Ultrasonic spray coating of PHA encapsulated silver particles for the development of safe Ag/PHA coated packaging films

Dries Hermans[1,*], Andrej Andjelic[1], Chris Vanheusden[1], Wouter Marchal[2], Wim Deferme[3], Anitha Ethirajan[4], Jan D'Haen[5], Roos Peeters[1], and Mieke Buntinx[1]

[1] Materials and Packaging Research & Services, [2] Analytical & Circular Chemistry, [3] Functional Materials Engineering, [4] Nanobiophysics and Soft Matter Interfaces, [5] Analytical & Microscopical Services Institute for Materials Research (imo-imomec), Hasselt University, Martelarenlaan 42, Hasselt, Belgium imec, imo-imomec, Wetenschapspark 1, Diepenbeek, Belgium

Context

Incorporating **silver nanoparticles (Ag NPs)** in **biobased** and **biodegradable** polymers such as **polyhydroxyalkanoates (PHA)** can introduce functionalities, such as **antimicrobial properties**[1].

However, the method must ensure **effective interactions** between **Ag** and **microorganisms**, while **minimizing Ag migration** under **safe limits**[2,3].

Therefore, this study aims to develop **stable dispersions** of **Ag NPs encapsulated in PHA** which are coated as **thin layers** at the **surface** of **extruded PHA films** and analysed for potential **Ag migration.**

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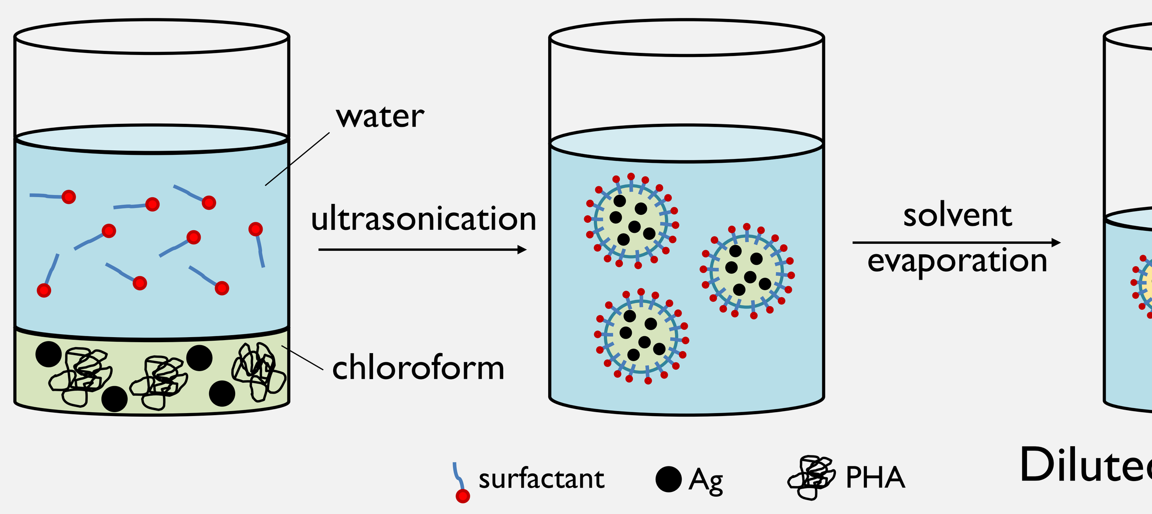
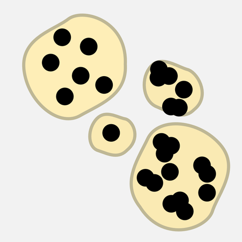
Methodology

