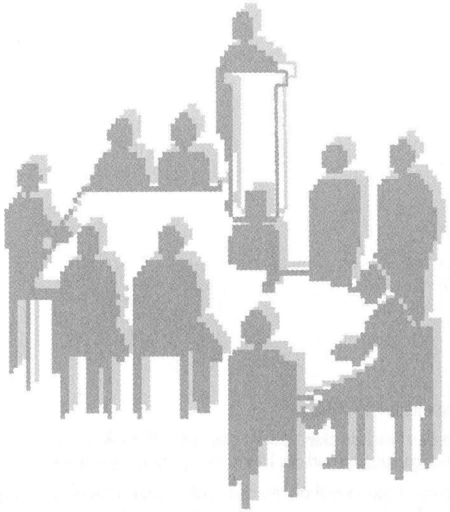
Kommission Reinhaltung der Luft
im VDI und DIN – Normenausschuss KRdL

# Environmental Odour Management

Odour emission – Odour nuisance – Olfactometry – Electronic sensors – Odour abatement

International Conference, Cologne,
17 to 19 November 2004



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# Minimum distances in Switzerland for pig housing systems with exercise yards and natural ventilation

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**Abstract**

The aim of this research was to compare the ambient odour from open and closed housing systems and from housing systems with and without an exercise yard. Odour plume inspections were carried out for ten housing systems with a fully slatted floor, forced ventilation and roof venting without an exercise yard; ten multi-surface systems with forced ventilation, roof venting and an exercise yard and 13 multi-surface systems with natural ventilation and an exercise yard. A comparison was also made of odour concentrations in exercise yards for cattle and pigs at different degrees of dirtiness.

Multi-surface systems in combination with solid flooring or perforated surfaces produce a greater odour impact than fully slatted systems. The ambient odour from housing with natural ventilation and exercise yards is greater than that from enclosed housing with forced ventilation. Pig exercise yards have a higher odour concentration than cattle exercise yards. Particular care is required in the case of ground-level odour sources at production sites with a cold air flow.

## 1. Introduction

A variety of new housing systems have sprung up on Swiss pig farms over the last ten years. Participation in the BTS (particularly animal-friendly housing systems) [1] and RAUS (regular outdoor exercise) [2] livestock housing programmes and various label schemes requires larger areas than conventional housing systems. Whereas enclosed housing with forced ventilation predominated in the past, the preference nowadays is for multi-surface systems with bedding and exercise yards.

The Swiss Ordinance on Air Pollution Control requires the separation distances from inhabited areas to be observed in accordance with the recognized rules of livestock housing when erecting new facilities [3]. These separation distances are calculated according to Richner and Schmidlin's recommendations [4]. However, they are not sufficient for new housing systems with natural ventilation or for exercise yards, particularly in pig farming. An increasing number of inquiries from farmers, affected residents and licensing authorities prompted an amendment to the regulations, which has now been drafted. The aim of this study was to compare the ambient odour potential of open and enclosed housing systems and of housing systems with and without an exercise yard.

There is a dearth of findings in the literature for the odour impact of pig housing systems with natural ventilation and exercise yards. The few references available are not backed up by experiments. Type of ventilation considerably affects odour dispersion. Housing units with forced ventilation constitute point sources in a first approximation. Exhaust air extraction with roof venting is generally characterised by a high outgoing velocity and a high exhaust height of outgoing air. Housing with natural ventilation has air flowing around and through it. Air exchange is wind-induced, in other words, chiefly dependent on wind direction and velocity. Diffuse sources in exercise yards and lateral openings are characteristic of ground-level odour release. The emissions of housing with natural ventilation has to date been described via an odour impact-based approach [5]. In terms of fluid technics, the nature and position of the vent holes in particular have a considerable effect on potential odour in the ambient air in the vicinity. Odours emitted at ground level, through the building wall or the roof (in the stagnation pressure area of the building) tend to linger in these areas, enriching the air locally with odour components [6]. The result is less odour dilution, accompanied by dispersion at ground level. If odour impact in the immediate vicinity is to be avoided, then high-level sources are preferable. If, on the other hand, odour impact at a greater distance is to be avoided, then ground-level emission ranks more favourably [7]. Moreover, solid manure handling systems with deep litter housing are rated better than slurry handling systems according to VDI 3471 [8].

