Size Distribution of Radioactive Particles in Loviisa NPP

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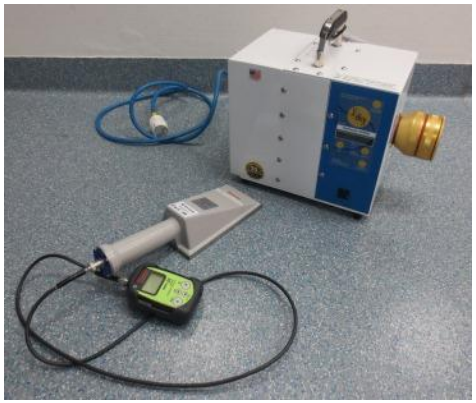
Loviisa NPP

- Located on the Baltic Sea on the Gulf of Finland in the town of Loviisa about 90 km east of Helsinki
- Two VVER-440 PWR reactors (operation started in 1977 and 1980)
- Yearly production ~8 TWh; about one-tenth of Finland's electricity production
- Unique design among the VVER-440 reactors
  - Changes in plant layout and safety features to comply with Western requirements: Containment, Ice condensers etc
- Plant follows the principle of continuous improvement for modernization of the plants and for improving safety

Air samples

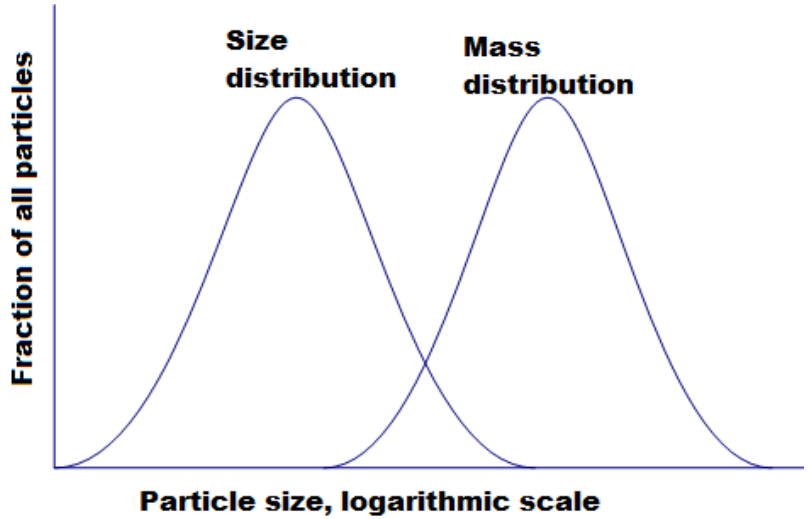
- Common way to measure particle contamination concentration in air is to take a sample with certain volume to a filterpaper and measure the activity of the filter.
- Used in RP field work at RCA and in defining the NPP discharges



- Questions
  - Is the filter paper efficient enough?
  - How do the sampling lines effect to the particle distribution that reaches the filter and does it play a role?
  - In calculations of the possible dose caused by internal radiation the particle size plays a role in dose conversion factors $h(g)_{j,h.}$ There are tabled ICRP values (1µm, 5µm), but which one to use?

Particle distributions

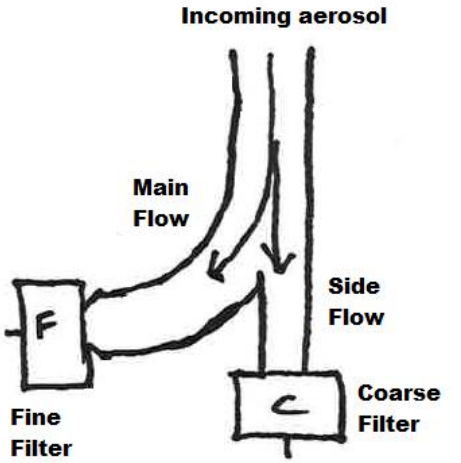
- For normal aerosol distribution the particle size and mass distribution differs
  - mass is usually gathered to larger particles even if their number is not so high



- For example Cigarette smoke mode ~ 0,2 µm
- In NPPs it is important to know the Activity Median Aerodynamic Diameter (AMAD)