i) Miniemulsion encapsulation



Diluted to 0.25 wt.% = **aqueous ink for USSC**

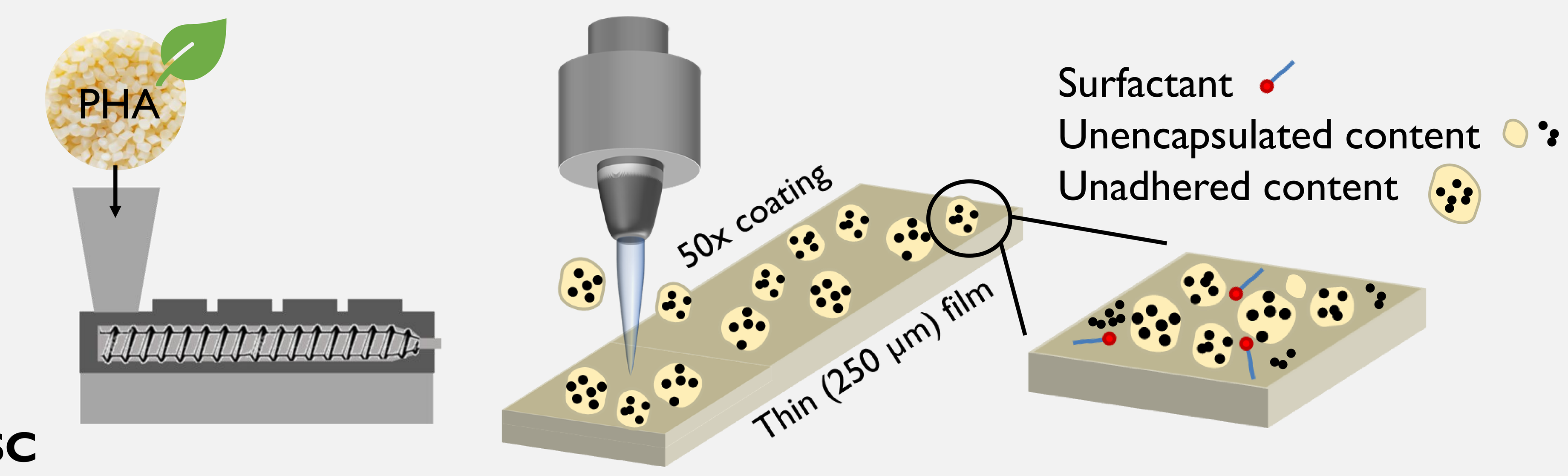
NP loading* (wt. %)	Z average (nm)	PDI (-)
1	140 ± 2	0.14 ± 0.02
5	189 ± 3	0.20 ± 0.02
10	228 ± 1	0.25 ± 0.02
40	259 ± 2	0.30 ± 0.03



<300 nm!

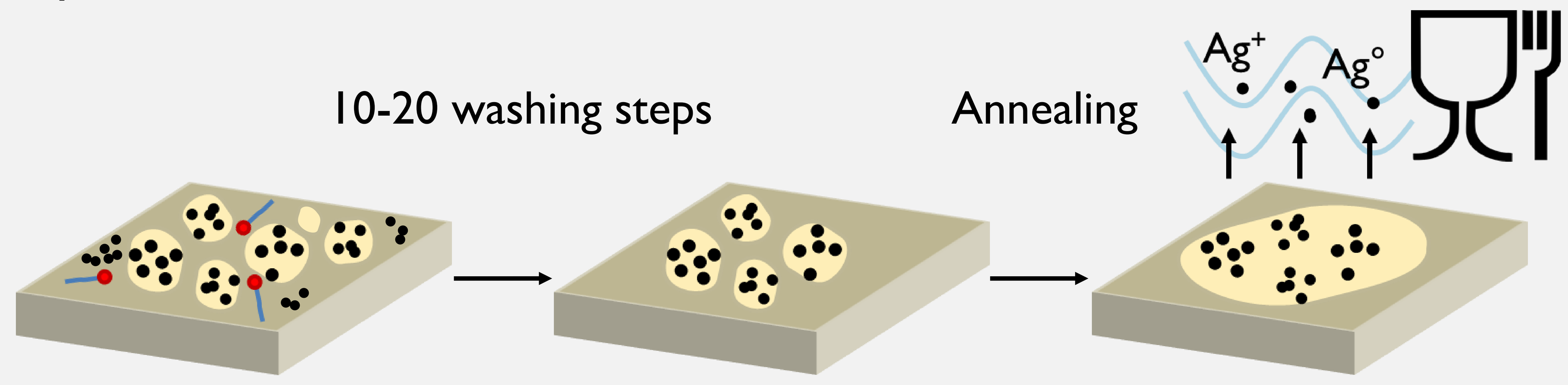
**Relative to PHA before sonication, although the final concentration can be different due to differences in encapsulation and losses during filtration.*

