Solid Manure in Europe.
Results of a survey by the Working group on solid manure of RAMIRAN

Déjections solides en Europe.
Résultats d'une enquête d'un groupe de travail du réseau RAMIRAN.

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Abstract

An ad-hoc working group of the FAO-network on animal waste management conducted a survey on solid manure management in European countries. The questionnaire sent out to experts in 23 countries consisted of the chapters types of solid manure and quantities produced; solid manure composition; solid manure use; nutrient losses; regulations, laws and recommendations; research and literature concerning solid manure. Responses were received from Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Northern Ireland, Norway, Portugal, Sweden, Switzerland and the United Kingdom. The most important results are:

- *Solid manure constitutes more than one third of the total manure production in Finland, England and Wales, Sweden, Switzerland, Italy and parts of Belgium.*
- *The data about solid manure production per animal and solid manure content varies considerably between countries, mainly because of differences in housing systems and farm management. An actual comparison between countries is difficult because of the lack of common definitions and terms.*
- *In most countries the most important solid manure category is that produced together with slurry in tied cattle stalls.*
- *Where possible, solid manure is mainly used on arable land, primarily potatoes, beet, maize and in northern countries cereals. Use on grassland is common primarily in mountain regions.*
- *Even though the scientific understanding of solid manure systems is considerable, especially in central and northern European countries, serious gaps remain, e.g. factors controlling solid manure composition, nutrient availability of solid manure (especially for nitrogen), long term efficiency of the nutrient cycle in solid manure farming systems. These gaps are greater than for slurry systems.*

Key words: solid manure, composition, management, utilisation, nutrient losses, survey, Europe

Résumé

Le groupe de travail ad-hoc du réseau FAO sur la gestion des déjections animales a conduit une enquête sur la gestion des déjections solides (fumiers) en Europe de l'ouest. Le questionnaire transmis à différents experts de 23 pays contenait des rubriques telles que le type de déjections solides et les quantités produites, la composition des déjections, l'utilisation et la gestion, les fuites, les réglementations et recommandations, puis la recherche de références existantes sur les déjections solides.

Les réponses au questionnaire ont été obtenues pour les pays suivants : Autriche, Belgique, Bulgarie, République Tchèque, Danemark, Finlande, France, Allemagne, Italie, Pays-Bas, Irlande du Nord, Norvège, Portugal, Suède, Suisse et Royaume-Uni.

Les principaux résultats sont les suivants :

- Les déjections animales solides représentent plus du tiers des quantités totales de déjections produites en Finlande, Angleterre et Ecosse, Suède, Suisse, Italie et en partie Belgique.
- Les données sur la production de déjections solides par animal et le contenu de ces déjections sont très variables d'un pays à l'autre, dû principalement aux différents types de bâtiments.
- Dans la plupart des pays, les déjections solides les plus importantes sont celles produites en stabulation par les bovins.
- Lorsque cela est possible, les déjections solides sont utilisées sur cultures arables, principalement pommes de terre, betteraves, maïs et sur céréales dans les pays du nord.

L'utilisation sur prairies se rencontre plutôt dans les régions de montagne.

Les méconnaissances sur les facteurs qui conditionnent leur composition, la disponibilité en éléments nutritifs et l'incidence à long terme sur la fertilité des sols, sont encore plus accrues pour les déjections solides comparativement aux lisiers.

Mots-clés : déjections solides, composition, gestion, utilisation, fuites, enquête, Europe.

1. Introduction

Solid manure makes up an important part of the organic fertilisers utilised in European countries. For animal welfare reasons its importance is increasing in many countries. Due to variable farm structure and management (housing and storage systems; time, rate and crop of application etc.) the nutrient content and the use of solid manure differs considerably over Europe. This hinders the comparison and exchange of national data and recommendations. At its last meeting in 1994 the ESCORENA Network on Animal Waste Management therefore established a

working group to make a survey about existing knowledge, recommendations and research concerning solid manure in European countries. The working group formulated and distributed a questionnaire to all members of the network. After receiving responses from most central and northern European countries it is possible to make a first summary of the results, to compare national data and recommendations and to identify some gaps of knowledge which should be treated by the network or other multi-national groups of experts.

2. Organisation of the survey

The questionnaire worked out by the working group consisted of six main chapters :

1. Types of solid manure and quantities produced
2. Solid manure composition
3. Solid manure use
4. Nutrient losses
5. Regulations, laws and recommendations
6. Research and literature concerning solid manure

To get as much information as possible in spite of limited scientific or statistical data, the questionnaire encouraged participants to give estimates based on personal experience where necessary. It also asked for existing practical recommendations to farmers and for copies of such documents (in English, German or French).

