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Exposure to Combustion Aerosols in Buildings - or how to make use of the Air Pollution

Exposure to Combustion Aerosols in Buildings – or how to make use of the air pollution

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The continuous measurement of the external air change rate of rooms in operation is of interest for several reasons: air hygiene, control of HVAC devices, energy- and power need. Internal tracer gases have shown their limitations in this area. New highly sensitive (down to 1 ng/m^3) and selective photoelectric detectors for traffic born aerosols open new perspectives: the use of such aerosols as external tracer gas. First measurements have demonstrated the principal feasibility of this method and further investigations of their limitations and their potential are going on.

An important issue concerning buildings is the air exchange. The reason therefore are health and energy saving aspects. The impact of air pollution on the health of people especially in agglomerations is undisputed. The aspect of energy saving by reducing the airflow is the more in focus the better the fabrication and isolation of buildings become. Up to 50% of the energy loss of modern houses is due to air exchange. The importance of controlled air exchange seems quite natural. This is the reason why it is important to develop adequate methods to deliver continuous data of buildings in operation. The methods already existing can't cover these demands for technical or cost reasons

The developement of the PAH-sensor now allows to fullfill this task. With its help it is possible to use traffic born aerosols as external tracer gas. The principle of the sensor is based on the photoelectric charging of the soot particles in a range below 1µm covered with polycyclic aromatic hydrocarbons. The detection limit is 1ng/m^3 .

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The idea is that there should be a correllation between the concentrations of PAH outdoor and indoor and the exchange of air through the building enveloppe. Picture 1 shows measurements performed in a room facing a highly frequented main road in Zürich. It can be seen that the signal of the sensor taking values indoor is following the oudoor signal slowly and washed out.

The mass balance of a room yields a reasonable link between the measured concentrations of PAH and the external air exchange rate :

$$\frac{dc_i}{dt} = -(n_e + n_d) \cdot c_i + n_e \cdot c_e \qquad (1)$$

c_i : internal PAH concentration

c_e: external PAH concentration

n_e: external air exchange rate $[h^{-1}]$

n_d: deposition rate $[h^{-1}]$

The solution of the mass balance equation is straight forward:

$$c_i(t) = n_e \cdot \int_{-\infty}^{t} e^{-(t-t')\cdot(n_e+n_d)} \cdot c_e(t') \cdot dt' \qquad (2)$$

the requested values: n_e and n_d being in the exponential. In this form, the equation (1) and its solution (2) suppose an immediate mixing of the internal air.

To find out how the aerosol is distributed in a room test measurements were made in a climate chamber of $70m^3$ volume at the EMPA in Dübendorf. The outdoor concentration of PAH was simulated to be a narrow peak with high concentration as can be seen in picture 2. There is also the answer of two sensors installed at different locations in the room. After about 1h they show the same signal meaning that the aerosol is distributed equally over the room. The transient – the time between the inlet and the complete mixing – is obviously dependent on the location. The decay of the PAH signal after mixing is exponential due to the mass balance equation which can be applied under the condition of complete mixing.

With these results we describe the air exchange mechanism as a linear answer with the outdoor concentration as incoming signal and the indoor concentration of PAH as the answer of the system. To take into account the mixing process of the air in the room, the exponential in (2) is replaced by a more general response function r(t) of the room :

$$c_{in}(t) = n_e \cdot \int_{-\infty}^{t} r(t-t') \cdot c_{out}(t')dt' \qquad (3)$$

c_{in} ... *indoor concentration*

c_{out} ... *outdoor concentratiion*

r ... *response function*

n_e ... *air exchange rate*

The fouriertransform of r, $\tilde{r}$, can be extracted by the convolution theorem.

$$\tilde{c}_{in}(\omega) = n_e \cdot \tilde{r}(\omega) \cdot \tilde{c}_{out}(\omega)$$

$$\Leftrightarrow n_e \tilde{r}(\omega) = \frac{\tilde{c}_{in}(\omega)}{\tilde{c}_{out}(\omega)} \qquad (4)$$

