Thought leaders in particulate matter…

Using precision measurement, science and environmental intelligence to answer complex environmental questions

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Beyond PM Concentration Single Particle Analysis

AUTOMATED HIGH THROUGHPUT SEM–EDS ANALYSIS FOR SINGLE PARTICLE CHARACTERISATION USING COST- EFFECTIVE FILTER-BASED SAMPLING.

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The Questions We're Asked to Answer

We're regularly asked practical questions that need single-particle insight.

Answering them confidently takes a robust dataset, typically 1,000 - 5,000 particles to establish:

a) Size distribution, by number and mass

b) What the particles are, and where they came from

c) Whether a specific source is present, and its contribution

d) Which advanced techniques to pursue, and what particle to target

The requirement: one automated technique - size and morphology of 1,000–5,000 particles & elemental composition of 1,000 in 2–3 hours.

Why is This Technique/Tool Needed?

1. **Particle identification** - What are the particles?
2. **Particle source attribution** – Where they come from, and whether they indicate a specific source
3. **Optical PM monitoring devices** – Correction factors, Morphology, Mass/density reconstruction
4. **Not all PM is the same/Public health** – Composition, Morphology, Size
5. **Screening tool for high-end instrument analysis** – Survey tool identifies where particles are and which justify further advanced techniques

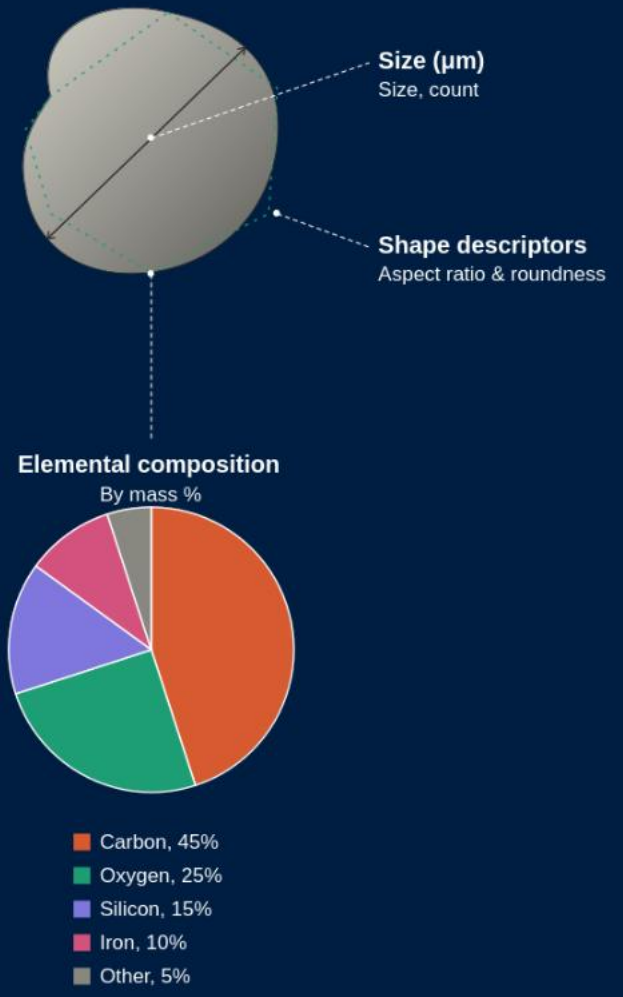
What Information Does The SEM-EDS Automated Analysis Provide Us?

We generate three main groups of data

1. Physical Characteristics
   - Particle size, size distributions, particle count, particle location, filter loading percentage

2. Particle descriptors/ Morphology
   - Aspect ratio, roundness, convexity, cuboidal, spherical

3. Elemental composition
   - Carbon, organics, metals, elemental mass percentage.



Where Does Automated SEM-EDS Sit?

Monitoring Questions
- Optical not matching gravimetric
- Is this monitor suitable for the site specific environment
- Is the correction factor still valid
- Can I trust my PM readings

Speciation Questions
- Are there harmful particles present
- Can you identify a particle of interest / Survey tool
- Particle location on substrate

Automated SEM-EDS 1000-5000 Individual Particles.

