

**Renewables study Work Area 4**

**CHAPTER 7**

**OPPORTUNITIES FOR ANAEROBIC  
DIGESTER CHP SYSTEMS TO TREAT  
MUNICIPAL AND FARM WASTES**

*Peter Frost,  
The Agricultural Research Institute of  
Northern Ireland,  
Science Service, DARD*

## 7.1 SUMMARY

1. Anaerobic digestion (AD) of organic wastes is a proven, well-trying and tested technology.
2. Many European countries are using or are interested in using biogas for combined heat and power production to supply electricity from renewable sources.
3. CAD schemes offer the most appropriate way forward for AD technology in Northern Ireland.
4. 9.7 m t/y of manure is produced from housed livestock in Northern Ireland (88% cattle; 7% pigs; 5% poultry) with potential to fuel 91 CAD plants (100,000 t/y input per plant). The energy potential from CAD of this manure is 73 MW<sub>e</sub> and 60 MW<sub>h</sub>.
5. With the exception of Belfast, Castlereagh, Carrickfergus and North Down there is sufficient manure produced by housed livestock to supply at least one CAD plant (100,000 t/y) per District Council area.
6. Average manure loading from housed livestock in Northern Ireland is 11.4 m<sup>3</sup>/ha of grassland and 31 m<sup>3</sup>/ha of silage area. District Councils with the greatest loadings (>14 m<sup>3</sup>/ha of grass) are Ards, Ballymoney, Cookstown and North Down.
7. Total cattle numbers per ha of grass can be used to predict the total manure loading from housed livestock per ha of grass within District Council areas. More cattle per ha equate to more total manure from all housed livestock per ha.
8. Total manure production from housed livestock could provide 73% and 40% of P and K requirements respectively for all of the grassland in Northern Ireland (soil indices of P2 and K1).

## Chapter 7. Anaerobic digester CHP systems

9. Manure produced by housed livestock in Northern Ireland could supply 145 kg total N, 90 kg total P<sub>2</sub>O<sub>5</sub> and 139 kg total K<sub>2</sub>O per ha of silage.
10. There is a potential surplus of P<sub>2</sub>O<sub>5</sub> on some farms in Northern Ireland.
11. When Northern Ireland is taken as a whole the major issue to address is redistribution of slurry rather than slurry surplus.
12. For CAD to be sustainable there must be sufficient land available, to utilise all of the crop nutrients contained in the digestate.
13. Nutrient management is a major issue that will determine the sustainability of CAD plants.
14. There is considerable potential for CAD to assist in central management of distribution of plant nutrients in manures together with minimising biosecurity risks (pathogen kill).
15. AD plants require effective hygiene and sanitation procedures to minimise disease transfer risk. Effective monitoring of sanitation is required.
16. CAD has potential to assist in meeting required standards for slurry storage.
17. CAD plants must be designed to eliminate odour.
18. Mechanical separation of digestate from CAD plants has considerable potential to help manage P<sub>2</sub>O<sub>5</sub> distribution to agricultural land.
19. To obtain the financial value of separated fibre, the fibre must be sanitised and a sustainable market identified.

## Chapter 7. Anaerobic digester CHP systems

20. Existing information on AD in Northern Ireland must be made use of in any further consideration of AD in Northern Ireland.

## 7.2 TECHNICAL FEASIBILITY OF ANAEROBIC DIGESTION

Anaerobic digestion (AD) of organic wastes is a proven, well-tried and tested technology that converts organic matter to biogas in the absence of oxygen. In temperate environments the microbiological process of digestion is normally accelerated by heating to either mesophilic (20-40°C) or thermophilic (50-60°C) temperatures. Products of AD are biogas [mixture of methane (60-80%), carbon dioxide (20-40%) plus low levels of hydrogen sulphide (0-3%), ammonia and nitrogen (0-5%)] and digestate (liquid). Digestate is typically spread on agricultural land and is a source of plant nutrients. Typically 40-60% of organic matter is converted to biogas with a typical calorific value of 17-25 MJ/m<sup>3</sup> (20 MJ/m<sup>3</sup> at 70% methane content). Biogas can be utilised by combustion in modified gas boilers to produce heat or in a combined heat and power unit to produce electricity and heat. Biogas can also be used as a vehicle fuel.

Some relevant reports detailing the technical feasibility of AD include: -

(a) Feasibility study concerning anaerobic digestion in Northern Ireland. Draft final report for Bryson House, ARENA Network and NI 2000 – not for citation or distribution.

(b) Biomass due diligence guide. Report presented to the Carbon Trust by Energy for Sustainable Development Ltd – final version 25 February 2004, reference P00730.

(c) Feasibility study for centralised anaerobic digestion for treatment of various wastes and wastewaters in sensitive catchment areas. Final project report for Environmental Protection Agency, County Wexford, 2002 – ISBN 1084095-087-0.

(d) Anaerobic digestion of farm and food processing residues. Good Practice Guidelines.

British

Biogen

<http://www.britishbiogen.co.uk/gpg/adgpg/adgpgfront.htm>

(e) Fivemiletown Biogas Initiative Economic Appraisal. Price Waterhouse Coopers, August 2001 (updated January, 2004).

### **7.3 AD IN EUROPE**

Many European countries are using or are interested in using biogas for combined heat and power (CHP) production to supply electricity from renewable sources. In Sweden prices for electricity and heat are relatively low and as a result biogas is also used for vehicle fuel. In countries such as Denmark, Germany and Austria, AD attracts investment subsidies (up to 40%), higher sale price on electricity (up to 80% of the consumer price) and reduced interest on bank loans (up to 4%). This has created incentives in these countries for building new plants.

The use of biological wastes as fertilisers on agricultural land creates a risk of spreading disease. This risk has led to pathogen control legislation in some countries which, depending on the type of feedstock used, affects the design and construction AD plants. Regulations in, for example, Germany, Austria and Sweden are based on knowledge from Denmark, which pioneered regulation in 1989. In general, regulations require the digestate to be pasteurised (70 °C; 1 h), though alternative combinations of time and temperature (e.g. 55 °C, 5.5 hours for thermophilic digestion) can be used. (<http://www.adnett.org/>).

Future AD issues across Europe include use of energy crops for biogas production, use of organic wastes for biogas production, hygienic effects of AD on pathogens in manure and organic wastes together with possible improvement in biogas production by microbiological measures. A successful outcome of a proposal for European-wide work in these areas will inform decision makers (administrative, political and industrial) when formulating legislative and support measures which promote the use of AD. In addition, the Environment DG is developing a biowaste directive on biodegradable waste management which is scheduled for 2004. This directive will likely

## Chapter 7. Anaerobic digester CHP systems

impact on AD plants through requirements for sanitation of digestate and imposition of heavy metal limits.