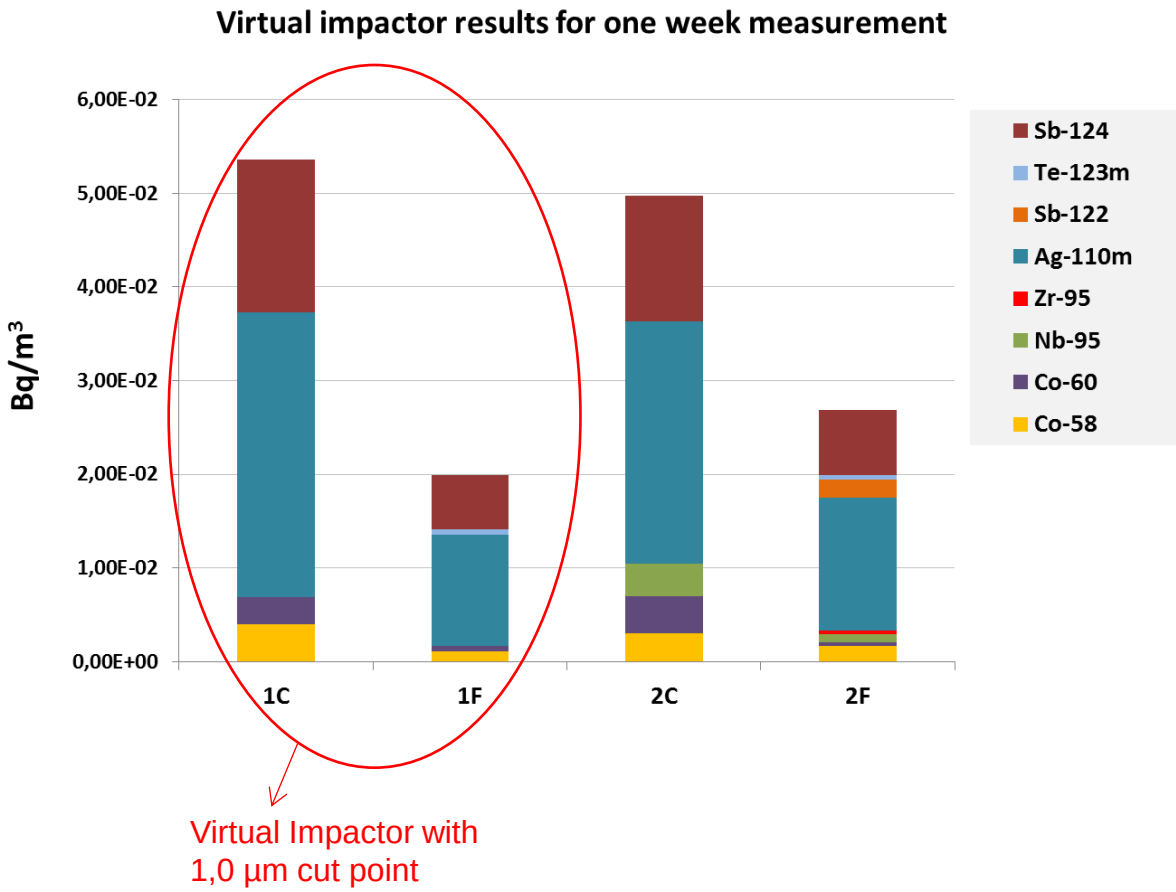
Measurement device 1: Set of two Virtual Impactors

- Divides particles with a certain cut point
- Particles are collected into two filters
  - Into Fine filter (F): particles smaller than the cut point
  - Into Coarse filter (C) particles larger than the cut point
- Only the vacuum pump needs electricity. Balance between filters are controlled with rotameters.
- Two virtual impactors were used:
  - Cut points 1,0 µm and 2,5 µm
- Measurements were done from ventilation channel in parallel with NPP stack monitors during outage time
- Filters were analyzed in NPP radiochemistry laboratory



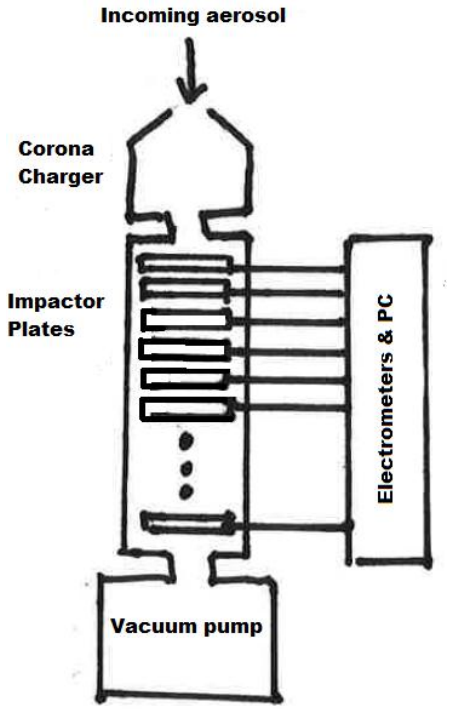
Virtual Impactor results

- 6 measurements were done from ventilation stack
- One measurement period was one week
- All results were similar
- Results showed that corrosion products are mainy attached to particles larger than 1,0 µm
- More nuclides were found in fine filters
  - More sample volume and lower laboratory MDA value
- Hard to get mass ”distributions”



