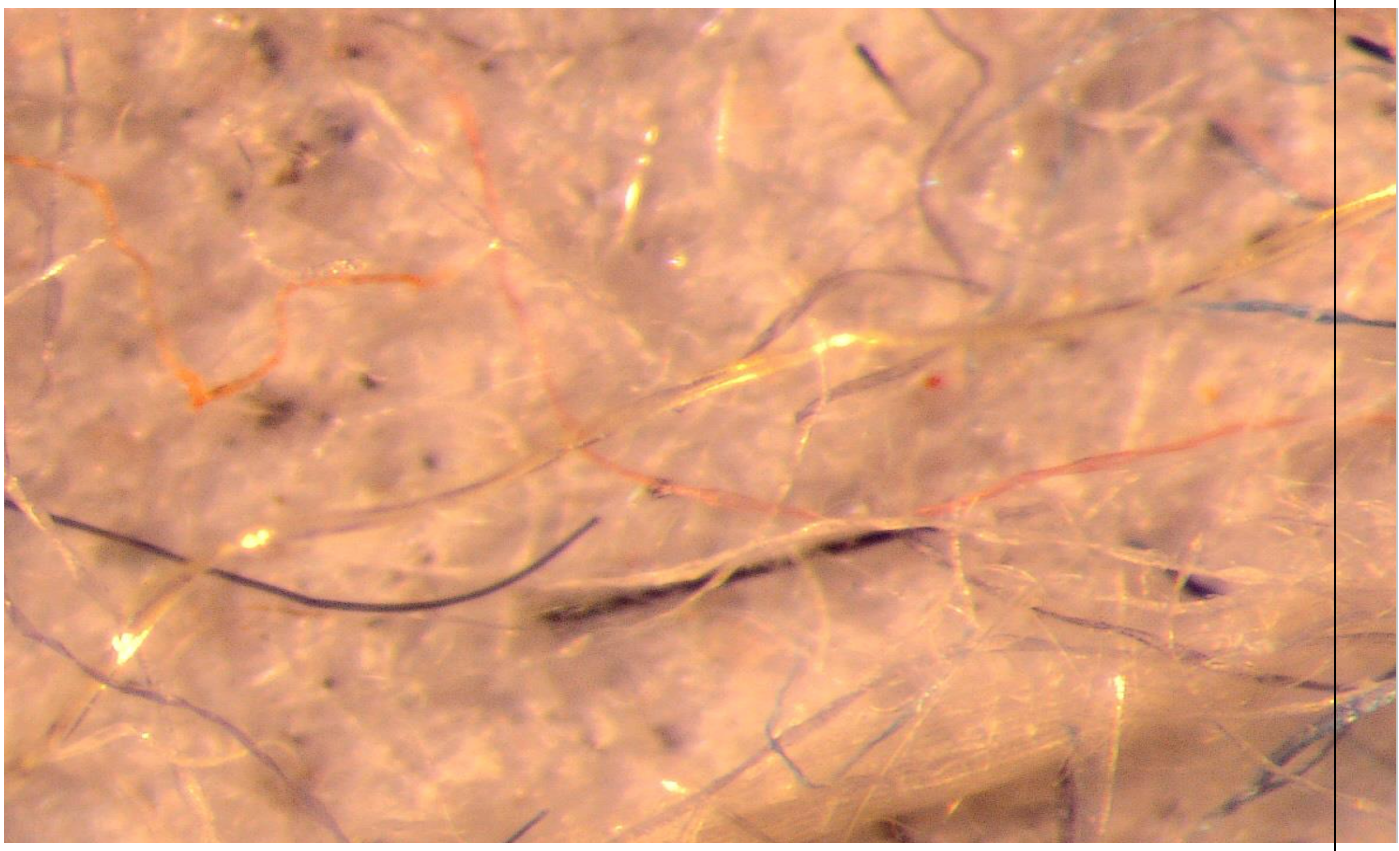
Exposure to airborne and deposited microplastics in indoor environments of the Netherlands



