

COILED GLASS TUBE WITH A RESERVOIR: A VERSATILE GAS SAMPLER FOR GASEOUS AND PARTICULATE MATTER WITH LOW BLANK VALUE

Tou S, Watanabe N

Graduate School Major in Environmental Engineering, Osaka Institute of Technology, Osaka, Japan,
535-8585, seikou40300@gmail.com

Introduction

Missing of ultra fine particles (UFPs, diameter of ca 0.1 μm) from gas sampling is observed and well explained¹⁾. Contact of gas and particle to liquid or solid phase is needed for collection. The mechanism is illustrated in Fig 1. When bulk gas involving gaseous and particulate substrate is introduced through a bent path, random motion of gaseous molecule will reach the wall, while a coarse particle with large inertia cannot turn but makes collision with the wall. However, UFPs is located between gaseous molecule and coarse particle; therefore, it will be transferred with bulk gas.

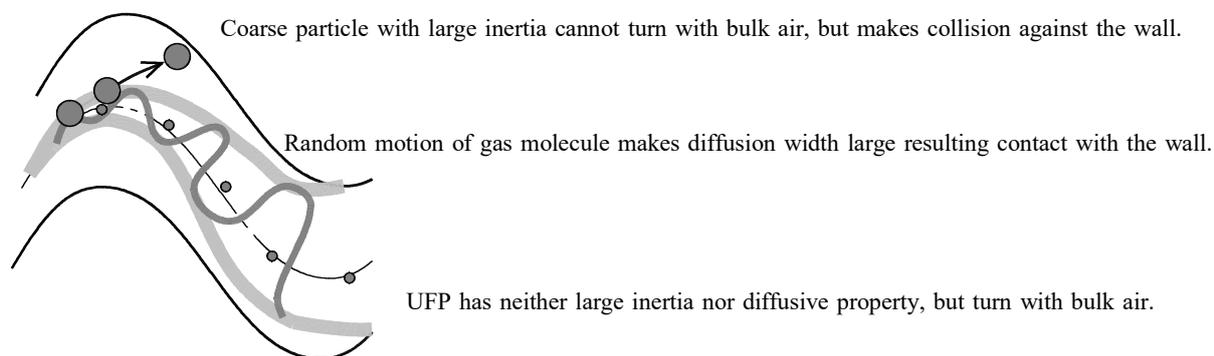


Fig 1 Collection mechanism of gaseous and particles in bent path

Off-gas from combustion involves fine particles through vaporization and nucleation²⁾. Measurement of those particles by aqueous trapping sometimes results in underestimation. Laboratory experiment introducing vaporized NH_4Cl into any aqueous gas bubbler/impinger shows white smoke overlaying the trapping water, which evidences the missing of particulate matter.

Medical and infectious field is the most anxious about missing UFPs, because size of viruses is the same with UFPs. Gas impinger could collect airborne viruses less than 10%³⁾, or 50%⁴⁾; hence, filter method is currently applied⁵⁾; however, still now any superior sampling method is desired.

A strategy to collect particles including UFPs is to make particles grow, which was evidenced to be applicable to salt⁶⁾. Introducing them into a coiled tube will give centrifugal force to collide to the wall,

which is rinsed with water to recover the analyte. In this article, the instrumentation is applied not only particulate but also gaseous samples.

Materials and methods

The experimental set-up is illustrated in Fig 2. Smoke of NH_4Cl was generated in a glassware by mixing 30 μL of 12 M HCl and 30 μL of 10% ammonium aquatic solution. The amount of smoke NH_4Cl was measured by direct vacuum sampling followed by dissolution with injected water. The smoke with air was drawn at a rate of 2 L min^{-1} to ceramic tube, which was kept at room temperature when particulate NH_4Cl was examined. When NH_4Cl in gaseous form was needed, the ceramic tube was heated at 900°C. The gas out of the ceramic tube was sampled using two serial impingers, containing 10 mL each, two coiled glass tubes in an iced bath, and a fritted reservoir. The size of the coiled glass tube were id: 1.8 mm, length: 1.5 m, coil radius: 32 mm, and revolution: 6.5 times. The fritted reservoir is a plastic syringe with a holed cap which is used to solid phase extraction. The inside of the coiled glass tube was rinsed with 3 mL of water to be analyte. The back side coiled tube was rinsed with the water from the reservoir. Concentration of NH_4Cl in this experiment was determined by electric conductivity, since no other chemicals was applied.

