Emission measurement of airborne pollutants in two municipal solid waste incineration plants in Switzerland

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Introduction

- In Switzerland, direct deposition of waste materials in landfill is banned since 2000
  → all non-recycled combustible waste must be incinerated in appropriate plants.
- Large sums have been invested in recent years on improving municipal solid waste incineration (MSWI) plants, especially on equipment to clean flue gases. All plants are fitted with: electrostatic filters, gas scrubbers, DeNOx, additional abatement systems.
- However, MSWI plants can still be an important source of pollutants, due to the very large amounts of wastes burnt.

Objectives

- To determine the efficiency of the abatement system of two MSWI plants.
- To assess the environmental impact of these MSWI plants.

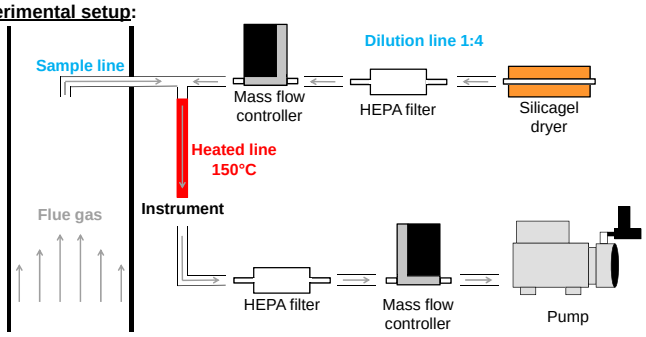
Field campaign

- Measurement of airborne pollutants at different locations of the abatement systems of two MSWI plants.
- Comparison of physico-chemical characteristics of particles sampled at the stack and at a near-field (~1 km) downwind site.

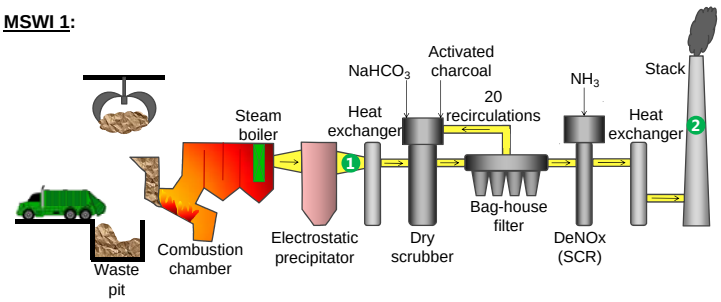
List of instruments:

Instrument	Time resolution	Parameter
CPC	1 sec	Particle number concentration
SMPS	2.5 min	Particle size distribution 10-700 nm
APS	20 sec	Particle size distribution 0.5-20 µm
Filter holder with polycarbonate filters → SEM/EDX → Ion chromatography	30 min	- Particle morphology, size, and elemental analysis - 7 selected anions (F^-, Cl^-, NO_2^-, NO_3^-, Br^-, PO_4^{3-}, SO_4^{2-})
VOCs sampling system - Tenax TA - Carboxen 569 → TD-GC/MS	20 min	Volatile organic compounds
Portable gas analyzer	1 sec	NO, SO_2, CO, CO_2, O_2

Experimental setup:

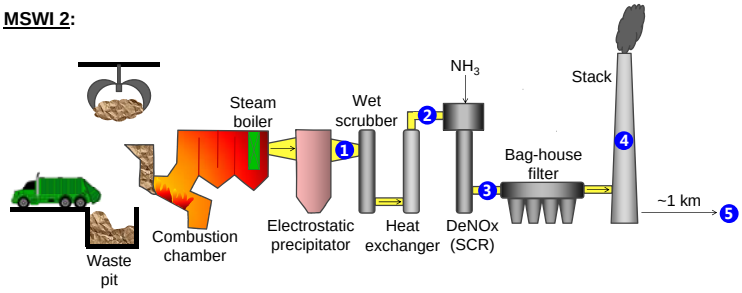


MSWI 1:



Locations of the measurements: ❶ After electro-filter ❷ Stack

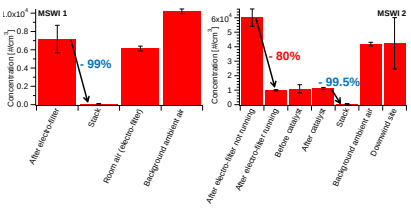
MSWI 2:



Locations of the measurements:
❶ After electro-filter ❸ After catalyst (DeNOx) ❺ Downwind site
❷ Before catalyst (DeNOx) ❹ Stack

