# Generation, characterization and traceability of microplastics

Design project - 2024

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## Abstract

Microplastics are tiny plastic particles less than 5 mm in size resulting from the fragmentation of larger plastic debris. Humans inhale these microplastics daily, yet the harmful effects they pose remain largely unknown. These microplastics can be found in different shapes, sizes which is why it is very difficult to deduce their effect on the human respiratory system.
In this project we adapt a device (SAGAS-Système automatisé de génération d'aérosols solides) capable of generating controlled concentrations of microplastics for human toxicology studies.

## Goals

- Characterization and production of microplastics.
- Establishment of calibration procedures to ensure the precise and consistent generation of controlled concentrations of microplastics.
- Identification of chemical markers that can be incorporated to trace the route of the polymers in human body.

## Method

- **Characterization and production of microplastics**: the plastics are going to be selected based on their solid state, uniform size and shape and representativeness of commonly used plastics (due to their widespread use in various industries).
- **Criteria for grinding microplastics**: Ensure optimal cryogenic conditions, maintain consistent grinding parameters, and prevent contamination uniform, high-quality microplastic particles. Make sure that the grinder is not going to melt the plastic(s).
- **Cryogenisation by liquid nitrogen**: Utilizes extremely low temperatures to embrittle microplastics, enhancing their fragmentation into uniform particles upon mechanical grinding → the plastics are going to ''freeze'' by immersing them in liquid nitrogen within 2 cylinders at -180°C for 5 min (to solidify them), followed by grinding in a machine with an internal ball at 25 Hz for 2min.
- **SAGAS machine**: First, an aerosol generator (PALAS RGB 1000 aerosol) is loaded with the microplastic particles into a steel cylinder. This cylinder undergoes a continuous thrust from bottom to top under the action of a piston which causes the particles to come out at its upper end. The particles are then driven by a rotating wire brush into which clean pressurized air is injected. This first mixture is transported via a conductive synthetic material tube to a cyclone which role is to sort particles larger than 10µm in order to sediment them in the disposal receptacle pot. The sorted mixture is then transported into the inhalation chamber where the concentration is measured by a laser photometer type device (Dustrak TSI). As the software linked to the SAGAS wasn't available anymore the leaves between the sections of the system were modified (red cross in Figure 1) to bypass the valves that were controlled by the software.

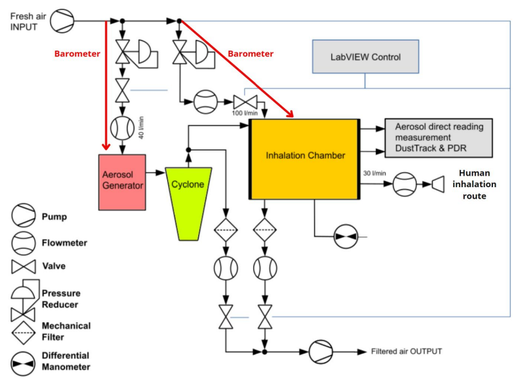


Figure 1 : SAGAS system

- **Inhalable concentrations calculation**: The calculation were made based on the *Systematic review of microplastics and nanoplastics in indoor and outdoor air: identifying a framework and data needs for quantifying human inhalation exposure*[1] which provides the following table of value of inhalable concentrations in MPS/kg−BW/day. To transform the concentrations into mg/m3 the equation and values from *Converting mg/L to Particles/L: Reconciling the Occurrence and Toxicity Literature on Microplastics*[2] and *Exposure Dose Guidance for Determining Life Expectancy and Exposure Factor (ATDSR)*[3] were used. For the calculation the particle is considered as a sphere.

| Location of Samples | Adults (≥ 21 years) | Pregnant Women (second trimester) | Adolescents (11 to < 16 years) | Young Children (6 to < 11 years) | Preschoolers (2 to < 6 years) | Infants (birth to < 1 year) |
|---|---|---|---|---|---|---|
| Indoor Combined ($n = 1$) | 507 | 775 | 709 | 1000 | 1493 | 1835 |
| Residential ($n = 4$) | 2192 | 3354 | 3068 | 4326 | 6456 | 7936 |
| School ($n = 1$) | 0 | 0 | 1477 | 2083 | 3986 | 4900 |
| Workplace ($n = 4$) | 1227 | 1877 | 0 | 0 | 0 | 0 |

Table 1: Average MPs exposure

$$C(MPs/m^3) = \frac{Dinh * BW}{IR * EF} \qquad y(mg/m^3) = \frac{\frac{\pi}{6} * \rho(g/cm^3) * C(MPs/m^3)}{10^9 (unitconversionfactor)}$$

Equation 1

where Dinh is inhalation exposure, BW is body weight, IR is intake rate and EF is exposure factor.

- **Identification of chemical markers**: Select a stable, non-detachable marker that adheres ethically and legally to safety standards, ensuring it is non-radioactive, harmless to humans, and environmentally benign, to accurately track polymers without dissociating during use.

## Results

The polymers corresponding to our criteria are polypropylene PP and Poly(methyl methacrylate) PMMA.

The results of grinding by cryogenisation gives size particles between 0.25µm and 13µm. We will focus on the one <10µm as they are filtered by the SAGAS. The size represents the diameter of our approximation.

