

# CHEMICAL CHARACTERISATION OF AIRBORNE NANOPARTICLES IN AN INDUSTRIAL SCENARIO

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en Milieu  
Ministerie van Volksgezondheid,  
Welzijn en Sport

# Introduction

- Atmospheric plasma spraying is applied at industrial scale to produce high-resistance coatings of metallic surfaces
- Due to the high energies applied, nanoparticles (NP) are released to workplace air and impact worker exposure in industrial facilities
- NP emissions have been characterised in terms of particle number concentrations, mean diameter and size distribution, but data are still unavailable regarding particle chemical properties and toxicity



# Atmospheric plasma spraying



- Different types: atmospheric plasma, HVOF, arc discharge
- Spraying of ceramics or metals (powder or wire)
- High potential for NP emissions

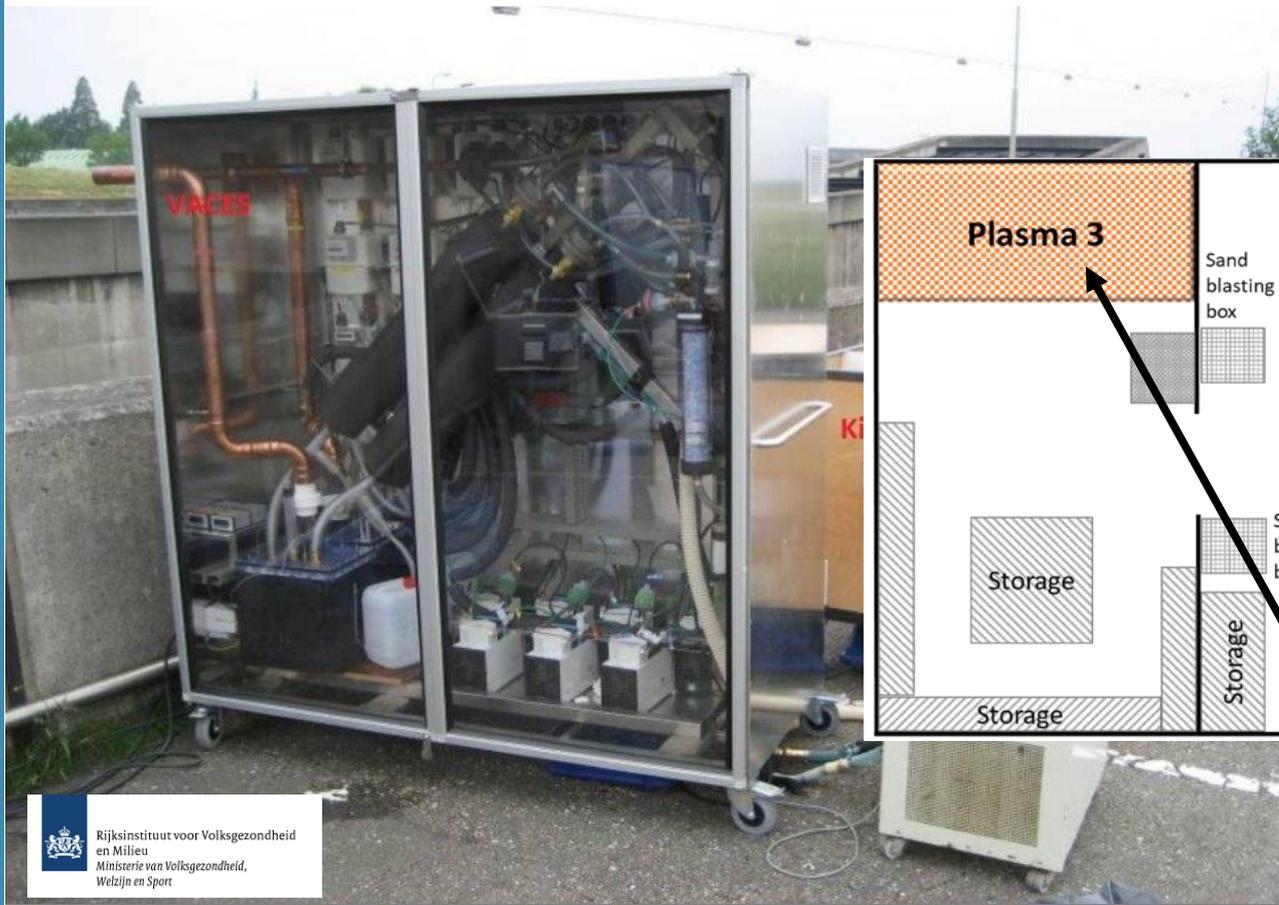
# Objectives

1. To **characterise the chemical composition** of coarse, fine and ultrafine aerosols emitted during plasma spraying in a real-world setting
2. To **support ongoing toxicity assessments** of the same aerosols
3. To **assess the usefulness of an aerosol concentrator** (VACES) for ultrafine particle sampling in industrial settings

