DUTCH NOTES ON BAT FOR PIG- AND POULTRY INTENSIVE LIFESTOCK FARMING

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1. INTRODUCTION

1.1. ABOUT THIS DOCUMENT

This document describes available environmental control techniques for the pig- and poultry intensive lifestock farms. The purpose of this document is to support the identification of BAT for the European pig- and poultry housing, following the requirements of article 16 of the Council Directive 96/61, concerning Integrated Pollution Prevention and Control (IPPC-Directive), which has been adopted on 24 September 1996.

The IPPC-Directive provides a definition of BAT (article 2, sub 11):
"Best Available Techniques" means the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where it is not practicable, generally to reduce emissions and the impact on the environment as a whole.

- *"Techniques" include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.*
- *"Available" techniques mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator.*
- *"Best" means most effective in achieving a high general level of protection of the environment as a whole.*

Furthermore, article 2 (11) of the IPPC-directive states that a number of considerations must be taken into account when determining best available techniques. These considerations are listed in annex 4 of the Directive and Table 1 provides an overview of these considerations.

TABLE 1 CONSIDERATIONS TO BE TAKEN INTO ACCOUNT WHEN DETERMINING BAT: ANNEX IV OF THE IPPC-DIRECTIVE (EC, 1996)

Considerations to be taken into account generally or in specific cases when determining best available techniques, as defined in Article 2 (11), bearing in mind the likely costs and benefits of a measure and the principles of precaution and prevention:

1. *the use of low-waste technology;*
2. *the use of less hazardous substances;*
3. *the furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate;*
4. *comparable processes, facilities or methods of operation which have been tried with success on an industrial scale;*
5. *technological advances and changes in scientific knowledge and understanding;*
6. *the nature, effects and volume of the emissions concerned;*
7. *the commissioning dates for new and existing installations;*
8. *the length of time needed to introduce best available technique;*
9. *the consumption and nature of raw materials (including water) used in the process and their energy efficiency;*
10. *the need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it;*
11. *the need to prevent accidents and to minimise the consequences for the environment;*
12. *the information published by the Commission pursuant to Article 16 (2) or by international organisations*

1.2. INTENSIVE LIVESTOCK FARMING IN THE NETHERLANDS

This document covers installations for the intensive rearing of poultry, production-pigs and sows. In the Netherlands 34 million hens are kept for the production of eggs and about 60 million broilers are kept for the production of meat. There also is a large amount of pig-places in the Netherlands: 1.4 million places for sows and about 7.2 million places for growing-finishing pigs. The Netherlands, Denmark, France, Germany and Spain are responsible for 72% of the sow-production in Europe. In the next chapter a broader discription of the scale of intensive lifestock farms in various member states is given.

1.3. DUTCH POLICY AND RELEVANT LEGISLATION AND REGULATION ON AMMONIA AND MANURE

1.3.1. Ammonia

To exploit an intensive livestock farm a permit based on the Environmental Management Act is required. The permit regulates the nuisance and the enviromental effects in relation to the housing. Important issue in the Netherlands is the emission of ammonia caused by intensive livestock farming and the acidification as a result of the ammonia-emission. Halfway through the 1980s the Dutch government embarked on a policy to address the manure and the ammonia problem. The policy was introduced in phases to give farmers the opportunity to meet enviromental demands and convert to enviromentally friendly production. The first phase from 1985 to 1991 was aimed at stabilising the situation and finding solutions. During the second phase, that lasted untill 1994, the focus was on gradually reducing the enviromental burden by tightening up standards and forcing farmers to adopt new technologies developed to that point. The third phase has involved further tightening of standards and mandatory application of more recently developed technologies. Generic ammonia policy will continu to focus on the developement of new technology. The policy on ammonia is nowadays based on three important generic technical measures:

1) Covered manure storage

A decree based on the Environmental Management Act regulates, to reduce the ammonia emission, that all manure storage facilitues built in the Netherlands after 1987 have to be covered. This measure should achieve a reduction of 75% of the ammonia emission.

2) Low emission housing

Various techniques are available that reduce the emission of ammonia from livestock housing particulary for poultry and pigs. The use of low-emission housing is not yet mandatory but it is encouraged via a certification system (Green Label). The Dutch government currently prepares a decree wich regulates a maximum ammonia-emission per animal-place. From 2000, Dutch farmers will be obliged to invest in low emission housing when they build new or renovate existing livestock housing as far as the systems are available in terms of the ALARA-principle. ALARA (As Low As Reasonbly Achievable) means that systems are technically feasible and that they are affordable for the sector

3) Low emission application of manure

Low emission application of manure is a relatively cheap method to reduce ammonia emission. Manure spreading accounts for about half of ammonia evaporation from agriculture. Low-emission application appears to be the most cost-effective measusre to reduce ammonia loss into the atmosphere. Numerous technical innovations have considerably improved low-emission application techniques and now they can be used on different soil types. A decree based on the Soil Protection Act regulates manure spreading on the land (periods and application techniques).

1.3.2. Manure

The livestock sector in the Netherlands is a highly intensive sector: i.e. very high stocking rates are found on a fairly limited land area. This is made possible by importing large amounts of animal food. As a result the livestock sector produces far more manure than is needed wich in turn leads to the over-application of manure on crops. Over recent years the manure policy was aimed at reducing the surplus of manure. Measures were introduced to cover production and sale. Manure production rights were introduced to restrict the production of livestock manure and animal food with low mineral contents were promoted. For the manure-production three laws are relevant: the Manure Act, the Manure Production Relocation Act and the Restructing Pig-breeding Act. These acts regulate the relocation of manure-production and a maximum manure production. The Manure Act also regulates the minerals acounting system. The minerals acounting system involves a registration of the mineral inputs (nitrogen and phosphate) used on a farm in fertilizers and animal food, and the mineral output in the form of products and manure. The difference between input and output is the mineral loss wich ends up in the enviroment. When the loss is larger than the allowable standard, a levy applies.

1.3.3. New developments

The Dutch Authorities are currently in a proces of changing the national legislation with respect to housing systems for intensive lifestock farms in the Netherlands. These changes involve both environmental and animal welfare standards. The final outcome of the proces is expected in September 1999 and will be reflected in the final version of this document.

1.4. CONTENTS AND DELIMITATION OF THE DOCUMENT

In this document, an attempt is made to include all relevant environmental aspects of the presented techniques. In this way, the integral weighing of available techniques is facilitated.
Economical aspects of presented techniques are given as well. This document comprises the following elements:

- Process description
- Emissions, economics and energy demand
- Candidate Best Available Techniques

The rules concerning covered manure storage and low emission housing are based on the Environmental Management Act. This act sees to the actitivities in the "appliance", wich is in fact the farmyard and the animal-housing. The permit based on the Environmental Management Act regulates the nuisance and the enviromental effects in relation to the housing. Manure-application does not take place in the appliance but the application-techniques are also added in this document as extra information. Those measures wich are based on the Manure Act and the Manure Relocation Act are not taken into account in this document, the Netherlands will deliver seperate information on these subjects.

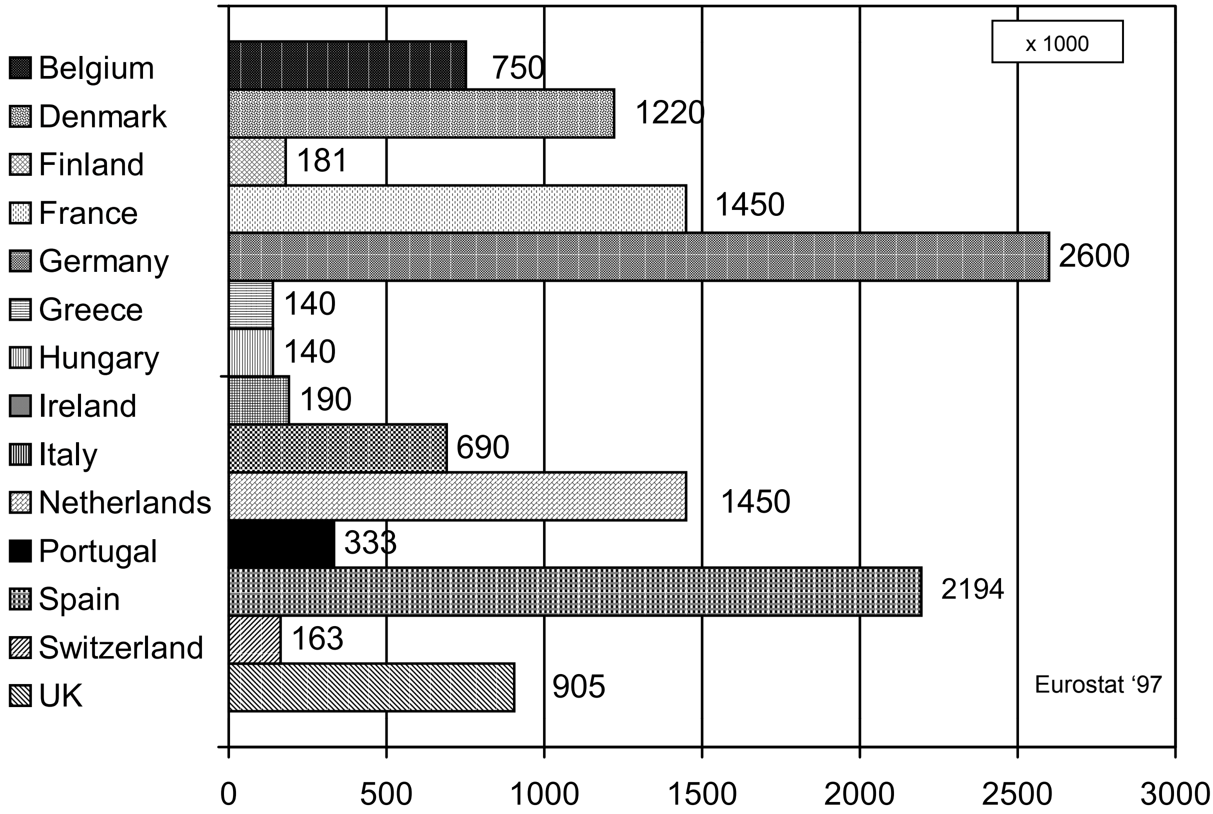
1.5. LOCAL ASPECTS

It should be noted that the identification of BAT at individual pig- or poultry farms is not necessarily the same for all European farms. The so-called “local aspects” may influence the selection of BAT between Member States, or even between pig- or poultry farms within a Member State. Relevant local aspects are for example nuisance (odour, noise, coarse dust) and local air or water quality.
In this document, local aspects have not been taken into consideration but the Netherlands will deliver separate information on these subjects.

2. PIG HOUSING SYSTEMS IN EUROPE: CURRENT TRENDS

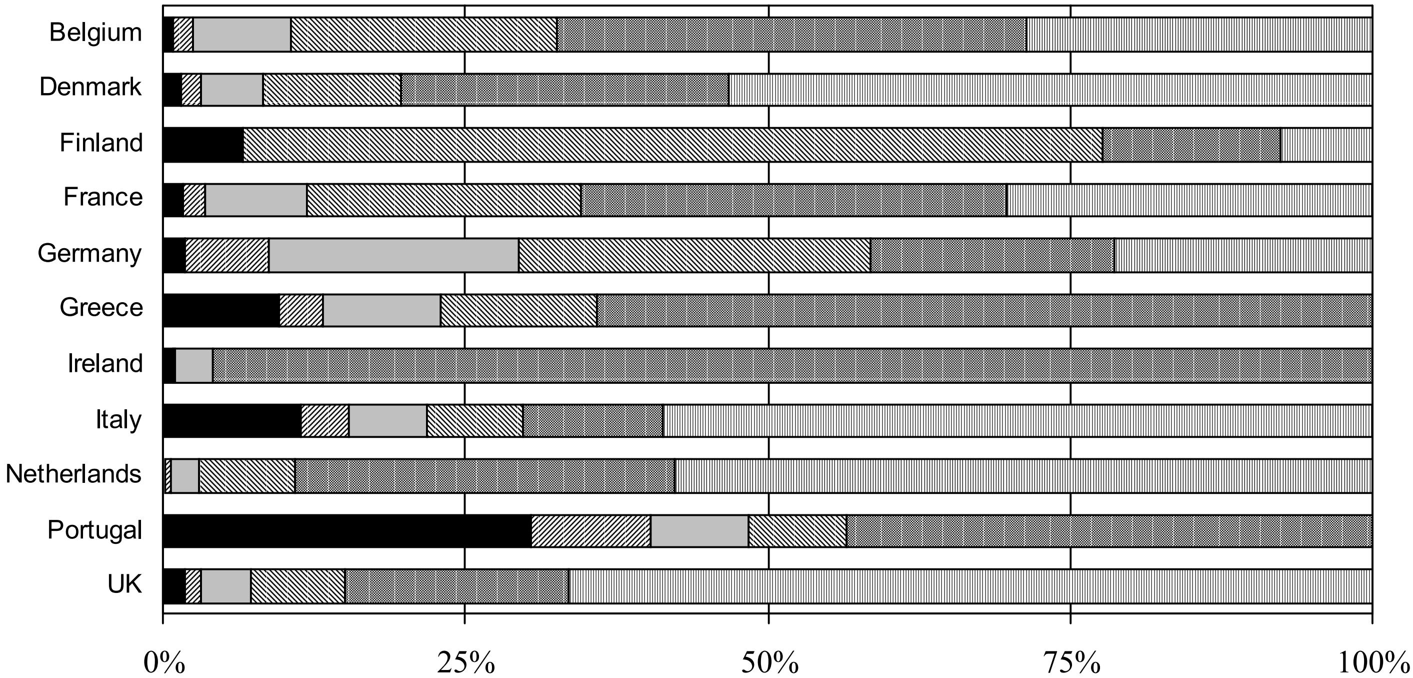
The distribution of sows between countries is presented in Table 2. The sow population data indicate that there are large differences between countries with respect to number of animals. Thus, five countries - Denmark, France, Germany, The Netherlands and Spain - have more than 1 Mio sows, which account for 72% of the total population of 12.4 Mio sows. The main pig producing countries are Germany and Spain. Nevertheless both countries import piglets or finishing pigs. Denmark and the Netherlands are export-oriented. The major part of the pig meat is sold to other countries.

TABLE 2 TOTAL NUMBERS OF SOWS PER COUNTRY



The herd structure is even more diverse (Table 3). Sow herd size is relatively larger in Denmark, Italy, the Netherlands and the UK as compared to the other countries, which have fewer farms with more than 200 sows. In the Netherlands almost 90% of the farms have more than 100 sows. Farms are often specialised in sows or finishing pigs. However, in Portugal more than 30% of the sows are located in farms with less than 10 sows/farm.

TABLE 3 DISTRIBUTION OF SOWS ACCORDING TO SOWS/FARM (%)



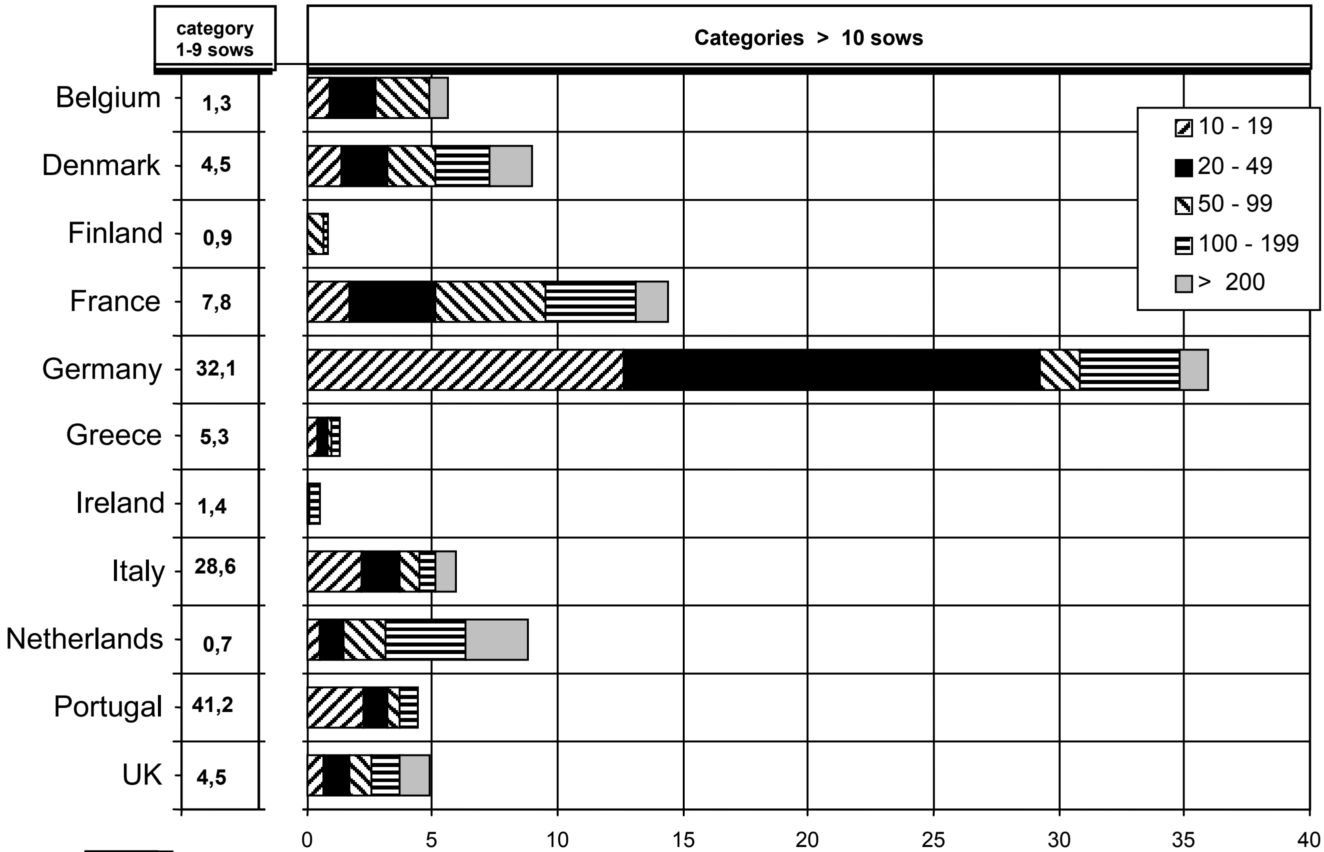
Farm size	UK	Portugal	Netherlands	Italy	Ireland	Greece	Germany	France	Finland	Denmark	Belgium
> 200	66,5		57,8	58,8			21,3	30,3	3,1	53,3	28,6
100 - 199	18,5	43,5	31,3	11,5	95,8	64,2	20,3	35,2	6,1	27,1	38,8
50 - 99	7,7	8	8,1	8		12,8	29,1	22,6	29,3	11,5	22
20 - 49	4,1	8,1	2,3	6,4	3,1	9,8	20,7	8,5		5	8,2
10 - 19	1,3	9,9	0,5	4	0,1	3,6	6,9	1,7		1,7	1,6
1 - 9	1,9	30,4	0,1	11,4	0,9	9,6	1,8	1,7	2,7	1,5	0,8

Farm size ■ 1 - 9 ▨ 10 - 19 □ 20 - 49 ▧ 50 - 99 ▩ 100 - 199 ▥ > 200

Eurostat '95

Herd size is relatively small in Germany where more than 40% of de sow farms have less than 10 sows (Table 4). This figure is even higher for Italy with 80% of the farms having less than 10 sows. However, these farms comprise only 11% of the total sow herd, while 2% of the farms hold 60% of the sow population. In Portugal 90% of de sow farms have less than 10 sows per farm, which comprises 30% of the sow population. In a German study of sectional and regional patterns of pig production in the EU Windhorst (1998) reported that the sectional concentration is high in countries such as Italy and France with a small number of large farms accounting for the majority of the pigs while the distribution pattern is more regular in Belgium, Denmark, The Netherlands, UK and Germany. The German study did not include data from Spain, Greece, Ireland and Portugal, which also have a high sectional concentration (EU-council report, 1997). Windhorst (1998) found that an increase in pig production is usually followed by structural changes such as an increase in herd size.