Monitoring Answers
- Particle size distribution
- Particle morphology and density
- Elemental composition
- Mass fraction reconstruction

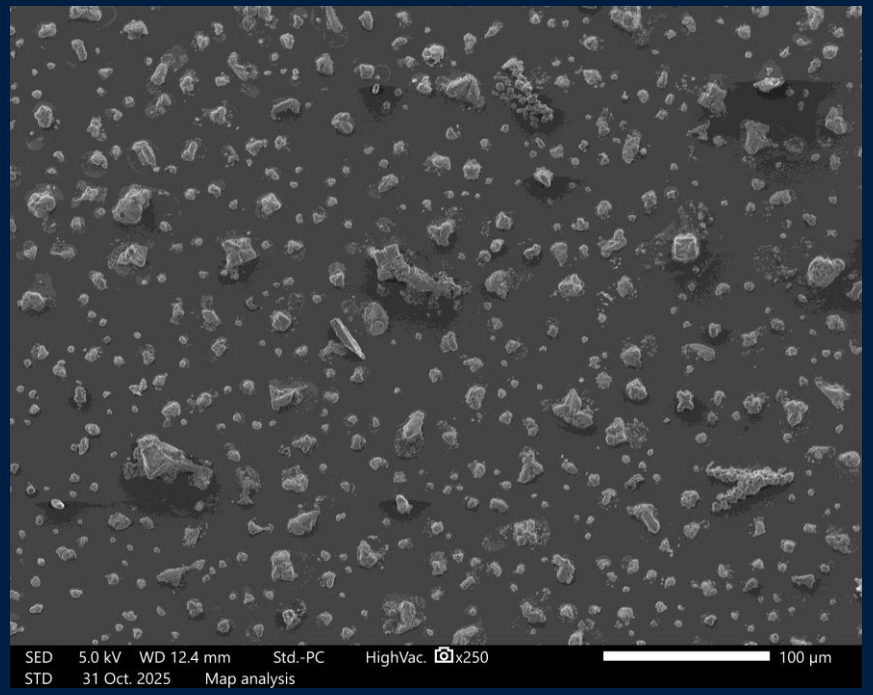
Speciation Answers
- Is the target particle present
- Quantity of target particle present
- Identifies particle location for further analysis
- Source attribution
- Filter suitability for high-end analysis

Why Automate?

Manual single-particle SEM–EDS gets this data, but it doesn't scale commercially, automation solves this:

1. **Cost reduction** – do not need an operator to locate, image and analyse every particle
2. **Turnaround reduction** – days of instrument run time down to 2–3 hours
3. **Sample size increase**– manual review covers tens of particles; robust statistics need thousands
4. **Consistency increase** – manual selection introduces operator bias; automation is consistently repeatable

The result: large data, at a fraction of the cost and time, with better statistics.

