

GSE MSc Architecture: Advanced Environmental and Energy Studies

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(Environmental and Sustainability Assessment, Management and Post
Occupancy Evaluation) Essay

COULD COMPOSTED ORGANIC WASTE, INCLUDING HUMAN
EXCRETA, REPLACE CHEMICAL FERTILISERS ON UK
FARMS?

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For the attention of Lucy Cartlidge

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Introduction

This essay relates to the lecture 'Environmental Impacts of Agriculture'.

Modern UK agriculture is heavily reliant on the petrochemical industry. Farming consumes finite resources, degrades SOM¹, uses non-sustainable ground water for irrigation and pollutes the environment (Pagella, S and Maxey, L, 2010). Nearly ten percent of the UK's GHG² emissions are generated by agriculture³ (Garnett, T 2008). Linear processes operate within the UK food chain. One such process extracts raw materials from the earth to make NPK⁴ fertilisers. If not leached into watercourses from farmland, these elements usually enter the sewerage system via human excreta or are sent to landfill as waste food. Together with land-filled garden waste, food residues, decompose anaerobically generating 20% of UK's methane emissions (WRAP⁵, 2008).

Nitrogen fertilisers are manufactured from natural gas using the energy intensive Haber Bosch process, (Pagella, S and Maxey, L, 2010), while phosphate fertilisers are manufactured from fast-depleting finite phosphate rock, deposits of which may last less than a century (EcoSanRes⁶, 2008).

The human body excretes NPK in urine and faeces that usually enter the sewerage system where they are mixed with greywater and a multitude of chemical pollutants before entering a sewage farm for treatment (Grant, N. et al 2005). This essay will explore whether diverting the organic matter waste stream to compost manufacture for application on farmland could eliminate the need for artificial fertilisers.

¹ Soil Organic Matter

² Greenhouse gas.

³ Including livestock production

⁴ Nitrogen, Potassium and Phosphate.

⁵ Waste Resources Action Programme

⁶ Ecological Sanitation Research

Critical Analysis

UK Fertiliser use

The macronutrients needed for plant growth regularly supplied by inorganic⁷ chemical fertilisers are nitrogen, phosphorus and potassium. Artificial fertilisers sold in the UK must contain these three elements and state their quantity (OPSI⁸, 1990). Fertiliser use is the largest energy input to food production (Pagella, S and Maxey, L, 2010).

Table 1. UK Consumption in tonnes of nutrients of Nitrogen Phosphorus and Potassium (NPK) fertilisers. 2007 was the last year with full available data.

Year	Nitrogen Fertiliser (N)	Phosphate Fertiliser (P ₂ O ₅)	Potash Fertiliser (K ₂ O)	Elemental Nitrogen	Elemental ⁹ Phosphorus	Elemental Potassium
2007	1,008,000	224,000	317,000	1,008,000	97,664	263,110

Source: FOA¹⁰ (2009) OPSI (1990)

Consumption of phosphate and to a lesser extent potassium fertiliser is of particular concern. While nitrogen can be fixed from the air by leguminous plants, phosphorus and potassium are usually mined from phosphate and potash bearing rock. There is growing concern over phosphate resources and 'peak phosphate' (Lewis, L 2008). Historically the UK has applied high levels of phosphate to farmland for decades. Mollison estimates these soils have 750 ppm phosphate in the top 4 cm and *the rest of the applied phosphate is bound up and unavailable in the top 20 cm* (1988).

'Bioaccumulators', plants that can draw phosphate from these bound reserves, such as comfrey should be grown and composted to make phosphate accessible by crops (Whitefield, 2004).

⁷ The term inorganic is used here to mean farming with artificially produced fertilisers (and pesticides) as opposed to the definition used in chemistry.

⁸ Office of Public Sector Information

⁹ Phosphorus pentoxide (P₂O₅) × 0.436 = Phosphorus (P); Potassium oxide (K₂O) × 0.83 = Potassium (K). Source OPSI 1990

¹⁰ Food and Agriculture Organization (of the United Nations)

Soil Degradation

Industrial agriculture has seriously degraded UK soils reducing SOM and nutrients. Eighteen percent of the SOM found in UK agricultural topsoil in 1980 had been lost by 1995 (POST¹¹, 2006). These losses continue. Bellamy et al estimate that for the last 25 years English and Welsh soils have lost 0.6% of their carbon content per year (2005), equal to 13 million tonnes of carbon a year: 8% of the nation's CO₂ emissions (Stanley and Halestrap, 2009).

farmer Rebecca Hosking has described soils as lifeless physical supports for growing crops as opposed to nourishing mediums in their own right (Natural World, 2009).