Final report for the Plastic Soup Foundation

Mahrooz Rezaei
Meteorology and Air Quality Group
Wageningen University & Research

February 2023

1. Introduction

The indoor environment is important to modern life due to the large proportion of time that people spend indoors. Microplastics (MP) are all around us, so we are constantly exposed to them (Noventa et al., 2021). Synthetic clothing is one of the most important sources of MPs in indoor environment (Chen et al., 2020; Prata, 2018). Other sources of MPs in indoor environment include interior furniture, food packages, plastic bottles, etc. Through wear and tear, small fragments of these synthetic materials are released and end up in the environment including the air we breathe.

Due to the small size and light weight of MPs they can get suspended in the air around us or get deposited on the surface. Airborne MPs in indoor air may lead to human exposure through inhalation or ingestion of the material deposited on the surface of our meal for example. Dermal contact to deposited dust are the other route of human exposure to MPs. The potential health risk of such exposure cannot be neglected especially for children. In order to accurately determine the actual risk of indoor MPs, we need to collect accurate data. Airborne MPs have been detected in different sites, such as France (Dries et al., 2017), Denmark (Vianello et al., 2019), China (Liu e al., 2019) and New Zealand (Knobloch et al., 2021). In the Netherlands there is only one recent study (Nizamali et al., 2023) in which only the deposited dust was tested for MPs in two different locations. However, knowledge regarding the presence of suspended MPs in indoor environment in the Netherlands is lacking. Considering this major knowledge gap, the current research aimed at answering the following research question by collecting both airborne and deposited samples in different indoor environments:

"To what extent are different indoor environments are polluted with airborne and deposited microplastics?"

2. Material and methods

2.1. Case studies

Sampling locations included a Household laundry room located in Wageningen city, a clothing shop in Wageningen city, a second-hand cloth shop in Utrecht city, a catering building within the campus of Wageningen University and a changing room in a gym located within the campus of Wageningen University. Table 1 and Figure 1 show more information about the sampling locations. All photos of sampling and analysis are shared with PSF separately.

Table 1. Locations of airborne microplastic samples.

Location no.	Location category	Date of Sampling	Address
1	Laundry room	12-14 July	Wageningen (Duivendaal 1A)
2	Fashion store	24-26 August	Wageningen Modehuis de Windt
3	2nd-hand store	30 Aug – 4 Sep	Utrecht (Emmaus Haarzuilens)
4	Catering area	17 Nov - 22 Nov	Forum Building, Wageningen University Campus
5	Gym	7Dec – 9 Dec	Sports center de Bongerd, Wageningen Campus

Figure 1. Air sampler and one Petri dish collecting microplastic in location 2.

2.2. Sampling

For this study both airborne and deposited samples were collected. Sampling was carried out between July and December 2022. At each location, 3 air samples were collected using the ARA-N-FRM air sampler equipped with Quartz filters and total suspended particles cyclone using an omnidirectional Louvered Inlet (Figure 2). The total sampling volume of the air for each sample were recorded separately.

Three deposited dust samples were collected using a quartz filter placed in a Petri dish. The area of the filter was 0.007 m^2.

Figure 2. ARA-N-FRM air sampler and Quartz filters used for sampling airborne microplastic.

