Decision support tool (DST) for the selection and technical validation of on-farm manure management options: design and specification report

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SUMMARY

This report defines the required technical scope of a computer-based package (the DST) to assist an informed agricultural advisor in the recommendation of best manure management/treatment systems for livestock farms in South East Asia. The related study represents part of a large current project "Livestock Waste Management in East Asia or LWMEA" which started in 2006 and which involves a large number of livestock farms within selected study areas each being fitted out with a greatly improved manure management system. The subsequent product proposed in this study (which is also known as a Decision Support Tool or DST), is intended for use both in the latter stages of the main LWMEA project and also beyond the project limits as a means of extending the beneficial influence across the geographical region.

The task of preparing the software itself remains to be done and will come under a new and separate contract: a proposed set of "Terms of reference" for such a contract are included as an annex to this report. The closeness of the subject matter of this DST and another DST (being prepared on agronomical considerations of land spreading manure), means that the two are expected to be prepared as a pair which is reflected in the proposed structure of the contract proposed.

RESUME

Ce rapport détermine l'étendue technique nécessaire d'un logiciel (un DST) dans le but d'aider un consultant d'agriculture pour lui proposer les meilleurs systèmes de gestion des fumiers (ou des lisiers) d'élevages en Asie de sud-est. L'étude liée représente une partie d'un grand projet actuel « Livestock Waste Management in East Asia (Gestion des effluents d'élevage en Asie du sud-est) ou LWMEA » qui a commencé en 2006 et qui implique un important nombre de fermes dans les régions spécifiées qui seront dotées d'un système de gestion/traitement très amélioré. Le produit de cette étude que nous allons proposer (qui s'appelle également un « Decision Support Tool » ou « Outil d'Aide à la Décision » ou DST) est impliqué même pendant la dernière phase du projet principal LWMEA et aussi au-delà du projet comme un moyen de propager l'influence positive au travers de la région géographique.

Le travail de la préparation du logiciel lui-même reste à faire et fera l'objet d'un nouveau contrât séparé : ainsi, nous avons proposé un « cahier des charges » pour définir tel contrat inclus en tant qu'une annexe. Etant donné que l'objet de ce DST se trouve proche d'un autre DST (qui est en cours de préparation, celui-ci basé sur des considérations agronomiques et sur l'épandage du lisier), nous pouvons espérer les deux seront produits de manière complémentaire – nous avons réfléchi à cette requête dans la forme du contrat proposé.

CONTENTS

1. INTRODUCTION

1.1 The purpose of decision support tools (DST)

The study described in this document forms part of the project "Livestock Waste Management in East Asia" or LWMEA, which is run by the World Bank (on behalf of the GEF – the Global Environmental Facility). Certain technical functions, including the work described, have been delegated to the Food and Agriculture Organisation (FAO) based in Rome. The LWMEA project, is based in three active countries within the region, China (Guangdong Province), Thailand and Vietnam; however, its influence is expected to extend to other neighbouring countries in the region. The nominal start date was August 2006 and it is expected to run through to late 2011.

Local project staff in each country will need to carry out a series of evaluations at the farms participating within the project followed by the deployment of appropriate manure management technology as identified. This exercise may need to be done dozens of times during this project and (in meeting the capacity building aspects) many more times outside the domain of the project. The broad idea is that the principle, once demonstrated within the confines of the project can be reproduced widely across the region. Thus the approaches of manure management demonstrated by the project can be broadly applied with the overall improvement to the environment being achieved.

There is clearly some common ground in each farm evaluation allowing some consistency in approach. However, there are also special features to consider which will in many cases modify the manure management system proposed and subsequently implemented. The role of a series of Design Support Tools (DST's) is to facilitate this process in a consistent and verifiable way. Not to constrain the operator but to enable a methodical evaluation, the identification of the principle options and the negotiation with the farmer and other involved parties leading to the selection of the best solution in each case.

1.2 Objectives of the required DST on manure treatment

The scope of this report is that of just one specific DST that is primarily concerned with a practical system that would be installed near a livestock farm to *treat* the manure to enable a series of environmental and health constraints to be more easily met. The consequence of this would be (a) modified livestock wastes that would then be land spread on local fields or discharged via fish ponds or local streams and (b) various products (including the manure itself) intended for *export – ie*: removal from the farming system.

However to fully achieve this, there is equally the need for a second similar tool to cover other aspects outside the immediate farmyard, especially in the land application of the manure to local fields in a way to respect a local nutrient balance. Thus, another DST (referred to here as the ***Agronomic DST***) is being separately prepared to meet this requirement and it is acknowledged that these two tools must be compatible and function together.

In summary, the manure treatment DST will need to:

- Support local technical staff in the methodical evaluation of a given farm wishing to participate in the scheme.

- Enable the identification of key environmental impacts from the current manure management procedures
- Propose broad strategies to achieve agreed and realistic targets of improvement
- Specifying appropriate manure management systems that can meet this objective(s)
- Provide some detail of design and installation
- Provide some degree of cost estimation
- Include methods for system monitoring and evaluation (is it properly installed; is it working?)

However, the DST will not be expected to:

- Provide a single prescriptive solution
- Serve as an inflexible and mandatory tool for environmental improvement
- Specify equipment of service suppliers – this will remain the choice of local engineers
- Provide a comprehensive solution such that there remains no role for technical discussion of the merits of specific options.

1.3 Delivery formats and training

Key questions to consider at the beginning of the exercise:

- Who would use it?
- What are the key questions asked when choosing a treatment system?
- What information is especially wanted?
- What format is preferred (excel, expert system, ….)
- What style - report, reference document, guide, FAQ, ….
- What level of detail is needed

What features to include:

- Provision of aids for promotion of management technologies to farmers and local people: eg: videos, illustrations, publicity
- Inclusion of cost calculation models
- Inclusion of help routines. Noted that training is essential but this can also be in the form of a "self-teaching" program
- Analytical procedures such as checklists to identify problems on a farm and question and answer routines (eg: EXPERT analysis approach).
- Operation manual to support the sustainable running of the systems after the formal project is finished.

The structure and delivery of the DST can greatly influence the work required in its preparation – changes midway in the process could greatly increase the amount of time and effort – hence this needs to be agreed and established at the beginning.

The first decision lies between a report (printed) delivery and that of an electronic format. The latter clearly allows for a high degree of interaction but this may lead to a substantial exercise requiring considerable testing. The approach of a guide has the advantage in that it is more easily defined and can include other published work in its appendices. The drawback here is that of its limited degree of interaction although question and answer procedures along with checklists can make up part of such a guide. Then there is the compromise of a dual approach making use of both formats.

In any case, consideration must be given to the training aspect of any package. This can initially be provided by means of specific workshops but in the longer timeframe, a degree of self-help will enable the wider use of the package beyond the scope of the current project.

2. REQUIREMENTS OF MANURE MANAGEMENT STRATEGIES

2.1 Pollution abatement issues

The main pollution impacts from livestock manure can be divided into four categories:

- Emissions,
- Soil pollution,
- Water pollution and
- Health risks

The main emission from livestock wastes is **ammonia** - over 50% of that present in manure can be lost from the farm buildings and in the subsequent handling and land spreading operations. If it is allowed to oxidise to nitrate then partially denitrify, up to 10%, or more, of the original ammoniacal nitrogen can be lost as **nitrous oxide** which is linked to both ozone depletion in the stratosphere and the global warming. Anaerobic activity both in the manure stores and in water logged soil can result in the emission of another greenhouse gas, **methane**. One final emission are the small amounts of organic chemicals that give rise to **odour** - although this is not associated with environmental damage, it is often the cause of many complaints - arguably, odour nuisance devalues the quality of living environment to those nearby.

The impacts of manure on water affects both surface waters and groundwater. The later tends to be only affected by **nitrates** (formed by the oxidation of ammonia) unless the water table is relatively high. Surface waters can be contaminated by direct release of manure (or diluted effluent) bringing with it **ammonia, phosphorous** and **organic matter**.

Any accumulation of manure components in soil can detrimentally affect the soil itself as well as crops subsequently grown on it. **Heavy metals** (ie, copper and zinc in this case) represent a constant threat to soil quality. Soil structure can be affected by **sodium** in particular and other salts in general. Excess **phosphorous** is also a soil pollutant. In due course this will be leached back to the river.

Concerns over **disease** resulting from manure mismanagement are well founded although it is the animals themselves at greatest risk. Some zoonotic diseases such as E-coli have become of particular concern although this along with campylobacter and salmonella (amongst others) are more of a problem resulting from poor practice at abattoirs. Rarely, there is direct infection of local people from zoonotic diseases resulting from ingesting of droplets originating from manure but applications to crops are of concern. It is noted that poor manure management in any region can also be a vector for the spreading of water borne human diseases that do not originate from the animals or their manure.

2.2 Handling issues

As well as the various environmental concerns linked to animal manures, there are a number of other factors that will feature in the selection of any management system. There are farm operation considerations such as easier collection of wastes (eg; flushing) or improved animal performance and welfare. One might expect the farmer to be concerned with providing adequate storage to take away the urgency for action at any one time. Improved pumping can also make life easier hence the pre-clarification of manure to avoid blockages is attractive. In drier areas, methods that allow lower water use have a clear advantage but even where rainfall is plentiful, less water means less liquid manure to be pumped, stored and disposed of. Lastly, in regions where expansion is important, poor manure handling systems can often be a hurdle to growth. If better systems are brought in the benefit will include the option to increase production.

2.3 Gaining benefits from treatment

Treatment of any waste rarely brings any benefits and almost never pays for itself. But there are a few exceptions that at least can make the uptake of technology easier by defraying costs. **Biogas production** is an obvious and well developed option. In cases where electricity is generated as a by -product. the income can cover investment costs in time. Use of manure as a **fertiliser** is well understood but transport can often be a barrier. In light of this, the production of compact solid products such as **compost** or dry organic fertiliser might be considered. Where fish farming is commonplace, use of solid manure (faces) as **fish feed** is an option - alternatively, the production of worm for fish feed via vermiculture can help justify investment into such technology. Lastly, in dry seasons, clarified water can have some benefit for irrigation to crops.

2.4 Key driving forces identified for manure technology

Reviewing the preceding factors that can influence the selection of a manure treatment or management system, it is important to set these in some sort priority. For the purpose of this project, the over riding concern is the impact on international waters and therein the pollutants potentially carried by rivers into such regions.. Hence the primary target must be the reduction of the key nutrients, phosphorous (P), nitrogen (all forms), (N), and organic matter (as represented by BOD) form entering the river systems.

Recognising the importance of gaining local support for any improved scheme, it is important to recognise local concerns as well. These include public and animal health concerns and not least of all, odour nuisance. Reducing emissions will not in itself be a high priority in the proposed technology but any technique employed should not make the matter significantly worse.

3. FARM SPECIFICATION PROCEDURES

On visiting a farm for the first time, there is a clear need to characterise the activity and to fit the farm into one of a dozen or so of principle types. This will enable some initial focussing and the concentration on a subset of methods. Within any such categorization, some degree of adaptation to the special features of the farm will be necessary but the first step is to choose the category. This will impact on three factors: the farm itself, the use of land in the local areas, and the degree of clustering of similar farms in the same area.

3.1 Determination of the livestock aspects of the farm

- Type of manure system in use: liquid (slurry) or bedding
- Type of bedding (if used)
- Pen design; ventilation considerations; use of wallows.
- Access issues (for visits and delivering equipment)
- Available area for installing treatment or other management equipment
- Available services (power, water, electricity, drainage etc)
- Security and safety considerations
- Existing collection of manure to a single location
- Other facilities such as storage

The initial questions will relate to the type and number of animals. Beyond this, its important to establish the production system and the current management of the manure produced – collection, removal, storage, treatment (if any), transport and final disposal. Some farms will have certain facilities such as above ground stores that may lead to the selection of one type of management system over alternatives.

3.2 Use of farm land in local area

- Crop type and nutrient needs
- Vulnerability of crop to contamination
- Area of available land
- Spreading constraints
- Proximity of field to farm
- Access onto the crop land

Again, the initial questions are easy enough and relate to what land is available and in terms of area, accessibility, land form and crop use. A key question is which land belongs to the farm or farmer and that which requires negotiation with neighbours.

3.3 Description extent of clustering of farms in local area

- Number and size of similar farms nearby (within 1 km)

- Number of size of similar farms in area (1 to 5 km)
- Other livestock activities in area (1 to 5 km)
- Other waste management activities in area (1 to 5 km)
- Geographical factors – topography, local rivers, sensitive areas
- Location of local housing

Its important to establish any farm groups where there may be some degree of readiness to cooperate even if centralised schemes are not possible. One concept is the installation of similar packages at several farms and thus gain some benefit from the economy of scale.

3.4 Methods for determining amounts of waste produced

- Volumes of effluents
- Analyse of effluents
- Water balances
- Volumes of solids
- Analysis of solids
- Nutrient load in N:P:K

This is dealt with in greater detail in section 4.2.

4. END USES FOR MANURE AND OTHER FARM LIVESTOCK WASTES

4.1 Nutrient balances and estimation of surpluses

Irrespective of effluent or process, one must ask what becomes of the polluting components if they are not broken down in the treatment. For the reactive organic material, oxidation to carbon dioxide and water is an acceptable endpoint as is the release of nitrogen as the gas N_2 where this is achieved. There is no similar transformation for phosphorous which will always be present at the end of treatment albeit in a concentrated form such as a sludge. For phosphorous and for the BOD fraction and nitrogen that are not released, there are four disposal routes: land application, export as products, release to rivers or export as manure out of the region.

There are two methods of estimating nutrient surplus. The first is based on the actual quantities of manures and effluents produced and removed from the farm. A typical analysis is applied to each waste stream and the annual, (or weekly or daily) amounts of N, P and K contained are thus deduced. The second method is based on the quantities of the same nutrients produced in the raw excreta produced by the animals. In this case, published values are applied to the number of animals held on the farm premises.

However, it does not follow that the two methods will produce results that agree: large losses of nitrogen (mostly as ammonia) can be expected from within the farm building before the manure is finally collected and taken for landspreading. Other losses can occur from the simple fact that not all of the animal waste can be collected; there are clear practical limitations for example whenever animals are moved and especially (in the case of cattle and sheep) when animals are allowed to graze. One must also consider what is added to the waste stream in terms of bedding or litter and allow for other losses such as from evaporation. The difference in the two approaches is summarized in Figure 1 below:

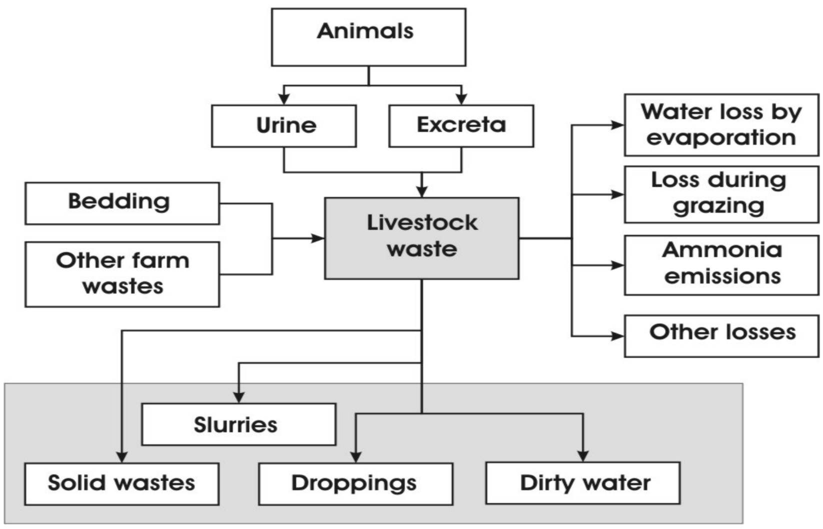

***Figure 1**: flow diagram showing the movement and division of animal wastes around a farm. Determining the nutrient load can be done at the point of defecation or from an assessment of the manures produced.*

4.2 Analysis based on manure volumes collected

Clearly each of the two methods described above has its own strengths and weakness. An assessment made on the basis of the quantity and quality of manures produced has the advantage in that it clearly represents the actual situation with respect to the environmental impact on the land surrounding the farm. In determining the excess, it is the manure applied to the land that is relevant and thus it may seem intuitive to work on this basis. However, allowance must be made for periods of grazing as the related animal droppings also makes up a significant part of the nutrient load on the local environment. But it is in the actual measurement that we find the biggest drawback to the approach; manures, especially solid manures vary widely in composition, even at the same farm, even within a single store. A great deal depends the farm management system such as the manure removal schedule and local weather can also be expected to greatly influence manure composition.

