Control of PM emission from livestock farming installations in Germany

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Abstract

In order to control the emission of particulate matter and to prevent harmful effects on people living in the vicinity of livestock installations in Germany, potential environmental effects are assessed during the licensing procedures. Assessment is based on the regulations of the Technical Instructions on Air Quality Control (TA Luft), which determines limit values for the immission of fine particles (PM10). These limit values are cited from the European Air Quality Daughter Directive.

For reasons of commensurability a detailed assessment whether the limit values are not exceeded is only required under certain conditions. Assessment is not necessary, if people do not permanently live in the vicinity of an installation and if the so-called bagatelle-emission rate, which is equivalent to a livestock of about e.g. 2,150 fattening pigs and 74,500 laying hens is not exceeded. It is also not required if the level of the initial load can be estimated as "low" or if the level of the additional load caused by an installation is "irrelevant" in terms of TA Luft (< 1.2 µg/m³) and additional measures for emission abatement are taken.

In contrast to the regulations of the TA Luft to control the immission load, regulations on emission limitation for total dust in general will not affect livestock installations.

Practical experience reveals, that there is a lack of sound data relating to the emission of PM from different production and housing systems and that there is a need to establish and to harmonise special measurement protocols for their determination.

Keywords: livestock installation, particulate matter, emission data, immission limit values

1 Introduction

Agriculture, namely livestock installations are a source of primary Particulate Matter (PM) and of ammonia, which is a main precursor for the forming of secondary aerosols in the atmosphere (table 1). Also on a local scale single intensive livestock installations or a high density of installations may contribute to a large extent to the PM immission load (Bleeker A. et al. 2007). So the control of PM emission is also in the focus of the licensing processes for the construction and operation of livestock installations under the Federal Immission Control Act (BImSchG).

2 Legal framework

In Germany, the legal basis for the protection of human health and environment against aerial pollutants is laid down in the Federal Immission Control Act (Bundes-Immissionsschutzgesetz – BImSchG 2002). According to the BImSchG livestock installation shall be constructed and operated in such a way, that this does not involve harmful effects on the environment or other hazards, considerable disadvantage and considerable nuisance to the general public and the neighbourhood (principle of protection).

In addition, precautions must be taken to prevent harmful effects on the environment, in particular by such emission control measures as are appropriate according to the state of the art ("Stand der Technik", which is equivalent to "Best Available Technology"). According to the precautionary principle harmful emissions must be reduced by technical means below a certain limit. Limits depend on the hazardousness of a pollutant, the size of an installation, the technical feasibilities and the economic efficiency of abatement technologies.

In detail, requirements are laid down in the First General Administrative Regulation Pertaining the Federal Immission Control Act (Technical Instructions on Air Quality Control – TA Luft of 24 July 2002). By this way several European Directives (esp. IPPC, NEC and European Air Quality Daughter Directive) have been adopted to German law. The requirements, especially emission and immission limit values and emission abatement techniques must be adhered to if industrial plants and other installations such as animal husbandries are constructed and operated, enlarged or in any other way substantial altered.

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In order to verify whether a livestock building project complies with these requirements, data on the emission of particulate matter are needed. For the measurement of these emission is very laborious and costly, data derived from scientific investigations are used.

Table 1:
Emission of primary particles from agriculture and animal husbandry respectively

Type of emission	Total emission of Germany (2005) [kt/a]	Agriculture [kt/a]	Agriculture [%]	Animal husbandry [kt/a]	Animal husbandry [%]
Ammonia[1]	619	590	95	494	79
Total dust	269[1]	–[3]	–[3]	–[3]	–[3]
	513 (1995)[2]	71	14	49	10
PM10	194[1]	20.5	10	19.3	8
	281 (1995)[2]	23	8	22	8
PM2.5	111[1]	4.7	4.2	4.7	4.2

[1] UBA (2007)
[2] Klimont Z. et al. (2002)
[3] no data available

3 Available data on PM emission

Most of the data that are available and used for the assessment of environmental effects of livestock installations have been published for the inhalable fraction according to DIN EN 481 for occupational health and safety purposes. Those data are often used equal to total dust data although the precipitation for particles > 100 µm is only about 50 % in those measurements. Table 2 summarizes the results of different investigations in Europe showing a wide span.