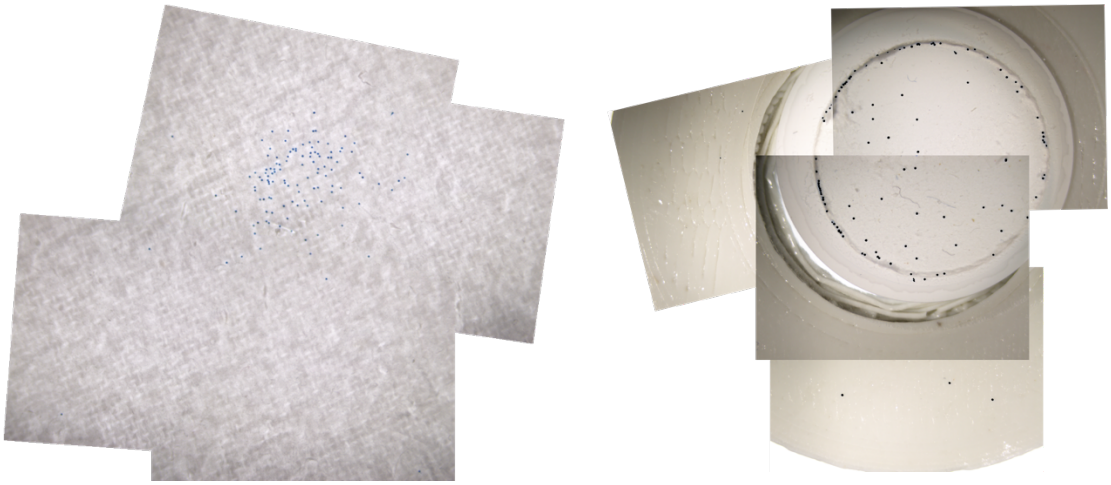
2.3. Microplastic extraction and identification

2.3.1. Developing methodology for extraction of microplastics from air samples

In order to be able to extract microplastic with high recovery rate, we first had to test our extraction methodology for air samples. This was mainly because, air samples are sensitive to contamination and the extraction procedure for air samples is new and different from soil, water and dust that we currently have the protocols for. For this study we first developed two protocols of extraction and used Blue Polyethylene (PE) for the spike sample (Figure 3). In protocol 1, we first placed the quartz filters in glass beakers, then added 5 ml of distilled water/H_2O_2 to each beaker. After vortexing the beakers for about 10 minutes, we put the beakers in the ultrasonic bath for 15 minutes. Finally, we removed and washed the filters using more water/H_2O_2. For protocol 2, we first rinsed the particles from quartz filters to beakers using water/H_2O_2. After vortexing the beaker for 10 minutes, we put the beakers in the ultrasonic bath for about 15 minutes. The digestion process was the same for both protocols and was done by leaving the beakers in the oven with aluminum foil (for avoiding contamination) at 40 °c overnight. After digestion, the water/H_2O_2 was filtrated to Anodics filters. Ethanol was used for removing all the particles from beakers. Anodiscs were gently removed and stored for further uFTIR analysis.

Figure 3. Blue Polyethylene (PE) used for spiking the Quartz filter.

Results of recovery test (Figure 4) showed that protocol 1 was a better method for extracting microplastics from air samples and quartz filters. Therefore, method 1 was used for all the air and deposited dust samples in this study. In each extraction setup, we could only analyze 10 samples at once, as we also included spike and blank samples to control the accuracy of the data. Figure 5 shows some of the steps of extraction protocol.



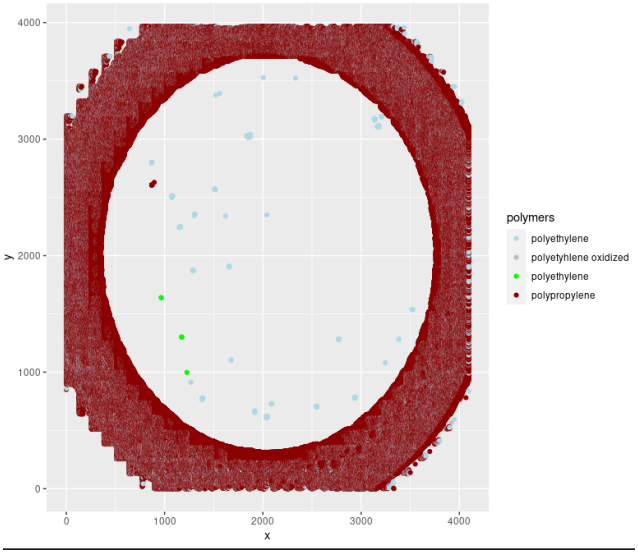


Figure 4. Spiked sample (top left picture) extracted microplastics using protocol 1 (top right picture), and the FTIR analysis of the extracted microplastics using protocol 1 (bottom picture).