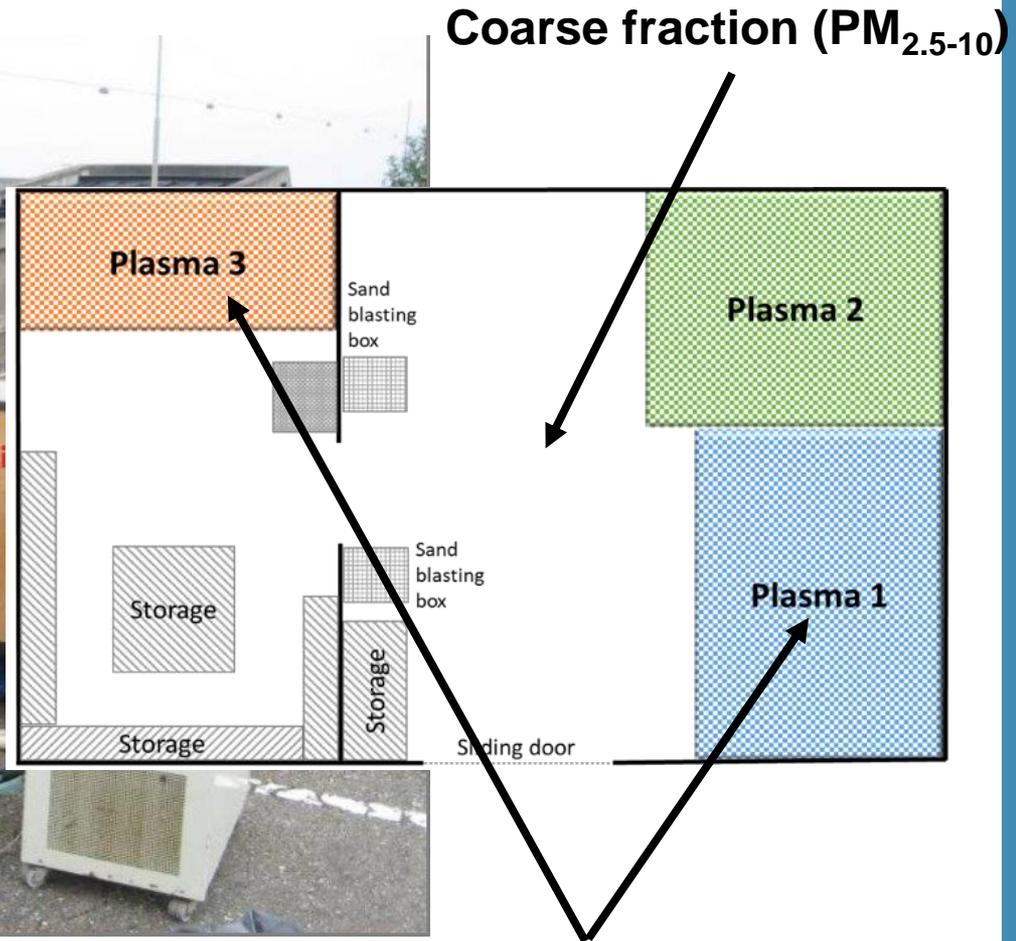
# Methodology

- Two different scenarios:
  - Booth #1: high temperature ( $5-20 \times 10^3$  °C), low velocity (200-500 m/s).
  - Booth #3: high velocity (425-1500 m/s), lower temperature ( $2.9 \times 10^3$  °C).
- Particles sampled onto Teflon filters and in liquid suspension using an aerosol concentration enrichment system (VACES; Kim et al., 2001)
- Filter acid digestion and analysis by ICP-MS, ICP-OES and XRF
- Analytical inter-comparison for quality assurance

