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Very low emissions of airborne particulate pollutants measured from two municipal solid waste incineration plants in Switzerland

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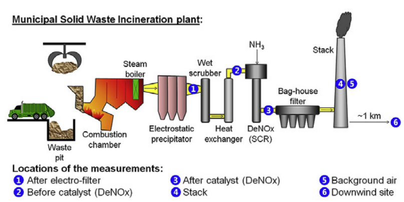
HIGHLIGHTS

- Pollutants emitted by two municipal solid waste incineration plants were measured.
- Electrostatic precipitators and bag-house filters removed >99% of particles.
- Particles released at the stacks were mainly NaCl and KCl (corrosive salts).
- The particle concentrations at the stacks were very low (<100#/cm^3).

GRAPHICAL ABSTRACT



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ABSTRACT

A field campaign has been performed in two municipal solid waste incineration (MSWI) plants in Switzerland, at Hinwil (ZH) and Giubiasco (TI). The aim was to measure airborne pollutants at different locations of the abatement systems (including those released from the stacks into the atmosphere) and at a near-field (~1 km) downwind site, in order to assess the efficiency of the abatement systems and the environmental impact of these plants.

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 ions 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.

The particle concentration decreased significantly at two locations of the plants: at the electrostatic precipitator and the bag-house filter. The particle concentrations measured at the stacks were very low (<100 #/cm^3), stressing the efficiency of the abatement system of the two plants. At Hinwil, particles sampled at the stack were mainly constituted of NaCl and KCl, two salts known to be involved in the corrosion process in incinerators. At Giubiasco, no significant differences were observed for the morphology and chemical composition of the particles collected in the ambient background and at the downwind site, suggesting that the incineration plant released very limited amounts of particles to the surrounding areas.

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1. Introduction

The total annual amount of waste in Switzerland is around 6 million tons (year 2014), of which recycled waste is the largest fraction (3′216′000 tons) followed by incinerated waste (2′791′000 tons) (Swiss Federal Office for the Environment, 2015). Municipal waste in Switzerland is estimated to be about 729 kg/person and year, of which about 390 kg is recycled and 339 kg is burned in incineration plants. The current regulation on the treatment of waste in Switzerland demands that all combustible waste has to be burned before deposition (in force since 2004). This is also the case for sewage sludge, which is not allowed to be used as fertilizer in agriculture to avoid soil contamination with heavy metals (in force since 2006, Mueller et al., 2013). Globally, incineration of municipal waste before deposition in landfill is a growing trend especially for densely populated countries (Ji et al., 2016). In countries such as Denmark, Sweden and Japan, incineration is utilized to treat around half or more than 70% of the municipal waste, while only less than 5% of the waste is deposited directly in landfills (Ji et al., 2016; Nixon et al., 2013).

Waste incineration processes could be an important source of airborne pollutants (Jones and Harrison, 2016, and references therein). Most of the studies performed at municipal solid waste incineration (MSWI) plants focused on the emission of specific chemical compounds which are known to be significantly present in the flue gas of the plants, such as mercury (Cheng and Hu, 2012; Presto and Granite, 2006; Svoboda et al., 2016; van Velzen et al., 2002) and other selected heavy metals (Dong et al., 2015; Zhang et al., 2008), engineered nanoparticles (Holder et al., 2013; Roes et al., 2012; Walser et al., 2012), dioxins (Finocchio et al., 2006; McKay, 2002; Tuppurainen et al., 2003; Zhou et al., 2015a), and volatile organic compounds (VOCs) (Liu et al., 2012). A limited number of studies focused on the measurement of the particle number concentration released from the stacks into the atmosphere (Buonanno and Morawska, 2015, and references therein). The 16 MSWI plants reported in that review had a median value of 5′500 #/cm^3 for the particle concentration in the stacks, with a 1st quartile at 1′000 #/cm^3 and a 3rd quartile at 57′000 #/cm^3. Thus, the particle concentration reported in the different studies is highly variable, and depends on the filtration techniques included in the abatement systems and the order in which the filters are located in the plant.

