SNAP CODES : **101001**
101002
101003
101004
101005
101006
101007
101008
101009
etc.

SOURCE ACTIVITY TITLE : **PARTICLE EMISSIONS FROM ANIMAL HUSBANDRY**
Dairy cattle
Other cattle
Fattening pigs
Sows
Horses
Laying hens
Broilers

NOSE CODES: **110.01.01**
110.01.02
110.01.03
110.01.04
110.01.05

NFR CODES : **4G**

1 ACTIVITIES INCLUDED

This chapter deals with primary particle emissions from ventilated animal housing systems. Due to the lack of reliable data, emissions from free-range animals, the storage and application of solid and liquid animal manures are not yet included in this chapter.

2 CONTRIBUTIONS TO TOTAL EMISSIONS

Apart from industry, traffic and private households, the agricultural sector is a considerable contributor to emissions of particulate matter (PM). Agricultural activities such as plant and animal production on both farm sites and fields cause PM emissions. Although a reduction of PM emissions is observed for Europe, an increasing proportion of primary PM_{10} emissions originates from agriculture including emissions from animal housing (Tab. 2.1). An earlier estimate by Klimont and Amann (2002) showed also a similar trend, i.e., European emissions from animal housing representing 2.7 and 4.3 % of total PM_{10} in 1990 and 2000, respectively. Klimont and Amann (2002) estimated that the major source of PM emissions from housing are poultry and pig livestock operations, which are responsible for 57 % and 32 % of PM_{10}

emissions and 50 % and 30 % of $PM_{2.5}$ releases, respectively. More recent calculations (RAINS, 2005) suggest that each of the above sources contributes about 40 % of the total PM_{10} and between 35 and 45 % of $PM_{2.5}$ emissions from animal housing.

Table 2.1: Estimated emissions of PM_{10} and the relative contribution of emissions from animal housing in Europe between 1990 and 2000 (RAINS, 2005) (emissions in Gg a^{-1}, share of animal housing in %)

	1990	2000
Overall PM emissions	Gg a^{-1}	Gg a^{-1}
Europe	10827	5085
EU25	4577	2346
Non-EU*	6250	2739
Share of emissions from animal housing	%	%
Europe	2.8	5.2
EU25	3.5	6.5
Non-EU*	2.3	4.0

* Including European part of Russia

Based on the results of the RAINS model calculations, animal housing represents about 35 % of the total European PM_{10} emissions from agricultural operations, that is, including arable land, storage and handling of agricultural products, open burning of agricultural residues, and emissions from off-road machinery (tractors, harvesters, etc.).

3 GENERAL

3.1 Description

In contrast to many trace gases, particulate matter does not only have effects on the chemical composition and reactivity of the atmosphere but also affects human and animal health and welfare. When breathed in, a particle-loaded atmosphere impacts on the respiratory tract. The observable effects are dependent on the particle size, so it is necessary to define different size categories as a function of particle size. The most important regulated particle matter categories include TSP, PM_{10} and $PM_{2.5}$ (see Definitions in Appendix A).

There are several sources of the enrichment of air-borne particulate matter within livestock buildings. The feed itself and the feeding process may contribute to 80 to 90 % of the total dust generation. Bedding materials like straw or wood shavings can also have extraordinary effects on the particle concentration in the livestock air. Depending on the type and the amount of litter and its spreading, its contribution can be between 55 and 68 % of the total airborne particulates observed. The animal skin, fleece or plumage of housed animals and their faeces and urine cause dust emissions which may contribute up to 12 % of the total dust amounts released within livestock buildings. To a lesser extent, particles may originate from friction against floors, walls and other structural elements and from the air intake into the house.

Animal activity may also lead to re-suspension into the livestock house atmosphere of dust already settled (re-entrainment).

3.2 Definitions

3.2.1 Particulate matter

For a detailed set of definitions of terms related to PM emissions from agricultural sources see Appendix A.

