Teagasc
The Science of Farming and Food

END OF PROJECT REPORT

PROJECT 4026

LAND SPREADING OF ANIMAL MANURES, FARM WASTES & NON-AGRICULTURAL ORGANIC WASTES

PART 1

MANURE (AND OTHER ORGANIC WASTES) MANAGEMENT GUIDELINES FOR INTENSIVE AGRICULTURAL ENTERPRISES

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MANURE (AND OTHER ORGANIC WASTES) MANAGEMENT GUIDELINES FOR INTENSIVE AGRICULTURAL ENTERPRISES

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SUMMARY

Properly managing manure (liquid and solid) and other organic wastes on farms is essential to achieving sustainability, both in environmental and economic terms. Recycling animal manures back to the land is the most sensible management option. Although considerable progress toward improving manure management has been made on many farms in recent years, environmental and regulatory requirements are demanding even greater changes. These changes pose considerable challenges for the larger intensive farms (*i.e.* Intensive Agricultural Enterprises, or IAE). At the core of these changes is achieving a better balance between the nutrient loads, particularly nitrogen (N) and phosphorus (P), contained in the manure, and crop requirements for nutrients. In addition, given the increasing environmental significance of atmospheric emission from agriculture, it is critical that producers minimise emissions to both air and water by following the Code of Good Agricultural Practice to Protect Waters from Pollution by Nitrates and employing the best available technologies.

The practical implications of achieving a closer balance between the needs of crops for nutrients and amounts of nutrients supplied by manure (and other organic wastes) are that IAEs must seek larger land spreading areas than have been traditionally used. At the same time, however, a variety of factors are influencing the availability of spread lands. These include revised P nutrient advice for grassland, the EPA BATNEEC Guidelines, the national Code of Good Agricultural Practice to Protect Groundwater from Pollution by Nitrates, and the national Rural Environment Protection Scheme all of which influence the supply of agricultural land that can be utilised for recycling of manure generated by IAEs. In addition, the localised concentration of IAEs in parts of the country and the general separation of these concentrated production areas from tillage areas impact seriously on the availability of spread lands. The restrictions noted above pose greater difficulties for existing compared with new enterprises.

For these reasons, Teagasc is proposing adequate time be given for existing IAEs to fully implement a manure and waste management strategy that will balance nutrient applications with removals. In this interim period, it is proposed that existing IAEs be allowed to use soil P storage as a mechanism to manage the practical and financial hardships that will accompany trying to obtain enough land to achieve a balance between nutrient inputs and outputs on spread lands.

The objective of the Teagasc Manure (and Other Organic Wastes) Management Guidelines for IAE are to provide an operational framework for the agronomically efficient and environmentally safe recycling of these organic by-products, maximising the benefits of nutrients they contain at minimum cost. The principles of the approach are equally applicable to the management of all manures and organic wastes applied to land. The approach includes programmes for controlling manure quantity and quality; operational procedures covering storage, transport and nutrient management; and a quality assurance programme. These Guidelines assign the importance of manure management on an equal footing with other production practices. Implementation of these Guidelines may entail higher costs compared with traditional practices. However, some of the benefits accruing from the improved management practices can partly or wholly offset the costs of implementation.

The introduction of regulations will serve to channel the course of livestock farming, poultry production, and other farming systems, particularly IAE, in so far as these regulations will modify current practices and promote technical changes. The implementation of these Guidelines will assist producers in optimising nutrient recycling and in complying with environmental regulations. However, they require a change in attitudes toward manure management, and the genuine commitment of all those involved.

INTRODUCTION

Crops are our primary source of food, either directly as plant materials or indirectly as feed for animals that produce milk, meat or eggs. Growing crops utilise inorganic minerals (nutrients) taken from the soil, including nitrogen (N), phosphorus (P) and potassium (K), to form biomass (grass or grains). When eaten and digested by humans or animals, plants supply the energy and nutrients required for growth and development. Unfortunately, this process is not 100% efficient, and a variable quantity of nutrients is voided in the faeces and urine.

In the case of farm animals, approximately 54 to 99% of the minerals ingested are excreted (Lynch, 1992; Hynds, 1994). The excreta, or manure, is returned directly to the soil either by the animals during grazing, or in the case of animals fed indoors, at some later time by land application following collection and storage. The soil's flora and fauna decompose the manure, eventually releasing the minerals back to the soil complex and making them available to the crop - thus completing the nutrient cycle. Providing an operational framework to ensure that the nutrients in manure* are effectively and safely recycled is one of the primary objectives of Teagasc's Manure (and Other Organic Wastes) Management Guidelines.

It has been estimated that 153 million tonnes (M t) of manure are produced annually in Ireland by farmed livestock (Carton and Magette, 1996). In terms of perspective, this aggregate quantity of manure would require 53% of the utilisable agricultural area (UAA, 4.43 M ha) if applied at a rate of 20 t per hectare (t/ha).

** The generic term manure used in this documents refers to both liquid and solid manures. Equally it can be applied to any other agricultural, munici - pal or industrial organic waste applied to land.*

However, of this amount of manure, only that produced when the animals are kept indoors requires management. Almost 43 M t produced by cattle and sheep requires storage and spreading annually. Pig and poultry enterprises produce an estimated 2.8 and 0.6 M t of manure, respectively, every year. In addition, approximately 0.3 M t of spent mushroom compost (SMC) requires management annually (Kelly, 1999). Only slightly more than 4 % of the UAA would be required each year to assimilate all IAE manure (and SMC) if it were to be applied at 20 t/ha. Twenty tonne per hectare would traditionally be considered a moderate application rate for these types of waste by-products.

It is generally accepted that Irish agricultural land has the capacity to safely assimilate the nutrient loads in animal manure and SMC. Consequently, land spreading is the most environmentally and economically sustainable management option available. Indeed, the national agricultural P balance reported by Tunney (1990) showed the P inputs to agriculture in concentrates (*i.e.* animal feed supplements) are just under 15,000 t while exports in farm produce are just over 31,000 t indicating the requirement for P inputs of 16,000 t to maintain the balance. Because P supplied by concentrates on cattle farms is accounted for in the foregoing balance, the net P "deficit" (*i.e.* P exports in excess of imports) indicates that there is potential for Irish farm land to assimilate an additional P load that would be generated by a substantial expansion in IAE. However, this potential can only be realised if the manure P is used as a direct substitute for chemical fertiliser P and if site characteristics conform to spread land criteria formulated to protect environmental quality.

Public scrutiny has focused on IAE in terms of their impact on water and air quality. The development of IAEs has largely been confined to a limited number of counties. For example, about 38% of the national sow herd are located in Cavan and Cork (Tuite, 1999). There is further concentration of IAE within areas of counties. For example, in Cork there is a significant concentration in the North Cork area (Fehily Timoney, 1999). In Monaghan, poultry and mushroom production account for 47% and 12%, respectively, of the gross agricultural output (GAO) compared with the national figures of 4% and 2%, respectively (MAWMS, 1994). Poultry enterprises account over 60% of the GAO for the Blackwater catchment, one of County Monaghan's seven river catchments.

The need to achieve nutrient balances in areas receiving animal manures has been recognised for 25 years in Ireland (O'Callaghan, *et al.* 1973). Following less-than-optimal manure management practices can lead to the soil's chemical/ physical assimilative capacity being exceeded. Increased soil test phosphorus (STP) levels, above those required to sustain crop production, are a characteristic outcome of such practice, particularly in areas with high concentrations of IAEs. Therefore, current land spreading practices for IAE manure are not sustainable in these regions and alternative manure management practices are required. This fact is recognised in national policy and is being implemented through the Environmental Protection Agency's (EPA) Integrated Pollution Control Licensing (IPC) requirements for intensive pig and poultry production units (EPA, 1997).

The control of emissions from agriculture to water is complex and challenging (Magette, 1998). This code addresses nutrient losses from field sources associated with the land spreading of manures and other organic wastes. Its primary focus is on IAE manure but the principles apply to other manures and organic wastes resulting from agricultural production (such as SMC). The adoption and application of this code at farm level will assist in reducing emissions to water. However, it is important to note that farm yard losses must also be addressed if progress is to be made in improving the environmental sustainability of Irish agriculture.

This End of Project Report outlines the Teagasc Guidelines for management of manure and other organic wastes from IAEs *via* land spreading. The Guidelines provide

- a sustainable agronomic and environmental framework for manure management based on land spreading;
- optimised manure nutrient recovery by the crop;
- compliance with the EPA's IPC requirements for the pig and poultry production sectors and with the national Code of Good Practice to Protect Waters from Pollution by Nitrates ("Nitrate COP") (Anon, 1996).
- a basis for establishing national standards for manure management;
- the confidence of i) the recipient farmers utilising imported IAE manure as a reliable substitute for inorganic fertilisers, ii) the public in terms of reduced potential environmental impact from manure management, iii) the authorities responsible for monitoring compliance with IPC licenses and planning conditions and iv) consumers in terms of quality, safe food production in a clean environment.

The Guidelines were presented in draft format as part of a widely distributed discussion document in January 1998 (Teagasc, 1998). Comments from interested parties were solicited, and have been analysed and incorporated as appropriate into this publication.

NUTRIENT CYCLES ON FARMS

A farm nutrient status analysis is an assessment of the quantity of nutrients entering, leaving or remaining on the farm. Nutrients generally enter the farm as fertilisers and, where animals are produced, as animal feed (INPUTS). In the case of mushroom production units, nutrients (mainly P) are imported in the fresh compost. The sale of milk, meat or plant produce is the main pathway by which nutrients leave these farming systems (OUTPUTS). Determining the extent to which nutrient INPUTS balance OUTPUTS on a farm provides an indication of the nutrient management strategy required.

