Physico-chemical qualification of a universal portable sampler for aerosols and water-soluble gases

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Abstract. Developing a universal portable air sampler based on electrostatic precipitation. The challenge is to collect micro and nanoparticles, microorganisms as well as toxic molecules with a portable device. Electrostatic precipitation is an efficient and gentle method to collect airborne microorganisms and preserve their cultivability. But the collection of toxic gases required is not possible in such a device. The collection of such gases requires a liquid into which they have to be solubilized. Two concepts are being evaluated. The first one is based on electrospray. The goal is to investigate the collection efficiency of water-soluble gases. The second concept is based on the semi-humid electrostatic precipitator. Their high collection efficiencies for particles were already demonstrated. In the present study they are both tested with water-soluble gases. Concentrations are measured in the liquid solution by Ion Chromatography and in the gas phase by Proton Transfer Reaction Mass Spectrometry.

1. Introduction

As part of the overall security program for the fight against the spread of toxic agents (CBRN-E) the Center of Atomic Energy (CEA) is developing a universal portable air sampler based on electrostatic precipitation. The challenge is to collect micro and nanoparticles, microorganisms as well as toxic molecules with a portable device.

Electrostatic precipitation is an efficient and gentle method to collect airborne microorganisms and preserve their cultivability. But the collection of toxic gases required is not possible in such a device. The collection of such gases requires a liquid into which they have to be solubilized. Tepper et al. [1-2] showed that it is possible to collect particles and soluble gases with an electrospray based device. Later Elio et al. [3] used an electrospray to make a wind generator that is able to collect airborne particles while the collection electrode is continually rinsed. Another way of adding water into an electrostatic precipitator is to inject water vapor. Galbrun et al. [4] demonstrated the collection efficiency of such a device for nanoparticles. Following their work a fairly simple universal portable sampler for aerosols and water-soluble gases may be developed.

The two concepts shown on figure 1 are being evaluated. The first one is the configuration previously studied by Elio et al. [3] for the collection of particles. The goal is to investigate the collection efficiency of water-soluble gases. The second concept is based on the semi-humid electrostatic precipitator of Galbrun et al. [4]. Their high collection efficiencies for particles were already demonstrated. In the present study they are both tested for the collection of water-soluble gases. Concentrations are measured by ion chromatography in the liquid solution obtained by rinsing the collection electrode. Concentrations of volatile organic compounds (VOCs) are also measured in the gas outlet of the experimental device by Proton Transfer Reaction Mass Spectrometry.

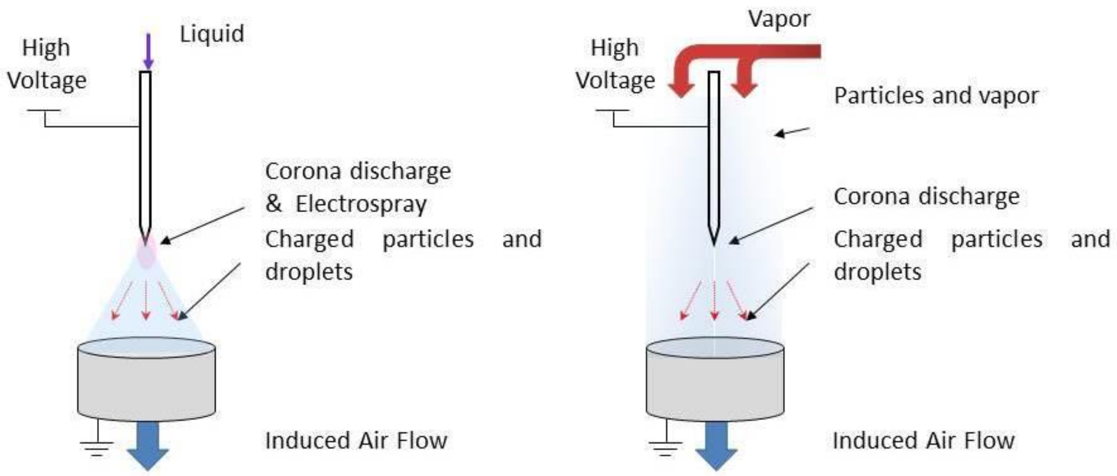

Figure 1. Schematic description of the two evaluated configurations: left, electrospray based design; right, electrostatic precipitation assisted by the presence of vapor.