Only few investigations have been carried out to determine PM10-concentrations. The proportion of PM10 is estimated pragmatically by so-called conversion factors that are derived from only few investigations (table 3).

Table 2:
Mean emission rates for inhalable dust (total dust), converted from the results of Takai H. et al. (1998) for Demark, Germany, England and the Netherlands; amended with data from Brehme G. (2003), LFL (2004) and Hinz T. (2005), summarized in KTBL (2006)

Animal category and housing system	Mean emission rate of investigations in Germany		Range of data of all investigations[1]	
	[mg/(AP h)][2]	[kg/(AP a)][2]	[mg/(AP h)][2]	[kg/(AP a)][2]
Pig fattening[3]				
- solid manure system	-	-	73 - 116	0.6 - 0.95
- liquid manure system	69	0.57	54 - 116	0.45 - 0.96
Sows[4]				
- solid manure system	226	1.9	43 - 226	0.36 - 1.9
- liquid manure system	49	0.4	36 - 255	0.31 - 2.14
Piglet rearing[5]				
- liquid manure system	22	0.18	21 - 41	0.17 - 0.34
Cows				
- solid manure system	91	0.8	72 - 170	0.6 - 1.5
- cubicle (liquid manure system)	406	3.6	25 - 406	0.2 - 3.6
Bull fattening				
- solid manure system	95	0.8	25 - 95	0.2 - 0.8
- liquid manure system	82	0.7	55 - 101	0.5 - 0.9
Calves				
- solid manure system	43	0.4	19 - 43	0.2 - 0.4
- liquid manure system	58	0.5	19 - 58	0.2 - 0.5
Laying hens				
- cage housing	2	0.02	1.4 - 3	0.01 - 0.03
- floor housing	40[6]	0.35[6]	6 - 14.8	0.05 - 0.13
- aviary (with aerated manure belt)	30[6]	0.27[6]	-	-
Broilers[7]				
- floor housing	4.2	0.03	2.8 - 9.3	0.02 - 0.06
Turkeys8)				
- floor housing	73	0.55	-	-
Ducks				
- rearing[9]	1.7	0.012	-	-
- fattening[9]	5.4	0.04	-	-

[1] Denmark, England, the Netherlands and Germany
[2] AP = animal place
[3] 343 days housing period
[4] 350 days housing period
[5] 346 days housing period
[6] LfL (2004)
[7] 264 days housing period
[8] turkey cock, 314 days housing period; Hinz T. (2005)
[9] 300 days housing period; Brehme G. (2003)

Table 3:
Proportion of PM10 of total dust (KTBL 2006)

Animal category and housing system	PM10-ratio of total dust		Source
	Measured data	Convention	
Pigs	0.31 0.45 0.4	0.4	Koch W. et al. (2002) Louhelainen K. et al. (1997) Berdowski J. J. M. et al. (1997)
Cattle	0.3 0.46 0.64 (0.33-0.87)	0.5	Koch W. et al. (2002) Seedorf J. (2003) Cathomas R. L. et al. (2002)
Poultry (in general)	0.46 0.4 0.15-0.16		Koch W. et al. (2002) Berdowski J. J. M. et al. (1997) Cravens et al. (1981)
Laying hens (cage housing)	0.33	0.3	TÜV Süddeutschland (2000)
Laying hens (aviary housing)	0.5 0.6	0.5	Hinz T. (2005) LfL (2004)
Laying hens (floor housing)	0.59	0.6	LfL (2004)
Broilers	0.4 0.58	0.5	Hinz T. (2005) TÜV Süddeutschland (2000)
Turkeys	0.25	0.3	Hinz T. (2005)

3 Provisions on air pollution control

The TA Luft (2002) determines limit values for the immission of fine particles (PM10), which are cited from the European Air Quality Daughter Directive (European Union 1999) (table 4).