Farm Nutrient Balances And Nutrient Management Strategies: Farms can be divided into three categories based on nutrient balances *i.e.* tillage farms with no livestock, grassland farms and intensive agricultural enterprises. On tillage farms the crops (*e.g.* wheat, barley, sugar beet) are exported off the farm. The resulting removal of the nutrients in the crop creates a farm nutrient deficit. The nutrient strategy is to balance the deficit with imported inorganic or organic fertilisers.

The second category of farms is grassland farms, where crop and animal production are directly linked *e.g.* dairy and drystock farms. The grass produced on the farm generally meets the animal's feed requirements. In some cases it may be supplemented with imported feed. Approximately 20% of the ingested nutrients are exported in animal product. The remainder is contained in the manure excreted by the animals. These nutrients are returned to the soil system either during grazing or at some other time by land spreading of the manure produced during the indoor feeding period. In general, there will be a farm nutrient deficit on these farms and the nutrient management strategy is to balance the deficit with imported inorganic or organic fertilisers.

The third category of farms is the IAE. Generally, there is no direct link between crop and animal production on these farms. Most nutrients are imported in the form of cereal-based animal feeds or in the form of imported substrates such as composts (poultry litter and straw are the primary ingredients) on mushroom farms. The sale of meat, eggs or mushrooms results in the export of a relatively small fraction of the imported nutrients, with the remainder staying at the production unit in the form of manure or organic by-products that must be managed. Therefore, an annual nutrient surplus is generated on an IAE, and the excess nutrients are contained in the manure or compost. The nutrient strategy is to export the manure to farms with nutrient deficits, *e.g.* grassland or tillage farms.

In theory, nutrients should be returned to the sources from which they originated. Unfortunately, the general trend in Ireland has been to spatially separate IAEs and the farms that produce the feeds and other raw products used by the IAEs. This fact, plus the nature and quantity of the manure and organic wastes produced by IAEs, creates logistical problems that militate against the recycling of the IAE manure and SMC to cereal producing land. Consequently, the traditional approach to manure and waste management has been to apply them to grasslands in close proximity to the enterprises. Because the nutrient deficit on grassland farms is relatively small, the nutrient supply in the applied IAE manure has generally exceeded the grass requirements for nutrients, particularly P. In some cases this situation may have been exacerbated by making no adjustment, on the recipient farms, in the inorganic fertiliser applications to take account of the nutrients already supplied by the IAE manure. The general outcome has been STP levels of the spread lands in excess of those required for crop production (Figure 1).

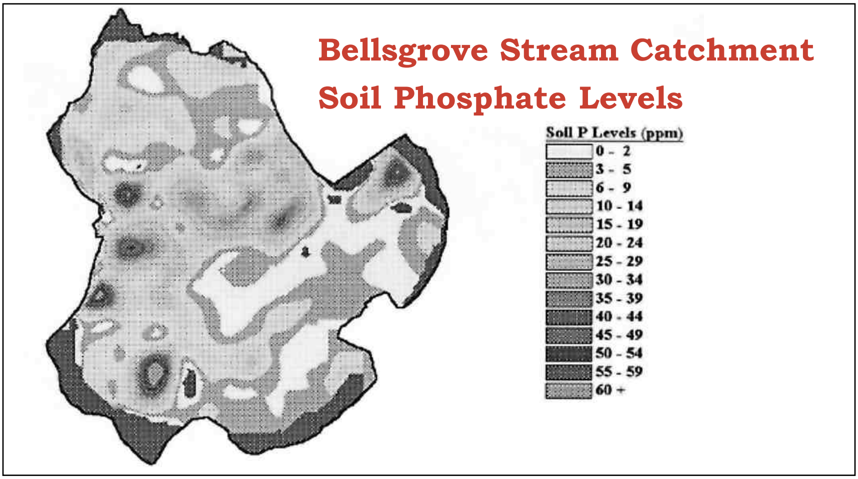

Figure 1. The distribution of STP levels within the Bellsgrove catchment County Cavan. Areas with elevated STP are generally associated with IAE. (Humphreys *et al.* 1996).

The potential for P loss to water is directly correlated with STP (Sharpley *et al.*1994); as STP levels increase so does the potential for P losses. A variety of natural factors can prevent potential P losses to water from becoming *actual* losses. Nevertheless, the practice of applying *ad infinitum* IAE manure and SMC, or indeed any source of P, to lands with STP levels significantly higher than agronomic requirements is no longer acceptable from a sustainability perspective. New and existing IAEs that utilise land as receivers of their manure must strive to achieve a better balance between the nutrient load in the IAE wastes and the nutrient needs of crop production.

This balance can only be achieved by transporting IAE manure and SMC to land with a nutrient deficit. Compliance with the EPA's BATNEEC Guidelines and adherence to the Nitrate COP are increasing the difficulties for IAE operators to secure spread lands. Likewise, enrolment of farm land into the Department of Agriculture and Food's Rural Environment Protection Scheme (REPS) (DAF, 1999) is significantly reducing the availability of suitable spread lands.

FACTORS THAT INFLUENCE AVAILABILITY OF SPREAD LANDS FOR IAE MANURE and OTHER ORGANIC WASTES

The Environmental Impact Assessment (Anon, 1989) and the EPA's BATNEEC Guidance (EPA, 1997) for the pig and poultry production sectors are the primary regulations relating to the acceptability of spread lands as receivers of manure from IAEs. The Nitrate COP also must be considered when securing spread lands. REPS participants must adhere to nutrient input limits, specifically organic N loads, on their lands. The restrictions established by the EPA's regulations, the Nitrate COP and REPS which influence the availability of spreadlands include:

- IAE manure cannot be applied to land where the existing STP exceeds 15 milligram per litre (mg/l) (according to Morgan's Test).

- In areas supporting high stocking rates, and provided surface and groundwater are in good condition, i.e. nitrate concentrations do not exceed 20 mg/l and there is no evidence of eutrophication caused by nitrates, the maximum quantity of manure and other organic materials applied to land, including that deposited by grazing animals, should be such as to ensure that the nitrogen contained therein does not exceed 250 kilogram per hectare per annum (kg/ha/annum). In all other areas, the nitrogen applied from these organic fertilisers should not exceed 210 kg/ha/annum. Lower application rates than those indicated should be observed in areas where the County Council indicates that this is necessary because nitrate level in ground waters, or because the P content of the slurry or other organic manure is causing or is likely to cause water pollution.

- The mandatory upper limit of organic N, 170 kg/ha/annum, for farmers participating in REPS constrains their potential to receive IAE manure.

Soil Test P Limits: The EPA BATNEEC Guidance Notes (EPA, 1997) establishes a STP limit of 15 mg /l for spread lands associated with intensive pig and poultry units. Soils with P levels greater than this are not permitted for the application of IAE manure. The EPA limit is based on the 1994 agronomic STP level for silage production (Gately, 1994) above which no P was recommended. This is significantly lower than the suggested Teagasc STP limit of 30 mg/l on IAE manure spread lands with low vulnerability for nutrient losses (MAWMS, 1994). This higher STP limit was proposed to accommodate the special circumstances of IAE nutrient surpluses. However, since then more recent research has demonstrated a relationship between STP and P loss to water (Sharpley *et al*, 1994; Tunney *et al*, 1999). This evidence, coupled with the demands for more sustainable nutrient management practices, has negated the applicability of the 30 mg/l STP limit.

It should be noted that the agronomic STP targets for crop production based on Teagasc fertiliser guidance (Gately, 1994 and Teagasc, 1998a) should be adopted on tillage and grassland farms (*i.e.* nutrient deficit farms). Applications of P to land with STP in excess of these targets are not recommended in most situations, as no agronomic benefits will result.

For example, on individual grassland farms, with annual P deficits, Teagasc advises that the manure produced on these farms be recycled to areas within the farm even when STP levels are above the agronomic targets, but only if management constraints (*e.g.* lack of suitable spread lands elsewhere on the farm) so require, and if a nutrient management plan (NMP) is implemented. The NMP may identify the uneven distribution of P on the farm, and will recommend that no P beyond that supplied in the manure be applied to areas with STP above agronomic targets. On such lands STP levels will eventually decline to below the agronomic limit provided no inorganic fertiliser P is used.

Teagasc research indicates that intensively farmed land will tend to have higher STP levels than extensively farmed areas. This was evidenced from the results of a recent Teagasc project, supported by the EU LIFE programme, to promote uptake of nutrient management planning on farms (Carton, 1996). In this study three catchments were examined, two of which had dairy farming as the predominant agricultural enterprise. The average stocking rates and STP in these catchments were 2.2 Livestock Units per hectare (LU/ha) and 10 mg/l, respectively. This compares with a mean STP of 6 mg/l in the third catchment, which had a lower average stocking rate (1.6 LU/ha - more extensive) and a more diverse mix of dairy and drystock farms. It is inevitable, therefore, that compliance with the BATNEEC STP limit will encourage IAE operators to seek the more extensive farms when selecting spread lands. (Ironically, it is in extensively farmed areas that enrollment of farmland in the REPS programme is most noticeable. As mentioned previously, the limitations placed on organic N loadings for REPS farms tends to eliminate them as potential recipients of manure from IAEs).