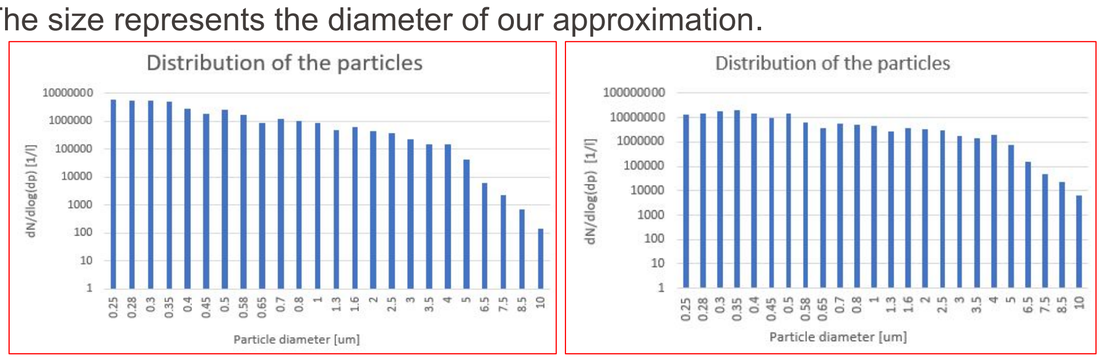


Figure 2: Size distribution in the inhalation chamber for PP (left) and PMMA (right)

According to Table 1 the inhalable concentration for an adult of 70kg in residential area equal to 2192 MPS/kg−BW/day, this value represents also the maximum exposure. The exposure factor is chosen equal to 0.38 as it corresponds to an exposure of 9 hours/day during 5 days which could represents the exposure of a person during work hours.

The following tables shows the diameter size, the number of particles and their corresponding concentration calculated based on equation 1. These results prove the feasibility of the creation of a determined and controlled concentration of MP thanks to the variation of the speed of the brush and piston of the PALAS.

| Diameter [µm] | N° of particles | y [mg/m3] |
|---|---|---|
| 0,25 | 6087720 | 0,0000001312742517 |
| 0,28 | 5518300 | 0,000000184430872 |
| 0,3 | 5690770 | 0,000000226841907 |
| 0,35 | 5082040 | 0,0000003602165468 |
| 0,4 | 2896120 | 0,0000005376993352 |
| 0,45 | 1822530 | 0,0000007655914362 |
| 0,5 | 2624150 | 0,000001050194014 |
| 0,58 | 1663050 | 0,000001639243636 |
| 0,65 | 886150 | 0,000002307276249 |
| 0,7 | 1259200 | 0,000002881732374 |
| 0,8 | 1013100 | 0,000004301594681 |
| 1 | 873400 | 0,000008401552112 |
| 1,3 | 489700 | 0,00001845820999 |
| 1,6 | 622400 | 0,00003441275745 |
| 2 | 441940 | 0,0000672124168 9 |
| 2,5 | 368190 | 0,0001312742517 |
| 3 | 222380 | 0,000226841907 |
| 3,5 | 148300 | 0,0003602165468 |
| 4 | 153160 | 0,0005376993352 |
| 5 | 44080 | 0,001050194014 |
| 6,5 | 6360 | 0,002307276249 |
| 7,5 | 2250 | 0,003544404797 |
| 8,5 | 690 | 0,0051596031 91 |
| 10 | 140 | 0,008401552112 |

| Diameter [um] | N° of particles | y [mg/m3] |
|---|---|---|
| 0,25 | 12993500 | 0,000001716663292 |
| 0,28 | 14444610 | 0,0000002411788326 |
| 0,3 | 19118970 | 0,0000002966394169 |
| 0,35 | 21055280 | 0,0000004710524073 |
| 0,4 | 15081870 | 0,0000007031452844 |
| 0,45 | 9491160 | 0,000001001158032 |
| 0,5 | 15330630 | 0,000001373330634 |
| 0,58 | 6454450 | 0,000002143626293 |
| 0,65 | 3905300 | 0,000003017207402 |
| 0,7 | 5900000 | 0,000003768419259 |
| 0,8 | 5106800 | 0,000005625162275 |
| 1 | 4638550 | 0,0000109866 4507 |
| 1,3 | 2827050 | 0,0000241376 5922 |
| 1,6 | 3891700 | 0,0000450012982 |
| 2 | 3372690 | 0,0000878931 6055 |
| 2,5 | 2884530 | 0,0001716663292 |
| 3 | 1825040 | 0,0002966394169 |
| 3,5 | 1432790 | 0,0004710524073 |
| 4 | 1889960 | 0,0007031452844 |
| 5 | 741110 | 0,001373330634 |
| 6,5 | 146950 | 0,003017207402 |
| 7,5 | 49340 | 0,004634990889 |
| 8,5 | 22700 | 0,006747173403 |
| 10 | 6360 | 0,01098664507 |

Table 2: Inhalable concentrations for PP (left) and PMMA (right).

For the proposed tracking methods, we suggested 2 different markers:
The first proposal suggests using non-toxic, stable fluorescent dyes like Nile Red to monitor microplastic inhalation, pending experimental validation.
The second proposal advocated for isotopic markers (Carbon 13 and Oxygen 16) for precise tracking of microplastics within biological tissues, through their technical feasibility and cost-effectiveness require further investigation.

## Future research direction

Further test should be done on the SAGAS system to determine a protocol (precise PALAS parameters) to generate a controlled inhalable concentration. It will be crucial to validate these hypothesis real-case studies on the proposed markers to see if they can accurately trace microplastics coming from the surrounding air.

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1.https://www.nature.com/articles/s41370-023-00634-x
2.https://pubs.acs.org/doi/10.1021/acs.est.1c04093
3.https://www.atsdr.cdc.gov/pha-guidance/resources/ATSDR-EDG-Life-Expectancy-Exposure-Factor-508.pdf