3.2.2 Housing types

Forced ventilated building: a building in which ventilation is provided by electrically powered fans.

Litter: Bedding material to provide some comfort to the animals and to absorb moisture (e.g. straw, wood shavings).

Slatted floor: A floor with slots that allow faeces and urine to drop into a channel or pit beneath.

Cubicle house: A building that is divided into rows of stalls or cubicles where animals lie when at rest but where animals are not restrained.

Cages: A closed building with forced ventilation, in which the birds are kept in tiered cages.

Perchery: A house for laying hens with forced ventilation, where birds have freedom of movement over the entire house and a scratching area. It contains different functional areas for feeding and drinking, sleeping and resting, scratching, egg laying.

(terminology in accordance with Pain and Menzi, 2003)

3.3 Emissions

Emissions of particulate matter (PM) occur from both housed and free-range livestock animals. Because of the lack of available emission data for free-range animals, the definition of emission factors have focused on housed animals. The mass flows of emitted particles are governed on the following parameters (examples in brackets), thus causing uncertainties in terms of predicted emissions (Seedorf and Hartung 2001):

- physical density and particle size distribution of livestock dust.
- type of housed animals (poultry vs mammals).
- kind of feeding system (dry versus wet, automatic versus manual, feed storage conditions).
- kind of floor (partly or fully slatted).
- the use of bedding material (straw or wood shavings).
- the manure system (liquid vs solid, removal and storage, manure drying on conveyor belts).

- animal activity (species, circadian rhythms, young and adult animals, caged and aviary systems).
- ventilation rate (summer vs winter, forced and natural ventilated).
- geometry and positions of inlets and outlets (re-entrainment of deposited particles caused by turbulences above the surfaces within the animal house).
- indoor climate in the livestock (temperature and relative humidity).
- the time-period of housing (whole year vs seasonal housing, e.g. cattle).
- the management (all-in and all-out systems with periods of empty livestock building due to cleaning and disinfection procedures vs continuously rearing systems, e.g. pigs).
- secondary sources due to farmers' activities (tractors, walking through the building to check on livestock)

3.3 Controls

A range of processing techniques are available to reduce concentrations of air-borne dust in livestock buildings. Measures like wet feeding, fat additives to feed, manure drying via conveyor belt systems, oil and/or water sprinkling are some examples of indoor techniques preventing excessive dust generation. Apart from these measures, end-of-pipe technologies are also available to reduce PM emissions significantly, in particular filters, cyclones, electrostatic precipitators, wet scrubbers or biological waste air purification systems. However, most of these are either considered too expensive, technically unreliable or not user friendly to be widely adopted by agriculture.

When applicable abatement techniques become available, emission factors will be added in the methodology to calculate the PM_{10} emissions.

4 FIRST ESTIMATE

4.1 Emissions from housed animals

Particle emissions may be related to animal numbers or animal place numbers according to

$$E_{\mathrm{PM}} = \sum_{\mathrm{ij}} \mathrm{n_{ij}} \cdot x_{\mathrm{t,i}} \cdot EF_{\mathrm{PM,ij}}$$

with E_{PM} emission of PM from animal husbandry (in kg a^{-1} PM)
$\mathrm{n_{ij}}$ number of animal places in an animal category i according to the census (in places) in a housing type j
$x_{\mathrm{t,I}}$ time fraction, during which animals of category i are housed (in a a^{-1})
$EF_{\mathrm{PM,ij}}$ emission factor for a given animal category i and housing type j (in kg place^{-1} a^{-1} PM)

For grazing periods, particle emissions from cattle, pigs, sheep and horses are considered to be negligible. The emissions are to be calculated assuming that the emissions are directly related to the time the animals are housed.