TABLE 4 DISTRIBUTION OF SOW-FARMS (X 1000) ACCORDING TO FARM SIZE

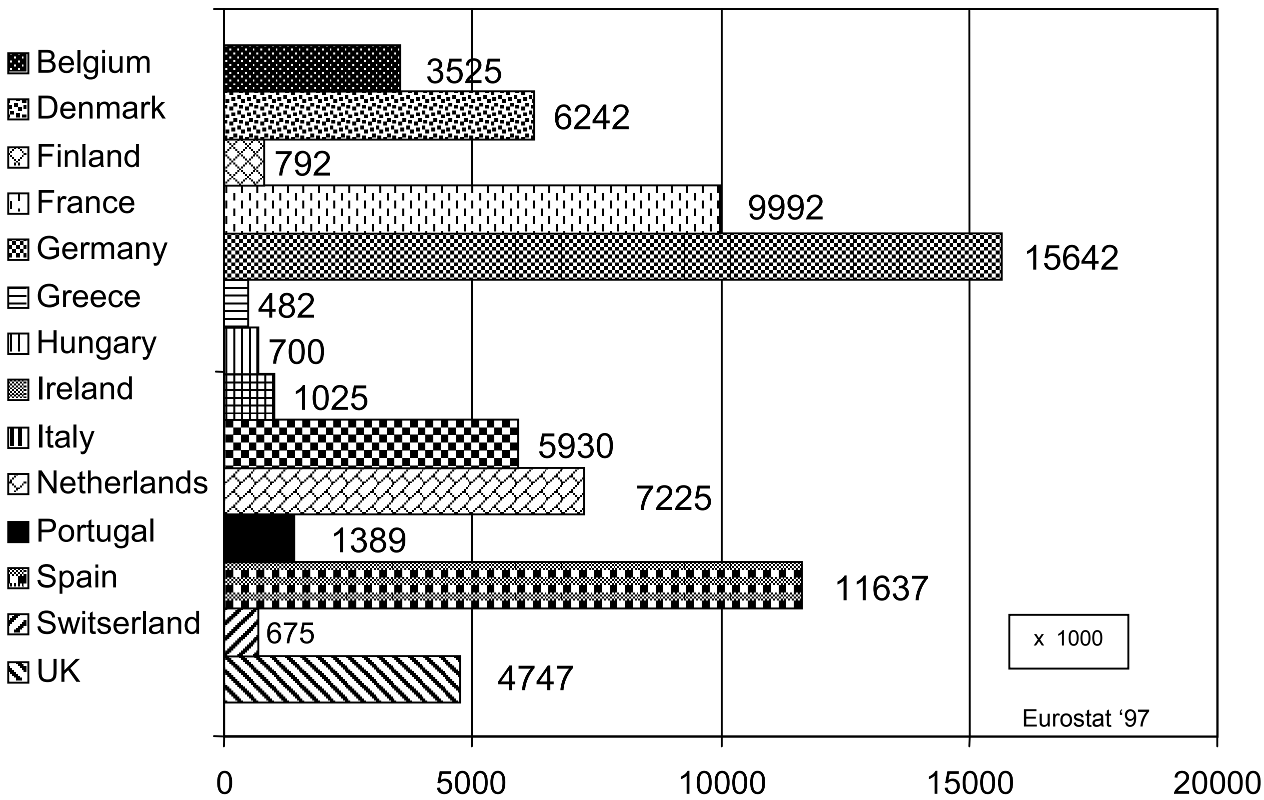


Farm size	UK	Portugal	Netherlands	Italy	Ireland	Greece	Germany	France	Finland	Denmark	Belgium
> 200	1,2		2,5	0,8			1,1	1,3		1,7	0,7
100 - 199	1,1	0,7	3,2	0,6	0,4	0,3	4	3,6	0,1	2,2	
50 - 99	0,9	0,5	1,6	0,8		0,2	1,6	4,4	0,7	1,9	2,2
20 - 49	1	0,9	1	1,5	0,1	0,4	16,6	3,4		1,8	1,8
10 - 19	0,7	2,3	0,5	2,2		0,4	12,6	1,7		1,4	0,9
1 - 9	4,5	41,2	0,7	28,6	1,4	5,3	32,1	7,8	0,9	4,5	1,3
total	9,5	45,6	9,6	34,4	1,9	6,6	77,1	22,2	5,2	13,6	9,0

Eurostat '95

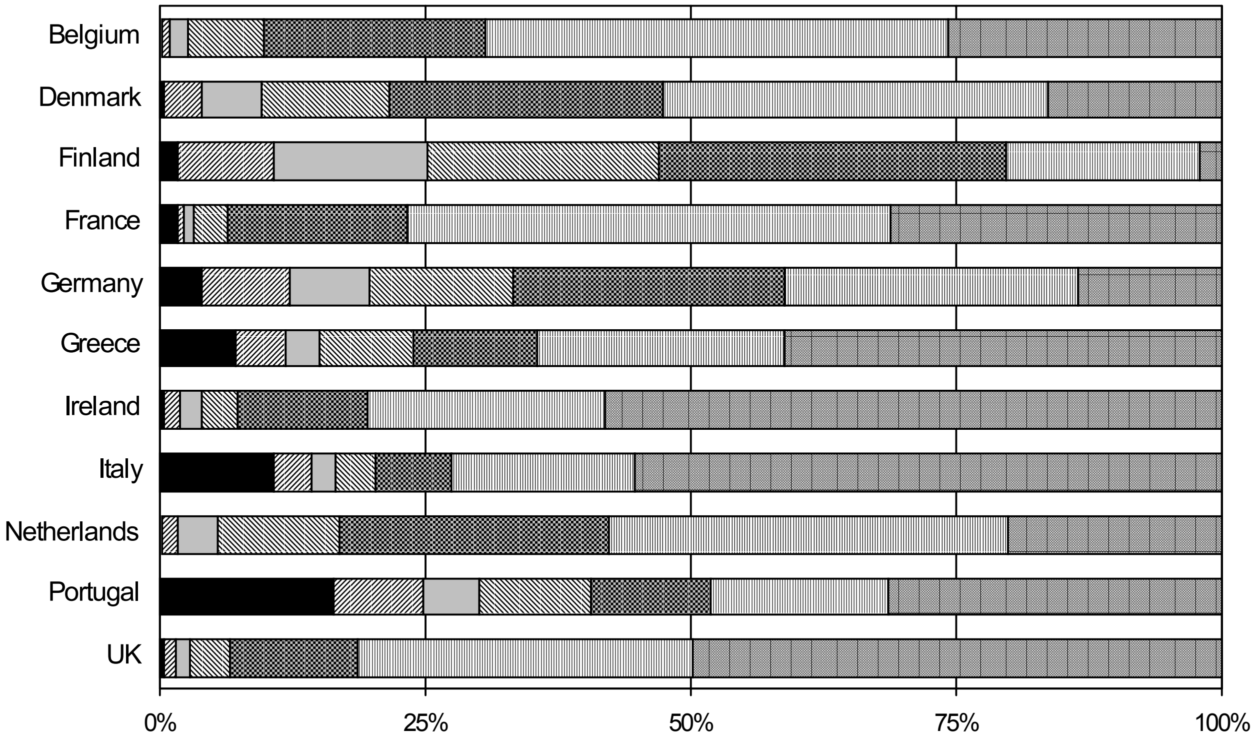
The growing-finishing pig population (Table 5) and the growing-finishing herd structure (Table 6 and 7) are comparable to the ones for sows.

TABLE 5 TOTAL NUMBER OF GROWING–FINISHING PIGS



The most specialised farms (> 1000 growing–finishing pigs) with relatively the largest numbers of growing – finishing pigs/farm are found in Italy (55,3%), Greece (41,4%), Ireland, (58,2%) and the United Kingdom (49,9%) (Table 6).

TABLE 6 DISTRIBUTION OF GROWING-FINISHING ACCORDING TO NUMBER OF GROWING-FINISHING PIGS/FARM (%)



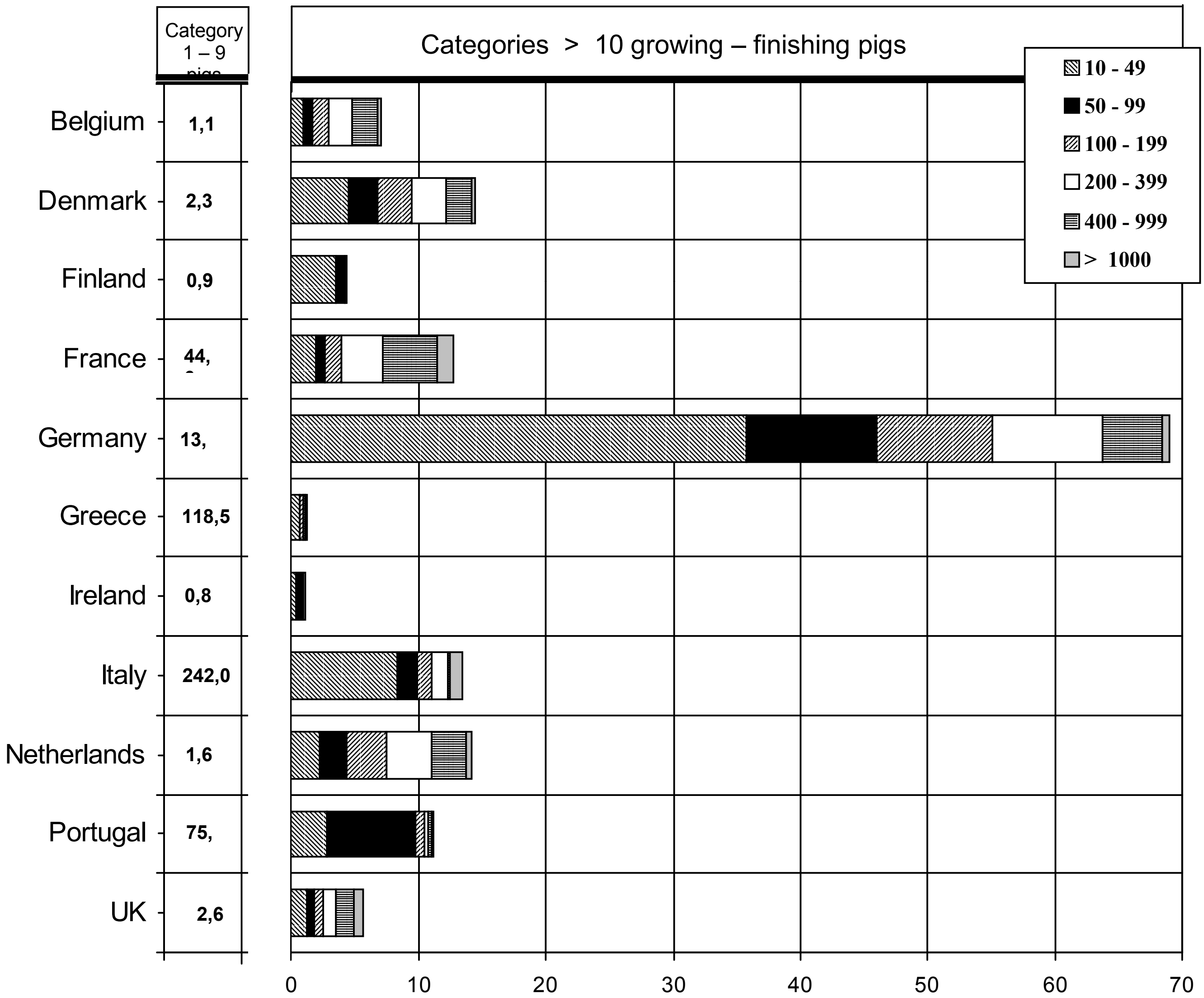
Farm size	UK	Portugal	Netherlands	Italy	Ireland	Greece	Germany	France	Finland	Denmark	Belgium
> 1000	49,9	31,4	20,2	55,3	58,2	41,1	13,5	31,2	2,1	16,4	25,7
400 - 999	31,4	16,7	37,6	17,2	22,4	23,1	27,6	45,5	18,3	36,2	43,7
200 - 399	12,2	11,3	25,3	7,2	12,2	11,7	25,7	16,9	32,6	25,7	20,9
100 - 199	3,6	10,5	11,6	3,8	3,3	8,9	13,5	3,2	21,9	12,2	7
50 - 99	1,4	5,3	3,8	2,3	2,1	3,1	7,5	0,9	14,4	5,5	1,8
10 - 49	1,2	8,5	1,4	3,4	1,5	4,7	8,2	0,7	9,2	3,7	0,8
1 - 9	0,3	16,3	0,2	10,8	0,4	7,1	4	1,6	1,6	0,3	0,1

Farm size	1 - 9	10 - 49	50 - 99	100 - 199	200 - 399	400 - 999	> 1000

Eurostat 95

According to Table 6 almost 95% of the growing-finishing pig farms in Italy have less then 10 animals, which account for only 11% of the total population, while 1% of the farms comprise more then 55% of the animals. A similar pattern is seen in Portugal where 94% farms hold only 16% of the pigs. In Germany two-thirds of the farms account for only 4% of the population.

TABLE 7 DISTRIBUTION OF GROWING-FINISHING FARMS (X 1000) ACCORDING TO FARM SIZE



Farm size	UK	Portugal	Netherlands	Italy	Ireland	Greece	Germany	France	Finland	Denmark	Belgium
> 1000	0,7	0,2	0,5	1	0,1	0,1	0,6	1,2		0,3	0,4
400 - 999	1,4	0,2	2,6	0,2	0,2	0,1	4,7	4,3		1,9	1,9
200 - 399	1	0,4	3,6	1,2	0,2	0,1	8,6	3,3	0,1	2,8	1,9
100 - 199	0,7	0,6	3,2	1,2	0,1	0,2	9,1	1,2	0,1	2,6	1,3
50 - 99	0,6	7	2,1	1,5	0,1	0,1	10,2	0,7	0,7	2,3	0,7
10 - 49	1,2	2,8	2,2	8,4	0,4	0,6	35,8	2	3,5	4,5	0,9
1 - 9	2,6	75,0	1,6	242,0	0,8	13,3	118,5	44,6	0,9	2,3	1,1
Total	8,2	187,5	15,8	256,4	1,9	14,4	187,5	57,3	5,2	16,7	8,2

Eurostat '95

Housing systems for mating (Table 8) follow a somewhat more diverse pattern. Almost 75% of all the mating sows are housed individually and of these more than 70% do not have access to straw. Only in Switzerland individual type housing systems with straw are increasing. In the UK 85% of sows are group housed and the proportion is increasing.

TABLE 8 HOUSING SYSTEMS FOR LACTATING SOWS IN EUROPEAN COUNTRIES (SOWS X 1000)

	No/restricted straw									With straw		
	Partly slatted			Fully slatted			Solid floor concrete			(partly) loose		
Countries	sows	%	tr.	sows	%	tr.	sows	%	tr.	sows	%	tr.
Belgium	131	70	↓	56	30	↑						
Denmark	168	55	↑	107	35	↓				31	10	↑
Finland										45	100	→
France	58	16	↓	261	72	↑	58	12	↓			
Germany	215	33	→	221	34	↑	130	20	↓	85	13	↓
Greece	16	45	↓	16	45	↓	4	10	↓			
Hungary	4	10	→	28	80	→				4	10	↓
Ireland	14	30	↓	33	70	↑						
Italy	17	10	↓	155	90	↑						
Netherlands	181	50	→	181	50	→					<1	→
Portugal	42	50	→	29	35	↑	8	10	↓	4	5	→
Spain	329	60	↓	219	40	↑						
Switzerland	37	90	↓							4	10	↑
UK	91	40	→	54	24	→				81	36	→
Total	1004	42	↓	54	44	↑	8	6	↓	85	**8**	→
	No/restricted straw						2863	**92**	→	with straw		

↑	Increasing	→	Steady	↓	Decreasing	↓↑	No general trend

In countries including Denmark, Finland, the Netherlands, Switzerland and the UK group housing systems are increasing due to legislation prohibiting confinement systems such as stalls and tethers, which are restricting the sows' ability to turn around (Table 9). Denmark has not prohibited individual confinement of sows in mating units, which is due to the fact that several Danish studies have indicated that group housing between weaning and 4 weeks post weaning might increase risk of embryo loss. As a consequence the number of live-born piglets/litter is reduced as compared to individual housing (Nielsen, 1998; Pedersen et al., 1995). The Danish increase in mating units for loose sows is more a reflection of requirements by British retailers demanding that sows are kept loose throughout the entire period from weaning to farrowing. In most other countries individual housing, i.e., stalls, is increasing while loose housing systems for mating are decreasing. In the UK a large part of the sow population is kept in outdoor units, which explains the relatively high number of sows kept in outdoor mating units.

TABLE 9 HOUSING SYSTEMS FOR MATING SOWS IN EUROPEAN COUNTRIES (SOWS X 1000)

	Individual housing						Group housing								
	No/restricted straw			With straw			No/restricted straw			With straw			Outdoor system		
Countries	sows	%	tr.	sows	%	tr.	sows	%	tr.	sows	%	tr.	sows	%	tr.
Belgium	186	99	↓							2	1	↑			
Denmark	278	91	↓				6	2	↑	21	7	↑			
Finland	23	50	↓				23	50	↑						
France	268	74	↑	94	26	↓									
Germany	423	65	↑	98	15	↓	130	20	→						
Greece	26	75	↑				9	25	↓						
Hungary	5	15	→				4	10	→	26	75	→			
Ireland	47	98	→							1	2	→			
Italy	35	20	↑				138	80	↓						
Netherlands	390	95	↓				12	3	↑	8	2	↑			
Portugal	67	80	↑				17	20	↓						
Spain	384	70	↑				164	30	↓						
Switzerland	10	25	↓	10	25	↑	10	10	→	41	40	↑			
UK	37	15	↓				25	10	↑	137	55	↑	50	20	→
Total	2179	68	↓↑	202	6	↓	366	17	→	178	7	↑	50	2	→
	Individual housing systems			2381	**74**	↓↑	Group housing systems						824	**26**	→

↑	Increasing	→	Steady	↓	Decreasing	↓↑	No general trend

Distribution of gestation systems is shown in Table 10. The pattern for gestation systems is similar to the one seen for mating units, i.e., most sows (70%) are kept in individual confinement systems such as stalls and tethers. However, group housing systems tend to increase overall, but particularly in those countries, which have prohibited stalls and tethers. In all countries tether systems are rapidly decreasing most of which is due to legislation banning the use of tethers (Council Directive, 1991).

In the UK most (80%) sows are group housed and have access to straw (60%). The high proportion of loose housed sows might be explained by the British welfare legislation requiring all sows to be loose housed from weaning to farrowing by 1999.

TABLE 10 HOUSING SYSTEMS FOR GESTATING SOWS IN EUROPEAN COUNTRIES (SOWS X 1000)

	Individual						Group housing								
	Tethered			Crates			No/restricted straw			With straw			Outdoor system		
Countries	sows	%	tr.	sows	%	tr.	sows	%	tr.	sows	%	tr.	Sows	%	tr.
Belgium	60	16	↓	300	80	↑	15	4	→						
Denmark	153	25	↓	336	55	↓	61	10	↑	24	4	↑	24	4	↑
Finland				27	30	↓				63	70	↑			
France	116	16	↓	254	35	↑	44	6	→	138	19	↓	65	9	→
Germany	130	10	↓	845	65	→	104	8	↑	221	17	→		< 1	↓
Greece	1	1	↓	25	35	↑	45	64	→						
Hungary				21	30	→	42	60	→	7	10	→			
Ireland	57	60	↓	29	31	→	3	3	↑	6	6	↑		< 1	↑
Italy				155	45	↑	179	52	↓	10	3	→		< 1	→
Netherlands	145	20	↓	544	75	↓	29	4	↑	7	1	↑			
Portugal	50	30	↓	83	50	↑	17	10	↑				17	10	↑
Spain	219	20	↓	570	52	↑	219	20	↓				88	8	↑
Switzerland	8	10	↓	33	40	↓	20	25	→	20	25	↑		< 1	↑
UK	45	10	↓	45	10	↓				271	60	↑	91	20	→
Total	984	16	↓	3267	54	↓↑	702	13	↑	767	12	↑	91	5	↑
	Individual housing systems			4251	**70**	↓	Group housing systems						1830	**30**	↑

↑	Increasing	→	Steady	↓	Decreasing	↓↑	No general trend

In Germany, Ireland and Portugal loose housing systems are also increasing even although these countries have not banned confinement systems for sows. The German trend might reflect general demands by the public for more welfare-friendly systems while the Irish development might reflect demands by British retailers. The reason for the Portuguese increase is not clear, but may be due to factors such as traditions, costs, etc., as mentioned earlier.

Sow housing in Spain and France is dominated by stalls and in Spain, France, Greece and Italy these systems are used increasingly. These countries have not yet been affected by the welfare debate to a large degree. The popularity of stalls in Spain, Greece and Italy might also be a reflection of the structure within the pig industry, which includes few but very large intensive pig units. Yet in these countries a large part of the gestating sows are housed in groups in small and old pig units. Pig production in Spain has grown rapidly in recent years and housing systems are usually based on American technology, which is known for being intensive.

Group-housing systems are frequently installed in non-insulated, cheaper buildings and bedding material is used to compensate for low temperatures. It is therefore not surprising that straw-based systems tend to increase and that the proportion of straw-based systems is similar to those without bedding. Several studies (e.g., Edwards et al., 1994) indicate that fiber might reduce aggression in group housing, which might be the reason for the increase in litter-based systems in countries such as the Netherlands and Ireland where access to straw is limited.