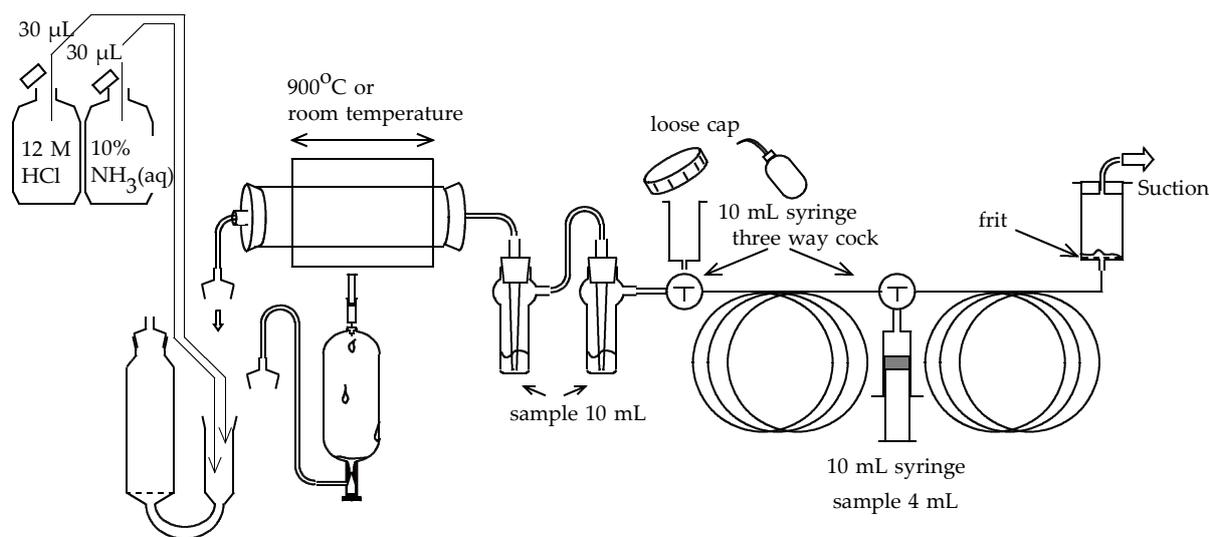


Figure 2 Generation of NH_4Cl in particulate or gaseous form, and collection by two impingers, two coiled glass tubes and a fritted reservoir

Results and discussion

The results using impingers, coiled glass tube, and fritted reservoir is given in Fig 3. Smoke NH_4Cl generated was $39.9 \pm 1.9\%$. Two impingers collected $25.2+2.3 = 27.5 \mu\text{g}$ (68.9%) and coiled glass tubes with a reservoir do $1.5+9.3 = 10.8 \mu\text{g}$ (27.1%), when particulate NH_4Cl was introduced. Although NH_4Cl has no information about particle size, one third of smoke NH_4Cl was missed from the impingers to be collected at coiled glass tube. Some water droplets running in the coiled glass tube was observed. The origin

of the droplets was mist and vapor brought from the impinger. Since the water was collected at the reservoir, second coil with the reservoir gave more than the first one. If the smoke NH_4Cl was vaporized in the ceramic tube, impingers and coiled glass tube with the reservoir collected $27.2 \mu\text{g}$ (68.2%) and $6.7 \mu\text{g}$ (16.8%), respectively. The lower recovery compared to the non-vaporized experiment was due to condensation loss at the gas transfer line.