After presentation at the network workshop in 1996 the questionnaire was sent to about 140 experts in 23 countries (21 European countries, Canada, Israel). Up to date 20 responses from 16 countries were received: Austria (A), Belgium (B), Bulgaria (Bu), Czech Republic (CR), Denmark (DK), Finland (SF), France (F), Germany (D), Italy (I), Netherlands (NL), Northern Ireland (NI), Norway (No), Portugal (P), Sweden (Sw), Switzerland (CH), United Kingdom (UK). While some of the questionnaires were filled out by one expert only, others compiled the information given by several experts from different institutes (e.g. Germany, Switzerland, United Kingdom).

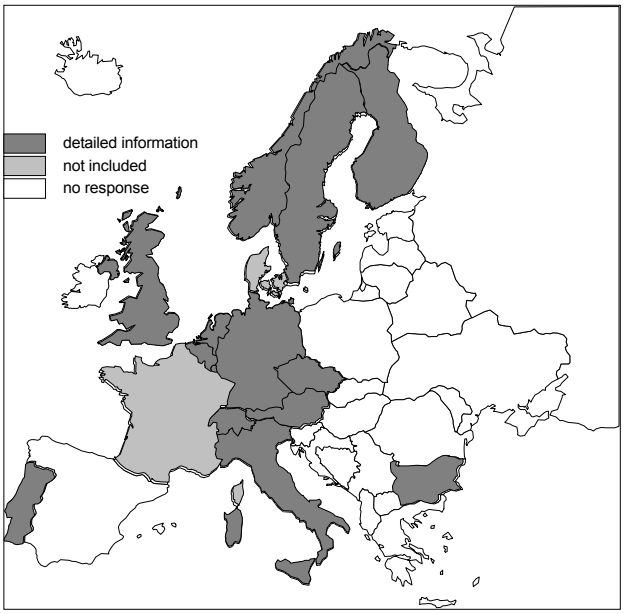

Figure 1
Countries included in this study

As expected, some responders did not answer all questions and answers varied in detail. The most detailed information was provided by the UK, Switzerland and Sweden. For some aspects the examples from these two countries are therefore used for a more detailed discussion. From France and Denmark the responses received could not yet be integrated in this report because they did not match the structure of the questionnaire or were incomplete. Unfortunately, only a very limited response was received from Southern or Eastern European countries. It can be assumed, that at least for most countries where no detailed response was received in spite of personal contacts established (e.g. France, Denmark, Hungary, Ireland), either solid manure is of relatively low importance or solid manure management has not yet been a topic of scientific interest.

For practical reasons it was not possible to re-contact responders concerning incomplete answers or confusing data.

3. Results

3.1 Importance of solid manure

Apparently, solid manure has the greatest importance in the Czech Republic, Finland and in parts of Belgium (Hesbaye region), where about 70% of the total manure production is reported to be solid manure. In Bulgaria up to 80% are assumed including slurry transformed to solid manure in lagoons. High values are

also reported in England and Wales (50%), Austria (40-50%), Sweden (approx. 40%), Switzerland (36%) and Italy (over 50% of cattle manure production). Other values reported are: Norway and Northern Ireland 10%, the Netherlands 6%.
The future development of solid manure production appears to be rather uncertain in most countries. From the Czech Republic the situation is reported to have stabilised after a phase of increasing importance due to problems with the slurry and animal welfare. An increasing importance is anticipated in the UK (mainly for pigs), in Switzerland, Germany, some districts of Norway and for cattle in Austria. In contrast, a decrease is expected in the Netherlands, in Sweden, in Finland and for pigs in Austria. In Italy, two experts expect a decrease, one an increase. The main reason given for an increase is animal welfare and consumers demand. In Italy, other advantages of solid manure mentioned are that it is easier to handle and store and that regulations are less severe than for slurry. The latter point could also apply in Switzerland. The main reason for an expected decrease is that solid manure is mainly produced on smaller farms, a significant number of which will probably close down in the future. From Sweden it is also reported that solid manure systems are not recommended because slurry, if correctly spread, will pose lower risks of environmental impacts. The Swiss example demonstrates that the importance of the two contrary developments can change in rather short time: Between 1960 and 1990 slurry systems replaced solid manure systems in most new buildings; in recent years animal friendliness became increasingly important. Therefore, a drastic change from slurry to solid manure systems is expected in the near future mainly for beef cattle and partly for pigs. Even between experts there is no consensus to the question, if slurry or solid manure systems are more ecologically sound.
According to the information received from Portugal and Bulgaria, the fertiliser value of manure in general has only recently been appreciated. Accordingly, manure management is still difficult to define and a differentiation between solid and liquid manure is very difficult.

3.2. Housing systems producing solid manure and their importance

Housing systems and relevant terminology apparently vary considerably over Europe. It was therefore sometimes difficult to compare responses from different countries. Furthermore, information in some cases lacked detail (e.g. x% solid manure production of cattle with no information of percentage of animals concerned). Therefore, the following overview includes only countries with more detailed information.
The very variable terminology used in different countries, the different way of presenting the information and some misunderstandings concerning the questions clearly showed that the first and probably most important step in reaching an understanding about the importance of solid manure across Europe would be to draw up a common terminology for housing systems and manure types.