Table 1 : quantities of organic wastes produced by cattle farms in Europe during a period of 4 months winter confinement according to animal and housing type – source Institut de l'Elevage (cited in Institut de l'Elevage *et al*, 2001).

Animal	**System**	**Straw consumption**	**FYM**	**Slurry**
		kg/LU/day	*t/animal*	*m^3/animal*
Dairy cow	Scraped floor	6 to 8	3.1	4.4
Dairy cow	Cubicles/slatted floor	0.5		7.2
Dairy cow	Cubicles with bedding	2 to 3	5.5	
Beef	Slatted floor	0		3.2
Beef	Bedding	4 to 5	2.5	
Beef	Scrapped floor	2 to 3	1.3	2.1

For liquid wastes (slurries) there is the additional problem of a varying dilution effect from wash water and from the addition of other farm effluents. It would be quite usual for the typical analysis to change between the winter and summer periods and not necessarily in a predictable way – a large dilution effect can be the result of winter rainfall on exposed manure stores or from excessive wash water applied during periods of hot weather in summer. Furthermore, it is not very easy to estimate the actual volumes produced day by day, especially for the solid wastes (slurries).

In response to these difficulties, it is often easier to use standard published figures where information at the farm is either lacking or uncertain. In order to estimate manure production at a farm (or just to check the reported quantities of manure produced) figures given in Tables 1 to 3 can be used.

Table 2 : quantities of livestock wastes produced over 1 month by pigs as a function of building type and the animal type – source : Institut Technique de Porc (cited in Institut de l'Elevage *et al*, 2001).

	Slurries	**Farm yard manures**	
	Slatted floor	Scrapped floor	Accumulated bedding
	m^3/animal/month	kg/animal/month	kg/animal /month
Gestating sows	0.40	75	150
Piglets	0.08		30
Fattening pigs (dry ration)	0.20		75
Fattening pigs (liquid ration)	0.12		

Table 3 : daily amounts of waste produced by poultry according to type of bird and housing system – source : ITAVI (cited in Institut de l'Elevage *et al*, 2001).

	System	**Amount per bird**
		kg/day
Egg layers	Slurry	0.20
Egg layers	Droppings at 80% TS	0.04
Ducks – high water use	Slurry at 2% TS	1.67
Ducks – low water use	Slurry at 15% TS	0.30

Examples of typical analyses of the main types of animal wastes are given separately in tables 4 to 6 that follow but it should be noted that these do not necessarily correspond to the quantities produced per animal given in the previous tables. To use both published figures for quantities and analyses of manures for a defined farm will incur a combined error. It is always preferable to include some real data if available. However, published or standard values are still useful for the purpose of providing a series of case studies on example farms that follow.

Table 4 : mean compostion of farmyard manure and slurries (as kg/tonne) produced by cattle and goats as a function of the building type. Nitrogen and phosphorous are given as the element – source: Institut de l'Elevage (cited by Institut de l'Elevage et al, 2001).

	Dry matter	**Organic matter**	**N**	**P**	**K**
Solid manures from goats	450	360	6.1	2.3	5.8
FYM from cattle					
Well compacted	221	180	5.8	1.0	7.9
Compact from straw flow systems	182	148	4.9	1.0	7.4
Loose	190	160	5.1	1.0	5.1
Cattle slurry from covered buildings					
Some bedding included	110	91	5.2	0.7	3.0
Slurry only	111	89	4.0	0.9	4.1
Dirty water	80	65	2.7	0.5	2.7

Table 5 : mean composition of manures and slurries from piggeries sampled at the building outlet prior to separation. Figures given as kg per tonne or m^3. Nitrogen and phosphorous are given as the element – source: Institut de l'Elevage (cited by Institut de l'Elevage et al, 2001).

	Dry matter	N	P	K
Gestating sows - slurry	16	2.8	0.4	2.1
Sows with piglets - slurry	37	35	12	1.9
Growers - slurry	82	8	25	3.6
Finishing pigs - slurry	82	7.9	3.4	4.1
Fattening on straw - solids	284	8	3.9	9.1
Fattening on sawdust - solids	320	7	4.4	7.4

The broad approach for the calculation is to estimate the various quantities of each type of manure and effluent produced depending on the animals held at the farm: this must be done for one calendar year to cover any seasonal variation. For each quantity of waste material, estimates for the nutrient content are made and aggregated to give a total for the farm. The nutrient capacity of the local land available for land spreading is then estimated taking into account any prohibited areas such as fields close to surface water or those with steep gradients. The relevant limits of nutrient application are applied for this area and estimated amounts of manure left by grazing animals subtracted. If the field capacity is *less* that the quantities of nutrient contained in the manure to be spread, then the difference represents an excess and this must be removed either by treatment of exportation of material to another site.

Table 6 : mean composition of solid and liquid wastes from poultry according to type. Figures given as kg per tonne or m^3. Nitrogen and phosphorous are given as the element – source ITAVL (cited by Institut de l'Elevage et al, 2001).

Animal	Waste type	Dry matter	N	P	K
Ducks	slurry	100	4,4	0,7	2,1
Layers	slurry	100	6,8	4,1	4,5
Layers	droppings	250	15	6,1	9,9
Layers	droppings dried in deep pit	800	30	17,5	23,1
Layers	droppings dried on belt	800	40	17,5	23,1
Broilers	litter	750	29	10,9	16,5
Turkeys	litter	650	27	11,8	16,5

It should be added that even if the quantity of nutrient contained in the farm wastes does not exceed field capacity, good application practice must still be followed respecting season, weather and crop needs to avoid unnecessary losses of nutrient and the resulting pollution effect.

4.3 Predicting N and P content based on the quantity and analysis of excreta

The clear advantage in this approach is that the problem of variability in the quality of manure or effluent produced is removed from the calculation. The assumption is that a given animal will eject a certain amount of N, P and K and that this represents the relevant amount to be used in calculating the impact of the farm on the environment. Where a subsequent excess is predicted owing to insufficient land, it remains for the farmer to demonstrate that an equivalent quantity has been removed from the farm either by exportation or treatment or both. The calculation is likely to be much easier and less open to errors of judgment. And there is no shortage of published data on both the quantity of dejection produced for an animal and for the related analysis. (Tables 7 and 8 below).

Table 8 : composition and mean volumes of animal excreta plus urine. Nitrogen and phosphorous are given as the element – source Ministry of Agriculture (Defra) (cited in The Agricultural Notebook, 1995).

Animal	**Weight**	**Manure produced**	**Dry matter**	**N**	**P**	**K**
	kg	kg/jour	kg/tonne	kg/tonne	kg/tonne	kg/tonne
Dairy cattle	550	57	100	5	0.9	4.1
Beef cattle	400	27	100	5	0.9	4.1
Fattening pig - dry rations	50	4	100	6	1.7	2.5
Fattening pig - liquid feed	50	7	80	5	0.9	1.7
Broiler	2	0.1	250	14	4.8	5.0

The quantities of N, P and K excreted by the animal can be usefully expressed as grams per kilogram *live weight* to enable some comparison between species. For nitrogen, this varies over a relatively narrow range from 0.34 to 0.70 g/kg.day. The lowest values are for dairy cows and the highest for poultry and fattening pigs. Similar values and trends are observed with data from a different source given in Table 10. Repeating the exercise for P gives a similarly narrow range of 0.06 to 0.24 with poultry the highest. For potassium, the range is 0.20 to 0.42 ; this time the higher value is for dairy cattle.

As a simple indication, one can use the average values for each of the analyses given in Table 8 to give mean N:P:K ratios. Defining N as 100, the values are 100:10:82 for cattle, 100:28:42 for pigs fattened on dry food and 100:34:36 for poultry. Crop requirements vary widely but as an example, one might take cereals which require a nutrient mix of around 100:30:70. One thus might expect an excess of nitrogen to correspond to an excess of phosphorous especially if applying poultry manure. If applying cattle manure, an excess of nitrogen is likely to correspond to an excess in potassium over crop needs.

However, the weakness of this analytical approach is that it does **not** take into account either nutrient losses at the farm or the contribution of added bedding materials. In the case of nitrogen, losses as ammonia can represent a large proportion of original nitrogen present in the fresh dung and urine – as much as 30% or more. Whilst emissions of N are undesirable they are, at present, not readily abated. This is recognized in the best practice guidelines as set out in the BREF notes for the implementation of the EU wide IPPC directive (European Commission, 2002) The only clear intervention measure described by this document is that of gas scrubbing with dilute acid, but although effective, this is not as yet listed as BAT owing to the large related costs.

Table 8: concentration of nitrogen and mean volumes of animal excreta (including urine). . Nitrogen and phosphorous are given as the element and units of kg/tonne and g/kg liveweight per day – source Ministry of Agriculture (Defra) (cited in The Water Code, 1998).

Animal	**Weight**	**Total excrement**	**Dry matter**	**N**	
	kg	kg/day	kg/tonne	kg/tonne	g/kg-l.w./day
Dairy cows	550	53	100	5.0	0.48
Beef cow	400	26	100	5.0	0.33
Bull	100	7	100	5.5	0.39
Sow and offspring	180	10.9	60	5,0	0.30
Piglets	7 to 18	1.3	100	7.0	0.76
Fattening pigs (dry ration)	18 to 35	2.7	100	7.0	0.70
Fattening pigs (dry ration)	35 to 105	4.5	100	7.0	0.45
Fattening pigs (soup)	35 to 105	7.2	60	4,5	0.46
Layers	2.2	0.11	300	16	0.80
Broilers	2.2	0.06	600	30	0.82

The current situation is thus one in which the manure collected is unlikely to contain as much nitrogen as implied by calculations based on the dejections produced by the animals and that some allowance needs to be made before estimating excesses. The situation for phosphorous is simpler in that losses are likely to be much smaller and, due to its relative insolubility in manures, most of it can be collected from around the farm with the various waste products. The potassium in farm wastes is invariably totally in solution and any liquid loss via seepage into the local ground around the farm will represent a loss of this element. However, as the given examples show, the relative quantities of potassium in animal wastes will rarely lead to an excess being applied to local fields if the limits for N and P are being respected.

The required calculation is one of predicting the annual production of N, P and K in the expected wastes from animals held at the farm. Some deduction is necessary to reflect losses which implies an element of judgment: one might think of 25% for N, 5% for P and 10% for K but there is relatively little data to be precise with such figures. Whatever deduction factor is used should be stated clearly. The remaining nutrient contained in the various waste materials is then compared to the estimated capacity of the field and the excess that has to be removed is deduced.

4.4 Land application

Where land application is acceptable it can be classified as one of three scenarios:

1. To crop land - nutrients utilised
2. To crop land - nutrients not needed
3. To waste ground

Ideally this should be to crop land where the nutrients are fully utilised. In reality, even with the most careful and controlled applications, some nutrient will inevitably be lost first to the soil then leached out into water if not taken up by soil activity. However, this represents the most attractive option in that there is at least the concept of sustainability present. More often though land application to crops includes nutrients that are *not* needed - the excess may be retained in the soil for a season but then it will be progressively released into the environment and ultimately to water. The policy of spreading manure onto waste ground is used but not recommended; inevitably the largest part of the applied material will not be utilised by vegetation and thus this will be released as pollution. The land itself will also accumulate residues from the applied manure and the soil will progressively show signs of pollution.

4.5 Disposal of effluents to streams and rivers

Although never officially encouraged, such practices are nonetheless common in many parts the world. Several systems can be identified:

- Direct release to rivers
- Release via ditches and drains
- Discharge via a sewer system
- Release via wetland or other biological barrier

Direct release to rivers is rarely condoned but it is not uncommon practice. It makes little difference whether the discharge to direct to the river of via a ditch or small stream; the load on the aquatic environment is the same. A heavy load on a small stream will quickly destroy fish and higher animals but down river the effect can be diluted. Large rivers once heavily contaminated can represent both a loss of food production and a serious health risk.

In such cases, there are set standards for discharge - this is especially so the organic matter content as BOD and sometimes for ammonia as well. Phosphorous levels are rarely specified directly but may be implied in part where a limit on suspended solids is set. Treatment to achieve the set standards is possible but it can be expensive and there is always the temptation to economise by switching off the operation at times! An alternative is to release the manure (or part treated effluent) to a sewer - this may be possible in some areas where the local municipal treatment works has spare capacity.

An alternative might be to release effluent to a river or stream but via a wetland or other biological barrier - this though is effectively a treatment which may or may not work - it should be assessed as such especially in terms of long term viability and effective capacity.

4.6 Sales of solid products

In the farm model, the export (including sale) option represents a means of removing some or all of the manure from the farm nutrient balance. It follows that the recipient of the exported manure or products must in turn respect their own local nutrient balance, but this is normally beyond the scope of the supplier to verify this any more than a manufacturer of chemical fertiliser can be sure of the proper use of his products.

The main outlets for the products of manure processing are:

- For fish feed
- As composted products
- As soil amendments
- Via feed to other processes

Dried faecal matter is in demand in parts of SE Asia as a fish feed; this is limited to local use by transport constraints. This can also be the case for composted products bound for use in horticultural production systems. If distances become excessive, transport costs wipe out any financial benefits. The exception is large centralised schemes located close to good transport links. The problem is then one of whether the farm is near enough to such a facility to justify sending material for processing.

Soil amendments differ from composts in that they are not intended as a growing media but rather to bring nutrient to soils used for crop production. The concept is close to one of "organic fertiliser" but high quality products equivalent to chemical fertilisers (such as being explored in Europe) are not envisaged here.

4.7 Export and other options

Exportation of manure or manure products may not always bring revenue but it remains a valid option even if some payment is necessary by the farmer. In some cases, it represents a cheaper option than investment in processing plant although some limited treatment (such as screening or storage) may still be necessary. Options come under four headings:

- Transportation out of area (lorry or pipeline)
- To centralised processing system
- Incineration (power generation)
- To land fill sites (solid wastes only)

The seemingly simple solution to dealing with local surpluses of manure is to transport it out of area: this of course assumes that there is a receiving area not too far away. If there is land nearby (< 5km) then one might consider transfer by pipeline. Otherwise roads will need to be good enough to allow transport by tanker. The destination could be other farms with a need for organic material but this is unlikely to be the case often.

Alternatively, there is the option of a centralised processing system. In this scenario, there is the benefit of economies of scale and a high degree of control on the process.

Dry (or dried) solids may be suitable for incineration as is the case of poultry litter in parts of Europe. As a very last resort (and not very satisfactory solution) there is the limited option of disposing the final (dried) effluent to land fill sites on the basis that it is totally unwanted.

5. SELECTION METHODS

5.1 Special regional considerations: Thailand, Vietnam, China

It is important not to apply models and strategies that work in Europe to the situation in other countries without first considering the special local circumstances. As a region, SE Asia has some particular differences that must be reflected in the strategy developed and the equipment and systems applied. In summary these are:

- Much lower incomes for livestock farmers and thus much less available funds for investment. Even with external grants and technical support, any scheme that implies a high investment cost is unlikely to be viable.