Table 4.1: First estimates of emission factors EF_{PM} for particle emissions from animal husbandry (housing) (for derivation see Appendix B)

Animal category	Housing type	Emission factor for PM_{10} kg animal^{-1} a^{-1}	Emission factor for $PM_{2.5}$ kg animal^{-1} a^{-1}
Dairy cattle	Tied or litter	0.36	0.23
	Cubicles (slurry)	0.70	0.45
Beef cattle	Solid	0.24	0.16
	Slurry	0.32	0.21
Calves	Solid	0.16	0.10
	Slurry	0.15	0.10
Sows	Solid	0.58	0.094
	Slurry	0.45	0.073
Weaners	Solid	n.a.	n.a.
	Slurry	0.18	0.029
Fattening pigs	Solid	0.50	0.081
	Slurry	0.42	0.069
Horses	Solid[1)]	0.18	0.12
Laying hens	Cages	0.017	0.0021
	Perchery	0.084	0.0162
Broilers	Solid	0.052	0.0068

n.a.: not available
[1)] wood shavings

6 RELEVANT ACTIVITY STATISTICS

Information is required on animal numbers or animal places, respectively, and for the prevailing housing systems or their frequency distribution. For grazing animals, the duration of the grazing season and the daily grazing time are needed.

7 POINT SOURCE CRITERIA

Emissions from animal husbandry may originate from houses and from feed lots etc. Emissions from animal houses should be treated as point sources.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

not applicable at this stage of knowledge

9 SPECIES PROFILES

10 UNCERTAINTY ESTIMATES

No uncertainty can be given for this first estimate methodology.

The emission factors are a first estimate only. Further uncertainties may arise from estimates of grazing times.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The basis of the estimate is a limited number of measurements in north western Europe of inhalable and respirable dust emissions from animal houses with forced and free ventilation related to livestock units. The current emission factors have been transformed into PM emissions per animal per annum using poorly defined factors. Only the main animal categories have been dealt with.

There is obviously the need to perform measurements of PM fluxes for all respective important housing systems and animal categories in all countries using this Guidebook.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Not relevant, as houses are considered to be point sources.

13 TEMPORAL DISAGGREGATION CRITERIA

Not relevant, as the data provided are annual means

14 ADDITIONAL COMMENTS

It is principally agreed that housing systems with litter (solid manure) are causing higher dust burdens than livestock buildings without litter (slurry), because bedding material such as straw consists of loose material, which becomes easily air-borne caused by mechanical agitations and therefore contribute to the overall indoor dust concentration considerably (Hinz et al., 2000). However, the contribution of the bedding material to airborne particles is contradictory to some extent. During winter for example, Takai et al. (1998) found in English dairy cow buildings with litter higher inhalable dust concentrations than in German cubicle houses with dairy cows, where slurry based systems were operated. Therefore, the calculated emission rates for particulate matters differed, too. Because the data from Takai and co-workers were taken for the first estimates here, the proposed emission factors in Table 4.1, A.1 and A.4 show a similar order for dairy and beef cattle.

Reasons for such deviations are due to the lack of sufficient information concerning quality and quantity of used bedding material (e.g. straw, chopped straw, wood shavings, sawdust, peat, sand, use of de-dusted bedding materials, mixtures of different materials, litter moisture, supplementation with de-moisturing agents, used mass of bedding material per animal), frequency of litter renewing (e.g. weekly vs. monthly), variations of animal density and its impact on dust liberating forces caused by the animal's activities or randomly high ventilation rates in cubicle houses resulting in relative higher emission rates in comparison to litter-based systems. In conclusion, more data need to be taken on emission rates of particulates in order to better determine both mean emission rates and variability of emission rates due to various environmental and management factors and is therefore also a target for prospective verification procedures.

15 SUPPLEMENTARY DOCUMENTS

16 VERIFICATION PROCEDURES

17 REFERENCES

European Committee for Standardization (CEN) EN 481 (1993): Workplace atmospheres, Size fraction definitions for measurement of airborne particles. Brussels, European Committee for Standardization.