2. Materials and methods

The two concepts presented above on Figure 1 are first tested with water-soluble gases injected in the device air inlet as shown on Figure 2. Two very different gases were chosen: hydrochloric acid (HCl), a water-soluble gas with a great affinity for water; methanesulfonic acid (MSA), a much more complex molecule with a reduced affinity for water compared to HCl. A volume of about 30 ml of both gases was slowly injected with a syringe into the air inlet. The gas was aspired by the device which air flow relies on the ionic wind between the discharging electrode and the collecting electrode [3]. Afterwards the collecting electrode was rinsed with pure water and the resulting solution was analyzed by ion chromatography (Dionex ICS 2000).

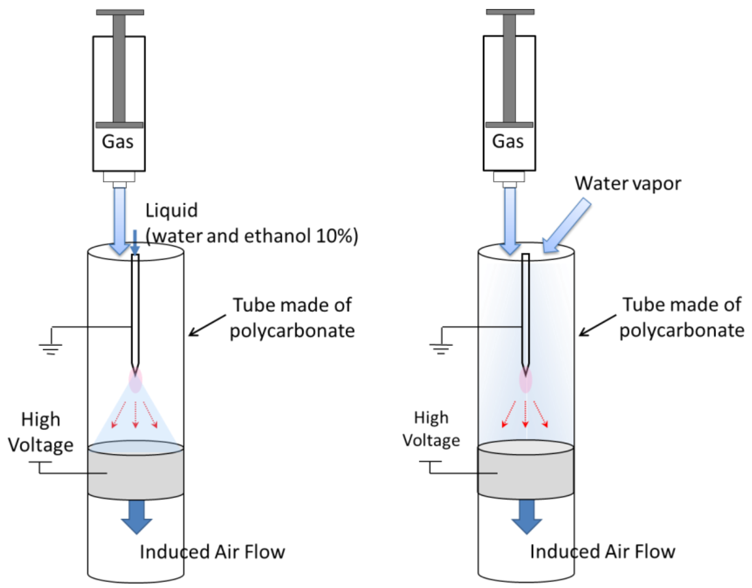

Figure 2. Schematic description of the experiments made to investigate the gas collection capacity: left, electrospray based design; right, electrostatic precipitation assisted by the presence of vapor.

When the device was used in the electrospray configuration, the liquid injected into the capillary was a mixture of water and ethanol (10%) [1] at a flow rate of about 10 µl/min. When the device was used in the vapor based configuration, water vapor was injected at 250 µl (liquid)/min.

Gases in the outlet were also analyzed by Proton Transfer Reaction Mass Spectrometry.

3. Results and discussion

Ion chromatography shows that a very high amount of chlore is present in the rinsing solutions when vapors of hydrochloric acid were injected. Also a high amount of methanesulfonic acid is present in the rinsing solutions when vapors of methanesulfonic acid were injected. These results, obtained in the two studied configurations, are summarized and shown on Figure 3. So adding an aqueous solvent by the mean of an electrospray or by the mean of an evaporator is therefore efficient to collect water-soluble gases.