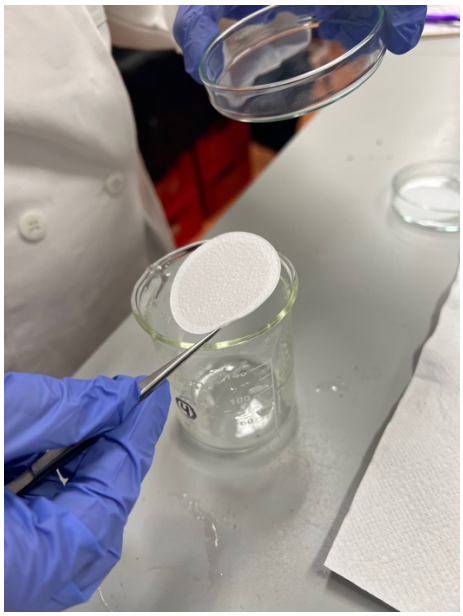


Figure 5. Extraction of microplastic from quartz filters, placing the filter in a glass beaker (top left), vertexing the beakers (top right), and ultrasonic bath (bottom).

2.3.2. Fourier Transform Infrared Spectroscopy (FTIR) analysis for microplastic identification

FTIR spectroscopy with 15x resolution was used for identification of MP. With this high resolution, smaller particles could get detected. Most of the MP studies in literature have used 4x resolution, as the time of analysis is significantly shorter. In the current study we spent one day for analyzing one or two samples. In total we spent about 30 days for FTIR analysis. One of the weaknesses of spectroscopy methods in MP detection is the underestimation of fibers. As fibers are long and thin particles and often twisted, the spectral reflectance of fibers is not recorded very well. For this reason, a combination of spectral and visual analysis (although time-consuming) was essential to detect all plastic particles.

2.3.3. Microscopic analysis for the identification of microplastics

Identification of fibers was conducted under the digital stereomicroscope (Leica MZ12) from AEW group of Wageningen University (Figure 6) by observing the filter area and obtaining photographs of fibers. Synthetic fibers were counted visually based on their surface characteristics as described in Prata et al., 2020. Natural fibers are generally more irregular and rougher while synthetic fibers have smooth and regular surfaces. Homogeneous color of synthetic fibers is another criterion for visual classification. When this characterization was not possible, the hot needle test (based on De Witte et al., 2014) was used for distinguishing between plastic and organic fibers. In the presence of a very hot needle, plastics will melt or curl, biological and natural material will not. Figure 7 is a good example of natural and synthetic fiber discrimination.

Figure 6. Visual identification of fibers under microscope.