ii) Film extrusion + Ultrasonic spray coating

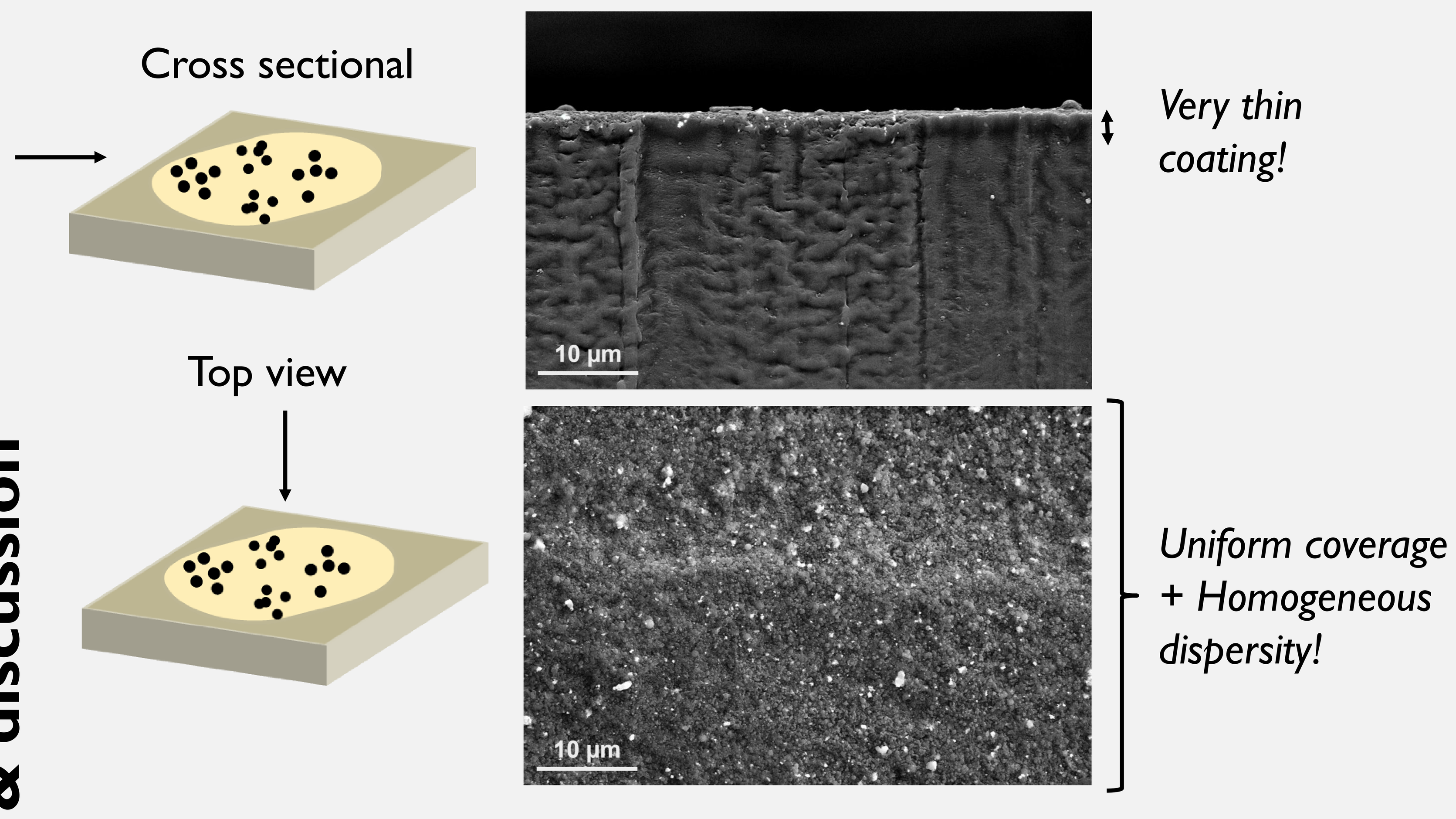


iii) Post-treatment

iv) Migration study

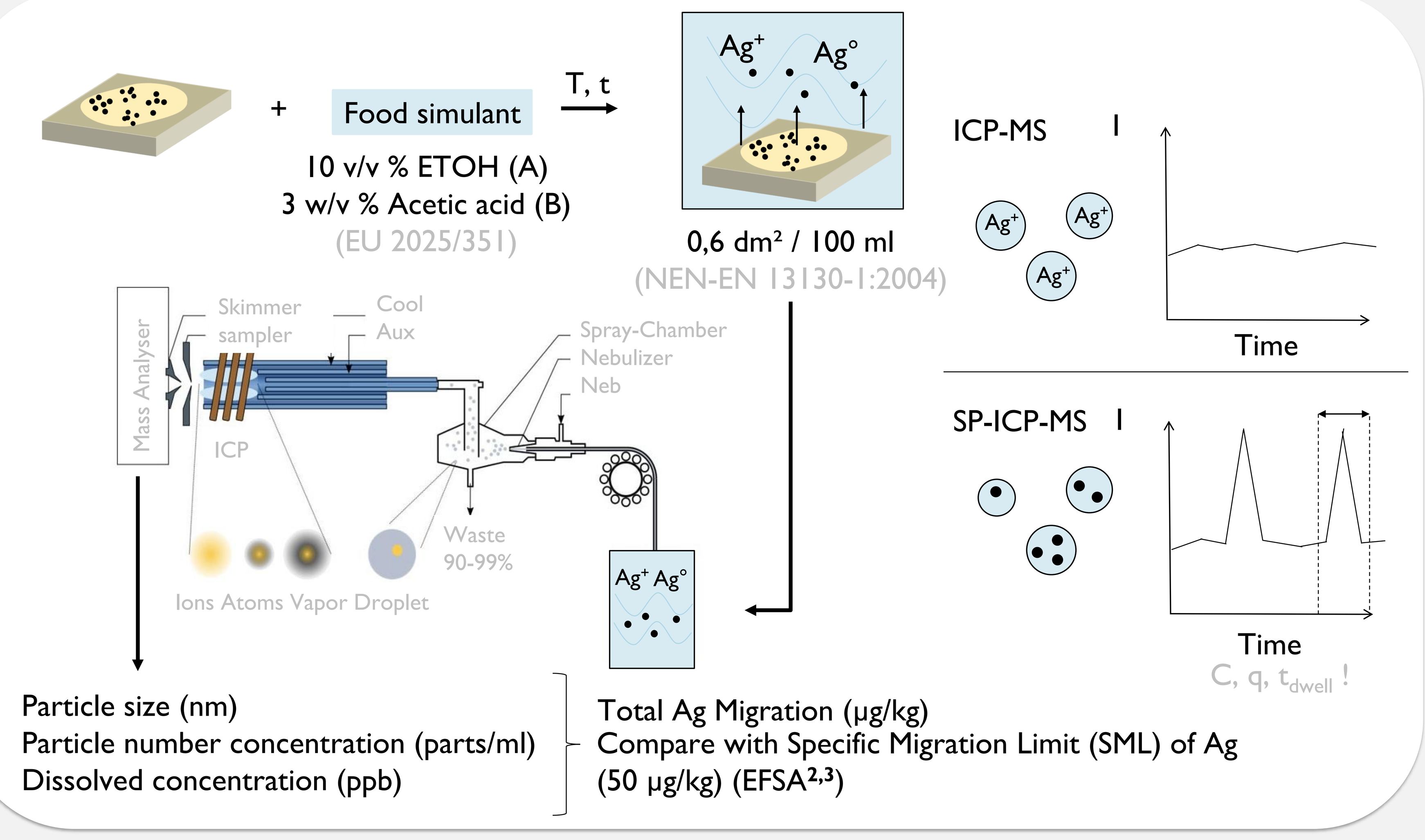


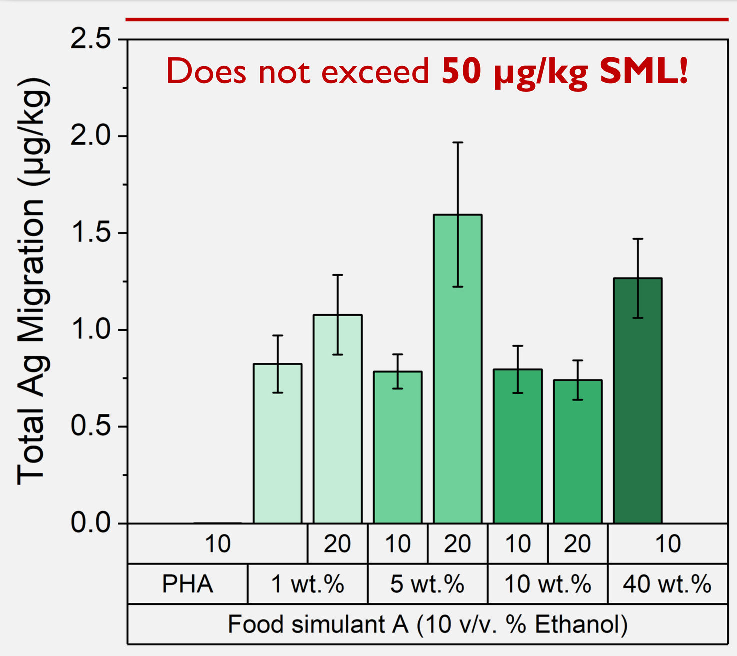
Results & discussion

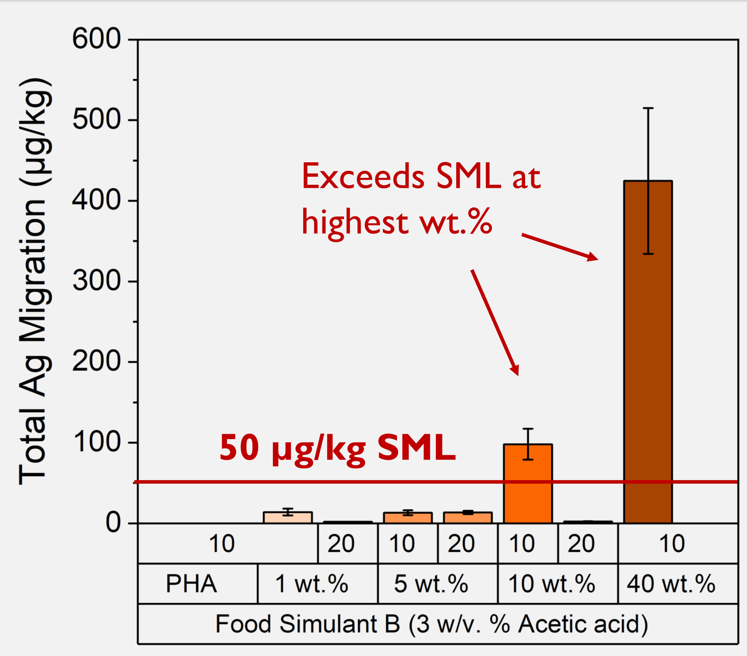


SEM images of 40 wt. % sample after 10 washing steps.

NP loading* (wt. %)	Washing steps	Ag content film (wt.%)
1	10	0.00090 ± 0.00001
1	20	0.00011 ± 0.00006
5	10	0.00121 ± 0.00014
5	20	0.00034 ± 0.00017
10	10	0.00137 ± 0.00045
10	20	0.00011 ± 0.00003
40	10	0.00558 ± 0.00355







Conclusion

- **Miniemulsion encapsulation** can be used to fabricate **Ag/PHA particles** (<300 nm), which are diluted to **aqueous inks** for **ultrasonic spray coating**.
- SEM shows **thin, uniform coating coverage** with **homogeneous particle distribution**, albeit some agglomeration.
- **Ag migration** was the **highest** in **acidic food simulant B**, but **remained** under **safe migration limits** at the lowest NP loadings in both **food simulant A and B.**

Outlook

- **Further optimization of post-treatment and NP loading** towards more **scalable** approach.
- **Antimicrobial testing** for validation of active packaging.
- **Comparison** with **non-encapsulated Ag.**
- **Comparison** between **coated** and **bulk** nanocomposites.
- **Biodegradation** assays (weathering, composting).

References

1. J.L. Castro-Mayorga, *et al. Antimicrob. Food Packag.* **1** (2025), 583–593.
2. M. Andreassen, *et al. EFSA J.* **23** (2025), e9316.
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4. TOFWERK. *What is Single Particle ICP-MS?* . Retrieved May 15, 2024.