Key AD issues in some European countries as reviewed by Burton and Turner (2003) include: -

**Germany** – price of €0.10/kWh electricity generated from biomass when fed into the public grid. This has resulted in a steep increase in agricultural biogas plants which now approach 2,000 units.

**Italy** – government incentives for non-fossil fuel generation of electricity [€0.13/kWh (April 1996)] discontinued in 1996 but now under revision.

**Denmark** – 20 CAD plants (30-300 t slurry/day) built between 1984 and 1998, each producing 1,500-20,000 m<sup>3</sup> biogas/day. On average 20% of biomass supplied to these plants is waste product from the food industry and households. Further development of CAD plant numbers is currently delayed pending environmental evaluation. There are a further 60 small-scale AD plants

([www.ens.dk/graphics/Pubikationer/Energiforskning\\_UK/Renewable\\_Energy](http://www.ens.dk/graphics/Pubikationer/Energiforskning_UK/Renewable_Energy)).

**Netherlands** – during 1980s and 1990s digesters were built on many dairy farms and on some pig farms. Most digesters are now abandoned due to low cost of local natural gas and technical problems.

**Greece** – government payment of €0.06/kWh electricity generated from biogas has resulted in increased interest in biogas systems.

**UK** – several large pilot schemes. One CAD scheme at Holsworthy, Devon.

#### 7.4 CENTRALISED AD VERSUS ON-FARM AD

AD plants can be designed as small on-farm units to deal with slurries produced at farm level. Alternatively, AD plants can be designed to deal with slurries from a number of farms along with co-digestion of other organic waste.

Many of the on-farm digesters built in the 1970s/early 1980s have closed as a result of various problems. Developments since the late 1980s have simplified design, improved operation, decreased costs and resulted in increased interest, particularly in Germany. According to the German Biogas Association, basic features of the newer on-farm AD systems include: -

- Predominantly mesophilic
- Residence times typically 10-30 days
- On-farm applications usually environmentally driven
- Opportunities to produce heat and electricity
- Opportunities for fibre production

[<<http://www.adnett.org>]

Frost and Beck (1991) in a report for DANI concluded that, at 1991 oil prices and capital costs for digesters, on-farm AD was not a viable economic proposition.

[Frost, J.P. and Beck, H. (1991). Anaerobic digestion of slurry. Internal DANI Technical Report]

Typical Centralised AD (CAD) plants use farm wastes as the predominant feedstock, but may also take non-toxic, industrial organic wastes from food processing and agro-industrial residues. These co-substrates frequently provide an additional source of income (through gate fees) and can improve the yield of biogas. CAD schemes may serve either a single large farm or several farms within a radius of about 10 km. The digestate produced is returned to the farmers for land application at the appropriate time, ensuring more effective use of nutrients. Potential economies are available to farmers due to substitution of inorganic fertiliser. Separation of the digestate and composting of the fibre can generate additional income through sale to non-

agricultural enterprises (e.g. landscape gardening). Basic features of Centralised AD include: -

- Can be thermophilic and mesophilic systems
  - Residence times typically 12-20 days
  - 0.1 - 1.0 MWe size range
  - Feedstock
    - farm wastes
    - non-toxic agro-industrial waste (disposal credit)
  - Process control can be more efficient than on-farm systems due to the use of trained staff
  - Usually include pasteurisation stage to destroy pathogens
  - Opportunities to produce heat and electricity
  - Better market opportunities for fibre owing to scale of operation
- [<<http://www.adnett.org/>]

The benefits of CAD are comprehensively documented in the Fivemiletown Biogas Initiative Economic Appraisal [PricewaterhouseCoopers, August 2001 (updated January, 2004)].

It is suggested that CAD schemes offer the most appropriate way forward for AD in Northern Ireland.

## 7.5 POTENTIAL ENERGY OUTPUTS OF CAD

Biogas yields from food processing wastes are often greater than those from farm animal excreta (Table 7a). Consequently, food-processing wastes are often used to enhance biogas yields as well as providing a source of useful revenue to the AD plant (see later).

**Table 7a. Indicative values for biogas production and energy output potential from one tonne of various feedstocks (derived from British Biogen, <<http://www.britishbiogen.co.uk/gpg/adqpg/adqpgfront.htm>>)**

Feedstock	No. animals to produce 1 t/d	Dry matter content (%)	Biogas yield (m <sup>3</sup> /t feedstock)	*Biogas yield (m <sup>3</sup> /t volatile solids)	Energy value (MJ/m <sup>3</sup> biogas)
-----------	------------------------------	------------------------	--	---	---

## Chapter 7. Anaerobic digester CHP systems

Cattle slurry (dairy and beef)	20-40	12	25	150-350	23-25
Pig slurry	250-300	9	26	310-620	21-25
Laying hen litter	8,000-9,000	30	90-150	310-740	23-27
Broiler litter	10,000-15,000	60	50-100	-	21-23
Food processing waste	-	15	46	460-1,230	21-25

\* range of values from the literature

### 7.6 VOLUMES OF SLURRY AVAILABLE FOR AD

In order to determine the potential for AD in Northern Ireland, a desktop study was carried out to estimate the quantities of manures (cattle, pigs and poultry) produced by housed livestock (Table 7b). All manure produced by housed livestock is potentially available as input for AD. In order to determine the potential for AD in different regions of Northern Ireland, the volumes of manures produced in each of the 26 District Council areas were calculated. These data indicate that for Northern Ireland as a total, there is a very large resource of manure that is potentially available for AD (see under CAD potential in Northern Ireland below). Of the total manure produced by housed livestock, cattle, pigs and poultry contribute approximately 88%, 7% and 5% respectively of the total. District Council areas producing the largest amounts of manure are Fermanagh (952 kt), Omagh (765 kt) and Dungannon (738 kt). The District Council areas with the greatest percentage of pig slurry are Cookstown (17%), Newtownabbey (14%), Magherafelt (13%), Armagh (12%) and Strabane (11%). The District Councils with the greatest percentage of poultry manure as proportion of total manure from housed livestock are Dungannon (17%), Ballymena (15%), Ballymoney (8%), Lisburn (7%), and Craigavon (7%).

There is, therefore, considerable manure resource available for AD across Northern Ireland.