Outdoor systems for gestation sows are increasing in a number of countries including Denmark, Ireland, Spain and Portugal - for reasons mentioned earlier.

Distribution of housing systems for weaned pigs is shown in Table 11. Most pigs are weaned between 3 and 4 weeks and are kept in small groups (8 – 12 pigs/pen). The majority of animals are housed in pens with fully slatted flooring and this system is becoming increasingly popular. Earlier farrowing pens were frequently used for weaned pigs, but this housing method is apparently decreasing except for Greece. Use of pens specifically designed for the weaned pig is increasing, which is due to the fact that environmental control and management is improved as compared to older systems.

TABLE 11 HOUSING SYSTEMS FOR WEANED PIGS (WEANING TO 25-30 KG) IN EUROPEAN COUNTRIES (PIGS X 1000)

	Farrowing pen			Without/restricted straw						With straw		
	(Partly) slatted			Partly slatted			Fully slatted			Fully solid concrete		
Countries	piglets	%	tr.	piglets	%	tr.	piglets	%	tr.	piglets	%	tr.
Belgium	45	2	→	405	18	↑	1689	75	↓	45	2	→
Denmark				1098	30	↑	2196	60	↓	366	10	→
Finland		?			?			?			?	
France	87	2	↓	696	16	→	3045	70	↑	522	12	↓
Germany	624	8	↓	780	10	↓	5694	73	↑	702	9	→
Greece	42	10	↑	105	25	↓	273	65	↑			
Hungary	42	10	↓	21	5	↓	357	85	↑			
Ireland	57	1	→	855	15	↓	4788	84	↑			
Italy	207	10	→	124	6	↓	1656	80	↑	83	4	↓
Netherlands	609	14	↓	1261	29	↑	2480	57	↓			
Portugal	50	5	↓	180	18	↑	750	75	↑	20	2	↑
Spain	82	5	↓	988	60	→	494	30	↑	82	5	→
Switzerland		?			?			?			?	↑
UK				679	25	↑	950	35	→	1086	40	→
Total	65	**5**	↓	679	20	→	950	67	↑	1086	**8**	→
							31564	**87**	↑			

↑	Increasing	→	Steady	↓	Decreasing	↓↑	No general trend

Systems with partly slatted flooring tend to decrease in popularity while fully slatted flooring is increasing except for Denmark, Belgium and the Netherlands. In Denmark systems with a covered lying area and two-thirds solid floor have become increasingly popular in recent years. Research indicates that this system is more energy efficient than conventional heated nurseries. Moreover, pen fouling is not a problem, which is one of the main reasons why pig producers select fully slatted flooring over partly slatted flooring. In Belgium and the

Netherlands there are strong incentives to reduce ammonia emission (Hendriks, 1997). Dutch studies (e.g. Voermans et al., 1992) have shown that increasing the amount of solid floor might reduce emission and farmers are rewarded for installing such systems.

A large proportion (40%) of the weaners in the UK is housed in relatively cheap straw-based systems. Mild climatic conditions and a tradition for use of low-cost housing systems requiring more labour input might be the main explanation for this result. Straw-based systems are also popular in Denmark and France. In both countries large amounts of straw are available and pig production is normally tied in with crop production (cereals). Furthermore, there has been a long tradition for using straw from crops in animal production.

The housing systems used for growing-finishing pigs (Table 12) are similar to the ones used for weaned pigs (Table 11) even although a larger part of the pigs are kept in systems with little or no use of straw. Partly and fully slatted flooring is equally represented, but there is a trend towards more fully slatted flooring - except for Belgium, Denmark, the Netherlands and Switzerland - reasons mentioned above.

TABLE 12 HOUSING SYSTEMS FOR GROWING–FINISHING PIGS IN EUROPEAN COUNTRIES (PIGS X 1000)

	Without/restricted straw									With straw					
	Partly slatted			Fully slatted			Solid concrete			Solid concrete			Deep litter		
Countries	finishers	%	tr.	finishers	%	tr.	finishers	%	tr.	finishers	%	tr.	finishers	%	tr.
Belgium	1092	31	↑	2291	65	↓				71	2	→	71	2	→
Denmark	2185	35	↑	3558	57	↓				312	5	→	187	3	→
Finland		?			?	↓					?	↑			
France	1099	11	→	7994	80	↑	599	6	→				300	3	↓
Germany	9385	60	↓	4693	30	↑				1251	8	↑	313	2	→
Greece	289	60	↓	193	40	↑									
Hungary	420	60	↓	280	40	↑									
Ireland	359	35	↓	615	60	↑				51	5	→			
Italy	3558	60[1]	→	1482	25	↑	890	15	↓						
Netherlands	5997	83	↑	1084	15	↓				145	2	↑			
Portugal	764	55	→	417	30	→	208	15	→						
Spain	5818	50	→	5818	50	↑									
Switzerland	135	20	↑	405	60	↓				135	20	↑			
UK	1756	37	↑	1803	38	↑				712	15	↓	475	10	→
Total	29580	47	↓↑	24784	44	↓↑	208	3	↓	847	4	↑	475	2	↓
	Systems without/restricted straw						65187	**94**	→	Systems with straw			4023	**6**	→

↑	**Increasing**	→	**Steady**	↓	**Decreasing**	↓↑	**No general trend**

[1] Including system with a solid floor with a slatted alley outside

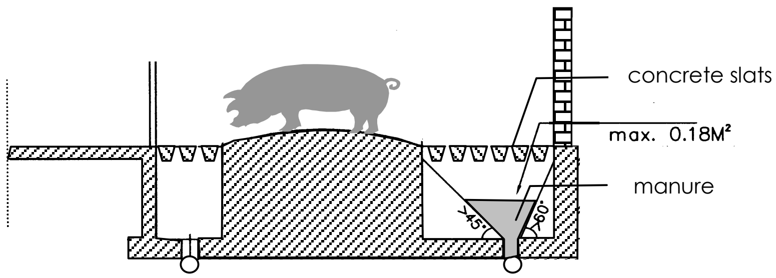
3. CANDIDATE BAT FOR REARING PIGS

3.1. PROCESS INTEGRATED MEASURES

3.1.1. Pen manure channel with slanted side wall(s), partly concrete slatted floor

Category: Rearing pigs
Ammonia emission: 1.2 kg NH_3/ pig place/ year

Description: Side wall(s) on a slope reduces the manure surface. This reduces the ammonia emission. Application is possible in pens with a convex floor. The convex floor separates both channels. The front channel is partially filled with water, because normally the pigs don't use the front area as a dunging area. Only spoiled feed concentrates come into the front channel. The water has manly a function to prevent a breeding ground for flies. Application is also possible in pens with a partly slatted concrete floor consisting of a solid concrete floor on a slope in front of the pen. The manure will be removed frequently by a sewage system. The slats are made of triangle iron bars. The manure channel has a width of at least 1.10 meter. The manure surface in the manure channel should not be larger then 0.18 m^2 per pig place. The surface of the sloping wall(s) should be made of smooth material to prevent attaching of the manure. A sloping wall at the backside is not required, but when a sloping wall is present, then this wall should have a slope between 60 an 90 degrees. The wall next to the solid concrete floor should have a slope of between 45 and 90 degrees. Slats are made of concrete.



Convex floor with concrete slats and side walls on a slope in the manure pit

Working principle:
- Limiting the manure surface in the manure channel,
- Remove the manure frequently by a sewage system.

Application: The system with slanted side wall(s) can be applied in new houses. In existing houses the applicability depends on the dimensions of the existing manure pit. Manure surface max. 0,18 m^2/ pig place.

Advantages: Compared to a fully slatted floor the ammonia reduction is 60%. In other words the remaining emission is 1.2 kg NH_3/ pig place/ year. This system is well applicable in new houses and in most of the existing houses. To implement this system only a few reconstructions are needed and hardly any management regulation. This system doesn't need any energy. The extra costs are almost zero.

Disadvantages: This system has no negative side effects.

Economics: The extra investment costs are 3 per pig place. This means by 60% reduction, 3.0 ⇒ 1.2 kg NH_3, 1.65 per kg NH_3. The extra costs per year are 0.50 per pig place. This means 0.28 per kg NH_3.

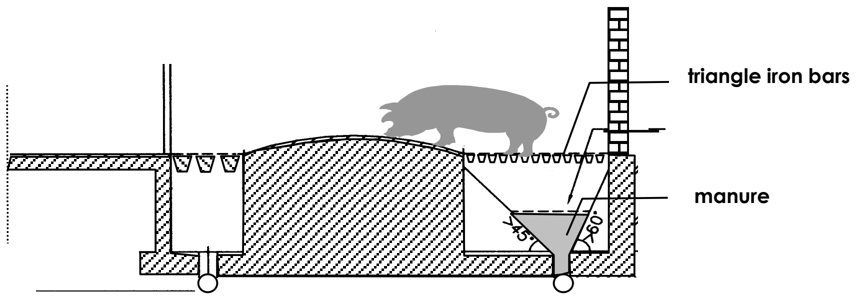
Reference pig places: In the Netherlands about 5.000 rearing pig places are equipped with this system. This system is developed recently (beginning 1999). Nowadays this system is being implemented in many new buildings and reconstructions.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport PV 4.22

3.1.2. Pen manure channel with slanted side wall(s), partly triangle iron bar slatted floor

Category: Rearing pigs
Ammonia emission: 1.0 kg NH_3/ pig place/ year

Description:
Side wall(s) on a slope reduce the manure surface. This reduces the ammonia emission. Application is possible in pens with a convex floor. The convex floor separates both channels. The front channel is partially filled with water. The water has mainly a function to prevent a breeding ground for flies. Application is also possible in pens with a partly slatted floor consisting of a solid concrete floor on a slope in front of the pen. The manure will be removed frequently by a sewage system. The slats are made of triangle iron bars. The manure channel has a width of at least 1.10 meter. The manure surface in the manure channel should not be larger then 0.18 m^2 per pig place. The surface of the sloping wall(s) should be made of smooth material to prevent attaching of the manure. A sloping wall at the backside is not required, but when a sloping wall is present, this wall should have a slope between 60 an 90 degrees. The wall next to the solid concrete floor should have a slope of between 45 and 90 degrees.



Convex floor with a sewage system and slanted side walls in the manure channel

Working principle:
- Limiting the manure surface in the manure channel,
- Fast discharging of the manure on the slatted area by using iron triangle bars,
- Remove the manure frequently by a sewage system.

Applicability: The system with side wall(s) on a slope can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit

Advantages: Compared to a fully slatted floor the ammonia reduction is 65%. In other words the remaining ammonia emission is 1.0 kg NH_3/ pig place/ year. This system doesn't need any extra energy.

Disadvantages: There are no negative side effects.

Economics: The extra investment costs are € 23 per pig place. This means at 65% reduction, € 12 per kg NH_3. The extra annual costs are € 15 per pig place or € 2.70 per kg NH_3.

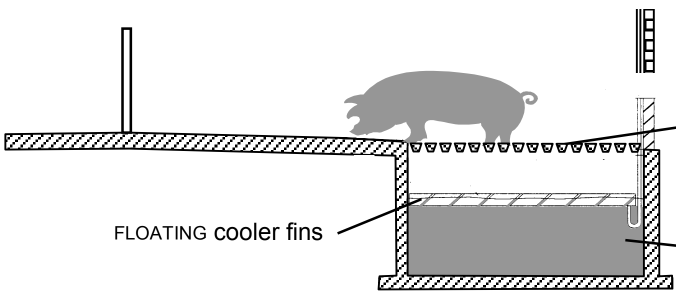
Reference pig places: In the Netherlands about 250.000 rearing pig places are equipped with this system. This system is developed just a few years ago. Nowadays this system is being implemented in most of the new buildings and reconstructions.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport PV 4.22

3.1.3. Manure surface cooling channel

Category: Rearing pigs
Ammonia emission: 1.5 kg NH_3/ pig place/ year (concrete slats)

Description: Floating fins on the manure will cool the surface of the manure. Groundwater is used as a coolant. A number of fins is installed in the manure pit. These fins are filled with water and are floating on the manure. The total surface of the fins has to be a minimum of 200% compared to the manure surface. Groundwater is used as a coolant, which afterwards is pumped back into the underground. The temperature of the groundwater is normally no higher than 12^0 C. The temperature of the top layer of the manure should be not higher than 15^0 C. Application is also possible in pens with a convex floor. The convex floor separates both channels. Slats are made of concrete .



Rearing pen, partly slatted floor with concrete slats and manure surface cooling.

Working principle:
- Cooling the manure.

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 50%. In other words the remaining emission is 1.5 kg NH_3/ pig place/ year.

Disadvantages: This system has higher energy consumption (extra 14 kWh/pig place). In some areas it is not desirable to pump up groundwater or to pump it back into the ground (a potential risk of groundwater pollution).

Economics: The extra investment costs are □ 30.40 per pig place. This means by 50% reduction, 3.0 $\Rightarrow$ 1.5 kg NH_3, □ 20 per kg NH_3. The extra annual costs are □ 5.50 per pig place. This means □ 3.65 per kg NH_3.

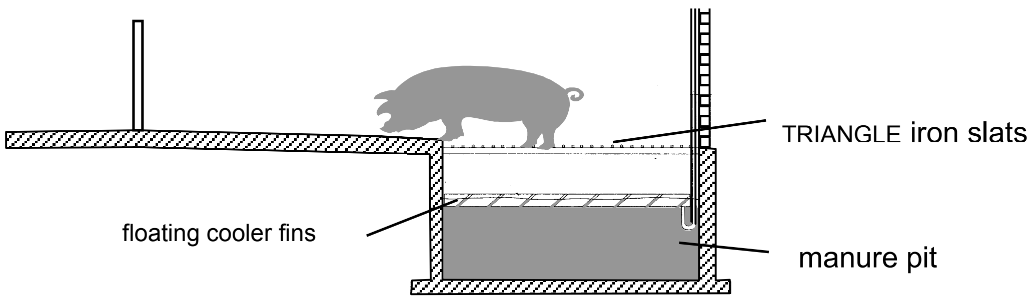
Reference pig places: In the Netherlands about 20.000 rearing pig places are equipped with this system. This system is developed just recently (early 1999). Nowadays this system is being implemented in many of reconstructions situations and in some new buildings.

Reference literature: Wageningen, IMAG-DLO, rapport 96-1003.

3.1.4. Manure surface cooling channel

Category: Rearing pigs
Ammonia emission: 1.2 kg NH_3/ pig place/ year (triangle iron bars)

Description: Floating fins on the manure will cool the surface of the manure. Groundwater is used as a coolant. A number of fins is installed in the manure pit. These fins are filled with water and are floating on the manure. The total surface of the fins has to be a minimum of 200% compared to the manure surface. Groundwater is used as a coolant, which afterwards has to be pumped back into the underground. The temperature of the groundwater is normally no higher than 12^0 C. The temperature of the top layer of the manure should be not higher than 15^0 C. Application is also possible in pens with a convex floor. The convex floor separates both channels. The slats are made of triangle iron slats.



Rearing pen, partly slatted (tri-bar) floor and manure surface cooling.

Working principle:
- Cooling the manure.

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 60%. In other words the remaining emission is 1.2 kg NH_3/ pig place/ year. This system is applicable in every design of a pen.

Disadvantages: This system has higher energy consumption (extra 14 kWh/pig place). The technique holds a potential risk of groundwater pollution.

Economics: Extra investment costs are □ 43 per pig place. This means at 60% reduction □ 24 per kg NH_3. The extra annual costs are □ 8 per pig placeor □ 4.50 per kg NH_3.

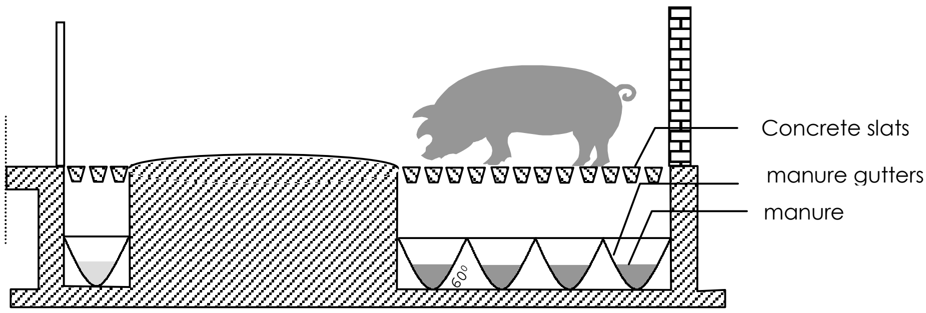
Reference pig places: In the Netherlands about 200.000 rearing pig places are equipped with this system. This system was developed just a few years ago. Nowadays this system is being implemented in many of reconstructions situations and in some new buildings.

Reference literature: Wageningen, IMAG-DLO, rapport 96-1003.

3.1.5. Manure channel with gutters, partly slatted floor with concrete slats.

Category: Rearing pigs
Ammonia emission: 1.2 kg NH_3/ pig place/ year

Description:
Small gutters limit the manure surface. This reduces the ammonia emission. Application is possible in pens with a convex floor. The convex floor separates both channels. Application is also possible in pens with a partly slatted floor consisting of a solid concrete floor on a slope in front of the pen. The manure will be removed frequently by a flushing system. The slats are made of concrete. The manure channel has a width of at least 1.10 meter. The gutters should have a slope of 60 degrees. The gutters should be flushed twice a day. The flushing will be done by the liquid fraction of the manure (after separation) and the dry matter content should not be higher then 5%.



Convex floor with concrete slats in combination with a gutter system

Working principle:
- Limiting the manure surface in the manure channel,
- Two times a day removing the manure by flushing.

Application:
The system with flushing gutters can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit.

Advantages:. Compared to a fully slatted floor the ammonia reduction is 60%. In other words the remaining ammonia emission is 1.0 kg NH_3/ pig place/ year.

Disadvantages: This system has an extra energy consumption due to flushing twice a day (extra 1,5 kWh/pig place). The implementation costs of the system are significant.

Economics: The extra investment costs are € 59 per pig place. This means at 60% reduction € 32.77 per kg NH_3. Extra annual costs per year are € 9.45 per pig place or € 5.25 per kg NH_3.

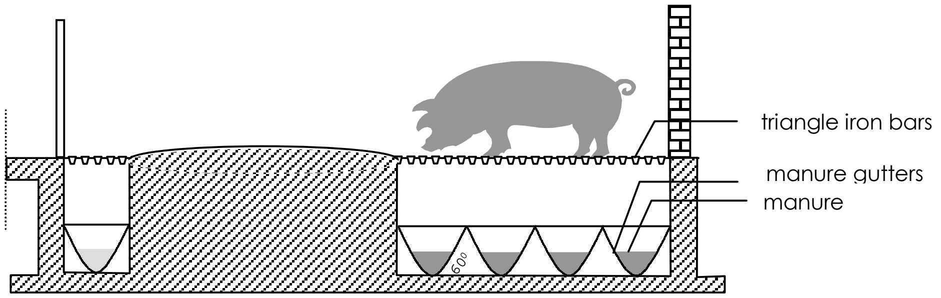
Reference pig places: In the Netherlands about 50.000 rearing pig places are equipped with this system. This system is developed just very recently (early 1999) for the rearing pigs.

Reference literature: Wageningen, IMAG-DLO, rapport P 98-44

3.1.6. Manure channel with gutters, partly slatted floor with triangle iron slats.

Category: Rearing pigs
Ammonia emission: 1.0 kg NH_3/ pig place/ year

Description:
Small gutters limit the manure surface. This reduces the ammonia emission. Application is possible in pens with a convex floor. The convex floor separates both channels. Application is also possible in pens with a partly slatted floor consisting of a solid concrete floor on a slope in front of the pen. The manure will be removed frequently by a flushing system. The slats are made of triangle iron bars. The manure channel has a width of at least 1.10 meter. The gutters should have a slope of 60 degrees. The gutters should be flushed twice a day. The flushing will be done by the liquid fraction of the manure (after separation) and the dry matter content should not be higher then 5%.



Convex floor with triangle iron slats in combination with a gutter system

Working principle:
- Limiting the manure surface in the manure channel;
- Removing the manure two times a day by flushing;
- Fast discharging of the manure on the slatted area by using iron triangle bars.

Application: The system with flushing gutters can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit.

Advantages: Compared to a fully slatted floor the ammonia reduction is 65%. The remaining ammonia emission is 1.0 kg NH_3/ pig place/ year.

Disadvantages:
This system has an extra energy consumption (extra 1,5 kWh/ pig place).

Economics:
The extra investment costs are € 79 per pig place. This means at 65% reduction € 40 per kg NH_3. The extra annual costs are € 12.50 per pig place or € 6.25 per kg NH_3.

