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# Measuring and modelling concentration fluctuations in the natural scale

## Free field trials with tracers krypton-85 and tetrahydrothiophen

*In simulation of odour emissions around livestock housing modelling of the fluctuation of material concentrations plays an important role. The calculation of odour frequencies is in the main supported by the statistical distribution functions as validated through free field trials with suitable tracers. Following dispersal trials with the radioactive tracer krypton-85 and the odorant tetrahydrothiophen, a comprehensive data collection has been produced creating the basis for analysis of the fluctuation-statistical characteristics of atmospheric trace materials.*

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## Keywords

Concentration fluctuations, probability density functions, odour immission

In the simulation and prognosis of odour frequencies a key role is played by the modelling of fluctuation behaviour of odours transported in the atmospheric windfield. This is because the standard deviations of material concentration are mainly at least as large as the average values so that odours can even be identified where the average is far under the odour threshold value [1]. Although there have also been attempts to numerically simulate fluctuation behaviour directly, statistical calculations are preferred, not least because of their practicability. This concerns dual-parameter distribution densities which show a sufficient measure of flexibility for describing the frequency distribution of fluctuating material concentrations and can at the same time still be applicable in model creation. Within the framework of the work here and on the basis of a comprehensive measurement data collection, three practical density distributions were investigated and evaluated regarding their higher statistical moments. However, the mathematical-physical results regarding fluctuation behaviour cannot be immediately converted into odour emissions because the exposition/efficacy relationship is dependant on subjective olfactory influences. The sensor recording of odour emissions through plume inspections is therefore necessary in order to gain an oversight over the effects of fluctuating odours.

### Measurement methods

In level terrain under free, mainly uninterrupted air movement (pasture with ~ 0.3 m grass height, average surface roughness $z_0 \approx 0.04$ m) the radioactive isotope $^{85}$Kr was, in irregular distribution, emitted from a plastic hose 2 m above ground. Depending on the trial, the emission periods lay between 9 and 24 min by mainly neutral to weak atmospheric stratification. At leeward distances of 50 m and 100 m the impulse rates were recorded with in-part highly-sensitive proportional counter tubes with a periodical development capacity of 1 s. The configuration of the 10 cylindrical Geiger-Müller counters as well as the 10 much more sensitive flat proportional counter tubes took place at 2 m height on circle segments with opening angles of 60°.

Between June 28, 2000 and May 18, 2001 a total of nine distribution trials using the given measurement methods were conducted. In the last four trials in the same time and position as the tracer $^{85}$Kr the odorant tetrahydrothiophen (THT) was released in order to record the time proportion for odour identification at selected counter tube positions by testers. Through registration odour recognition times the aim is to compare the olfactoric „overlapping pattern“ with that of the tracer $^{85}$Kr as measured at the counter tubes. With this not only information on the correlation between the overlapping samples as well as the effects of odour emissions can be gathered, but also detailed comparisons between observed odour frequencies and overlapping frequencies arrived at through calculation only. The odour threshold value and the most important chemical/physical characteristics of the odorant THT are in the DVGW literature [2].

### Trial results

Using conversion factors for the tracer concentration time series (kBq/m$^3$), the measured impulse rates were converted. From this, not only the average and variance of the concentration can be determined but also higher statistical moments such as obliquity and kurtosis. The comparison between measurement and model calculation showed first of all that the averages of the observed tracer concentration could be reproduced with the GAUSS Exhaust Gas Plume Model in the framework of the usual error margin for individual meteorological situations when, for the spread parameter, the following approach according to the TAYLOR theory [3] was selected:

$$\sigma_{y,z}(x) = \frac{\sigma_{v,w} \cdot t(x)}{\sqrt{1 + t(x)/(2 \cdot T_{L\,y,z})}}$$

Incuded in this are the standard deviations of the wind velocity components v and w; t(x)

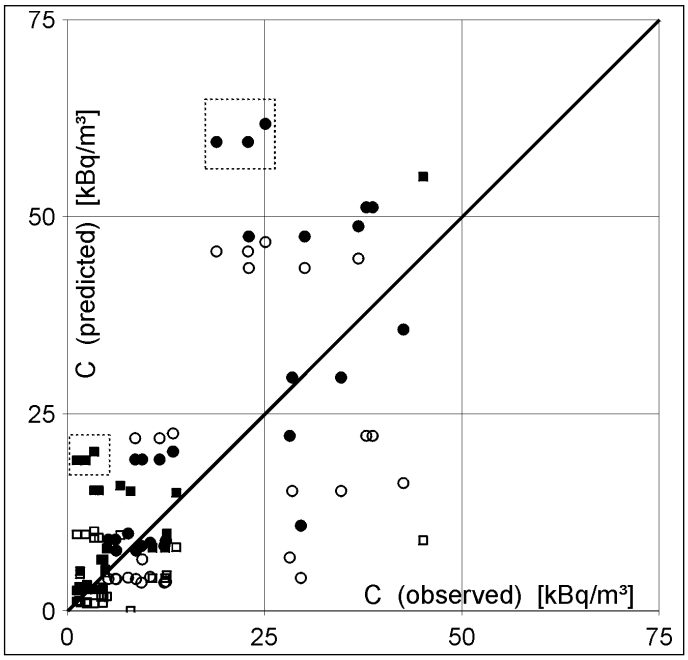


*Fig. 1: Correlation diagram of measured and computed mean tracer concentrations in kB/m³. Circles relate to cylinder counting tubes and squares to area counting tubes. Filled symbols are computed results according to Technical Instructions on Air Pollution Control.*

the transport time and $T_L$ the so called Lagrange scale time. Measurement and calculation have a smaller degree of agreement for the cases where spread parameters are determined according to the parametric scheme of the TA Luft, appendage C for source heights under 50 m [4]. In this case an underestimation of the average trace material concentration up to a factor of 5 is possible in individual cases.