<u>Cattle</u>
Housing systems producing only solid manure seem to be important mainly for beef cattle in the UK (60%), Sweden 10-20%), Finland (40-50%), Switzerland (10%),

Germany and Italy. For dairy cows they are reported only from Sweden (5% of cows, 15% of young stock). In the Netherlands, Germany, Norway, Switzerland (15% of young stock) and Italy, whilst such appear to exist, they are of negligible importance only.

Housing systems producing solid manure which contains most of the dung and some urine and slurry were reported from Switzerland (30-70% of cows, 60% of young stock), Sweden (50-60%), Finland (approximately 50%), Italy (approx. 60% of cows) and Austria. In most cases such systems appear to be used in tied stalls with daily removal of the solid manure. The proportion of the excreta collected in the solid manure is variable, especially for urine. In Sweden, Finland and Switzerland differentiated information was given which shows a considerable variability even within the country. In Sweden 30 to 100% of the urine (together with most or all the dung) is collected in the solid manure depending on the type (straw, sawdust) and quantity of bedding material used. In Swiss systems only small proportion of urine and 50-90% of the dung is collected in the solid manure, depending on availability of straw, possibilities to use solid manure in arable crops and regional practice. Systems producing only solid manure on part of the surface and only liquid manure in other parts are reported for dairy cows in the UK (15%) and for beef cattle in Finland (40-50%). In Germany and Switzerland such systems are sometimes used in "Tretmist"-systems for beef cattle, where the bedding area is situated on an slightly inclined plain, such that the lower layers of the manure slowly move to the area without bedding where the manure is removed at regular intervals.

No details about cattle housing systems producing solid manure were received from the Netherlands, Norway and Northern Ireland where solid manure production is uncommon for cattle and from Belgium, Portugal, the Czech Republic and Bulgaria where detailed information on housing systems was apparently not available. Many countries also report significant regional differences in housing systems depending primarily on farm structure. Especially in Switzerland and Sweden differentiated information about manure production exist for the different housing systems.

In most countries only straw is used as bedding material for cattle. In Sweden some systems are also run with sawdust and in Finland peat is sometimes utilised. In most countries the amount used is 1.5-3 kg per cow per day in tied stall systems with solid manure plus slurry production and 5-14 kg per cow per day for solid manure-only systems. For systems producing solid manure on part of the surface values are 3.5-5.5 kg in Italy and 5-10 kg in the UK (depending on animal weight).

Other herbivores

For horses all reports (CH, D, S, No, Bu) received are based on systems producing only, or primarily, solid manure. The amount of bedding material varies between 2.5 and 12 kg per animal per day. Usually straw is used; in Sweden and Norway also wood shavings or peat.

For sheep and goats reports came from Switzerland, the Netherlands, Norway and Bulgaria. In Switzerland and Norway it is clear that only solid manure is produced, for the other countries it can be assumed. In Norway a wire mesh floor and wood shavings are utilised, otherwise straw is used as bedding material.

Pigs

For sows solid manure systems are important mainly in Austria (65 % of the animals), the UK (45%), Sweden (40-70%) and Finland (80%). They are of lesser importance in Germany (25% of manure production), Switzerland (3%) and Bulgaria (10% of the sows). In Norway, 5%, and in the Netherlands, 1.7%, of the manure production of pigs is in the form of solid manure without differentiation given between sows and fattening pigs. While only part of the urine is collected in the solid manure in the Scandinavian countries, other countries report mainly solid manure only systems. The bedding material apparently is straw, apart from Finland, Norway Italy and the UK where wood shavings or sawdust are also used.

Of the fattening pigs 45% in the UK, about 40% in Austria, 15% in Germany, 20% in Finland, 3% in Switzerland and less than 1% in Italy are kept on solid manure systems.

Poultry

Broilers and turkeys are predominantly kept on deep litter systems with wood shavings as bedding material (Germany and UK, straw also). In most countries hens also produce mainly solid manure, be it in deep pit systems where the manure is collected over a longer period or in belt systems (cages or aviary) with more frequent removal. Apparently, laying hen excreta are partly collected in liquid form in Italy (99%), Northern Ireland (50%), Sweden and the Netherlands (approx. 55%).

3.3. Solid manure production per animal unit

Cattle

For tied housing systems producing solid manure and slurry the quantity of solid manure produced per dairy cow per year varies between 4.4 and 16 t. If values are standardised at 365 days housing period they still vary between 5.4 and 23.6 t. This wide variability can mainly be explained by the variable proportion of the excreta collected in the solid manure. The lowest values are reported from Switzerland (5.4, 8 and 9 t year^{-1} depending on the region; 8 t year^{-1} mean guide value) where, together with most of the urine a significant part of the dung is collected in the slurry. The highest values are reported from Sweden where all dung and 25-50% of the urine is collected in the solid manure. Values between 12 and 16 t are reported from Germany, Italy and Finland. From Switzerland and Sweden variable values are reported depending on regional practice, straw availability, utilisation opportunities for solid manure (CH) and proportion of urine collected (S).