Reference pig places:
In the Netherlands about 50.000 rearing pig places are equipped with this system. This system is developed just very recently (early 1999) for the rearing pigs.

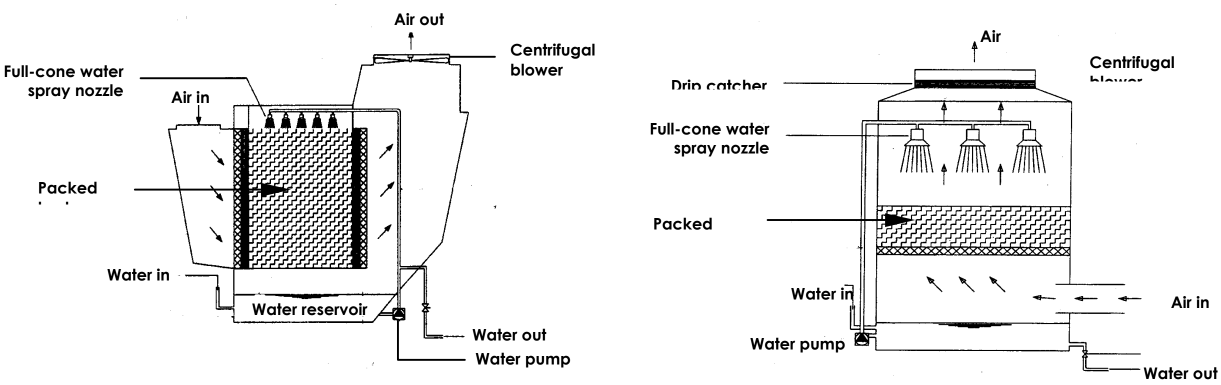
Reference literature: Wageningen, IMAG-DLO, rapport P 98-44

3.2. END-OF-PIPE MEASURES

3.2.1. Bioscrubber

Category: Rearing pigs
Ammonia emission: 0.8 kg NH_3/ pig place/ year

Description: All the ventilation air of the pen will be lead through a biofilter unit. A biolayer formed on the surfaces of the packed material absorbs ammonia so that it can broken down by microbes. Water circulation keeps the biolayer moist and nutrients available for the microorganisms.



Bioscrubber design

Working principle:
- Ammonia absorption and biological breakdown

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings with forced ventilation. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 70% on average (50-90%). In other words the remaining emission is 0.8 kg NH_3/ pig place/ year. There are no adaptations needed inside the building. This system is applicable in every design of a pen.

Disadvantages: The water consumption is increased with about 1 m^3 per pig place and in accordance with this an extra effluent is produced. This system has a higher energy consumption (extra 35 kWh/ pig place).

Economics: The extra investment costs are € 49 per pig place. This means by 70% reduction, 3.0 $\Rightarrow$ 0.8 kg NH_3, € 22.25 per kg NH_3. The extra costs per year are € 16.70 per pig place. This means € 7.60 per kg NH_3.

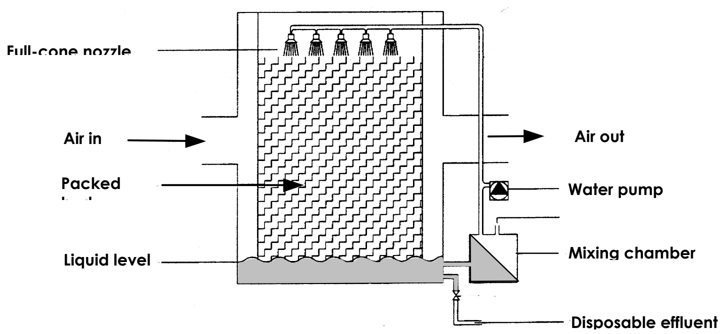
Reference pig places: In the Netherlands about 100.000 rearing pig places are equipped with this system. This system was developed just a few years ago. Nowadays this system is being implemented in some reconstruction situations.

Reference literature: Wageningen, IMAG-DLO, rapport 423. EurAgEng, Vinkeloord 1997, Proceedings pages 521 – 544.

3.2.2. Chemical wetscrubber

Category: Rearing pigs
Ammonia emission: 0.3 kg NH_3/ pig place/ year

Description: Al the ventilation air of the pen will be lead through a chemical scrubbing unit. In this unit an acid scrubbing liquid is pumped around. By contact of the ventilated air with the scrubbing liquid the ammonia will be absorbed by the acid liquid. After that the clean air leaves the system. Diluted sulphuric acid is the most used scrubbing liquid in this system. Hydrochloric acid solutions may also be used.



Chemical wetscrubber design

Working principle:
- Ammonia absorption: $2\ NH_3 + H_2SO_4 \rightarrow 2\ NH_4^+ + SO_4^-$.

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 90%, depending on the quantity of acid and the residence time of the ventilated air in the system. The remaining emission is 0.3 kg NH_3/ pig place/ year. There are no adaptations needed inside the building. This system is applicable in every design of a pen.

Disadvantages: This system can’t be used in a natural ventilated pig house. The effluent from the scrubber contains increased levels of sulphate or chloride, depending on the type of acid used. This system has higher energy consumption (extra 55 kWh/ pig place).

Economics: The extra investment costs are □ 43 per pig place. This means by 90% reduction, 3.0 $\Rightarrow$ 0.3 kg NH_3, □ 15.95 per kg NH_3. The extra costs per year are □ 14 per pig place. This means □ 5.20 per kg NH_3.

Reference pig places: In the Netherlands about 100.000 rearing pig places are equipped with this system. This system was developed just a few years ago. Nowadays this system is being implemented in some reconstruction situations.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport P 1.178.

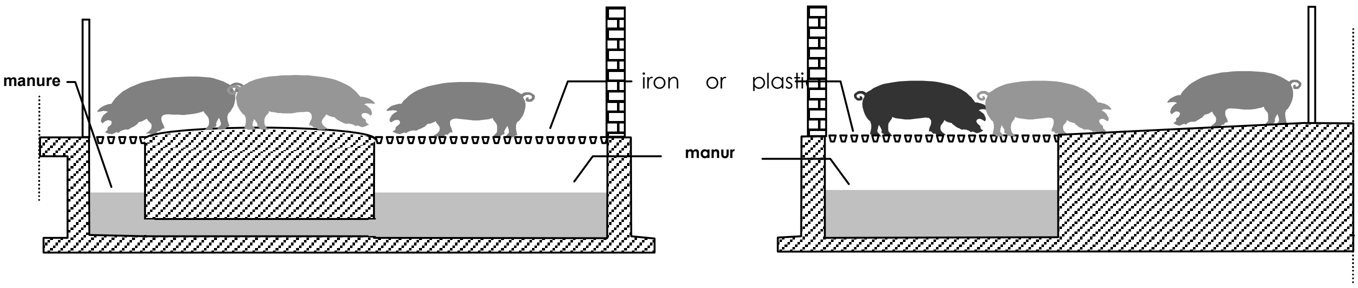
4. CANDIDATE BAT FOR WEANED PIGLETS

4.1. PROCESS INTEGRATED MEASURES

4.1.1. Partly slatted or a convex floor with iron or plastic slats.

Category: weaned piglets
Ammonia emission: 0.34 kg NH_3/ pig place/ year

Description: Using a partly concrete solid floor reduce the manure surface. Limiting the manure surface reduces the ammonia emission. Application is possible in pens with a convex floor. The convex floor separates both channels. Application is also possible in pens with a partly slatted floor consisting of a solid concrete floor on a slope in front of the pen. The design of the slats can be done in iron or plastic (not concrete slats).



Partly slatted and convex floor with iron or plastic slats

Working principle:
- Limiting the manure surface in the manure channel.

Application: The system with partly slatted floor or a convex floor can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit.

Advantages: This system is well applicable. To implement this system only a few reconstructions are needed.

Disadvantages: This system has no negative side effects

Economics: Compared to a fully slatted floor the ammonia reduction is 43%. In other words the remaining ammonia emission is 0.34 kg NH_3/ pig place/ year. The extra investment costs are nearly zero.

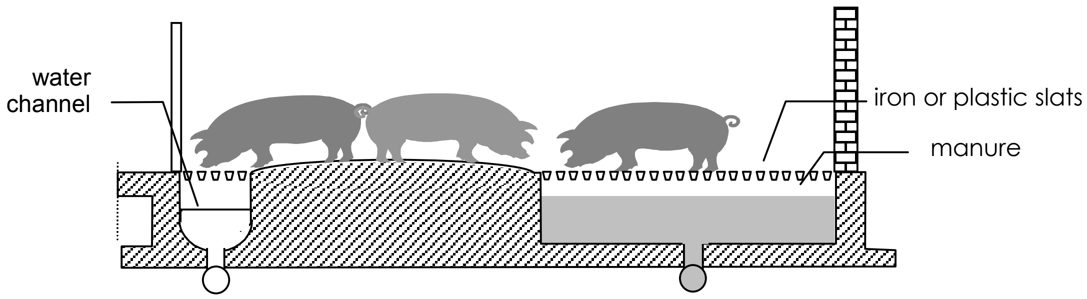
Reference pig places: In the Netherlands about 1.000.000 weaned piglets places are equipped with this system.

Reference literature: Wageningen, IMAG-DLO, rapport P 1.141

4.1.2. Shallow manure pit with a channel for spoiled drinking water.

Category: weaned piglets
Ammonia emission: 0.26 kg NH_3/ pig place/ year

Description:
Using a partly concrete solid floor reduce the manure surface. Limiting the manure surface reduces the ammonia emission. Application is possible in pens with a convex floor. The convex floor separates both channels. The front channel is partially filled with water, because normally the pigs don't use the front area as a dunging area. Only spoiled feed concentrates come into the front channel. The water has manly a function to prevent a breeding ground for flies.



Shallow manure pit with a channel for spoiled drinking water in front in combination with a convex floor with iron or plastic slats

Working principle:
- Limiting the manure surface in the manure channel,
- Fast discharging of the manure on the slatted area by using iron triangle bars,
- Remove the manure frequently by a sewage system.

Application: The system with a convex floor can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit.

Advantages: Compared to a fully slatted floor the ammonia reduction is 55%. The remaining ammonia emission is 0.26 kg NH3/ pig place/ year. This system is well applicable, especially in new houses. To implement this system only a few reconstructions are needed and hardly any management regulation. This system doesn't need any energy. The costs are also low.

Disadvantages: There are no negative side effects.

Economics: The extra investment costs are □ 5.65 per pig place. This means by 55% reduction, 0.6 $\Rightarrow$ 0.26 kg NH3, □ 16.60 per kg NH3. The extra costs per year are □ 0.45 per pig place. This means □ 1.35 per kg NH3.

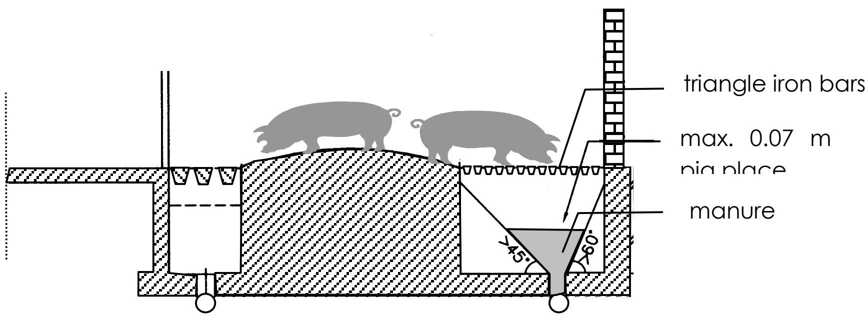
Reference pig places: In the Netherlands about 250.000 weaned piglet places are equipped with this system.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport PV P1.41

4.1.3. Pen manure channel with side wall(s) on a slope, partly triangle iron bar slatted floor

Category: Weaned piglets
Ammonia emission: 0.17 kg NH3/ pig place/ year

Description:
Side wall(s) on a slope reduce the manure surface. This in its turn reduces the ammonia emission. Application is possible in pens with a convex floor. The convex floor separates both channels. The front channel is partially filled with water, because normally the pigs don't use the front area as a dunging area. Only spoiled feed concentrates come into the front channel. The water has mainly a function to prevent a breeding ground for flies. Application is also possible in pens with a partly slatted floor consisting of a solid concrete floor on a slope in front of the pen. The manure will be removed frequently by a sewage system. The slats are made of triangle iron bars. The manure surface in the manure channel should not be larger then 0.07 m2 per pig place. The surface of the sloping wall(s) should be made of smooth material to prevent attaching of the manure. A sloping wall at the backside is not required, but when a sloping wall is present, then this wall should have a slope between 60 and 90 degrees. The wall next to the solid concrete floor should have a slope of between 45 and 90 degrees.



Convex floor with triangle iron slats in combination with sewage system and side walls on a slope in the manure channel

Working principle:
- Limiting the manure surface in the manure channel,
- Fast discharging of the manure on the slatted area by using iron triangle bars,
- Remove the manure frequently by a sewage system.

Applicability: The system with side wall(s) on a slope can be applied in new houses. To implement this system in existing houses only a few reconstructions are needed.

Advantages: Compared to a fully slatted floor the ammonia reduction is 72%. The remaining ammonia emission is 0.17 kg NH3/ pig place/ year. This system doesn't need extra energy.

Disadvantages: There are no negative side effects.

Economics: Extra investment costs are € 4.55 per pig place. This means at 72% reduction € 10.60 per kg NH3. Extra annual costs are € 0.75 per pig place or € 1.70 per kg NH3.

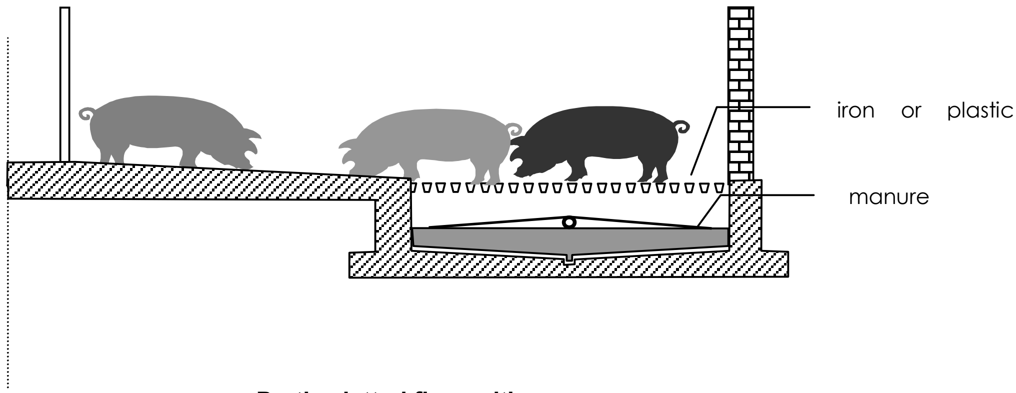
Reference pig places:
In the Netherlands about 50.000 weaned piglet places are equipped with this system. This system is recently developed (1998). Nowadays this system is being implemented in most of the new buildings and reconstructions.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport PV P4.31

4.1.4. Manure scraper under the slats

Category: weaned piglets
Ammonia emission: 0.18 kg NH_3/ pig place/ year

Description:
Mucking out frequently the manure reduces the ammonia emission. The floor of the manure pit has to be very smooth and fit with a top coating. Application is possible in pens with a convex floor. The convex floor separates both channels. Application is also possible in pens with a partly slatted floor consisting of a solid concrete floor on a slope in front of the pen. The design of the slats can be done in iron or plastic (not concrete slats).



Partly slatted floor with a manure scraper

Working principle:
- Removing frequently the manure in the manure pit outside the building.

Application: The system with partly slatted floor or a convex floor can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit, but mostly difficult to apply.

Advantages: This system is applicable in every width and length of a manure pit.

Disadvantages: This system is not easily applicable in an existing pig house. To implement this system some reconstructions are needed in the manure pit. The working of the system is vulnerable due to the wear of the top coating on the floor. This system is expensive.

Economics: Compared to a fully slatted floor the ammonia reduction is 70%. In other words the remaining ammonia emission is 0.18 kg NH3/ pig place/ year. The extra investment costs are □ 68.65 . This means by 70% reduction, 0.6 ⇒ 0.18 kg NH_3, □ 164 per kg NH_3. The extra costs per year are □ 12.30 per pig place. This means □ 29.30 per kg NH_3.

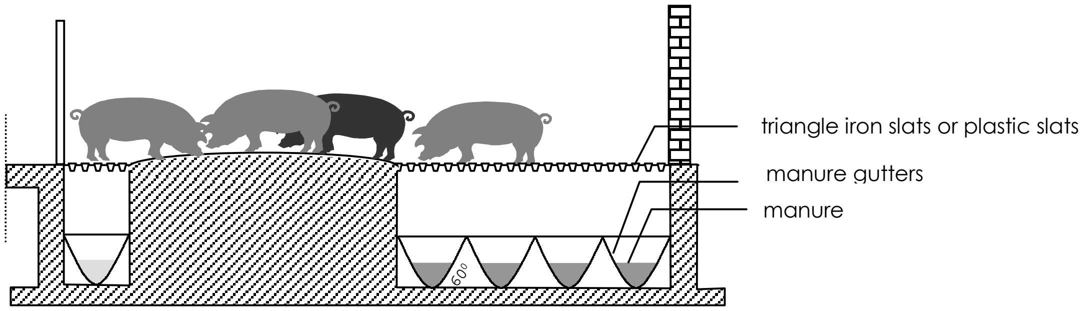
Reference pig places: In the Netherlands about 40.000 weaned piglet places are equipped with this system.

Reference literature: Wageningen, IMAG-DLO, rapport P 92-1001

4.1.5. Manure channel with gutters, partly slatted floor with triangle iron slats.

Category: Weaned piglets
Ammonia emission: 0.21 kg NH_3/ pig place/ year

Description:
Small gutters limit the manure surface. This reduces the ammonia emission. Application is possible in pens with a convex floor. The convex floor separates both channels. Application is also possible in pens with a partly slatted floor consisting of a solid concrete floor on a slope in front of the pen. The manure will be removed frequently by a flushing system. The slats are made of triangle iron slats or plastic bars. The gutters should have a slope of 60 degrees. The gutters should be flushed twice a day. The flushing will be done by the liquid fraction of the manure (after separation) and the dry matter content should not be higher then 5%.



Convex floor with triangle iron slats in combination with a gutter system

Working principle:
- Limiting the manure surface in the manure channel,
- Removing the manure two times a day by flushing.
- Fast discharging of the manure on the slatted area by using iron triangle bars,

---

Application: The system with flushing gutters can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit.

Advantages: This system is well applicable. To implement this system only a few reconstructions are needed.

Disadvantages: This system has an extra energy consumption due to flushing twice a day (extra 0,75 kWh/ pig place). The implementation costs of the system are significant.

Economics: Compared to a fully slatted floor the ammonia reduction is 65%. In other words the remaining ammonia emission is 0.21kg NH_3/ pig place/ year. The extra investment costs are □ 25 per pig place. This means by 65% reduction, 0.6 ⇒ 0.21 kg NH_3, □ 64.10 per kg NH_3. The extra costs per year are □ 4.15 per pig place. This means □ 10.65 per kg NH_3.

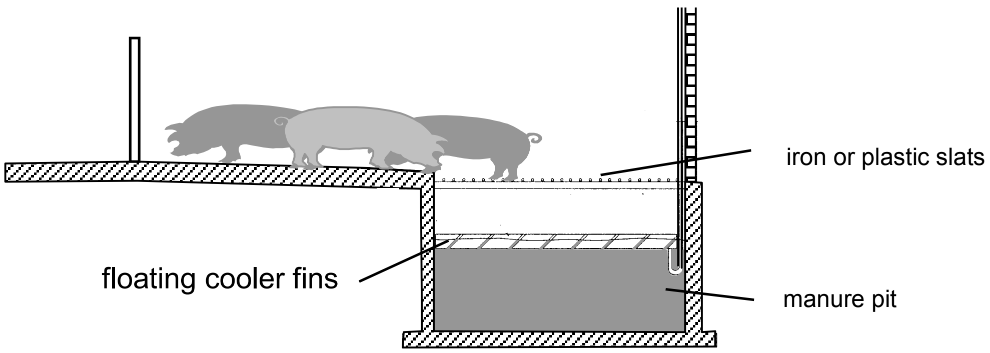
Reference pig places: In the Netherlands about 75.000 weaned piglets places are equipped with this system.