- Smaller farms: although larger farms are emerging, most animal production still comes from relatively small units. This further limits the scope for elaborate schemes although there is the option for community schemes and centralised manure handling.

- Roads and transport: generally these are poor in rural areas and schemes implying haulage of large volumes over distances more than a kilometre are unlikely to be practical. In some areas, tractors are very limited in availability and the maximum size of a single load is thus reduced to that which can be pulled by animal or manually. Pipeline transport remains and alternative option - this may well be more readily offered as a local service.

- Limited land availability: this varies across the region but often there is insufficient local land to receive the full nutrient load contained in the manure produced by the livestock farm. The worked example below (section 5.4) sets out an approach to identify the surplus of nutrients and then to look at a limited treatment to deal with this part alone.

- Temperatures: compared to Europe, local temperatures are 10 deg.C or more higher making animal cooling a much greater factor in management and building design. Stocking density has to be lower, and access to cooling water important. The link between animal husbandry and water management is particularly important.

In addition to regional features, there are also special local factors to consider. The list is potentially very long and a few examples alone are given below. More important is to take note of any defining features of a farm or local area before specifying a farm waste strategy or a process or equipment.

- In some regions of Vietnam, pig production is concentrated in "production villages" with a large number of small units located close (or within) the village boundaries.

- In Guangdong Province (China), the land is especially hilly with most flat terrain given over to fish ponds - there is a close link between fish and pig production.

- The use of wallows (shallow baths) are used in some farms in Thailand with the consequential production of large volumes of dilute effluent.

- In some regions, the collection of some of the solid dung for drying and subsequent sale as a feed substrate for fish ponds is common practice.

5.2 Identifying the most appropriate strategy

Once data on the farm and region has been gathered, the next step must be to set out a *viable* strategy. This has several benefits but mostly, it enables the identification of what conditions actually need to be met in a successful scheme and that which is not important. Crucially, a strategy must be formulated and agreed before moving onto equipment specification although the costs of the latter in any proposed option will always be a factor. The key questions that a proposed strategy must address include:

- What is the expected fate of the manure - eg: export as products; local land spreading; to fish ponds; discharge (of very dilute effluents) to rivers etc.

- What are the maximum level of environmental impacts that can be tolerated in the local area of the farm?

- What management and/or treatments are necessary in order to meet an environmental impact not exceeding the minimal conditions set.

- What special local conditions exist and how does the proposed strategy address these.

- Financially, how can the investment costs be met and how can the running of the system be funded and sustained.

- How vulnerable is the proposed approach to minor changes in the local circumstances.

To some extent, the process will be iterative. This is set out conceptually in Figure 2. This may seem daunting but in reality, in many cases the path will be fairly self-evident. The important issue here is a structured and methodical approach to the process of decision making.

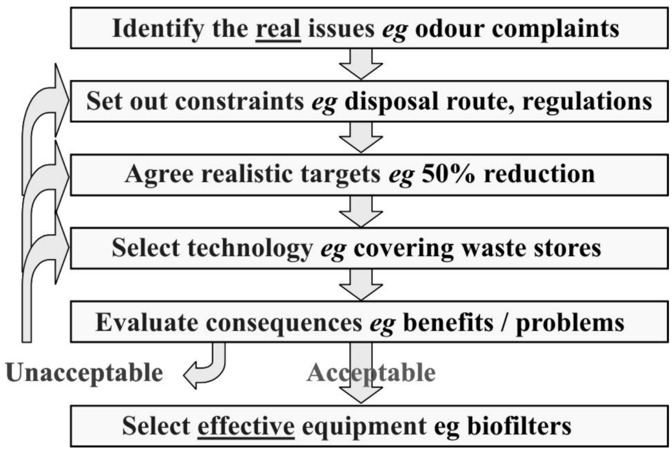

Figure 2*: schematic representation of the decision making process enabling the ultimate selection of appropriate and effective equipment that meets the farm requirement.*

A strategy will be proposed that seems to meet the requirements of the farm and the environment. Analysis will reveal some short-comings and so the strategy is revised. Eventually, agreement is needed that satisfies all parties and meets the main purposes of the exercise. At this point, one can consider the equipment and process options.

5.3 Which technology ?

There has been many reviews and publications on the various treatment processes that could be suitable for the treatment of effluents from livestock farms (for example, Texier et al, 1999, Burton and Turner, 2003, Levasseur, 2004, Daumer et al, 2005). In addition, there are studies on small treatment systems for effluents that can be applied in part to the small farm (eg: Boutin et al, 1998). A very large list could be prepared of all the options especially on including the specific commercial options that have been developed in recent years. However, there is a great deal of duplication and some of the systems are clearly unsuitable for the smaller livestock farm. The list set out in Table 10 below is not intended to be exhaustive, nor a particular recommendation; rather, it represents the more common technologies indicating those which are more suitable for the category of farm set out in this report.

Table 9: evaluation of selected options. *** best to ● worst.

Option	Investment cost	Land needed	Operating cost	Energy need	Staff time need	Reference
Screw press	*	***	**	**	**	Levasseur 2004
Centrifuge	●	***	**	*	**	Levasseur 2004
Belt filter	*	**	*	**	**	Texier 1999
ADVA lagooning	**	●	***	***	***	Mara, 2004
Aerobic treatment	*	**	*	●	**	Levasseur 2004
Windrow composting	***	*	**	***	●	Haug 1993
Straw/slurry composting	**	*	**	***	*	Levasseur 2004
Soil filter	●	●	**	***	*	Martinez 1997
Anaerobic digestion	●	**	**	**	**	Burton et al, 2003
Sedimentation	***	**	***	***	***	Levasseur 2004

In ***Annex 3*** there is a summary of existing technology. In ***Annex 4***, there is a detailed assessment of 28 of the most appropriate options for Asian farmers. Included processes generally meet or could meet most of the following criteria:

- Low investment cost
- Low running cost
- Low maintenance cost

- Limited requirement for specialised inputs
- Effective removal of one or more manure components
- Underlying principles and technology established
- Availability

The strengths and weaknesses of some examples are set out in Table 9 above. The effectiveness of the process in reducing organic load is given in Table 10.

Table 10: evaluation of main options as listed above in terms of performance. Removal performance: *** over 80 %, ** 40-80%, * 10-40%, ● below 10%. Mechanism of removal: A biological degradation, B lost as emissions, C exported in solid products.

Option	Nitrogen		Phosphorous		Organic matter	
Screw press	*	C	**	C	**	C
Centrifuge	*	C	***	C	**	C
Belt filter	*	C	***	C	**	C
Lagooning	**	B	***	C	***	A
Aerobic treatment	***	A	●	C	***	A
Windrow composting	**	B	**	C	**	A
Straw/slurry composting	**	B	**	C	**	A
Soil filter	**	A	**	C	***	A
Anaerobic digestion	●	C	●	C	***	A
Sedimentation	●	C	**	C	**	C

5.2 Selection protocol

Equipment selection follows two broad levels of decision making: the first to chose the type of system (eg: separation or anaerobic digestion) and the second to select the best supplier or contractor assuming that there is a choice available.

In many cases, the selection of equipment or process will come down to just 2 or 3 options of which one will appear as the clear main option. This will especially be so if the strategy is well established giving a clear specification of the sort of approach that will satisfy both farmer and the local people and environment. If biogas production or the manufacture of compost for export is the preferred route, the related systems will clearly be a digester or composter.

The decision making then moves on to what type of digester or composting system is suitable. This question may be partly answered when considering aspects of the farm and farmer situation - basic composting would be implied for a small farm but a more involved scheme producing a high quality product may be the better option for a large farm or a cluster of farms working together.

Beyond specifying the system comes the actual choice of machines and contractors to install the process. This depends on the method of installation. If the option of using a contractor is to be followed, then, providing one has confidence in the company, they can be expected to select the apparatus such as pumps, mixers or the provision of lined lagoons etc. In this case, the crucial step is to ensure that the specification part of the contract is as precise as possible making the minimum requirements both clear and obligatory. For simpler schemes relating to a small farm such as the purchase of a separator, then the protocol needs to set out a list of key factors to consider along with some basic scoring system. As such a series of options may be considered and the best selected. As an example, the purchase of a slurry pump to transfer 10 tonnes of slurry per day:

- Maximum flowrate (determines running time)
- Provision to chop entrained bedding
- Maximum power of motor
- Single or three phase electricity
- Ease of dis-assembly to clear blockages
- Weight
- Resistance to corrosion (pig slurry is very corrosive)
- Guarantees
- Servicing and spare parts

5.3 Working out cost estimates

Once a scheme has been fully described and agreed, the cost needs to be precisely defined before one can move to contractual arrangements. This covers both investment and the subsequent running costs. The former might be provided by a contractor who will take full responsibility for the project but some prior appreciation of the likely elements would still be important to enable judgement of the value of the package on offer. Some aspects of the running costs may be indicated by the supplier but a more comprehensive evaluation is important to ensure the long term sustainability of the installed manure management process.

Investment costs can be estimated by following the classic breakdown of any project costs with the typical headings:

- Specific costs of listed items of equipment
- Installation and commissioning costs
- Pipes and services
- Site preparation costs
- Monitoring and instrumentation
- Consultancy fees

A second list should be added of elements that effectively defray these costs:

- Grants for local and national governments
- Any existing facilities that can be used in the proposed scheme such as available manure stores or buildings

- Any component of the new process that has other uses around the farm such as the purchase of a tractor for manure transportation..

For operation costs a similar list exists such as:

- Electricity and fuel
- Other services
- Specialist labour
- Farm staff input
- Maintenance costs
- Finance costs (including the option of a write off cost)
- Fees

Against this may be specific incomes from the running of a scheme:

- Sale of biogas produced
- Sale of dried solids for fish ponds
- Sale of compost products
- Sale of nutrients in manure land-spread
- Subsidies

Not all of these items need be as a true cash flow. For a livestock farmer with local crops, the use of manure for crop fertilisation will enable a reduction in the purchase of chemical fertiliser which is implicitly a financial benefit from the scheme.

5.4 A worked example

An example farm is taken with details has set out in Table 11 below. We need to decide what are the limits for N and P application. This will depend principally on the crop and the stage of crop production. If we take the examples of 450 kg N and 200 kg P per hectare, then the available land of 10 hectares, has a capacity is 4500 kg and 2000 kg per year of N and P respectively. This equates to the need to remove at least 4750 kg of nitrogen (56%) and 1300 kg of phosphorous (40%) from the farm system. In this example, all the surplus nutrients could be removed by exporting most of the solid manure which contains 5750 kg and 2800 kg of N and P respectively.

It would follow that the relatively small amounts of liquid manure are most easily disposed of by land-spreading locally. Beyond this application, there would remain a residual field capacity to receive a further 1000 kg of N and 1500 kg of P. Thus, in terms of N, at least 83% of the solid manure must to taken off site (if left untreated) to ensure that all the surplus nitrogen is removed - this will easily include the excess phosphorous. However, in terms of P, only 47% of the solids need to be exported.

Treatment could be most conveniently *windrow composting* to prepare a product that would be more acceptable for other farms and which is more easily handled. Most compost procedures imply an inadvertent loss of nitrogen (as ammonia) which typically will equal around half of the original content. Thus if such composting is chosen, the final N in the product might be expected to be around 2900 kg with a local field spare capacity (once the liquid had been applied) of 1000 kg: thus the amount of solids to be exported is reduced to 66% in this example.

Table 11 : details of farm used in worked example. Figures from tables 2 and 5

Animal numbers		**Building type**	**Waste type**	**Available field area for spreading (ha)**
Sows	150	Straw bedding	Farmyard manure	
Piglets to 5 kg	1,000	Straw bedding	Farmyard manure	10
Fattening to 100 kg	1,000	Solid floor	Slurry	

		Wastes		**N**	**P**	**K**	**N**	**P**	**K**
		Per animal kg/month	All animals tonne/yr	Concentration kg/tonne			as Total kg/an		
Sows	Solids	***400***	720	***8.0***	***3.9***	***9.1***	5750	2800	6550
Piglets to 5 kg	Slurry	***30***	360	***2.8***	***0.4***	***2.1***	1000	150	750
Fattening to 100 kg	Slurry	***75***	900	***2.8***	***0.4***	***2.1***	2500	350	1900
Total							***9250***	***3300***	***9200***

As well as reducing the nitrogen content (albeit with the release of ammonia), composting would also produced a more stable product with reduced odour and a reduced hygiene risk; as such its attractiveness for sale would be increased although the value would depend on local markets and the final quality achieved. The annual amount exported would be around 5-700 tonnes allowing for the addition of a mass of green waste to ensure a good blend. The N and P contained (around 2900 and 1800 kg respectively) might be expected to have a maximum value in terms of chemical fertilizer saved) of 2400 US$ on the basis of 50 cents per kg of nutrient.

6. EVALUATION METHODS

As well as tool to propose a suitable system for a given farm or farm scenario, the DST needs to provide some specification of the related control and monitoring system that will ensure a satisfactory operation of the process. At the first level, this will enable confirmation that a proposed system can achieve a certain target at the point of conception. Subsequent to installation , a control strategy will sustain an optimal performance and related parameters will enable confirmation of this. Separate environmental monitoring will confirm the broad benefits of the installed system.

6.1 Control and monitoring parameters

Parameters can in fact be divided in to three main groups:

1. *System parameters*: such as mass and volume flow rates, temperatures, biogas production (if applicable), pH (if applicable), operation time of pumps, mixers and equipment, redox and dissolved oxygen values (with respect to aeration) and so on. All of these do no more than confirm that a given system is running as planned. This is no guarantee of satisfactory performance - if the original concept was wrong, even if the installed system works perfectly, it will not achieve the desired objectives.

2. *System performance parameter*: theses relate to the products of the process and include parameters relating to the "end of pipe" analysis such as biological oxygen demand, residual N and P, ammonia, concentration of specific (indicator) organisms, heavy metals, odorous compounds etc. In the selection of any system, a certain level of performance may be expected if operated correctly. This needs to be considered in the selection process as it is rarely possible to easily modify performance once installed.

3. *Environmental impacts*: this can be predicted from the measured outputs at the end of the pipe but more generally, it ought to be established separately if possible such as the relative change in the quality of local streams or in the measured emissions of odours or specific pollutant gases. Of special note are combined systems such as might occur with treatment prior to land spreading or export of products. Full assessment implies consideration of all the streams produced at there point of impact on the local environment.

6.2 Evaluation and scoring of options

Evaluation can take place at two stages: firstly in the conception and design stage in order to establish that the proposed technology is suitable in meeting the proposed targets. In this case, there needs to be enough available information to confirm predicted performance and this should match up with a realistic scientific understanding and it be definable with a credible mass balance covering the components of concern, especially N, P and organic matter. The second stage of evaluation relates to the actual performance of the installed

system and will reflect how well it is operated and maintained. It is the former that will play the greater part in the DST system – as well as leading to a range of options, the expected performance of each should be available to enable an informed decision.
Process assessment can be done in a number of ways but a degree of simplicity will ensure that some objective comparison is possible. One might start with a simple data gathering exercise as set out in the example table below (Figure 3):

Which environmental problems will be tackled?		
☐	Removal of nutrient surpluses	
	% reduction of N expected	
	% reduction de P expected	
	% reduction of organic matter expected	
☐	Offensive odours from buildings and after field spreading	
	% reduction of odour expected	
☐	Contamination of surface and underground water	
	% reduction de N expected	
	% reduction de P expected	
☐	Abatement of air emissions	
	% reduction of N_2O emission expected	
	% reduction of CH_4 emission expected	
	% reduction of NH_3 emission expected	
☐	Pathogen and hygiene risks	
	Reduction in pathogen numbers (units de $\log_{10}$) expected	
☐	Soil pollution from heavy metals	
	% reduction in copper and/or zinc expected	

***Figure 3**: example of an evaluation procedure based around a checklist for a given proposed technology to manage and treat livestock manure.*

A simple system of scoring might enable an overall evaluation. For example, for an emission of a specific gas or the reduction of a component in the liquid phase, one might propose:

5 reduction of 50%
2 reduction 10-50%
0 no change
-1 increase by 10-30%
-3 increase by over 30%

Repeating this (albeit modified scores and weighting for each parameter as appropriate) and adding to give an overall score may allow some degree of ranking. However, crucially, certain constraints must be met and the process must always be affordable. None the less, if the basic rules can be agreed and applied to the most common treatment and management options, this should allow a degree of consistency in the evaluation of the options available. The list given in ***Annexe 4*** includes some scoring but only in the form of a number of stars; the difficulty will remain agreeing equivalence between certain opposing factors which must reflect the local priorities. As such, the DST developed can be expected to be customised at least to represent a version for each of the three participating countries and possible with one or two regional variations such as for the north and southern regions of Vietnam.