For housing systems producing solid manure on part of the surface and slurry on the rest, solid manure quantities of 8 to 15 t per cow per year are reported. In the UK quantities are estimated at between 10 and 15 t according to animal weight (450 to 650 kg). The rest of the variability can probably be explained by the proportion of excrements collected in the solid manure.

In housing systems producing only solid manure, quantities per cow per year (at 365 days housing period) are 18 t in Switzerland, 18 to 21.5 t in Germany (depending on source of information) and 32 t in Sweden. Only part of this difference can be explained by the higher milk-yield and the higher amount of straw used in Sweden. A possible further source of difference is that animals are also housed for part of the day during the "non-housing" period, without this being accounted for in the questionnaire.

For non-dairy cows and young breeding cattle solid manure quantities vary between 1.6 and 18 t or, standardised at 365 days housing period, 3.2-18 t per animal per year. Comparisons are difficult because of the variable weight of the animals. In general, relations between countries and between housing systems are similar to those for dairy cows.
For beef cattle solid manure production per animal per year (standardised at 365 days housing period) varies between 4 and 15 t. Only for the UK are estimates for different age groups given. The variability is probably due to the production system (e.g. 500 kg end weight: CH with 14 months, UK with >2 years) and to different housing systems. If housing systems producing only solid manure are compared, production per animal per year varies between 7 t (CH, SF) and 14 t (S).
Pigs
For sows (including piglets) values for solid manure production vary between 2.7 (CH, No) and 3.7 t $year^{-1}$ (UK, D) for solid manure-only systems and from 2 (SF) to 4.7 t $year^{-1}$ (S) for other systems. For fattening pigs quantities per place per year mostly vary between 0.8 (S, A) and 1.6 t (UK, CH, D, I, S). Exceptions are values for Bulgaria (3 t), a system with wood shavings in Italy (0.6 t) and a sawdust-compost system (manure accumulated over 1 year) Finland (0.25 t). Differentiated estimates for four animal categories are given for the UK (weaners 0.45 t, "growers" 0.97 t, "cutters" 1.48 t, "bacon" 1.62 t).
Poultry
For hens a solid manure production of 0.02 to 0.04 t per animal place per year is reported from most countries. Exceptions are 0.014 t in Bulgaria, 0.048 t in Portugal and 0.065 t in Austria. In most cases differences can be explained by the housing system: deep pit systems which accumulate the manure over a longer time period being higher than belt systems. For broilers values given vary between 0.006 and 0.015 t per animal place per year (exception: P 0.044 t), for turkeys between 0.03 and 0.057 t, if a mean value between males and females is assumed for the UK.

3.4. Solid manure content

For the nutrient content of solid manures nearly all countries reported a system of guide values used by extension services and farmers. These values are based mainly on analysis results from a larger number of samples. From Switzerland and Germany they are reported to be the results of analysis results and balance calculation on animal excreta with standard rations (combined with manure production values).
From the UK, Switzerland, the Netherlands, Germany, Northern Ireland, Belgium, Portugal, Austria, the Czech Republic and Bulgaria phosphorus and potassium contents were reported in P_2O_5 and K_2O, from Sweden, Norway, Finland and Italy in P and K. Content values were mostly given per unit fresh material. As a control the content per unit dry matter was also calculated. Nevertheless, the variability between countries was hardly lower for the content per unit dry matter.
In many countries contents are given for less animal categories than manure production; probably because it is often difficult to make a clear distinction between categories under farm conditions and because contents will also vary within a certain range. Because of the limited number of categories and often limited information which contents match which housing system, only the range and mean

values reported are presented in table 1 (more detailed information can be provided by H. Menzi). Within animal species no further differentiation is made. If only ranges were reported, the central value of the range was used in mean value calculations.
For all animal categories ranges between values from different countries are considerable. This demonstrates that it is rather unsatisfactory simply to compare manure contents in different countries without better knowledge about feeding practices, housing systems, slurry produced together with the solid manure etc.

Cattle

With one exception (suckling cows in Finland) the reported dry matter content of solid manure is between 16 and 30%, with an average value of 22%. The organic matter content is between 63 and 90% of the dry matter. For most countries the P_2O_5 content reported is around 3 kg t^{-1}, the K_2O content around 7 kg t^{-1}. The total nitrogen content reported shows a wide variability between 2 and 7.7 kg t^{-1}, with a mean value of 4.8 kg t^{-1}. The information concerning plant available nitrogen is given in different forms: some countries give values without definition how they are derived, others differentiate between mineral (N_{min} or N_{NH4}) and organic N (N_{org}). If N_{min} is assumed to be equivalent to plant available N, plant available N reported varies between 0.5 and 2-3 kg t^{-1} with a mean value 1.3 kg t^{-1} or 26% of N_{total}. The highest values are reported from Switzerland, where plant available N is defined as N which becomes available within two years under optimal conditions and thus is always higher than the mineral N content at the time of spreading. Low values (10%) are especially used in the UK and for loose housing dairy systems in Belgium.