Over 20% of grassland and 27% of tillage land soil samples received at Johnstown Castle Analytical Services Laboratory in 1995/1996 had STP levels above the BATNEEC limit levels (Coulter and Tunney, 1996). Manure spread lands associated with IAEs generally have had high soil P levels. For example, it was shown that more than 30% of mushroom farms, 50% of poultry farms and 60% of pig farms had spread land soils with P levels greater than 15 mg/l (MAWMS, 1994). In contrast, fewer than 10% of farms with grass based enterprises had STP levels in excess of 15 mg/l (MAWMS, 1994). Equally, high P "hot spots" within a County Cavan catchment were generally associated with IAE developments (Figure 1).

The implication of these findings is that IAE operators will have greater difficulties than heretofore in securing spread lands within the 15 mg/l STP limit set by the EPA.

Code Of Good Agricultural Practice: The Nitrate COP sets a voluntary organic N load limit of 250 kg/ha/annum in areas with no water quality problems. This limit can be reduced to 210 or 170 kg/ha/annum in areas experiencing water quality problems.

Under this Code, grassland farmers are practically excluded from receiving poultry litter or slurry. On average, applications of poultry litter and slurry at the lowest practically achievable rates* supply approximately 260 and 280 kg organic N/ha, respectively. Therefore, generally only tillage farms will be able to receive poultry manure without exceeding the COP limit. The potential of the tillage land spreading option is not without its problems due to the variable crop response to manure N. Improved slurry/manure spreading systems which can reliably achieve lower spreading rates are required to ensure the viability of the land spreading option for poultry litter and slurry.

The organic N supplied in pig manure and SMC applications, at 20 and 10 t/ha, respectively, are approximately 80 kg/ha. Therefore, only grassland farms with stocking rates of less than 2.0 LU/ ha (≈ 170 kg organic N/ha) can accept IAE manure and remain in compliance with the even highest Nitrate COP organic N limit of 250 kg organic N/ha. Concern over ground water quality in some parts of the Country may result in lower organic N limits being set, i.e. 210 and 170 kg/ha. If N limits were set at 210 kg/ha, the implications for pig manure and SMC applications are that they will be restricted to grassland farms with stocking rates of less than 1.8 and 1.3 LU/ha. If a 170 kg/ha N limit is set, pig manure and SMC applications would be confined to farms

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** The lowest practicaly achieveable liquid manure application rate is in the range 15 to 20 t/ha using the typical (and widely used) vacuum tanker. Lower application rates can only be achieved with improved and more expensive application control systems, or by intentionally diluting the slurry. For solid manure, an application rate of 10 t/ha can be reliably achieved using typical rear discharge machines.*

with less than1.4 and 1.0 LU/ha stocking densities, respectively. These constraints highlight the wisdom of locating these IAEs in close proximity to tillage areas. However, even in these areas, the Nitrate COP limit on organic N applications will increase the difficulties for IAE operators in securing an adequate portfolio of spread lands on which to manage the manure and other organic wastes they generate. The extent of these difficulties may not yet be fully realised.

REPS: The enrollment of farm land in REPS will exclude significant land areas for use as sites for managing IAE manure. REPS farmers with stocking rates higher than 1 LU/ha (1LU/ha ≈ 85 kg organic N/ha) are practically excluded as receivers of IAE manure if they are to remain in compliance with the mandatory 170 kg/ha/annum organic N limit set by the scheme. Only REPS farmers that generate organic N loads of less than 110 kg/ha, equivalent to a stocking rate of 1.3 LU/ha, can accept pig slurry (assuming the lowest practically achievable application rate of 15 t/ha) and remain in compliance.

The use of poultry manure on REPS farms is not a viable proposition because of their high N content. Fortunately for poultry producers, significant quantities of poultry litter are used in making mushroom compost, and is not applied directly to land. However, the resulting SMC is typically managed by land spreading following the production of the mushrooms. Although the dilution of the poultry manure with straw reduces the N concentration, making land spreading of SMC more practical than spreading the original poultry manure, there are still constraints on SMC application due to the P it contains (Maher and Magette, 1997).

SMC applied at the lowest practical achievable rates (10 t/ha using a rear discharge spreader) will supply almost 80 kg organic N/ha. Consequently, only REPS farmers with organic N loads of less than 90 kg/ha, equivalent to a stocking rate of just over 1 LU/ha, can accept SMC and remain in compliance with the REPS limit.

In addition, REPS participants who can accommodate IAE manure are by definition more extensive with relatively low nutrient requirements. Therefore, they may be less willing to accept nutrients from external sources, especially if they perceive that doing so may jeopardize their REPS contract. In a recent study prior to the introduction of REPS, only one third of farmers with stocking rates less than 1.25 LU/ha indicated that they were willing to accept IAE manure for application to their land, even if it was given free (MAWMS, 1994).

The Government have set a national target for a 30% uptake of REPS by farmers by the end of 1999 in its recently published Sustainable Development Strategy. The implications of REPS for IAE operators in terms of securing spread lands are similar to those posed by BATNEEC Guidance and the voluntary Nitrate COP. In short, obtaining suitable spreadlands will be more difficult than in the past.

Revised P Recommendations for Grassland: Teagasc have recently revised their P use guidance for grassland (Teagasc, 1998a). These set lower agronomic STP targets for grazing and silage ground than previously advised (Gately, 1994). When soils are above these targets, additional P will not give agronomic benefits and are, therefore, not recommended in most cases. The revised recommendations have reduced the P requirements for silage and grazing by approximately 50 and 40%, respectively, largely by recognising the contributions of concentrates to the P balance in grass-based systems.

Applying nutrients at rates that meet crop requirements, including in some cases improving soil fertility, is the foundation on which Teagasc's nutrient management guidance is based. The reduced P recommendations for grassland increase the practical difficulty of achieving this balance when using IAE manure and wastes. This reinforces the desirability of directing these by-products to tillage areas whenever possible. However, as illustrated by Tables 1 and 2, manures from IAEs generally supply more P than required by even tillage crops.

Table 1: The average P (kg/ha) supplied by pig and poultry slurry, poultry litter and spent mushroom compost applied at the lowest practically achievable spreading rates			
Pig Slurry (15t/ha)	**Poulrty Slurry (15t/ha)**	**Poulrty Lit - ter (10t/ha)**	**Spent Mushroom Compost (10t/ha)**
21	75	90	42

Note: Nutrient values for slurries, litter and spent mushroom compost used were from the Nitrate COP. These are guide values only and will vary between IAEs. An application of 10 t/ha of poultry litter will exceed the Nitrate COP limit of 250 kg organic N/ha.

Table 2: The P recommendations (kg/ha) for a range of crops at soil P index 3 (STPrange of 6.1 to 10.0 mg P/1).				
Grazing (2 to 2.5 LU/ha)	**Silage (2 cuts)**	**Cereals**	**Potatoes**	**Sugar beet**
12	0	20	60	30

Note: Soil index 3 is the target STP for most grass-based and tillage systems.

Except for pig slurry, annual application of IAE manure at the rates indicated in Table 1, will result in an over supply of P compared with crop requirements. The magnitude of the surplus is greatest for poultry slurry and litter (Figure 2). The P recommendations are greater at the lower soil P indices, therefore the surplus P applied will be proportionately smaller. Consequently, annual balancing of nutrient inputs with outputs is difficult to achieve in practice when IAE manure is land spread, particularly for soils with STP levels in soil P index 3 range.

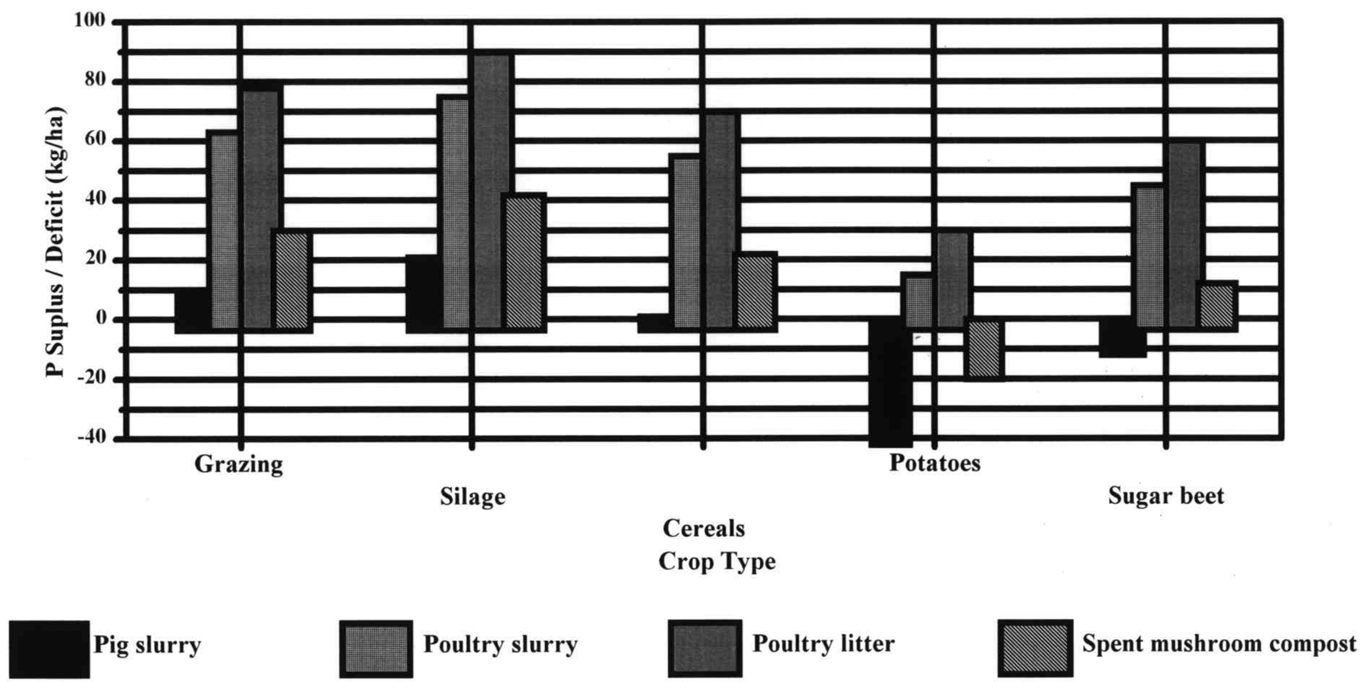

Figure 2. The P surplus/deficit (kg/ha) following manure applications at the lowest practical achievable spreading rates to range of crops.