6.3 Final checks

The proposed protocol for evaluation of options at the time of selection and of the performance of the installed system, will comprise a series of elements as outlined above. It may be useful to include a series of checklists that can be quickly run through at the end of any given process to ensure that all principle constraints have been observed and that the emerging option is considered at least *satisfactory* in each of the main categories. The formation of such checklists is an exercise in its own right but this may include the following elements:

At the design and selection stage. For example, does the proposed package:

- achieve a significant reduction in nitrogen/phosphorous released to the environment?
- make good use of farm resources
- represent a practical option for the farmer
- provide adequate rewards to the farmer
- represent an affordable option for investment
- require running costs within the scope of the farm

For each question, the answer may be one of (i) yes exceeds requirement, (ii) satisfactory, (iii) some minor shortcomings (iv) serious shortcomings that need further attention. Separate lists would be expected for (a) the evaluation of the system at the design and selection stage and (b) that of the installed and operation process.

7. CONSTRUCTION OF THE DST

7.1 Overview and relationship to the agronomic DST on nutrient balance

Building the Treatment DST is expected to comprise six broad stages of work:

1. Setting out the broad structure
2. Identifying data to be collected and processed
3. Development of individual modules
4. Assembling of components into a coherent and working system
5. Testing of the package on volunteers
6. Training and dissemination

The separate *Agronomic DST* covers the nutrient aspects related to land spreading of livestock manures. This is closely related to the objectives of the *Manure Treatment DST* which leads to the need for a common approach and the option of a single combined package. In response to this a *common reference document* is required that will be included in each contracts for the preparation of the two DST's. A highly integrated approach has been set out in such a reference document given in Annex 2: effectively, a the product will be a single package but with distinct parts relating to each of the DST's.

7.2 Setting out the broad structure

Putting together a DST package for treatment systems that will significantly assist the user implies a serious effort equivalent to that required in preparing a piece of software – realistically this will be in the order of 12-24 man.months of effort. It is important to avoid the temptations of using short-cuts or to be superficial at any point because we are asking the final user to have a great deal of trust in the advice that the package produces – poor or inadequate information will quickly lead to a loss in confidence in the system.

The first step in the process is to map out of the tasks involved including the definition of a realistic timeframe – a minimum 12 months but better as 15 to 18 months to allow room for adequate feedback and development. This ought to be laid out to show timing and the interrelation of tasks. Crucial will be some *milestones* – checkpoints at various stages to allow feedback and confirmation that the developing package is meeting expectations. However delivered (paper, software or both), the package will have a modular structure and thus one can expect that elements can be prepared and reviewed separately to some extent.

Figure 4 provides some idea of a suitable project structure which clearly goes far beyond writing a detailed programme: there is also the compiling of data and procedures (with respect to treatment processes), information gathering, testing early versions on possible users and the subsequent revisions based on the feedback received.

In addition there needs to be consideration of the interface between the two DST's that effectively need to work together in a consistent way. A proposed contract (given in Annex 1 and including Annex 2 as a common reference document) goes further in precisely defining specific roles between two separate contractors: this approach will be necessary in the event of the production of a single combined DST package.

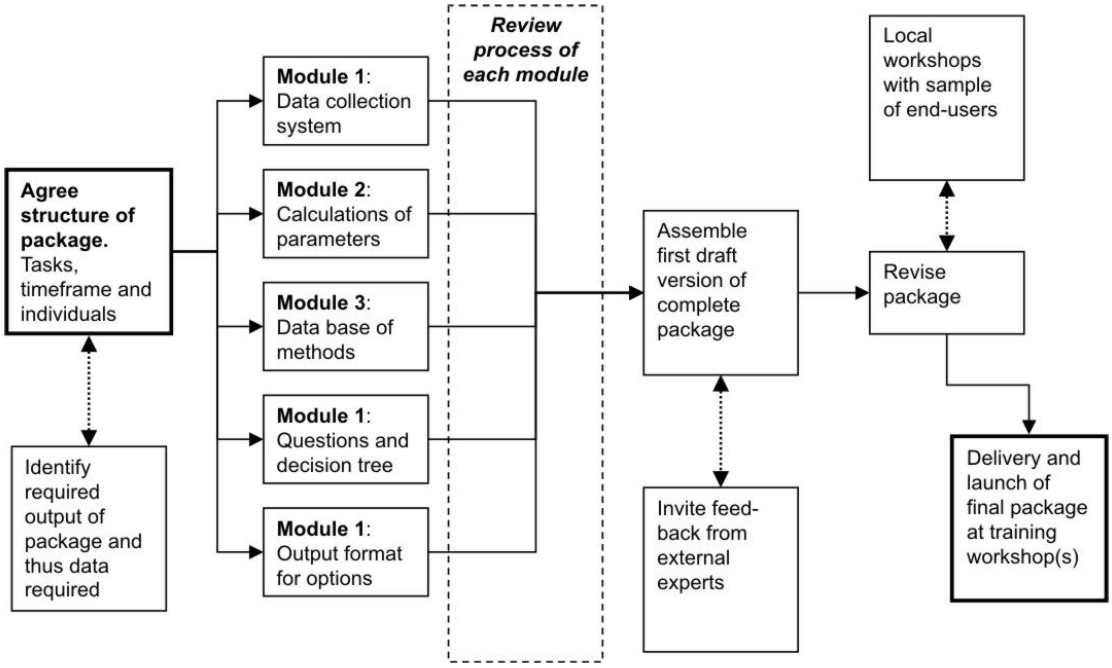

Figure 4*: an example of the organisation of a project to design and construct a DST to be used within and beyond the domains of the LWMEA project*

7.3 Collection of the data – a data-file approach

Data required for the operation of the software falls into three groups:

- That relating to the design procedures
- That specifying the farm
- That setting out farmer preferences

Compiling information on design procedures for the various treatment options will represent a large part of the work even though a great deal of published material already exists. As well as establishing the most reliable sources, choices will be necessary based on what is most appropriate for inclusion in a package intended for use in the S.E Asia region. One can foresee 8 to 10 principal treatment categories in total plus the various sub-sections:

- composting of solid materials;
- anaerobic digestion of liquids;
- aerobic treatment of effluents;
- lagooning systems;
- separation and screening technologies;
- sedimentation and clarification;
- storage strategies;
- solar drying of solids.

Beyond the process description there will be specification of dimensions, materials, installation procedures and costs. To rationalise the data collection process and the related need to frequently update such data, the approach of a "data-base file" is proposed. This would initially be set up as a complete source of all standard values required to run *both* principal DST programs; as such it would also serve as a *common source*. Clearly values would need to be entered for each and every parameter – the cost per metre of 40mm plastic pipe, the specific gravity of sow manure, the calorific value of biogas, the load capacity for manure in hand-pulled barrows ….. the list could run into hundred's of such values. In some cases, informed guessed will be needed to enable early versions of the software to run. However, by using a database that is external to the principal software, subsequent revision as better data becomes available will be relatively straightforward.

Some input data will clearly relate specifically to an individual farm such as number of animals, field area and use, local hazards etc. This information must be provided for a realistic evaluation but it ought to be available and indeed it may be easier to obtain via a farm visit by an advisor. This aspect of the work will imply the development of a series of pro-formers to enable the collection of specific data as required by the package to ensure a good and reliable analysis.

Details of farm itself: name, address, regional authority etc.	
Farm type	☐ Cattle ☐ Pigs ☐ Poultry ☐ Others
Numbers of animals	☐ Cattle ☐ Pigs ☐ Poultry ☐ Others
Areas of farmland nearby (hectares)	☐ Rice and cereal crops ☐ Permanent crops and orchards ☐ Vegetables ☐ Waste ground ☐ Pasture ☐ Other land
Waste type (tick all that apply)	☐ Farmyard manure ☐ Dirty water (concentration below 10 kg/m^3) ☐ Slurry (10-30 kg/m^3) ☐ Slurry (30-60 kg/m^3) ☐ Slurry (over 60 kg/m^3)
Local environmental hazards	☐ Nearby stream ☐ Nearby well or bore hole ☐ High risk crops ☐ Local housing ☐ Health issues

Figure 5*: example of data collection sheet that will collectively provide the starting point for the DST process in assessing the farm in terms of most suitable manure management technology.*

An example is given in Figure 5 above but this is very limited; one would envisage a visit to a farm and that a comprehensive set of data is collected along with related information on the impact of the farm on the local area. In the case of a software package, this same data might be typed in using a lap top computer during the farm visit but some aspects such as pencil drawings or sketches to show farm layout might still be better done on paper.

The third set of data relates to farmer preferences which suggests an interactive approach driven by a decision tree. Essentially, there will always be preferences but this needs to be presented in a structured way to avoid impossible combinations. Thus one might envisage an interactive program serving for data input that offers choices but prevents certain impracticable combinations. Alternatively, the user, having made a first choice, proceeds down a subsequent path with the various sub-options then available – effectively the user is "talked" through the process rather than having all offered in one list. In any case, it is likely that the software user will need to go through the selection procedure several times: initially in setting up the input data to describe the farm and farmer needs and subsequently to react to the options presented by the program.

7.4 Development of individual modules

The program code itself will be written based on a series of program schematics that set out the precise structure required. The broad design is set out in Figure 6 showing modules for input, output, database and computation. A separate computation program will be needed for the Agronomic DST but the two both appear as there is clearly a certain level of data exchange. In reality, the modules themselves will comprise many sub-routines.

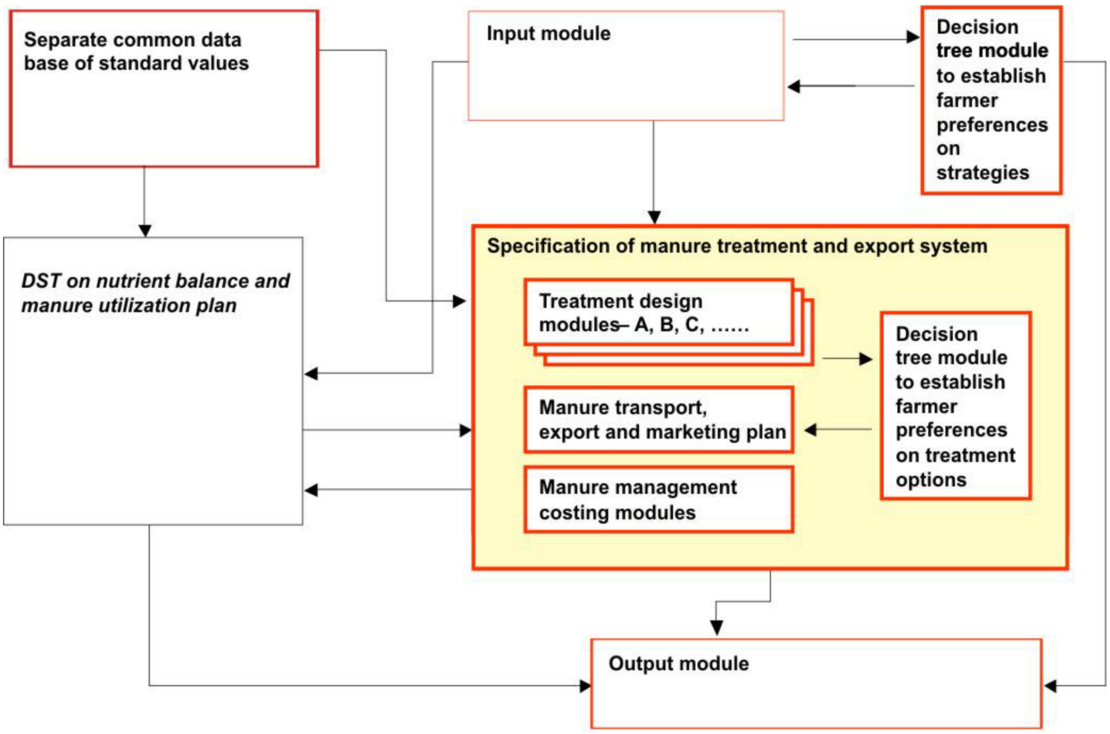

Figure 6: schematic showing the principal components of the DST package envisaged including the relationship with the parallel Agronomic DST.

7.5 Assembling of components into a coherent and working system

In the early stages of development, one can easily envisage the preparation and testing (in a software sense) of separate parts of the program – such represents a manageable exercise that should eliminate most local programming problems. Beyond this, there is the separate task of combining subroutines and thence complete modules such that each supplies data to the other as required in the overall scheme of the package. Even if modules run satisfactorily as separate routines, their combination can be expected to reveal a new series of programming faults that must be resolved by the process of de-bugging that can become very protracted and thus difficult to estimate time-wise. The complete package may require some final routines to be added such that satisfactory operation is achieved.

7.6 Testing of the package on volunteers

A package that *apparently* runs satisfactorily in the laboratory may not be suitably functional for two distinct reasons;

- Program faults in response to un-tested data combinations
- Difficulties in use from the user point of view

Both require the early versions of the software package to be tested by independent users at an early stage. The problem of program faults may be intrinsic to the programming itself or due to unforeseen situations producing poor or unrealistic designs. This is potentially a serious flaw in any such software and with a huge number of scenarios, only extensive testing can ultimately remove the risk of strange or absurd recommendations.

The second series of problems relates to the user interface and the way the program proceeds from the point of view of the user. The program should be relatively easy to use with an abundance of directions and clear instructions to direct the user – as far as possible, it should be intuitive: this can only be assessed by trials with individuals largely unaware of the program to remove any familiarity that would otherwise over-score ease of use.

The function of the program relates more to how representative it is of the likely farming scenarios in the region. Excessive questions on bedding in the tropical country where it is rarely used is clearly inappropriate and an early involvement of local farming experts would quickly reveal this. Likewise, a lack of interaction on “wallows” which are commonplace on pig farms in Thailand would leave the farm inadequately described and the wrong manure system may result.

Only extensive testing will eliminate these types of program weakness; inevitably,, once released for project or (later) for general use, such faults will be found and rectified in subsequent released versions. However, as far as possible, investment in time to minimise the need for frequent revision is desirable not only because of the time necessary for preparing and sending out new versions but also because of a negative image that can be generated from poorly tested software.

7.7 Delivery and training

The final stage of the DST preparation process is by no means the least – delivery and training need to be especially well organised to ensure the uptake of the new package both within and beyond the project. Clearly, the number of training sessions will be limited thus the preparation of a guide of usage ought to be included in the process. There may be some merit in considering "training trainers" but the limitations of this must be understood as a certain degree of dilution of the key messages may occur as a result. It is not just the output of the DST that is of importance – of equal importance is how this information is used in the defining and implementation of improved and appropriate manure management strategies at the farm and local level.

7.8 A proposed TOR for the preparation of the required DST

A draft TOR (Terms of Reference) document is included with this report in ***Annex 1***; related to this is a common reference document (***Annex 2***) to ensure a consistent approach between this potential contract and that for the separate Agronomy DST that will be prepared at the same time. Some indication of the work input needed and the related budget is included.