Temperate countries contain 75% of the world's soil carbon (Bellamy et al, 2005), so it is particularly important for the UK to reverse these losses. Crop cover and no-till systems can be used to help heal soils, together with applications of compost.

Compost

Compost is an excellent source of SOM. It lasts an average of eighteen years in UK soils before oxidising to CO₂ and water. Humus, the most stable form of SOM, can last a great deal longer. Compost improves every soil type, including the structure, water and nutrient holding capacity and drainage. It enhances soil microbial activity, combats erosion and provides nutrients (Whitefield, P 2004).

¹¹ Parliamentary Office of Science and Technology

Source material.

Compost is made from 'waste' organic matter. According to WRAP, four million tonnes of collected municipal and commercial waste produced two million tonnes of compost (2008): a 2:1 conversion of raw materials to finished compost. If all 24.5 million tonnes¹² of available organic waste was composted the yield could be 12.25 million tonnes of compost.

Table 4: UK organic waste arising by sector million tonnes

	Municipal	Commercial and industrial	Total million tonnes
Kitchen/food	6.1 ¹³	5.7	11.8
Garden	6.4	4.2	10.6
Other	0	2.6	2.6
Total	12.5	12.5	25

Source: ERM (2006) based on data for 2003/04 in WRAP (2008)

There is a however an even larger stream of available organic matter.

¹² 500,000 tonnes is home composted

¹³ Note: More recent data suggest that the food waste fraction of municipal waste may be as high as 6.7 million tonnes, but this may be offset by a smaller garden waste component.

Human excreta.

Faeces and urine are a rich source of NPK and other elements necessary for plant growth. Indeed untreated sewage irrigates a tenth of the world's crops (Pearce, F 2004).

Table 3 – Average statistics for urine and faeces

	Mean faeces / person / day	Mean urine / person / day	Mean total / person / day	Mean total / person / year	Total for the UK¹⁴ (Tonnes)
Approximate quantity wet.	202.5g	1150g	1352.5g	493,663g	27,152,368
Approximate quantity dry.	52.5g	60g	112.5g	41,063g	2,258,515
Total Dry Basis					
Nitrogen	3.15g	10.20g	13.35g	4,873g	268,010
P ₂ O ₅	2.21g	2.25g	4.46g	1,626g	89,437
K ₂ O	0.92g	2.25g	3.17g	1,157g	63,615
CaO	2.36g	3.15g	5.51g	2,012g	110,667
Carbon	26.25g	0.60g	26.85g	9,800g	539,032
Elemental Nitrogen	3.15g	10.20g	13.35g	4,873g	268,010
Elemental Phosphorus	0.96g	0.98g	1.94g	709g	38,995
Elemental Potassium	0.76g	1.87g	2.63g	960g	52,800
Elemental Calcium	1.69g	2.25g	3.94g	1,439g	79,127
Elemental Carbon	26.25g	0.60g	26.85g	9,800g	539,032
C:N Ratio	8.33:1	0.06:1	2.01		268,010

Source: Grant, N. et al 2005

It is essential in a sustainable farming system that these nutrients are returned to the growing cycle.

¹⁴ Includes a reduction of 10% to account for the 20% of the population below the age of 15

Sewage sludge

Some nutrients from human excreta are already applied to farmland as biosolids.

The equivalent of 1.3 million tonnes of dry solids of sludge are produced each year in England and Wales a by-product of sewage treatment (Water UK, 2006).

Extrapolated for the entire UK population¹⁵ this figure is 1.47 million. Sixty-two percent of these biosolids were returned to farmland (Water UK, 2006). However of the phosphate in sewage only 64% comes from urine and faeces. The rest from other sources such as detergents (UK water, 2008)

Table 4 – The fate of Nitrogen and Phosphorus recovered from sewage sludge (No potassium is recovered).