Phosphorus applied in excess of crop requirements (removals) will increase STP reflecting the soil's ability to "store" P. The time-tested practice of managing soil fertility to provide a reserve of nutrients in the soil, which can be subsequently "drawn down" by the crop, is based on the ability of soil to store nutrients. This "storage capacity" is not unlimited, however, and the "tenacity" with which stored nutrients are retained depends on a variety of factors. Consequently, a sustainable balance must be achieved between the extent of soil storage and environmental risk. From this perspective, the soil P "storage" capacity allowed for use by IAE operators is currently determined by the BATNEEC STP limit of 15 mg/l. Once the STP reaches this limit, manure applications to these lands must cease and new spread lands with lower STP must be utilised.

Just as P additions in excess of crop removals will increase STP, so too removals in excess of P additions will decrease STP. Thus, as crop production continues in the absence of added nutrients, the store of soil nutrients will be depleted. The time frame for the P "build up" and "draw down" will vary depending on soil type and cropping practices. A programme of soil testing to monitor STP must accompany each NMP to assure that the STP limit of 15 mg/l is not exceeded. The frequency of testing should reflect the proximity of STP to 15 mg/l. The closer STP levels are to the limit, the more frequently soil testing should be conducted (*e.g.* every 1 to 2 years).

Teagasc is recommending that the actual annual P application rates of manure used by an IAE should be at the discretion of the IAE operator abiding by the constraints of BATNEEC and the Nitrate COP. Within those constraints, an operator could choose to apply P at a higher or lower rate (kg/ha/year). The larger the P surplus applied on an annual basis (*i.e.* high application rate), the faster the turnover of the spread lands and visa-versa. Adherence to the Nitrate COP will ensure that excessive manure application rates will be avoided.

Groundwater Protection Schemes: The Department of the Environment and Local Government, the Environmental Protection Agency and the Geological Survey of Ireland have issued new guidelines for the protection of groundwater (DoELG/EPA/GSI, 1999). They have developed and proposed a response matrix based on a vulnerability rating for both source and resource protection in terms of the suitability for land spreading. The application of this will have implications for spreadland suitability in some areas of the country.

Site Assessment: There is evidence that differences exist between areas within catchments in the extent to which they lose nutrients to water (Guberek *et al*, 1996; Heathwaite *et al*, 1998). Consequently, areas within catchments can be classified in terms of risk or vulnerability to nutrient losses. While the process of ranking fields or catchments in Ireland is at early stage of development, the conceptual framework of risk assessment does provide a mechanism to assist in assessing the suitability of spread lands for IAE manure applications. On a relative basis, only sites ranked as having a "low" potential to lose nutrients to water should be used to "store" surplus P from applied IAE manure (i.e. build up STP to 15 mg/l). "High risk" areas should not be used for IAE manure applications.

The analytical tools by which to quantitatively define areas according to their potential for losing nutrients to water generally are not yet available for Irish conditions. Decision criteria have been suggested (Magette, 1998), and research is continuing in order to validate these, as well as other (Daly, 1999), ranking procedures. In absence of quantitative procedures, first principles can be used to make relative comparisons about the nutrient loss risk associated with specific areas. For example, from a P loss perspective "low" risk sites would be expected to have freely draining soils which are not P saturated (*i.e.* with an ability to store P - such soils will generally have high iron and aluminum contents). Ideally, such sites would be located some distance away from surface waters that are susceptible to P

contamination (*e.g.*, lakes).
In contrast, areas with a "high" risk of contributing P to waters would be those having both a high soil P saturation and hydrologic connectivity to the drainage network (Heathwaite et al, 1998). Soils with high soil P saturation have a limited ability to absorb additional P because of low iron and aluminum contents (*e.g.* peats) or high P content. In areas where soil infiltration rates tend to exceed rainfall intensities, the most hydrologically active areas tend to be at the bases of hillslopes closest to natural drainage networks (Dunne and Leopold, 1978). Specific caveats regarding spreading on artificially drained land are prescribed in the EPA BATNEEC Guidance notes for intensive pig and poultry units (EPA, 1997).

Buffer Zones: The exclusion of buffer zones, prescribed in BATNEEC and in the Nitrate COP around water sources and houses will further diminish the land available for use as spread lands. For example, 12 to 15% of land will be excluded in areas with a high land to water ratio while in areas with low land to water ratios this may be up to 35%.

Farmyards: The condition of the farmyards on recipient farms should be considered when locating spread lands. This is important because of their potential to contribute to water pollution. The Regulatory Authorities may consider water quality monitoring to assess the effectiveness of the IAE manure management programme. If farmyards on recipient farms are contributing to water pollution these could overshadow the benefits of practices such as nutrient management planning.

Other Considerations: The EPA IPC license for intensive pig and poultry units has a requirement for supplementary spread lands over and above those required to assimilate the nutrient load in the manure. This is set at 50% of the spread land area acquired by agreement for new enterprises. Finally, written agreements between the IAE and recipient farmers are required once all proposed spread lands are identified.

Implications: The restrictions, noted above, on spread land availability have significant implications for the land spreading of IAE manure. Future IAEs have the option to locate in areas of the Country where they can accommodate the implications of the constraints on spread land availability. Ideally, new IAEs should locate in the tillage areas where the crops are produced that are used to feed the pigs and poultry, and to supply raw material for mushroom compost. Such a strategy facilitates the recycling of the manure nutrients back to the areas from which they originated. However, achieving this goal will require both a clear national policy about the future development of IAE, and an educational campaign to overcome local fears about the potential impacts of IAEs. Both efforts will be essential, particularly as many tillage areas have no historical associations with IAEs. Fairness and understanding must be stressed at the local level so that public opinion will not result in unnecessary and costly delays in the planning/licensing process.

The restrictions noted above pose more difficult problems for existing enterprises. Finding additional spread lands in areas that already have high IAE concentrations can only be accomplished by searching at greater distances from the production unit. Due to the numbers of existing IAEs that could seek land simultaneously, demand could well outstrip supply in the short to mid-term. In addition, the transport of manure over long distances will add a cost to production that was not envisaged when the existing units were constructed. This oversight is a shared responsibility between the producers and planning authorities. For these reasons, adequate time must be given for existing IAEs to fully implement a manure management strategy that will balance nutrient applications with removals. In this interim period, Teagasc proposes that existing IAEs be allowed to use soil P storage as a mechanism to manage the practical and financial hardships that will accompany trying to obtain enough land to achieve a balance between nutrient inputs and outputs on spread lands. Where feasible IAEs should strive to achieve as quickly as possible a balance between the nutrients (especially P) applied in the manure/organic waste and the crop requirements of the spread land areas.

National acceptance of the concept of soil P "storage", in combination with site risk assessment, is critical for the viability of land spreading of manure from IAEs. Without this, the practicality and economics of the land spreading as a management option for IAE manure is questionable. As already noted, the Nitrate COP and REPS constraints on organic N loads, and the BATNEEC STP limit of 15 mg/l are creating significant difficulties in the acquisition of suitable land, especially for exisitng IAEs. As currently structured, these constraints make achieving compliance for some poultry enterprises almost impossible. Any downward revision of the current BATNEEC STP limit will have dire consequences for IAEs. *There is no economically viable technical alternative to land application for managing wastes from these production systems.* The introduction of new controls/schemes or changes in current environmental policy and regulations that are likely to impact on spread land availability require careful consideration. The implications of the individual controls/changes and their combined effect with existing restrictions must be carefully examined. The development of clear national policies regarding not only environmental protection but also the development of policies for a sustainable national agriculture are important in this respect.

TEAGASC MANURE (and OTHER ORGANIC WASTES) MANAGEMENT GUIDELINES FOR IAE

The objective of the Teagasc Manure (and Other Organic Wastes) Management Guidelines for IAE are to provide an operational framework for the agronomically efficient and environmentally safe recycling of these organic waste by-products, maximising the benefits of nutrients they contain at minimum cost. The adoption of these Guidelines will require a genuine and continuous commitment by top management and those personnel "on the ground" if they are to achieve their objectives.
The management Guidelines for manure and other organic wastes is based on the following framework elements:

- **Manure quantity and quality;**
- **Reducing manure nutrient content;**
- **Operational procedures;**
- **Quality assurance.**

A systematic approach to manure management planning will assist in developing the customised farm-based strategies required for site specific situations that make each production unit unique. This approach requires the preparation of a written plan that addresses the major elements of the Guidelines noted above.

Manure Quantity And Quality: A manure management plan must include actions for controlling, monitoring and minimising the quantities generated, and improving their qualities in terms of an inorganic fertiliser substitute. Aside from environmental benefits, the advantages of such actions to the producer are numerous. Minimising the quantities (volumes and nutrient concentrations) of manure produced will result in savings in storage, transport and land spreading costs. These savings can be used to partially or wholly offset the costs that may be associated with their implementation. Improving manure quality provides the assurance (customer care) required by recipient land owners in terms of accepting manure as a reliable and economic substitute for inorganic fertilisers. Together, manure minimisation and quality control make it easier to correctly recycle the manure to the land.