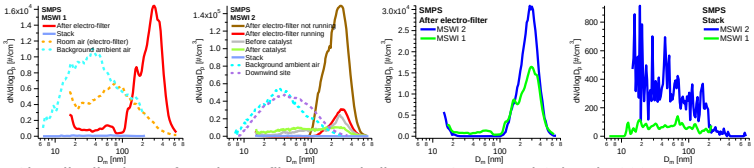
Results and discussion

Particle number concentration:

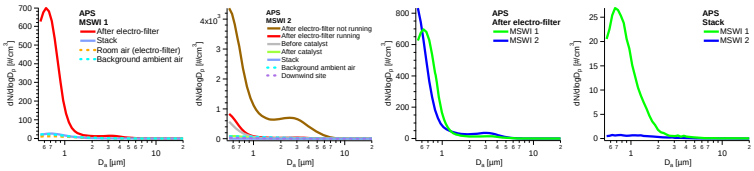


- Particle concentration drops at two locations of abatement system: at the **electro-filter (-80%)** and at the **bag-house filter (-99.5%)**.
- At the stacks, very low particle concentration (< 100 #/cm³)
  → Abatement systems very efficient.

Particle number size distribution:



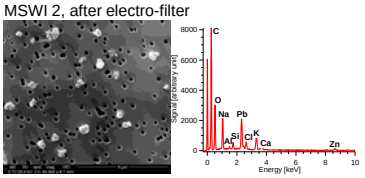
Size distributions after electro-filter very similar at MSWI 1 and 2 (mode 300 nm, narrow distribution). These particles are removed downstream in the abatement system, where size distributions become very broad (from 30 to 300 nm).



Electro-filter not running → particles mainly in submicron range with significant contribution of coarse particles (mode 2.5 µm). Electro-filter running → coarse particles almost completely removed, system downstream contains only fine particles (< 1 µm).

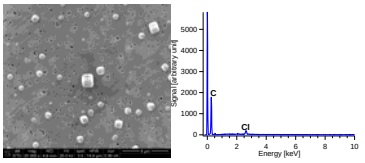
Particle morphology, size, and elemental analysis:

MSWI 2, after electro-filter

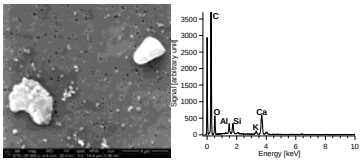


- **Stack:** homogeneous shapes (cubes and spheres) and sizes (< 1 µm). EDX → Cl, without Na (possibly NH_4Cl).
- **Downwind site:** heterogeneous shapes and sizes. EDX → no signal of Cl.

MSWI 2, stack



MSWI 2, downwind site



Water soluble anions:

- High concentrations of Cl^- at the stacks
  → Confirm results from SEM/EDX.
- Low concentrations of Cl^- at the downwind site
  → Limited impact of MSWI plants to the surrounding areas.

Site	Location	F^-	Cl^-	NO_2^-	NO_3^-	Br^-	PO_4^{3-}	SO_4^{2-}
		[µg/m³]						
MSWI 2	Background air (stack)	< DL	4.8	< DL	3.1	< DL	< DL	0.8
MSWI 2	After catalyst	< DL	< DL	< DL	6.7	< DL	< DL	33.7
MSWI 2	Before catalyst	< DL	22.7	< DL	< DL	< DL	< DL	22.7
MSWI 2	After catalyst	< DL	16.0	< DL	< DL	< DL	< DL	< DL
MSWI 2	After electro-filter	< DL	28.0	< DL	< DL	5.6	< DL	< DL
MSWI 2	Downwind site	< DL	4.5	< DL	4.0	< DL	< DL	0.6
MSWI 1	Stack	< DL	8.3	< DL	0.6	< DL	9.6	1.9
MSWI 2	Stack	< DL	430.6	< DL	2.0	< DL	33.7	< DL
MSWI 2	Stack	2.3	148.9	< DL	< DL	< DL	9.8	2.3
MSWI 2	Downwind site	< DL	0.9	< DL	0.5	< DL	3.1	0.5

Conclusion

- The particle number concentration dropped significantly at two locations of the MSWI plant: after the **electrostatic precipitator** and after the **bag-house filter**.
- The particle number concentration at the stacks was very low (< 100 #/cm³)
  → **abatement systems very efficient**.
- At the stacks, particles had a relatively uniform shape and size, and were possibly constituted of NH_4Cl salt. We did not see considerable amount of this type of particles at the downwind site, and the concentrations of chloride were rather low there
  → **the incineration plants released very limited amounts of particles to the surrounding areas**.