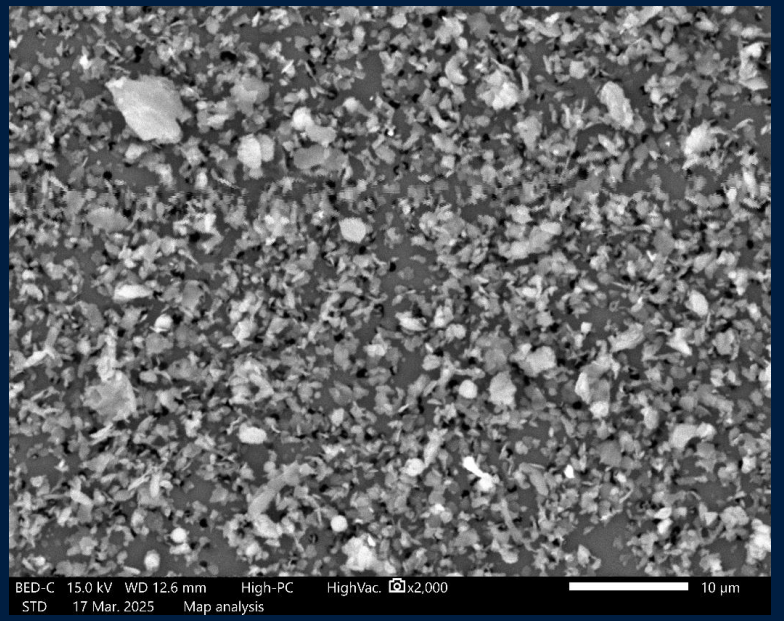


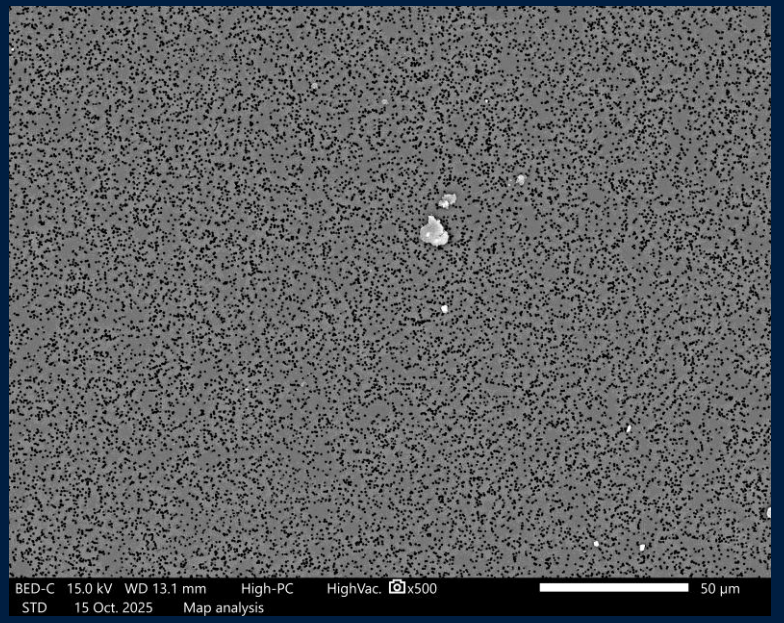
Filter Sampling

The quality of your filter sampling drives the quality of the single-particle data.

- Controlled particle loading of filters is key for successful particle boundary identification, elemental detection and capturing a statistically relevant number of particles.

- Limitations/complexities and solutions to these
  - **Poor particle identification** – Overloading (Controlled sampling, >55% filter area covered)
  - **Low particle count** - Underloading (Controlled sampling, <10% filter area covered)
  - **Background interaction** (Background Correction)





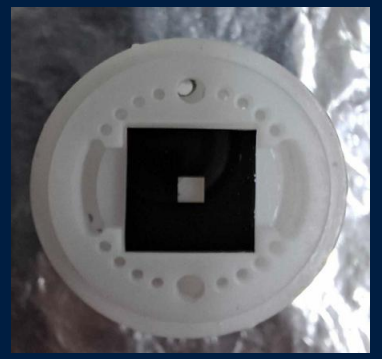
Low-Cost Sample Substrates

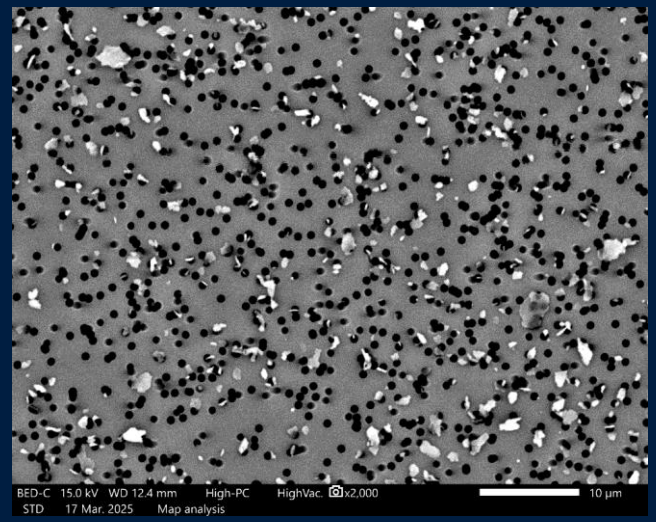
A key requirement for this automated method to work is the filters.

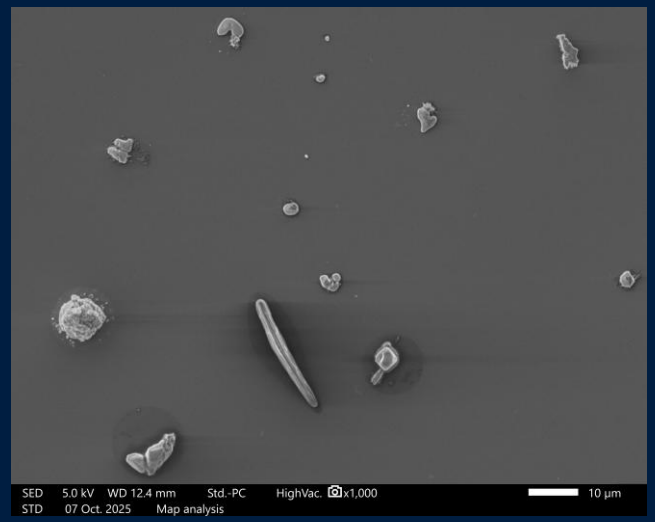
Need to be:
- Consistent in their elemental composition
- As flat as possible

We use:
- Polycarbonate - 25 mm
- Silicon carbide - 10 mm
- Calcium Fluoride - 10 mm

For the silicon carbide window, a custom-built impactor was designed and housed within a standard 25mm cartridge.