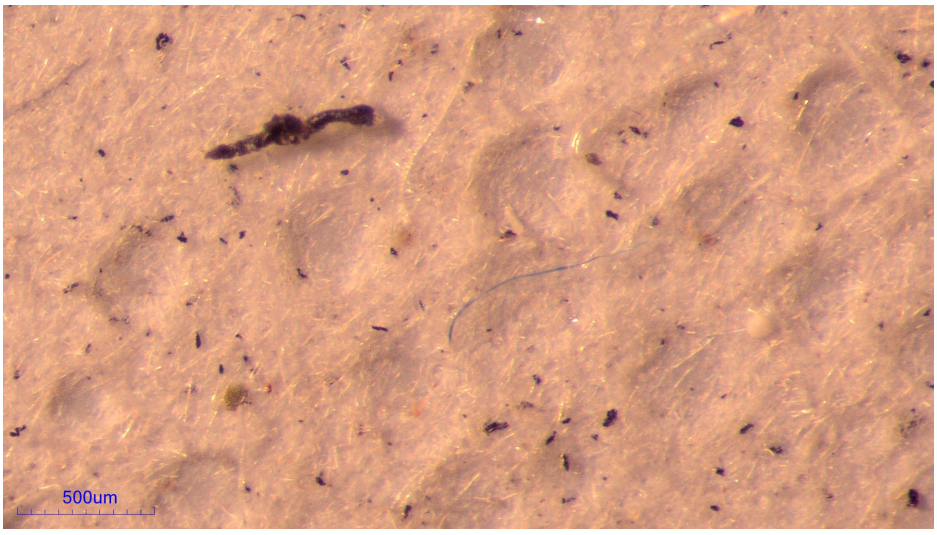


Figure 7. Discrimination between natural and synthetic fiber under microscope (40x). The black fiber is natural, but the thin blue fiber is synthetic. Picture is from one of the deposited dust samples collected at the secondhand clothing shop in Utrecht on 31 August 2022.

2.3.4. Data analysis

The most time-consuming step of this project was the data analysis. FTIR provides big data that was analyzed using APA and SiMPle softwares (Primpke et al., 2019) in combination with the reference spectral database provided by Primpke et al. (2018). Each sample with 15x resolution took at least 3 days to get analyzed. Analysis of MP content and properties were conducted using R software.

3. Results and Discussion

3.1. Microplastic content, airborne concentration and deposition flux

In total, 797 MP were found in the deposited samples and 407 MP in airborne samples. Microplastic deposition flux was then calculated considering the surface area of the filter and the duration of sampling in the unit of MP m^{-2} day^{-1}. MP deposition fluxes were in the range of 1000 MP m^{-2} day^{-1} in the laundry room and 3662.34 MP m^{-2} day in catering area of the university. Deposition of MP is considered as one of the pathways into human body through ingestion and dermal contact which reveals the risk for human health within indoor buildings specially where people are eating.

Airborne microplastic were calculated in the unit of MP m^{-3} of air by considering the sampling time and air flow rate of the air sampler. This was in the range of 1.92 MP m^{-3} to 10.19 MP m^{-3} for laundry room and the second-hand clothing shop, respectively. The airborne MP concentration was significantly high in the second-hand shop (10.19 MP m^{-3}) and the gym (8.98 MP m^{-3}). This can be related to the high volume of clothing in the second-hand shop and the busy changing room of the gym and mainly correlated to the textile synthetic plastics. Results were consistent with other studies conducted in Denmark (3.5-15 MP m^{-3}, Vianello et al., 2019), Portugal (0.9-1.1 MP m^{-3}, Xumiao et al., 2021), Korea (3-4 MP m^{-3}, Choi, et al., 2022), USA (2.5-20 MP m^{-3}, Gaston et al., 2020), Paris (1-60 MP m^{-3}, Dris et al., 2017).

Table 2. MP content, deposition flux and concentration in air of the study sites.

Location no.	Location category	MP in deposited dust (No. ± STD)	MP in airborne samples (No. ± STD)	MP deposition flux (MP m^{-2} day^{-1})	MP concentration in air (MP m^{-3})
1	Laundry room	147 ± 23.62	27 ± 2.08	1000	1.92
2	Fashion store	75 ± 13.72	53 ± 3.21	1071.43	3.78
3	$2^{nd\text{-}hand}$ store	179 ± 19.10	143 ± 2.64	2557.14	10.19
4	Catering area	282 ± 14.85	58 ± 13.43	3662.34	4.13
5	Gym	114 ± 2.12	126 ± 29.87	1357.14	8.98

STD = standard deviation

3.2. Microplastic compositions of airborne and deposited samples

In total, 11 polymer types were detected in airborne samples and 13 polymer types in the deposited samples. The relative percentage of polymers in deposited dust samples were in the order of: PMMA> PVC> PE > PP > N > R > PET> EVA > POM > PCL > PSU > PEEK > PC > PS. This was a bit different for airborne samples which was in the order of N > PMMA > PP > PE > R > PET > POM > PVC > PCL > PC > EVA > PC.