**Table 7b. Quantities (t or m<sup>3</sup>) of undiluted manure produced from housed cattle pigs and poultry within each District Council area (see Annex 1 for assumptions and methodology)**

District Council	Housed cattle	Housed pig	Housed poultry	Housed total
Antrim	321,553	9,081	23,357	353,991
Ards	314,209	17,671	4,722	336,602
Armagh	544,771	79,136	37,270	661,178
Ballymena	448,205	13,553	79,599	541,357
Ballymoney	316,527	32,809	30,524	379,860
Banbridge	372,156	14,977	19,619	406,752
Belfast	13,884	0	0	13,884
Carrickfergus	27,094	795	28	27,917
Castlereagh	59,409	1,359	28	60,796
Coleraine	340,800	8,151	23,413	372,365
Cookstown	461,616	104,577	37,635	603,829
Craigavon	206,441	20,492	16,077	243,010
Derry	139,006	1,173	337	140,517
Down	364,279	30,955	6,774	402,008
Dungannon	551,372	59,143	127,916	738,431
Fermanagh	928,659	3,624	19,534	951,817
Larne	202,225	1,957	1,715	205,896
Limavady	195,461	371	2,220	198,053
Lisburn	292,306	33,138	24,762	350,206
Magherafelt	351,275	53,077	10,737	415,089
Moyle	180,943	5,093	6,071	192,106
Newry&Mourne	577,016	40,010	17,202	634,228
Newtownabbey	101,918	17,286	3,794	122,999
NorthDown	43,527	188	0	43,715
Omagh	683,558	60,371	20,574	764,503
Strabane	459,694	59,455	6,774	525,923
<b>Total</b>	<b>8,497,902</b>	<b>668,444</b>	<b>520,685</b>	<b>9,687,030</b>
% total	87.7	6.9	5.4	100
Max	928,659	104,577	127,916	951,817
Min	13,884	0	0	13,884
SdevP	214,855	27,649	27,560	245,168

## 7.7 QUANTITIES OF FOOD WASTE PRODUCED

The Carbon Trust (2004) considered there was insufficient information available to determine the amount of food processing waste produced in the UK. However, the Carbon Trust (2004) suggested that, due to the size of the industry, tens of millions of tonnes per year would be available annually in the UK. PricewaterhouseCoopers (2004) indicated a total of 85 members of the Northern Ireland Food and Drinks Association and that the 7 of these companies in the Fivemiletown area produced 12,791 t/y waste. Mahoney *et al.* (2002) indicated a total of 668,485 t/y of wet sludge from the food and beverages industries in Ireland.

Whilst the quantity of food processing waste produced in Northern Ireland has not been obtained it is estimated from the above that on a *pro rata* basis, *circa* 150,000 t/y would be available.

## 7.8 CAD POTENTIAL IN NORTHERN IRELAND

The potential number of CAD plants in Northern Ireland is indicated in Table 7c.

**Table 7c. Potential number CAD plants in Northern Ireland. Assumes a plant size with 107,000 t/y input – all inputs on wet basis (information derived from Table 7b and PricewaterhouseCoopers (2004))**

Source of input to CAD (% of total input)	No. Digesters	Cattle slurry (% of total available)	Pig slurry (% of total available)	Poultry manure (% of total available)	Food processing waste (% of total available)
Housed livestock manure (100%)	91	100	100	100	0
Housed cattle and pig slurry (100%)	86	100	100	0	0
Housed cattle and pig slurry (90%) Poultry manure (10%)	49	51	51	100	0
Housed cattle and pig slurry (60%) + Poultry manure (10%) + food processing waste (30%)*	5	4	4	10	100

\*assumes 150,000 t/y available

The total housed livestock manure resource in Northern Ireland (Table 7b) has potential to fuel 91 CAD plants of 100,000 t/y input (Table 7c) with a potential energy output of 73 MW<sub>e</sub> and 60 MW<sub>h</sub> (Table 1; Nordberg, 2003).

With the exception of Belfast, Castlereagh, Carrickfergus and North Down there is sufficient slurry produced by housed livestock (Table 7b) to supply at least one CAD plant (100,000 t/y) per District Council area.

Suitability of location and proximity of inputs will contribute to determining the final number of CAD systems. Nevertheless, there is potential for at least 5 CAD systems (Table 3) in Northern Ireland and for a total output of 6 MW electricity plus 5 MW heat (1.2 MW<sub>e</sub> plus 1 MW<sub>h</sub> per plant).

## 7.9 NUTRIENT MANAGEMENT FOR NORTHERN IRELAND

All agriculturally based CAD schemes distribute digestate back to agricultural land, normally that of the supplying farms. Raw slurry and digestate are rich in plant nutrient (N, P and K) and should/must be applied to agricultural land in accordance with crop requirements for plant nutrients (Codes of Good Agricultural Practice).

Financial viability of most CAD schemes requires revenue *via* gate fees for digestion of organic wastes from industries outside farming. Consequently, if recycling of digestate is limited to those farmers supplying the digester then each farm will receive a greater volume of digestate and quantity of nutrients than supplied in raw slurry to the CAD. At the CAD in Holsworthy, some supplying farmers have indicated receipt of 70% more digestate than the volume of slurry supplied. Clearly this imbalance of export with import has potential to cause excess nutrient loading to agricultural land. To overcome this potential problem many CAD schemes across Europe export digestate to land other than that of supplying farms (particularly arable land).

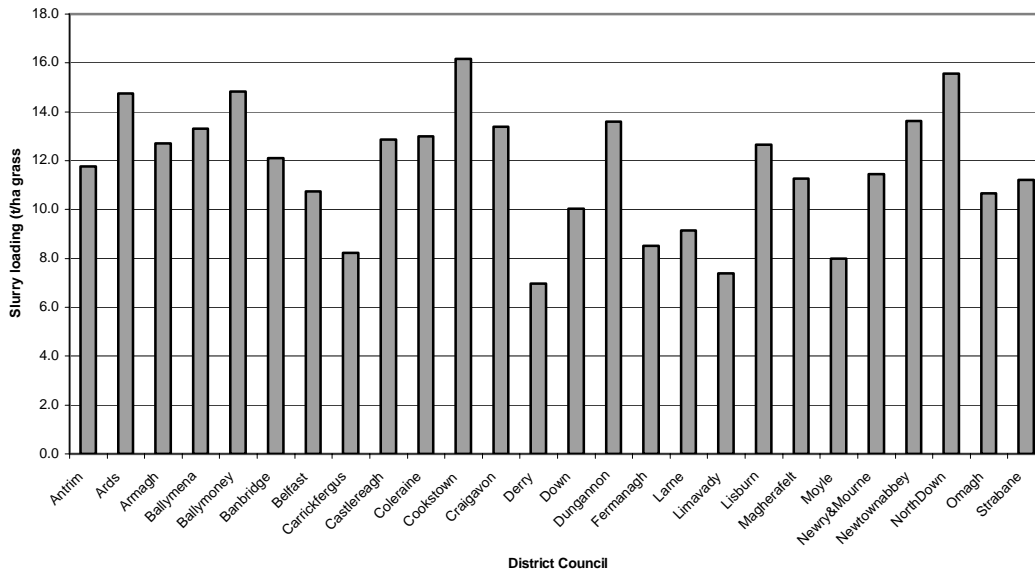
For CAD to be sustainable there must be sufficient land available, within and without the scheme, to utilise sustainably all of the crop nutrients contained in the digestate. Thus nutrient management is highlighted in this report as a major issue for consideration when determining the feasibility of any CAD scheme.