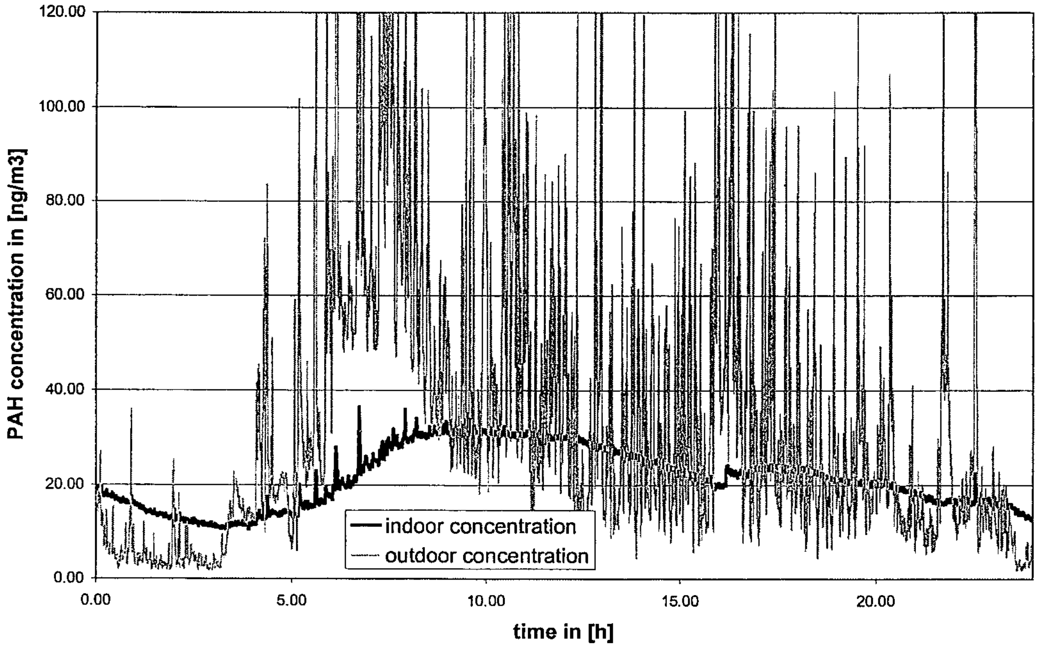
For the long time part of r(t), the exponential form should be valid. In the Fourier picture, this means:

$$\tilde{r}(\omega) \cong \frac{n_e + n_d}{(n_e + n_d)^2 + \omega^2}$$

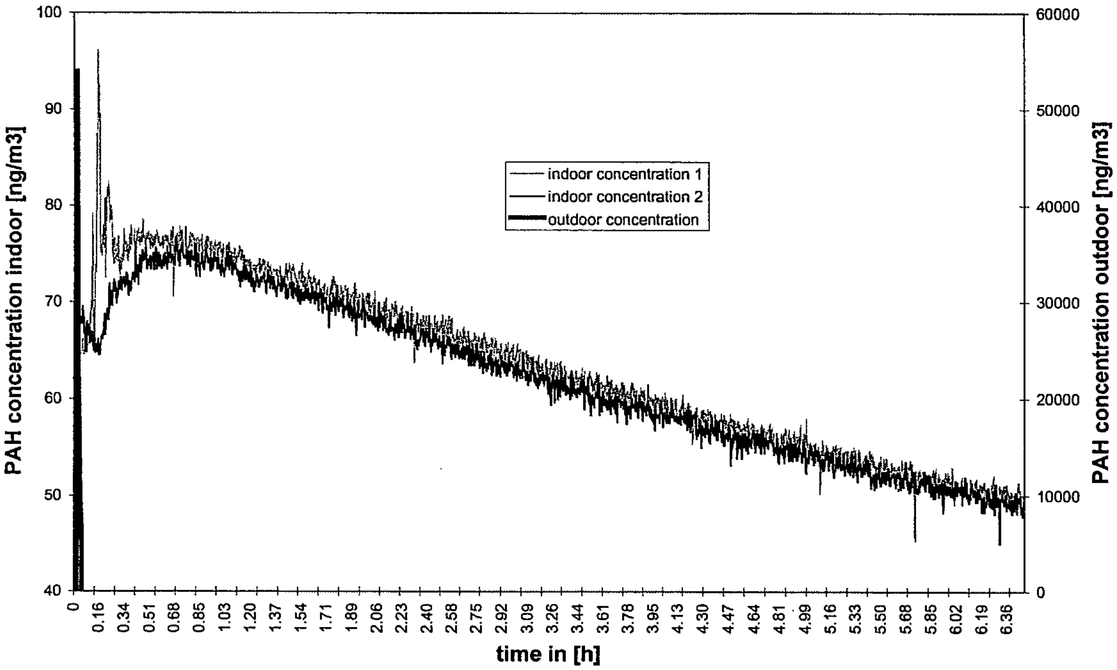
for the low frequency part of $\tilde{r}(\omega)$.