Table 4:
Immission limit values of TA Luft (2002) for PM10

Concentration limit value [µg/m³]	Averaging period	Remarks	Level of initial immission load classified as "low" [µg/m³]	Level of additional immission load classified as "irrelevant" [µg/m³]
40	1 year	-	< 34	1.2
50	24 hours	≤ 35 exceedances per year permissible	≤ 15 exceedances per year over the last 3 years	-

During the licensing process of a livestock installation project the assessment whether those limit values are not exceeded is necessary only for those places of interest, where within a distance of 1 km from the installation people could not only temporarily be exposed to PM immissions, as it is the case e.g. in dwelling areas.

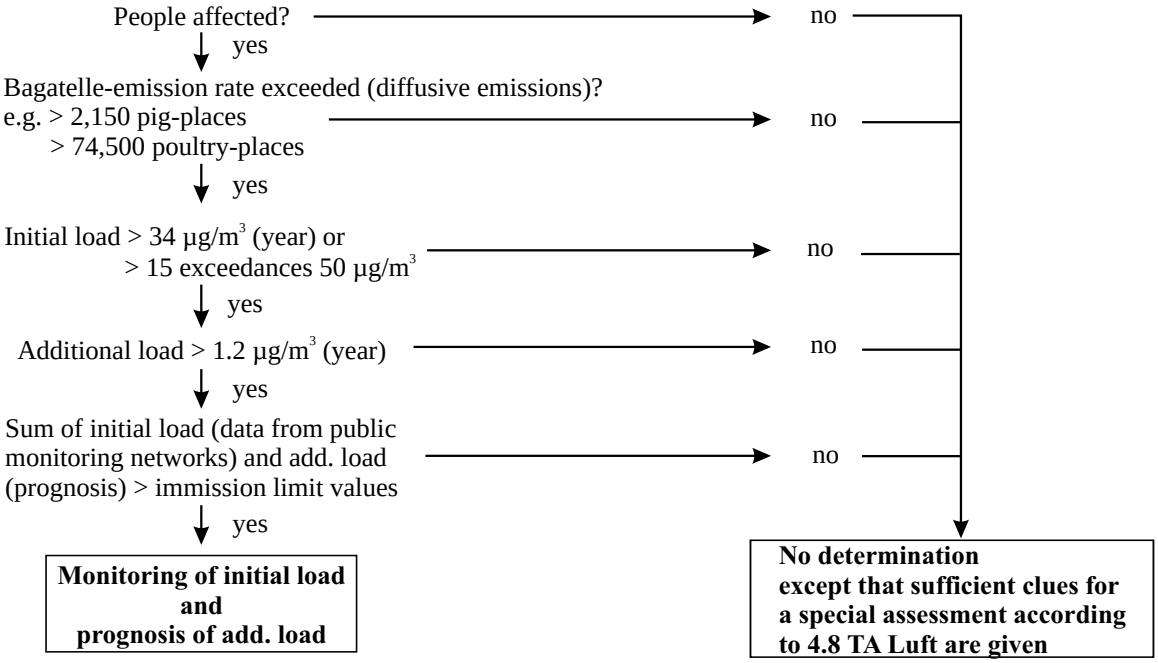

Figure 1:
Assessment scheme relating to PM10 immission according to TA Luft (2002)

For reasons of commensurability the competent authority shall dispense with the need to determine the immission load in detail, if in the case

- of a low emission mass flow rate (cf. 4.6.1.1 TA Luft) or
- of a low initial load (cf. 4.6.2.1 TA Luft) or
- of an irrelevant additional load caused by the installation (cf. 4.2.2 TA Luft) and additional measures for emission abatement

it can be assumed that harmful effects on the environment cannot be caused by the installation. The examination follows the scheme illustrated in figure 1.

In contrast to the regulations to control the immission load, regulations of the TA Luft on emission limitation for total dust in general will not affect livestock installations.

3.1 Low emission mass flow rate

Immission of PM10 are usually not determined, if the emission of a livestock installation do not exceed the so-called bagatelle-emission rate of 0.1 kg/h of total dust. The bagatelle-emission rate is equivalent to a livestock of about e.g. 2,150 fattening pigs and 74,500 laying hens in conventional housing systems taking the rounding adjustment (0.149 kg/h, cf. 2.9 TA Luft) into account.