Filter Samplers

Our automated particle analysis method is independent of your sampling source, it can be applied to:

- Outdoor AQ
- Indoor AQ
- Reference/Bulk particulate
- Soil/Water

Filter Mote

Koala

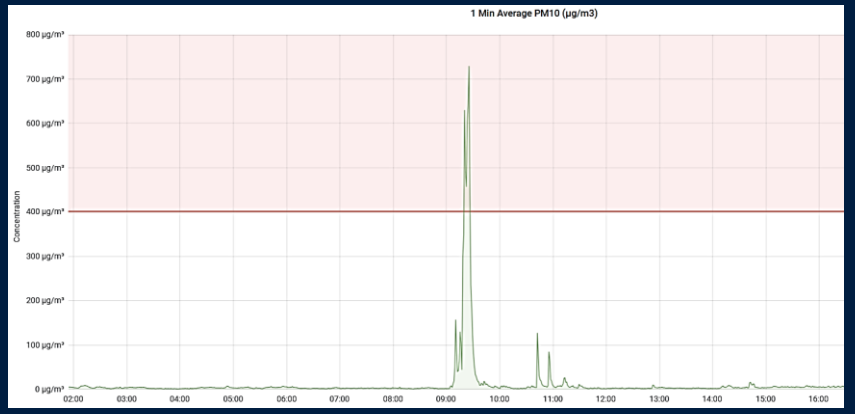
Donut

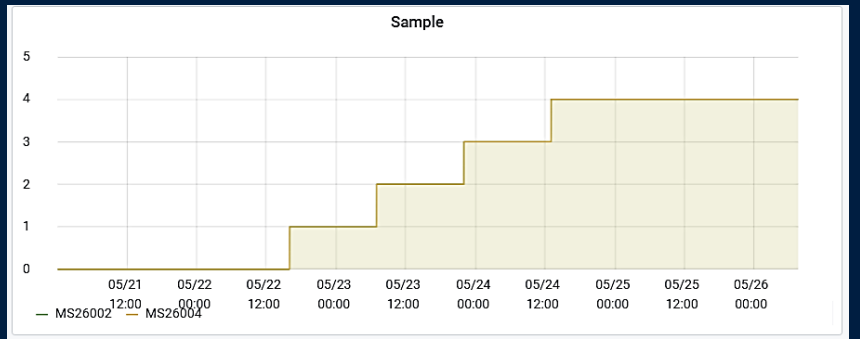
Filter Sampler	Particle Source	Size Cut	Flow Rate	Sampling Duration
Filter-sampler (Outdoor)	Ambient Auckland Airshed	TSP	2 L/min	24 Hours
Koala (Indoor)	Vehicle Workshop	TSP	1 L/min	12 Hours

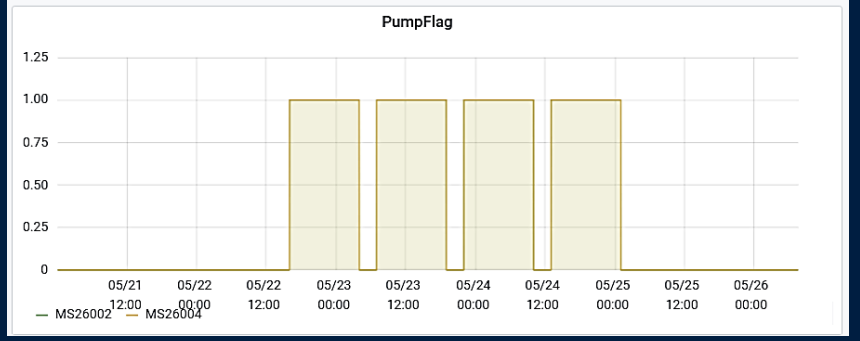
Automated Targeted Sampling

The automated capabilities of the method extend to the sampling devices.

- AWS-connected devices: real-time data, remote control of sampling
- Trigger at set concentrations or times
- Multi-sampler allows multiple filter substrates to be sampled at a single location
- Allows for controlled filter loading