The annual quantities of manure produced should be monitored and recorded. Expected annual quantities produced by the operation should be determined from close observation of operation, or in the absence of direct observations calculated using published data. A comparison of the actual and expected production will provide an indication of possible operational problems (*e.g.*, tank leakage, dilution with water) that can negate manure quantity minimisation efforts. (Note that in the case of units requiring an IPC licence, manure minimisation, monitoring and record keeping are required activities.)

With animal manures, dilution with water is the primary controllable factor that affects the volumetric quantities that must be managed. Surveys of pig and poultry manure have shown that mean dry matter values vary between 32 and 80 gram dry matter per kilogram of waste (g DM/kg) for liquid pig manure and within the range 8 to 210 g DM/kg for poultry manures (Tunney and Molloy, 1975; O'Bric, 1992; McCutcheon, 1995). Although feeding regimes (*e.g.* water to meal ratios) can account for small variations in some of the dry matter contents, these results suggest considerable dilution of manure on some units. In addition to increasing the volume that must be managed, the dilution of manure results in a corresponding variation in the nutrient concentration. This variability in turn reduces its quality in terms of a reliable replacement for inorganic fertiliser. Consistency in the nutrient concentration of manure is an important element in terms of quality assurance for farmers receiving manures from external sources (as well as their own). As such, quality assurance will facilitate procuring and securing the long term commitment of farmers to be receivers of IAE manure.

Manure and SMC quality, especially in terms of consistency in nutrient concentration, will increase in importance as tillage farmers are targeted as recipients. This is because tillage crops are more sensitive to nutrient inputs, particularly N, than the grass crop. Tillage farmers will demand manure with a consistent nutrient composition to complement their efforts in growing high quality marketable produce. They also will demand a product that is relatively easy to handle.

Every manure management plan should indicate the steps being taken to minimise the amount of water entering the manure storage tanks. Drinking systems should be kept in good working order to prevent leakage, and wash water should be held to a minimum consistent with good animal husbandry and clean food practices (Lynch, 1998). Extraneous sources of water, such as roof and yard runoff should be excluded from tanks. In addition, attention should focus on managing clean water in the yards around the unit. Clean water should be diverted from areas soiled by animal excreta and spilled feed to minimise the amount of dirty water that must be collected and managed. Dirty water also should be controlled by minimising the dirty areas of yards. A separate dirty water storage system may be a more cost effective way to manage this dilute wastewater than collecting it in manure storage tanks where it will dilute the nutrient concentration of the slurry.

Quantities of SMC are easier to control because of the very different nature of the production system compared with pig and poultry enterprises. On average a 900 bag mushroom house with 5 cycles per year will produce 270 t of SMC. Dilution of SMC with water is not an issue affecting the quantities of SMC generated. Rather, the quantities of SMC to be managed are a function of expected mushroom yields and, to a lesser extent, the type of production system used. However, the "quality" of SMC is very much affected by the plastic bags used in the "bag and tunnel" system of production. These must be removed and managed separately before the SMC can be land applied. In this regard, SMC from the so-called "shelf" production systems is an easier to manage by-product than SMC from bag and tunnel systems, as compost is placed loose on shelves, negating the need for plastic bag containers. Numerous considerations must be made before adopting the shelf system, however (Staunton *et al.* 1999).

Reducing Manure Nutrient Content: It may sound ironic in light of the foregoing discussion, but reducing the quantities of nutrients, particularly N and P, in manure generated by IAEs should be an essential part of every management plan. The previous section focused on assuring that nutrients in manure are as concentrated as possible. However, there are direct benefits to be gained by minimising the nutrient content of the manure. Firstly, in the case of manure, minimising the excretion of nutrients by animals (*e.g.* increasing nutrient retention by improved feed efficiency) increases production efficiency. This can be accomplished by changing feed formulations and/or managerial practices. Secondly, lowering the N and P content in manure reduces the spread land areas required to properly manage it. This not only simplifies the task of obtaining spread lands, but also minimises transport costs. Thus the cost of implementing strategies for reducing the nutrient inputs in the feed and making other managerial changes to improve feed conversion efficiencies can be offset by the reduced difficulties and costs of procuring and using spread lands.

The potential of changes in animal feeding strategies to reduce the nutrient contents in IAE manure are discussed in more detail elsewhere (Lynch, 1998). Current feed conversion efficiencies should be calculated, targets for improvement set and the strategies to achieve them outlined as part of the manure management plan. The current N and P level in the diet should be noted and targets set for reducing the levels in the feed. The composition of the diet should be discussed with the feed compounder and animal nutritionist to assess the possibilities and costs of reducing the feed N and P contents.

Operational Programme: The objectives of the operational programme are to ensure that manures from IAEs are appropriately stored and transported to the site at which they will be utilised, and that it is then applied correctly. The operational programme should be described in a written plan covering

- **Storage;**
- **Transport;**
- **Nutrient management planning**

Adoption and implementation of an operational programme addressing these processes by IAE operators will considerably reduce the attention currently focused on IAEs by regulatory bodies and the public in general.

Storage: Information should be assembled about the design (including capacity) and siting of the storage facilities with their relevant equipment (*e.g.* access, agitation and emptying equipment).

The purpose of the manure storage facilities is to contain manures safely. Storage is a strategic necessity as continuous land application of manure is usually not feasible or recommended in Ireland because of either or both environmental and agronomic considerations. Manure and SMC applications in winter should be avoided on agronomic principles. Winter applications of manure place nutrients in the soil-plant system when there is little or no demand for them by crops. In addition, there is a risk of damaging soil structure with land spreading equipment in winter.

Environmentally, winter applications of manure are unwise because there is an increased risk of nutrient losses. Winter applications of manure are not permitted in many European countries nor on Irish farms participating in REPS. Growing concern about water quality, particularly groundwater, in some areas of the country may result in the introduction of a ban on manure spreading during these months. Achieving control of manure spreading date is dependent on providing structurally sound facilities with adequate capacities to contain the manure (and rainwater in the case of uncovered structures) until they can be land spread. Design capacities are determined by the rate at which the manure is generated and the required storage period. The duration of the required storage periods often are specified by local regulations and are related to the availability of suitable spreading windows during which the manure can be applied to land. BATNEEC requirements and national guidelines on the storage requirements, siting and construction specifications are available elsewhere (EPA, 1997; Anon, 1999).

Provision must be made for the appropriate health and safety requirements in the design and management of the manure storage facilities. Where necessary a programme to achieve the required safe storage capacity should be prepared and the cost implications outlined.

Generally, providing adequate manure storage should not create difficulties for new IAEs requiring IPC licences. In contrast, it will likely pose significant challenges for existing units as the costs of upgrading the facilities are high and site constraints imposed by existing building layouts can be formidable. The BATNEEC requirements to include a professional certification of the integrity of storage units and a minimum of 6 months storage are sound guidelines for all production units, regardless of size. However, there are significant costs associated with achieving this level of storage. For example, it has been calculated that the addition of 10 weeks storage for an existing 350 sow unit or 12 weeks storage to an existing 600 sow unit will cost £50,000 and £110,000, respectively (Tuite, 1996). Therefore, flexibility for the provision of adequate and safe storage facilities on existing IAEs will be required by operators in terms of IPC license applications.

Transport: Adequate supervisory methods must be put in place to ensure manure transport is conducted responsibly. This includes the logging of the date and quantity of manure removed, its destination, and the person transporting the manure in a "Manure Movement Record Book". The transport system should facilitate the safe, efficient and clean transfer of the manure or SMC from the IAE to the spread lands. All transport vehicles should be leak proof, road worthy and kept clean and well presented. Any mud and/or manure adhering to tyres should be removed before leaving the field to avoid contaminating the road and creating nuisance conditions.

Nutrient management planning: Nutrient management planning is the foundation in the design of any manure management programme involving land application. It is based on "nutrient recycling" rather than "waste disposal", the latter approach having evolved during a time when increasing agricultural output was the sole objective, without due regard to environmental impact.

Nutrient management on farms requires a Total Quality Management (TQM) approach. Simply, this means that nutrient management must be accepted as being on a par with other production functions, such as animal or crop health management. This approach is required because reducing nutrient losses associated with the land spreading of manure is as essential to long term sustainability as is profitably producing high quality food and fibre. Implementing a TQM approach to nutrient management requires a refinement/development in the traditional approach to the task. Consequently, the complexity of, and the costs and the commitment to, the task are increased.

Nutrient management planning involves several steps: assessment, analysis, decision making, evaluation and refinement.

(i) Assessment. The purpose of the assessment step is to evaluate farm resources that will influence nutrient management, especially potential spread lands, numbers and types of animals, and the condition of the farmyard. Suitable land areas that can safely assimilate the nutrients contained in the IAE manure are required. Identifying spread land areas and describing them in terms of usage, size, unique features (*e.g.*, swallow holes, sensitive groundwater), and location relative to waterways, roads and neighbours is a major element of the assessment process. It is during this stage that spreadlands can be identified as "low" or "high" risk in terms of their suitability for storage of P *i.e.* build up to 15 mg/l. Generally, there will be a number of different recipient farms associated with each IAE. Once potential spread land fields are located, soils information, topography and cropping histories must be compiled. The types and numbers of animals associated with the land must be recorded.

Many farmers have traditionally derived considerable benefits from IAE manure and SMC in terms of using these to partially or wholly meet crop nutrient requirements. The arrangements between IAE producers and recipient farmers were generally local, informal and unmonitored. Greater controls are now required than formerly because environmental objectives are now included in the nutrient planning process and legislative requirements.

