, breastmilk.

Li et al. (2023) Potential Health Impact of Microplastics, Environ. Health, 1, 4, 249-257.

Konklúziók

1. A mikró szálak koncentrációjának csökkentése a textilipar és a wc papír gyártás modernizációjával, a mosógépek új generációja hatékonyabb szűrőkkel
2. Meg kell állítanunk a PET palackok és a műanyag élelmiszer dobozok gyártását. Visszaállítani az üveg palackok alkalmazását fém kupakokkal az ásványvíz esetében
3. Meg kell állítanunk a tenger gyümölcsei fogyasztását
4. A kozmetikai iparban az elsődleges mikró műanyagok alkalmazását ásványi szemcsékkel kell helyettesíteni

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