The starting point in determination of the potential for agricultural land in Northern Ireland to receive nutrients from digestate is an estimation of the slurry loadings per hectare (Table 7d).

**Table 7d. Calculated quantities of undiluted manure produced by all housed livestock in Northern Ireland and manure loadings for each District Council area (see Annex 1 for assumptions and methodology)**

District Council	Manure total		Manure t/ha grass	Manure t/ha silage
	volume housed livestock t/year	Manure t/ha total area farmed		
Antrim	353,991	10.0	11.8	NA
Ards	336,602	11.3	14.7	NA
Armagh	661,178	11.4	12.7	NA
Ballymena	541,357	10.2	13.3	NA
Ballymoney	379,860	11.3	14.8	NA
Banbridge	406,752	10.2	12.1	NA
Belfast	13,884	7.9	10.7	NA
Carrickfergus	27,917	7.5	8.2	NA
Castlereagh	60,796	9.2	12.9	NA
Coleraine	372,365	9.5	13.0	NA
Cookstown	603,829	13.4	16.2	NA
Craigavon	243,010	11.5	13.4	NA
Derry	140,517	4.9	7.0	NA
Down	402,008	8.4	10.0	NA
Dungannon	738,431	12.3	13.6	NA
Fermanagh	951,817	7.3	8.5	NA
Larne	205,896	6.4	9.1	NA
Limavady	198,053	4.8	7.4	NA
Lisburn	350,206	10.3	12.7	NA
Magherafelt	415,089	7.9	11.3	NA
Moyle	192,106	4.9	8.0	NA
Newry&Mourne	634,228	10.0	11.5	NA
Newtownabbey	122,999	11.5	13.6	NA
NorthDown	43,715	11.2	15.6	NA
Omagh	764,503	8.4	10.7	NA
Strabane	525,923	7.3	11.2	NA
<b>Total</b>	<b>9,687,030</b>			
<b>Average</b>		<b>9.0</b>	<b>11.4</b>	<b>30.5</b>
Max	951,817	13.4	16.2	NA
Min	13,884	4.8	7.0	NA
Standard deviation	245,168	2.31	2.49	NA

It is apparent from data presented in Table 7d that if it were possible to distribute the total quantity of slurry produced from housed livestock in Northern Ireland over all grassland, application rates would be 11.4 m<sup>3</sup>/ha. Whilst data for silage areas within each District Council area were not available, the data presented in Table 7d indicate an average loading across Northern Ireland of about 31 m<sup>3</sup>/ha of silage area. Data presented in Table 7d also indicate that there is considerable variation in theoretical slurry loadings from housed livestock across the 26 district council areas. For ease of interpretation these loadings are presented graphically in Figure 7i.



**Figure 7i. Undiluted manure quantities (t/ha of grass) from housed livestock for each District Council area in Northern Ireland**

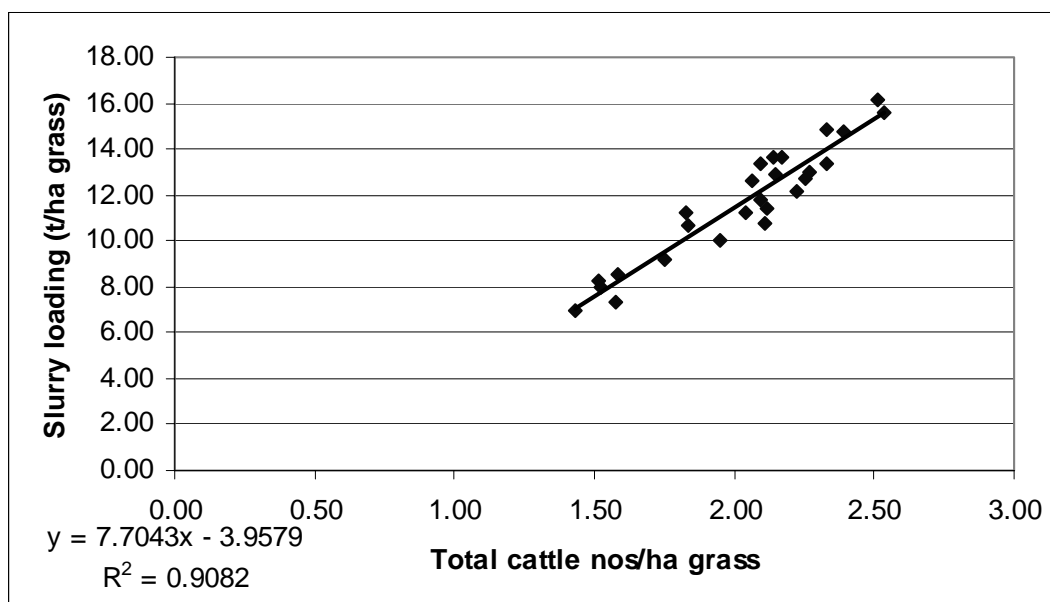
District Councils with the greatest loadings (>14 m<sup>3</sup>/ha of grass) are Ards, Ballymoney, Cookstown and North Down.

It is interesting to note that across the District Council areas there is no strong relationship between the proportion of total manure arising from pigs and poultry and the manure loading per unit area of grass (Annex 2). There is, however, a strong relationship between the proportion of total manure arising from non dairy cattle and the quantity of manure per unit area of grass. Thus, those District Councils with the lowest loadings of manure per ha of grass (Table 7d and Figure 7i) are also those with the greatest proportion of non-dairy cattle slurry i.e.

$$\begin{aligned} \text{Manure loading from all housed livestock (t/ha grass)} &= \\ &- 0.2018 \times (\text{volume of all housed non dairy slurry as \% total housed manure volume}) \\ &+ 23.643 \\ R^2 &= 0.77 \end{aligned}$$

Further regression analyses were carried out of manure loadings from housed livestock per ha of grass on the number of livestock per ha (Annex 3). There

was a strong correlation ( $R^2 = 0.91$ ) between total cattle numbers and manure loadings per ha of grass (Figure 7ii). Thus for District Council areas, total cattle numbers per ha of grass can be used to predict the total slurry loading per ha of grass.