# Methodology



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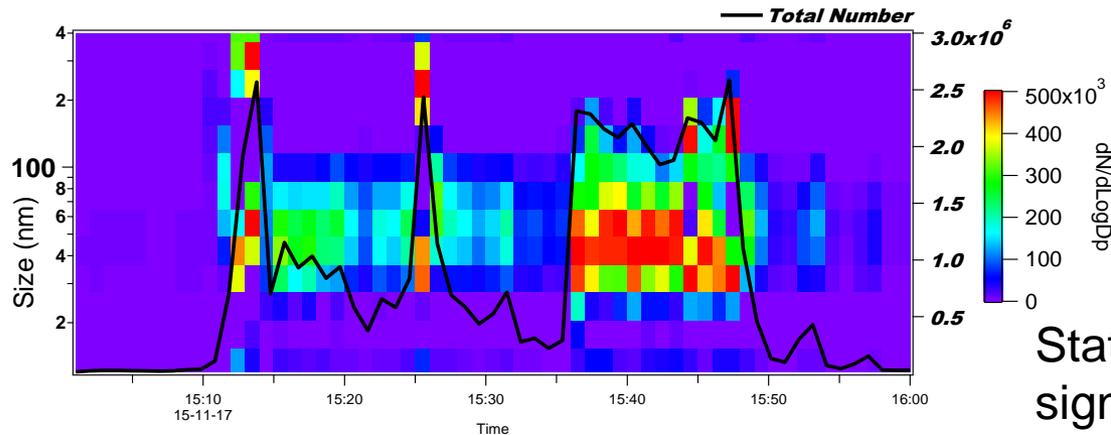
Coarse (2.5-10  $\mu m$ ), Fine (0.2-2.5  $\mu m$ ) and Ultrafine ( $<0.2 \mu m$ )

Booth #1: feedstock = ANVAL 50/50 (Cr+Ni) + Amdry 6228 ( $Al_2O_3+TiO_2$ )

Booth #3: feedstock = Woka 3702-1 (WC, CrC, Ni)

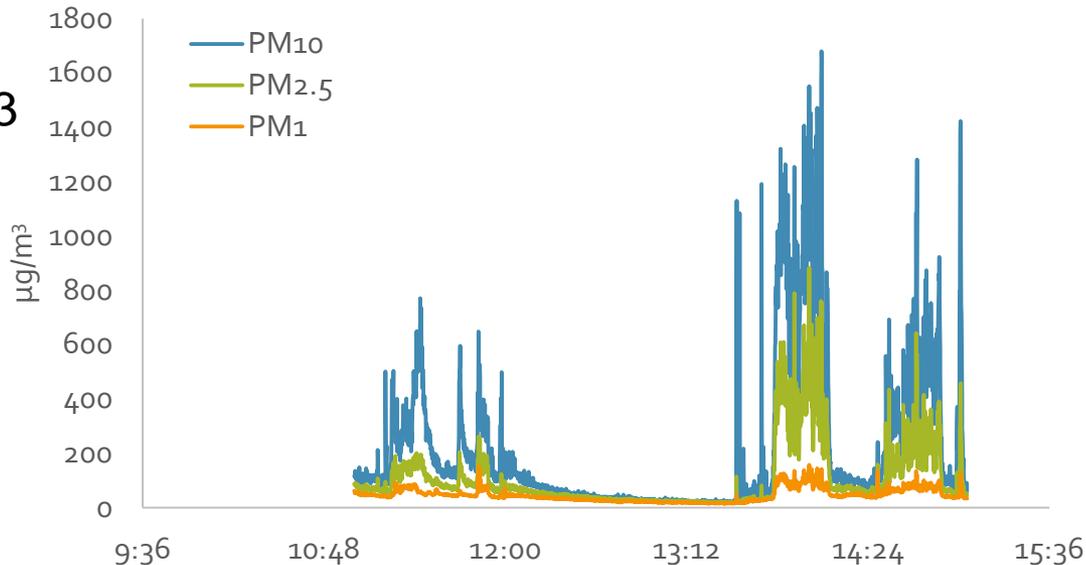
# Results: Emissions and exposure impacts