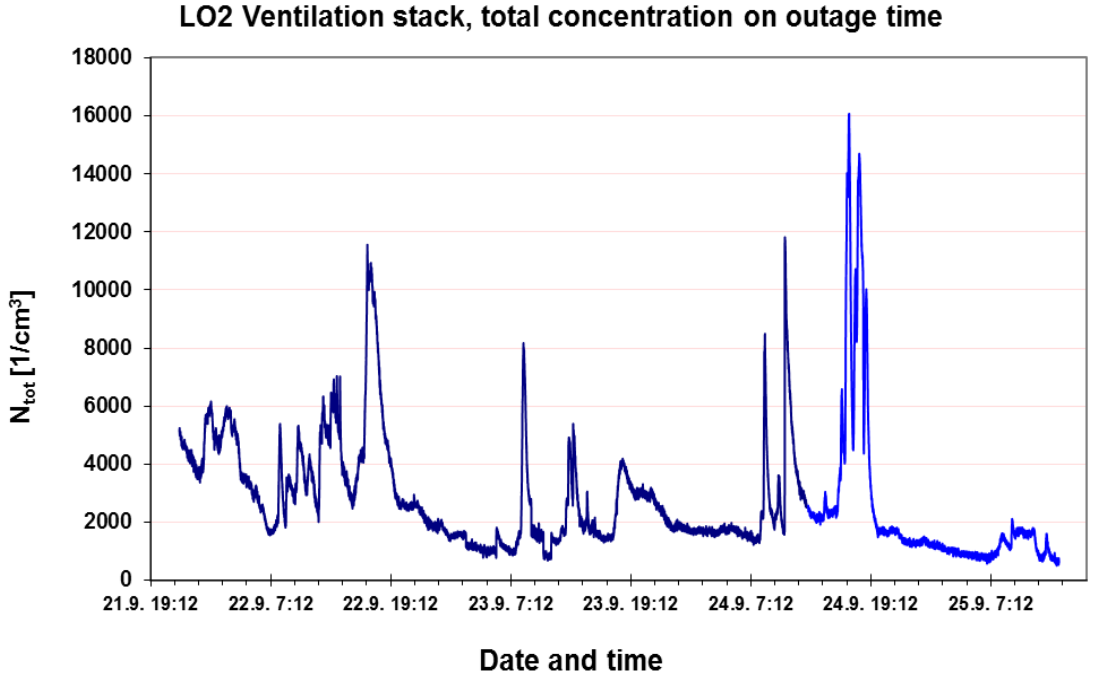
Measurements device 2: ELPI

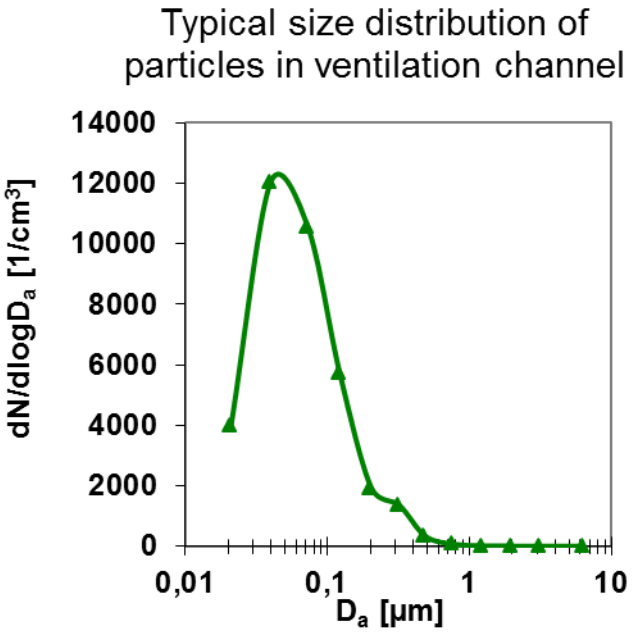
- Electrical Low Pressure Impactor
  - Incoming aerosol is charged and directed to cascade impactor
  - Current from different impactor plates are measured and the concentration of particles is calculated
  - For AMAD collection plates can be measured in radiochemistry laboratory
- Possibility to get mass distribution with long measurement periods
- By shutting down the ELPI corona charger it is possible to measure if particles are originally electically charged
- Measurements were done in reactor hall and in ventilation stack