(ii) Analysis: The analysis step of NMP is designed to determine nutrient supplies and crop nutrient needs. The soils of the spread lands should be analysed by sampling and laboratory analysis to provide an indication of the ability of the soil to supply nutrients to the crop. Soil testing provides the basis on which nutrient recommendations for efficient agronomic crop production are made. The importance of complying with the Teagasc recommendations for soil sampling (Culleton *et al.* 1996) cannot be over- emphasised as a means of "quality control" (Appendix 1). The accuracy of soil tests is affected by random, spatial, sampling, seasonal and analytical variations; following the Teagasc recommendations for collecting soil samples helps minimise these variations. Once collected, soil samples should only be tested in approved laboratories.

Representative samples of the manure (and SMC) from IAEs as well as from the farms receiving the IAE manure should be collected and analysed for nutrient content. Procedures for manure sampling are outlined in Appendix 2. Manure (and SMC) analyses are needed so that the nutrients they contain can be correctly assessed. This information will facilitate a more accurate nutrient management plan (NMP) for the recipient farmer. For *preliminary* planning, standard "book" values will suffice, in the absence of measured manure nutrient values.

The output from the assessment and analysis phases is a suitably scaled map(s) of the areas to be used for the land spreading of the IAE manure, together with calculations regarding the quantities of nutrients that can be applied to each area, and nutrient availability in the manure. All farms, appropriately indexed, on which land spreading will occur, should be indicated. A more detailed plan of each referenced spread land area should include the following information:

- Locations of soil sampling areas with an appropriate referencing system;
- A summary table of the date and results of all soil analysis;
- All rivers, streams, wells, residences, bedrock exposures and buffer zones;
- Regional aquifer classification;
- Regional soil classification and subsoil classifications;
- Ground water vulnerability;
- A table with details of all farms shown on map.

The nutrient recommendations for the Irish crop production are outlined in "Soil Analysis and Fertiliser, Lime, Animal manure and Trace Element Recommendations" (Gately, 1994)", and for grassland in recently revised recommendations on P usage (Teagasc, 1998a). The crop specific recommendation are based on either or both the soil fertility level (as determined by soil analysis) and crop production targets. The objectives of the Teagasc nutrient guidelines are to balance nutrient inputs with crop requirements and to satisfy soil fertility requirements.

In some cases professional assistance will be required in completing the analysis phase of NMP.

(iii) Decision making: Once the assessment and analytical phases have been completed, recommendations on the quantities of manure and/or fertiliser to apply to each field can be determined. Strictly speaking, these suggestions will apply to each soil sampling area, rather than each field. In the decision making phase of nutrient management planning, the farmer, in consultation with the person drafting the NMP, evaluates these recommendations and decides on the most practical strategy for implementing them.

The implementation of the NMP is more likely to succeed if the plan is practical and makes sense to the farmer. Farmers receiving IAE manure (or SMC) should be consulted during the drafting of the plan and be encouraged to "take ownership" in the plan by participating in the decision process that determines how the plan will be implemented. Farmers should receive copies of the NMPs prepared for their land and understand fully the plan objectives and importance.

(iv) Evaluation: Accurate record keeping is as essential to successful nutrient management as it is to other aspects of the farming operation. Teagasc recommends that record keeping supplemented by regular soil and manure testing, is the most practical means to objectively evaluate the success of nutrient management planning. Record keeping also is an inseparable aid to good manure management and emphasises the dynamic nature of the nutrient management planning process.

The design of a record keeping scheme that captures only information essential to evaluating the success of the nutrient management programme is crucial from the viewpoint of the participating farmers. In the least, accurate tallies of the quantities of nutrients from all sources used in a given field should be recorded. Recording the specific times at which nutrients are applied also is important. Any practical difficulties in implementing the plan should be noted.

To date, Teagasc has focused on getting nutrient management planning accepted as the nutrient management strategy on Irish farms. The process has been accepted at policy level, but implementation at farm level has been slow except where it is mandated as part of another programme (e.g., REPS or IPC licensing). Costs and complexity are often quoted as reasons for the slow uptake. Therefore, little attention has been paid to the practicalities of the evaluation step. Farmers should put in place procedures to ensure the records are evaluated on an on-going basis. The value of the assessment, analysis and decision making steps of nutrient management planning will be undermined if the implementation of the resulting plan is not monitored.

(v) Refinement: The NMP can only be effective if it is implemented, continually re-evaluated, and revised or refined as necessary to reflect current conditions. Both farmers and IAE operators should periodically assess the NMP to assure that it is meeting the purpose for which it was designed. It is especially important to make such an assessment whenever changes take place on the recipient farms (or IAEs) that affect nutrient sources and demands. These changes can include increases or decreases in animal numbers or types, alterations in cropping systems, adoption of different feed rations, or anything else that impacts on the source of, or need for, nutrients.

The preparation of an NMP, the keeping of the necessary records combined with periodic evaluations and refinements are essential for the operation of IAE requiring an IPC license. These steps are nothing less than a business-like approach to nutrient management. Such an approach is central to changing the public perception about IAEs and assuring the regulatory authorities that manure management, when properly implemented, can minimise the potential of IAEs to adversely impact water quality.

Quality Assurance: As with other parts of the food production chain, the purpose of a quality assurance programme for manure management is to ensure application of operational strategies and systems, compliance with legislation, prevention of pollution, customer satisfaction and sustainability of the overall manure management plan. The plan should have

- clear objectives
- planned activities
- defined inputs
- defined outputs
- unambiguous responsibilities
- defined work practices
- performance indicators
- record keeping and monitoring
- programme reviews.

The quality assurance programme, like the other elements noted above, is an integral part of the manure management plan. The unwavering commitment of IAE farm operators to the quality assurance elements of their plans is essential. In a general way, the perceived absence of any quality assurance toward manure management on IAEs has contributed to their poor public image.

LAND SPREADING OF MANURE and OTHER ORGANIC WASTES

The land spreading of manure and other organic wastes such as SMC should follow the Nitrate COP. Cognisance also should be taken of the land spreading guidelines set out in the BATNEEC guidance. (Note that IAEs needing an IPC license are required to follow the BATNEEC guidance; quite likely, requirements contained in the Nitrate COP also will be imposed during the licensing process if conditions warrant.)

Date of Spread: The timing of manure application should coincide with periods of vigorous crop growth. For grassland, this is achieved by application earlier (spring - early summer), rather than later in the year. There are a number of opportunities when manure can be applied to grassland for silage production. These include early spring (February - early March), after first cut silage (late May -June), and after second cut silage (late July - early August). As a last resort, manure can be spread in autumn before the grazing animals are brought indoors for the winter, but this late autumn spreading window should be avoided in most circumstances.

Manure application to tillage crops should be made as close to planting time as possible. As with grassland, autumn applications to some tillage crops may be technically feasible, but should be avoided due to environmental hazards.
The availability of machinery to meet peak spreading demands should be anticipated. Variable and unpredictable weather combined with variable soils can create problems with the availability and duration of each of the spreading windows.

Spreading Rate and Methods: The efficient recycling of nutrients in manure requires properly and well maintained equipment. The typical equipment used in the majority of liquid manure application systems is the vacuum tanker fitted with a splash plate. This system can transport and apply large volumes of liquid manure relatively cheaply, with few breakdowns, and has a minimal maintenance requirement. For solid manure the rear discharge spreader or the "sideflinger" spreader are the two most common types of spreading equipment.

Control of application rates using a vacuum tanker is poor on many farms. This can result in either under- or over- applying nutrients to the crop. Inaccurate nutrient applications will result in unsatisfactory crop responses, which in turn can lead to unfair criticism of the manure management plan.

Application rates using the splash plate and vacuum tanker are controlled by the tractor speed and, to a lesser extent, the angle of the splash plate. Calibration trials should be performed to establish this relationship for a given spreading system. Then, care must be taken to set up the tanker properly and ensure the correct forward speed is established that gives the target application rate. The use of a single application rate is suggested in the absence of good control systems fitted to spreaders. This practice will ensure that in-field adjustments are kept to a minimum, however, this recommendation assumes that the required application rates among various spread lands are not vastly different. In general, with liquid IAE manure the suggested application rate is between 15 and 20 t/ha. With a conventional splash plate, evenness of spread is rarely satisfactory. Careful setting and adjustments can improve performance, but these are usually not done.

Better control of solid manure can be achieved with rear discharge spreaders than with "sideflinger" machines. Application rates as low as 10 t/ha can be achieved in most field situations with a well maintained rear discharge spreader and a careful operator. Modifications of the rear discharge machines are possible and must be employed to achieve the lower application rates (i.e. less than 10 t/ha) that are required with poultry slurry and litter.

Recent developments with slurry spreading technology include injection and band spreading (Lenehan, 1991). Both the band spreader and shallow injector offer the potential to significantly reduce odour emissions and ammonia volatilisation. Where soil and cropping systems allow, injection of liquid wastes and slurries is the preferred method of application under BATNEEC guidance for intensive pig and poultry units. In tillage system, surface spreading and immediate incorporation also is acceptable. The use of splash plate technology is not favoured under BATNEEC guidance. For IAEs not needing an IPC licence, Teagasc recommends that farmers adopt a vigorous quality management (correct spreading rate and date; implementation of nutrient management, record keeping and evaluation) approach with the splash plate before upgrading to the newer spreading techniques. The new technologies will complement good manure management, but they do not provide solutions to poor management.

The emergence of specialist contractors for IAE manure land spreading operations is considered to be inevitable considering the relatively few manure spreading windows, the transport logistics and the requirement to manage large quantities of manure. This type of development will facilitate the use of the more sophisticated spreading equipment capable of achieving greater accuracy with spreading rates combined with application recording systems.