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ANNEXES

Annex 1: *Terms of reference document for the preparation of a DST software package for the selection of most appropriate manure management technology in SE Asia*

Annex 2: *The common reference document defining the work structure and division of responsibilities between the two principle contractors who will deliver the single software package as defined (related to Annex 1)*

Annex 3: *Resume of main treatment technologies*

Annex 4: *Evaluation of suitable technologies for livestock farms in SE Asia*

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ANNEX 1

Terms of reference document for the preparation of a DST software package for the selection of most appropriate manure management technology in SE Asia

Context

1. The required work described in this document forms part of the project "Livestock Waste Management in East Asia" which is managed by World Bank (on behalf of the GEF – the Global Environmental Facility). The project, referred to as the LWMEA project, is based in three active countries within the region, China (Guangdong Province), Thailand and Vietnam; however, its influence is expected to extend to other neighbouring countries in the region. The nominal start date was August 2006 and it is expected to be completed in a 5 year period.

2. Some technical parts of this project are managed by the Food and Agriculture Organization of the United Nations (based in Rome and with a regional office based in Bangkok). One of these responsibilities is to prepare a series of DST's (Decision Support Tools) that will be used by project partners and others to fulfil commitments both within and beyond the duration of the project.

3. Two DST's of relevance here are (a) that forming the subject of this TOR (terms of reference document) which concerns the management (and especially the related treatment) of livestock manures and (b) that forming the subject of a separate TOR which concerns the land application of manure in an agronomic context. These two pieces of work will be carried out by separate organizations working together to produce a single combined DST software package.

4. The structure of the software package comprising the two mentioned DST's and the division of work between the two assigned contractors is set out in the attached Annex 2. The organisation fulfilling this TOR is referred to as **Org-A**. Work ascribed to **Org-B**, will be completed by a separate organization governed by its own separate contract and TOR but which will include the same Annex 1 attached to this TOR.

Definitions

5. TOR means *Terms of Reference* Document which forms part of a binding contract between the contractor and the Food and Agriculture Organization of the United Nations. Other than this TOR (also referred to as *Manure Treatment TOR*), reference is made to a second TOR to be fulfilled by a separate contractor; this later is also referred to here as the *Agronomic TOR*).

6. Org-A refers to the contractor fulfilling the work described in this TOR. References in this document to work falling to *Org-B* mean specifically the contractor fulfilling the work set out in the parallel Agronomic TOR.

7. The term *software package* represents the combined inputs from the two TOR's. This will be a single seamless piece of software that can run on any modern computer carrying appropriate commonly available Microsoft software. It will represent the DST requirements covered under the two TOR's.

8. The duties to be completed in fulfilling the contract related to this TOR include the preparation of the described software package along with a series of additional tasks as listed below.

9. *Project partners* refers to the three countries involved in the LWMEA project, China (Guangdong Province), Thailand and Vietnam. The broader term *East Asia* or region refers to countries in the geographic region of Asia that have coastline bordering the South China Sea or which include rivers that drain into the same sea.

10. The term *livestock production* refers specifically to pig and poultry but may include other species of farm animal where similar manure management practices apply.

11. The term *livestock farm* refers to any building plus surrounding land that is intended for the production of animals. The boundaries of the farm will be those as specified by the farmer – they will be deemed to include land available for use by the farmer. The term *farm system* will refer to a group of farms (all types) adjoining or nearby which share a common agreed interest in accepting and using manures produced in a structured way defined by a manure management plan.

12. The removal of manure or manure products *beyond* the boundary of the farm system will be termed *manure export*. Agronomic assessments will only apply to the farm system as defined by the operation of the software. Assuring and assessing the agronomic use of manure *exported* whether for sale or as a paid service, will be outside the scope of the DST software package.

13. *Emissions* are defined as any gas causing harm to the environment produced directly or indirectly from livestock manure. The principal gases of concern are noted as ammonia, those contributing to global warming (nitrous oxide and methane), hydrogen sulphide and those contributing to offensive odour. Carbon dioxide from manure is not considered harmful in that the net contribution to the environment from a balance farming system is zero.

14. *Water pollution* from livestock manure is defined as the contamination of surface or groundwater by excess nutrient or from any toxic components that may be present. It is noted in the context of the LWMEA project, the primary objective is to reduce the contamination of water reaching (eventually) the South China Sea with the specific nutrients, phosphorous and nitrogen.

15. Health risks is defined as a probability function relating to becoming ill as the result of one or more pathogenic organisms. A second and distinct parameter is the magnitude or consequence of suffering a specific illnesses (the hazard) caused by the pathogens that may be present; only the first parameter is deemed controllable. Thus an *improved health situation* is one in which the probability of farm staff (and local people) succumbing to illness caused by pathogens originating form manure linked to manure *is reduced.* Conversely, a *worsened health situation* is that produced by changes increasing the probability of such people succumbing to illness.

Time schedule

16. The duration of the project shall be 15 months from a mutually agreed start date. An proportionate extension to the final deadline is permitted should events within the LWMEA project which are beyond the control of the contractor cause delays. Otherwise, agreed delays are only acceptable with prior agreement of the FAO project officer.

17. An initial meeting between Org-A and Org-B along with representatives of the three country project groups will be arranged within the first three months to confirm preferences on the general structure of the software package and a system of communication and inputs during development.

18. An interim meeting between Org-A and Org-B along with representatives of the three country project groups will be arranged between 9 and 12 months of project duration to review a first version of the developed software package.

19. The finalised package along with associated documentation will be available before the end of month 15. The intention is that this will coincide with the launch workshop, the final duty of the defined work; however, in the event of timing difficulties, the launch workshop may be delayed by mutual agreement with the FAO by up to 3 months beyond the nominal end of the project, *i.e.* up to 18 months after the start date.

Overall objectives and deliverables of the TOR

20. The complete joint outputs from this work will comprise: (a) a CD-ROM containing the DST software itself and related files, (b) a paper copy of a project report, (c) a paper copy of a comprehensive guide describing the software, its use and operation (prepared with Org-B), (d) a series of meetings run in SE Asia with local groups corresponding to the initial preparation, a mid-term revision and the final product launch and (e) the preparation of a series of summary fact sheets intended for distribution amongst the farming community. In addition, the same electronic software will be posted on to an existing website designated by the FAO. Full details of the software are set out in the common reference document (Annex 2).

21. The CD-ROM delivered will contain the following files: (a) the principle program, (b) the revisable data-file used with the main program, (c) an electronic copy of the operation guide, (d) an electronic copy of the set of farmer-friendly fact sheets and (e) an electronic copy of any related reference material acquired during the project implementation.

22. Delivery packages comprising (a) copies of the CD-ROM (b) the software guide and (c) a set of farmer fact sheets, will be supplied to the FAO, project partners and those participating in the related meetings and at the final launch workshop. Production and distribution of packages beyond these contacts will not be part of this project. The total number of packages produced as an output from this project will be 20.

23. The target audience for the software will be the level of farm advisor or technical consultant or the equivalent. The target audience of the farmer fact sheets will be the livestock farmer themselves. Within the scope of this project, all communication and products will be solely in *English*; subsequent translation to Asian languages is anticipated but this falls outside the scope of the work defined here.

Specific tasks to be completed

24. An initial meeting will be held in SE Asia with Org-B (and other regional project partners) to specify the framework and protocol of the Data-file. The software will be MS Idealist or an agreed equivalent that is compatible with MS Excel/Visual Basic. The same meeting partners will agree on the precise structure and format of the input and output modules for the main programme, including the preferred style of layout and interaction.

25. The construction of a first version the data-file program will be done by with contributions from Org-B relating to agronomic parameters, fixed values and other related key information. Contributions relating to the treatment system will be supplied by Org-A.

26. The construction of a first version of the input file of the main program. Modules relating to the acquisition of essential and option data will be supplied by Org-B. A first algorithm on an appropriate decision tree will be prepared.

27. A detailed plan of the principal module for the specification of a manure treatment (and exportation regime) will be formulated and laid out schematically detailing the main options to be included and the equivalent structure of the program proposed including data exchange with the nutrient plan module (see the common reference document in Annex 2). This plan will include modules for each of the main treatment processes, transport and sale estimations and costings for the combined proposed package. Treatment schemes will be grouped under five headings as set out in Figure 1 below. Also included will be a first algorithm on the interactions to be proposed for the program user.

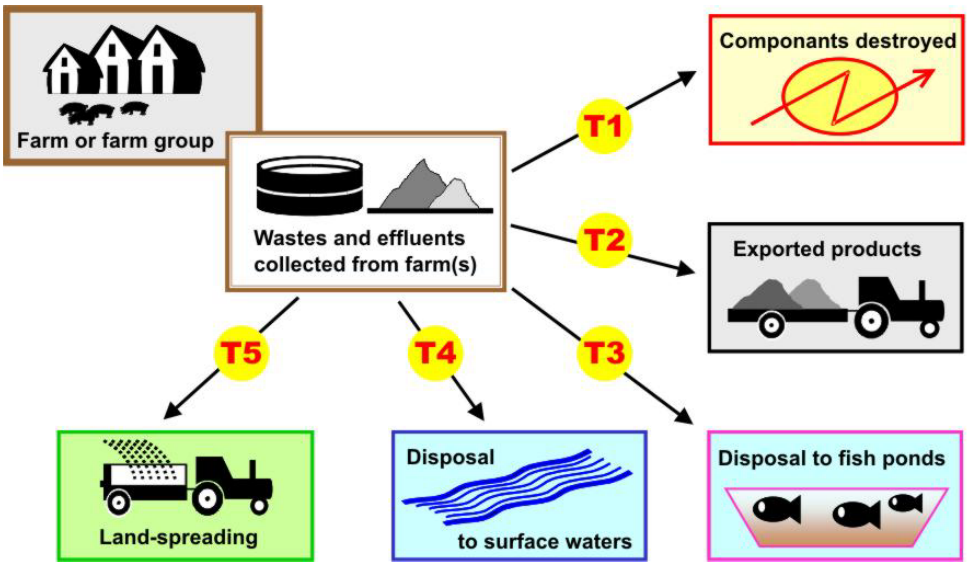

Figure 1: the manure treatment options will be classified under one of five headings depending on the principal disposal route specified, T1 treatments imply the removal of components such as nitrogen or carbon as harmless emissions; T2 includes any scheme that is based on the export of some or all of the manure; T3 covers schemes enabling safe nourishment of fish ponds; T4 are schemes enabling safe disposal to canals, streams and rivers and T5 are treatments that enable safe applications to crops.

28. A detailed schematic plan for the output module will be prepared including examples of possible delivery formats. This will take in to account the desired output

29. *A first review meeting* between Org-A and Org-B will be held in Europe to asses progress and any revision to plans necessary and the implementation of any corrective action in the event of unforeseen problems.

30. Subsequent to the first review meeting (item 29), the input and data-base modules will be revised. Revisions will also be made to the schemes for the principal (treatment) and output modules.

31. A first version of the program for the principal (treatment) module will be written but this version including only composting, which is one of the 7 or 8 principal treatments envisaged (the list extending to include systems based on: composting, anaerobic digestion, aerobic treatment, lagooning, separation, sedimentation, storage and drying). The program will include part-complete modules for export/transport and costing. A part complete decision tree will be included to enable evaluation of the approach.

32. A first programmed version of the output module will be prepared including sections setting out information supplied from the agronomic module prepared by Org-B.

33. *A second review meeting* between Org-A and Org-B will be held in Europe to asses progress and any revision to plans necessary and the implementation of any corrective action in the event of unforeseen problems. A specific target will be the establishment of the transfer of required data between those modules making up the principal program and the data-file.

34. A revised versions of the data-file, input and output modules and of the principal (treatment module) will be prepared.

35. A first combined software package including the most recent version of the principal (agronomic) module will be assembled to test out interactions.

36. Additional treatment options will be programmed in to the principal (treatment) module. This will include design, transport/export and the related costings. The target at this stage will be to include at least four treatment schemes.

37. An second meeting will be held in SE Asia with Org-B (and other regional project partners) to gain feedback on the first version of the software package. It is not expected to be complete but the principles of operation should be clear. The same meeting will identify any remaining gaps in the proposed package and further considerations in its expected use.

38. Further revisions to all the program modules will be made in response to the regional meeting (item 37), especially with respect to the decision trees that enable selection and interaction: these will be accordingly expanded.

39. The remaining treatment options will be written and added to the principal (treatment) module.

40. A second complete version of the package will be assembled using the most recent contributions from Org-B.

41. *A third review meeting* between Org-A and Org-B will be held in Europe to asses the combined software package and to identify any final revisions necessary ahead of developing a final version. Any remaining program incompatibilities will be resolved.

42. Revisions of all modules will be carried out and (on receipt of revised modules form Org-B), a revised complete package will be prepared. This will comprise all elements intended in the final version.

43. A structured programme for software testing will be carried out using both internal staff and project partners. A test routine and evaluation sheet will be sent out with copies of the prototype software.

44. *A final review meeting* between Org-A and Org-B will be held in Europe to asses the response to the prototype software package. The same meeting will also set out the titles of a series of summarising fact sheets intended for general use; these will go out as a set and include 10 to 20 representing treatment and agronomic subjects. The same meeting will be used to organise the launch workshop in SE Asia.

45. Final revisions will be made to the various modules of the software package. A final version will be assembled using the submitted revised modules from Org-B; this will be checked and confirmed as the definitive version within the scope of this project.

46. A series of fact sheets will be prepared relating to the treatment aspects of manure management (estimated as 5 to 10 in total).

47. A full operating guide for the software will be prepared *jointly with Org-B*. This will include a description of the software and its structure and limitations, how data in the data-file can be subsequently updated and the operation procedure itself for the package. An electronic copy of this will be included with the CD-ROM provided.

48. A separate project report will be prepared for FAO use only.

49. Packages will be prepared (indicated as 20 sets) and distributed to partners the remaining stock held by the FAO. A package will include the CD-ROM, a set of fact sheets and a hard copy of the project report and software guide.

50. A launch workshop will be arranged at a date and location convenient for the FAO and as many partners and interested partners as possible. This is planned as either a single regional workshops or a series of three, one each in the three participating countries. The workshop will comprise a series of lectures to describe the package and training sessions to for users.

Resolution of difficulties

51. In the unlikely event of delays or the lack of timely input from Org-B, the first approach will be by informal contact and thence via the formal progress meetings structured into the programme of work. If the short-coming remains unresolved for more than 4 weeks, a formal record will be made copying to the FAO. If the project work effort is compromised by the such delays or the incomplete provision of required input on the part of Org-B, a formal note will be made in the final project report.

52. In the event of delays in the provision of elements of the software package required from Org-B, dummy modules will be used as an interim measure to allow some progress. Such modules will provide an arbitrary data set to enable the functionality of the combined system to be assessed. If the omission of contribution is not rectified within a reasonable time frame during the project, a proportionate extension to the completion date of the project will be granted without penalty.

53. The none provision of any defined modules, appropriate code or key information on the part of Org-B will result in an incomplete software package (lacking these same components) being accepted as a conclusion to this work without penalty. In such an eventuality, the option of fulfilment of this same deficient work as additional tasks within the current TOR (Treatment) is an option but subject to subsequent separate agreement.

Staff commitment and estimated budget

54. The following budget (Table 1) are proposed for the work to be carried out as specified by a series of tasks under items 24 to 50. The two components are (a) man.days each defined as a period of 8 hours and inclusive of salary and general overheads and (b) a figure of incurred costs including travel and subsistence, software and any other costs incurred in the fulfilment of this project.

55. The day rate (inclusive of all overheads) is given as a mean for the range of all staff involved as 550 US$ (or 400 euro)

56. Figures are given in US dollars but calculations are on the basis of the current exchange rate of 1.38 US$ per euro. Recalculation may be necessary in the event of any further pronounced movements in the exchange rate (*ie* by more than 5% of this quoted value).