The relationship of peak value to average value p/m the measured concentration time series varied over two ranges of figures and can take a value of p/m >100 in extreme marginal areas of the tracer plume. In the centre of the tracer plume peak values of more than 3.5 were reached, but only with a frequency of 1 %. In all the spread trials a reduction of p/m as well as growth in the intermittency in line with increasing distance from the source were observed. The intermittency is a measurement of that time proportion on a precise location affected by emissions where tracer or odour concentration can no longer be identified. Additionally, a linear relationship between the peak/average relationship p/m and the strength of the concentration fluctuations can be determined. The fluctuation strength or intensity $i^2$ stands in relationship with the average and the variance of the trace material concentration:

$$i^2 = \frac{\sigma_c^2}{\overline{C}^2}$$

From the three investigated spread densities the Gamma distribution delivered in total the best agreements with the observed overlapping frequencies. Conversion results with the Weibull-Distribution by which structurally similar quantile profiles are shown as with the first-mentioned probability density function agree less well with the measurement values. With the logarithmic normal distribution, the degree of correlation between measured and calculated overlapping frequencies is in total even a little lower.

In principle the odour of the applied odorant THT can be identified and applied for the determination of overlapping frequencies by testers even over larger distances of more than 100 m. The sensory identification examples agree well in some cases with the overlapping patterns of the tracer concentration at the same test location. However, the data basis of the usable THT measurement series is not large enough for the quantitative assessment of the exceptionally complex relationship between exposition (pollution) and odour effect, with the help of correlation coefficients. If one compares the observed odour frequencies over a period of around 10 min with pure model calculations, appropriately large deviations of a factor of 2 and over are shown. Hereby lie the unavoidable sensory uncertainties e.g. in the order of (improvable) model inaccuracy. Next to the reliable calculations of the trace material concentration average values, the fluctuation intensity had a dominant influence on the simulation of overlapping frequencies. Attempts to establish parameters for this decisive model factor are planned [5]. Improvements in model construction should above all concentrate on this parameter: on a precise establishment of parameters regarding fluctuation intensity in association with emission-geometrical and meteorological influential variables.

## Literature


[1] *Lung, T.*: Lagrangesches Partikelmodell – Numerische Simulation der Spurenstoffausbreitung. Schriftenreihe WAR 81, TH Darmstadt, 1994

[2] DVGW Arbeitsblatt G 280: Technische Regel Arbeitsblatt G 280 – Gasodorierung. Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH, Bonn, 1999

[3] *Taylor, G. I.*: Diffusion by continous movements. Proc. London Math. Soc. Ser. 2 (1921), no. 20, pp.196

[4] TA Luft: Erste allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz – Technische Anleitung zur Reinhaltung der Luft (TA Luft), GMBl. Nr. 7 vom 28. 2. 1986

[5] *Hanna, S. R.*: Concentration fluctuations in a smoke plume. Atmos. Envir. 18 (1984), no. 6, pp.1091-1106


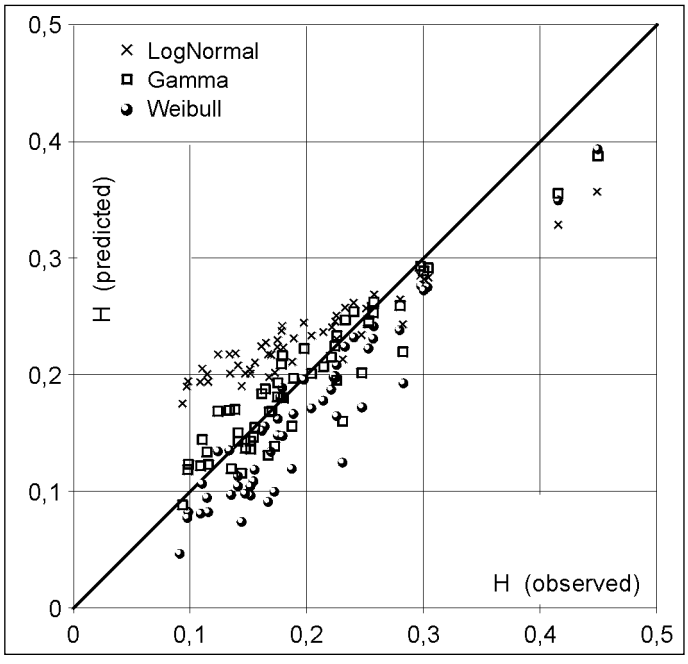


*Fig. 2: Frequency of exceeding H of tracer concentration measured versus results computed. In the model calculations with 3 density functions the fluctuation intensity $i^2$ was taken over from the measurements and the intermittence was set with $\mu = 1$*