Figure 8 shows the distribution of polymers in both airborne and deposited samples. Comparing polymer types in airborne and deposited samples revealed some evidence about their potential to remain airborne and their higher risk of inhalation. PE, N, R, PC were higher in airborne samples compared to deposited samples. There was no PC found in all the deposited samples and PS, PSU, PEEK polymers were not found at all in airborne samples. This might show the potential of PC polymers to stay airborne for a longer time and thus higher risk of inhalation of such polymers. However, further laboratory study in required for measuring the settling velocity of different polymers.

Interestingly, some polymers were only found in one specific location. PS for example was only found in the deposited sample from the laundry room. PS is one of the polymers used in textile. Likewise, PSU and PEEK were only found in deposited samples collected in the catering area of the campus. These polymers are thermoplastics that are mainly used in food preparation application and thus potentially originated from the catering site.

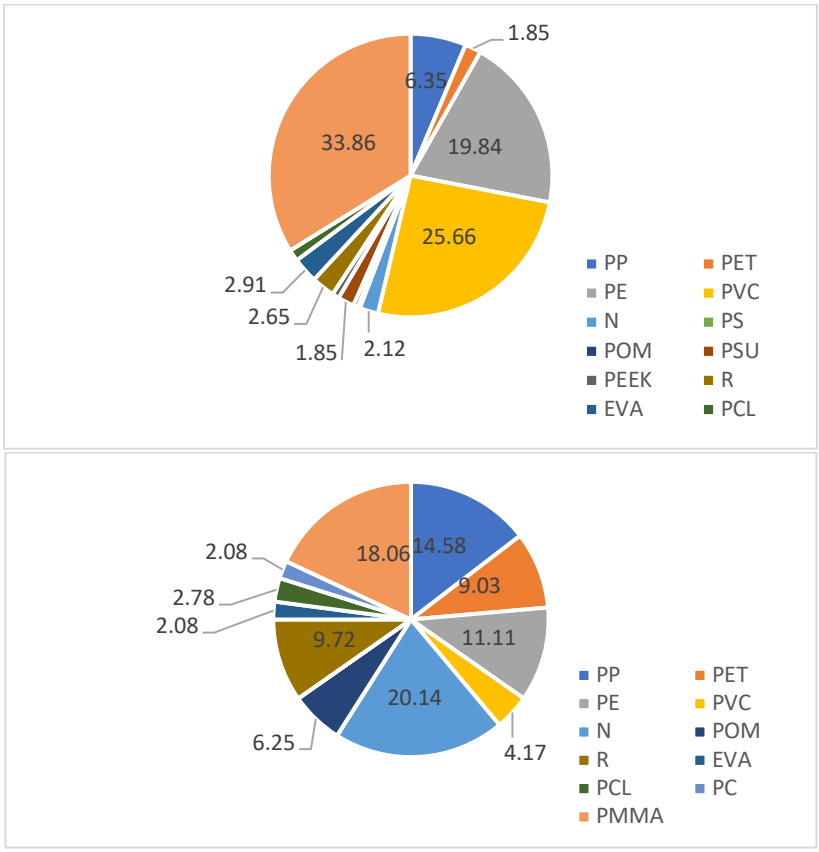


Figure 8. Relative frequency distribution of polymers (%) amongst deposited (top picture) and airborne (bottom picture) samples.

PP = Polypropylene, PE =Polyester, N = Nylon, R = Rubber, PCL = Polycaprolactone, PMMA = Polymethylmethacrylate, PET = Polyethylene, PVC = Polyvinylchloride, POM = Polyoxymethylene, EVA = Ethylenevinylacetate, PC = Polycarbonate, PS = Polystyrene, PSU = Polysulfone.