It must be noticed, that livestock housings are treated as diffuse sources. This means, that the bagatelle-emission is only 10 % compared to an industrial source with high stacks.

3.2 Low initial immission load

The existing initial immission load of PM10 is low, if the annual mean does not exceed 34 µg/m³ and if the daily immission load of 50 µg/m³ is not exceeded for more than 15 days a year over the last three years.

Table 5 gives an overview on the concentration of PM10 in different regions of Germany. Highest levels are usually monitored in congested urban areas and at sites influenced by and close to major roads.

In rural areas the immission concentration usually remains under the level of the TA Luft (2002) indicating a low initial load if there are no site specific conditions that have to be taken into account. This is also indicated by the distribution of measured PM10 concentrations, which show a strong correlation between the annual mean value and the number of days exceeding 50 µg/m³ (figure 2).

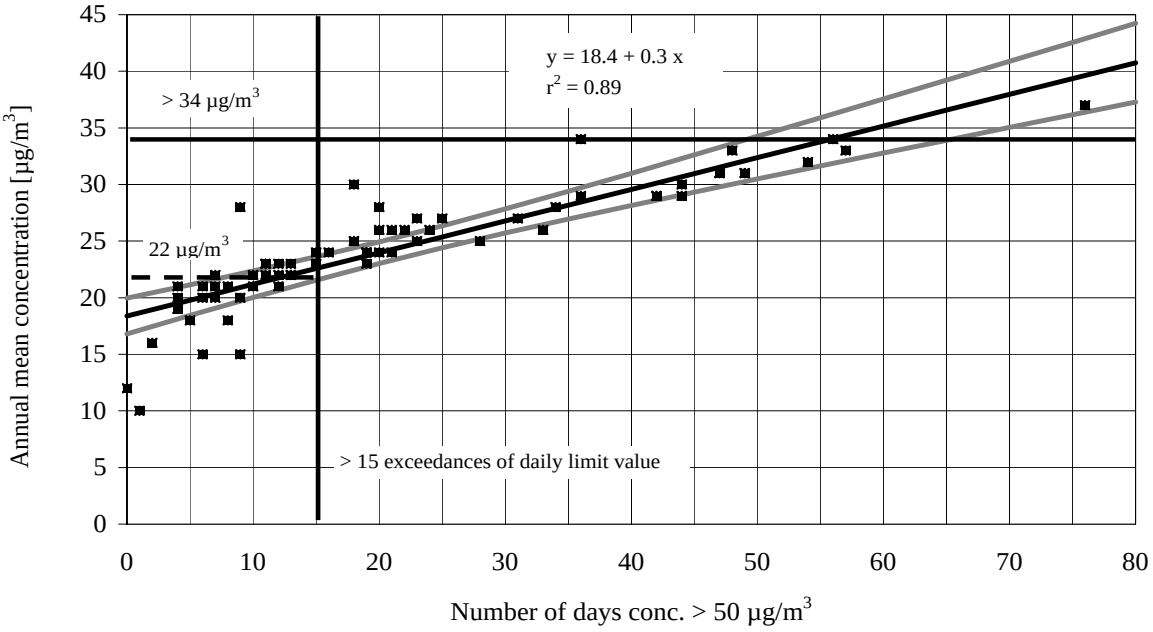

Figure 2:
Correlation between the number of days exceeding the daily limit value of 50 µg/m³ and the annual mean concentration of PM10; regression line and confidence interval for the mean value with 99 % confidence level (Lower Saxony 2003 – 2005; Niedersächsisches Umweltministerium 2006)

Table 5:
Typical ranges of concentrations of PM10 at different locations in Germany 2001 (Lahl U. 2005)

Location	Rural site	Urban site	Traffic site
Annual mean concentration [µg/m³]	10 - 18	20 - 30	30 - 45
Number of days exceeding the daily limit value of 50 µg/m³	0 - 5	5 - 20	15 - 100

As the level of the mean annual concentration for PM10 is more homogeneous in the wide-range and easier to prognose than the number of days exceeding the daily limit (Umweltbundesamt Wien 2005), with the help of this graph annual mean concentrations can be transposed to a number of exceedances of the daily limit value (Fierens F. et al. 2006; Torfs R. et al. 2007). In the case of Lower Saxony it can be stated with a 99 % confidence level, that the number of exceedances of the daily limit value will be below 15 if the annual mean concentration measured or prognosed in rural areas is below 22 µg/m³.