Booth #1



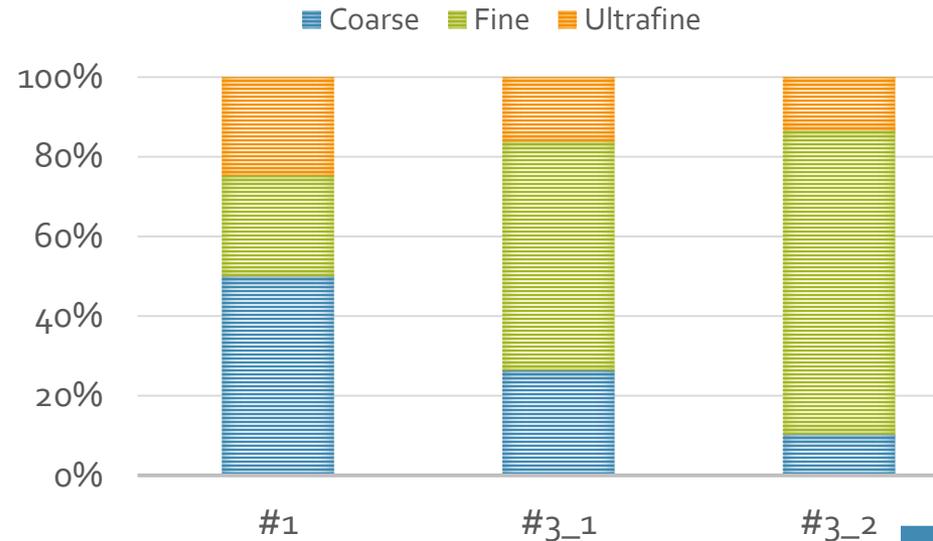
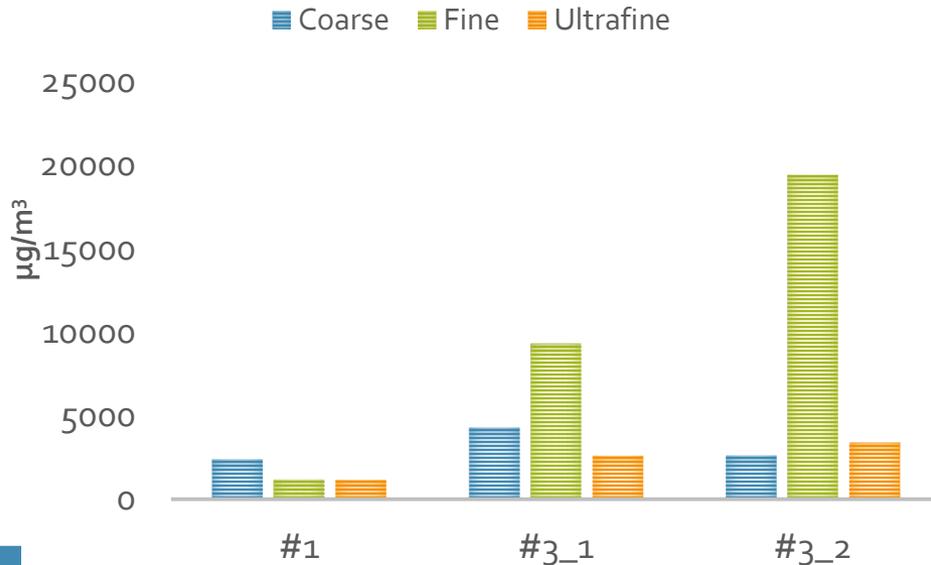
Statistically significant increases (Asbach et al., 2012)

Booth #3



VACES samples = representative of exposure

# Results: Mass concentrations



- Very high particle mass concentrations (8-hr sampling)!
- Fine=19 mg/m<sup>3</sup> (#3\_2); UF=3 mg/m<sup>3</sup> (#3\_2); Coarse, 4 mg/m<sup>3</sup> (#3\_1)
- Relative contributions:
  - Coarse is dominant in Booth#1
  - Fine is dominant in Booth#3

**Markedly different aerosols/concentrations due to type of spraying/controls**

# Results: chemical composition

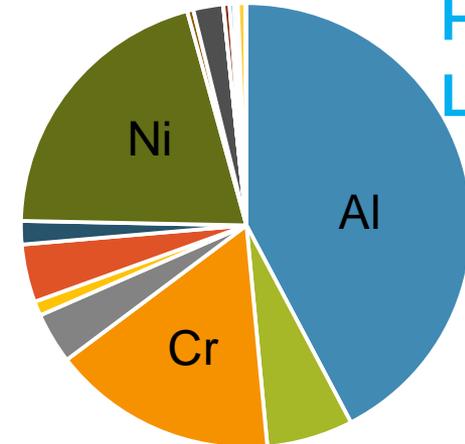
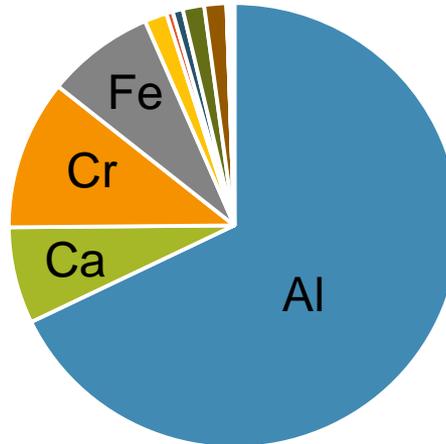
Fine: Emission area (#1)

Ultrafine: Emission area (#1)

