Karl-Heinz Krause and Stefan Linke, Brunswick

Dispersion of Airborne Substances from Animal Husbandry - Standardised Graphs

Use of Dimensionless Presentation of Results for Environmental Impact Assessment

In former times distance diagrams sufficed for determining if the distance to the nearest residential area was adequate, based on VDI livestock husbandry guidelines on odour loads. Nowadays, in environmental impact assessment often not only odour but also the whereabouts of ammonia, dust and germs are scrutinized. Based on dispersion simulation it is possible to make standardised graphs of all relevant substances with the dimensionless description of the dilution ratios. The advantage is being able to recognise the classifications at a glance. Overestimates or underestimates about the immission situation are identified.

Dr.-Ing. Karl-Heinz Krause and Stefan Linke are members of the scientific-technical staff of the „Institut für Technologie und Biosystemtechnik“ (Head: Prof. Dr.-Ing. A. Munack and Prof. Dr. K.-D. Vorlop) of the „Bundesforschungsanstalt für Landwirtschaft (FAL)“ in D-38116 Braunschweig, Bundesallee 50; e-mail: *karlheinz.krause@fal.de*

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The aim is to determine the immission concentration C_i as a function of the emitted mass stream, product of source concentration C_0 and volume stream $\dot{V}_0$. The index 0 refers to the source. In the case of forced ventilated systems in livestock husbandry, this volume stream is determined by animal physiology, DIN 18910 [1] e.g., in the case of free ventilation it depends on the outside wind conditions. That means that complex calculations of the flow through hollow spaces have to go ahead. The emitted mass stream is always expressible in the form of a product of source concentration and volume stream. For the immission concentration $C_i(x,y,z)$ it is received

$$C_i(x,y,z) = C_0 D \quad (0 \leq D \leq 1) \qquad (1)$$

Average Immission Value

D characterises the dilution. This describes how the emitted volume stream is dissolved in the atmospheric one. The dilution D eludes from analytical description with the increase in complexity of wind relations at fluid flow around and over obstacles. If the meteorological parameters wind direction α, wind velocity U and the atmospheric turbulence as dispersion class AK are classified, then there are 36 classes of wind direction of 10°, 9 classes of velocity and 6 classes of dispersion classes and altogether 1 944 combinations with different frequencies within the year. For the dimensionless average value, at an immission location then follows

$$\frac{C_i}{C_o} = D = \sum_{\alpha,U,AK}^{36,9,6} D_{\alpha,U,AK} H_{\alpha,U,AK} \qquad (2)$$

D may altered by the dilution part $D_{\alpha,U,AK}$ and the frequency parts $H_{\alpha,U,AK}$ that results in 1 in the sum. The right part in eq. (2) means that the dimensionless average value of concentration is independent of the properties of special substances.

Limits for dilution

With the permissible limit average concentration of a substance the limit dilution is determined by means of the source concentration. For a forest system the limit value of ammonia is fixed at 7 µg/m³. With the source concentration of 8 mg/m³ a limit dilution is found at $D_{threshold,substance} = 0.875\ 10^{-3}$. In the same way the other substances are treated in *Table 1*.

The determination of limit values for dilution is somewhat complicated with respect to odour. An average values is not smelt, although it is used with special factors in several dispersion models. Odours are detected during a period t that is related to a special combination of meteorological parameters. During a year the periods of odour detection cumulate. In simulation prognosis, the density distribution of the momentary values of concentration is used to determine the exceeding probability $w_{\alpha,U,AK}$ of the odour detection threshold of c_S = 1 GE/m³ [2].

$$w_{\alpha,U,AK} = \frac{1}{2}\left(1 - erf\,\frac{-\ln\frac{C_i}{C_S} + \frac{b^2}{2}}{b\sqrt{2}}\right) \qquad (3)$$

In eq. (3) b describes the variance of the log-normal distribution and *erf* the error function. Together with the frequency of the meteorological parameters with reference to the year $H_{\alpha,U,AK} = t_{\alpha,U,AK}/t_{Jahr}$ the odour detection frequency follows

Table1 : Determination of dilution threshold $D_{threshold,substance}$ by means of $C_{threshold,substance}$. The odour threshold refers to a village area (MD-area) with an allowed yearly frequency of 10 % of the hours of the year.

Daten Rinderhaltung	Ammoniak	PM_{10} - Staub	Endotoxine	Geruch
C_0	8 mg/m³	1,95 mg/m³	20 ng	80 GE/m³
$C_{Grenz,\ Substanz}$	7(Wald) µg/m³	40 µg/m³	0,01 ng	0,597 GE/m³
$D_{Grenz,\ Substanz}$ [-]	$0{,}875 \cdot 10^{-3}$	$20{,}5 \cdot 10^{-3}$	$0{,}5 \cdot 10^{-3}$	$7{,}464 \cdot 10^{-3}$

$$H_{Geruch,xx} = \sum_{\alpha,U,AK}^{36,9,6} w_{\alpha,U,AK} H_{\alpha,U,AK} \quad (4)$$

As criterion of decision of permissibility of odour impacts, the limit odour frequency, depending on the area of concern, can be written

$$H_{Grenz,Geruch,xx} = \begin{cases} 0{,}03\, bei\ xx = WA-Gebiet \\ 0{,}10\, bei\ xx = MD-Gebiet \\ 0{,}1\, bei\ xx = WA-Gebiet \\ 0{,}15\, bei\ xx = MD-Gebiet \end{cases} \quad (5)$$

The figures of the first two rows refer to real time procedures, the both beneath to so-called immission time assessments, which do not allow a mathematical attribution of odour detection to the average values of concentration. A limiting value oriented at human „health“ is not available.