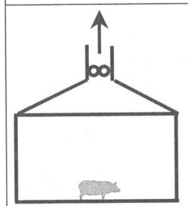
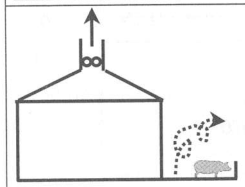
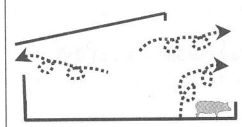
## 2. Method

### 2.1 Housing systems

Ambient odour plume inspections were carried out on pig farms between June and August 2002. Different types of housing were distinguished (Table 1): ten housing systems with a fully slatted floor, forced ventilation, roof venting and no exercise yard served as the reference (f-e). A further ten farms had multi-surface systems with forced ventilation, roof venting and an exercise yard (f+e). Thirteen farms had multi-surface systems with natural ventilation and an exercise yard (n+e). Most of the farms were involved in fattening but there were also some breeders and combined operations.



Table 1: Schematic representation of housing systems studied, with details of ventilation, number of farms, animal category and livestock units (LU)

| Schematic representation | Description,<br>housing system, ventilation, location of exhaust air exit<br>number and type of farms, livestock units $\bar{x}$ (min-max) |
|---|---|
|  | f-e (**f**orced ventilation, without **e**xercise yard)<br>Fully slatted floor, insulated housing,<br>forced roof ventilation with chimney<br>10 farms, of which 6 fattening, 4 combined<br>77 LU (48-132) |
|  | f+e (**f**orced ventilation, with **e**xercise yard)<br>Multi-surface system, insulated housing with exercise yard,<br>forced roof ventilation with chimney, diffuse from exercise yard<br>10 farms, of which 5 fattening, 2 breeding, 3 combined<br>49 LU (7-104) |
|  | n+e (**n**atural ventilation, with **e**xercise yard)<br>Multi-surface system, outdoor climate housing with exercise yard,<br>open fronted housing, natural ventilation, eaves, ridge and cross-ventilation and also diffuse from the exercise yard<br>13 farms, of which 12 fattening, 1 combined<br>47 LU (24-83) |

The area provided per livestock unit varied in the three types of housing studied (1 LU corresponds to 500 kg liveweight). Fig. 1 shows regressions between the number of livestock units and the total area. The area available was more than twice as big in the multi-surface systems with an exercise yard, f+e and n+e, as in the housing with a fully slatted floor and no exercise yard (f-e).

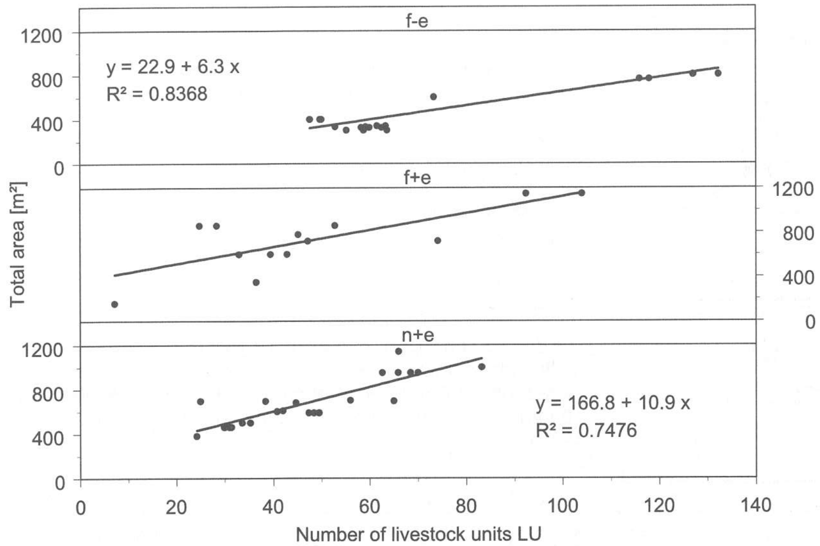



Fig. 1: Regression between the number of livestock units and total available area in the three housing systems

### 2.2 Odour plume inspections

Three panelists each recorded their odour perception in terms of intensity every ten seconds over a ten-minute period, using a hand-held PC (Psion Series 3a) with Olfacto software. They were positioned at three different distances from the housing, in the prevailing odour plume. A minimum of two recordings were made on each farm with three individual inspections in each case. Odour perceptions of an intensity rating of two $I_2$ (a slight odour) or more were included in the evaluation. In order to achieve a better expressiveness, the intensity very slight $I_1$ was not considered. A weighted odour intensity index was then calculated (Equation 1). This had a high correlation with the detection frequency ($r^2$=0.97) and was used in subsequent analyses under the term odour intensity.

$$\textit{Odour intensity index} = \frac{(I_2 \cdot 2 + I_3 \cdot 3 + I_4 \cdot 4 + I_5 \cdot 5 + I_6 \cdot 6)}{60} \qquad (1)$$



The following meteorological parameters were recorded with the aid of a mobile weather station during the odour inspections (Table 2).