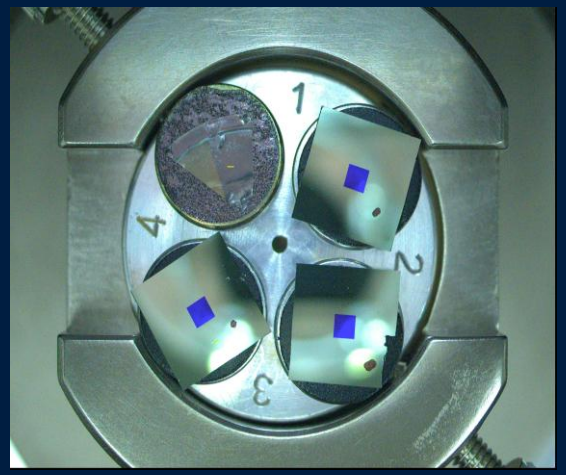




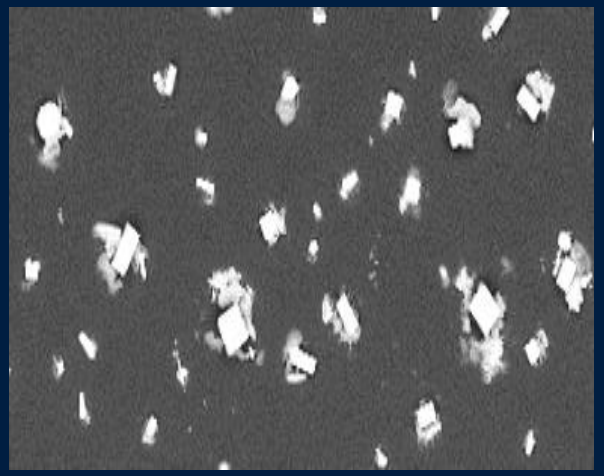
Automated SEM–EDS Analysis Workflow.

Two stages:

1. Screening for analysis suitability (50-150 particles)

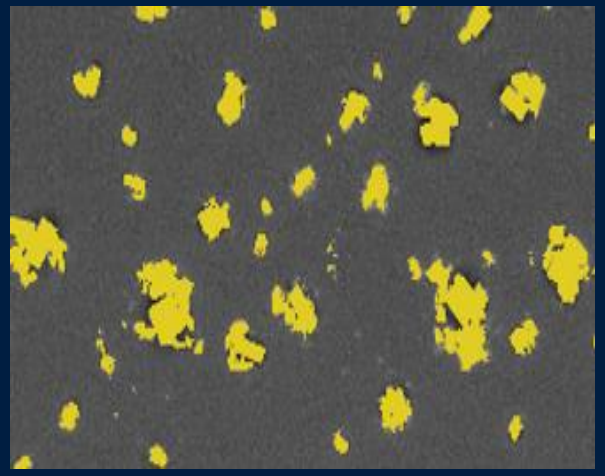


Step 1.
- Filter Preparation
- Preliminary observation



Step 2. -
- Capture one x1000 Image & execute automated single-image analysis
- Establish filter-specific Analysis conditions
- Filter area coverage
- Particle count

2. Automated analysis (1000-5000 particle)



Step 3.
- Execute automated acquisition & capture required FOVs
- Individual Particle & Elemental data captured
- ImageJ Macro script batch process

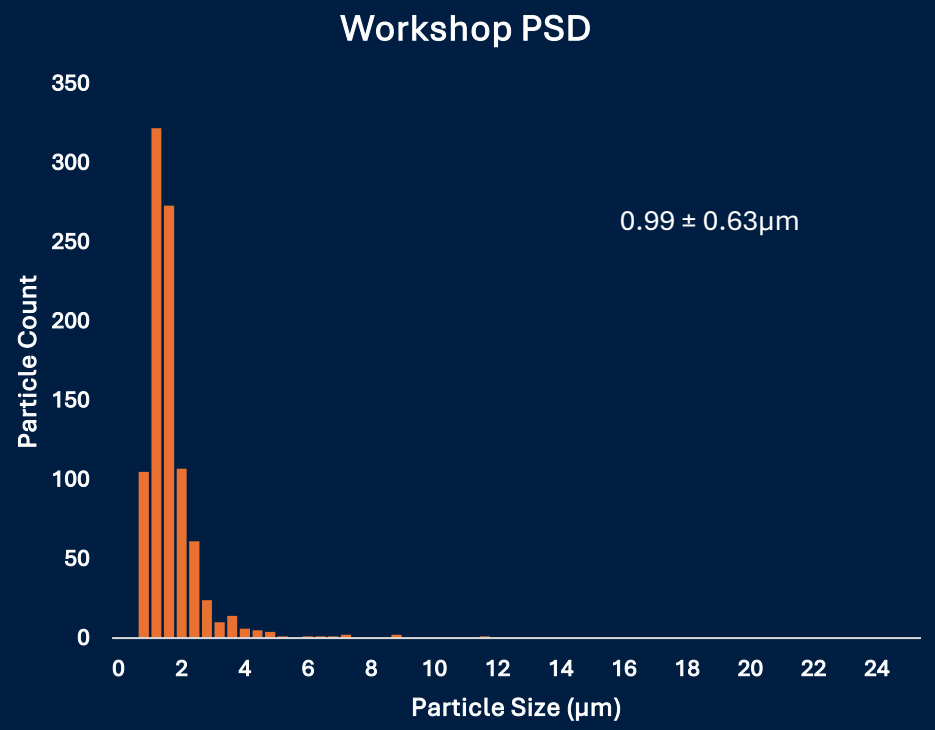
Step 4.
- Particle descriptor data is expanded using formulae outlined in ISO 9276
- Data output in CSV
- The data set is injected into an automated report generator, combined with sampling metadata if available.