In picture 3 the fouriertransform of r together with a curve fitted to the low frequencies can be seen. The curve is representing the fouriertransform of an exponential function. The values of air exchange rate and depostion rate were evaluated from this fit to be 0.2 and 0.15 roomvolumes per hour respectively.

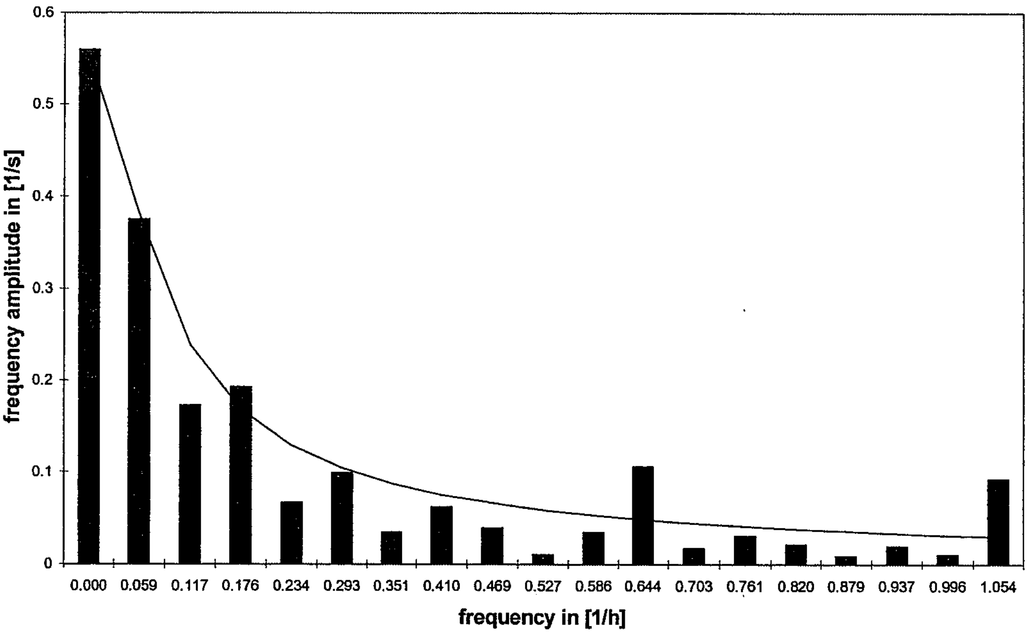
These values seem quite resonable but still have to be compared with field measurements with tracer gas which is in progress.



Picture 1: Field measurement of indoor and outdoor PAH concentration



Picture 2: Measurement in the climate chamber. The outdoor peak is very high and narrow.



Picture 3: Evaluation of the measurement results obtained in the field measurement (see Picture 1).