Hinz, T., Sonnenberg, H.; Linke, S.; Schilf, J.; Hartung, J. (2000): Staubminderung durch Befeuchten des Strohs beim Einstreuen eines Rinderstalles. Landtechnik, 55, 298-299.

Klimont, Z.; Amann, M. (2002): European control strategy for fine particles: the potential role of agriculture. Landbauforschung Völkenrode, special issue 235, 29-35.

Pain, B.; Menzi, H. (2003): Glossary of terms on livestock manure management. RAMIRAN. http://www.ramiran.net/DOC/Glossary2003.pdf.

RAINS (2005): RAINS On-line model available from http://www.iiasa.ac.at/rains Calculations based on the CP_CLE_Aug04(Nov04) scenario.

Seedorf, J.; Hartung, J. (2001): A proposed calculation procedure for the amount of emitted particulate matter from livestock buildings. Dtsch. tierärztl. Wschr., 108, 307-310.

Takai, T.; Pedersen, S.; Johnsen, J.O.; Phillips, V.R.; Holden, M.R.; Sneath, R.W.; Short, J.L.; White, R.P.; Hartung, J.; Seedorf, J.; Schröder, M.; Linkert, K.H.; Metz, J.H.M.; Koerkamp, P.W.G.; Uenk, G.H.; Wathes, C.M. (1998): Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. J. agric. Engng. Res., 70, 59-77

18 BIBLIOGRAPHY

19 RELEASE VERSION, DATE AND SOURCE

Version: 1.1

Date: July 2006

Jens Seedorf	Ulrich Dämmgen
Institute for Animal Hygiene, Welfare and Behaviour of Farm Animals	Federal Agricultural Research Centre
University of Veterinary Medicine,	Institute of Agroecology
	Bundesallee 50

Foundation
Bünteweg 17p
30559 Hannover
Germany

38116 Braunschweig
Germany

Zbigniew Klimont
International Institute for Applied
Systems Analysis
2361 Laxenburg
Austria

20 Point of Enquiry

Any comments on this chapter or enquiries should be directed

Ulrich Dämmgen

Federal Agricultural Research Centre
Institute of Agroecology
Bundesallee 50

38116 Braunschweig
Germany

Tel +49 531 596 2601
Fax +49 531.596 2599
Email: ulrich.daemmgen@fal.de

Nicholas John Hutchings

Department of Agroecology
Danish Institute of Agricultural Sciences
PO Box 50, Research Centre Foulum

8830 Tjele
Denmark

+45 8999 1733
+45 8999 1819
Nick.Hutchings@agrsci.dk

APPENDIX A

Particulate matter - definitions

Particulate matter (PM) is defined as particles of solid or liquid matter suspended in air. They are characterized by their origin (primary and secondary particles), their particle size, their composition and their potential physiological pathways.

Primary emissions are directly emitted by a source. Secondary particles are formed in the atmosphere by chemical reactions of certain gases that either condense or undergo chemical transformation to a species that condenses as a particle (Seinfeld, 1986). (The expression “secondary particle” is also sometimes used to describe redispersed or resuspended particles.)

To make particle size comparisons possible, the so-called aerodynamic diameter (d_{ae}) is used to standardize the expression of different particle sizes. The aerodynamic diameter (d_{ae}) is the diameter (in µm) of an idealized spherical particle of unit density (1 g cm^{-3}) which behaves aerodynamically in the same way as the particle in question (e.g. with regards to its terminal settling velocity). It is used to predict where particles of different size and density may be deposited in the respiratory tract. Particles having the same aerodynamic diameter may differ in dimension and shape. Due to the heterogeneity of particles the sampling characteristics of sampling devices have to be standardized. From that point of view the so-called collection efficiency (CE) is an important specification. The CE is usually expressed as the 50 % aerodynamic cut-off diameter (d_{50}). Such a d_{50} is generally assumed to be the size above which all particles larger than that size are collected to 50 % at least. The CE is usually determined using monodisperse particles. The cut-off curves may vary in sharpness and will depend on the type of sampler (Henningson and Ahlberg, 1994).