Case Studies

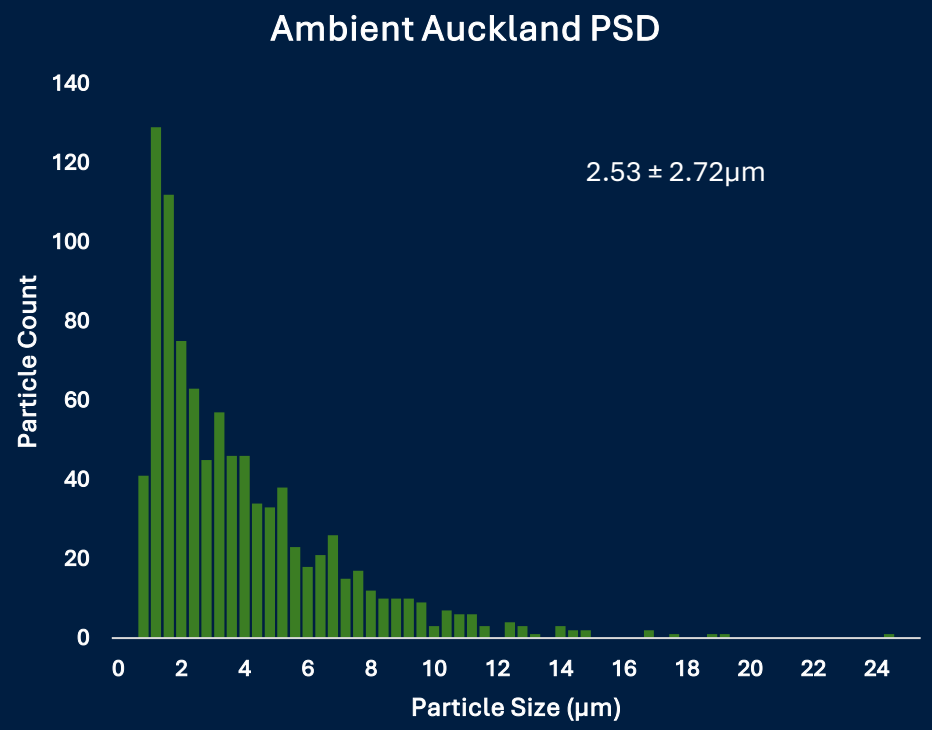
1. Machinist Workshop in South Auckland

2. Ambient Auckland Air

Individual Physical Particle: Particle