High T  
Low V

Ni and Cr volatilise at approx 2500°C

Present in UF as new particle formation

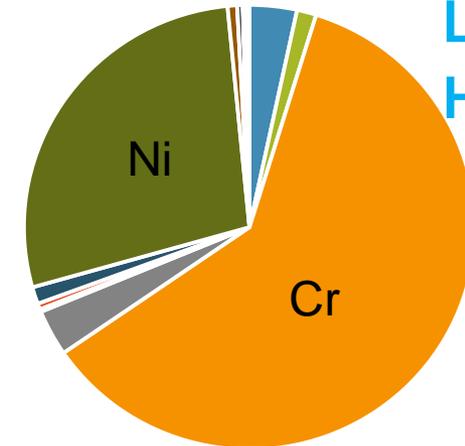
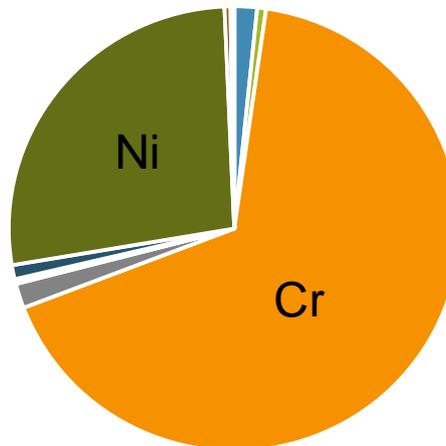


Fine: Emission area (#3)

Ultrafine: Emission area (#3)

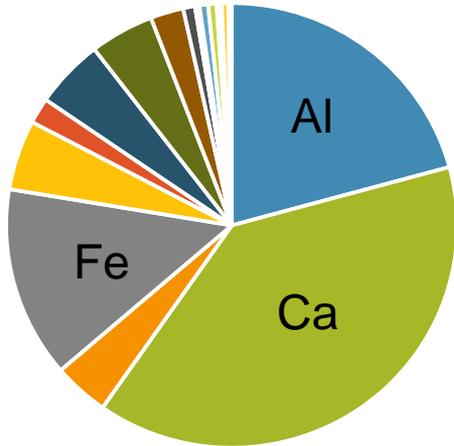
Low T  
High V

Ni and Cr: emitted as UF and fine

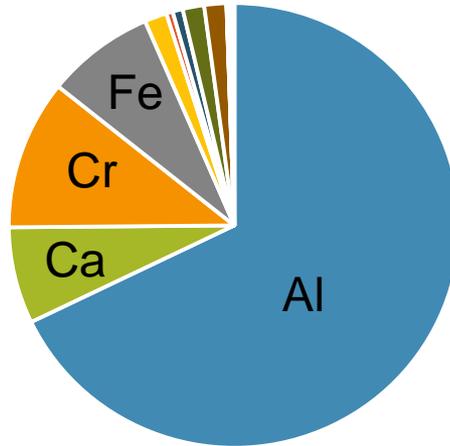


# Results: chemical composition

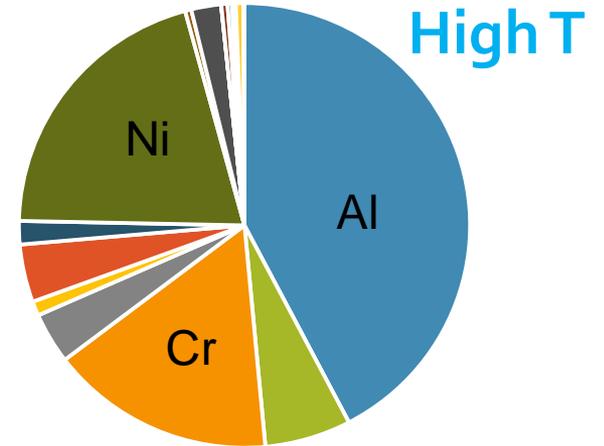
Coarse: Exposure area (#1)



Fine: Emission area (#1)

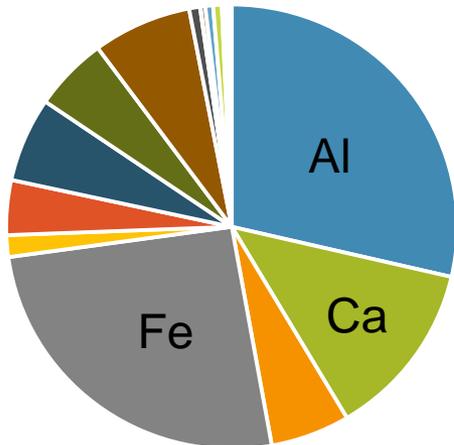


Ultrafine: Emission area (#1)