	%	Tonnes	Total Nitrogen	Total Elemental Phosphorus (from urine and faeces)	Available Nitrogen	Available Elemental Phosphorus (from urine and faeces)
Agriculture (as treated biosolids)	62%	908,916	27,267	14,266 (9,130)	4,090	7,133 (4,565)
Incinerated	19%	278,539	8,356	4,372 (2,798)	1,253	2,186 (1,399)
Land reclamation	11%	161,259	4,838	2,531 (1,620)	726	1,266 (810)
Landfill	1%	14,660	440	230 (147)	66	115 (74)
Other (including non-food crops)	7%	102,620	3,079	1,611 (1,031)	462	805 (515)
Total	100%	1,465,993	43,980	23,010 (14,727)	6,597	11,505 (7,363)

Source: DEFRA Fertiliser recommendations for agricultural and horticultural crops (2000), UK Water (2006).

Comparing table 3 and 4, table 5 shows that few of the nutrients excreted in human urine and faeces are returned to the land as biosolids. Nearly 80% of the phosphorus is lost and all the potassium.

Table 5. Nutrient loss from human excreta in conversion to sewage sludge

	Human urine and faeces	Returned to the land as sewage	Nutrients lost	Percentage returned	Percentage lost
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¹⁵ 61.38 (Population of UK) / 54.43 million (Population of England and Wales) * 1.3

		sludge			
Nitrogen	297,789	27,267	270,522	9.2%	90.8%
Phosphorus	43,327	9,130	34,197	21.1%	78.9%
Potassium	58,667	0	58,667	0	100.0%

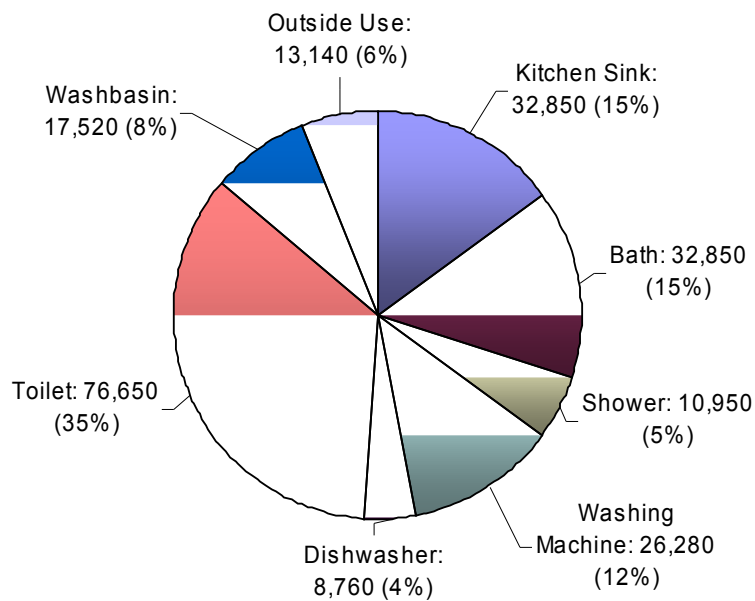
Furthermore sewage sludge is contaminated with heavy metals, household chemicals and pollutants from industry and agricultural run-off (Grant, N, et al, 2005).

Bypassing the sewerage system

Mixing a small quantity of human excreta with a large quantity of clean water simply to move the material is a shameful waste of resources (Harper and Halestrap, 1999).

Thirty-five percent of the UK domestic potable water supply is flushed down the toilet (Thornton, 2007). A paradigm shift is required.

Figure 1. UK water use.