Total suspended particulate matter (TSP) refers to the entire range of ambient air matter that can be collected, from the sub-micron level up to 100 µm in d_{ae}. Particles with a d_{ae} larger than 100 µm will not remain in air for a significant length of time.

PM_{10} is the fraction of suspended particulate matter in the air with d_{ae} less than or equal to a nominal 10 µm, which are collected with 50 % efficiency by a PM_{10} sampling device. These particles are small enough to be breathable and could be deposited in lungs, which may cause deteriorated lung functions.

A further TSP-related size fraction is $PM_{2.5}$, which describes particles with an aerodynamic diameter d_{ae} less than or equal to nominal 2.5 µm and capable to be collected by measuring devices with 50 % collection efficiency. Exposure to considerable amounts of $PM_{2.5}$ can cause respiratory and circulatory complaints in sensitive individuals. $PM_{2.5}$ also causes reductions in visibility and solar radiation due to enhanced scattering of light.. Furthermore, aerosol precursors such as ammonia (the source of which is mainly agriculture) form $PM_{2.5}$ as secondary particles through chemical reactions in the atmosphere.

For toxicological purposes, further dust classifications have been introduced e.g. to characterise occupational settings. For this reason, the terms “inhalable dust”, “thoracic dust” and “respirable dust” were introduced.

To imitate the different breathable particle fractions (inhalable, thoracic, respirable) sampling criteria were defined by conventions, which define curves with the desired sampling performance of a sampler in terms of the fractional collection for particles up to 100 µm (CEN EN 481, Fig. 1). Therefore, the term inhalable dust is widely used to describe dust qualities that might be hazardous when deposited anywhere in the respiratory system, including the nose and mouth. It has a d_{50} of 100 µm and consequently includes the big and the small particles. Consequently, many dust emission data relate to 'inhalable dust' (e.g. Takai et al., 1998).

EPA describes inhalable dust as that size fraction of dust which enters the respiratory tract, but is mainly trapped in the nose, throat, and upper respiratory tract. The median aerodynamic diameter of this dust is about 10 µm.