The emission of toxic pollutants from MSWI plants can induce harmful health effects to people living or working close to the plants. A series of epidemiological studies have been conducted to determine the health effects in the vicinity of landfills and incinerators and among workers at waste processing plants (Porta et al., 2009, and references therein). Most of these studies focused on the following health outcomes: cancer (Scungio et al., 2016), birth defects and reproductive disorders (Cordier et al., 2004), respiratory diseases (Shy et al., 1995). Only a few studies established limited relationships between pollutant emissions from incinerators and specific health effects, but these studies usually suffer from a low statistical power, and a lack of information on the exposure assessment, chemical and toxicological data on specific compounds, and possible confounding factors.

The emission of a wide range of pollutants from the waste incineration processes requires sophisticated abatement systems for the exhaust air. Thus, incineration plants are generally equipped with electrostatic precipitators and bag-house filters for the elimination of particles, DeNOx and scrubbers (wet or dry) for the abatement of specific gaseous species (e.g. nitrogen oxides, dioxins, furans, mercury, acidic gases, VOCs) (Le Cloirec, 2012; Vehlow, 2015). In Switzerland, the introduction of the Ordinance on Air Pollution Control (OAPC) in 1986 led to significant investments in the infrastructure of incineration plants for emission reduction. Especially the emission of ultrafine particles was reduced to a total of 30 tons per year, which corresponded to only a few per mills of the total emissions of ultrafine particles in Switzerland (Hügi et al., 2008). On the other hand, the above mentioned development also demonstrates the importance of monitoring and control of emissions from waste incineration.

The aim of the present project was to assess the environmental impact of MSWI plants, and the efficiency of their abatement systems. For that purpose, a field campaign was conducted at two different MSWI plants in Switzerland (Hinwil in Canton Zürich [ZH] and Giubiasco in Canton Ticino [TI]) in December 2015 and April 2016. Particles and gases were measured at different locations of the abatement systems of the two incineration plants, and additional measurements were performed at the Communal Stadium of Giubiasco, a site located <1 km downwind of the MSWI plant of Giubiasco, in order to assess the environmental impact of that plant to the surrounding areas.

2. Description of the municipal solid waste incineration plants

2.1. Giubiasco (TI)

First operated in 2010, Giubiasco's MSWI plant is designed to treat 67 MW or 160′000 tons of solid waste annually. It is positioned south from a waste water treatment plant and west of the A2 Highway in the municipality of Giubiasco on about 40′000 m^2 of land (Fig. 1). The plant uses two lines to incinerate waste on moving grates with an estimated operation of 8′000 h a year. The heat produced in the furnaces is used to generate electrical energy by a steam turbine, whereas the excess heat is distributed in a district heating system to various users in the form of hot water. All in, nearly 100 GWh electricity and 20 GWh heat are produced every year; this is enough to meet the average electrical energy demand of 23 000 families and the average heat demand of 2′300 households in the region (Bergomi, 2015).

The incineration plant has a complex abatement system to remove particles and gases emitted during the incineration process (Fig. 2). The abatement system consists of an electrostatic precipitator with three units, a wet scrubber with three units (the first two units for the removal of HCl, HF, H_2SO_4, mercury and other heavy metals, and the third unit for the removal of SO_2), a DeNOx system based on the selective catalytic reduction (SCR) technology, in which nitrogen oxides are reduced into N_2 with the addition of ammonia in the presence of a catalyst, and finally bag-house filters before the release into the atmosphere through a stack.

2.2. Hinwil (ZH)

The incineration plant of Hinwil (Fig. 3) comprises three ovens, in which the thermal decomposition of the waste takes place. Each of these ovens is followed by its own electro-filter for the dust removal. Then, the gas flows coming from the three ovens are mixed, and then separated in two parallel paths. On each path, the gas is first treated with sodium bicarbonate ($NaHCO_3$) in order to remove HCl, SO_2, SO_3, and HF. The gas recirculates 20 times in the reactor for high efficiency of removal of these compounds. The last step is the reduction of nitrogen oxides with a DeNOx system also based on the SCR technology (like at Giubiasco), in which ammonia (NH_3) is added to reduce NO and NO_2 into N_2. The remaining dioxins and furans are also destroyed during this step. The operating temperature of the catalyst is quite low at Hinwil, around 180–190 °C, compared to other incineration plants where the temperature reaches 230–240 °C. However, when the catalyst is