57. The total budget proposed is **195,000 USD** (142,000 euro) reflects the scale of the work required as described. A lower figure will require some reduction in the scope of work.

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Table 1: draft budget for work described under this TOR document

Item	Man-days	Cost *USD*	Travel and Subsistence *USD*	Other costs *USD*	Total *USD*	Comment
24	**15**	7500	5000	0	12500	2 people, 2 days in Asia + 3 days travel + 5 days prep.
25	**10**	5000	0	2000	7000	Software costs
26	**10**	5000	0	0	5000	
27	**10**	5000	0	0	5000	
28	**10**	5000	0	0	5000	
29	**8**	4000	2000	0	6000	2 people, 2 days at mtg + 2 days travel
30	**10**	5000	0	0	5000	
31	**15**	7500	0	0	7500	
32	**10**	5000	0	0	5000	
33	**4**	2000	0	0	2000	2 people, 2 days at mtg no travel
34	**10**	5000	0	0	5000	
35	**20**	10000	0	0	10000	
36	**30**	15000	0	0	15000	
37	**12**	6000	5000	0	11000	2 people, 2 days in Asia + 3 days travel + 2 days prep.
38	**10**	5000	0	0	5000	
39	**30**	15000	0	0	15000	
40	**10**	5000	0	0	5000	
41	**8**	4000	2000	0	6000	2 people, 2 days at mtg + 2 days travel
42	**10**	5000	0	0	5000	
43	**15**	7500	0	1000	8500	Incurred costs of external people assisting with testing
44	**4**	2000	0	0	2000	2 people, 2 days at mtg no travel
45	**10**	5000	0	0	5000	
46	**20**	10000	0	0	10000	
47	**20**	10000	0	0	10000	
48	**5**	2500	0	0	2500	
49	**5**	2500	0	2000	4500	Material costs
50	**20**	10000	5000	500	15500	2 people, 3 days in Asia + 3 days travel + 8 days prep.
TOTAL	**341**	**170500**	**19000**	**5500**	**195000**	

Version 3 : 24 July 2007

ANNEX 2

The common reference document defining the work structure and division of responsibilities between the two principle contractors who will deliver the single software package as defined

General context

1. This document forms the common part of two distinct terms of reference (TOR) documents; these will in turn form part of the contract to be made with each of the two selected contractors to prepare the defined software package. The project is expected to run for 15 months duration from the signing of contracts.

2. The two contractors are referred to as **Org-A** who will concentrate on the engineering issues relating to the collection, storage, treatment and export of manure and manure products from a livestock farm and **Org-B** who will concentrate on the agronomic issues relating to the manure nutrient evaluation and the application of manure (raw and treated) and related products on the defined surrounding fields.

3. The product is a software package described as a "DST or Decision Support Tool" for application within the livestock industry (especially pig and poultry production) across SE Asia including southern China. This is required as part of the project "Livestock Waste Management in East Asia" which is managed by World Bank (on behalf of the GEF – Global Environmental Facility) with the technical requirement requiring the DST being managed by the Food and Research Council of the United Nations.

The complete product described as the DST package will comprise: (a) the software itself, (b) a detailed report describing its use and operation, (c) two series of small workshops with local groups (typically 2-3 people each and one in each of the three participating countries) corresponding to the initial preparation and a mid-term revision, (d) the final joint regional workshop for the software launch and (e) the preparation of a series of summary sheets intended for distribution amongst the farming community.

Summary of the required software package

4. The final software package will comprise sections produced by each of the two partners but which will work together as a seamless single unit in the final delivered product. The general scheme is set out in **Figure 1** with tasks in bold boxes relating to Org-A and those in boxes edged in fine double lines relating to Org-B.

5. The final DST software package will be structured as two separate programs: the **main program** which will comprise an input module (including interrogative decision trees), an output module, data handling and calculating routines; regular revisions on this part of the package are not expected. The second program is the **database of information** that will include all fixed information and assumptions that will enable the program; a feature of this part of the package will be the facility for frequent updates as better data becomes available.

6. It is envisaged that the package will be developed beyond its delivery and launch (as specified by the contract) on the basis of improving data supplied to the database of information; this would for example include validation and testing of some of the principles assumed in the assembly of the package. However, this additional work will not form part of the contract to deliver the principal DST software package.

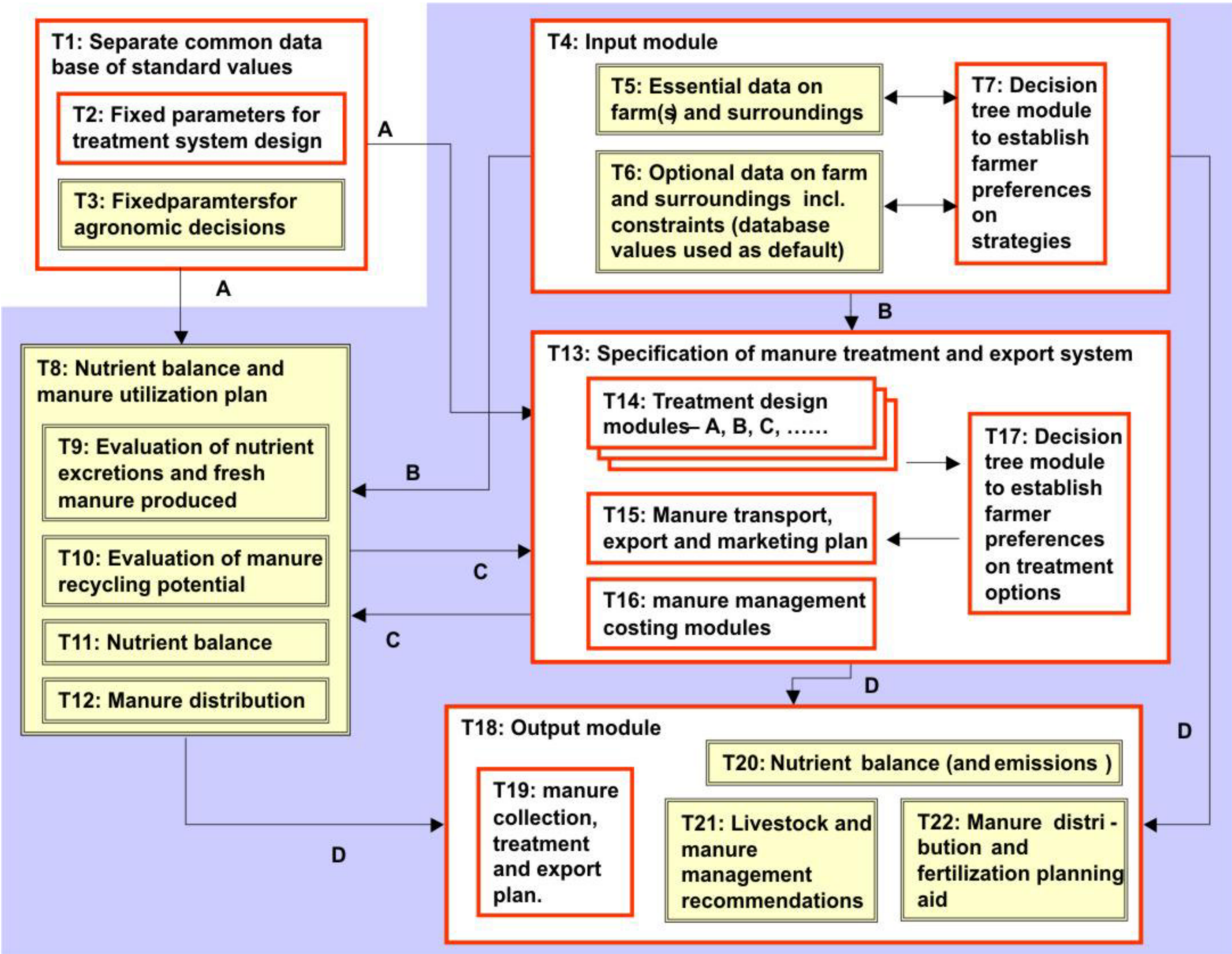

Figure 1: block diagram showing the broad structure of the software package and the division of responsibilities between each of the two partners designated Org-A and Org-B. Transfer of data between modules defined: A fixed inputs as available in most recent version of data-file, B input data as defined by user, C – exchange of derived information between principal operation systems; D – output data to be displayed on screen in a user friendly form or sent to an export file.

Required collaboration between Org-A and Org-B

7. To fulfil the terms of the related contracts both partners agree to a minimal level of collaboration comprising:

a) review meetings alternating between their normal work premises (or at a mutually agreed third location). A minimum of four such meetings will be held during the project no more than 4 months apart.
b) use of a common programming platform based on Micosoft Excel/Visual Basic and frequent exchange of software modules as versions become available.[D1]

c) shared responsibilities for three collaborative workshops in SE Asia as described in item 4 above and of the production of summary leaflets on the good use of livestock manure.

MODULE 1: database of information

8. In order to simplify the inevitable revisions of the program, all fixed data will be compiled in a separate database which will be run alongside the main program. This will enable easier revision and the option (at a later date but not part of this contract) of an interactive resource on the internet.

Task 1: Separate common data base of standard values Org-A

9. Task 1 represents the construction of the data base and the related protocol for its population with data, operation with the main program and its periodic revision.

Task 2: fixed parameters for treatment system design Org-A

10. The database will include both values considered to be the best available (such as aerator efficiency) and estimates of others that will be taken as default in the absence of data submitted when operating the program (such as costs of materials). It will include:

- all standard values for the main treatments (composting, AD, aeration, separation etc);
- physical properties of manure, water and effluents, as far as these are not calculated farm specifically by the DST;
- data on processes and changes in manure properties for manure storage and main treatments (e.g. proportion of nutrients in different types of manure, degradation of organic matter, evapo-transpiration, nutrient removal)
- materials of construction and related physical properties;
- costs for materials, services and labour;
- standard constraints in construction and operation;
- standard market data;
- standard transport costs and capacities;

Task 3: fixed parameters for agronomic decisions Org-B

11. As for task 3 except the subject area is essentially crop nutrition and raw manures.

- required nutrients of main crop types
- timing of application;
- limitations such as no nitrogen on rice after flowering or health constraints;
- fish pond nutrition loads;
- volumes of excreta from different animal types;
- proportion of waste as liquid, solid;
- bedding types and characteristics (if used);
- transport consideration (to local fields);
- plausibility limits;
- default values for livestock management.

MODULE 2: operational program

Task 4: Input module **Org-A**

12. The task here involves constructing a user interface to present information and questions and to receive information as inputted. The module will include checks that supplied data is sensible and warning when key data is missing. When non-essential data is lacking, default values will be offered.

Task 5: essential data on farm(s) and surroundings **Org-B**

13. This is everything that defines the farm (or farm group) – one might expect such information as animal numbers, age, type, production intensity, housing type, present manure management, land area, crops, rainfall etc. It is crucial to establish the limits of what are described as local fields (including those available belonging to the neighbours) that can be used for recycling. Details will be needed of the crop type and which manure (or manure product) is acceptable. Manure (and manure products, of positive or negative cost) that are sent *outside* this defined farming area are deemed to have been ***exported*** and no further consideration will be given here to their agronomic use. It is noted though that in the real case, the farmer who exports manure may still retain liability for their correct subsequent use.

Task 6: optional data on farm and surroundings including constraints **Org-B**

14. This covers necessary data but such things as might be reasonably taken from default values such as feeding, water consumption, fertilizer application (quantity and timing) for certain crops or nutrients applied to fish ponds. Constraints will also be specified in this module such as what crops can not receive untreated manure because of quality or health concerns. Where the user can't offer better values, the database defaults will be used.

Task 7: decision tree module to establish farmer preferences on strategies **Org-A**

15. Once the farm is defined, the user will need to clarify a series of preliminary options and preferences in order to determine an analysis sequence. Thus the farmer will agree/disagree with a series of options – spreading on his own farm, exporting (including sale) of manures and related products, marketing potential (saleable products), readiness of neighbouring farms to receive manure, use of dung in local fishpond, use of biogas, compost etc. This evaluation must also flag out possible restrictions that have to be taken into account (e.g. health and odour issues, transport and spreading during rainy season, readiness of neighbouring farms to use manure). The idea is that some preliminary analysis may be possible to identify at the outset whether realistic solutions are possible or if the farmer needs to relax one or more constraints.

Task 8: Nutrient balance and manure utilization plan based on meeting the first limiting nutrient **Org-B**

16. The overall purpose of this segment is to evaluate the nutrient surplus based on (a) the estimated amounts generated at the farm, (b) that which is required by local crops and (c) any local restrictions or preferences by the farmers involved.

Task 9: evaluation of nutrient excreta and fresh manure produced **Org-B**

17. Calculation of nutrient excretion and amount and composition of fresh manure produced based on management data (T6) and the numbers of animal types specified.

Task 10: evaluation of manure recycling potential **Org-B**

18. Detailed evaluation of manure recycling potential including own use for crops and/or fish production. The marketing potential for solid manure selling and liquid manure export to other crop or fish farms is covered in T5 and T15 . The evaluation must also take into account restrictions flagged out in T7. In this exercise the neighbouring farms that shall receive manure must also be involved in the process: *ie:* their readiness to receive manure, or to have manure pipes going over their land and their expectations concerning the cost (positive, free, negative) must be reliably known.

Task 11: nutrient balance **Org-B**

19. For evaluation of the initial situation: calculation of nutrient balance (surplus) based on results of T9, recycling potential and nutrient requirements of different crops. The result shows the nutrient surplus: ie: that which must be removed to ensure a balanced environment. Alternatively, this becomes the pollution load if not dealt with. For evaluation of future scenarios: same calculation but taking into account the effect of treatment (T14).

Task 12: manure distribution and storage potential needed **Org-B**

20. Based on the nutrient recycling potential (T10) and the available manures and nutrients after treatment (T16/T14) a fertilization plan for all the farms/crops included in the scheme is established. It can be used to determine what quantity of what manure shall be applied at what time on different crops or in fish production. This will also show the necessary storage capacity. This module does not yet deal with the distribution of the manure to specific farms and the logistics of the distribution. This will be dealt with in the planning aid included within the output model T18.

Task 13: Specification of manure treatment and export system **Org-A**

21. This segment will propose one or more handling systems based on the farm specification, standard data, the defined nutrient surplus (from T8) and farmer preferences. A further option is to include an iteration loop following treatment specification: segment T8 is then fed with revised data on available nutrient after treatment to provide the nutrient balance for the planning scenario(s).

Task 14: treatment design modules – A, B, C, …… **Org-A**

22. A substantial piece of programming as a design package will be needed for each of the main options – storage, composting, drying, AD, aeration, separation, settling, lagooning – and for each, a series of sub-options can be expected where variations exists such as for AD. Once the design is specified in T17, the effect of the treatment on the amount of manures and nutrients, pathogens and BOD will be assessed. This will also provide the inputs needed for

T12 about the amount and composition of treated manures. Assumed values will be specified in the database (T1).

***Task 15: manure transport, export and marketing plan* <u>Org-A</u>**

23. Exported manure (and related products) are those defined as removed from the local farming system. Separate from the farm based design, calculations will be included to provide figures for moving and selling the manure and its products (compost, sludges, dried dung, biogas etc). In the case of raw manure, export is defined as that implying movement well beyond the natural boundaries of the livestock farm – several km typically. Because it is virtually impossible to have data on manure use beyond the defined farming area, *exported* manure will not feature in agronomic calculations although its appropriate subsequent use may remain a responsibility of the farmer.

***Task 16: manure management costing modules* <u>Org-A</u>**

24. Accurate costs will depend greatly on the reliability of data but reasonable estimates should be possible at least to distinguish between the cheaper and expensive options. Cost estimates will be provided for each option covering (a) investment, (b) running and (c) maintenance. The expected return on sold products will be used to defray the associated cost.