Reference literature: Wageningen, IMAG-DLO, rapport P 94-1005

4.1.6. Manure surface cooling channel

Category: Weaned piglets
Ammonia emission: 0.15 kg NH_3/ pig place/ year

Description: Floating fins on the manure will cool the surface of the manure. Groundwater is used as a coolant. A number of fins is installed in the manure pit. These fins are filled with water and are floating on the manure. The total surface of the fins has to be a minimum of 200% compared to the manure surface. Groundwater is used as a coolant, which is pumped back into the underground after use. The temperature of the groundwater is normally no higher than 12^0C. The temperature of the top layer of the manure should be not higher than 15^0 C. Application does not depend on the pen design, a convex or a partly slatted floor. The slats are made of iron or plastic bars.



Pen for weaners, partly slatted floor and manure surface cooling.

Working principle:
- Cooling the manure.

Application: This system is easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen is not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 75%. The remaining emission is 0.15 kg NH_3/ pig place/ year. This system is applicable in every design of a pen.

Disadvantages: This system has higher energy consumption (extra 6.5 kWh/ pig place). In some areas is not desirably to pump groundwater or to pump it back into the ground (a potential risk of groundwater pollution).

Economics: The extra investment costs are € 24 per pig place. This means by 75% reduction, 0.6 $\Rightarrow$ 0.15 kg NH_3, € 53.30 per kg NH_3. The extra costs per year are € 4.40 per pig place. This means € 9.75 per kg NH_3.

Reference pig places: In the Netherlands about 150.000 weaned piglets places are equipped with this system. This system is developed just a few years ago. Nowadays this system is being implemented in many of reconstructions situations and in some new buildings.

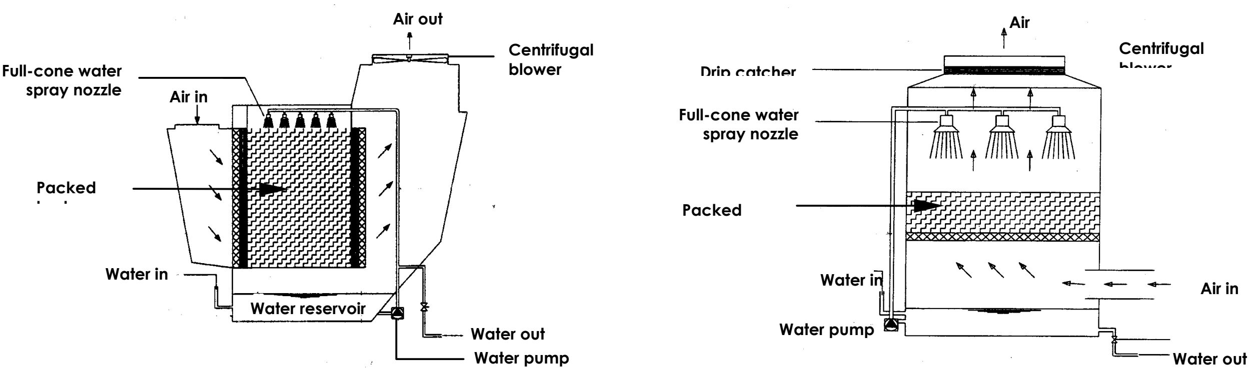
Reference literature: Wageningen, IMAG-DLO, rapport 97-1002.

4.2. END-OF-PIPE MEASURES

4.2.1. Bioscrubber

Category: Weaned piglets
Ammonia emission: 0.18 kg NH_3/ pig place/ year

Description: All the ventilation rate will be lead through a biofilter unit. A biolayer formed on the surfaces of the packed material absorbs ammonia so that it can broken down by microbes. Water circulation keeps the biolayer moist and nutrients available for the microorganisms.



Bioscrubber design

Working principle:

- Ammonia absorption and breakdown.

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 70% on average (50-90%). In other words the remaining emission is 0.18 kg NH_3/ pig place/ year. There are no adaptations needed inside the building. This system is applicable in every design of a pen.

Disadvantages: This system can’t be used in a natural ventilated pig house. The water consumption is increased with about 1 m^3 per pig place and in accordance with this an extra effluent is produced. This system has higher energy consumption (extra 8 kWh/ pig place).

Economics: The extra investment costs are □ 10 per pig place. This means at 70% reduction □23.80 per kg NH_3. The extra annual costs are □ 3.35 per pig placeor □ 7.95 per kg NH_3.

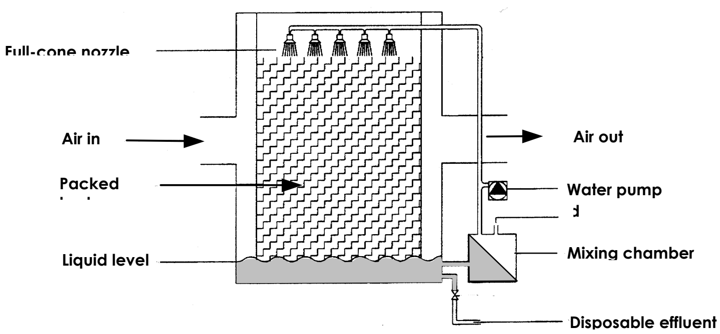
Reference pig places: In the Netherlands about 20.000 weaned piglet places are equipped with this system. This system is developed just a few years ago. Nowadays this system is being implemented in some reconstruction situations.

Reference literature: Wageningen, IMAG-DLO, rapport 423. EurAgEng, Vinkeloord 1997, Proceedings pages 521 – 544.

4.2.2. Chemical wet scrubber

Category: weaned piglets
Ammonia emission: 0.06 kg NH_3/ pig place/ year

Description: All the ventilation rate will be lead through a chemical scrubbing unit. In this unit an acid scrubbing liquid is pumped around. By contact of the ventilated air with the scrubbing liquid the ammonia will be absorbed by the acid scrubbing liquid. After that the clean air leaves the system. Diluted sulphuric acid is mostly used in this system, but a hydrochloric acid solution may also be used.



Chemical wet scrubber design

Working principle:

- Ammonium absorption: $2\ NH_3 + H_2SO_4 \rightarrow 2\ NH_4^{+} + SO_4^{-}$.

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 90%, depending on the quantity of acid and the residence time of the ventilated air in the system. The remaining emission is 0.06 kg NH_3/ pig place/ year. There are no adaptations needed inside the building. This system is applicable in every design of a pen.

Disadvantages: This system can't be used in a natural ventilated pig house. The effluent contains increased levels of sulphate or chloride, depending on the type of acid used. This system has higher energy consumption (extra 10 kWh/ piglet place).

Economics: The extra investment costs are □ 9.00 per pig place. This means by 90% reduction, 0.6 ⇒ 0.06 kg NH_3, □ 16.65 per kg NH_3. The extra costs per year are □ 3.00 per pig place. This means □ 5.55per kg NH_3.

Reference pig places: In the Netherlands about 40.000 weaned piglet places are equipped with this system. This system is developed just a few years ago. Nowadays this system is being implemented in some reconstruction situations.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport P 1.178.

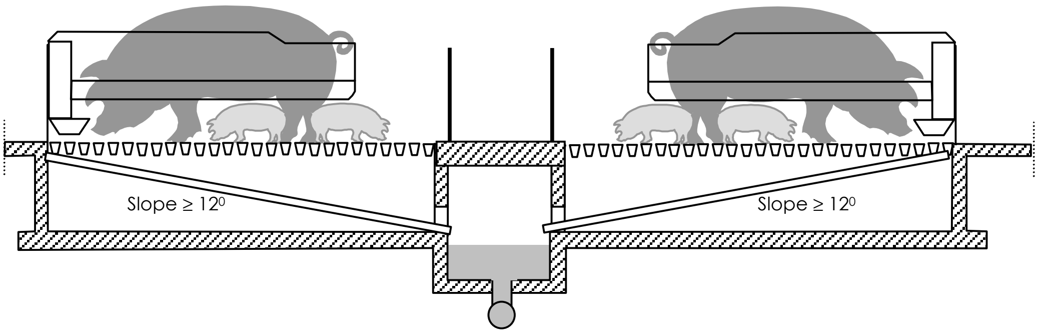
5. CANDIDATE BAT FOR FARROWING SOWS

5.1. PROCESS INTEGRATED MEASURES

5.1.1. Board on a slope under the slatted floor.

Category: Farrowing sows
Ammonia emission: 5.0 kg NH3/ sow place/ year

Description: A board with a very smooth surface is placed under the slatted floor and can be adapted to the dimensions of the pen. The board is deepest at the end of the pen and has a slope of at least 12 degrees. The collecting manure pit is connected with a sewage system. The manure should be removed weekly by the sewage system. Application does not depend on the pen design, a fully or a partly slatted floor. The slats are made of iron or plastic.



Working principle:
- Limiting the manure surface,
- Remove the manure frequently by a sewage system.

Application: This system is easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen is not critical for the applicability of the system. In the mean time a new system has been developed (see 5.1.3) which is based on the same principles as the described system. That new system, a combination of a water and manure channel, has a higher ammonia reduction and is not more expensive than this system. That's the reason why this system is no longer popular.

Advantages: Compared to a fully slatted floor in combination of a manure storage pit, the ammonia reduction is 40%. In other words the remaining emission is 5.0 kg NH3/ pig place/ year. This system is applicable in almost every design of a pen.

Disadvantages: This system has no negative side effects.

Economics: The extra investment costs are □ 260 per pig place. This means by 40% reduction, 8.3 ⇒ 5.0 kg NH3, □ 78.80 per kg NH3. The extra costs per year are □ 29.50 per pig place. This means □ 8.95 per kg NH3.

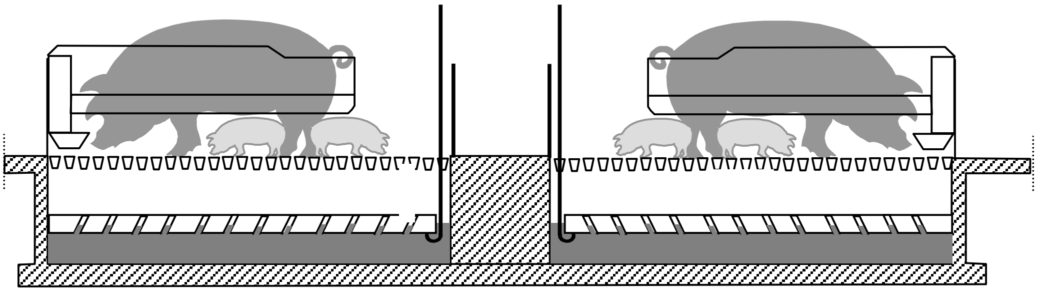
Reference pig places: In the Netherlands just a few sow places are equipped with this system. This system is overruled by a new system (see 5.1.3) which is based on the same principles, but has a different design.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport PV P1.134

5.1.2. Manure surface cooling channel

Category: Farrowing sows
Ammonia emission: 2.4 kg NH_3/ pig place/ year

Description: Floating fins on the manure will cool the surface of the manure. Groundwater is used as a coolant. A number of fins is installed in the manure pit. These fins are filled with water and are floating on the manure. The total surface of the fins has to be a minimum of 200% compared to the manure surface. Groundwater is used as a coolant, which is pumped back into the underground after use. The temperature of the groundwater is normally no higher than 12^0 C. The temperature of the top layer of the manure should not be higher than 15^0 C.



Farrowing pen with floating cooler fins

Working principle:
- Cooling the manure.

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 70%. Thus, the emission is 2.4 kg NH_3/pig place/year. The system is applicable in every design of a pen.

Disadvantages: This system has higher energy consumption (extra 18 kWh/ pig place). In some areas is not desirable to pump up groundwater or to pump it back into the ground (a potential risk of groundwater pollution). The systems is relative expensive.

Economics: The extra investment costs are □ 302 per pig place. This means by 70% reduction, 8.3 $\Rightarrow$ 2.4 kg NH_3, □ 51.20 per kg NH_3. The extra costs per year are □ 54.25 per pig place. This means □ 9.20 per kg NH_3.

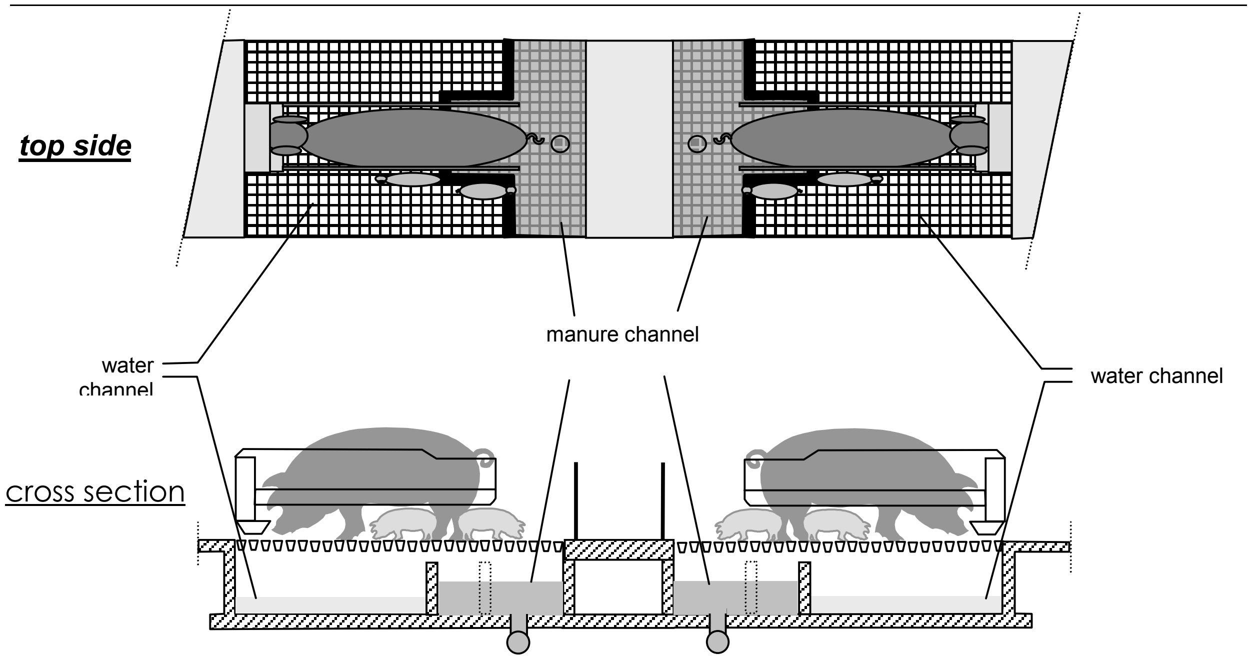
Reference pig places: In the Netherlands about 10.000 farrowing pens are equipped with this system. Nowadays this system is being implemented in many reconstruction situations and in some new buildings.

Reference literature: Wageningen, IMAG-DLO, rapport 97-1002.

5.1.3. Combination of a water- and manure channel.

Category: Farrowing sows
Ammonia emission: 4.0 kg NH_3/ sow place/ year

Description: The sow has a fixed place and as a result it is foreseeable where the dunging area will be. The manure pit is split up into a wide water channel at the front and a small manure channel at the backside. This reduces the manure surface tremendously, which in turn reduces the ammonia emission. The front channel is partly filled with water. The slats are made of iron or plastic.



Combination of a water- and manure channel.

Working principle:
- Limiting the manure surface,
- Remove the manure frequently by a sewage system.

Application: This system is easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen is not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor in combination of a manure storage pit, the ammonia reduction is 50%. In other words the remaining emission is 4.0 kg NH_3/ pig place/ year. This system is applicable in almost every design of a pen.

Disadvantages: This system has no negative side effects.

Economics: The extra investment costs are □ 60 per pig place. This means at 50% reduction □ 13.85 per kg NH_3. The extra annual costs are □ 1.00 per pig place or □ 0.25 per kg NH_3.

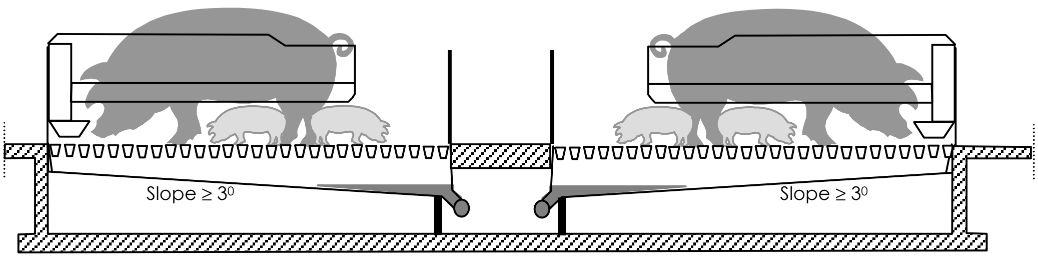
Reference pig places: In the Netherlands 50.000 sow places are equipped with this system. This system is very popular in the Netherlands.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport PV P1.169

5.1.4. Manure pan

Category: Farrowing sows
Ammonia emission: 2.9 kg NH3/ sow place/ year

Description: A prefab pan is placed under the slatted floor and can be adapted to the dimensions of the pen. The pan is deepest at the end of the pen and the pan has a slope of at least 3 degrees. The pan is connected with a sewage system. Every three days the manure should be removed by the sewage system. Application does not depend on the pen design, a fully or a partly slatted floor. The slats are made of iron or plastic slats.



Working principle:
- Limiting the manure surface,
- Remove the manure frequently by a sewage system.

Application: This system is easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen is not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor in combination of a manure storage pit, the ammonia reduction is 65%. In other words the remaining emission is 2.9 kg NH3/ pig place/ year. This system is applicable in almost every design of a pen.

Disadvantages: This system has no negative side effects.

Economics: The extra investment costs are € 280 per pig place. This means by 65% reduction, 8.3 ⇒ 2.9 kg NH3, € 53.85 per kg NH3. The extra costs per year are € 45.85 per pig place. This means € 8.80 per kg NH3.

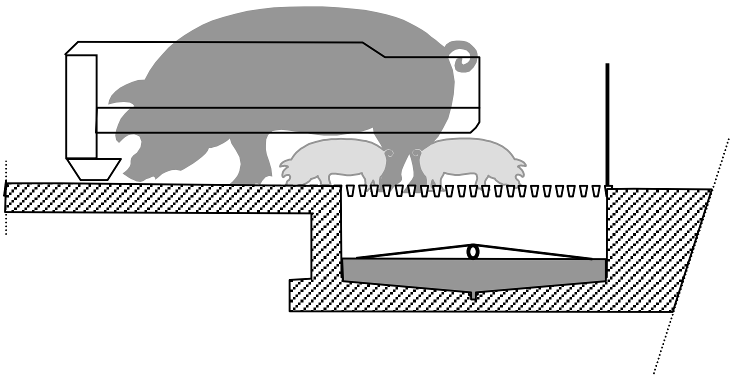
Reference pig places: In the Netherlands about 10.000 sow places are equipped with this system. This system is just developed (at the end of the year1998). Nowadays this system is being implemented in many of reconstruction situations and in new buildings.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport PV P1.201

5.1.5. Manure Scraper

Category: Farrowing sows
Ammonia emission: 4.0 kg NH3/ sow place/ year

Mucking out frequently the manure reduces the ammonia emission. The floor of the manure pit has to be very smooth and fit with a top coating. Application is possible in pens with a partly or fully slatted floor. The slats can be made of iron or plastic (no concrete slats).



Partly slatted floor with a manure scraper

Working principle:
- Removing the manure frequently to the manure pit outside the building.

Application: The system with a partly or fully slatted floor can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit, but it is mostly difficult to apply.

Advantages: This system is applicable in every width and length of a manure pit.

Disadvantages: This system is not very applicable in an existing pig house. To implement this system some reconstructions are needed in the manure pit. The working of the system is vulnerable due to the wear of the top floor. The electricity consumption is 3.5 kWh per sow pen. This system is expensive.

Economics: Compared to a fully slatted floor the ammonia reduction is 50%. In other words the remaining ammonia emission is 4.0 kg NH3/ pig place/ year. The extra investment costs are □ 785. This means by 50% reduction, 8.3 ⇒ 4.0 kg NH_3, □ 182.55 per kg NH_3. The extra costs per year are □ 147.20 per pig place. This means □ 34.20 per kg NH_3.

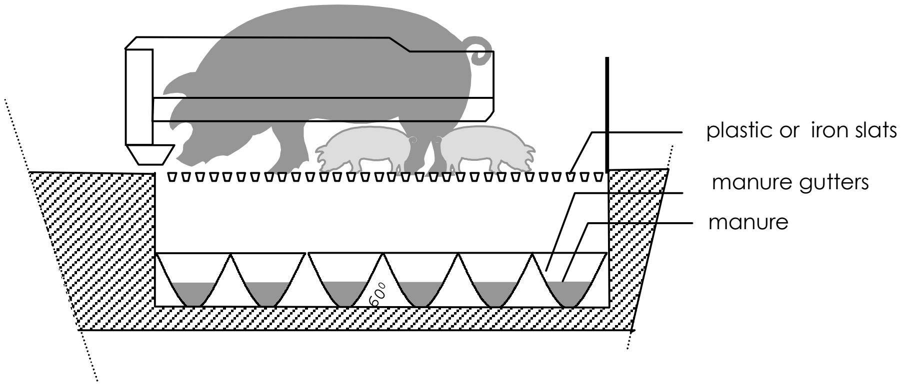
Reference pig places: In the Netherlands about 1.000 farrowing sow places are equipped with this system. Nowadays this system is not implemented any more.