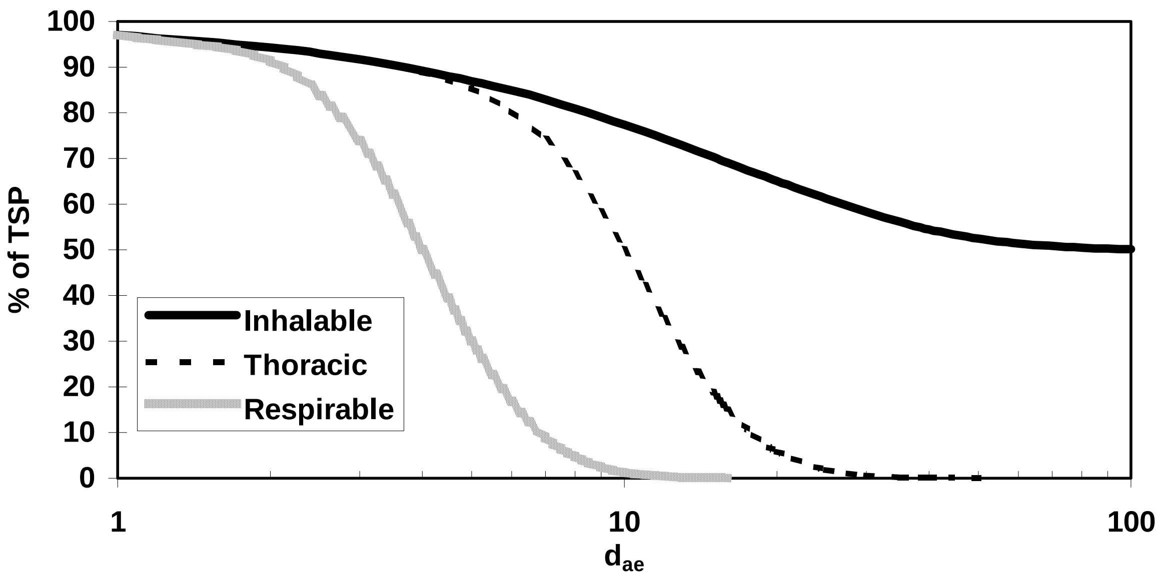

Fig. A1: Sampling criteria for inhalable, thoracic and respirable particles expressed as percentage of TSP.

According to Fig. A1 the thoracic dust fraction is related to a d_{50} of 10 µm indicating particles, which are mainly able to deposit in the airways of the lung (e.g. bronchi). The term "respirable dust" describes airborne particles, which are capable of invading the smaller airways and the alveoli of the lung, where the gas-exchange takes place. In the past, several definitions for respirable dust were proposed. Apart of definitions which specify respirable dust as particles with an aerodynamic diameters smaller than 7 µm, the Australian Standard AS 2985-1987 defines respirable dust as dust with a 50 % cut-off point of 5 µm. ACGIH (1998) defined respirable dust as having a 50 % cut-point of 3.5 µm. To reach world-wide consensus on the definition of respirable dust in the workplace, a compromise curve was developed with a 50 % cut-point of 4 µm. This standard definition is also implemented in CEN EN 481.

References

Australian Standard AS 2985-1987 (1987) Workplace Atmospheres: Method for Sampling and Gravimetric Determination of Respirable Dust, Standards Australia, Sydney.

Henningson, E.W.; Ahlberg, M.S. (1994): Evaluation of microbiological aerosol samplers: A review. J. Aerosol Sci., 25, 1459-1492.

Seinfeld, J.H. (1986): Atmospheric Chemistry and Physics of Air Pollution. Wiley, New York.

Takai, T.; Pedersen, S.; Johnsen, J.O.; Phillips, V.R.; Holden, M.R.; Sneath, R.W.; Short, J.L.; White, R.P.; Hartung, J.; Seedorf, J.; Schröder, M.; Linkert, K.H.; Metz, J.H.M.; Koerkamp, P.W.G.; Uenk, G.H.; Wathes, C.M. (1998): Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. J. agric. Engng. Res., 70, 59-77

APPENDIX B

Derivation of emission factors

Due to the lack of directly measured PM_{10} emissions, emission factors for PM_{10} from animal housing have to be derived from measurements of inhalable dust. Takai et al. (1998) summarized the experimental results obtained in a comprehensive study peformed in England, The Netherlands, Denmark and Germany in tables relating emissions of inhalable and respiratory particles from animal houses to livestock units. For horses, values obtained by Seedorf and Hartung (2001) serve as source. These data are listed in Table B1.

Transformations are needed to convert livestock units into animal numbers. In addition, inhalable and respirable dust concentrations have to be transformed into the respective PM concentrations. However, the resulting "correction factors" have to be used with care, because the representativeness of these factors is poorly understood. As a consequence, the methodology is considered a first estimate methodology rather than a simpler methodology.

Table B1: Measured dust emissions (all data except horses: Takai et al. 1998; horses: Seedorf and Hartung, 2001)

Animal category	Housing type	Emissions	
		ID mg LU^{-1} h^{-1}	RD mg LU^{-1} h^{-1}
Dairy cattle	Litter	89.3	28.0
	Cubicles	172.5	28.5
Beef cattle	Litter	85.5	16.0
	Slats	113.0	13.7
Calves	Litter	132.0	27.3
	Slats	127.5	19.5
Sows	Litter	448.5	47.5
	Slats	345.8	47.8
Weaners	Litter	n.a.	n.a.
	Slats	1021.0	75.5
fattening pigs	Litter	725.5	71.0
	Slats	612.3	66.0
Horses	Litter[1)]	55	n.a.
laying hens	Cages	636.3	78.3
	Perchery	3080.7	595.3
Broilers	Litter	3965.8	517.5

n.a.: not available; ID: inhalable dust; RD: respirable dust
[1)] wood shavings

In order to get mean emissions per animal head, means of these data have to be divided by the average weight of the animals in the respective category. Livestock unit (LU) is here defined as a unit used to compare or aggregate numbers of different species or categories and is equivalent to 500 kg live weight. A list of relevant LUs is given in Table B2.