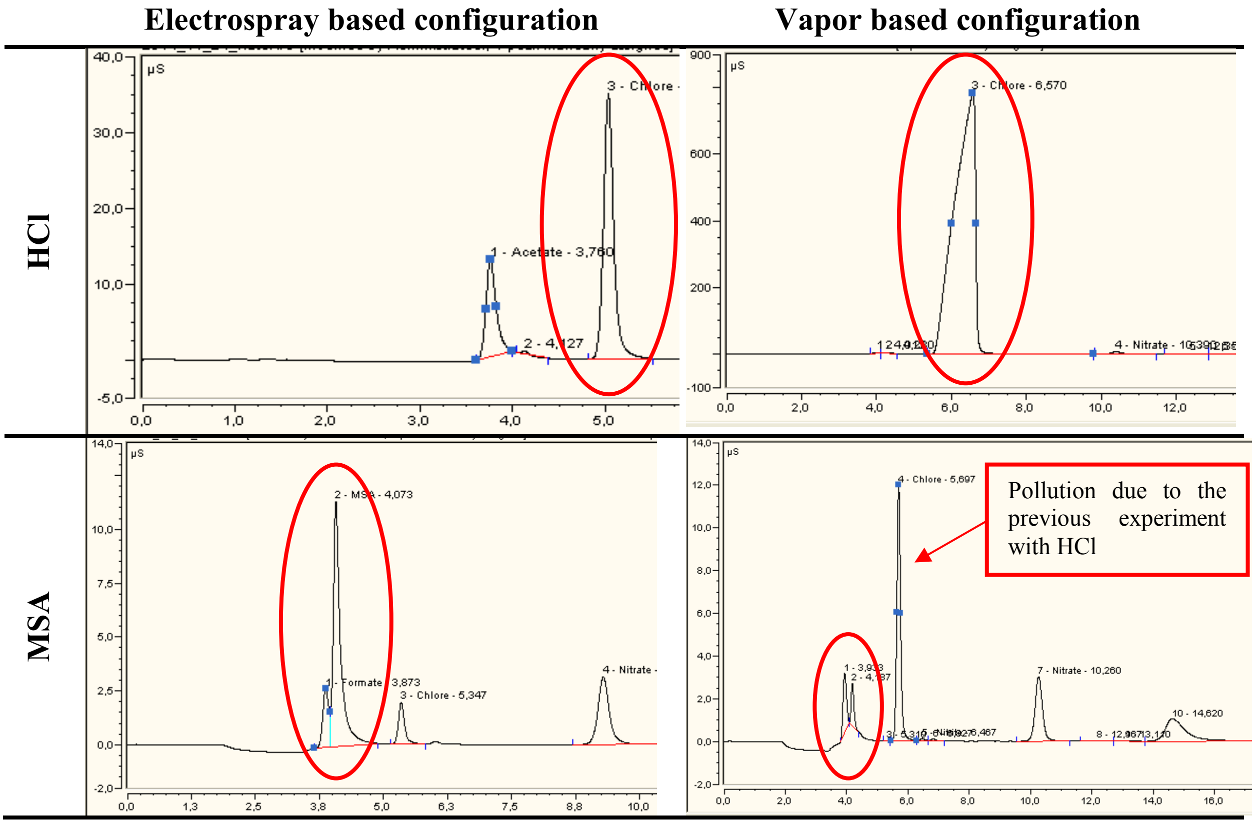

Figure 3. Concentrations of ions in the rinsing solution for each configuration and for gases tested in the experiments.

Next, the amount of volatile organic compounds was measured by Proton Transfer Reaction Mass Spectrometry in the gas outlet, when ambient air only was present around the experimental device. It revealed that methanol was produced in the electrospray based configuration. Also it revealed that acetone was produced when water vapour is injected in the electrostatic precipitator. These gases were not detected prior to the injection of ethanol (10%) or water vapour.

Ethanol was used by Tepper et al. [1]. It reduces the surface tension of aqueous solutions so that smaller droplets can be produced by electrospray based devices. Here the presence of methanol may be understood as a breakdown of the ethanol in the corona discharge. Since methanol is a toxic compound a new way of reducing the surface tension of water has to be found.

The presence of acetone when water vapour is injected in the electrostatic sampler is surprising. Traces of it can be found in ambient air but here it is due to an unknown chemical reaction in the semi-humid electrostatic sampler. It is also a toxic compound and its production must be avoided. This point is critical and further researches must be led to find a way to suppress the presence of this compound.

4. Conclusion

The present study shows that adding an aqueous solvent by the mean of an electrospray or by the mean of an evaporator is efficient to collect water-soluble gases. But, for both configurations, toxic volatile organic compounds were found in the gas outlet. It is therefore required to find a way to avoid the production of these compounds to be able to obtain an electrostatic sampler that is able to collect gases.

Acknowledgments
This work was supported by the CBRN-E R&D research program from CEA.

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