Reference literature: Wageningen, IMAG-DLO, rapport P 92-1002

5.1.6. Flushing system with manure gutters

Category: Farrowing sows
Ammonia emission: 4.0 kg NH3/ sow place/ year

Small gutters limit the manure surface. This reduces the ammonia emission. Application is possible in pens with a partly or fully slatted floor. The manure will be removed frequently by a flushing system. The slats are made of triangle iron slats. The gutters should have a slope of 60 degrees. The gutters should be flushed twice a day. The flushing will be done by the liquid fraction of the manure (after separation) and the dry matter content should not be higher than 5%.



Flushing sytem with manure gutter

Working principle:
- Limiting the manure surface in the manure channel;
- Removing the manure two times a day by flushing;
- Fast discharging of the manure from the slatted area by using iron triangle bars.

Application: The system with flushing gutters can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit.

Advantages:. Compared to a fully slatted floor the ammonia reduction is 60%. In other words the remaining ammonia emission is 3.3 kg NH_3/ pig place/ year.

Disadvantages: This system has an extra energy consumption (extra 8.5 kWh/ pig place).

Economics: The extra investment costs are □ 535 per sow place. This means by 60% reduction, 8.3 ⇒ 3.3 kg NH_3, □ 107 per kg NH_3. The extra costs per year are □ 86.00 per pig place. This means □ 17.20 per kg NH_3.

Reference pig places: In the Netherlands about 500 farrowing sow places are equipped with this system.

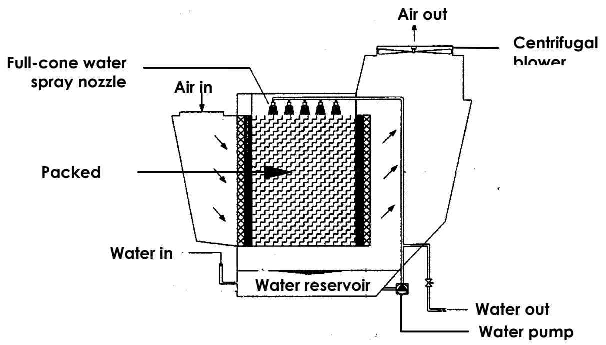
Reference literature: Wageningen, IMAG-DLO, rapport 93-1004

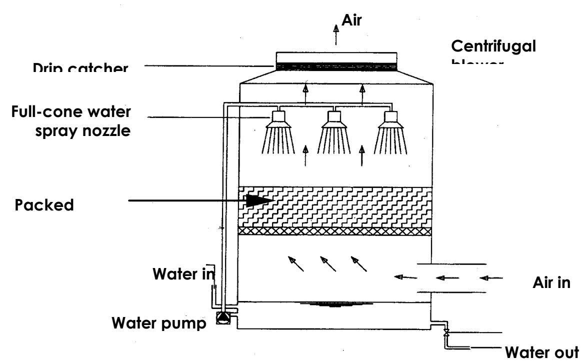
5.2. END-OF-PIPE MEASURES

5.2.1. Bioscrubber

Category: Farrowing sows
Ammonia emission: 2.5 kg NH_3/ pig place/ year

Description: All the ventilation rate will be lead through a biofilter unit. A biolayer formed on the surfaces of the packed material absorbs ammonia so that it can broken down by microbes. Water circulation keeps the biolayer moist and nutrients available for the microorganisms.





Working principle:
- Ammonia absorption and breakdown.

Bioscrubber design

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings, but only if forced ventilation is applied. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 70% on average (50-90%). In other words the remaining emission is 2.5 kg NH_3/ pig place/ year. There are no adaptations needed inside the building. This system is applicable in every design of a pen.

Disadvantages: The water consumption is increased with about 1 m^3 per pig place and in accordance with this an extra effluent is produced. This system has higher energy consumption (extra 35 kWh/ sow place).

Economics: The extra investment costs are □ 111.35 per pig place. This means by 70% reduction, 8.3 $\Rightarrow$ 2.5 kg NH_3, □ 19.20 per kg NH_3. The extra costs per year are □ 32.75 per pig place. This means □ 5.65 per kg NH_3.

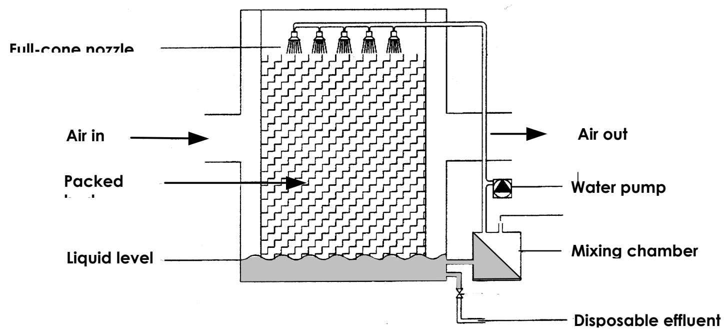
Reference pig places: In the Netherlands about 1.000 farrowing sow places are equipped with this system. This system was developed just a few years ago. Nowadays this system is being implemented in some reconstruction situations.

Reference literature: Wageningen, IMAG-DLO, rapport 423. EurAgEng, Vinkeloord 1997, Proceedings pages 521 – 544.

5.2.2. Chemical wetscrubber

Category: Farrowing sows
Ammonia emission: 0.8 kg NH_3/ pig place/ year

Description: All the ventilation rate will be lead through a chemical scrubbing unit. In this unit an acid scrubbing water is pumped around. By contact of the ventilated air with the scrubbing liquid the ammonia will be absorbed by the acid scrubbing liquid. After that the clean air leaves the system. Diluted sulphuric acid is mostly used in this system. Hydrochloric acid may also be used.



Chemical wet scrubber design

Working principle:
- Ammonium absorption: $2\ NH_3 + H_2SO_4 \rightarrow 2\ NH_4^+ + SO_4^-$.

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 90%, depending on the quantity of acid and the residence time of the ventilated air in the system. The remaining emission is 0.8 kg NH_3/ pig place/ year. There are no adaptations needed inside the building. This system is applicable in every design of a pen.

Disadvantages: This system can't be used in a natural ventilated pig house. The effluent contains increased levels of sulphate or chloride, depending the type of acid used. This system has higher energy consumption (extra 100 kWh/ sow place).

Economics: The extra investment costs are □ 83.65 per pig place. This means by 90% reduction, 8.3 $\Rightarrow$ 0.8 kg NH_3, □ 11.15 per kg NH_3. The extra costs per year are □ 28 per pig place. This means □ 10.40 per kg NH_3.

Reference pig places: In the Netherlands about 2.000 farrowing sow places are equipped with this system. This system is developed just a few years ago. Nowadays this system is being implemented in some of reconstructions situations.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport P 1.178.

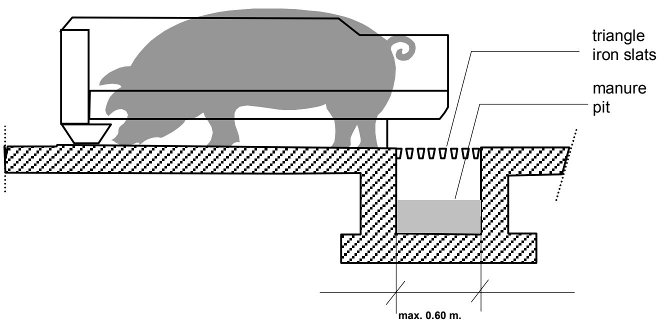
6. CANDIDATE BAT FOR MATING AND GESTATING SOWS

6.1. PROCESS INTEGRATED MEASURES

6.1.1. Small manure pit

Category: Mating and gestating sows
Ammonia emission: 4.0 kg NH3/ sow place/ year

If mating and gestating sows are kept in stalls the ammonia emission can be reduce by using a small manure pit with a maximum width of 0.60 m. The manure pit is equipped with triangle iron slats.



Stalls with a small manure pit

Working principle:
- Limiting the manure surface in the manure channel,
- Fast discharging of the manure on the slatted area by using iron triangle bars.

Application: The system with partly or fully slatted floor can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit, but it is mostly difficult to apply.

Advantages: This system is applicable in new houses and is not expensive.

Disadvantages: There are no specific disadvantages to this system.

Economics: Compared to a standard system (with a larger manure surface) the ammonia reduction is 40%. The remaining ammonia emission is 2.4 kg NH3/ pig place/ year. The extra investment costs are □ 17.75. This means by 40% reduction, 4.2 ⇒ 2.4 kg NH_3, □ 9.85 per kg NH_3. The extra costs per year are □ 5.80 per pig place. This means □ 3.25 per kg NH_3.

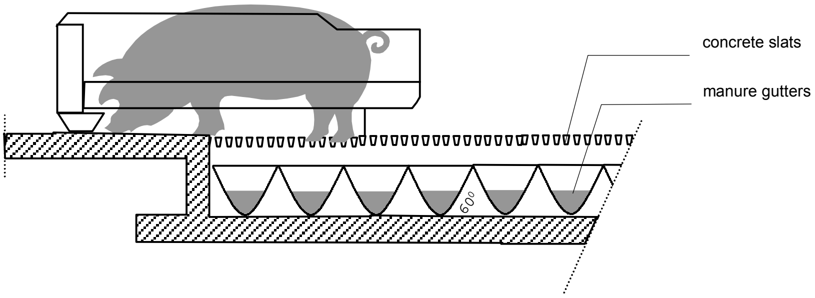
Reference pig places: In the Netherlands about 1.500 mating and gestating sow places are equipped with this system.

Reference literature: Rosmalen, Research Institute for Pig Husbandry, rapport PV P1.158

6.1.2. Flushing gutters

Category: Mating and gestating sows
Ammonia emission: 2.5 kg NH3/ sow place/ year

Small gutters limit the manure surface. This reduces the ammonia emission. Application is possible in individual stalls and in group housing systems. The manure surface should not be higher than 1.10 m^2. The manure will be removed frequently by a flushing system. The slats are made of concrete. The gutters should have a slope of 60 degrees. The gutters should be flushed twice a day. The flushing will be done by the liquid fraction of the manure (after separation) and the dry matter content should not be higher than 5%.



Flushing system with manure gutter.

Working principle:
- Limiting the manure surface in the manure channel,
- Removing the manure two times a day by flushing.

Application: The system with flushing gutters can be applied in new houses. In existing houses the applicability depends on the design of the existing manure pit.

Advantages: This system is well applicable. To implement this system only a few reconstructions are needed.

Disadvantages: This system has an extra energy consumption due to flushing twice a day (extra 0.5 kWh/ sow place). The implementation costs of the system are significant.

Economics: Compared to a fully slatted floor the ammonia reduction is 40%. In other words the remaining ammonia emission is 2.5 kg NH_3/ pig place/ year. The extra investment costs are □ 161.80 per pig place. This means by 40% reduction, 4.2 ⇒ 2.5 kg NH_3, □ 95.20 per kg NH_3. The extra costs per year are □ 57.90 per pig place. This means □ 34.05 per kg NH_3.

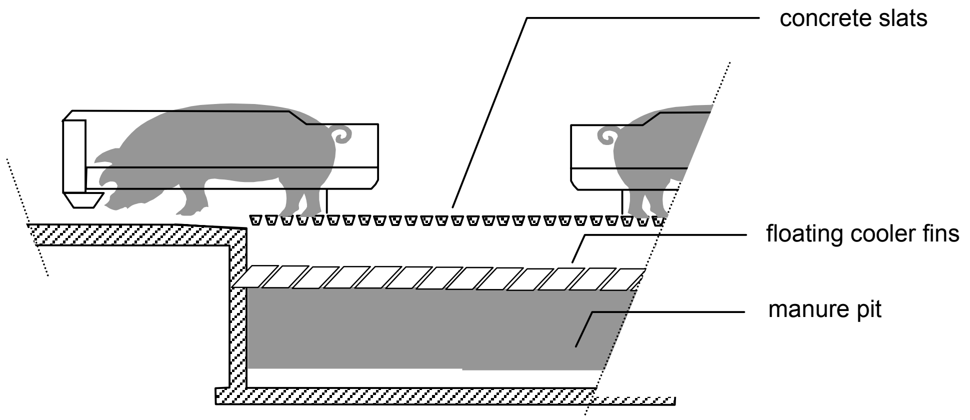
Reference pig places: In the Netherlands about 1000 mating and gestating sow places are equipped with this system.

Reference literature: Wageningen, IMAG-DLO, rapport P 95 -1004

6.1.3. Manure surface cooling channel

Category: Mating and gestating sows
Ammonia emission: 2.2 kg NH_3/ pig place/ year

Description: Floating fins on the manure will cool the surface of the manure. Groundwater is used as a coolant. A number of fins is installed in the manure pit. These fins are filled with water and are floating on the manure. The total surface of the fins has to be a minimum of 115% compared to the manure surface. Groundwater is used as a coolant, which is pumped back into the underground after its use. The temperature of the groundwater is normally no higher than 12^0 C. The temperature of the top layer of the manure should be not higher than 15^0 C. Application is also possible in individual stall and group housing systems. The total manure surface should not be higher than 1.10 m^2 / sow. Slats are made of concrete.



Individual stalls concrete slats and manure surface cooling.

Working principle:
- Cooling the manure.

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 50%. Thus, the emission is 2.2 kg NH_3/ pig place/ year. The system is applicable in every design of a pen.

Disadvantages: This system has higher energy consumption (extra 8.5 kWh/ pig place). In some areas is not desirably to pump groundwater or to pump it back into the ground (a potential risk of groundwater pollution).

Economics: The extra investment costs are € 112.75 per pig place. This means by 50% reduction, 4.2 ⇒ 2.2 kg NH_3, € 56.35 per kg NH_3. The extra costs per year are € 20.35 per pig place. This means € 9.25 per kg NH_3.

Reference pig places: In the Netherlands about 3.000 mating and gestating sow places are equipped with this system. Nowadays this system is being implemented in many of reconstructions situations and in some new buildings.

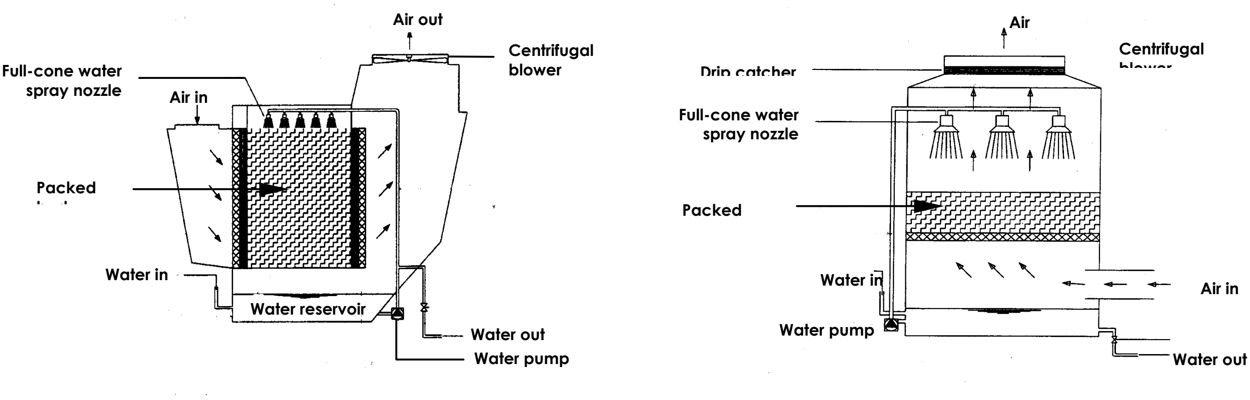
Reference literature: Wageningen, IMAG-DLO, rapport 97 -1002.

6.2. END OF PIPE MEASURES

6.2.1. Bioscrubber

Category: Mating and gestating sows
Ammonia emission: 1.3 kg NH_3/ pig place/ year

Description: All the ventilation rate will be lead through a biofilter unit. A biolayer formed on the surfaces of the packed material absorbs ammonia so that it can broken down by microbes. Water circulation keeps the biolayer moist and nutrients available for the microorganisms.



Bioscrubber design

Working principle:
- Ammonia absorption and breakdown.

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 70% on average (50-90%). In other words the remaining emission is 1.3 kg NH_3/ pig place/ year. There are no adaptations needed inside the building. This system is applicable in every design of a pen.

Disadvantages: This system can't be used in a natural ventilated pig house. The water consumption is increased with about 1 m^3 per pig place and in accordance with this an extra effluent is produced. This system has higher energy consumption (extra 35 kWh/ pig place).

Economics: The extra investment costs are € 111.35 per pig place. This means by 70% reduction, 4.2 ⇒ 1.3 kg NH_3, € 38.40 per kg NH_3. The extra costs per year are € 16.70 per pig place. This means € 5.75 per kg NH_3.

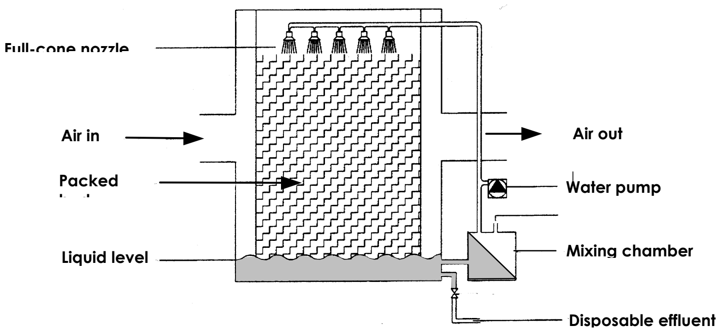
Reference pig places: In the Netherlands about 1.000 mating and gestating sow places are equipped with this system. This system was developed just a few years ago. Nowadays this system is being implemented in some reconstruction situations.

Reference literature: Wageningen, IMAG-DLO, rapport 423. EurAgEng, Vinkeloord 1997, Proceedings pages 521 – 544.

6.2.2. Chemical wetscrubber

Category: Mating and gestating sows
Ammonia emission: 0.4 kg NH_3/ pig place/ year

Description: All the ventilation rate will be lead through a chemical scrubbing unit. In this unit an acid scrubbing water is pumped around. By contact of the ventilated air with the scrubbing liquid the ammonia will be absorbed by the acid scrubbing liquid. After that the clean air leaves the system. Diluted sulphuric acid is mostly used in this system. Hydrochloric acid may also be used.



Chemical wet scrubber design

Working principle:

- Ammonium absorption: $2\ NH_3 + H_2SO_4 \rightarrow 2\ NH_4^+ + SO_4^-$.

Application: This system is very easy to implement in both new buildings and reconstruction of existing buildings. The design of the pen and the size of the pen are not critical for the applicability of the system.

Advantages: Compared to a fully slatted floor the ammonia reduction is 90%, depending on the quantity of acid and the residence time of the ventilated air in the system. The remaining emission is 0.4 kg NH_3/ pig place/ year. There are no adaptations needed inside the building. This system is applicable in every design of a pen.

Disadvantages: This system can't be used in a natural ventilated pig house. The effluent contains increased levels of sulphate or chloride, depending the type of acid used. This system has higher energy consumption (extra 52.5 kWh/ pig place).

Economics: The extra investment costs are 62.75per pig place. This means by 90% reduction, 4.2 $\Rightarrow$ 0.4 kg NH_3, 16.50 per kg NH_3. The extra costs per year are 25.05 per pig place. This means 6.65 per kg NH_3.

Reference pig places: In the Netherlands about 2.000 mating and gestating sow places are equipped with this system. This system is developed just a few years ago. Nowadays this system is being implemented in reconstructions situations and in some new buildings.

Reference literature: Wageningen, IMAG-DLO, nota 423. EurAgEng,Vinkeloord 1997, Proceedings pages 521 – 544.

7. CANDIDATE BAT FOR SLURRY AND MANURE APPLICATION TECHNIQUES

7.1. REFERENCE TECHNIQUE

The reference for manure application techniques is defined as emissions from untreated slurry or solid manure spread over the whole soil surface (‘broadcast’). For slurry, for example, this would be with a tanker equipped with a discharge nozzle and splash-plate. Ammonia emissions from slurry irrigation systems have been less studied but could be as high as the reference case. For solid manures, the reference case would be to leave the manure on the soil surface for a week or more. Emissions will vary with the composition of the slurry and manure and with prevailing weather and soil conditions. Abatement efficiencies will also vary relative to reference emissions depending on these factors, so figures quoted should be regarded as indicative only.