ODOUR EMISSIONS

Manure and odour emissions are almost synonymous. This is particularly true for pig and poultry operations. Data from England indicates that there are about 4000 complaints annually about odours from farming (Pain, 1994). Pig and poultry farmers were reported as being responsible for over 57% and 22%, respectively, of the complaints. Land spreading causes more public odour complaints than any other component of manure management. A recent Irish survey found 81% of odour complaints recorded by Local Authorities derived from land spreading (Doherty, 1996). Therefore, farmers in general and in particular IAE operators must address odour emissions as part of their manure management plan. A review of odour control for intensive Irish pig producers is currently near completion (Lawlor and Lynch, 1999).

In general, a detailed log should be maintained of manure management activities by date, combined with recording of all odour complaints and the actions taken to resolve the complaints. These data will help establish a possible pattern of odour emissions, which will assist in refining the appropriate operational changes required to minimise the emissions. These records will also document the commitment to being a good neighbour.

There are three sources of odour from animal producing activities. These are the housing/yard area, the manure storage area and the land spreading areas. Odour nuisance from each of these areas can be reduced in all but the most restrictive situations.

Housing-Yard Area: Approximately, 30% of odour complaints from livestock farms relate to the farm buildings and silage pits (Pain, 1994). Odours in the housing and yard areas originate from the animals themselves (body odours), from feed materials, and from the manure storage channels or tanks. Practices associated with good animal husbandry facilitate odour control. It is important to keep pig pens, houses and feed stores clean.

Ensure correct stocking rate is maintained and feeding and drinking facilities are located properly. Well-designed and correctly installed slats should be self cleaning. For facilities designed for continuous manure removal, maintenance of the mechanical apparatus to assure its efficient removal is essential. Removal of slurry while fresh will also help reduce odour emissions from animal houses.

Providing adequate ventilation for humidity and temperature control in buildings that house animals should disperse odours at non-objectionable levels in the outside atmosphere. It also ensures a safe and healthy environment for the operators and animals. The position of the ventilation outlet can have a significant impact on emissions. The higher the outlet the greater the potential dilution of the odorous exhaust air. Avoid ventilation outlets along the sides of buildings below a slatted floor or immediately over the slurry collection channel.

It is possible to treat odorous air using a bio-scrubber or bio-filters. Reductions of up 80% in odour emissions have been recorded using these devices (Shirz, 1991). In a bio-scrubber odorous compounds are dissolved in a water film or mist in a treatment chamber having a treatment medium with a large surface area. Bio-filters use material (e.g. peat, wood chips) with large surface areas to provide habitats for micro-organisms that break down odorous compounds contained in the air that is force through the filter. At present, however, these air cleaning devices are considered to be too expensive for controlling odour emissions from livestock buildings.

Keeping yards clean of animal manures and spilled feeds will not only minimise odour generation, but also control flies and other pests, as well as contribute to the appearance of an efficiently operated enterprise.

Manure Store: Manure stores are responsible for 22% of odour complaints from farming in the UK (Pain, 1994). In general, the most important means of controlling odours from a manure storage facility is by correctly siting the facility. Maximising the distance between the store and neighbouring houses, and locating it in an exposed area increase the potential for dilution of odorous air (and decrease the potential for nuisance conditions developing).

In general, the odour emissions from manure stores will be greatest during agitation just prior to emptying the tank for land spreading (Carney and Dodd, 1989). The creation of a suitable shelter belt (*e.g.*, by planting trees) may help disperse odours from slurry stores. It is important to ensure the correct spacing of trees to allow the wind pass through them.

Land Spreading: As noted above, land spreading of manures is the major source of odour complaints from farming. Odours from poultry manure were found to be the most detectable during land spreading. Pig manure odour was the next most detectable, and cattle manure was the least detectable of the three liquid manures (Carney and Dodd, 1989). The odours emitted from land spreading are released during and just after spreading. The total emissions per unit area of manure spread are much smaller during, than after spreading, with the former being less than 1% of the latter (Phillips et. al., 1991). There is a rapid decline in odour emissions, with small diurnal fluctuations, within the first two hours following spreading. Odour concentrations generally reach background values within 24 to 48 hours following application.

Reductions in the odour emissions associated with land spreading are achieved by reducing the concentrations of the odorous compounds in the air following land spreading (changing the method of spread) or by reducing the quantities of odorous compounds in the slurry (treatment).

Odour concentrations immediately after manure spreading increase with increasing application rate (Pain and Klarebeck, 1988). The low target application rates (15 - 20 t/ha) for IAE manure, to control nutrient application rates, will contribute to lower odour concentrations following spreading.

Injection or incorporation of manure immediately after application to tillage land will reduce odour emissions. However, only immediate "ploughing in" will give worthwhile reduction (Pain *et al.* 1991). Low emission spreading techniques, *e.g.* band spreading, shallow injection, reduce total odour emissions during spreading compared with the conventional splash plate method (Phillips *et al*. 1991). Equally, the emissions after spreading are generally lower for band spreading and shallow injection. Teagasc recommends the use of band spreading for applying liquid manure from IAEs not requiring IPC licences or where soil conditions inhibit injection, as a means to control odour emissions that are likely to cause public nuisance.

It should be noted that the low emission spreading techniques also reduce ammonia emissions during land application. There is growing European concern about this emission. In the Netherlands, legislation requires the use of injection systems to control ammonia losses from land spreading. National emissions ceilings for ammonia will be one element of both the forthcoming multi-pollutant/multi-effects protocol under the UNECE Convention on Long-Range Transboundary Air Pollution (Doc EB.AIR/WG.5/R.80) and an EU Directive on national emissions ceilings under the EU acidification strategy. Emissions of ammonia also have a bearing on the estimation of emissions of nitrous oxides from agricultural soils which are reported annually to the Framework Convention on Climate Change and the EU Monitoring Mechanism for CO_2 and other Greenhouse Gases (Decision 93/389/EEC). Against this background it is likely that there will be pressure in the future to adopt practices to reduce gaseous emissions from agriculture.

Manure Additives: There are many manure additives on the market which claim to reduce odour emissions. However, farmer experience with these products is variable. Methodologies for their evaluation have not been standardised. Indications from European research and Teagasc experience with these compounds indicate they are rarely effective in noticeably reducing odours from slurry. The cost of additives can be high.

Slurry Treatments And Odour: Separating manure solids and liquid, and either aerobic or anaerobic digestion, are treatment strategies that reduce odour emissions following their land application. However, these are expensive to operate and will require careful consideration before adoption.

Common Sense: Maintaining good relations with neighbours is essential to reducing odour nuisance from IAE. Keeping a tidy unobtrusive unit and a common sense approach to potential complaints are important factors in being good neighbours(Lawlor and Lynch, 1999). In addition a common sense approach to the land spreading of manure can help reduce odour nuisance. In this regard some some practical suggestions include:

- Avoid using irrigators or rain guns to land spread liquid manure;
- Avoid spreading manure at times when the risk of causing odour nuisance to the public is greatest *e.g.* weekends or public holidays;
- Spread when weather conditions are bright and sunny;
- Spread early in the day;
- Avoid spreading manure when the wind direction is toward population centres or neighbours houses;
- Where manure is spread on tilled soil or land that is to be ploughed, incorporate the material as quickly as possible following application;
- Use a band spreader or shallow injector in areas sensitive to odour emissions.

REFERENCES

Anon (1996). Code of good agricultural practice to protect waters from pollution by nitrates. Department of the Environment & Department of Agriculture, Food and Forestry. Dublin. 57 pp.

Anon, (1989). S.I. No. 349 of 1989. European Communities (Environmental Impact Assessment) Regulations 1989. Stationary Office, Dublin.

Anon, (1999). Guidelines and recommendations on the control of pollution from farmyard wastes (revised). Department of Agriculture and Food. Dublin. (In press.)

Carney, P.G. and Dodd, V.A. (1989). The measurement of agricultural malodours. Journal of Agricultural Engineering Research, 43. 197 - 209.

Carton, O. T. (1996). Project Report, August 1, 1994 to January 22, 1996. LIFE93/IRL/A15/3116 - Farm Nutrient Management. Teagasc, Johnstown Castle, Wexford. 78 pp.

Carton, O.T. and Magette, W.L. (1996). Manures - waste or resource. IN: Proceedings of 1996 Annual Conference, Athlone. IEI, 22 Clyde Road, Dublin 4.

Coulter, B. S. and Tunney, H. (1996). The background to the P debate. In: Phosphorus recommendations for grassland - good agronomic practice (Eds: O. T. Carton, M. Ryan and W.L. Magette). Teagasc, 19 Sandymount Ave., Dublin 4. 1 - 15.

Culleton, N, Byrne, E. and Coulter, B. (1996). Soil sampling. In: Phosphorus recommendations for grassland - good agronomic practice. (Eds: O.T. Carton, M. Ryan and W.L. Magette). Teagasc, 19 Sandymout Ave.,Dublin 4. 65-77

DAF (1999). Department of Agriculture and Food, Rural Environment Protection Scheme, Agri-Environmental Specifications. Revised, 1 January, 1999. Dublin. 86 pp

Daly, K. (1999). An environmental appraisal of the P dynamics of Irish grassland soils. PhD Dissertation. Trinity College Dublin.

DoELG/EPA/GSI (1999). Groundwater Protection Schemes. Published by The Department of the Environment and Local Government, Environmental Protection Agency and the Geological Survey of Ireland. 24 pp.