3.3. Microplastic size distribution

Size of MP is one the most important criteria when talking about human health. As smaller particles can easily find their way into human body as well as suspending in the air for a longer time. Size of all MPs detected in this study were between <20 µm to maximum of 200 µm. With about 90% of the particles in both airborne and deposited samples being smaller than 25 µm. This reveals a high risk for inhalation and ingestion of MP. Only 1.13 % of MP in deposited samples and 2.4 % of MP in airborne samples were ≥100 µm in diameter. Figure 9 presents the size distribution of MPs for both deposited and airborne samples in all study sites.

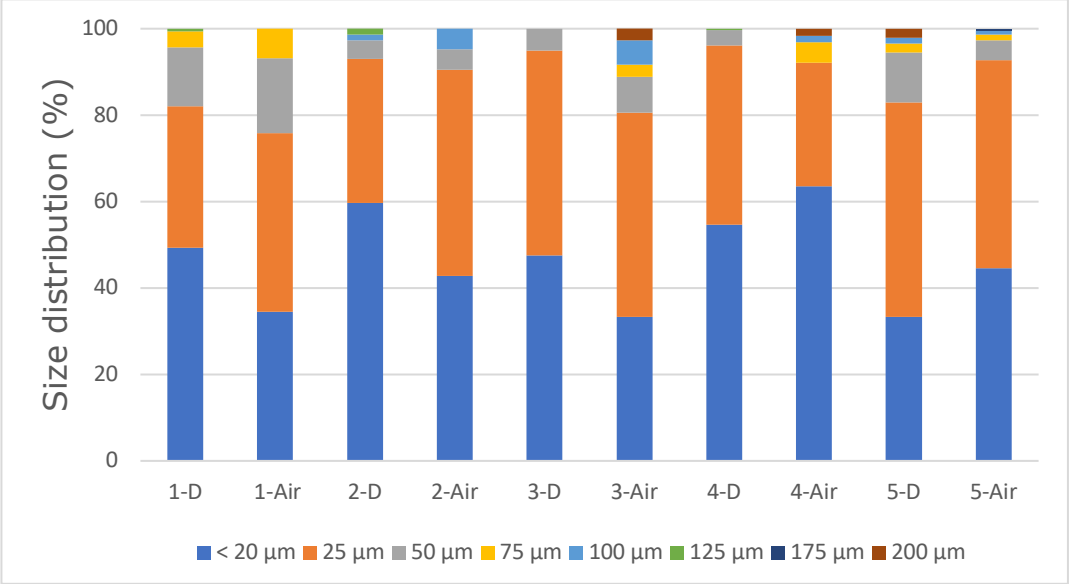


Figure 9. Size distribution of microplastics (%) in both deposited (D) and airborne (Air) samples of all study sites.

4. Outreach activities

Apart from the work on the scientific aspect of the project, I was also involved in several outreach activities.

1) Microplastic extraction and identification lab tour, 14 September 2022.

Kiki Dethmers , Harmen Spek and one intern from PSF visited Wageningen University. During the visit, we had a meeting with the chair holder of Meteorology and Air Quality group of Wageningen University, and we visited several labs currently used for MP analysis.

Photo taken on 14 September at Wageningen University in FTIR room.

2) Collaboration with Dace Satre Sietina, artist working with PSF. On 16 Nov. 2022, Dace visited Wageningen University and we brainstormed about how she can visualize airborne MP and later paint them. She visited Meteorology and Air Quality Group and we looked at the samples under microscope and LDIR visual data. This possibly can raise public awareness about airborne microplastics. This is mainly because airborne microplastics are not visible but their risk for human health is great.

Photo taken on 16 November at Wageningen University.

3) Interview with PSF media team about fashion-relate microplastics. On 15 December 2022, PFS media team visited me at Wageningen University, and we recorded several videos in an interview format in the MP laboratory and Forum Building at the university campus.