Table 2: Summary of meteorological parameters recorded, measuring principles used and details of measuring accuracy and data storage

| Sensor: WindObserver II (Gill, Hampshire, GB) | | | |
|---|---|---|---|
| Parameter | Measuring principle | Resolution | Interval |
| Wind velocity | 2-axis ultrasonic anemometer | 0.01 m/s | Mean in 10 s |
| Wind direction | | 1 ° | Individual value in 10 s |
| Sensor: ALMEMO FH A646 AG (Ahlborn, Holzkirchen, D) | | | |
| Parameter | Measuring principle | Accuracy | Interval |
| Air temperature | NTC | 0.1 °C | Individual value in 10 s |
| Rel. humidity | Capacitive thin film sensor | 2 % | Individual value in 10 s |

A mixed-effects linear model was used to describe the odour intensity for the purposes of statistical analysis of the structured data. This model permits a direct comparison of the individual housing systems. All the relevant factors could thus be taken into account in the calculation, along with random effects such as farm, date and inspection during data gathering. The parameters relevant to odour impact were also determined by means of a multiple regression.

### 2.3 Olfactometry

To reveal any influence of the type of floor (solid flooring or perforated) and degree of dirtiness of the exercise yard on the ambient odour potential, air samples were taken from exercise yards in housing systems f+e and n+e. A covering cap was put on the floor in the exercise yard itself. The air samples were collected in 10-litre nalophane bags, using a vacuum sampler. The odour concentration was then determined with the aid of the TO6 (ECOMA) olfactometer. Data gathered previously by the authors for solid floor cattle exercise yards were used for comparison [9].

## 3. Results

### 3.1 Comparison of odour intensity in the different housing systems

The independent variable odour intensity is accounted for by the parameters housing type, distance, number of livestock units, wind velocity and panelist (Equation 2, Table 3).

*Odour intensity = ƒ ( housing type + distance + LU + wind velocity + panelist)* (2)

Table 3: F-value and significance of parameters in the mixed-effects linear model (lmefit) in accounting for odour intensity

| Parameter | F-value | p-value |
|---|---|---|
| Housing type | 10.99 | 0.0005 |
| Distance | 94.33 | <.0001 |
| LU | 19.10 | <.0001 |
| Wind velocity | 16.80 | 0.0001 |
| Distance : wind velocity | 16.93 | 0.0001 |
| Panelist | 10.92 | <.0001 |

Figure 2 shows odour intensity plotted against distance, according to the model. This is based on 60 livestock units and a wind velocity of 1 and 4 m/s, respectively. The multi-surface system with natural ventilation and an exercise yard n+e produced the greatest odour intensity. The odour intensity was greater with the multi-surface system with roof venting with an exercise yard f+e than with the fully slatted floor with roof venting without an exercise yard f-e.



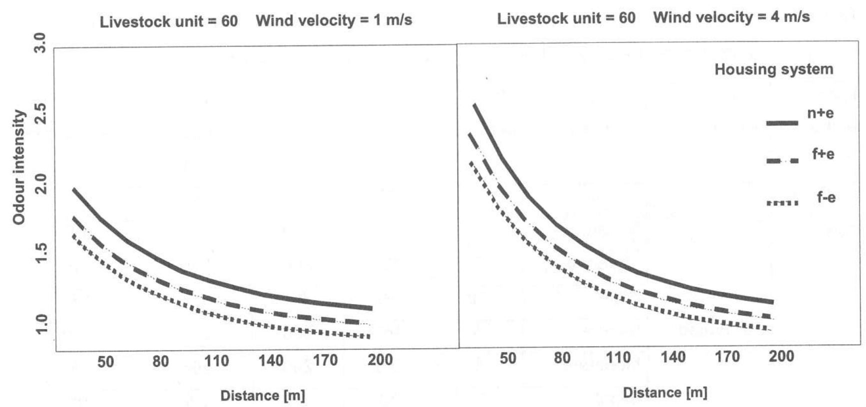



Fig. 2: Representation of odour intensity with the three housing systems f-e, f+e and n+e based on the mixed-effects linear model at a wind velocity of 1 and 4 m/s with 60 livestock units

A multiple regression was used to identify parameters relevant to odour intensity. The following parameters were significant with respect to odour intensity: housing type, distance from housing, livestock units (LU), total area, area not under cover and the dirtiness of the exercise yard.

### 3.2 Odour concentration in exercise yards

Another focus of attention was the factors affecting odour concentration in exercise yards. The median for odour concentration in pig exercise yards varied between 58 and 520 OU/m³ (Table 4). The degree of dirtiness of the exercise yard was responsible for the greatest variation in odour concentration in the case of pigs. For the same degree of dirtiness, solid flooring resulted in a slightly higher odour concentration than a perforated surface.