7.2. ABATEMENT TECHNIQUES

The abatement techniques include machinery for decreasing the surface area of slurries and burying slurry or solid manures through incorporation into the soil. The techniques included are:

I. Band-spreading;
II. Trailing shoe or ‘sleigh-foot’ machines;
III. Injection - open slot;
IV. Injection - closed slot;
V. Incorporation of surface applied manure and/or slurry into soil.

The average ammonia abatement efficiency of the techniques relative to the reference is given in table 1. The efficiency is valid for soil types and conditions that allow infiltration of liquid for techniques (i) - (iv) and satisfactory travelling conditions for the machinery. The table also summarises the limitations that must be taken into account when considering the applicability of a specific technique and an indication of the cost.

A number of factors must be taken into account in determining the applicability of each technique. These factors include: soil type and condition (soil depth, stone content, wetness, travelling conditions), topography (slope, size of field, evenness of ground), manure type and composition (slurry or solid manure). Some techniques are more widely applicable than others. Because the manure is distributed though relatively narrow pipes in techniques (i) - (iv), even though most machines incorporate a device for chopping and homogenising the manure, they are not suitable for very viscous slurries or those containing large amounts of fibrous material e.g. straw. Injection techniques are potentially very efficient but they do not work well on shallow, stony soils, which may result in damage to grass sward and increase the risk of soil erosion. Incorporation is not applicable on permanent grassland. Comments on applicability are included in the descriptions of the technique below and summarised in table 1.

Band-spreading, trailing shoe and injection machines are normally fitted to the rear of a slurry tanker which is either towed by a tractor or is part of a self propelled machine. An alternative is for the applicator to be attached to the rear of the tractors and slurry transported to it by a long ‘umbilical’ hose from a tanker or store located off the field. Such umbilical systems avoid the need to take heavy slurry tankers onto the land.

<u>Band-spreading.</u> Band-spreaders discharge slurry at or just above ground level through a series of hanging or trailing pipes. The width is typically 12 m with about 30 cm between

bands. The technique is applicable to grass and arable land e.g. for applying slurry between rows of growing crops. Because of the width of the machine, the technique is not suitable for small, irregularly shaped fields or steeply sloping land. The hoses may also become clogged if the straw content of the slurry is too high.

Trailing shoe. This technique is mainly applicable to grassland. Grass leaves and stems are parted by trailing a narrow shoe or foot over the soil surface and slurry is placed in narrow bands on the soil surface at 20 - 30 cm spacings. The slurry bands should be covered by the grass canopy so the grass height should be a minimum of 8 cm. The machines are available in a range of widths up to 7 - 8 m. Applicability is limited by size, shape and slope of the field and by the presence of stones on the soil surface.

Injection - open slot. This technique is mainly for use on grassland. Different shaped knives or disc coulters are used to cut vertical slots in the soil up to 5 - 6 cm deep into which slurry is placed. Spacing between slots is typically 20 - 40 cm and working width 6m. Application rate must be adjusted so that excessive amounts of slurry do not spill out of the open slots onto the surface. The technique is not applicable on very stony soil nor on very shallow or compacted soils where is impossible to achieve uniform penetration of the knives or disc coulters to the required working depth.

Injection - closed slot. This technique can be shallow (5 - 10 cm depth) or deep (15 - 20 cm). Slurry is fully covered after injection by closing the slots with press wheels or rollers fitted behind the injection tines. Shallow closed-slot injection is more efficient than open-slot in decreasing ammonia emission. To obtain this added benefit, soil type and conditions must allow effective closure of the slot. The technique is, therefore, less widely applicable than open-slot injection. Deep injectors usually comprise a series of tines fitted with lateral wings or ‘goose feet’ to aid lateral dispersion of slurry in the soil so that relatively high application rates can be achieved. Tine spacing is typically 25 -50 cm and working width 2 - 3 m. Although ammonia abatement efficiency is high, the applicability of the technique is severely limited. The use of deep injection is restricted mainly to arable land because mechanical damage may decrease herbage yields on grassland. Other limitations include soil depth and clay and stone content, slope and a high draught force requiring a large tractor. There is also a greater risk of nitrogen losses as nitrous oxide and nitrates, in some circumstances.

Incorporation. Incorporating manure spread on the surface by ploughing is an efficient means of decreasing ammonia emissions. The manure must be completely buried under the soil to achieve the efficiencies given in table 1. Lower efficiencies are obtained with other types of cultivation machinery. Ploughing is mainly applicable to solid manures on arable soils. The technique may also be used for slurries where injection techniques are not possible or unavailable. Similarly, it is applicable to grassland when changing to arable land (e.g. in a rotation) or when reseeding. Ammonia loss is rapid following spreading manures on the surface so greater reductions in emissions are achieved when incorporation takes place immediately after spreading. This requires that a second tractor be used for the incorporation machinery which must follow close behind the manure spreader. A more practical option might be incorporation within the same working day as spreading the manure, but this is less efficient in reducing emissions.

TABLE 13 CATEGORY 1 ABATEMENT TECHNIQUES FOR MANURE APPLICATION TO LAND

Abatement measure	Type of manure	Land use	Emission reduction (%)	Applicability[a2]	Costs[1)] ECU per m^3
Band-spreading	Slurry	Grassland	10	Slope (tankers <10 %, umbilical < 20 %), not for slurry that is viscous or has a high straw content, size and shape of field.	0.68
Band-spreading	Slurry	Arable	30	Slope (tankers < 10 %, umbilical < 20 %), not for slurry that is viscous or has a high straw content, size and shape of the field, possibility of applying to growing crop between rows.	0.68
Trailing shoe	Slurry	Mainly grassland	40	Slope (tankers < 20 %, umbilical < 30 %), not viscous slurry, size and shape of the field, grass height should be about 8 cm	1.33
Injection (open slot)	Slurry	Grassland	60	Slope < 12 %, greater limitations for soil type and conditions, not viscous slurry	2.51
Injection (closed slot)	Slurry	Mainly grassland, arable land	80	Slope < 12 %, greater limitations for soil type and conditions, not viscous slurry.	2.51
Incorporation - immediate (costs for < 4h)	Solid manure and slurry	Arable land	80	Only for land that can be easily ploughed	Slurry: 0.67 dairy 0.53 other cattle 1.05 pigs Manure: 1.32 dairy, other cattle, sheep & goats 1.47 pigs 3.19 layers 6.19 broilers
Incorporation - within same working day	Solid manure and slurry	Arable land	50-90 for manure depending on type 40 for slurry	Only for land that can be easily ploughed	As above

1) Costs are annual operating costs based on use of contractors and depend on the application rate per hectare.

8. CANDIDATE BAT FOR SLURRY STORAGE

8.1. INTRODUCTION

At present, there are no proven techniques for reducing ammonia emissions from stored solid manures. This section relates only to techniques for slurry storage. After removal from animal houses, slurry is stored either in concrete or steel tanks or silos or in lagoons, often with earth walls. The latter tend to have a relatively larger area per unit volume than the former.

Emissions from slurry stores can be reduced by decreasing or eliminating the airflow across the surface by installing a cover; by allowing the formation of a crust; or by reducing the surface per unit volume of the slurry store.

When using an emission abatement technique in manure stores, it is important to prevent loss of the conserved ammonia during spreading on land by using an appropriate low emission application technique.

8.2. REFERENCE TECHNIQUE

The baseline for estimating the efficiency of an abatement measure is the emission from the same type of store, without any cover or crust on the surface. Table 14 gives an overview of the different emission abatement measures for slurry tanks and their efficiency in reducing emissions.

8.3. ABATEMENT TECHNIQUES

The most well proven and practicable technique to reduce emissions from stored slurry is to cover the slurry tanks or silos with a solid lid, roof or tent structure. Sealed tanks of canvas reinforced by glass fibre are also available for this purpose. While it is important to guarantee that covers are well sealed to minimise air exchange, there will always need to be some small openings or a facility for venting to prevent the accumulation of inflammable gases, such as methane.

TABLE 14 EMISSION ABATEMENT MEASURES FOR SLURRY STORAGE

Abatement measure	Livestock class	Emission reduction (%)[1]	Applicability	Costs (ECU per m^3/yr.)[2]
Rigid lid or roof	All	80	Tanks & silos only	8.00
Flexible cover or floating sheet	All	60		1.10 – tanks 1.25- lagoons

1) Reductions are expressed relative to emissions from an uncovered slurry tank/ silo.
2) Costs refer to the cost of the lid only, and do not include the cost of the silo.

9. CANDIDATE BAT FOR LAYING HENS

9.1. INTRODUCTION

In The Netherlands about 34 million laying hens are kept for the production of consumption eggs. These hens are kept in various systems. We can distinguish between systems for wet and systems for dry manure. Because of the longer transportation distance of the manure in The Netherlands, it is preferred to produce dry manure, so that the transportation of water is not necessary. That is the reason that more and more systems for dry manure are applied in the Netherlands.
In this chapter the types of housing systems for laying hens that are kept in The Netherlands are described, and for each system the amount of ammonia that is produced by that system is shown.

9.2. HOUSING SYSTEMS FOR LAYING HENS.

The various types of housing systems in which laying hens are kept are;

1. Manure storage under the cages in an open storage
2. Manure removal by way of scrapers to a covered storage
3. Manure removal by way of manure belts at least twice a week to a covered storage
4. Deep-pit and canal systems
5. Manure belts with forced drying (2 types)
6. Deep litter and aviary systems (2 types)

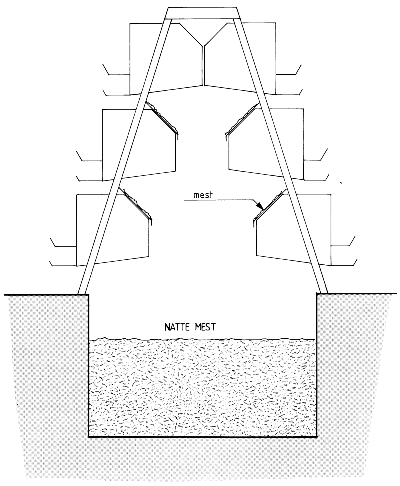
The systems 1, 2 and 3 are systems for wet manure and the systems 4, 5 and 6 are for dry manure.

9.3. PROCESS INTEGRATED MEASURES

9.3.1. Manure storage under the cages in an open storage

Category: Laying hens
Ammonia emission; 0.083 kg NH3/ hen place/year.

Description: In this housing-system cages are placed over an open manure pit. The manure pit has the width of the cages. Because the manure is stored over a longer period these systems produce a lot of smell and ammonia. The cages which are used in this system are flat-deck cages or stair-step cages. This system does not occur so much in The Netherlands because the ammonia emission is too high and the cages do not easily meet the European rules for welfare of laying hens. The ammonia amount of this system comes to 0.083 kg NH3 per hen-place per year.



Working principle;
- The manure is gathered on plastic flaps under the cages
- After that, the manure is stored in an open pit under the cages for a longer period

Applicability: The system can be used in new and existing houses.

Advantages: A simple system, simple to handle and low in price.

Disadvantages: This system produces a lot of ammonia and smell in comparison with a manure belt system. Because there are manure rests a plague of flies can occur.

Economics: This system is considered as the reference system.

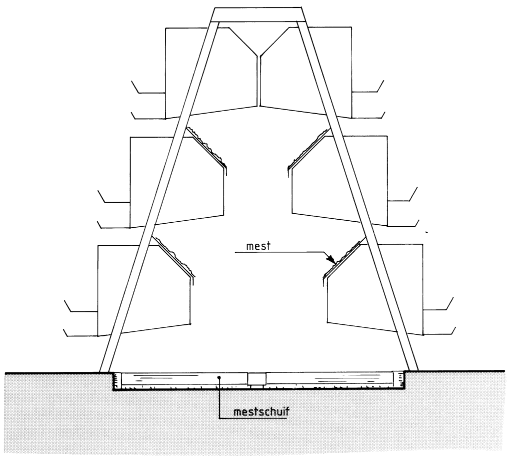
Reference hen places: In the Netherlands about 2.453.000 hens are kept in this system. This is an old system that is not used in new buildings and therefore it disappears.

Reference literature: Wageningen, IMAG nota 353 (HAB)

9.3.2. Manure removal by way of scrapers to a closed storage

Category: Laying hens
Ammonia emission: 0.083 kg/ hen place/year.

Description: In this system the cages are placed over a manure canal that has the width of the cages. The manure produced by the hens drops on a plastic flap or a plate under the cages. From here the manure goes into a manure canal. In that canal a scraper is installed that brings the manure to a covered storage. The manure in the canal is transported to a closed storage, daily or several times per week. The bottom of that canal is made of concrete. After several years the concrete floor becomes rough and a film of manure remains on the floor. The manure on the plastic flaps or plates and the manure film on the floor together cause a lot of ammonia emissions.



Working principle:
- The manure is gathered on plastic flaps or plates under the cages.
- Daily or several times a week the manure is brought to a closed storage with scrapers.

Applicability: The system can be used in new and existing houses.

Advantages: A simple system, simple to handle for a low price. Compared to the reference system (9.2.1), the ammonia emission is the same, but the smell is less because there are less anaerobic spots.

Disadvantages: High ammonia emissions and smell in comparison with manure belt system.

Economics: This system is considered a reference system.

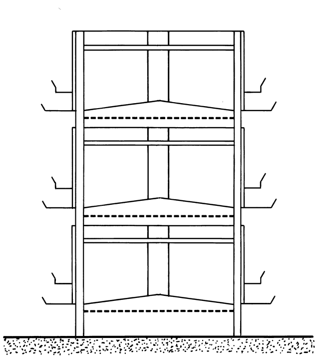
Reference hen places: In the Netherlands about 1.543.000 laying hens are kept in this system. It is an old system that is not used in new buildings and therefore it disappears.

Reference literature: Wageningen, IMAG Nota 353 (HAB)

9.3.3. *Manure removal by way of manure belts at least twice a week to a closed storage*

Category: Laying hens
Ammonia emission: 0.035 kg NH3/ hen place/year

Description: In this system the manure is transported to a closed storage at least twice a week. The manure that is produced by the hens is collected on a manure belt that is situated under the cages for the animals. These manure belts that are made of polypropylene or trevira, transport the manure to a closed storage. The manure belts are very smooth and very easy to clean. Because the system is so easy to clean, no manure remains on the belts and because the manure is transported twice a week to a closed storage the ammonia emission is low. The ammonia emission of this system is 0.035 kg NH3 per hen-place per year. Because the ammonia emission is so low, this system is a Green-label system.



Working principle:
- The manure produced by the hens is gathered on manure-belts underneath the cages.
- The manure-belts transport the manure to a close storage twice a week.
- There are no manure-rests left on the manure-belts.

Applicability: These cages with manure belts can be used in new and existing houses. In the Netherlands these cages are only used in existing houses because in new houses dry manure systems are preferred above wet manure systems.

Advantages: Compared with 9.1.1 and 9.1.2 this system gives an ammonia reduction of 58%. There is also less smell in the house. Because the manure is transported out of the house and no manure-rests are on the manure belts the climate in the house is better.

Disadvantages: With this system wet manure is produced instead of dry manure which is preferred in The Netherlands.

Economics: The extra investment costs are € 1.14 per hen-place. This means by 58% reduction € 23.6 per kg NH3. The extra costs per hen per year are € 0.17

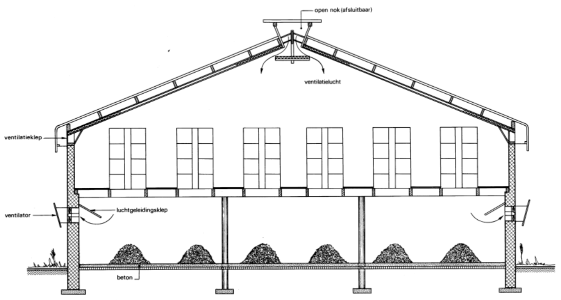
Reference hen places: In the Netherlands about 3.524.000 hens are kept in this system. This system is only incidentally installed in a new situation.

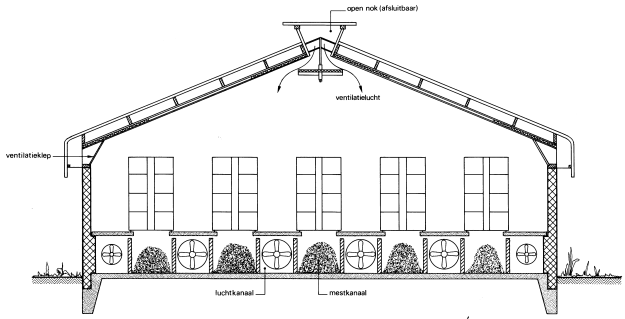
Reference literature: Wageningen IMAG nota 353 (HAB)

9.3.4. Deep-pit and canal systems.

Category: Laying hens
Ammonia emission: 0.386 kg NH3 / hen-place/ year.

Description: In a deep-pit house and a canal house the manure is dried with the ventilation air that leaves the house. The ventilators that remove the ventilation air from the laying house are placed on the lower half of the building. By this flow of warm air the manure that is stored in the pit is dried. The manure can be stored in the pit for more than a year where heating by fermentation occurs. This fermentation will result in a high ammonia emission level. To get a good drying result the manure on the plates underneath the cages should be pre-dried for about 3 days. After 3 days the manure has a dry material content of about 35-40%. Because of the fermentation in the manure storage the ammonia emission is very high, that means 0.386 kg NH3 per hen-place per year (10 times higher than a Green Label system). A canal house works in the same way as a deep-pit house.





Working principle:
- A current of warm air that leaves the hen-house passes the manure which is stored in a pit.
- This warm current of air dries the manure.
- The manure is stored in a deep-pit house for about 2 years.
- The manure in a canal house is stored for 6 months.

Applicability: This system can only be applied in a new construction because the system needs a deep-pit of about 250 cm. A canal house needs a pit of about 100 cm.

Advantages: With this hen house dry manure is produced, which can be transported over a long distance. This is very important in the Netherlands because there is too much manure. Because the manure is dried so quickly, there is less smell.

Disadvantages: Compared with 9.2.1 and 9.2.2 the NH_3 emission is 4.5 times higher. Compared with 9.2.3 the NH_3 emission is 11 times higher. In practice there are a lot of problems with canal and deep-pit houses because the amount of ammonia is so high so that it is hard to work in them. Besides that there are a lot of flies. These flies can cause dirty eggs.

Economics: This system is considered the reference system for dry manure systems.

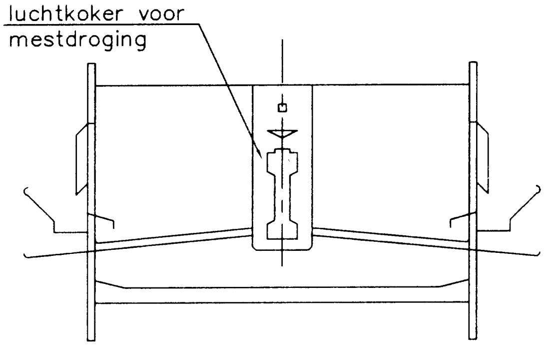
Reference hen places: In the Netherlands 2.545.000 hens are kept in these systems. They are all existing houses. The system is not used in new buildings.

Reference literature: not available

9.3.5. Manure belts with forced drying

Category: Laying hens
Ammonia emission: 0.035 kg NH3/ hen-place/ year.

Description: The manure from the hens is collected on a manure belt. For each tier there is a manure-belt. Over the belt a tube is placed which blows air (preheated) over the manure that is gathered on the manure belt. The manure is removed from the house once a week to a covered storage outside the house where the manure can be stored for a longer period. There is also a possibility to bring the manure in a container and remove it from the farm within two weeks. When a forced drying system is installed with a drying capacity of $0.4m^3$ per hen per hour, a drying period of 7 days and a dry material content of the manure of at least 45% is achieved, the NH3 emission is 0.035 kg NH3 per hen-place per year.



Working principle:
- The manure is gathered on a belt under the cages.
- By way of an air stream with pre-heated air the manure is dried in 7 days
- After this drying period the manure is transported out of the hen-house.
- No manure rests are on the belt because the belt is so smooth.

Applicability: This system can be applied in new and existing houses. It can be built in tiers from 3 to 10.

Advantages: With this system it is possible to get a very low NH3 emission. With this system there is also less smell in the house. The preheated air dries the manure but also the climate in the cages close to the animals is very good. That gives better technical results.

Disadvantages: There are no negative side effects.

Economics: The extra investment cost are □ 2.05 per hen-place/year. This means by 60% reduction □ 42.70 per kg NH3. The extra costs per hen per year are □ 0.57.