3.3 Irrelevant additional immission load

Despite high initial loads a project might be licensable if the additional load caused by an installation is classified as irrelevant (1.2 µg/m³) in terms of TA Luft (2002). This level is as low, that it is lost in the natural fluctuation of the background concentration, i.e. it is more or less a zero load. To comply with this value, the mean concentration of dust in the air of e.g. a typical pig confinement building, which is about 2 mg/m³ (Seedorf J. and Hartung J. 2002), must be diluted by a factor of 1,000.

The modelling of the dispersion of fine particles as prescribed in the TA Luft (Lagrange particle model) is based on the same assumptions as for ammonia concerning the velocities of deposition and sedimentation. In analogy to ammonia and in dependency on the topographical and meteorological conditions the distance, where the immission concentration reaches the level of the irrelevant additional load in the main wind direction, can be estimated (figure 3). It can be stated, that e.g. in the case of pigs the irrelevant distance for PM10 is smaller than for ammonia and even smaller than for odour according to the minimum distance regulation of the TA Luft (2002) to prevent odour compliances (cf. 5.4.7.1 TA Luft).

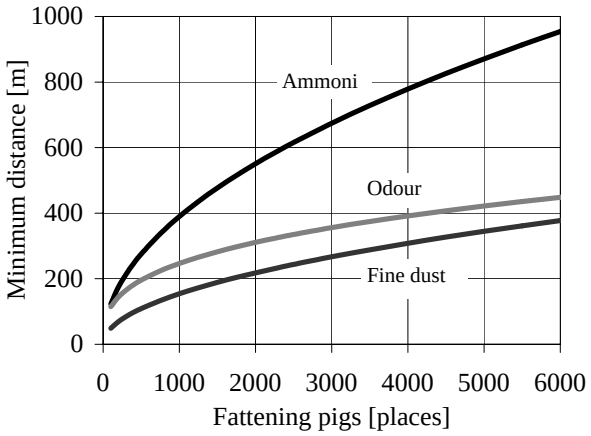

Figure 3:
Minimum distances for ammonia and odour according to TA Luft for fattening pigs. The irrelevant distance for PM10 (1.2 µg/m³ additional load) is calculated on the same assumptions as for ammonia.

4 Conclusions

In Germany emission of PM are controlled during the licensing process of livestock installations. In practise only the regulations of the TA Luft concerning the limitation of immission of PM10 are relevant, for the emission limit values, that are applying to total dust, are not exceeded in livestock installations.

There are some provisions in order to simplify the execution of the immission load regulation, but they do not take effect in all cases. For example, the bagatelle-emission rate that equals to installations with 2,150 pigs or 74,500 laying hens in conventional housing systems, in the case of alternative housing techniques such as littered pens or floor housing systems may be exceeded by even a smaller livestock. In addition, the criteria of the TA Luft indicating a low initial immission load may be exceeded under specific site conditions (e.g. coastal areas with high natural sea spray concentrations, sites being influenced by congested urban areas or local sources). Finally, if a livestock installation e.g. in the case of an enlargement or any other substantial alteration does not keep the minimum distance regulations towards the next dwelling area, additional measures for emission abatement must be taken.

For the adequate prognosis of the emission and the immission caused by a livestock installation reliable and differentiated emission data are missing. Up to now measurements are often carried out under occupational safety and health aspects and corresponding sampling methods. Thus, a lot of data that have been published relate to the inhalable fraction and/or the respirable fraction. Hardly any data have been published for PM10 emission. No data are available for natural ventilated housings. In addition, it can be assumed that measurements based on separating techniques

have usually not been carried out with an isokinetic sampling method for this requires an additional expenditure of labour. There is an urgent need to establish and harmonise sampling procedures for the measuring of emission of particulate matter from livestock housing systems.

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