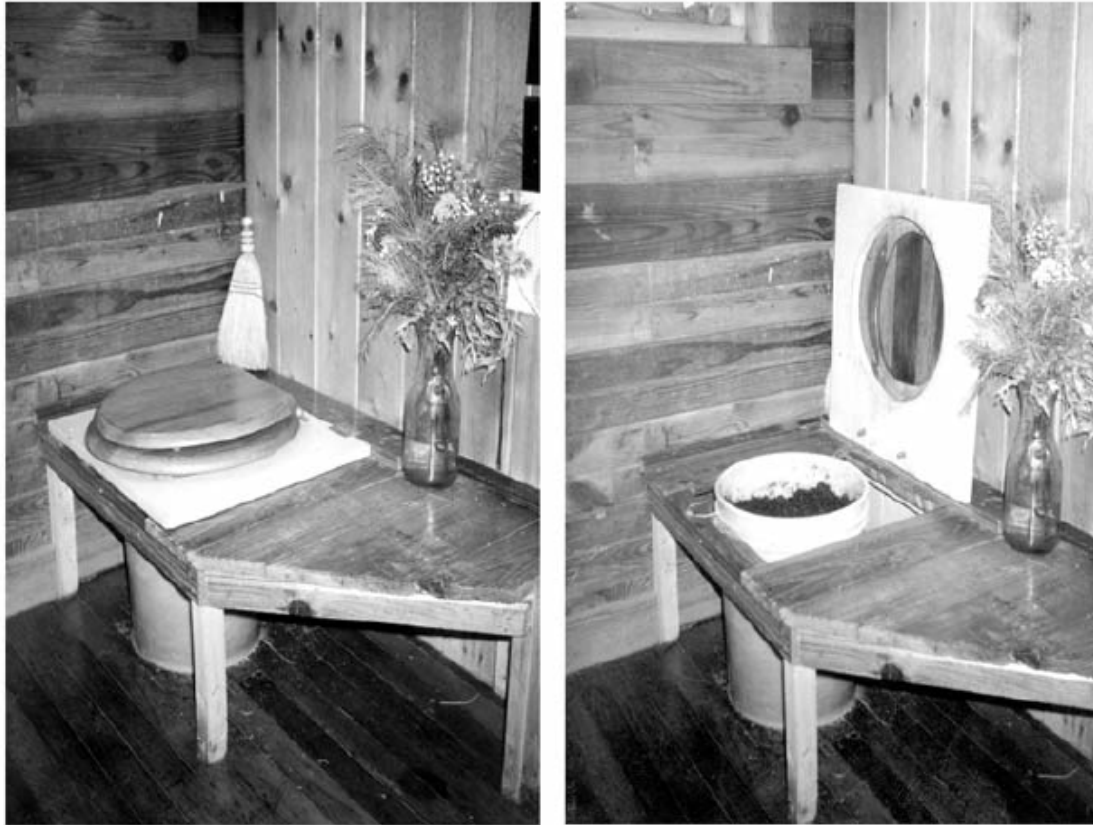
Source: Thornton, J (2007)

Compost toilet

Jenkins' studies have shown that human faeces and urine can be composted together to produce fertile pathogen-free compost. The excreta are collected from an indoor compost toilet, basically a 20-litre container housed in a wooden framework with a toilet seat fitted. This is emptied on a weekly basis onto an outdoor heap. The

excreta are thoroughly covered both in the house and in the pile. Jenkins uses well-rotted sawdust as a cover (2005).

Figure 2. Homemade compost toilet.



Source: Jenkins, 2005

Unfortunately, with an annual production of 171,800 ODT¹⁶ a year, (McKay, 2003)

there is insufficient sawdust available to supply the UK population.

Separating Urine

An alternative to collecting all human excreta in one vessel is to separate out the urine, or only the male urine either by using a urine-separating toilet or by having separate collection vessels. The use of human urine, diluted 10:1 with water to fertilise arable land has been successfully undertaken by the Stockholm Water Company (Steinfeld, 2004).

Applications of urine provide necessary plant growth nutrients, but they do not provide the high carbon humus that balanced compost does. Furthermore the urine

¹⁶ Oven dry tonnes

holding vessel can become contaminated with faeces. But, if insufficient soak material can be found, urine separation could be considered.

A suitable cover material

Human excreta would need to be stored before being collected by the municipal authority on a weekly basis. If urine were collected separately it would need to be stored in a sealed container to minimise nitrogen losses (Steinfeld, 2004). Faeces, or a mixture of faeces and urine in a compost toilet would need a suitable cover material. This material must:

- have a high carbon content in order to balance the high levels of nitrogen.
- be available in large quantities in the UK.
- be dry and bulky enough to balance the high moisture content of excreta.

To calculate how much cover material is needed one must consider how much carbon is needed to balance the nitrogen produced in the excreta.