Horses, sheep and goats

According to the information received from seven countries horse manure typically has a dry matter content around 30 %, a N_{total} content around 6 kg t^{-1} and a P_2O_5 and K_2O and plant available N content similar to that of cattle manure. Sheep and goat manure generally has a higher nutrient content than horse manure.

Pigs

No differentiation between solid manure from sows or fatteners was reported. Pig manure typically has a dry matter content between 20 and 25%. Its N and P_2O_5 content is higher than that of cattle manure. In most countries the proportion of N_{total} being plant available is similar as for cattle. Again Switzerland has the highest and the UK the lowest values of plant available N.

		DM	N_{total}	N plant available		P_2O_5	K_2O	Mg
		%	kg/t	kg/t	% of N_{total}	kg/t	kg/t	kg/t
Cattle	range	16-43	2-7.7	0.5-2.5	9-50	1.0-3.9	1.4-8.8	0.7-2.1
	average	22.3	4.8	1.3	26	3.0	5.7	1.1
Horses	range	25-54	5-8.2	0.4-2.1	25-33	1.8-3.2	2.0-9.0	0.8-1.8
	average	32.1	6.1	1.5	28	2.7	5.9	1.2
sheep, goats	range	25-48	6.1-8.6	1.3-2.6	23-31	2.3-5.2	5.7-16	1.1-3.5

	average	30.6	7.8	2.0	26	4.0	9.9	2.1
pigs	range	20-30	4-9	0.7-6	10-50	1.9-9.2	2.5-7.2	0.5-2.5
	average	23.8	6.8	2.4	26	6.3	4.9	1.4
hens	range	22-55	13-45	5.1-25	37-60	8-27	6-15	1.2-6
	average	40.6	23.6	10.9	49	16.6	10.7	3.1
broilers	range	45-85	18-40	2.0-15	24-50	6.9-25	6.7-23	2.5-6.5
	average	60.3	30.0	7.6	34	18.5	17.1	4.2
turkeys	range	54-65	20-33	4.0-16	17.5-50	17-25	6.0-21	2.4-6.3
	average	55.9	24.5	8.0	30	19.9	16.2	3.9

Table 1
Range and average values reported for the nutrient content of solid manure from different animal categories.

Poultry

As expected, poultry manure in all countries has a considerably higher nutrient content than cattle or pig solid manure. For broilers and turkeys there is generally good agreement between values from different countries as well as between the two animal types: average values of 55-60% DM, 23-30 kg t^{-1} N_{total}, 19 kg t^{-1} P_2O_5 and 17 kg t^{-1} K_2O. For hens the variability is much greater because belt and deep pit systems cannot always be differentiated. In general, solid manure from laying hens has a somewhat lower content than that of broilers or turkeys. With average values between 30 and 50% the proportion of N_{total} assumed to be plant available is notably higher in most countries than for cattle and pig solid manure.

Heavy metal content

Only the UK and Switzerland reported about the heavy metal content of solid manure (table 2). The data from the two countries generally agrees well except for somewhat higher copper and cadmium contents of pig an poultry manure in the UK. For copper, these differences can be explained by known differences in the feed content, for cadmium the reason was not yet investigated.

	copper (Cu) µg g^{-1} DM		zinc (Zn) µg g^{-1} DM		cadmium (Cd) µg g^{-1} DM		lead (Pb) µg g^{-1} DM	
animal type	CH	UK	CH	UK	CH	UK	CH	UK
dairy cows	23.9	31.4	118	145	0.17	0.42	3.8	2.2
beef cattle	22.0	15.6	91	63	0.15	0.14	2.8	1.4
pigs	66.2	346.0	375	387	0.12	0.68	2.6	2.8
broilers/turkeys	43.8	92.4	349	403	0.29	0.38	2.9	2.9
laying hens	35.2	65.6	425	423	0.31	1.03	2.2	9.8

Table 2

Copper, zinc, cadmium and lead content per unit dry matter (DM) of solid manure produced by different animal types in Switzerland (CH) and the United Kingdom (UK).