**Figure 7ii. Regression of undiluted manure loading (t/ha of grass) from all housed livestock on total cattle numbers per ha of grass (each data point represents a District Council) (see Annex 3, equation 10)**

Nutrient management is important for sustainable agriculture. Matching crop requirements to nutrient application is imperative. Table 7e lists the nutrient requirements for grass grown for silage and for grazing.

**Table 7e. Plant nutrient requirements for silage (4 cut system) and for grazing (RB209, 2000)**

Soil P index	P 1	P 2	P 3
Soil K index	K 0	K 1	K 2
Silage annual $P_2O_5$ required (kg/ha)	115	90	20
Silage annual $K_2O$ required (kg/ha)	350	260	200
Grazing annual $P_2O_5$ required (kg/ha)	40	20	0
Grazing annual $K_2O$ required (kg/ha)	60	30	0

It is the quantity of plant nutrients applied, rather than volume of manure applied, that is important. The quantities of manure nutrients produced within each district council area of Northern Ireland are summarised in Table 7f. Nutrient loadings from manure for each council area are indicated in Table 7g.

Chapter 7. Anaerobic digester CHP systems

**Table 7f. Nutrients produced by housed livestock in Northern Ireland  
(see Annex 1 for assumptions and methodology)**

District Council	Manure Housing total Undiluted volume t (m <sup>3</sup> )/y	Manure Total N Housing All animals t/y	Manure Total P <sub>2</sub> O <sub>5</sub> Housing All animals t/y	Manure Total K <sub>2</sub> O Housing All animals T/y
Antrim	353,991	1,749	1,102	1,684
Ards	336,602	1,372	769	1,492
Armagh	661,178	3,224	2,015	2,982
Ballymena	541,357	3,506	2,407	2,995
Ballymoney	379,860	2,026	1,295	1,862
Banbridge	406,752	1,896	1,152	1,902
Belfast	13,884	50	28	56
Carrickfergus	27,917	104	57	116
Castlereagh	60,796	231	123	267
Coleraine	372,365	1,826	1,139	1,788
Cookstown	603,829	3,064	1,932	2,730
Craigavon	243,010	1,224	771	1,145
Derry	140,517	517	288	576
Down	402,008	1,628	947	1,668
Dungannon	738,431	5,174	3,643	4,135
Fermanagh	951,817	3,810	2,229	4,046
Larne	205,896	786	442	868
Limavady	198,053	758	433	827
Lisburn	350,206	1,801	1,141	1,663
Magherafelt	415,089	1,784	1,060	1,737
Moyle	192,106	818	489	836
Newry&Mourne	634,228	2,687	1,592	2,723
Newtownabbey	122,999	546	326	526
NorthDown	43,715	166	88	196
Omagh	764,503	3,256	1,928	3,274
Strabane	525,923	2,141	1,223	2,197
<b>NI Total</b>	<b>9,687,030</b>	<b>46,142</b>	<b>28,618</b>	<b>44,287</b>
Council average		1,775	1,101	1,703
Max		5,174	3,643	4,135
Min		50	28	56
Standard deviation		1,285	853	1,150

**Table 7g. Desktop calculation of plant nutrient loading (kg/ha) in Northern Ireland**

	Housed total N kg/ha Grass	Housed total P <sub>2</sub> O <sub>5</sub> kg/ha Grass	Housed total K <sub>2</sub> O kg/ha Grass
Antrim	58	37	56
Ards	60	34	65
Armagh	62	39	57
Ballymena	86	59	74
Ballymoney	79	51	73
Banbridge	56	34	57
Belfast	39	21	43
Carrickfergus	31	17	34
Castlereagh	49	26	56
Coleraine	64	40	62
Cookstown	82	52	73
Craigavon	67	43	63
Derry	26	14	29
Down	41	24	42
Dungannon	95	67	76
Fermanagh	34	20	36
Larne	35	20	39
Limavady	28	16	31
Lisburn	65	41	60
Magherafelt	48	29	47
Moyle	34	20	35
Newry&Mourne	49	29	49
Newtownabbey	61	36	58
NorthDown	59	31	70
Omagh	45	27	46
Strabane	46	26	47
<b>Average</b>	<b>54</b>	<b>33</b>	<b>53</b>
Max	95	67	76
Min	26	14	29
Standard deviation	18	13	14
kg/ha silage	145	90	139

It is estimated that the total manure production from housed livestock would provide 73% and 40% of P and K requirements respectively for all of the grassland in Northern Ireland (assuming soil indices of P2 and K1 for all grassland; a grazing area of 530,440 ha; a silage area of 317,800; 100% P<sub>2</sub>O<sub>5</sub> available; 90% K<sub>2</sub>O available).

Not all grassland in Northern Ireland is accessible for manure spreading due to, for example, topography. It is assumed that all the silage area (317,800 ha) is accessible by harvesting machinery and hence will also be accessible

by slurry tankers. It is further assumed that all of the silage area is suitable for spreading slurry. Based on these assumptions, the total manure produced by housed livestock in Northern Ireland would supply totals of 145 kg N, 90 kg P<sub>2</sub>O<sub>5</sub> and 139 kg K<sub>2</sub>O per ha of silage. At average soil indices of P2 and K1 this would supply available P and K of 100% and 48% respectively of the requirements for silage.

In addition to grassland, arable crops require nutrients. Allowance for nutrient requirements for the 37,761 ha arable crops would lower the nutrient loading on grassland.

From the data presented it is apparent that when Northern Ireland is taken as a whole the major issue to address is redistribution of slurry rather than slurry surplus.

CAD systems have potential to play an integral role in slurry redistribution whilst performing an important role in minimising biosecurity risks (pathogen kill).

### 7.10 NUTRIENT MANAGEMENT AT FARM LEVEL

Of 254 fields sampled by DARD on 55 intensive dairy farms throughout Northern Ireland for the Vision Nutrient Management Project, 60% had soil indices of P3 or greater and 22% had indices of K2 or greater (Table 7h). Analysis of over 10,000 soils sampled as part of the DARD Countryside Management Scheme indicated that over 40% had higher levels of P than required for intensive agriculture and 45% were deficient in K.

**Table 7h. Percentage distribution of soil K and P indices of fields sampled throughout Northern Ireland for the Vision Nutrient Management Project (J Bailey, personal communication)**

Percent of fields sampled at different soil indices for K and P					
	0	1	2	3	4
K		31	46	18	4
P	1	8	31	47	13

## Chapter 7. Anaerobic digester CHP systems

It is estimated that for an intensive dairy farm with soil indices of P3 and K2, there could be a deficit of 204 kg N/ha, a surplus of 35.5 kg total P<sub>2</sub>O<sub>5</sub>/ha and a full supply of total K<sub>2</sub>O (deficit of 10% available K<sub>2</sub>O). No account has been taken of young stock.