To minimise nitrogen losses without inhibiting the composting process a C:N ratio of 25:1 is required (Jenkins, 2005).

The following potential cover materials were investigated.

- Wheat straw
- Chipped woody biomass
- Paper
- Miscanthus

These materials also add small amounts of nutrients.

Table 6: Carbon and nutrient values of excreta and potential cover materials.

	Carbon (C)	Nitrogen (N)	Phosphorus (P)	Potassium (K)	C:N ratio
All faeces and urine	2.3%	0.99%	0.14%	0.19%	2.4:1
All faeces but only female urine	3.72%	1.06%	0.19%	0.22%	3.5:1
Faeces only	13.0%	1.56%	0.47%	0.38%	8.3:1
Urine only	0.5%	0.89%	0.09%	0.16%	0.5:1
Straw (15% moisture)	34%	0.50%	0.06%	0.77%	68:1
Miscanthus (15% moisture)	35%	0.43%	0.03%	0.47%	83:1
Chipped woody biomass (40% moisture)	27%	0.24%	0.01%	0.06%	113:1
Paper (Moisture content 10%)	42%	0.27%	0.02%	0.10%	156:1

Source: Grant, N. et al 2005, Powelson, et, al 2008, Walsh (Ed) and Jones, (Ed) 2001, Woodenergy.ie , 2006 & Sassine et al, 2005.

Wheat straw

Seven million tonnes of wheat straw are produced annually in the UK. Thirty percent is used on the farm, thirty percent is sold and forty percent is chopped and incorporated in the soil (BEC¹⁷, 2008). These latter two portions could be diverted for use as a cover material, providing 4,900,000 tonnes: enough to compost all UK human faeces, but no mixed excreta.

Table 7. Quantities of wheat straw required in order create a 25:1 carbon / nitrogen ratio when mixed with UK human excreta.

	Annual tonnes for UK	Annual nitrogen (Tonnes)	Annual phosphorus (Tonnes)	Annual potassium (Tonnes)
All faeces and urine	27,152,368	268,010	38,995	52,800
Straw	28,206,341	141,032	15,987	217,725
Total	55,358,709	409,042	54,982	270,525
All faeces but only female urine	15,608,847	165,624	29,147	34,055
Straw	16,562,442	82,812	9,388	127,845
Total	32,171,290	248,437	38,535	161,900
Faeces only	4,065,327	63,238	19,300	15,309
Straw	4,918,544	24,593	2,788	37,966
Total	8,983,870	87,831	22,088	53,275

Source: Grant, N. et al 2005, Powelson, et, al 2008

¹⁷ Biomass Energy Centre

Woody biomass

Evelein investigated how much forestry biomass would be available in the UK for the production of biochar. 1,452,962 ODT¹⁸ would be available from the years 2007-2011 equating to 2,421,603 tonnes of chipped biomass at 40% moisture content (2008). This would represent half the cover material needed to compost human faeces only.

Table 8. Quantities of woody biomass required in order create a 25:1 carbon / nitrogen ratio when mixed with UK human excreta.

	Annual tonnes for UK	Annual nitrogen (Tonnes)	Annual phosphorus (Tonnes)	Annual potassium (Tonnes)
All faeces and urine	27,152,368	268,010	38,995	52,800
Woody biomass	28,808,612	69,141	2,593	17,285
Total	55,960,980	337,151	41,587	70,085
All faeces but only female urine	15,608,847	165,624	29,147	34,055
Woody biomass without male urine	16,963,956	40,713	1,527	10,178
Total	32,572,804	206,338	30,674	44,233
Faeces only	4,065,327	63,238	19,300	15,309
Woody biomass	5,018,922	12,045	452	3,011
Total	9,084,249	75,284	19,752	18,320

Source: Grant, N. et al 2005, Woodenergy.ie, 2006

¹⁸ Oven dried tonnes

Paper and card

In 2006 the UK generated 12,121,000 tonnes of waste paper and card. 8,617,000 tonnes were collected for recycling of which 4,040,000 tonnes was recycled in the UK and the rest exported. If the UK stopped sending paper for export then 8,081,000 million tonnes would be available as a cover material. This exceeds the requirement for faeces alone and could provide cover for some mixed excreta.