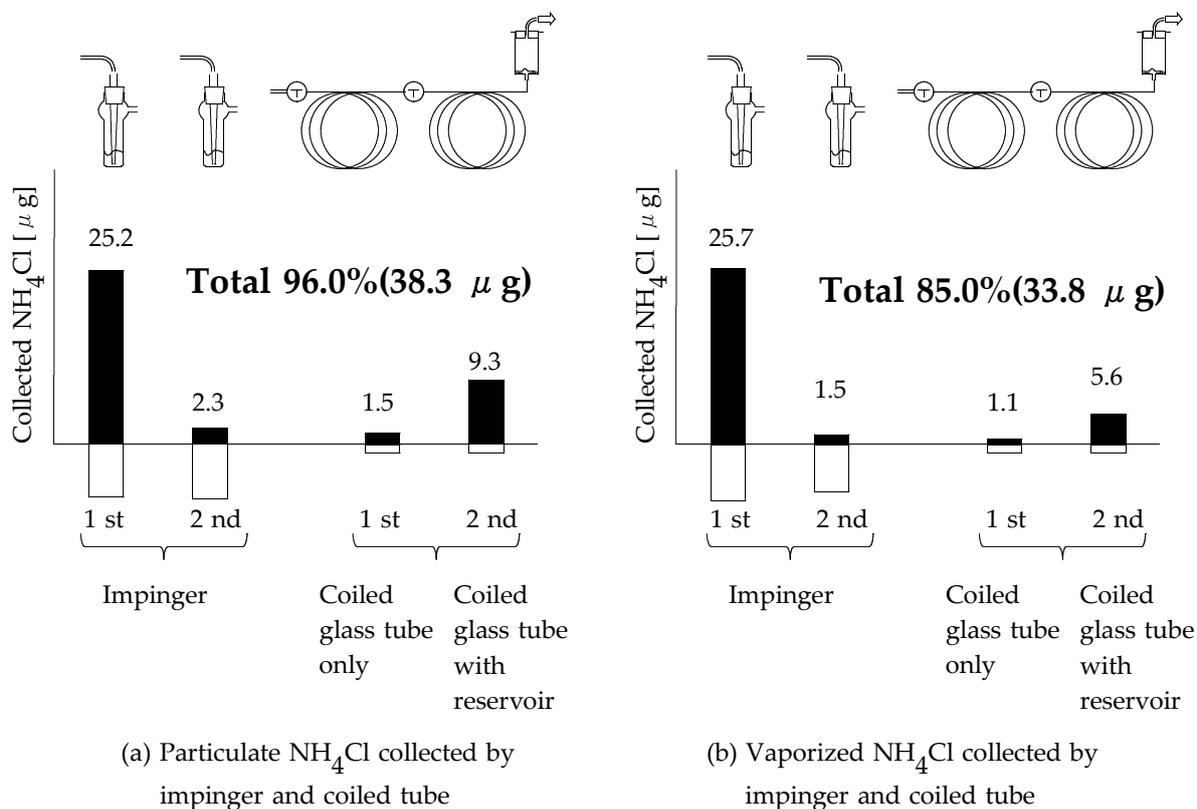


Figure 3 Collected NH_4Cl using two impingers, two coiled glass tubes, and a fritted reservoir

Even if the impingers are removed and the gas was directly introduced to coiled glass tube, sufficient recovery was achieved (Fig 4). Besides the good recovery, the low blank value of coiled tube is notable. Data from glass impinger was accompanied by a blank value as high as is $6 \sim 9 \mu\text{g}$, which is illustrated by white-painted bar directed to minus $7.5 \mu\text{g}$ in Fig 3. On the other hand, the blank value of coiled glass tube was $1.0 \sim 1.4 \mu\text{g}$ ($1.2 \mu\text{g}$ in Fig 3).

Subsequently, we developed a new gas sampling train involving reaction-moisturization U tube, coiled glass tube, and a fritted reservoir shown elsewhere⁷⁾. Analyte is drawn from the inlet of the train without dismantling the set-up; therefore, stable blank value was kept.

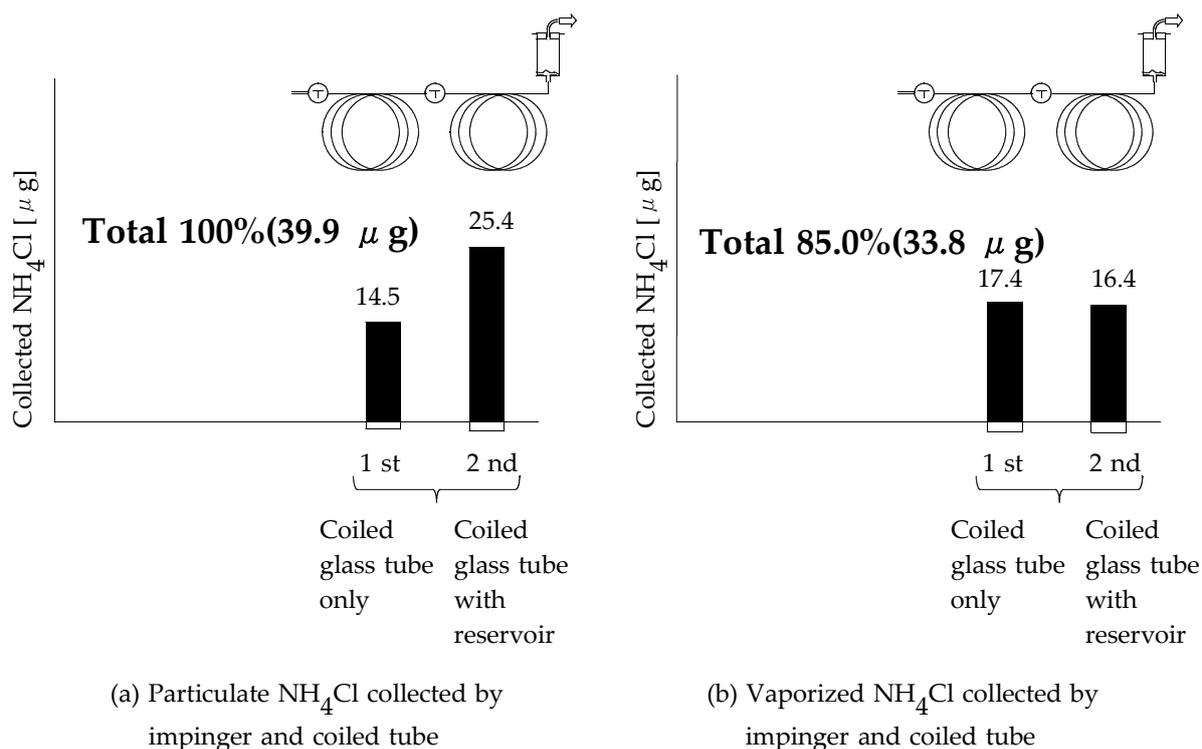


Figure 4 Collected NH_4Cl using two coiled glass tubes, and a fritted reservoir

Conclusion

Traditional gas sampling methods using impinger have been pointed out to have particles missing problem, which was a big issue of measurement of airborne virus. However, from this research, the coiled glass tube with a dew reservoir resulted in sufficient recovery of NH_4Cl fume. Moreover, the blank value of impingers was 6 to 9 μg whereas that of coiled glass tube was 1.0 to 1.4 μg . Coiled glass tube equipped with a dew reservoir on-line installed has an advantage of collecting particulate matter as well as low blank value.

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