Acknowledgements

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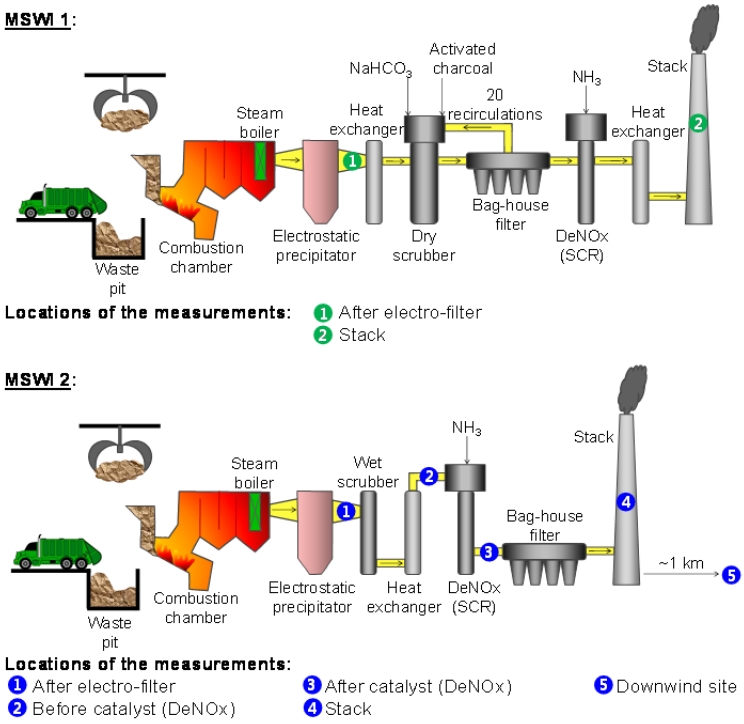
Summary:

A field campaign has been performed in two municipal solid waste incineration (MSWI) plants in Switzerland. The aim was to measure particles at different locations of the abatement system and those released from the stacks into the atmosphere, in order to assess the efficiency of the abatement system and the environmental impact of these plants.

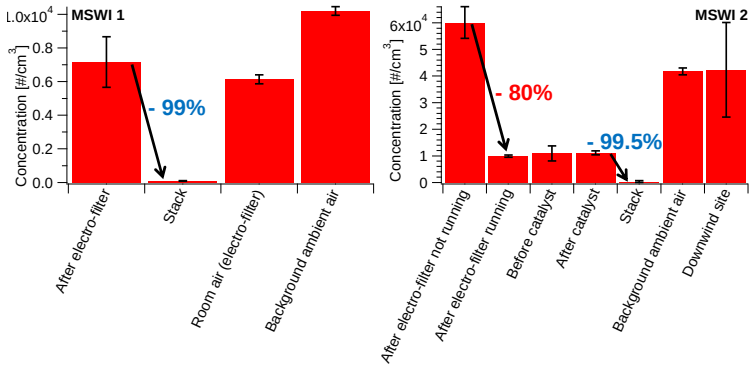
Both incineration plants were equipped with an electrostatic precipitator, a DeNOx system based on the selective catalytic reduction (SCR) technology, and a bag-house filter. The main difference between them was the presence of a dry scrubber at MSWI 1, and a wet scrubber at MSWI 2.



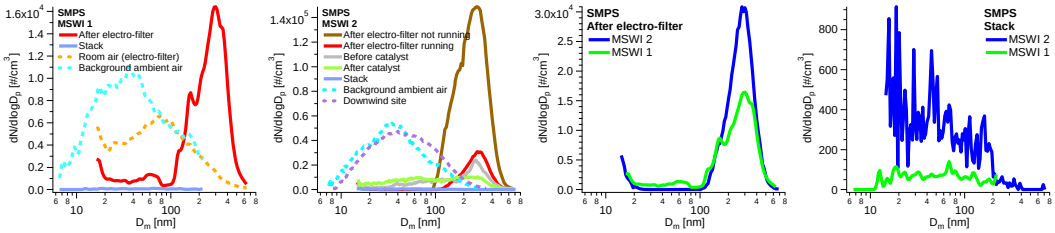
During this study, we measured the particle number concentration with a condensation particle counter (CPC), and the size distribution with a scanning mobility particle sizer (SMPS) and an aerodynamic particle sizer (APS). We also sampled particles on filters for subsequent analyses of the morphology, size and elemental composition with a scanning electron microscope coupled to an energy dispersive X-ray spectroscope (SEM/EDX), and of water soluble anions by ion chromatography (IC). Finally, volatile organic compounds (VOCs) were sampled on adsorbing cartridges and analyzed by thermal desorption-gas chromatography/mass spectrometry (TD-GC/MS), and a portable gas analyzer was used to monitor NO, SO_2, CO, CO_2, and O_2.

