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Abstract

Aerosol Measurements by OPC Aided by QCM Mass Sensor †

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Abstract: Atmospheric aerosols, as well as particulate matters or suspended particulate matters (PMx), impact climate and affect human health, directly or indirectly. PMx is one of the most important pollutants monitored for air quality evaluation. Optical particle counters and quartz crystal microbalances are used to measure mass in a fixed volume. However, when used separately, these devices can show some issues. In this work, we propose combining these devices to obtain results that include particle counting, mass measurement, and, in particular cases, discrimination between solid and liquid aerosols. By using both instruments together, we can overcome the limitations of each and obtain more accurate and comprehensive data on air quality.

Keywords: QCM; aerosol; PMx; optical particle counter

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1. Introduction

Aerosol particles are defined as solid or liquid particles suspended in air (or gas), forming a mixture [1,2]. The quartz crystal microbalance (QCM) and optical particulate counter (OPC) can be used together in certain applications to provide complementary information about the properties and behavior of particle matters (PMx) [3]. Although the OPC provides information about the size of PMx, it does not provide a direct measurement of the PMx mass concentrations, which can result in incorrect data depending on the composition of the aerosol (liquid, solid). On the other hand, the QCM output is related to the total mass accumulated on the QCM without any information about the size of PMx. Furthermore, with a QCM with an integrated heater [3], it is possible to perform a thermogravimetric analysis to distinguish between aerosol phases (liquid and solid). In this paper, we propose combining these devices to obtain results that include particle counting, mass measurement and discrimination between solid and liquid aerosols.

2. Materials and Methods

In order to evaluate the functioning of the proposed device (OPC+QCM), we designed and developed a suitable adapter to connect the OPC to the QCM properly, after a 3D fluid-dynamic simulation. The prototype was tested using an aerosol generator to produce and deliver different aerosol samples to the device inlet. In particular, we tested two aerosols: (a) "NaCl aerosol", nebulizing a solution of sodium chloride at a 0.3 M concentration, and (b) an "e-liquid", which is a combination of propylene glycol (PG, 70%) and vegetable glycerin (VG, 30%). An electronic board was designed to acquire and record the output signal data Δf (frequency variation).

3. Discussion

When the NaCl sample was introduced into the device, both salt and water particles could be counted (by OPC), resulting in a total count that did not differentiate between the phases of the aerosol. At the same time, the salt particles may be in the gas phase and may undergo a phase transition, forming a solid deposit on QCM electrodes, generating frequency variation (Δf). After the heating period, performed by an integrated heater on QCM (red dashed line), the solid phase remains on the surface, highlighting that the QCM mass output is only related to the solid phase (see Figure 1).

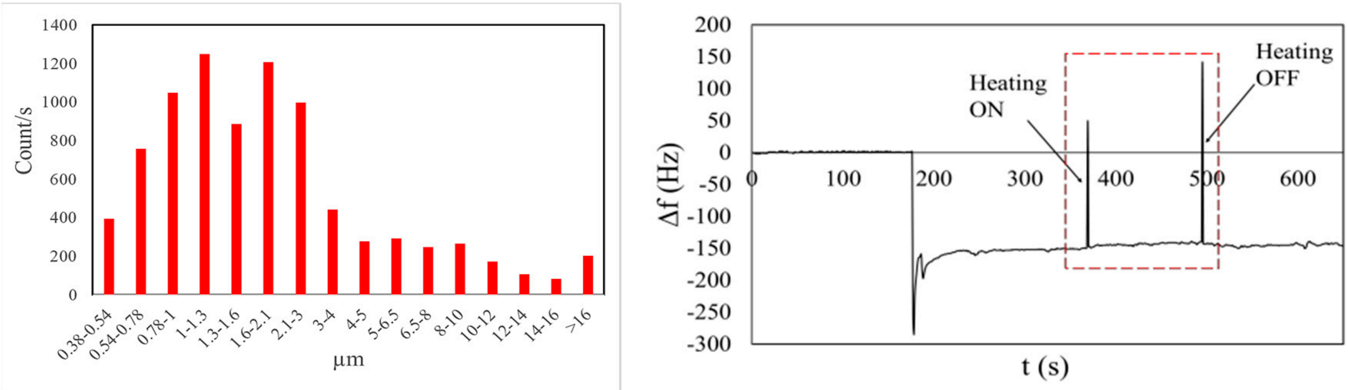

Figure 1. Results of the measurements of a sample of nebulized NaCl aerosol by OPC (on the **left**) and QCM (on the **right**). The red dashed line shows the heating area, highlighting when the heat is on.

In Figure 2, we report an example of the measurement results for the e-liquid aerosol sample. The OPC measures the aerosol (on the left of Figure 2), which in this case is in a single phase (liquid). At the same time, when the e-liquid aerosol is deposited on a QCM, it produces a Δf similar to the previous case. However, after the heating period (red dashed line), the liquid phase desorbs from the QCM, recovering the initial start frequency. This result, taking into account the QCM mass sensitivity, indicates that there is no solid phase in the aerosol.

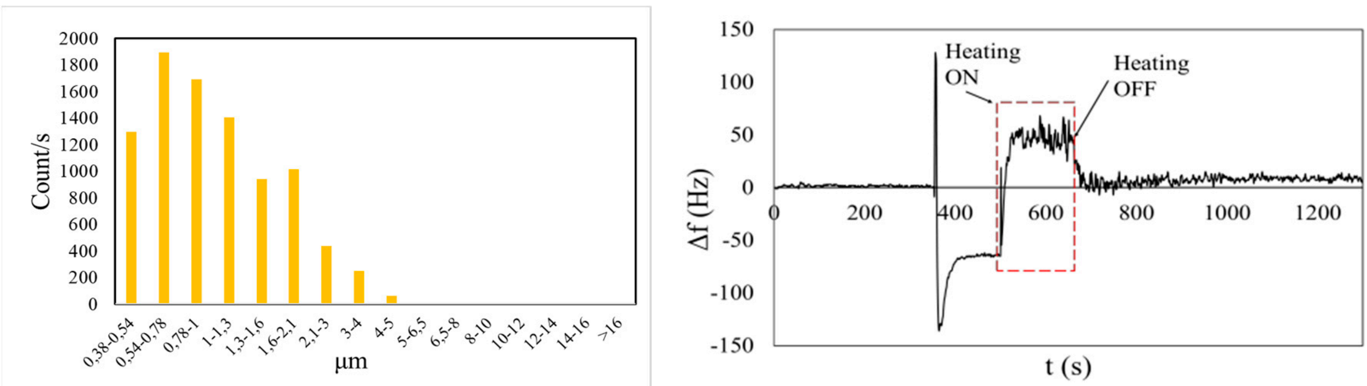

Figure 2. Results of the measurements of a sample of nebulized "e-liquid" aerosol by OPC (on the **left**) and QCM (on the **right**). The red dashed line shows the heating area highlighting when the heat is on.

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