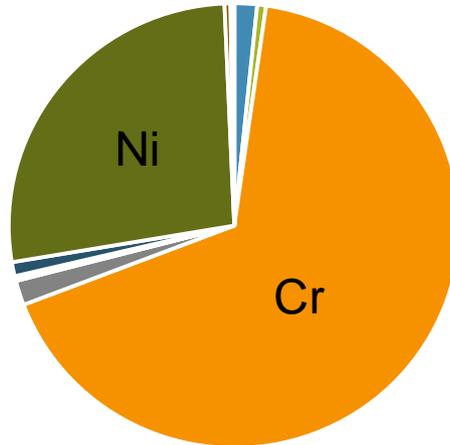


High T

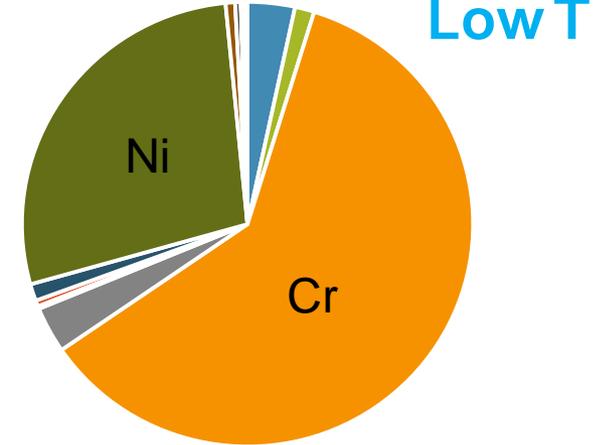
Coarse: Exposure area (#3)



Fine: Emission area (#3)



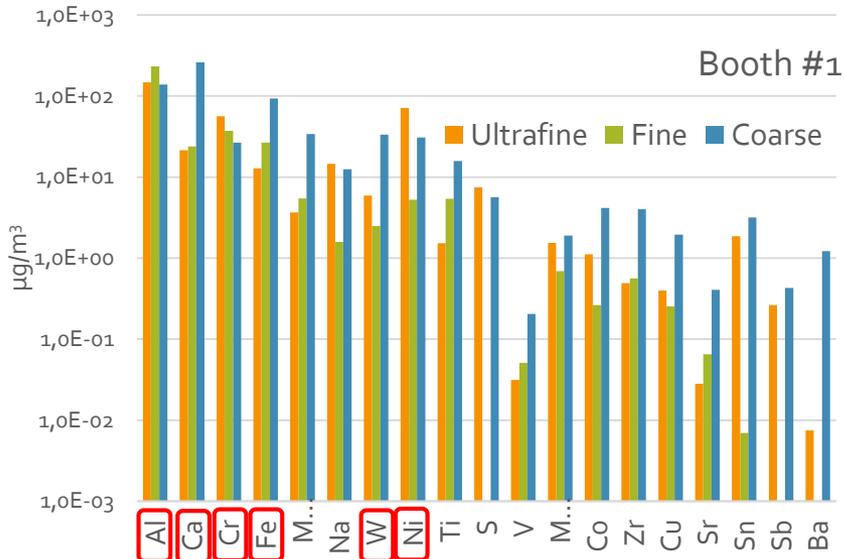
Ultrafine: Emission area (#3)