3.5. Solid manure use

Crop

Data about solid manure use is available in greatly varying detail. Detailed survey results were reported from Switzerland, Sweden and Finland. Apparently, there is a tendency for solid manure to be used on arable crops in regions where this is possible: UK about 70 % of cattle solid manure and 90% of pig and poultry solid manure, Sweden and Finland about 80%, Switzerland 50%. The main arable crops receiving solid manure in most countries are potatoes and sugar beet. It is also often used on maize in Switzerland, Italy, Austria and the Czech Republic, on cereals in Scandinavian countries and Italy and on oilseed in Norway, Sweden and the Czech Republic. Considerable use of solid manure on grassland is reported from Switzerland (50%; in hill and mountain areas), Austria, Scandinavian countries, the Netherlands (except organic farms), the UK (30% of cattle and 10% of pig and poultry solid manure), Norway and for cattle solid manure in Germany and Italy.

Application time

Spring is the most important application time of solid manure in most countries. Only in the Czech Republic autumn application is most important. Detailed figures received are: S 60% in spring, 40% in autumn, SF 35-60% in spring 20-50 in autumn, CH 50% in spring, 15 % in summer and 20 % in each in autumn and winter. Winter spreading is reported to have stopped almost completely in Finland during the past years. No reports on this topic were received from other countries.

Application rate

The UK, the Netherlands, Belgium and Austria report cattle and pig solid manure to be used at rates of 20-40 t ha^{-1}. Higher rates were reported from Norway (40-60 t ha^{-1}), Italy (40-60 t ha^{-1}), Finland (average in a 1986 survey 38 t ha^{-1} and in Southern Finland in 1995 44 t ha^{-1}) and Bulgaria (20-150 t ha^{-1}, typical 20-60 t ha^{-1}). Lower rates were reported for grassland in Switzerland (10-30 t ha^{-1}), from Germany (20-30 t ha^{-1}) and from Northern Ireland (20 t ha^{-1}). In Switzerland (and one report from Germany) recommendations enclose wider ranges to allow a better adjustment to prevailing conditions: e.g. 10-40 t ha^{-1} on cereals and rape seed and 10-50 t ha^{-1} for potatoes and beet. It is interesting to compare these recommendations with actual amounts applied according to a survey on over 100 Swiss farms during the years 1991-96 (about 400-600 ha each year receiving solid manure). The average rate over all crops decreased from 25.6 t ha^{-1} in 1991 to 17.2 t ha^{-1} in 1996. Average rates for different crops were 14 t ha^{-1} on leys, 20 t ha^{-1} on maize, 16 t ha^{-1} on winter wheat, 19 t ha^{-1} on winter barley, 25 t ha^{-1} on potatoes and 21 t ha^{-1} on beet. Thus, the mean rate actually applied on these farms was always at the lower end of the recommended range and rates clearly decreased in recent years. This can be mainly attributed to a new ecological subsidies programme limiting the amount of nitrogen and phosphate used in fertiliser inputs which was introduced in 1994 and in which over 80% of the farms now participate (1998).

Application technique

Few details are given about the spreading equipment in most countries. In Switzerland rear discharge manure spreaders are most common, in the UK side discharge spreaders. In Switzerland, side discharge systems are used primarily in mountain areas, because they allow the application of low rates (down to below 10 t ha^{-1}, important for solid manure use on extensively managed grassland) and can be used to spread manure in hilly terrain up to 10 m wide from the roadside. From Sweden side discharge systems are also reported to be used for manure from solid manure-only housing systems. For "semi-liquid manure“, a manure containing all dung and 50% of the urine, special systems with “rollers instead of rippers“ are reported. Hand spreading was reported for most solid manure in Bulgaria, about 12% in Finland and on some alpine pastures and small mountain farms in Switzerland.

Rapid incorporation (within one day) is reported only from Sweden (73% of the farms), from Bulgaria and on a smaller scale from the UK. In most other countries no special attention is given to this point and the solid manure is usually incorporated after some days in the course of ploughing or harrowing.

3.6. Nitrogen losses from solid manure

The reports about N-losses from solid manure in animal houses, during storage and after application were in variable detail. This information is summarised in table 3; direct comparison of the data is not easy because of the variable basis, units and categories used.

In cattle houses there is obviously a clear difference between tied and loose housing systems, but the greatest difference can be observed for poultry. This is probably due to very different housing systems as well as to uncertainties about ammonia and other N-losses.

For storage losses the information received can be divided into two groups: NL,S, No, SF, Bu with N-losses around 20% of N_{total} and UK and CH with ammonia (or gaseous) losses of 3-5% of N_{total} for cattle solid manure. These differences probably arise because the figures for the first group take into account total N-losses including those in seepage water while the second group gives only gaseous losses because it is assumed that seepage water from the solid manure store should be collected in the slurry and thus, is not lost.

For application losses, countries can be grouped in to two groups, The UK, Switzerland and the Netherlands with losses of 60-70 % of the total ammoniacal nitrogen (TAN) applied and the other countries with losses of generally below 20% of total nitrogen applied. Depending on the TAN-content assumed, the two groups might be quite comparable. Assuming a TAN-content of 10-20% of N_{total}, the approximately 65% of TAN losses reported by the UK, CH and NL would be equivalent to 7-13 % of N_{total}. Actual measurements of ammonia emissions from solid manure application are only reported from Switzerland and the UK.