Table B2: Conventional livestock units

	Weight kg animal^{-1}	Transfer factor LU animal^{-1}
Calves	50 to 100	0.1 to 0.5
Young cattle	450 to 650	0.6 to 1.2
Dairy cow	600 to 650	1.2
Horses		0.8 to 1.5
Boars		0.3
Sows		0.3
Fattening pigs		0.12
Piglets		0.01
Sheep		0.1
Laying hens		0.0031
Chicken		0.0015

The quantities of inhalable and respirable dust have to be transformed into quantities of PM_{10} and $PM_{2.5}$. Transformation factors for cattle are derived from a 24 hour PM monitoring survey that was made in a cubicle house with dairy cows and calves, housed on slatted floor and solid floor with straw. The one-day survey was conducted with an optical particle counter, which recorded the mass concentrations of total dust, PM_{10} and $PM_{2.5}$. The result of this investigation was used to calculate the conversion factor for PM_{10} (Seedorf and Hartung, 2001), while the conversion factor for $PM_{2.5}$ was determined later (Seedorf and Hartung, unpublished). The conversion factors for pigs were derived from Louhelainen et al. (1987). Horses were assumed to have a transformation factor similar to cattle. For poultry, this methodology makes the assumption that the concentration of inhalable dust is approximately the same as that of PM_{10}, and that the concentration of respirable dust may be considered to be of the same order of magnitude as that of $PM_{2.5}$. However, simultaneous measurements of inhalable dust and PM_{10} in a turkey barn have recently shown that the mean ratio between both dust fraction was lower than 1.0, namely approximately 0.6 (Schütz et al. 2004). Overall the real quantitative relationships between dust fractions have to be verified in future. Nevertheless, for a very first estimate some of these transformation factors are compiled in Table B3.

Table B3: Transformation factors for the conversion of inhalable dust (ID) and respirable dust (RD) into PM_{10} and $PM_{2.5}$

Animal type	Transformation factor for PM_{10} kg PM_{10} (kg ID)$^{-1}$	Transformation factor for $PM_{2.5}$ kg $PM_{2.5}$ (kg ID)$^{-1}$
Dairy cows(101001)	0.46 [1)]	0.30 [2)]
Other cattles (101002)	0.46 [1)]	0.30 [2)]
Fattening pigs(101003) (including weaners)	0.45	0.08
Sows (101004)	0.45	0.08
Horses[)3] (101006)	0.46 [1)]	0.30 [2)]
	kg PM_{10} (kg ID)$^{-1}$	kg $PM_{2.5}$ (kg RD)$^{-1}$
Poultry	1.0	1.0

1) Seedorf and Hartung (2001), the same conversion factor for horses is assumed as for cattle
2) Seedorf (2001) unpublished

The resulting emission factors in kg animal^{-1} a^{-1} are listed in Table B4.