The median for odour concentration in cattle exercise yards was 26 OU/m³ and was thus significantly lower than the values for pig exercise yards. A lower odour emission is assumed for exercise yards for cattle compared to pigs. Moreover, the degree of dirtiness and hence the frequency and effectiveness of yard cleaning are relevant to odour release.

Table 4: Odour concentration results for solid and perforated exercise yards and at different degrees of dirtiness of cattle and pig exercise yards

| Type of animal | Type of flooring | Degree of dirtiness | No. of samples | Odour concentration OU/m³ | | | |
|---|---|---|---|---|---|---|---|
| | | | | Mean | Median | Bottom quartile | Top quartile |
| Cattle [9] | Solid | No info. | 42 | 55 | 26 | 14 | 64 |
| Pigs | Solid | Severe | 4 | 508 | 520 | 325 | 690 |
| | | Moderate | 5 | 308 | 300 | 220 | 410 |
| | | Slight | 12 | 98 | 88 | 85 | 125 |
| | Perforated | Severe | 3 | 463 | 460 | 320 | 610 |
| | | Moderate | 5 | 262 | 260 | 200 | 290 |
| | | Slight | 2 | 58 | 58 | 25 | 91 |

**4. Conclusions and changes to separation distance**

The separation distance was calculated according to Richner and Schmidlin [4] for each farm of reference type f-e. The odour intensity at the separation distance with type f-e was equated with the odour intensity with the new housing types f+e and n+e, taking into account the farm data. The necessary separation distance could thus be deduced. Correction factors greater than one increase the separation distance, while those less than one reduce the distance. Changes to the correction factors were applied with respect to the housing system and ventilation (Table 5.) Multi-surface systems, exercise yards and natural ventilation require higher correction factors. As a result, the separation distances with open housing systems and exercise yards on pig farms are increased by 25 to up to 50 % in comparison with closed housing systems with forced roof ventilation.



Table 5: Changes to correction factors with respect to housing system and ventilation

| Correction factors so far | $f_k$ | New correction factors | $f_k$ |
|---|---|---|---|
| **Housing system** | | | |
| Open front, non insulated housing (no forced ventilation) | | Housing with forced ventilation | |
| | | -without exercise yard | 1.0 |
| -without straw filter | 0.8 | -with exercise yard (multi-surface system) | 1.15 |
| -with straw filter | 0.5 | Housing with natural ventilation | |
| Enclosed housing | 1.0 | -without exercise yard with deep litter, single compartment | 0.6 |
| | | -without exercise yard, multi-surface system | 1.0 |
| | | -with exercise yard, multi-surface system | 1.15 |
| **Ventilation** | | | |
| Lateral or via a chimney with cowl | | Forced ventilation | |
| -no protected subjects in immediate vicinity | 1.0 | Vertical roof venting | |
| -protected subjects in immediate vicinity | 1.2 | -kH >1.5 m and h >3 m above highest buildings, H >10 m | 0.8 |
| Large-area ground level air exit | 1.0 | -kH <1.5 m or h <3 m above highest buildings or H <10 m | 1.0 |
| Vertical roof venting | | Lateral exhaust air exit | 1.1 |
| -kH >1.5 m and h >3 m above highest point of roof, H >10 m | 0.8 | Natural ventilation | 1.1 |
| -kH <1.5 m and h < 3 m above highest point of roof, H <10 m | 1.0 | | |

h = effective source height, H = exhaust air exit height above ground,
kH = chimney height above ridge

The following conclusions may be drawn:

- Multi-surface systems in combination with solid or perforated flooring produce greater ambient odour than fully slatted systems.
- Odour impact from housing with natural ventilation and exercise yards is greater than from enclosed housing with forced ventilation.
- Exercise yards for pigs produce higher odour concentrations than exercise yards for cattle. The odour emission can be reduced by more effective, more frequent cleaning.

**5. Production site aspects**

Particular care is required with respect to the choice of production site in the case of ground-level odour sources such as exercise yards, open housing or lateral exhausted air exits. Cold air flow is likely to occur at sites with a slope of 3.5 % or more [10]. Here, low wind velocities tend to prevail at ground level. The cold air flows with the slope or down the valley and also from forested areas towards land with no or only slight vegetation cover (meadows, pasture and farm land). The more homogeneous the land use (for instance, only meadows and pasture), the less marked is the cold air flow; the more diverse the land use (buildings, forest, bushes, fields, meadows) the more marked it is. Cold air is produced in conditions of few clouds, light wind and little renewal. Cold air flow occurs at sunset and before twilight. Smoke tests are a good way of assessing the relevance of cold air flow and locating the cold air flow path. An area with an extended separation distance should be allowed for in the direction of cold air flow.

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