### *Assumptions*

Soil indices of P3 and K2

Stocking rate of 2.5 cows/ha

Silage area - 60% grass area first cut receives slurry by mid March

Grazing area – 40 % receives slurry

Winter housing period – 6 months

Slurry nutrients excreted per head - 48 kg N; 19 kg P<sub>2</sub>O<sub>5</sub>; 48 kg K<sub>2</sub>O per 6 months (RB209)

### *Plant nutrients requirement (kg)*

	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Silage (0.6 ha)	204	12	120
Grazing (0.4 ha)	120	0	0
Total (kg/ha)	324	12	120

It is clear from this estimate that there is potential for plant nutrient surplus (particularly P) on individual farms. Any further addition of plant nutrients from digestate will present a further potential problem.

### **7.11 CASE STUDY – CAD NUTRIENT MANAGEMENT**

Table 7i lists concentrations of N, P and K in the input and output of the CAD at Holsworthy. Note that these data are for a single day and are indicative only.

**Table 7i. N, P and K concentrations Holsworthy, sampled 17 September 2003 (Holsworthy Biogas, 2003, personal communication)**

	Raw input	Digester 1	Digester 2
Total solids (g/l)	87.8	56.6	59.2
Total Nitrogen (Kjeldahl) (g/l)	8.58	8.15	8.10
Total Phosphorous (mg/l)	1,750	1,020	1,090
Total Potassium (mg/l)	4,500	3,630	3,600
Ammonium–N (mg/l)	4,600	5,820	5,740

Based on experience with Swedish pilot and full-scale plants, Nordberg (2003) calculated that a CAD plant with an input of 107,000 t/y (DM 11.4%) would have a digestate output of 101,000 t/y (7 % DM). Data in Table 7j indicate a range in estimated plant nutrient composition of the digestate from a CAD plant.

**Table 7j. Composition of digestate from 107,000 t/y CAD producing 101,000 t/y digestate**

	Dry matter (%)	Dry matter t/y	Total N t/y	Total P <sub>2</sub> O <sub>5</sub> t/y	Total K <sub>2</sub> O t/y
Nordberg (2003)	7.2	7,320	561	329	313
Holsworthy (2003) Biogas	5.8	7,320	821	107	365
Price Waterhouse Coopers (2004) Waterhouse	NA	NA	549	317	311
			67% from farm livestock	69% from farm livestock	98% from farm livestock

It is estimated from data in Table 7j that the output of a 107,000 t/y digester would require, for sustainable utilisation, a silage area of 5,350-16,450 ha (all land within 4.1-7.2 km radius of plant) for the total P<sub>2</sub>O<sub>5</sub> in digestate and 1,555-1,825 ha (all land within 2.2-2.4 km radius of plant) for the total K<sub>2</sub>O in digestate (assuming soil indices of P3 and K2; availabilities P and K of 100%). It is further estimated that for soils with an index of P3, 19-59 CAD plants

would produce sufficient available  $P_2O_5$  for the total silage area in Northern Ireland (317,800 ha).

It is evident that  $P_2O_5$  will be the limiting nutrient in terms of sustainable use of the nutrients.

Note that at a soil index of P0, 382-1,175 ha (all land within 1.1-1.9 km radius of plant) silage area would be required for sustainable utilisation of the available  $P_2O_5$  output (50% total  $P_2O_5$ ) in the digestate from each 107,000 t/y CAD plant. PricewaterhouseCoopers (2004) indicated an input of 54,600 t/y cattle slurry at 6% dry matter to the proposed Fivemiletown digester - equivalent to 3,400 dairy cows (at 16.1 m<sup>3</sup> slurry/dairy cow/ ½ y). It is calculated (assuming all livestock slurry input to the digester is from dairy cows) that this number of dairy cows would require a silage made from 816 ha (assuming 2.5 dairy cows/ha; 60% grass area receives slurry for first cut silage) with a  $P_2O_5$  requirement of 16 t or 73 t at soil indices of P3 and P2 respectively. A silage area of 816 ha equates to silage plus grazing area of 1,360 ha (all land within 2.1 km radius of plant). The total  $P_2O_5$  output from 3,400 housed dairy cows is estimated at 65 t (19 kg total  $P_2O_5$  output/dairy cow/ ½ y), equivalent to 79 kg total  $P_2O_5$ /ha of grass for silage required by these cows. Each dairy farm will be required to receive approximately 30% more digestate than slurry inputted. Therefore, in this example digestate returned to each dairy farm would give 92-284 kg total  $P_2O_5$ /ha of grass for silage. Depending on soil P index, stocking rate and P concentration in digestate, there is potential for considerable excess. Data in Table 7k suggest that at soil index P2, dairy farms stocked at 2.5 cows/ha would require 3-215% additional area to spread digestate.

**Table 7k. Silage grass areas and P<sub>2</sub>O<sub>5</sub> balances for 3,400 dairy cows (assuming 2.5 cows/ha; 70% grass area receives slurry for first cut silage; 54,700 m<sup>3</sup> slurry / ½ y at 7% DM; 19 kg P<sub>2</sub>O<sub>5</sub>/dairy cow per ½ y)**

	Soil Index			
	P0	P1	P2	P3
P <sub>2</sub> O <sub>5</sub> required for silage (kg/ha)	140	115	90	20
Grass area required for silage feed (ha)	817	816	816	816
Dairy cow total P <sub>2</sub> O <sub>5</sub> output (t/6 months)	64.6	64.6	64.6	64.6
Available P <sub>2</sub> O <sub>5</sub> output from cows (t/6 months)	32.3	32.3	64.6	64.6
Silage area required for available P <sub>2</sub> O <sub>5</sub> output from cows (ha)	231	281	717	3,230
Total P <sub>2</sub> O <sub>5</sub> in digestate returned to dairy farms (t) (Table 6j)	75-231	75-231	75-231	75-231
Available P <sub>2</sub> O <sub>5</sub> in digestate returned to dairy farms (t)	38-116	38-116	75-231	75-231
Silage area required for available P <sub>2</sub> O <sub>5</sub> returned to dairy farms in digestate (ha)	269-826	327-1,005	836-2,569	3,759-11,560

Based on the soil analyses indicated in Table 7h, it is calculated that the requirement for P<sub>2</sub>O<sub>5</sub> on 816 ha of silage area on dairy farms supplying the CAD is 39 t/y (Table 7l). If the total volume of digestate (101,000 t) is returned to this area the potential supply of P<sub>2</sub>O<sub>5</sub> is 107-329 t/y (Table 7l). If the volume of digestate applied on these farms is that supplied plus 30% the total P<sub>2</sub>O<sub>5</sub> supplied would be 75-231 t /y (Table 7k).