ELPI Results: Total Concentration

- Typical particle number concentration was very low even during outage, ~1000 – 40 000/cm^3
  - In big European cities (Rome, Barcelona) N_{tot} average level can be over 40 000/cm^3 with peaks as high as 175 000 /cm^3 /1/
- Mode typically under 0,1 µm

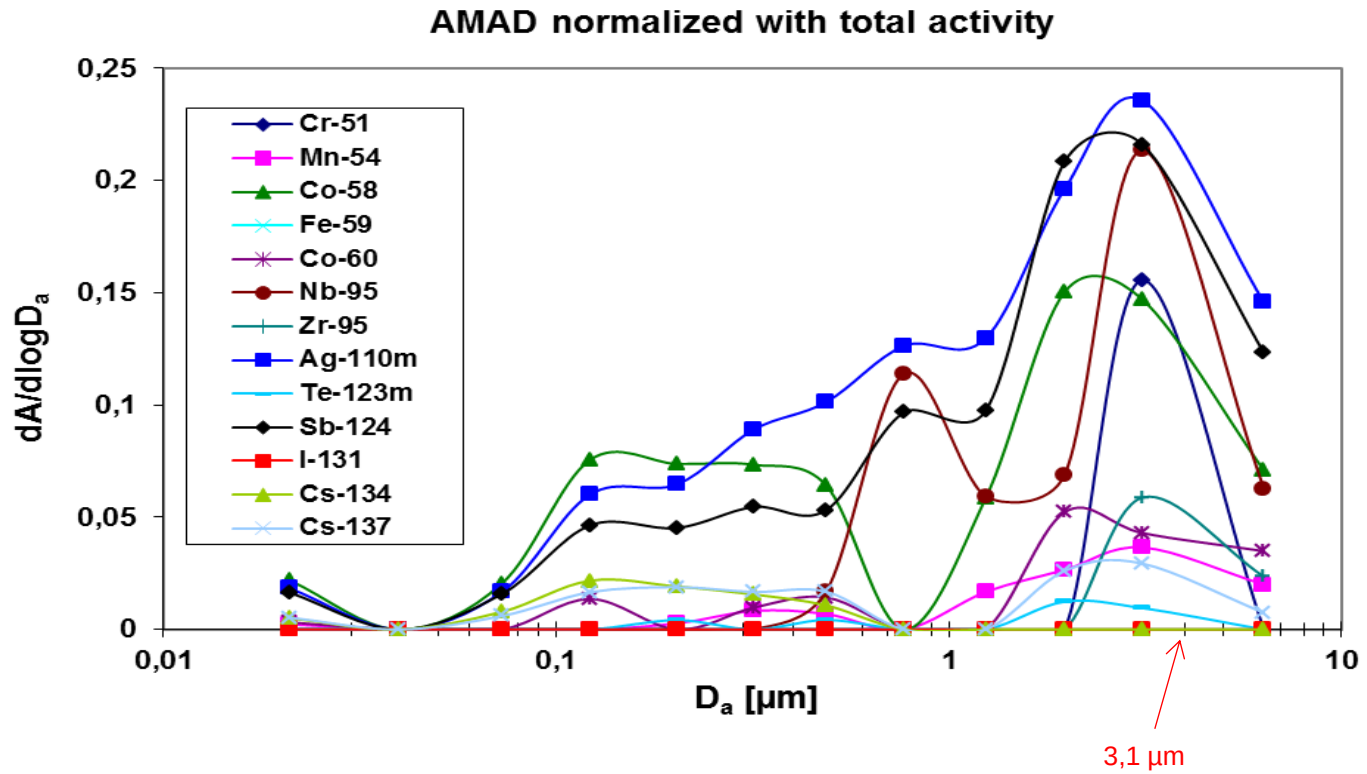




/1/ Aalto et al. 2005 ”Aerosol Particle Number Concentration Measurements in Five European Cities…”

ELPI Results

- Over 60 % of activity is attached to particles over 1 µm.
  - AMAD for total gamma is 1,8 µm
  - For most common nuclides Ag, Sb and Nb: AMAD 1,7- 2,3 µm (GSD 1,6 – 1,8)