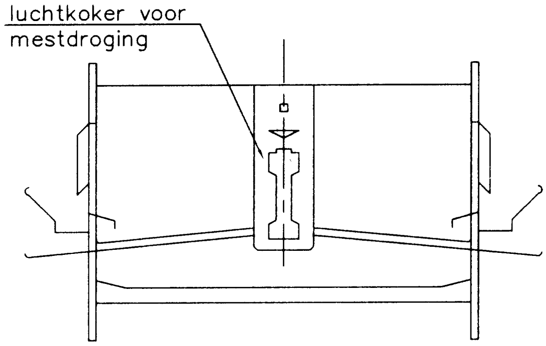
Reference hen places: In the Netherlands 14.598.000 hens are kept in this system. The system with the NH3 emission of 0.035 kg / hen /year was developed about 12 years ago.
Nowadays this system with forced drying on the manure belts is being implemented in most of the new buildings and reconstructions.

Reference literature: Wageningen, IMAG nota 353 (HAB)

9.3.6. Manure belts with improved forced drying.

Category: Laying hens
Ammonia emission: 0,010kg NH3/ hen-place/ year.

Description: The manure produced by the hens is collected on manure belts. For each tier there is a manure-belt. Over the manure-belt a tube is placed which blows air (preheated) over the manure that is gathered on the manure belts. The manure is removed out of the house once every five days to a covered container that must be removed from the farm within two weeks. To dry the manure a forced drying system must be installed with a drying capacity of 0.7m3 per hen per hour and a temperature of 17°C of the air. The drying period is maximum 5 days and the manure must have a dry material of at least 55%. The NH3 emission of this system is 0.010kg NH3/ hen-place/year.



Working principle:
- The manure is gathered on belts under the cages;
- By way of an air stream with pre-heated air (17°C) the manure is dried in 5 days;
- After this drying period the manure is transported out of the hen-house;
- No manure rests are on the belt because the belt is so smooth.

Applicability: This system can be applied in new and existing houses. It can be built in tiers from 3 to 10.

Advantages: With this system it is possible to get the lowest NH3 emission. With this system there is also less smell in the hen-house. The pre heated air dries the manure but also the climate in the cages close to the animals is very good. And this gives better technical results.

Disadvantages: A disadvantage is that much electricity must be used to dry the manure.

Economics: The extra investment cost are € 2.50 per hen-place/year. This means by 73% reduction € 34.25 per kg NH_3. The extra costs per hen per year are € 0.80 (including electricity costs).

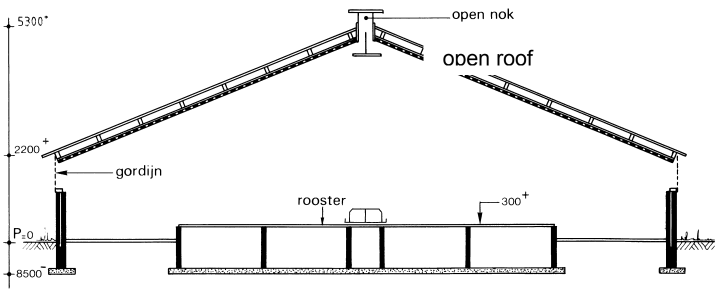
Reference hen places: In the Netherlands about 2.000.000 hens are kept in this system. The system with the NH3 emission of 0,010 kg / hen /year was developed about 2 years ago. Nowadays these systems with forced drying on the manure belts is being implemented in most of the new buildings and reconstructions.

Reference literature: Beekbergen, PP–Uitgave no. 63

9.3.7. Deep litter systems with and without forced drying

Category: Laying hens
Ammonia emission: 0.125 kg NH3/ hen-place / year.

Description: In the Dutch deep-litter houses 7 hen are kept per m^2. 33% of the useable area for the animals is covered with litter, and 67% are slats. These slats are mostly made of wood or artificial material. Laying nest, feed installation and the water supply are placed on the slats to keep the litter dry.
In the old systems the ventilation is done by way of natural ventilation. A new system can reduce the ammonia emission by applying forced ventilation. This is done by way of tubes that blow 1.2 m^3 air per hen-place per hr with a temperature of 20°C over the manure that is stored under the slats. The ammonia emission of this system is 0.125 kg per hen-place per year.



Working principle:
- Scratching area at the side walls (1/3 of the usable area).
- In the middle slatted floor with feed water and laying nests.
- Manure storage under the slats during the laying period (14 months).
- Tubes underneath the slats for manure drying.

Applicability: The system can only be used in hen houses with space enough underneath the slats. Traditionally the manure pit has a depth of 80 cm, when using this system it is necessary to have an extra 70 cm.

Advantages: Compared to the traditional deep-litter system (0.315kg NH_3) the ammonia reduction of this system (0.125 kg NH_3) is 60%. An other advantage is that farmers like these kinds of systems because the traditional housing-system is not changed

Disadvantages: The energy input in this system is high. In the tubes a temperature of 20°C is necessary. Because of that a heating system must be installed. Also the current of air over the manure costs money. For a good result 1.2 m^3 air per hen per hour is blown over the manure. When using this system the depth of the pit must be an extra 70 cm.

Economics: The extra investment cost are □ 3.07 per hen-place. This means by 60% reduction (0.315→ 0.125 kg NH3) □ 16.13 per kg. The extra annual costs are □ 1.21/hen place.

Reference hen-places: In the Netherlands about 8.098.000 hens are kept in a traditional deep litter system (without forced drying). Because this system is very new, only 40.000 hens are kept in this system. It is expected that in future this system will be used on several farms.

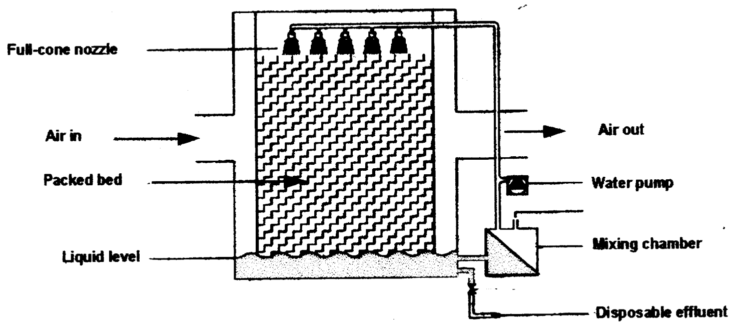
Reference literature: Beekbergen: Research Institute for Poultry Husbandry; rapport PP 81.

9.4. END-OF-PIPE MEASURES

9.4.1. Chemical wet scrubber

Category: Laying hens (deep litter)
Ammonia emission: 0.095 kg NH3/ broiler-place/ year.

Description: All the ventilation rate will be lead through a chemical scrubbing unit. In this unit an acid scrubbing water is pumped around. By contact of the ventilated air with the scrubbing liquid the ammonia will be absorbed by the acid scrubbing liquid. After that the clean air leaves the system. Diluted sulphuric acid is mostly used in this system. Hydrochloric acid may also be used.



Chemical wetscrubber design

Working principle:
- Ammonium absorption: $2\ NH_3 + H_2SO_4 \rightarrow 2\ NH_4^+ + SO_4^-$.

Application: This system is very easy to implement in new houses or existing houses.

Advantages: Compared to a traditional deep litter-system the ammonia reduction is 70%, according to the quantity of acid and the length of stay of the ventilated air in the system. The remaining emission is 0.095 kg NH3/hen-place /year. There are no adaptations needed inside the building.

Disadvantages: The system can not be used in a natural ventilated house. In the disposable effluent there is more sulphate or chlorite, depending on the use of the acid. The system has a higher energy consumption.

Economics: The extra investment costs are □ 3.18 /hen-place. This means □ 14.55 per kg NH3. The extra annual costs are □ 0.67/hen place

Reference broiler places: In The Netherlands about 12.000 layers are kept in this system.

Reference literature: DLO research rapport nr.98-1002, Proceedings pages 521 – 544.

9.5. OVERVIEW OF THE DISTRIBUTION OF LAYING HEN SYSTEMS IN THE NETHERLANDS

TABLE 15 DISTRIBUTION OF THE MENTIONED SYSTEMS IN THE NETHERLANDS IN MAY 1998

System		Hen places (x1000)	Hen places (%)	NH_3 emission (kg/hen place/year)	NH_3 reduction (%)
Wet manure system	• Manure storage under cages in open storage	2453	7.0	0.083	Reference
	• Manure removal with scrapers to covered storage	1543	4.4	0.083	Reference
	• Manure removal with manure belts at least twice a week to a covered storage (Green label)	3524	10.1	0.035	58
Dry manure system	• Deep pit and canal systems	2545	7.3	0.386	Reference
	• Manure belts with forced drying (Green Label)	14598	41.9	0.035	[85%?]
	• Manure belts with improved forced drying	2000	5.7	0.010	[90%?]
	• Traditional deep litter and aviary systems	8098	23.3	0.315	Reference
	• Deep litter and aviary system with forced ventilation	40	0.1	0.125	60%
Total		34801	100		

TABLE 16 DISTRIBUTION OF THE MENTIONED SYSTEMS IN THE NETHERLANDS IN MAY 1998

	Number of hen-places	Percentage of hen-places
Total number of hen-places	**34.801**	
Cage systems	**26.673**	**77%**
Dry manure systems	19.143	55%
Wet manure	7.506	22%
Green label systems (dry and wet)	19.274	72% (of cages)
Deep litter and aviaries	**8.098**	**23%**

The above mentioned table shows that 72 % of the hens kept in cages, is kept in a system with a low ammonia emission. The reason why so many people use these systems is,
- better technical results (micro climate)
- less smell
- better climate in the poultry house
- less dust
- better and cleaner circumstances to work

10. CANDIDATE BAT FOR BROILERS

10.1. INTRODUCTION

In The Netherlands there are about 60 million places for broilers, animals kept for the production of meat. The broilers are kept in a density from 18 to 24 animals per m^2. New leglislation is expected concerning the density of broilers. In the future a farmer is not allowed to keep more than about 35 kg broilers per m^2.

10.2. REFERENCE SYSTEM

Traditionally, broilers are kept in houses with a fully littered floor. To prevent ammonia emission it is important to keep the litter as dry as possible. Another way to prevent ammonia emission is litter with about 45 % dry material, but that dry material is too wet and gives bad technical results.
The dry matter content of the litter and the emission of ammonia depend on;

- The drinking system
- Duration of the growing period
- The density
- The use of floor insulation

A simple way to reduce ammonia is to prevent water spillage. Nipple drinkers or cups do not spill water. The ammonia emission of a traditional broiler house is 0,050 kg NH3 per broiler-place per year.

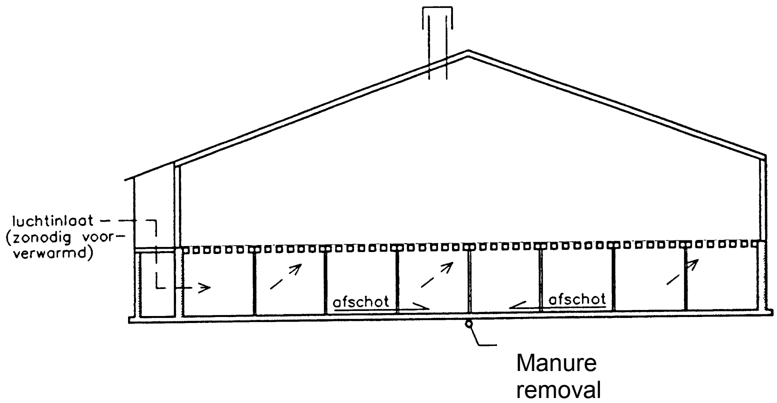
In the past ammonia low systems were developed in The Netherlands, but these systems were not good enough for practice. No new ammonia low systems are installed at the moment Some of the manufacturers do pilots with their systems at this moment. All new developed systems had a forced drying system in which air was blown through the litter. If the litter is made as dry as possible, the ammonia emission will be low.

10.3. PROCESS INTEGRATED MEASURES

10.3.1. Perfo-floor for broilers

Category: Broilers
Ammonia emission: 0.014 kg NH3 /broiler-place / year**.**

Description: The system is characterised by a continuous updraught air stream through a perforated floor. This floor is covered with litter that can be used by the animals. Because of the continuous air flow the litter is getting dryer (> 70% dry material) and this results in lowr ammonia emissions. The total surface of the perforations must be at least 4%. Per broiler-place 2m^3 [per hour?] ventilation air must be used.



Working principle:
- a perforated floor covered with litter
- minimum surface of the perforations 4%
- a continuous air stream through the litter
- minimum ventilation 2m^3 per broiler-place

Applicability: The system can only be used in new buildings because a pit with a depth of 2 m under the perforated floor is necessary.

Advantages: Compared with a traditional housing system for broilers the ammonia emission is reduced with 70%. In summer there is less heat-stress by the animals because there is an air-stream close to the animals. The animals are cleaner because the litter is very dry.

Disadvantages: Because of the overpressure, air passes the perforations in the floor. This system doubles the electricity use and costs. The investments are higher and because the litter is so dry there is more dust in the broiler-house.

Economics: The extra investment costs are □ 65.90/m^2. With a density of 20 broilers that is □ 3.41/broiler-place. This means □ 97.73 per kg NH_3. The extra running costs are □ 0.37/broiler-place/year.

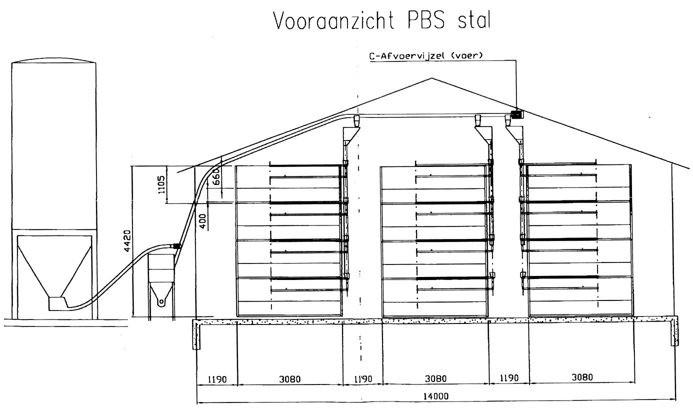
Reference broiler places: In the Netherlands about 300.000 broilers are kept in this system. The system is still new.

Reference literature: Aanvraag Groen Label, CHV nv Veghel

10.3.2. Floating floor system for broilers.

Category: *Broilers*
Ammonia emission: *0.005 kg NH3/broiler-place /year*

Description: The system is characterised by a continuous downward draught through a floating floor that is covered with litter on which the broilers live. The ventilation air is removed through dedicated ventilation ducts under the floating floor. The floating floor is made of a perforated polypropylene belt. The compartments in which the animals live have a width of 3m and a length according to the length of the house. The floating floor system is composed of tiers (3 or 4). After the growing period the floating floor can transport the broilers to the end of the house where the animals are placed in containers for transport to the slaughterhouse.



Working principle:
- a floating floor covered with litter
- a continuous downward air stream through the litter
- the ventilation air (4.5 m^3/broiler-place per hour) is substracted under the floating floor.

Applicability: This system can be used in new and existing broiler-houses. Because the system is built up in tiers there must be enough height to install the system.

Advantages: Compared with a traditional housing system for broilers, the ammonia emission is reduced with 90%. In summer there is less heat-stress by the animals because there is an air stream close to the animals. The animals are cleaner because the litter is dry. There is no dust problem because the ventilation air is removed from the system.

Disadvantages: More electricity is needed to operate the ventilation air fans. The investments are higher compared with a traditional system.

Economics: The extra investment cost are € 2.27 higher/broiler-place. This means € 50.45/kg NH_3. The extra annual costs are € 0.38/broiler place.

Reference broiler-places: In The Netherlands about 45.000 broilers are kept in this system. This low figure can be explained from the fact that the system is very new.

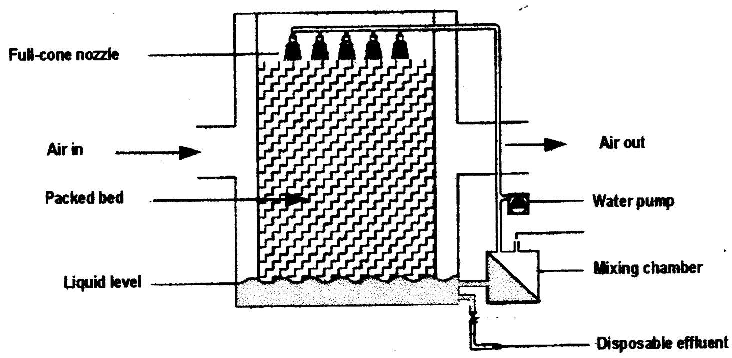
Reference literature: Beekbergen, PP uitgave nr. 28

10.4. END-OF-PIPE MEASURES

10.4.1. Chemical scrubber

Category: Broilers
Ammonia emission: 0.015 kg NH3/ broiler-place/ year.

Description: All the ventilation rate will be lead through a chemical scrubbing unit. In this unit an acid scrubbing water is pumped around. By contact of the ventilated air with the scrubbing liquid the ammonia will be absorbed by the acid scrubbing liquid. After that the clean air leaves the system. Diluted sulphuric acid is mostly used in this system. Hydrochloric acid may also be used.



Chemical wetscrubber design

Working principle:
- Ammonium absorption: $2\ NH_3 + H_2SO_4 \rightarrow 2\ NH_4^+ + SO_4^-$.

Application: This system is very easy to implement in new houses or existing houses.

Advantages: Compared to a traditional broiler house the ammonia reduction is 70%, according to the quantity of acid used and the residence time of the ventilated air in the system. The remaining emission is 0.015 kg NH3/broiler-place /year. There are no adaptations needed inside the building.

Disadvantages: The system can not be used in a natural ventilated house. In the disposable effluent there is more sulphate or chloride, depending on the use of the acid. The system has a higher energy consumption.

Economics: The extra investment costs are □ 3.18/broiler place. This means □ 90.91 per kg NH_3. The extra annual costs per broiler-place are □ 0.66.

Reference broiler places;
In The Netherlands about 50.000 broilers are kept in this system.

Reference literature: Wageningen: DLO research rapport nr.98-1002

11. CANDIDATE BAT FOR POULTRY MANURE PROCESSING

11.1. INTRODUCTION

In The Netherlands more and more farmers wish to make the manure dryer than it is made on the manure belts with forced drying in the laying house. When the manure is dryer one can make pellets of the manure, which are easier and cheaper to transport than wet material. This situation is specific to the Netherlands because there is an oversupply of manure and thus a need for export of the manure.

11.2. TECHNIQUES AFTER DRYING THE MANURE ON THE MANURE-BELTS.

Special techniques were developed to make the manure dryer than the usual 45 to 55% dry material. These techniques can only be used together with the manure belts with forced drying. A minimum requirement for the manure to be treated for extra drying is a dry matter content of at least 45%. By application of the mentioned techniques, the manure has a dry matter content of 80% after 72 hours. The techniques for additional drying are:

- controlled fermentation;
- drying tunnel with perforated manure belts;
- drying tunnel.

The achievements of these systems compared to traditional open manure storage are given in table 17 and table 18.

TABLE 17 ACHIEVEMENTS OF MANURE HANDLING TECHNIQUES FOR LAYING HENS IN HOUSES WITH MANURE BELTS

Manure handling technique	Emission of the housing (per laying hen per year)	Emission of storage (per laying hen per year)	Total Emission (per laying hen per year)	Dry matter content after application
Open manure storage (traditional)	0,035 kg NH3	0,050 kg NH3	0,085 kg NH3	65%
Controlled fermentation	0,035 kg NH3	0,005 kg NH3	0,040 kg NH3	80%
Drying tunnel perforated belts	0,035 kg NH3	0,015 kg NH3	0,050 kg NH3	80%
Drying tunnel	O,035 kg NH3	0,015 kg NH3	0,050 kg NH3	80%

TABLE 18 ACHIEVEMENTS OF MANURE HANDLING TECHNIQUES FOR LAYING HENS IN HOUSES WITH MANURE BELTS WITH IMPROVED FORCED DRYING

Manure handling technique	Emission of the housing (per laying hen per year)	Emission of storage (per laying hen per year)	Total Emission (per laying hen per year)	Dry matter content after application
Open manure storage (traditional)	0,010 kg NH_3	0,050 kg NH_3	0,060 kg NH3	65%
Controlled fermentation	0,010 kg NH_3	0,005 kg NH_3	0,015 kg NH3	80%
Drying tunnel perforated belts	0,010 kg NH_3	0,015 kg NH_3	0,025 kg NH3	80%
Drying tunnel	0,010 kg NH_3	0,015 kg NH3	0,025 kg NH3	80%

12. DUTCH PROPOSAL FOR BEST AVAILABLE TECHNIQUES

P.M.

[The Dutch Authorities are currently in a proces of changing the national legislation with respect to housing systems for intensive lifestock farms in the Netherlands. These changes involve both environmental and animal welfare standards. The final outcome of the proces is expected in September 1999 and will be reflected in the final version of this document.]