Low T



# Results: Element size distribution

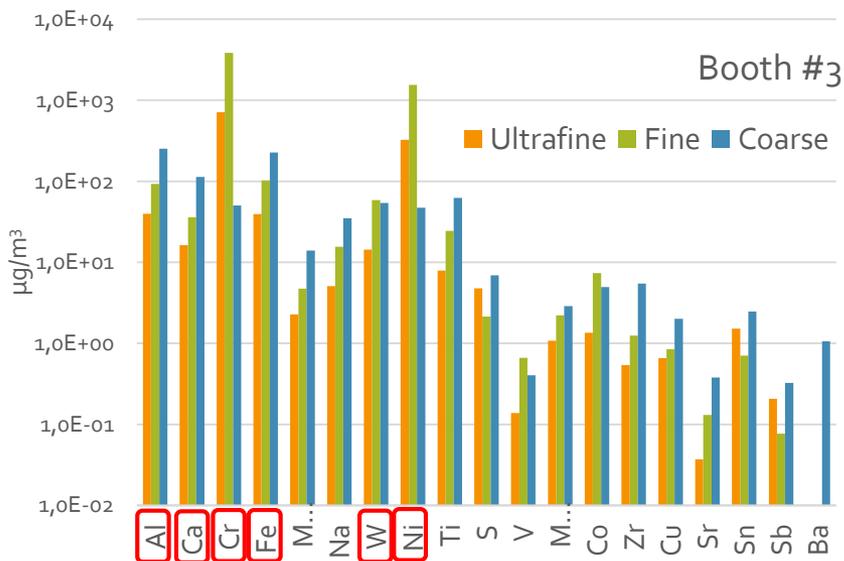


Major enrichment in hazardous metals (Cr, Ni, W) sourcing from feedstock

Also major elements (Al, Ca, Fe) with mixed source origins

In Booth #1 metals in UF

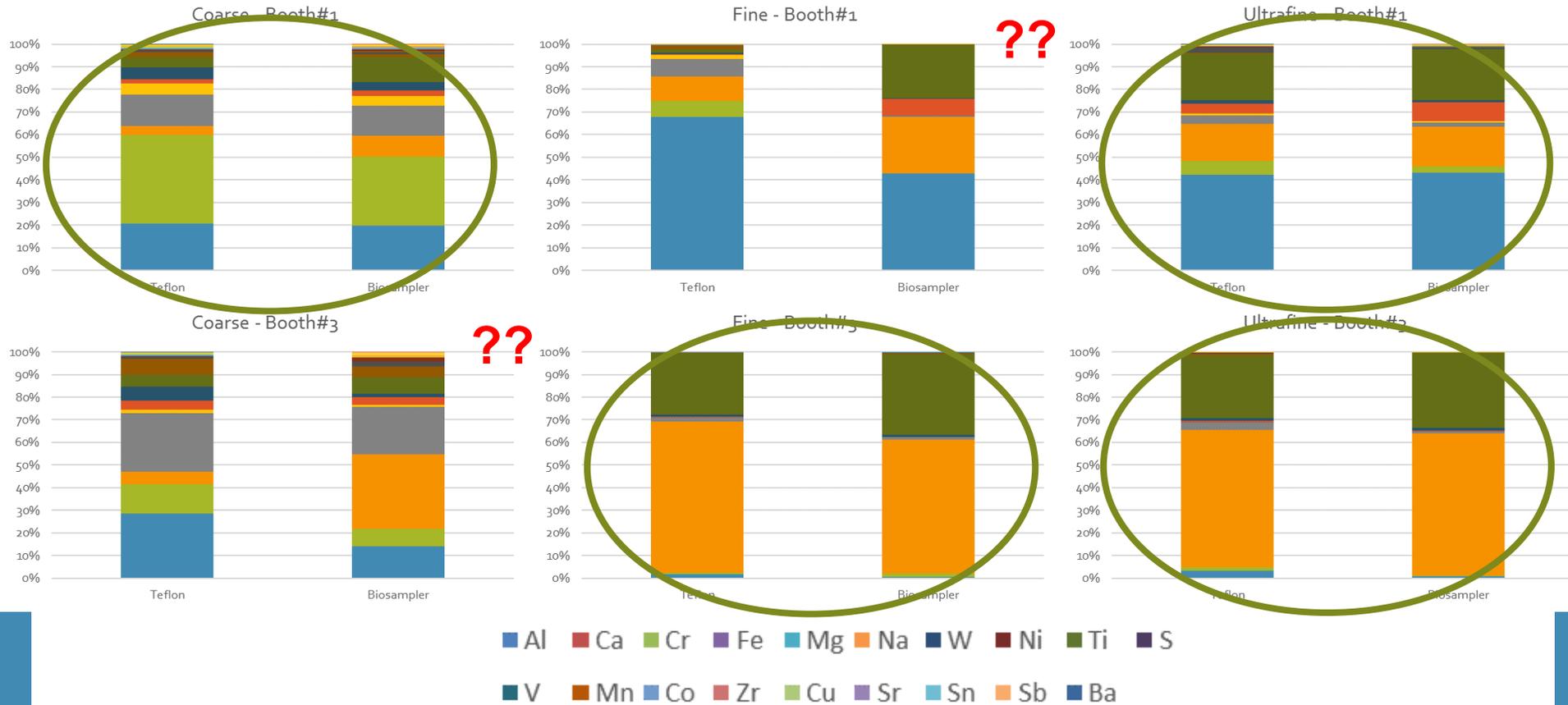
In Booth #3 metals mainly present in Fine



Fine and UF vs. Coarse: Fine and UF determined by feedstock, coarse similar composition for both booths with clearly different markers (S, Mo, Zr, Sn, Ca, Fe)

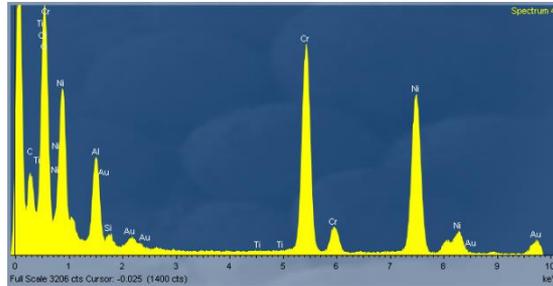
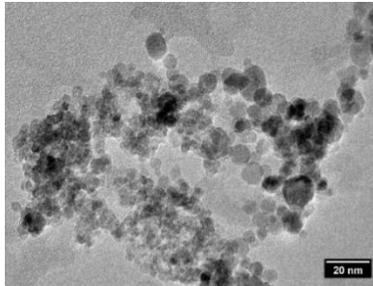
High % undetermined mass (30-50% recovery): why? Comparison with other studies?