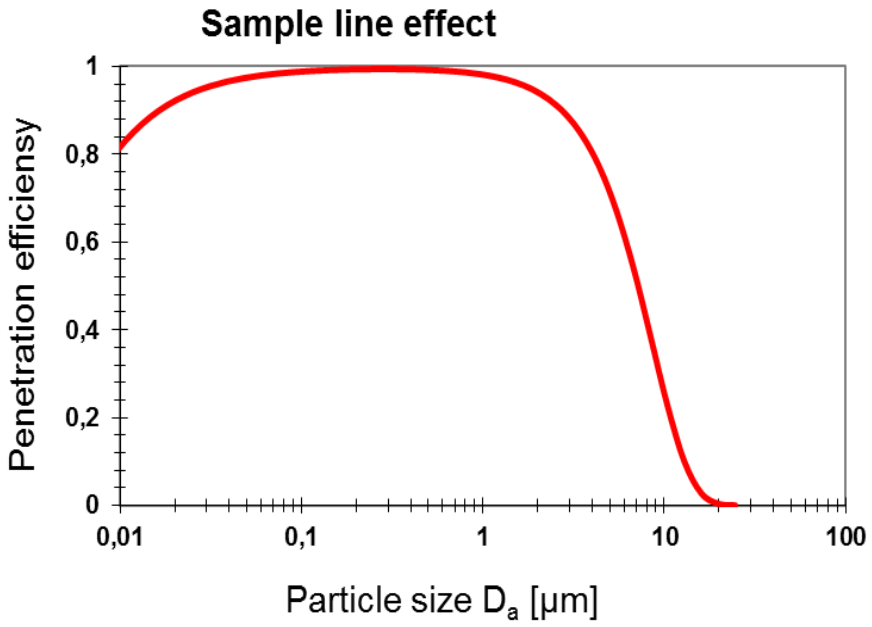


Results quite similar than measured values in some other NPPs. (Temelin, Czech Republic /2/)

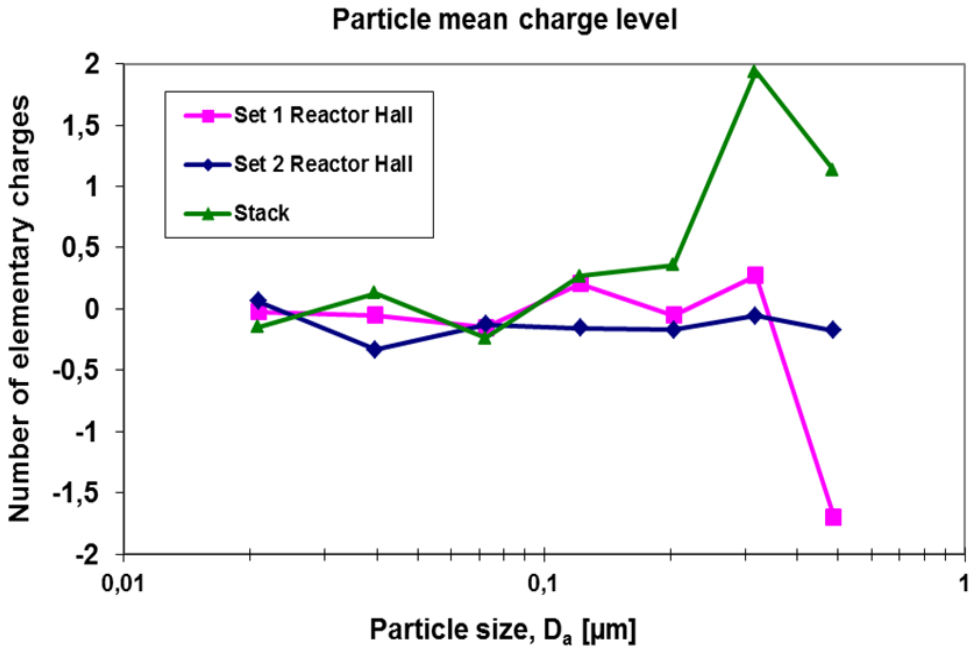
/2/ P. Rulík, "The Radioactive Aerosol Particle Size Distribution in the Air Effluents from Nuclear Power Plants obtained by the Use of Cascade Impactor"

Sample line effect and Particle Charge Level

- Theoretically modelled sample line shows rapid decrease with large particles
- Still OK for particles < 5 µm



- Results showed no evidence of particle charges
  - → No electrostatic deposition to surfaces or possibility to electrostatic precipitation (ESP) of radioactive particles without charging them



Conclusions

- Usually during normal operation particle concentrations are too low for good statistics
- Conservative approach and same equipment still used on RCA for field air contamination samples
- Most filters are ok for field sampling
- Sampling lines have effect, but still quite ok if the lengths are reasonable
- For internal dose calculations AMAD value 1,0 µm should be used