***Task 17: decision tree module to establish farmer preferences on treatment options* <u>Org-A</u>**

25. Faced with a series of options, the user (farmer) will then proceed through a series of questions to assist with the analysis and thus the identification of the best option in this case.

***Task 18: Output module* <u>Org-A</u>**

26. Once a choice is finalized (perhaps by running the program several times), a detailed file will be generated to enable its implementation (or at least wider discussion on pursuing this option).

27. The output module will summarize the results in different form according to user specific needs. The content of these outputs will comprise results from T8-T17 and relevant information from T4-T6. Furthermore, it can also include practical recommendations for good practice as well illustrative examples and background information that might help the user to understand and properly implement the suggested strategy. Generated files can be in the chosen electronic format. Information for farmers will also be provided in user-friendly printed documents. The design of the different outputs can take into account country and user specific requirements.

***Task 19: manure treatment system and export plan* <u>Org-A</u>**

28. This will include estimates of costs, strengths and weaknesses of the manure management package proposed. This report will be equally for the external contractor who will deal with the implementation of the manure management plan. In addition, there will be a summary of technical details needed for the operation of the treatment facilities including some instructions and recommendations for the proper running and maintenance of the facility.

29. A scheme will be presented on the quantities of manure (and manure products of treatment) that will be exported beyond the domain for the farming system. The nutrients contained will not be included in the local mass balance but some comment may be included of a cautionary nature to cover risks (environmental and health) that may be inadvertently transported to other regions.

Task 20: nutrient balance (and emissions) **Org-B**

30. Summary of the nutrient (P, K_2O, Mg, Ca …) and heavy metal (Cu, Zn, possibly others …) balance situation for the initial and a future scenario (if relevant). It might also include a summary of the emission data that is available as a by-product of the calculation (NH_3, discharge) or specific emission calculations (GHG).

Task 21: livestock and manure management recommendations **Org-B**

31. Practical recommendations about proper livestock management (feeding, water use, ventilation and cooling, manure collection etc.) and manure handling (as far as not covered by T19; e.g. prevention of run-off and overflow losses, transport and spreading options).

Task 22: manure distribution and fertilization planning aid **Org-B**

32. User interface with T12. The user can optimize the dosing and distribution of different types of manure to different crops and farms and to determine what supplementary chemical fertilizer is needed. The tool can also provide the basic framework to organize the logistics of the distribution of manure to different farms.

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ANNEXE 3

Resume of main treatment technologies

Various set publications can be consulted for an overview of the main technologies for the management and treatment of livestock manures (eg: Burton and Turner, 2003). What follows is a resume intended to familiarise the reader with the principle options and how they may be used in the situation of developing livestock agriculture in SE Asia.

1. Physical technologies

Mixing

Mixing of tank contents is a key part of any process although it doesn't in itself impart any change to the average effluent composition. In provides a homogeneous feed to subsequent stages enabling a steady operation of what is often a continuous process producing a consistent treatment. Variations in the effluent can result from the natural separation of the suspended matter either into a floating layer or a settled sludge. The composition of effluents entering a treatment plant can be normally expected to vary as a result of many factors such as the periodic washing routines. Maintaining a steady feed to the treatment plant requires large feed tanks to provide buffering and again mixing is necessary. A great deal of research has gone into mixing theory and equipment and many reviews have been produced (eg Cumby, 1990). Common weaknesses include inadequate power input (a minimum of $10W/m^3$ is recommended - Cumby, 1987) and poor selection and location of equipment especially in large stores.

Mechanical screening

Screening is a simple way of removing the coarse matter from effluents and thus greatly improving its ease of handling. If large quantities are present such as in livestock manures then the separated fibre can be useful in subsequent composting processes. In this case, it is important to ensure a high solids concentration in the separated fibre (ie 25%+) which leads to the selection of the more elaborate equipment such as screw and belt presses. However, if the main purpose of the operation is the removal of relatively small quantities of coarse matter (eg to protect equipment) then simpler screens will suffice. These have the advantage of higher throughput but a wetter fibre product is produced.

Separation and clarification

A more rigorous clarification of wastewater effluents is based on settlement. This can be by natural gravitation or enhanced by the use of flocculants and/or centrifugation. Gravity settling works best with dilute effluents (TS below 25 kg/m^3) due to the production of large volumes of sludge with increased dry matter (Martinez et al, 1995). Centrifugation can produce concentrated sludges and a high degree of clarification but equipment is expensive and throughput modest. In either case, separation is more complete than simple screening as finer particles are included in the removed sludge layer. This extends to a more effective removal of some of the specific components of the effluent as shown in table 1. Whereas the screen and screw press only make a significant difference (ie, removal in excess of the concentrate volume) to the TS, the decanter centrifuge also removes Kjeldahl nitrogen and phosphorus. The laboratory test indicates the maximum extent of physical separation which can also include certain metals but not the highly soluble potassium.

2. Biological processes

Biological processes for waste treatment are those in which microbial activity represent the principle activity. In the case of the treatment of animal manure, this implies the breakdown of a large part of the organic matter either aerobically (such as aeration, composting or treatments by wetlands) or anaerobically (such as in digestion processes with the production of biogas). In aerobic treatments, the products of a biological treatment are likely to be some biomass production but mostly respiration gases and water. For anaerobic activity, there will also be the production of simpler organic compounds (especially volatile fatty acids) which can, in the presence of methanogenic bacteria, be further broken down into methane and carbon dioxide. In either case, the complete process should see the removal of virtually all the readily bio-degradable material leaving a relatively stabilised product. Aerobic treatment can lead to losses of nitrogen either as ammonia or (if nitrifiers are present) as the products of de-nitrification (especially di-nitrogen gas). The effect on phosphorous is limited although the process can affect solubility. For effluents, an adequate biological treatment will enable an easier sedimentation by the removal of many of the organic components that stabilise the flocs and thus which inhibit settling.

Composting

There is no shortages of publications and guides on this technique of which one standard text is Haug (1995). In principle, if well managed, this process can transform an organic substrate into a stable hygienic product. This process requires both oxygen and sufficient humidity to enable the aerobes to function. The supply of oxygen in particular is crucial and can be provided by frequent turning of the compost pile or from forced ventilation. The most common and practical system is that based on windrows.

According to the composition of the raw materials, its porosity and its moisture, the windrow (pile) will need to be turned or aerated more or less frequently. Some care is needed to minimise the release of ammonia (and offensive odours) as well as methane which can be produced if aeration is inadequate or inconsistent. A good blend is important and it is often necessary to add materials rich in lignin (green waste, especially twigs and small branches, sawdust and bedding, chopped tree bark etc) – as such, a good structure of the pile is ensured but moisture must not be allowed to fall below 50%.

The value of composting is closely linked to sufficient biological activity to raise the temperature of the mix above 60 deg.C thus greatly reducing both pathogenic organisms and weed seeds. Such a rise in temperature would be expected anyway as a simple indication of microbial activity although the precise value also relates to such factors as reactive organic load, aeration rate, ambient temperature and the level of containment. Compost processes that fail to achieve this temperature may be considered to be incomplete or at least requiring a greatly extended period of time. In satisfactory composting in a batch process; maximum activity is achieved within 2 to 3 days and by day 10 the temperature has settled back to ambient indicating a completed process. A shortcoming of composting animal manures in the emission of ammonia produced which can equate to a large proportion of the nitrogen in the original mix. This corresponds closely to temperature as might be expected. Losses can be reduced by in-vessel processes and the use of higher C:N ratio's by incorporating more straw.

Biological treatment by aeration

Adequate aeration involves dissolving enough oxygen into liquid manure in order to replace an anaerobic system (chemically reducing) with an aerobic environment for microbial activity. As a result, organic matter, characterized by BOD_5 (biological oxygen demand), is rapidly oxidized to relatively harmless products such as carbon dioxide and water. The removal of the same material also takes away the main cause of the offensive odours associated with organic effluents and many pathogens that are strict anaerobes are destroyed. Under certain conditions (eg, treatment times of 3+ days and a dissolved oxygen concentration above 1ppm) nitrification of ammonia to nitrites and nitrates can occur with nitrogen release (as N_2) in the subsequent de-nitrification, although the pollutant gas, nitrous oxide (N_2O) can also be produced as an unwanted bi-product (Burton et al, 1993).

Continuous aerobic treatment is nutrient-limited and is thus independent of both temperature and aeration level within limits. In the case of temperature, activity should be kept within the mesophilic range (ie 15 to 45oC); at higher temperatures thermophilic activity takes over leading to poorer performance (Burton et al, 1995). Unless nitrification is desired, the aeration level is not critical so long as enough oxygen is supplied to meet the demand. For all but the most dilute effluents this still implies large volumes of air based on anticipated reduction of the organic load expressed as COD or chemical oxygen demand (Figure 2). Short treatments have the additional problem of requiring a high intensity of aeration ie the hourly oxygen requirement per unit volume; this tends to rule out the more efficient but gentle bubble type diffuser type aerators.

Aeration systems are commonplace at sewage treatment works and some experimental units are also being used for treating stronger effluents such as farm slurries (figure 3). Trials with this system using pig slurry revealed degradation of 93% of the ammoniacal nitrogen, 67% of the Kjeldahl nitrogen, 43% of the COD content but only 8% of the total dry matter (Burton et al, 1998). The implication is that aeration only removes the reactive part of the organic matter leaving much of the inert material (including the suspended matter) unaffected. Batch aeration is straightforward and sometimes preferred for dealing with small effluent volumes; it is also relatively cheap to install in existing storage tanks or lagoons. However, it can result in control problems due the variable load and the treatment tends to be inconsistent. A compromise might be sequential batch processing (Lo et al, 1990) which can also incorporate a settling stage.

Reed beds

Most reedbed systems fall into one of two categories horizontal and vertical flow. Horizontal flow systems are more easily designed and controlled with the effluent running through the sub-surface layer to the collection point. Several units may be used in series to ensure an even distribution. The drawback lies with the relatively heavy dose of nutrients falling on the plants near the entry point – for strong effluents, this can damage or kill the plants. The alternative vertical system requires more elaborate drainage but the load is more evenly applied.

The technology is very popular with dilute effluent treatment owing to both its simplicity and the appearance of a environmentally-friendly approach. The weakness comes with the relatively large areas needed and limitation of effluent concentrations. Generally, effluents with a BOD in excess of 500 ppm need a recycle stream to dilute the feed thus implying larger beds. Reed beds are not suitable for effluents with a BOD in excess of 5000 ppm. Thus its role with most farm effluents is reduced to a final stage of treatment prior to discharge or irrigation.

Anaerobic digestion and biogas production

Anaerobic digestion (AD) is well established as a treatment for a wide range of organic effluents and many reference books can be consulted on its application to municipal and food industry wastes (Tchobanoglous et al, 2002). It is also increasingly established for the treatment of livestock wastes with many commercial plants in Germany, Italy and Denmark (Burton and Turner, 2003). However, many of these projects concern large farms often with co-digestion with industrial wastes and the production of electricity – both bringing in additional revenue By contrast, the application of this technology to the medium and smaller farm is limited as the investment and running costs of electricity are less easily justified. The option remains for a group of farms in one region of a centralised treatment with costs spread evenly amongst all participants. Nonetheless, AD units may have a role even on small farms as the treatment can still greatly reduce the organic load and related odours producing a relatively stable digestate.

Crucial to the viability to an investment in AD is a genuine use for the biogas produced. This may be for heating purposes or for the thermal treatment of effluents produced where there is a specific health risk. However, unless there is a demand for heat at local premises such as a nearby factory, it is unlikely that any scheme will earn money although there may be savings in heating costs.

AD technology does have one advantage over aerobic treatment in that running costs are relatively small and digesters can be very simple in design – this is reflected in the wide scale use of such technology throughout many poorer parts of Asia. However, it does require a longer treatment time (in excess of 20 days for the simpler units) and offers little in the way of an effective measure to deal with nutrient surplus although a subsequent sedimentation of the digestate can remove the phosphorous as a sludge concentrate. Lastly, AD shares with any storage process the feature that numbers of pathogens in the effluent can be expected to fall if back mixing is avoided.

Lagooning

At first glance, the concept of treatment by what appears to be extended storage may appear inadequate. Nonetheless, the use of a series of lagoons to achieve a range of treatments is well established and popular in parts of the world for both the treatment of municipal wastewater (also know as Waste Stabilisation Ponds) and increasingly, for farm effluents as well. The subject is thoroughly reviewed by Mara (2004) with respect to the application of such technology in the Third World but it is also popular in North America where land is readily available. The need for space is a clear constraint for a process that is otherwise low technology. Retention times can be expected to run into weeks or months especially in cooler climates. This combined with a limit to the depth of a few metres results in the need for many hectares to ensure adequate treatment; in wetter areas, the collection of significant volumes of rain can greatly increase the capacity required.

Several lagoons are normally required or alternatively a single large lagoon divided up into zones although this is not always a simple option owing to the variable depths needed. Of special importance is to ensure that the lagoon or lagoons in the later stages which provide an aerobic treatment stage are shallow (Mara, 2004 suggests one to one and a half metres depth). Intermediate or facultative ponds can be a little deeper (up to 2 metres) and the first ponds, where anaerobic activity dominates, can be as deep as practical (up to 5 metres). Treatment times need to be longer in cold weather to compensate for slower biological activity – a complete process for animal slurry including spare capacity can easily need 100 days or more in total. Thus taking as an example a medium livestock farm annually producing 3000 m^3 of effluent, an available area of land around 1500m^2 (0.15 hectare) is implied.

The theory behind lagooning is one of natural biological activity coupled with limited physical (sedimentation) and chemical processes. For the first stage, anaerobic processes dominate and the production of biogas can be expected. For this reason, covers may be considered to collect and utilise this gas or at least to burn it to avoid emissions of methane to atmosphere. Even with pre-treatment, the early stages will include a high degree of settlement that lead to the need for periodic sludge removal. In the later stages, aerobic activity dominate and the supply of oxygen from the air can be limiting. In some cases, this can be supplemented by surface aerators to avoid an excessively long retention time. Periodic emissions of odour and ammonia are difficult to avoid during changeable weather unless all lagoons are covered – a costly process. If several stages are used with a long residence time (over 100 days), a substantial reduction in many pathogenic bacteria can be expected as is also observed with any organised storage system.

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ANNEXE 4

Evaluation of suitable technologies for livestock farms in SE Asia

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Abatement scores for nitrogen (N), phosphorous (P) and organic load:

*	No or negligible effect (< 5% reduction)
**	Minor effect (5 to 20% reduction)
***	Some benefit (20 to 50% reduction)
****	Major benefit (> 50% reduction)

Estimated costs are only an indication. Allowance is made of inputs from farm staff and/or local resources. Unless stated otherwise, they are based on a farm with 500 pigs (SPP) producing liquid manure at 2% dry matter.

Typical investment costs

$	No or trivial costs (below 0.1 US$ per SPP)
$$	Minor costs (0.1 to 1 US$ per SPP)
$$$	Moderate costs (1 to 10 US$ per SPP)
$$$$	High costs (over 10 US$ per SPP)

Likely running costs

$	No or trivial costs (below 0.1 US$ per pig produced)
$$	Minor costs (0.1 to 0.5 US$ per pig produced)
$$$	Moderate costs (0.5 to 2 US$ per pig produced)
$$$$	High costs (over 2 US$ per pig produced)

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1. Screening

Description	Removal of larger suspended matter (over 5mm in size) by means of static grid or mesh.
Investment	Simple technology that can be put together using local resources Investment, $, Running $
Operation	little attention apart from the periodic removal of screen blockages
Effectiveness:	N *; P *; Organic **
Other benefits	Easier to handle liquid manure
Down side	Blockage causes high liquid loss with solid run off.