	UK	CH	NL	D	S	No	SF	P	CR	Bu	A
houses	kg N per 550 kg LW	% of N_{total}									g LU^{-1} day^{-1}
cows (tied		7%		<5%		6%	3-6%		6.5%	5-10%	5.8 NH_3, 0.62 N_2O

stall)											
cows (loose h.)	5.3 kg	15%		25-50%	20%						
beef cattle	7.08 kg	15%									
pigs	22.2 kg	15%			25%	13%	6-12%				
hens (belt syst.)		60%				7%	5-10%				
hens (deep pit)		20%									
broilers	21.6 kg	20%									
storage	g N m^{-2} d^{-1}	% of $N_{solub.}$	% of N_{total}								g LU^{-1} $year^{-1}$
Cows	2 g	30%	dep. Duration	25-50%	25%	20%	18-23%		dung 5.8% dungwater 13.5% total 19.3%	35%	stacked: 1040 NH_3, 1315 N_2O composted: 6710 NH_3, 341 N_2O
beef cattle	0.91 g	30%	2 m. 10-14%	25-50%	25%	20%					
pigs	2 g	30%	4 m. 16-19%	25-50%	25%	20%	17-22%	up to 80%			
poultry	5.5 g	20%	6 m. 21-23%	25-50%	25%	9%	9%				
application	% of TAN applied			% of N_{total}	% of N	% of N_{total}					g LU^{-1} $year^{-1}$
cattle	65%	60-70%	60%	<5%	5-50% dep. On season, crop,	15-20%	2-18%		dung 6.8% dungwater 3.0% total 9.8 %	5-10%	stacked: 1970 NH_3, 0 N_2O composted: 0 NH_3, 0 N_2O
pigs	65%	60-70%	60%	<5%	incorp.	15-20%	2-18%				
hens		25%	60%	<5%		15-20%	2-24%				
broilers	35%	25%	60%	<5%		15-20%					

Table 3:
Nitrogen losses from solid manure in animal houses, storage and after application as reported from different European countries. (UK-United Kingdom, CH - Switzerland, NL - Netherlands, D - Germany, S - Sweden, No - Norway, SF - Finland, P - Portugal, CR - Czech Republic, Bu - Bulgaria)

If approximate average values from table 3 are used to calculate total N-losses from cattle solid manure management, these can be estimated at 20-40% of N_{total}. Only from Austria specific information was reported on N_2O emissions and on differences in emissions between stacked and composted solid manure. These experimental results show that total gaseous nitrogen losses during storage and after application are about 60% higher for composted than for stacked solid manure (5736 and 3313 g N LU^{-1} $year^{-1}$ respectively), but N_2O emissions are nearly four times as high for stacked than for composted solid manure.

3.7. Other storage losses

To the question of losses other than nitrogen responses were received only from Switzerland, Sweden, Norway, the Czech Republic and Bulgaria (table 4). In CH, S and N it is assumed that no losses of P_2O_5, K_2O, Mg and Ca occur because any seeping losses should be collected in the slurry. In the CR and Bu losses from the solid manure are at least partly counted as actual losses. Losses of total matter are assumed to be at least 25%, dry matter losses at 10 to 30%.

	FM	DM	OM	N	P_2O_5	K_2O	Mg	Ca
Switzerland: loss in SM (%) of this collected in slurry (%)	25 25	10 25		25 50	5 100	15 100	5 100	5 100
Sweden source 1) source 2)	 25-50		10-20 25-50		insignificant			
Norway	29	15			0	0	0	
Austria stacked SM composted SM		35 60		7.5 11				
Czech Republic			30-40 and more		dung 10% dungwater 3.6% total 13.6%	dung 8.4% dungwater 14% total 22.4%		
Bulgaria	20-30%; 15-20% collected in slurry if tank available							

Table 4

Losses during storage of solid manure as reported from Switzerland (CH), Sweden (two reports received) and Norway. (FM - fresh matter, DM – dry matter, OM - organic matter, N - nitrogen, P_2O_5 - phosphate, K_2O – potash, Mg - magnesium, Ca - calcium)

3.8. Solid manure "exported" from agriculture

Apparently, solid manure export from agriculture is of small importance all over Europe. Reported most often is the combustion of poultry, horse or sheep/goat manure (UK, S, I, P, Bu), the use in horticulture (D, SF, S, Bu), the use for mushroom production (CH, NI) and fertiliser production (mainly poultry manure; I, B, NL?, CH). In Portugal poultry manure is also used in animal feed. Even though the information received is not sufficient to the amount of solid manure leaving agriculture, it appears that this "export" is most important in Portugal (20% of sheep and goat manure; sheep and goats are the most important animal category in this country) and the UK (today 340'000 t, later possibly 500'000 t year $^{-1}$; this is approximately 15-20% of the broiler and turkey manure produced).