Size Distributions

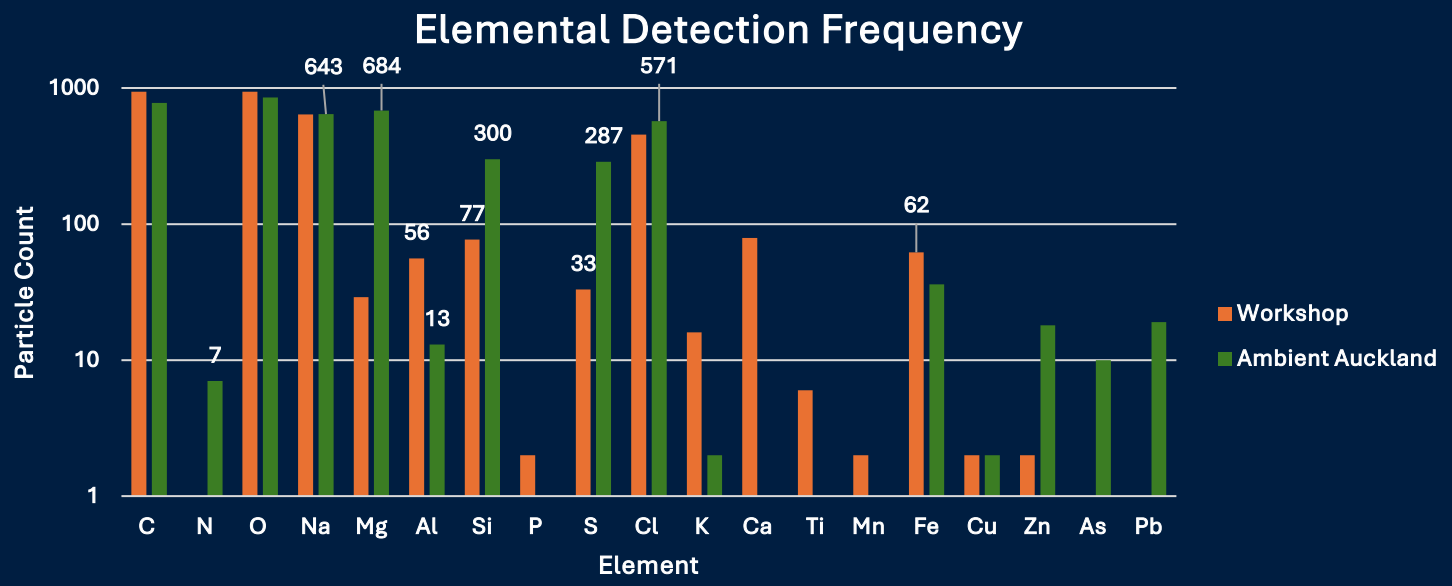


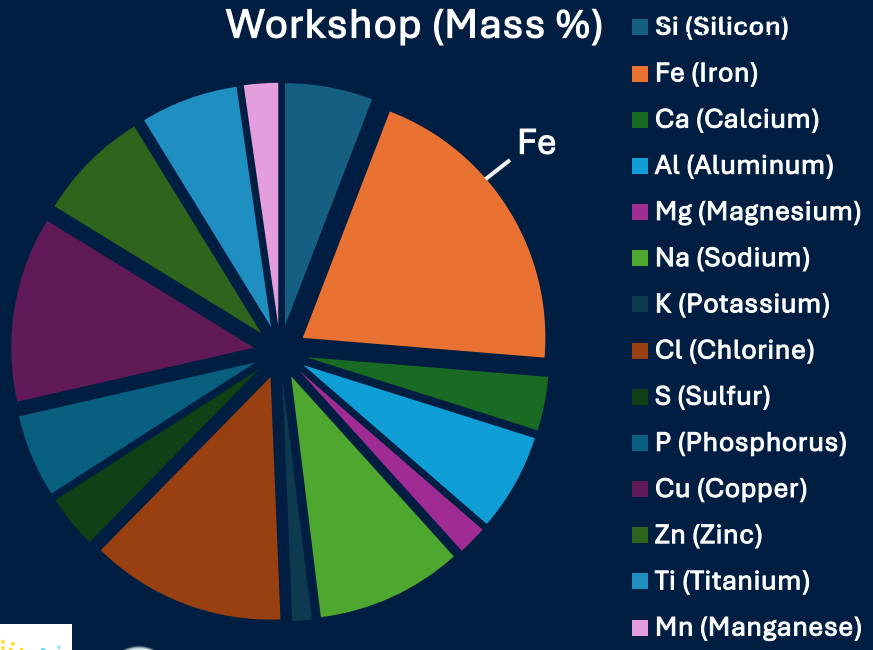
- Dominated by PM2.5
- Small Standard Deviation