2. Separation machines

Description	Wide range of powered mechanical devices for removing coarse suspended matter from liquid manures. All involve screens with finer holes than simple screens (above) - removal of matter down to 1mm size. Simpler designs tend to produce a wetter "solid" but clarification of liquid similar. Use of brushes to keep screens clean. Screw press represents the most high-tech option with solids reject of over 20% dry matter.
Investment	Machines need to be bought in but installation using local resources possible. Investment, $$$, Running $$
Operation	Some staff training but equipment largely automatic and trouble free. Main problem lies with screen blockage or damage.
Effectiveness:	N; * P; * (P ** if lime added); Organic ***

Other benefits	Easier to handle liquid manure; useable solids for composting.
Down side	Rarely technical failure.

3. Sedimentation

Description	Use of shallow vessels to induce settlement of suspended matter.
Investment	Can be very low if local resources available to build lagoons of vessels. Liners (if required) can significantly add to cost. Investment, $$, Running $
Operation	Periodic removal of accumulated sludges
Effectiveness:	N; * (N ** if losses of ammonia encouraged) P ***; Organic ***
Other benefits	Useful clarified waste water for irrigation purposes.
Down side	Sludge removal and disposal can be a big problem. Large areas needed but storage may be a benefit.

4. Centrifugation methods

Description	Machine to clarify slurry by high centrifugal forces.
Investment	Expensive; must be bought in and set up by specialist Investment, $$$$, Running $*$$*
Operation	Minimal attention once set up; all servicing must be done by specialist
Effectiveness:	N; ** P; * (P *** if lime added); Organic ***
Other benefits	Very dry solid product (cake) produced; high degree of clarification; small area needed.
Down side	Failures occur and can be expensive to remedy. Regular maintenance necessary.

5. Solar drying

Description	Drying of liquid manure by spreading thinly over large exposed areas. Only product is a dry solid.
Investment	Little equipment to be purchased; only preparation of site needed. Investment, $, Running $
Operation	Can be labour intensive - automated systems possible but they would add significantly to cost.
Effectiveness:	N; **** P; **** Organic ****
Other benefits	Possibly saleable product.
Down side	Large areas needed; large emissions of ammonia (and odour); only effective in dry warm seasons.

6. Filtration processes

Description	Physical removal of suspended matter by use of filter screens or packed bed of sand or gravel.
Investment	*Little specialist equipment in the case of packed beds; filter machines would need to be bought in but are unlikely to be a serious option.* Investment, $, Running $$
Operation	Wastewater (only) is passed through a packed filter bed. Little attention during filtration operation but periodic cleaning of bed necessary.
Effectiveness:	N; * P **; Organic ***
Other benefits	Production of a water suitable for some cleaning and irrigation purposes
Down side	Limited to dilute wastewaters (below 1% dry matter). Frequent problems with blockages.

7. Aerobic treatment of wastewater

Description	Inducement of aerobic activity to achieve the breakdown of organic matter within the effluent. Supply of oxygen (via air) is an essential part of the process and often accounts for most of the running cost. Demand led by the reactive part of the organic matter as represented by the BOD measurement. Very wide range of aeration devices. If enough aeration is supplied, the potential is there to remove virtually all ammoniacal N and BOD.
Investment	Varies according to the technology used; simple aerators may be cheaper to buy but more costly to run. Key factor is the "efficiency" of the aerator given as kg of oxygen transferred per

kWh of electricity consumed. The best are bubblers (3-10) the worst intensive surface aerators (<1). Low intensity aerators necessary imply large volumes of liquid held up.
Investment, $$ to $$$, Running $$ to $$$$

Operation: Processes tend to be highly automated and continuous. Batch operation fraught with problems especially from foam generation.

Effectiveness: N; ** to **** P; * Organic ** to ****

Other benefits: Very effective odour abatement; pathogen control.

Down side: Costly to run: adequate aeration must be supplied. For piggery slurry at 5% this implies the supply of ~100 m^3 of air for each m^3 of effluent.

8. Percolating biological filters

Description: Variation on the aeration theme. Effluent is passed through a bed packed with inert or (sometimes) biological material. Entrained biomass and air percolating into the system achieves breakdown of BOD by aerobic activity. Use of biodegradable packing material lends to a composting system and avoids the need to periodically clean the biofilter from sludge debris build up.

Investment: Systems tend to be cheap involving little specialist equipment. In the most basic form, they can be made by local people using local materials. Only pumps and pipes need to be bought in.
Investment, $$, Running $$

Operation: Main demand is on farm labour; treatment units need regular attention; in the case of vegetable material, there are compost handling duties as well.

Effectiveness: N **; P **; Organic ***

Other benefits: Useful compost product

Down side: Filters using inert material only suitable for dilute effluents (<1%)

9. Centralised biogas (anaerobic treatments)

Description: High tech system optimised for the efficient production of biogas. Comprises tanks to collect and mix feed effluents, main biogas reactor (often warmed to 30-40 deg.C), collection vessels and gas handling equipment. Larger units may include electricity generation. Wide range of equipment and processes. High degree of control in largest units. Option of sludge removal as a separate product.

Investment: High. Even small units need to be installed by specialist companies.
Investment, $$$, Running $$$

Operation: Some specialist involvement needed but day to day work can be done by local staff. Various regular duties necessary.

Effectiveness: N *; P ** (P *** if sludge management); Organic ****

Other benefits: Biogas product; pathogen control.

Down side: There must be a genuine use for the biogas produced. In cooler weather, some biogas must be used to warm reactor.

10. Farm/home-based biogas units

Description: Small and simple biogas units designed for small farms located near to households. Many designs but often involve only a single reaction vessel (often below ground) that is periodically fed and discharged. Even more basic units comprise a single bag. Some development to allow multi-chamber options. Gas only used for heating.

Investment: Usually small with greatest demand on local people to set up system. Some systems sold as a package.
Investment, $$, Running $

Operation: Relatively simple; no specialist inputs normally.

Effectiveness: N *'; P *; Organic **

Other benefits: Biogas product

Down side: Limited treatment; irregular gas production.

11. Anaerobic lagoons with biogas collection

Description	Large lagoons (used also for storage) fitted with impermeable cover. Gas collection and utilisation (including electricity generation). Differs from normal AD in that there is little or no mixing of reactor content nor management of sludge. Large area needed.
Investment	Comparable with that for a lagoon. Supply and fitting of cover is a specialist operation. Lagoon can be constructed by local people but it must meet the standards set by those installing the cover. Investment, $$$, Running $$
Operation	The best systems need relatively little attention but a series of operations must be followed. Periodic removal and disposal of sludge necessary.
Effectiveness:	N *; P ***; Organic ***
Other benefits	Storage facility
Down side	Land area needed; sludge disposal requires removal of cover and access to lagoon.

12. Lagooning systems

Description	One or more open lagoons connected in series to induce a series of biological operations. The depth and quality of effluent are factors in determining whether anaerobic or aerobic activity dominates. Volumes held equate to many week's of manure production.
Investment	Mostly local labour plus hire of earth-moving equipment. In porous soils, liners will be necessary. Investment, $$, Running $
Operation	Very simple; little attention other than the periodic removal of accumulated sludge.
Effectiveness:	N **; P ***; Organic ***
Other benefits	Storage facility
Down side	Odours and flies. Sludge disposal problem. Ammonia emissions.

13. Large compost processes

Description	Tonnage quantities of solids organic waste products (manure, bedding, vegetable wastes etc) blended and composted to produce a homogeneous product with the option of sale. Usually, intensive process with the use of machines for mixing, aerating and handling. Aerobic activity essential along with the warming of the mass to at least 60 deg.C.
Investment	Purchase of a variety of machines necessary along with some site preparation. Investment, $$$, Running $$
Operation	Mostly a range of duties carried out by local people. The high tech options allow for a degree of automation but composting at this scale will need a large staff commitment.
Effectiveness:	N **; P ***; Organic ***
Other benefits	Saleable product; some pathogen control.
Down side	Uncertain markets for compost produced; road haulage and other transport issues.

14. Farm/home-based compost schemes

Description	1-10 tonnes batch processing - one step on from "garden compost schemes". Various methods - all involve the building of a pile (heap) which will mature in 4-8 weeks. Produced compost for local use only.
Investment	Minimal; provision of protection against rain in wet areas necessary. Investment, $, Running $
Operation	Significant local labour input necessary; frequent attention in managing the pile well including turning to induce aeration. More elaborate schemes may include pipes to aid air ingress.
Effectiveness:	N **; P **; Organic **
Other benefits	Management technique for a range of solid wastes.
Down side	Limited treatment; importance of good management and sensible end use.

15. Reed beds and wetlands

Description	Constructed wetland in which an area of reeds is planted in a gravel bed. The bed is contained within a lined area to retain water/effluent. The passage of the effluent can be horizontal or vertical through the bed. Fine material is retained by the root system and broken down along with some dissolved matter by aerobic bacterial activity.
Investment	Although low tech in principle, the setting up of an effective reedbed (or similar wetland) must follow a specific design; some specialist input necessary although most work can be done by local people. Investment, $$ to $$$, Running $$
Operation	Periodic attention necessary but infrequent.
Effectiveness:	N **; P ***; Organic ***
Other benefits	Reed crop.
Down side	Only suitable for dilute (<1%) effluents. Bed performance declines with age and seldom exceeds 10 years before major refurbishment needed. Large area of land needed.

16. Soil filters

Description	Designated area of land set aside to receive effluents. Similar to wetlands but treatment reliant on passage of liquid through soil system. Horizontal or vertical flow options. Reliance on dominant aerobic activity.
Investment	Minimal unless there is a need to line the area to prevent effluent escape. Better systems include proper drainage systems, collection and recycling of effluents. Investment, $ to $$, Running $
Operation	Little attention normally.
Effectiveness:	N **; P ***; Organic ***
Other benefits	None
Down side	Total system failure if overloaded - soil becomes fouled and results in surface flooding. Vulnerability to rainfall.

17. Flocculents (to aid settling)

Description	Chemicals such as aluminium or ferric salts added to liquid effluent to aid settlement. Used in conjunction with sedimentation processes and centrifugation. Can achieve good clarification.
Investment	Cost of the chemical plus dosing pump. Investment, $, Running $$
Operation	Simple (as for sedimentation)
Effectiveness:	N *; P **; Organic ** (see sedimentation)
Other benefits	None
Down side	Environmental pollution from chemicals.

18. Acids (to inhibit ammonia release)

Description	Mineral or organic acids added to manure or flushing systems to combat ammonia release. Used in conjunction with other processes and/or land spreading.
Investment	Cost of chemical Investment, $, Running $$
Operation	Dosing in of acid.
Effectiveness:	N *; P *; Organic *
Other benefits	Avoiding ammonia losses
Down side	Hazards from acids; no effective treatment by acidification alone.

19. Lime (to precipitate phosphorous and metals)

Description	Adding of lime to liquid slurry to aid precipitation and settlement of phosphorous and heavy metals. Used in conjunction with settlement systems.
Investment	Cost of mineral; mixing equipment Investment, $$, Running $$

Operation	Dosing in of chemical; can be done automatically.
Effectiveness:	N *; P **** (with settlement); Organic **
Other benefits	Removal of heavy metals. Some pathogen control from increased pH
Down side	Increased ammonia emission.

20. Disinfectants (to sterilise)

Description	Variety of chemicals added to destroy pathogens. Also known as sanitisers.
Investment	Cost of chemical Investment, $, Running $$
Operation	Dosing in or application of chemicals
Effectiveness:	N *; P *; Organic *
Other benefits	Pathogen control
Down side	Handling hazards; no other treatment benefit. Presence of organic matter greatly increases the quantities of chemical needed.

21. Collection systems

Description	One or more vessels with associated pipework to enable the efficient collection of liquid effluents from the farm. Usually gravity fed. Vessels can be of many types/designs and above or below ground. Used in conjunction with treatment of land application system.
Investment	Variable depending on the quality of the system. Investment, $$ to $$$, Running $
Operation	Few duties; occasional removal of accumulated sludges.
Effectiveness:	N *; P *; Organic *
Other benefits	Removal of effluent away form animals and people.
Down side	No actual treatment achieved by simple storage.

22. Water minimisation options (including water re-use).

Description	Wide range of techniques based around reduced water use at the farm and re-use of treated effluent for such duties as washing, flushing and irrigation. Main benefit is the reduction of effluent volume enabling easier transportation and smaller storage facilities. Often used in conjunction with other treatment system.
Investment	Variable reflecting the extent of the system used. Investment, $$ to $$$$, Running $ to $$$
Operation	Variable but usually within the scope of farm staff.
Effectiveness:	N *; P *; Organic *
Other benefits	Reduced water consumption
Down side	No direct treatment achieved.

23. Flushing technologies

Description	Specific water minimisation option in which clarified liquid manure is used to clean out manure in and around animal houses. Related settlement process. Flushing stream can be dosed with acid to cut ammonia losses.
Investment	Pipework and pumps. Investment, $$$, Running $$
Operation	Regular (daily) but following exist cleaning practices.
Effectiveness:	N * ; P *; Organic *
Other benefits	Improved farm management; reduced odour and pathogen problems.
Down side	Not a treatment in itself; benefit only realised if coupled to sound manure management system.

24. Containment and storage strategies

Description	Similar to collection systems but attention directed to enabling timely land application of manures to gain full benefit.
Investment	Cost of storage facilities and related pumps and pipework

	Investment, $$ to $$$, Running $
Operation	Few duties; occasional removal of accumulated sludges..
Effectiveness:	N * ; P *; Organic *
Other benefits	Enables good disposal strategy
Down side	Not a treatment in itself; benefit only realised if coupled to sound manure management system

25. Transport and pipelines

Description	System of pipeline and pumps to transfer effluents to disposal point away from farm. Distances and sophistication of system varies widely depending on local needs.
Investment	Variable. Investment, $$ to $$$$, Running $$
Operation	Periodic pumping of effluent.
Effectiveness:	N * ; P *; Organic *
Other benefits	Enables very good disposal strategy
Down side	Not a treatment in itself; benefit only realised if coupled to sound manure management system

26. Timed land application

Description	This is the seasonal application of manure based on the crop requirement at that time. Applications are avoided when the land is bare or at times when the crop would be harmed.
Investment	Application equipment. Transport pipework. Investment, $$, Running $$
Operation	Mostly farm staff with some initial guidance from crop specialists.
Effectiveness:	N ****; P ****; Organic ****
Other benefits	Reduction in requirements for inorganic fertilisers.
Down side	Need for storage during times when spreading is not permissible. Access issues to the land; transport problems. Requirement of suitable land.

27. Land application management plan based on land type & use

Description	Modification of land spreading strategy to allow for local land conditions. Even if crop requirements are clearly defined, certain high risk areas are avoided such as land close to rivers water supplies and sloping ground. Some benefit (to reduce run off) may be achieved from the use of injection methods.
Investment	Some specialist equipment may be needed; additional storage requirements. Access to additional land area. Investment, $$, Running $$
Operation	Some additional training but otherwise see 2.4.6 above.
Effectiveness:	N ****; P ****; Organic ****
Other benefits	Avoidance of river pollution
Down side	In sandy soils there is still the risk of the contamination of ground water.

28. Land spreading systems

Description	Use of machinery to achieve better spreading of manures on to the field. Many designs exist including tankers drawn behind tractors, irrigation systems injection, band spreading etc. Equipment with even spreading enables a higher crop utilisation of the nutrients in the manure.
Investment	*Purchase of specialist equipment.* Investment, $$ to $$$, Running $$
Operation	Can be done by farm staff with some training.
Effectiveness:	N *; P *; Organic *
Other benefits	Satisfactory disposal of manure.
Down side	No actual abatement benefit unless effluent is applied to a growing crop. Health risks to food crop.