The P concentrations of digester inputs and output are vitally important.

**Table 7l. P<sub>2</sub>O<sub>5</sub> requirement for 816 ha silage (soil P indices as per Table 7h)**

	Soil P index				
	P0	P1	P2	P3	P4
Silage area (ha)	8.2	65.3	253.0	383.5	106.1
P <sub>2</sub> O <sub>5</sub> requirement (t)	1.1	7.5	22.8	7.7	0

Total P<sub>2</sub>O<sub>5</sub> requirement silage 39.1  
(t)

It is evident that there is a potential surplus of P<sub>2</sub>O<sub>5</sub> on some farms in Northern Ireland and that on these farms application rates of digestate will be limited by P<sub>2</sub>O<sub>5</sub>.

Nutrient management is thus a major issue that will determine the sustainability of CAD plants.

## 7.12 NUTRIENT PARTITIONING OF DIGESTATE

It is evident from the preceding that removal from digestate of plant nutrients that are surplus to crop requirements would be a major benefit. It is possible to mechanically separate slurry and digestate into fibre and liquid fractions. The standard “farm-type” separator will partition nutrients in proportion to dry matter. Separated fibre has potential for transport to farms, other than those associated with the CAD, that have requirement for the plant nutrients contained in the fibre i.e. movement of plant nutrients from areas of surplus to areas of deficit. Additionally, the fibre can be composted to give an added value product that can be used as a “peat substitute” for landscaping and gardening (see below under “other considerations”). Table 7m summarises separator performances.

**Table 7m. Nutrient separation efficiency of common manure separators (Burton and Turner, 2003)**

	Belt press	Sieve Drum	Screw press	Sieve centrifuge	Decanter centrifuge
<i>Separation efficiency %</i>					
of dry matter	56	20-62	20-65	13-52	54-68
of nitrogen	32	10-25	5-28	6-30	20-40
of phosphorous	29	10-26	7-33	6-24	52-78
of potassium	27	17	5-18	6-36	5-20
Volume reduction (%)	29	10-25	5-25	7-26	13-29

The proposal for the CAD plant at Fivemiletown includes provision for a decanter centrifuge – the most efficient type of separator (Table 7m).

Using a decanter centrifuge to separate the digestate from a 107,000 t/y CAD could result in outputs as indicated in Table 7n.

**Table 7n. Nutrient partitioning following decanter centrifuge separation of 101,100 t of digestate (107,000 t/y digester input)**

	Volume (t/y fresh)	Dry matter (%)	Total N (t/y)	Total P <sub>2</sub> O <sub>5</sub> (t/y)	Total K <sub>2</sub> O (t/y)
Whole digestate	101,000	7.2	569	329	313
Separated liquid	71,710- 87,870	2.6-4.7	341-455	72-158	250-297
Separated fibre	13,130- 29,290	13.4-38	114-228	171-257	16-63

The mean partitioning of P<sub>2</sub>O<sub>5</sub> in digestate is 0.35:0.65 separated liquid to fibre (Table 7n). It is estimated that a decanter centrifuge would partition 329 t P<sub>2</sub>O<sub>5</sub> in digestate as 115 t in separated liquid and 214 t in fibre. Spreading all of the separated liquid on 816 ha silage area (Table 7l) would provide

almost 3 times the  $P_2O_5$  requirement indicated in Table 7h. Should digestate return to supplying farms be limited to the volume supplied plus 30% (Table 7j) the quantity of  $P_2O_5$  returned in separated liquid would be 26-81 t/y. At the lower end of this range the  $P_2O_5$  supplied is less than requirement for silage (Table 7l).

Clearly the concentrations of  $P_2O_5$  in digester inputs and digestate together with soil P concentrations are required to determine the nutrient balance for each CAD scheme.

There is therefore considerable potential for CAD plants to assist in centrally managing distribution of plant nutrients in manures.

### **7.13 BIOSECURITY**

Disease is a major issue in centralised slurry management. Steffan *et al.* (<http://www.adnett.org/> accessed 20 May,2004) refer to detailed sanitation studies by Bendixen in Denmark. Within Europe hygiene requirements for AD-treated feedstocks of agricultural or domestic/municipal origin have been set by Denmark, Germany and Austria. For mesophilic AD, these requirements are for 1 h at 70°C. Whilst there is currently some debate over appropriate indicator organisms, all agree that AD plants require effective hygiene and sanitation procedures to minimise the disease transfer risk. Effective monitoring of sanitation is required.

Biosecurity issues related to CAD are reviewed in paper 7 (1).

### **7.14 MUNICIPAL WASTES**

The use of municipal wastes has not been considered as part of this report. It is noted that the current Farm Quality Assurance Scheme does not permit application of sewage sludge on members' farms.

### **7.15 ADDITIONAL ROLES OF AD IN NI**

Proposed Nitrate Vulnerable Zone regulations in Northern Ireland will require all farms to have 5 months slurry storage. In addition, there is a requirement under the Silage Effluent and Agricultural Fuel Oil Regulations (2003) that all new slurry stores must comply with specified design and construction standards. Under the Integrated Pollution Protection Control regulations all targeted pig and poultry manure stores must comply with emission control standards.

Provision of digestate stores is an integral part of all CAD schemes. CAD offers the potential opportunity to assist farms in meeting required standards of slurry storage.

The odour from digestate is less than from the raw material inputted to a digester. However, AD plants produce odour, the amount depending on type of storage, waste type and plant design. It is important that CAD plants are designed to eliminate odour through appropriate use of combustion, biofiltration, scrubbing etc.

### **7.16 OTHER CONSIDERATIONS**

PricewaterhouseCoopers (2004) and Nordberg (2003) highlighted issues for successful setting up and running of CAD plants. Information contained in these documents should be utilised in development of CAD plants in Northern Ireland.

It is important that digestate returned to agricultural land is of known fertiliser value. This will require chemical analysis of digestate. In Europe there is a demand for digestate from farmers who do not input to the CAD. These farmers pay for the digestate. This fact together with the economics of operating a plant make it extremely unlikely that a CAD plant will pay farmers to take digestate.

There is considerable potential financial value of separated fibre. To achieve this potential the fibre must be sanitised and a sustainable market identified. At present there is no identified market for fibre.

### **7.17 CURRENT POSITION OF CAD IN NORTHERN IRELAND**

At the time of writing, a proposal for a CAD plant in Northern Ireland has received an offer of funding from DARD through PBSP Rural Development Funding for grant assistance towards the costs of pre-construction activities (Phase 1). On successful completion of Phase 1, DARD will make available further assistance for the construction of the Plant (Phase 2).