Measurements after the electrostatic precipitator were performed in two conditions, with the precipitator running and stopped. 90% of particles larger than 1 µm and 80% of submicron particles were removed when the electrostatic precipitator was running. Then, the DeNOx system removed up to 97% of the nitrogen oxides. Finally, the two incineration plants had bag-house filters at the end of

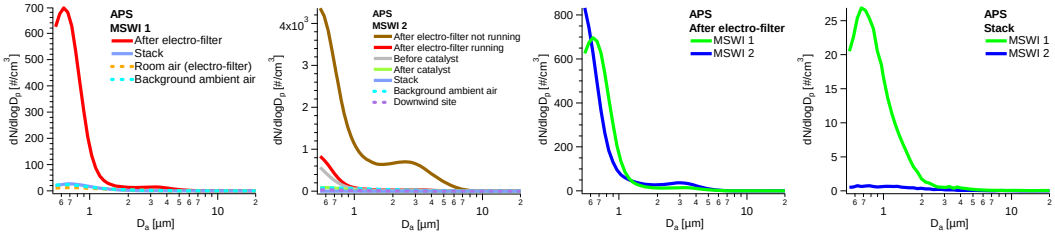
their abatement system. The filters had a significant effect in the abatement of particles, given that the particle concentration dropped by more than 99% (from 10'000 #/cm^3 before the filter down to 50-100 #/cm^3) in the stack.



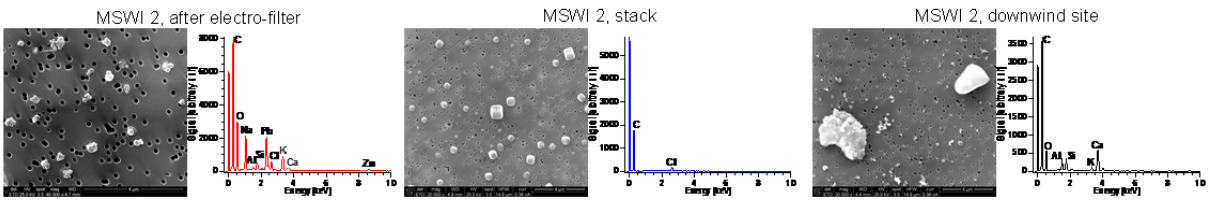
Size distributions measured with an SMPS are given in the following figure. Size distributions after the electro-filter were very similar at MSWI 1 and 2, with one mode centered at 300 nm (in mobility diameter, D_m) and a narrow size distribution. These particles were removed downstream in the abatement system, where size distributions became very broad (from 30 to 300 nm). Size distributions measured at the downwind site were very different, with one mode centered at 40 nm.



The following graph shows size distributions measured with an APS (in the range 0.5-20 µm). When the electro-filter was not running, particles were mainly in the submicron range with significant contribution of coarse particles (mode centered at 2.5 µm). When the electro-filter was running, coarse particles were almost completely removed, and the system downstream contained only fine particles (< 1 µm).



The following figure shows a few images and elemental analyses from the SEM/EDX. At the stacks, particles had a quite homogeneous morphology and size. Indeed, particles were either cubic or spherical, and their size was almost always smaller than 1 µm. However, particles sampled at the downwind site were much more heterogeneous, both in terms of shape and size. The elemental analysis of particles sampled at the stacks showed only one single signal of Cl, without the presence of Na. This result suggests that Cl was not under the form of NaCl, but probably under the form of NH_4Cl, because of the very high amounts of ammonia injected upstream, in the DeNOx. We did not see considerable amounts of this type of particles at the downwind site.



Results obtained with the ion chromatography are given in the following table. We notice very high concentrations of chloride in the stacks, which confirm results obtained with the SEM/EDX. Thus, chloride may be used as a tracer of MSWI plant emissions. At the downwind site, the chloride concentrations were rather low. This result, coupled to the absence of cubic or spherical particles similar to those sampled at the stacks, suggest that the MSWI plants have a limited impact to the surroundings area.

Site	Location	F^-	Cl^-	NO_2^-	NO_3^-	Br^-	PO_4^{3-}	SO_4^{2-}
		[µg/m³]						
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MSWI 2	Downwind site	< DL	**0.9**	< DL	0.5	< DL	3.1	0.5