# Results: Filters vs. Liquid suspensions

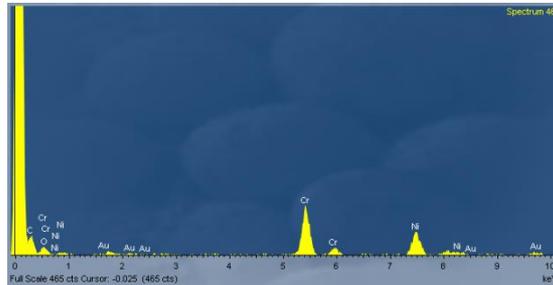
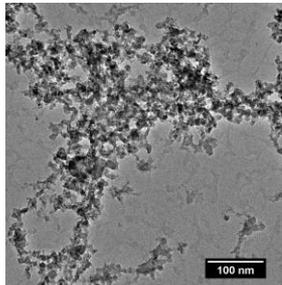


Large similarities for UF#1, UF#3, Fine#3, Coarse#1  
 Differences for Fine#1, Coarse#3: why?

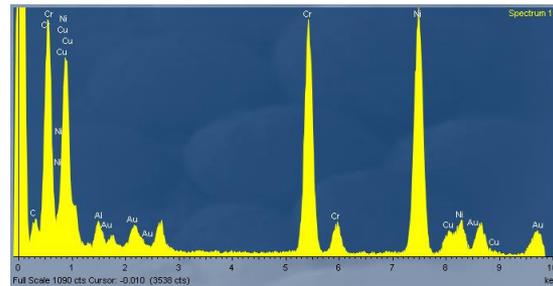
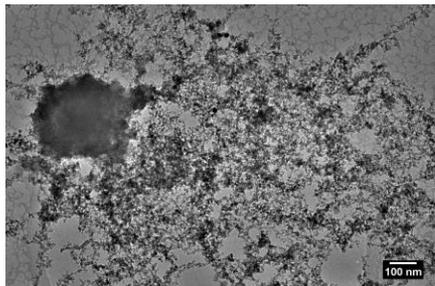
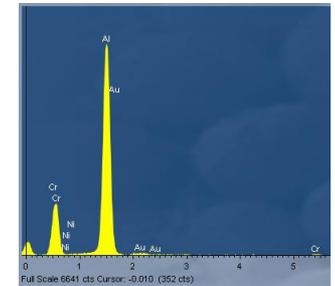
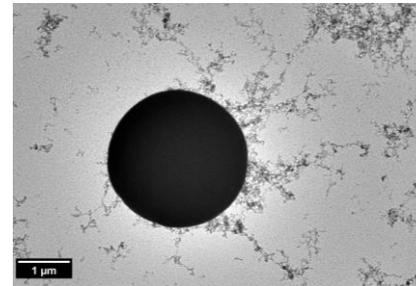
# Results: TEM images



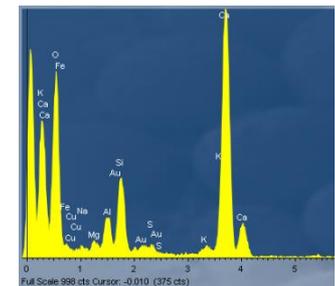
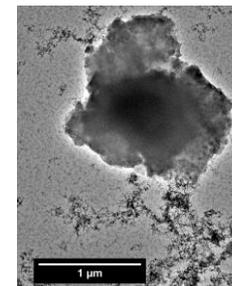
Spherical Cr/Ni/Al UF particles (booth #1)



Irregular Cr/Ni UF particles (booth #3)



Spherical Al fine particle (booth #1)



Coarse Al/Ca background particles  
(worker area)

# Conclusions

## **Plasma spraying scenario:**

- Particle impacts on exposure dependent on spraying technique and local controls
- Different aerosol compositions as a function of the feedstock
- Process temperature = key parameter defining element fractionation

## **Tool:**

- The aerosol concentrator VACES is a useful tool to characterise the size-resolved chemical composition of workplace aerosols
- Logistics - complicated!

## **Next steps:**

- Comparison with bulk material composition (enrichment factors)
- Links with toxicity assessments to understand toxicity mechanisms

# Thank you for your attention!

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