3.9. Regulations, laws, recommendations

As national legislation can vary in structure and approach and because the questionnaire was organised such that experts could mention legislation and recommendations they judged relevant rather than filling in how specific aspects are treated, this survey can not give a comprehensive overview on the topic. Nevertheless, the results summarised in table 5 can show different interesting aspects :

– Only Portugal and Bulgaria reported that so far there was no legislation with direct impact on solid manure management. Nevertheless, the reports from most countries show clearly that solid manure is much less governed by legislation than slurry management.

– Many countries report about water protection legislation giving guidance for solid manure management. This demonstrates that as for manure in general water protection is the major legislative concern regarding manure management.

– From five countries it was reported that a code of good agricultural practice gives guidance to farmers concerning environmentally friendly manure and nutrient

management. It can be assumed that other countries have similar recommendations.

– Switzerland, the Netherlands and Finland appear to have the strongest control on the nutrient and manure management. These countries not only have restrictions about manure application in winter and the maximum application rate, but also clear limits concerning the nutrient balance. In Switzerland and Finland these restrictions are made in the framework of ecological subsidies. In both countries over 80% of the farmers participate in these voluntary programs.

– Only from Switzerland are animal welfare regulations reported to have a strong influence on housing types. Nevertheless, reports concerning the growing importance of solid manure systems (chapter 3.1) indicate that this is or shortly will be the case in other countries too.

– Restrictions concerning solid manure stores near farm building (mainly collection of seepage water) are only reported from the UK, Switzerland and Italy. Minimum storage capacity for solid manure is only prescribed in Sweden and for new buildings in Switzerland.

– Nowhere, at present, is the storage of solid manure in field heaps regulated.

– An obligation to rapidly incorporate solid manure exists only for winter application (December-February) in Sweden.

– Only the UK reports odour regulations concerning solid manure. In Switzerland similar recommendations exist for new animal houses and manure stores.

	UK	CH	NL	D	S	SF	I	B	A	NI
Water Pollution		X		x		x		x	x	x
Code of good practice	x	X			x			x	x	x
Nutrient balance		X	x			x			x	
Application rate		X	x			x	x		x	
Application time		X	x		x	x	x			
Housing systems, animal welfare		X								
Storage near buildings	x	X					x			
Storage capacity		X			x					
Storage in field heaps										
Incorporation					x					
Odour	x	X								

Table 5

Overview of subjects concerning solid manure treated in laws and regulations in different European countries. (UK - United Kingdom, CH - Switzerland, NL - Netherlands, D - Germany, S - Sweden, NI - Northern Ireland, SF - Finland, I - Italy, B - Belgium, CR - Czech Republic).

3.10. Ongoing research

Because the information concerning ongoing research projects and recent scientific publications on solid manure was variable in detail and because the RAMIRAN-conference in Rennes in May 1998 demonstrated that research on solid manure and other organic solids used as fertiliser is rapidly gaining in importance in different countries, a more detailed survey on this topic will be made by the members of the Working Group on Solid Manure.

4. Conclusions

This survey can certainly not claim to give a comprehensive picture of solid manure management all over Europe. If such as task were actually possible, it would require a much greater input than possible for this survey. It could only be done in the framework of a network of several experts from every European country. Nevertheless, the results of this survey, in spite of the remaining gaps and uncertainties, can be a valuable aid for national experts to see how their solid manure management compares to that in other countries and to promote awareness about gaps in knowledge and the potential for improvement.

The first step necessary for a more comprehensive overview of (solid) manure management in Europe would be the establishment of common definitions and terms for housing systems, manure types, farming systems etc.. This will probably require a close collaboration of experts from as many countries as possible and/or somebody visiting farms in every country and major region to draw up a comprehensive description of systems used in a standardised common terminology.

Even more than for slurry, solid manure management varies considerably over Europe due to differences in natural conditions, farm structure, tradition, policy etc.. The scientific understanding and characterisation of solid manure systems is considerable, especially in central and northern European countries. Nevertheless, there remain serious gaps both in knowledge and technology which are greater than for slurry, for example concerning factors controlling solid manure composition, nutrient availability of solid manure (especially for N), long term efficiency of the nutrient cycle in solid manure farming systems, possibilities for a better control of solid manure quality, practical difficulties in achieving even and accurate spreading of solid manures (particularly important for poultry manures), ecological impacts of solid manure management etc.

Concerted efforts on solid manure by experts from as many countries as possible could be very beneficial for all the participants as well as for policy makers and extension services all over Europe. The Working Group on Solid Manure of RAMIRAN and the EU-Concerted Action "Recycling Organic Solids in Agriculture" can be a good framework for such efforts. Nevertheless, solid manure systems are so complex that the understanding about them will always remain partial and that considerable regional differences will remain.

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