Photo taken on 15 December at Forum Building of Wageningen University with the view of the air sampler.

5. Communication and dissemination of results

The results of this study will be shared with the international media as well as presented at the Plastic Health Summit in May 2023. Finally, the results will be published in a high impact scientific journal.

6. References

Chen, G., Feng, Q., Wang, J., 2020. Mini-review of microplastics in the atmosphere and their risks to humans. Sci. Total Environ. 703, 135504.

Choi, h., Lee, I., Kim, H., Park, J., Cho, S., Oh, S., Lee, M., Kim, H. (2022). Comparison of microplastics characteristics in the indoor and outdoor air of urban areas of South Korea. Water Air Soil Pollution. 233:169.

De Witte, B., Devriese, L., Bekaert, K., Hoffman, S., Vandermeersch, G., Cooreman, K., Robbens, K. (2014). Quality assessment of the blue mussel (Mytilus edulis): Comparison between commercial and wild types. Marine Pollution Bulletin, 85(1): 146-155.

Dris, r., Gasperi, J., Mirande, C., Mandin, C., Guerrouache, M., Langlois, V., Tassin, B. (2017). A first overview of textile fibers, including microplastics, in indoor and outdoor environments, Environ. Pollut. 221: 453–458.

Gaston, E., Woo, M., Steele, C., Sukumaran, S., Anderson, S. (2020). Microplastics differ between indoor and outdoor air masses: insights from multiple microscopy methodologies, Appl. Spectrosc. 74: 1079–1098.

Knobloch E., Ruffell H., Aves, A., Pantos, O., Gaw, S., Revell, L.E. (2021). Comparison of deposition sampling methods to collect airborne microplastics in Christchurch, New Zealand. Water, Air, Soil Pollut., 232 (4).

Liu, k., Wang, X.,Fang, T.,Xu, P.,Zhu, L.,Li, D. (2019). Source and potential risk assessment of suspended atmospheric microplastics in Shanghai. Science of the Total environment. 675: 462-471.

Nizamali, J., Mintenig, S. M., Koelmans, A.A. (2023). Assessing microplastic cahractristics in bottled drinking water and air deposition samples using laser direct infrared imaging. Journal of Hazardous Materials. 441 (129942).

Noventa, S., Boyles, M.S., Seifert, A., Belluco, S., Jim´enez, A.S., Johnston, H.J., Tran, L., Fernandes, T.F., Mughini-Gras, L., Orsini, M. (2021). Paradigms to assess the human health risks of nano-and microplastics. Microplast. Nanoplast. 1: 1–27.

Prata, J.C., 2018. Airborne microplastics: consequences to human health? Environ. Pollut. 234, 115–126.

Prata, J.C., Castro, J.L., da Costa, J.P., Duarte, A.C., Cerqueira, M., Rocha-Santos, T. (2020). An easy method for processing and identification of natural and synthetic microfibers and microplastics in indoor and outdoor air. MethodsX 7, 100762.

Primpke, S., Dias, P.a., Gerdts, G. (201(). Automated identification and quantification of microfibres and microplastics. Anal. Methods. 11:16.

Primpke, S.,Wirth, M., Lorenz, C., Gerdts, G. (2018). Reference database design for the automated analysis of microplastic samples based on Fourier transform infrared (FTIR) spectroscopy. Anal. Bioanal. Chem.410: 21.

Vianello, A., Jensen, R.L., Liu, L., Vollertsen, J. (2019). Simulating human exposure to indoor airborne microplastics using a Breathing Thermal Manikin, Scientific Reports. 9:8670.

Xumiao, L., Prata, J.C., Alves, J.R., Duarte, A.C., Rocha-Santos, T., Cerqueira, M. (2021). Airborne microplastics and fibers in indoor residential environments in Aveiro, Portugal. Environmental Advances. 6:100134.