Doherty, P (1996). Agricultural Odours. An Irish perspective of the nuisance. M. Sc. thesis. Sligo Regional Technical College. Sligo. 78 pp.

Dunne, T. and L. B. Leopold, (1978). Water in environmental planning. W. H. Freeman & Company, New York. 818 pp.

EPA (1997). Integrated Pollution Control Licensing. Batneec guidance note for the pig production sector. EPA, Wexford.

Fehily Timoney, (1999). A study of options for the treatment/management of pig slurry. A study commissioned by Cork County Council. Cork. 169 pp

Gately, T. (1994). Soil analysis & fertiliser. lime, animal manure & trace element recommendations. Teagasc, Johnstown Castle, Wexford.

Gburek, W. J., A. N. Sharpley and H. B. Pionke. (1996). Identification of critical source areas for phosphorus export from agricultural catchments. IN: Advances in Hillslope Processes, Vol. 1. (Eds: M. G. Anderson and S. M. Brooks). John Wiley & Sons Ltd., London, England. 263-282

Heathwaite, L., A. N. Sharpley and W. J. Gburek. (1998). Integrating phosphorus and nitrogen management at the catchment scale. IN: Proceedings, Practical and Innovative Measures for the Control of Agricultural Phosphorus Losses to Water, (Eds: R. H. Foy and R. Dils). 16 - 19 June 1998, Greenmount College, Antrim, Northern Ireland.

Humphreys, J., Tunney, H. and Duggan, P (1996). Phosphorus loss from soils to water in the Belsgrove Catchment Co. Cavan. Cavan County Council, Courthouse, Cavan and Teagasc, Johnstown Castle, Wexford. 38 pp.

Hynds, S. P. (1994). A nutrient balance model for typical Irish farming systems. M. Sc. Thesis. Sligo Regional Technical College. Sligo. 83 pp

Kelly, J. (1999). Teagasc census of mushroom production. Mushroom Newsletter 3 (Winter 98/99) p 4.

Lawlor, P and Lynch, B. (1999). Control of odour from intensive pig production - A desk study. Teagasc, Moorepark, Cork. (In press.)

Lenehan, J.J. (1991). Machinery developments for safe application of wastes to land. IN: Proceedings of Environmental Impact Conference management, treatment and land spreading of manures and wastes, September 11 -12 1991, Johnstown Castle, Wexford. IEI, 22 Clyde Road, Dublin 4.

Lynch, B. (1992). Feeding to minimise waste. IN: Proceedings of the 20th Annual Symposium on Pig Health, Dublin. 8 - 21.

Lynch, B. (1998). Potential to reduce manure volume and nutrient content on pig and poultry farms. IN: Draft Guidelines for Nutrient Use in Intensive Agricultural Enterprises. (Ed: O. T. Carton) Teagasc, Johnstown Castle, Wexford. 73 - 85.

Magette, W. L. (1998). Factors affecting losses of nutrients from agricultural systems and delivery to water resources. IN: Draft Guidelines for Nutrient Use in Intensive Agricultural Enterprises. (Ed: O. T. Carton). Teagasc, Johnstown Castle, Wexford. 6-31.

Maher, M. and W. L. Magette. (1997). Solving the spent mushroom compost problem. IN: Proceedings, 12th National Mushroom Conference and Trade Show, Dublin. (Eds: L. Staunton and J. Grant). 73-82

MAWMS (1994). Monaghan Agricultural Waste Management Study. Teagasc, Johnstown Castle, Wexford.

McCutcheon, G. (1995). A study of the dry matter of pig slurry. Diploma in Rural Environment Management thesis. University College Dublin.

O'Bric C. (1992). Nutrient values of cattle and pig slurries. M.Sc. (Agriculture) thesis. National University of Ireland.

O'Callaghan, J. R., Dodd, V.A. and Pollock, K.A. (1973). The long term management of animal manures. Journal of Agricultural Engineering Research, 18. 1-12.

Pain, B. F. (1994). Odour nuisance from livestock production systems. IN: Pollution in livestock production systems (Eds: I. Ap Dewi, R.F.E., Axford, I. Fayez M. Marai and H.M. Omed). CAB International UK. 241 - 263.

Pain, B.F. and Klarebeck, J.V. (1988). Anglo-Dutch experiments on odour and ammonia emission from land spreading of livestock wastes. Research Report 88 - 2 IMAG - DLO, Wageningen.

Pain, B.F., Phillips, V.R., Huijsmans,, J.G. M., and Klarenbeck, J.V. (1991). Anglo-Dutch experiments on odour and ammonia emission following the spreading of piggery waste on arable land. Rapport 91 - 9 IMAG-DLO Wageningen. 28 pp

Phillips, V.R., Pain, B.F. Clarkson, C.R. and Klarenbeck, J.V. (1991). Studies on reducing odour and ammonia emissions during and after the land spreading of animal slurries. IN: Proceedings of Environmental Impact Conference management, treatment and land spreading of manures and wastes, September 11 -12 1991, Johnstown Castle Wexford. IEI, 22 Clyde Road, Dublin 4.

Sharpley, A.N., Charpa, S.C., Wedepohl, R., Sims, J.T., Daniel, T.C. and Reddy, K.R. (1994). Managing agricultural phosphorus for protection surface waters; issues and options. Journal of Environmental Quality. 23 (3). 437 - 451.

Shirz, S. (1991). Practical application of bioscrubbing technique to reduce odour and ammonia. IN: Odour and ammonia emissions from livestock production. (Eds: V. C. Nielsen, J.H., Voorburg, and P. L'Hermite). Elsevier Press, London. 92 - 96.

Staunton, L., O'Connell, T. and Kiernan, E. (1999). Feasibility of shelf growing in Irish mushroom tunnels. IN: Proceedings, 2nd All-Ireland Mushroom Conference and Trade Show, (Eds: M. Kilpatrick and J. Grant). Monaghan, Ireland. 39-53.

Teagasc (1998). Draft guidelines for nutrient use in intensive agricultural enterprises. (Ed. O.T. Carton). Teagasc, Johnstown Castle, Wexford. 107 pp.

Teagasc (1998a). Nutrient advice for phosphorus and potassium fertiliser. Grazing and silage. Johnstown Castle Research Centre, Soils and Analytical Services Department. July 1st 1998.

Tuite, P. (1996). The challenge in the pig production sector. In: Seminar Proceedings "IPC licensing for the pig and poultry production sectors: A new Challenge" November 1996. IEI, 22 Clyde Road, Dublin 4.

Tuite, P. (1999). Teagasc survey of commercial pig units in Ireland in January 1999. Teagasc, Dublin. 2 pp.

Tunney, H (1990). A note on the balance sheet approach to estimating the phosphorus fertiliser needs of agriculture. Irish Journal of Agricultural Research. 29. 149 -154.

Tunney, H. and Molloy, S. (1975). Variations between farms in N, P, K, Mg and dry matter composition of cattle, pig and poultry manures. Irish Journal of Agricultural Research. 14. 71 - 79.

Tunney, H., Coulter, B., Daly, K., Kurz, I., Coxon, C., Jeffery, D., Mills, P, Kiely, G., and Morgan, G. (1999). Quantification of Phosphorus Loss to Water Due to Soil P Desorption. Preliminary Draft Final Report for the Environmental Protection Agency. 215 pp

Appendix 1. Soil sampling procedure

- Identify discrete areas of the farm that are uniform in soil type, slope, drainage and cropping history.
- Take a composite sample consisting of 20 individual cores in each designated area.
- Cores should be taken to a depth of 100 mm
- Cores should be taken in a "W" shape across the sampling area.
- Avoid unusual areas like old fences & ditches, water trough and gateways
- Avoid dung and urine patches, where fertiliser was stored or spilled
- Do not sample for P and K until 6 months after the last application of P and K fertiliser
- Sample at the same time of year on each sampling occasion
- Fill in soil identification form completely (including details on texture)
- Include information on crop to be harvested and stocking rates to get a fertiliser recommendation as well a nutrient status statement

Appendix 2. Manure/biosolid sampling procedure

Samples of manure or biosolid should be collected from each storage facility to determine dry matter and nutrient concentration (total N, NH_4-N, P and K) by analysis in a competent laboratory. The difficulties in taking a representative manure sample are recognised, especially when agitation is not possible *e.g.* when the manure is stored in tanks under the animal houses.

Ideally, liquid manure should be fully agitated before taking a sample where agitation is practical and safe. If the manure store contents cannot be thoroughly mixed, extra care and more samples will be needed to assure that a representative sample of the contents is collected. The preferred sampling procedure is to use a plastic pipe which takes a column of slurry from the tank.

Every effort should be made to take samples from a number of locations around the tank. Each sample should be placed in a suitable container and mixed. A sub-sample of the resulting mixture should be taken and sent without delay to the laboratory for analysis.

The sampling procedure for solid manure and SMC is to take approximately 10 cores from a depth of 100 to 300 mm from the surface of the heap. Samples from the surface 100 mm should be avoided. The cores should be mixed and a sub sample taken for analysis.

In the case of liquid manure, an alternative approach is to use the "slurry meter". This provides a rapid on-farm test of dry matter and a crude estimate of nutrient concentration. However, to maximise the accuracy of readings from the "slurry meter" a number of samples should also be taken and sent to the laboratory for chemical analysis to provide verification of the meter readings.

The frequency of manure sampling and analysis should be appropriate to the size of the units and anticipated fluctuations in management practice (animal numbers, feeding regimes, rations etc). The larger the unit and the larger the variation in fed inputs the more frequent should be the sampling. In general, manure samples should be taken just prior to emptying of each storage facility. Once a pattern of quality has been established the frequency of sampling can be reduced to once a year.

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