Phase 1 activities include environmental impact assessment and a nutrient management plan. In addition, a baseline study is required to enable the performance of the plant and its operations to be measured and evaluated for their impact on agriculture, the environment and the economy of the area.

Pending positive outcomes of Phase 1, construction of the proposed CAD will provide an invaluable demonstration project for Northern Ireland.

## **Annexes**

## Chapter 7. Anaerobic digester CHP systems

### Annex 1

### Assumptions and methodology used in calculation of slurry volumes and plant nutrient quantities excreted by housed livestock in Northern Ireland (cells highlighted in yellow indicate figures used for calculations)

DARD COGAP p91		Major variation between reference sources on NPK concentrations in slurry																			
		Census equivalent (JPF)	DARD COGAP p91	DARD COGAP p91	DARD COGAP p91	ADAS 2001 p 22	ADAS 2001 p 22	ADAS 2001 p 06	ADAS 2001 p 06	RB209 p34 calculated	RB209 p34 calculated	RB209 p34 calculated	RB209 p42	RB209 p44	RB209 p44	JPF calculate d	JPF calculate d	JPF calculate d	RB209 p34	RB209 p34	RB209 p34
		Body weight	DM%	kg or l/d	Period housing (%)	Total N kg/m^3	Total P2O5 kg/m^3	Total K2O kg/m^3	Total N kg/m^3	Total P2O5 kg/m^3	Total K2O kg/m^3	Total N kg/m^3	Total P2O5 kg/m^3	Total K2O kg/m^3	Housing Total N kg/y	Housing Total P2O5 kg/y	Housing Total K2O kg/y	Housing Total N kg/y	Housing Total P2O5 kg/y	Housing Total K2O kg/y	
Dairy cows		650	10	64	50																
Dairy cows	Dairy Cow	550	10	53	50	5.0	2.0	5.0	5.0	2.0	5.0	4.0	2.0	5.0	48.4	19.3	48.4	48.0	19.0	48.0	
Dairy cows		450	10	42	50																
Suckler cows	Beef Cow	500	10	32	50	5.0	2.0	3.8				3.5	2.0	3.8	29.2	11.7	22.2				
Beef bullock (>2y)	Other 2 years Diary heifers 2 y Breeding bulls	500	10	32	25	5.0	2.0	3.8	5.2	2.0	5.2	3.5	2.0	3.8	14.6	5.8	11.1	15.0	5.8	15.0	
Beef bullock (1-2y)	Other 1-2 year Diary heifers 1-2 y Beef heifers	400	10	26	66	5.0	2.0	3.8	5.0	1.9	5.0	3.5	2.0	3.8	31.3	12.5	23.8	31.0	12.0	31.0	
Grower/fattener (0.5-1y)	Other 6-12 m	180	10	13	50	5.0	2.0	3.8				3.5	2.0	3.8	11.9	4.7	9.0				
Calf (0-0.5y)	Other <6 m	100	10	7	50	5.5	2.0	3.8				3.5	2.0	3.8	7.0	2.6	4.9				
DARD COGAP p91		Census equivalent (JPF)	DARD COGAP p91	DARD COGAP p91	DARD COGAP p91	ADAS 2001 p 22	ADAS 2001 p 22	ADAS 2001 p 06	ADAS 2001 p 06	RB209 p34 calculated	RB209 p34 calculated	RB209 p34 calculated	RB209 p45	RB209 p45	RB209 p45	JPF calculate d	JPF calculate d	JPF calculate d	RB209 p34	RB209 p34	RB209 p34



**Annex 2**

**Regression equations for slurry loadings (t/ha grass) in each of 26 District Councils in Northern Ireland on the proportion of slurry from housed livestock in each district arising from different species**

**Equation 1 : Pig slurry**

Slurry loading from all housed livestock (t/ha grass) =  
 $0.2506 \times (\text{pig slurry \% of total slurry}) + 10.24$   
 $R^2 = 0.24$

**Equation 2 : Poultry manure**

Slurry loading from all housed livestock (t/ha grass) =  
 $0.2562 \times (\text{poultry manure \% of total slurry}) + 10.643$   
 $R^2 = 0.19$

**Equation 3 : Pig slurry + Poultry manure**

Slurry loading from all housed livestock (t/ha grass) =  
 $0.2018 \times (\text{pig slurry + poultry manure \% of total slurry}) + 9.696$   
 $R^2 = 0.34$

**Equation 4 : All Cattle**

Slurry loading from all housed livestock (t/ha grass) = -  
 $0.2018 \times (\text{all cattle slurry \% total slurry}) + 28.876$   
 $R^2 = 0.34$

**Equation 5 : Dairy slurry**

Slurry loading from all housed livestock (t/ha grass) =  
 $0.1528 \times (\text{dairy slurry \% total slurry}) + 6.9669$   
 $R^2 = 0.32$

**Equation 6 : All Non-Dairy cattle**

Slurry loading from all housed livestock (t/ha grass) =  
 $- 0.2018 \times (\text{all non dairy slurry \% total slurry}) + 23.643$   
 $R^2 = 0.77$

**Annex 3**

**Regression equations for slurry loadings (t/ha grass) in each of 26 District Councils in Northern Ireland on the number of livestock in each district**

**Equation 7: Pig slurry**

Slurry loading from all housed livestock (t/ha grass) =  
 $3.181 \times (\text{pig nos./ha grass}) + 10.17$   
 $R^2 = 0.33$

**Equation 8: Poultry manure**

Slurry loading from all housed livestock (t/ha grass) =  
 $0.0588 \times (\text{poultry nos./ha grass}) + 10.593$   
 $R^2 = 0.25$

**Equation 9: Pig slurry + Poultry manure**

Slurry loading from all housed livestock (t/ha grass) =  
 $0.0594 \times (\text{pig} + \text{poultry nos./ha grass}) + 10.554$   
 $R^2 = 0.25$

**Equation 10: Total Cattle**

Slurry loading from all housed livestock (t/ha grass) =  
 $7.7043 \times (\text{total cattle nos./ha grass}) - 3.9579$   
 $R^2 = 0.91$

**Equation 11 : Dairy slurry**

Slurry loading from all housed livestock (t/ha grass) =  
 $10.94 \times (\text{dairy cow nos./ha grass}) - 7.4567$   
 $R^2 = 0.63$

**Equation 12 : All Non-Dairy cattle**

Slurry loading from all housed livestock (t/ha grass) =  
 $8.5663 \times (\text{non-dairy cattle nos./ha grass}) - 2.3938$   
 $R^2 = 0.52$