REAL-TIME MONITORING OF AIRBORNE FORMALDEHYDE CONCENTRATIONS BASED ON A MICROFLUIDIC ANALYTICAL DEVICE: APPLICATION TO FIELD MEASUREMENTS

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ABSTRACT
A new analytical method based on microfluidic device for formaldehyde detection was developed and patented. This 4 kg fully automatic instrument has a response time of 10 min, a temporal resolution of 2 seconds and a detection limit of 1 µg m^{-3}. Our formaldehyde micro-analyser was then used for continuous monitoring during field campaigns in schools for several weeks. Our measurements were found to be in excellent agreement with those measured with the ISO 16000-3 reference method (active sampling on DNPH cartridges).

KEYWORDS: Formaldehyde, microfluidic device, continuous monitoring, indoor air, field campaign.

INTRODUCTION
Indoor air quality (IAQ) is a growing concern due to the harmful effects of airborne pollutants on human health. Among them, formaldehyde is a major and harmful pollutant of indoor air due to its multiple sources and its carcinogenic effect. This work reports the development of a novel analytical method based on microfluidic technologies for the detection of low airborne formaldehyde concentrations, representative of those found in indoor air, i.e. 10-100 µg.m^{-3}.

EXPERIMENTAL
The new analytical technique operates as follows: 1) gas sampling, 2) gaseous formaldehyde uptake into the aqueous solution using an annular gas/liquid flow at room temperature (see figure 1), 3) derivatization reaction with acetylacetone solution at 65°C producing 3,5-Diacetyl-1,4-dihydrolutidine (DDL) and 4) fluorimetric DDL detection. The novel microfluidic instrument is compact and highly portable (4kg).

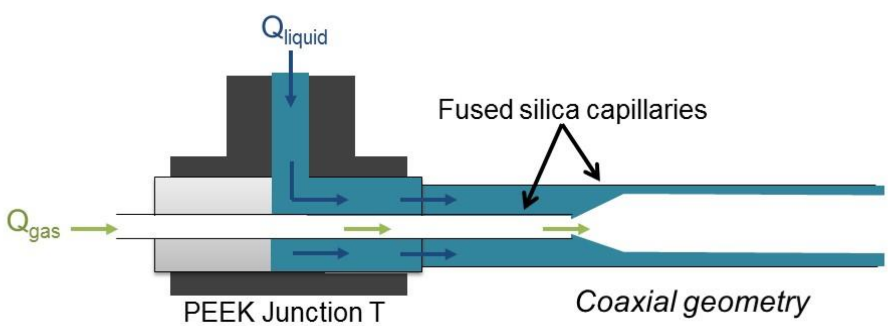

Figure 1: *Scheme of the microfluidic set-up used for establishing an annular flow.*

RESULTS AND DISCUSSION
Laboratory experiments were performed to determine the experimental conditions permitting to obtain a stable annular flow, i.e. gas to liquid flow rate ratios greater than 1000. From liquid and gas calibrations, an uptake yield of 100% demonstrating the high efficiency of the specific microfluidic device used for trapping of airborne formaldehyde. Our microfluidic analytical method allows quantifying formaldehyde in near real time with a delay of ten minutes and a temporal resolution of two seconds. The corresponding detection limit of our new formaldehyde micro-analyser is around 1 µg m^{-3} (0.8 ppb) which is fully adapted to indoor air quality.

This formaldehyde microanalyser was then deployed during several field campaigns and compared with the ISO 16000-3 reference method (active sampling on DNPH cartridges) as illustrated in figure 2 [1,2]. Formaldehyde was always detected and its concentration, ranging from 2 to 25 µg m^{-3}, was strongly influenced by the ventilation status.

Our data are in excellent agreement with those obtained by the reference method ISO 16000-3 and the first generation of formaldehyde analyser developed in our laboratory. The microfluidic instrument can convincingly measure very rapid changes (< few minutes) in formaldehyde concentrations as during the window opening whereas reference method ISO 16000-3 can only provide an average concentration over its chosen sampling time, i.e. several tens of minutes or several hours.

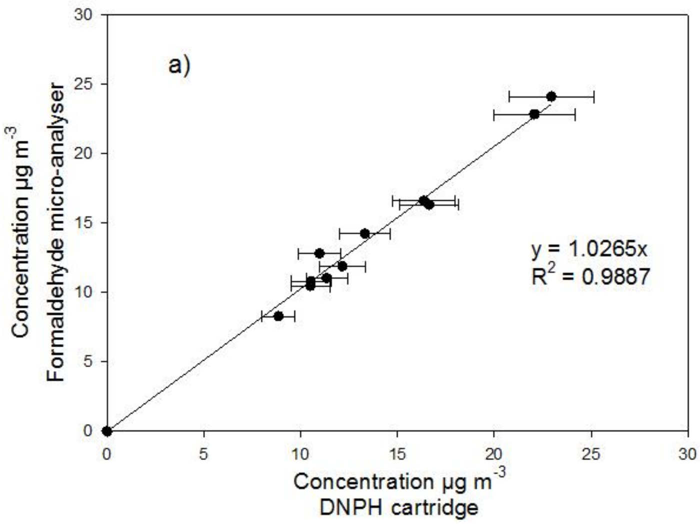

Figure 2: *Inter-comparison of our results with the reference ISO 16000-3 method (air sampling on DNPH cartridges coupled to HPLC/UV analysis).*

The microfluidic approach needs very low amount of reagent, i.e. 17µL min^{-1}, so that 100 mL reagent can achieve analyses during more than 98 hours against only 91 minutes before with the previous formaldehyde analyser [3]. Finally, the full gaseous formaldehyde uptake will allow a calibration from liquid standard solutions of formaldehyde. This point constitutes a significant advantage compared to the analytical methods requiring gaseous calibration, especially since gaseous formaldehyde cylinders are not stable over time. In addition, liquid calibrations are very easy and much more adapted for *in-situ* field measurements.

CONCLUSION

Our novel microfluidic formaldehyde microanalyser is therefore extremely sensitive, accurate, precise, powerful and robust. It is standalone and can operate continuously over long time period. This new formaldehyde microanalyser is now marketed by the company In'Air Solutions from 2017. In addition, currents works are in progress to develop a new microfluidic fluorescence cell in order to reduce the liquid volume needed for formaldehyde detection and consequently both liquid flow rate and autonomy.

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