Because the average immission value that leads to limit frequency at real time procedure is always greater than the sum of the parts by accumulation, the limit dilution of odour is given by

$$D_{Grenz,Geruch,xx} = \frac{C_{Grenz,Geruch,xx}}{C_o} = \frac{C_S}{C_o}\beta$$

with

$$\beta = \exp\left[\frac{b^2}{2} - b\sqrt{2}\, erf^{-1}\left(1 - 2H_{Grenz,Geruch,xx}\right)\right]$$

erf^{-1} determines the inverse of the error function. With the limit dilution according to eq. (6) and eq. (7), an adequate expression to eq. (2) is available. The dilution of odour depends on the relationship of concentration at the odour threshold with respect to that at the source, multiplied by the parameter β.

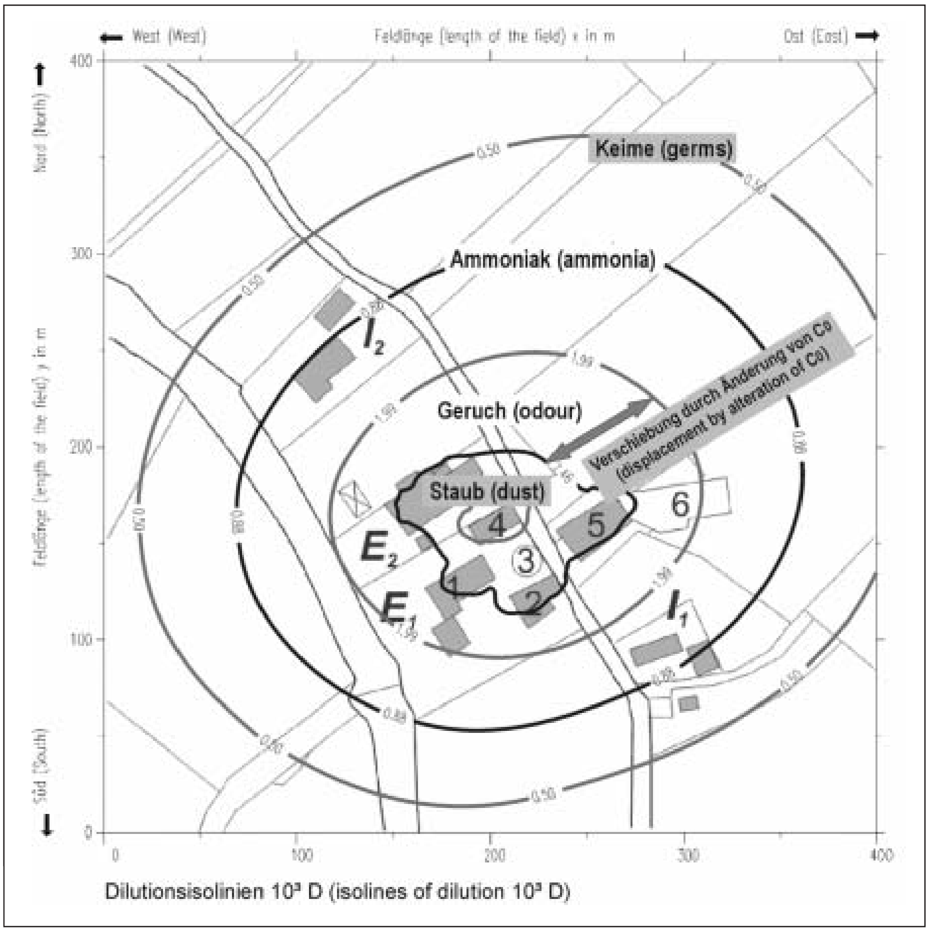

Fig 1: Example of neighbour farms with cattle production emitting odour, ammonia, dust and germs into the environment: E1 and E2. The isolines characterize the pre-load by the two plants. Two dwelling houses in the immission areas I1 and I2, not belonging directly to agriculture, must be taken into consideration, if in farm E1 the facilities will be enlarged by the stable 6.

Example of application

Within the environmental impact assessment it must be checked, whether the site of the plant E_1 with cattle husbandry may cope with a further stable (no. 6) in form of cubicle housing especially when another plant E_2 with cattle husbandry is in the neighbourhood (*Fig. 1*).

The result of the simulation calculation shows the isolines of the dilution in *Figure 1* as mentioned in *Table 1*. The curves of odour and dust are on the area of the farmyards E_1 and E_2. The dilution isolines of ammonia and germs show much greater distances to the farms. The bouquet of odour involves ammonia, too. Obviously the phytotoxical effect is rated higher than the inhalation effect concerning human beings and animals. With concern to odour, the value of 80 GE/m^3 of source concentration is chosen from the KTBL-script 126 [3]; this value is confirmed in the scientific report published as KTBL-script 338 [4]. Changing to such values, gained by the standard EN 13725 [5], declared as improvements with regard to the precision of the olfactometry, a dilution limit of $1{,}99 \cdot 10^{-3}$ is found for C_0 = 300 GE/m^3. An alteration of the location of the isolines is caused by the amount of concentration of the source (*Fig. 1*).

Results

The fact is to be recorded that the expansion of substances following the air movement without inertia like ammonia, dust, germs and odour substances is always the same. Referring to dilution, then it is simple to check, which are the differences between the different substances with concern to the environmental effects. Time will tell if rightly.

Literature

Books are identified by •

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