Table B4: Emission factors for inhalable dust, respirable dust, PM_{10} and $PM_{2.5}$

Animal category	Housing type	Animal weight	Conversion factor	Emission factors *EF*			
				ID	RD	PM_{10}	$PM_{2.5}$
		kg animal^{-1}	LU animal^{-1}	kg animal^{-1} a^{-1}	kg animal^{-1} a^{-1}	kg animal^{-1} a^{-1}	kg animal^{-1} a^{-1}
Dairy cattle	Litter	500	1.0	0.78	0.25	0.36	0.23
	Cubicles	500	1.0	1.51	0.25	0.70	0.45
Beef cattle	Litter	350	0.7	0.52	0.10	0.24	0.16
	Slats	350	0.7	0.69	0.084	0.32	0.21
Calves	Litter	150	0.3	0.35	0.072	0.16	0.10
	Slats	150	0.3	0.34	0.051	0.15	0.10
Sows	Litter	150	0.3	1.18	0.12	0.58	0.094
	Slats	150	0.3	0.91	0.13	0.45	0.073
Wean-ers	Litter	20	0.04	n.a.	n.a.	n.a.	n.a.
	Slats	20	0.04	0.36	0.026	0.18	0.029
Fatte-ning pigs	Litter	80	0.16	1.02	0.10	0.50	0.081
	Slats	80	0.16	0.86	0.093	0.42	0.069
Horses	Litter [1]	400	0.8	0.39	n.a.	0.18	0.12
Laying hens	Cages	1.55	0.0031	0.017	0.0021	0.017	0.0021
	Perch-ery	1.55	0.0031	0.084	0.0162	0.084	0.0162
Broilers	Litter	0.75	0.0015	0.052	0.0068	0.052	0.0068

n.a. not available
[1] wood shavings

The emission factors EF_{PM10} and $EF_{PM2.5}$ given in Table B4 are mainly of a similar order of magnitude as those used in the RAINS model for livestock operation (Klimont et al., 2002) (see Table B5). However, for cattle there is an obvious deviation in case of $EF_{PM2.5,}$ which might be caused by different detection methods used for $PM_{2.5}$ measurements (e.g. optical related measurements versus non-inertial sampling methods). Therefore, the proposed $EF_{PM2.5}$ for cattle and horses in Table B4 should in particular be used with care.

Table B5: PM_{10} emission factors EF_{PM10} as used in the RAINS model (Klimont et al. 2002)

Animal type	EF_{PM10} kg animal^{-1} a^{-1}	$EF_{PM2.5}$ kg animal^{-1} a^{-1}
Poultry	0.0473	0.0105
Pigs	0.4376	0.0778
Dairy cattle	0.4336	0.0964
Other cattle	0.4336	0.0964
Other animals [1]	n.a.	n.a.

[1] sheep, horses and fur animals
n.a.: not available

References

Klimont, Z.; Cofala, J.; Bertok, I.; Amann, M.; Heyes, C.; Gyarfas, F. (2002): Modelling particulate emissions in Europe - a framework to estimate reduction potential and control costs. Interim Report IR-02-076, International Institute for Applied Systems Analysis, Laxenburg, Austria, 169 pp.

Louhelainen, K.; Vilhunen, P.; Kangas, J.; Terho, E.O. (1987): Dust exposure in piggeries. Eur. J. Resp. Dis., 71, Suppl. 152, 80-90.

Schütz, A.; Seedorf, J.; Klasmeier, E.; Hartung. J. (2004): PM 10 measurements in a turkey barn - first results, methods and limitations. 13th World Clean Air and Environmental Protection Congress and Exhibition, London, UK, August 22 - 27, 2004. ERRATUM: http://www.tiho-hannover.de/einricht/itt/allgemein/erratum.htm

Seedorf, J.; Hartung, J. (2001): A proposed calculation procedure for the amount of emitted particulate matter from livestock buildings. Dtsch. tierärztl. Wschr., 108, 307-310.

Takai, T.; Pedersen, S.; Johnsen, J.O.; Phillips, V.R.; Holden, M.R.; Sneath, R.W.; Short, J.L.; White, R.P.; Hartung, J.; Seedorf, J.; Schröder, M.; Linkert, K.H.; Metz, J.H.M.; Koerkamp, P.W.G.; Uenk, G.H.; Wathes, C.M. (1998): Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. J. agric. Engng. Res., 70, 59-77