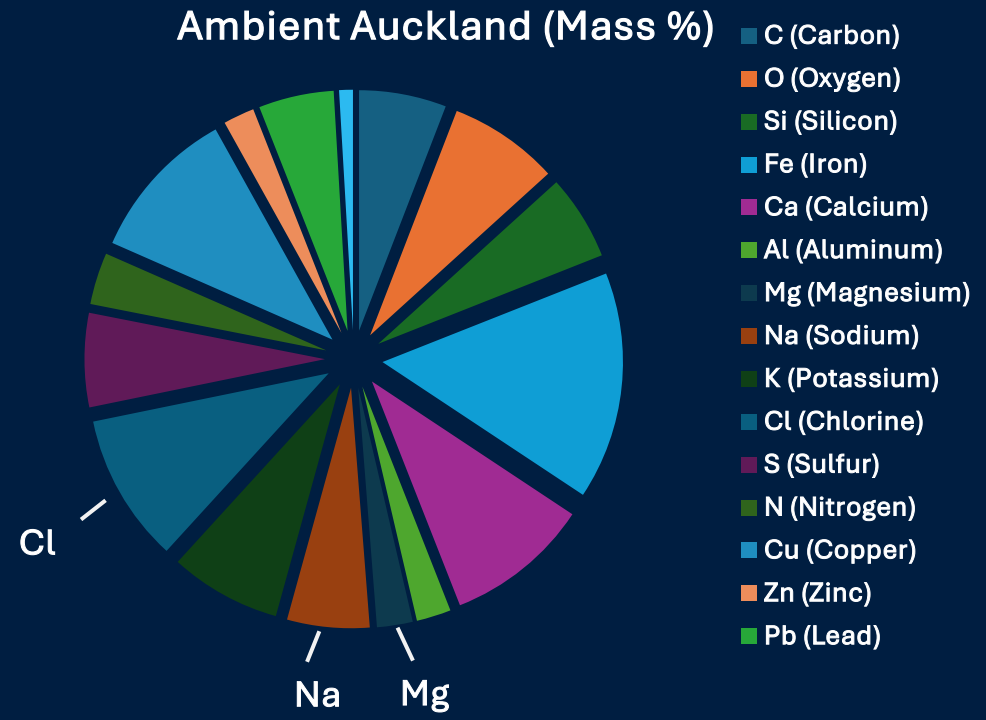


- Dominated by PM10
- Larger Standard Deviation

Elemental Detection Frequency and Mass Percentage



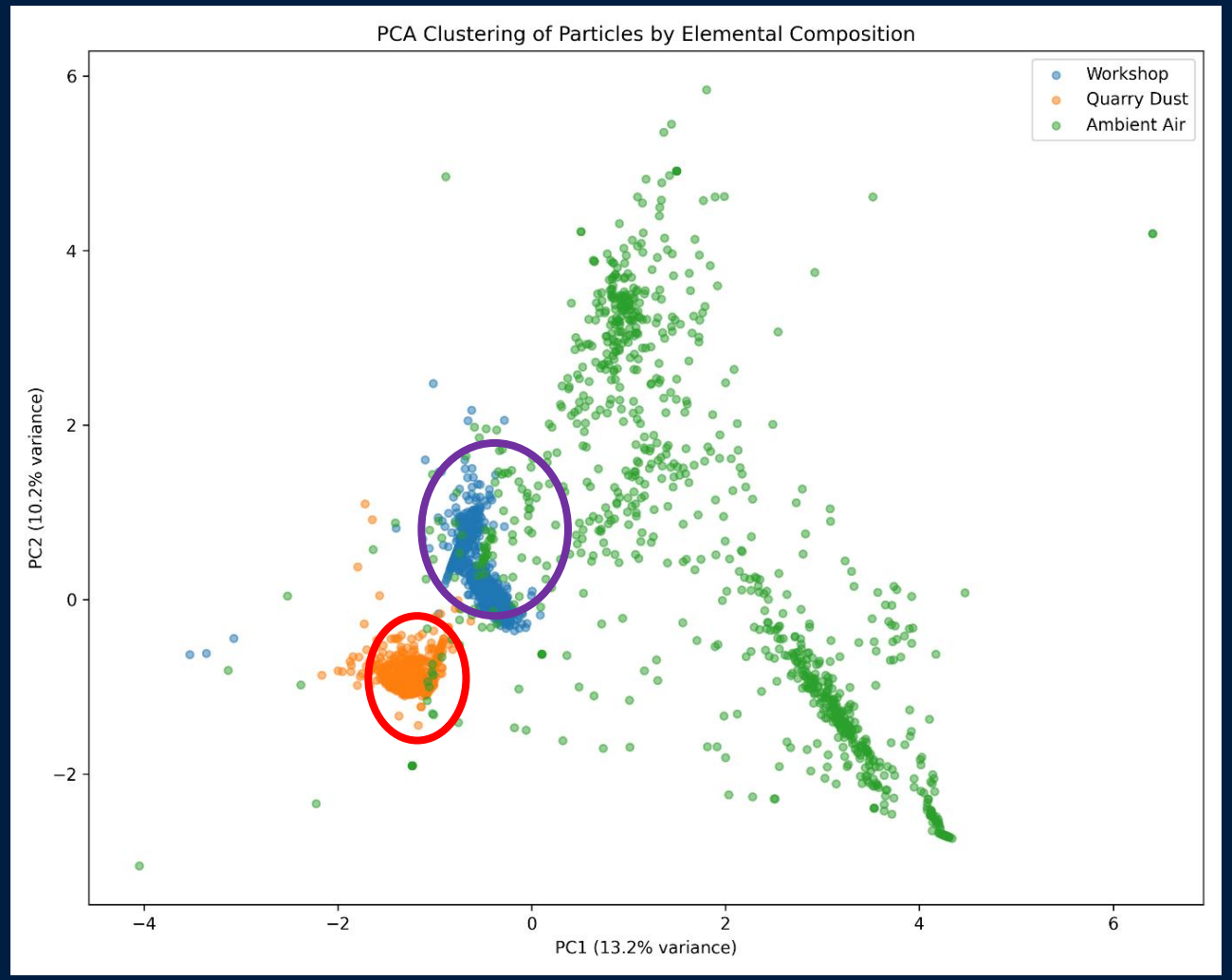




Source attribution – Principal Component Analysis

- **Every source has its own fingerprint:** quarry dust, workshop dust, and ambient air each form their own distinct group when plotted by elemental makeup – proof the method tells sources apart, not just detects particles.
- **Consistent within a source:** particles from the same source cluster tightly together.
- **Mixed environments look mixed:** ambient air, which draws from many contributors, spreads across a wider range – exactly what you'd expect from a real-world mixed environment.

The result: a dataset you can use to tell where particles came from, not just what they are.



Summary

1. It's fast and cost-effective enough to use operationally

2. You can adjust and trust your optical PM readings

3. Directed particle targeting for advanced analytical analysis

4. It fits the equipment and workflows you already run

Questions?

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Sorry for the accent!

Thank you