Table 9. Quantities of paper required in order create a 25:1 carbon / nitrogen ratio when mixed with UK human excreta.

	Annual tonnes for UK	Annual nitrogen (Tonnes)	Annual phosphorus (Tonnes)	Annual potassium (Tonnes)
All faeces and urine	27,152,368	268,010	38,995	52,800
Paper	17,164,713	46,345	3,368	16,669
Total	44,317,081	314,355	42,362	69,469
All faeces but only female urine	15,608,847	165,624	29,147	34,055
Paper without male urine	10,047,882	27,129	890	9,757
Total	25,656,729	192,754	30,038	43,812
Faeces only	4,065,327	63,238	19,300	15,309
Paper	2,971,202	8,022	583	2,885
Total	7,036,529	71,261	19,883	18,194

Source: Grant, N. et al 2005, Sassine, et al 2005.

Miscanthus

The EEA¹⁹ investigated how much UK farmland could be converted to biomass production without affecting wildlife (2006). The grass miscanthus can yield 18 ODT ha⁻¹ (Boyle, 2004), but 12 to 16 are more usual (DEFRA, 2007, & Walsh et al, 2001).

Table 10. Potential yield of Miscanthus at 12 and 16 ODT on land that could be converted to biomass production without affecting wildlife.

	Hectares	12 ODT ha ⁻¹ (Tonnes at 15% moisture)	16 ODT ha ⁻¹ (Tonnes at 15% moisture)
2010	824,000	11,632,941	15,510,588
2020	1,118,000	15,783,529	21,044,706
2030	1,584,000	22,362,353	29,816,471

Source: EEA, 2006, DEFRA, 2007 Walsh (Ed) and Jones, (Ed) 2001

At the higher yield almost the whole miscanthus crop in 2030 could provide the cover material for all human excreta.

Table 11. Quantities of miscanthus required in order create a 25:1 carbon / nitrogen ratio when mixed with UK human excreta.

	Annual tonnes for UK	Annual nitrogen (Tonnes)	Annual phosphorus (Tonnes)	Annual potassium (Tonnes)
All faeces and urine	27,152,368	268,010	38,995	52,800
Miscanthus	24,592,718	104,519	8,362	114,971
Total	51,745,085	372,529	47,356	167,771
All faeces but only female urine	15,608,847	165,624	29,147	34,055
Miscanthus	14,464,533	61,474	4,918	67,622
Total	30,073,380	227,099	34,065	101,676
Faeces only	4,065,327	63,238	19,300	15,309
Miscanthus	4,276,122	18,174	1,454	19,991
Total	8,341,448	81,412	20,754	35,300

Source: Grant, N. et al 2005, DEFRA, 2007 Walsh (Ed) and Jones, (Ed) 2001

A combination of cover materials chosen from those available and supplemented with miscanthus could supply all the necessary cover material for human excreta in the UK. **Urine would not need to be separated out.** This would use all the waste wheat straw and woody biomass in the country, all the waste paper not recycled domestically and would require 22% of 2030 miscanthus crop at the higher yield.

¹⁹ European Environment Agency

Table 12. Quantities of a combination of cover materials required in order create a 25:1 carbon / nitrogen ratio when mixed with UK human excreta.

Cover material	Material ('000 Tonnes)	Water ('000 Tonnes)	Excreta balanced (%)	Carbon (Tonnes)	Nitrogen (Tonnes)	Phosphorus (Tonnes)	Potassium (Tonnes)
Straw	4,900	735	17.4%	1,666,000	24,500	2,777	37,823
Woody biomass	2,422	969	8.4%	653,833	5,812	218	1,453
Paper	8,082	808	47.1%	3,403,717	21,819	1,585	7,847
Sub-total Cover	100%	2,512	72.9%	5,723,550	52,131	4,581	47,124
Miscanthus	6,675	1,001	27.1%	2,354,681	28,370	2,270	31,207
Total Cover	22,078	3,513	100.0%	8,078,231	80,500	6,850	78,330
All faeces and urine	27,152	24,894		635,396	268,010	38,995	52,800
Total excreta and cover	49,230	28,407 (57.7% ²⁰)		8,713,627 (17.7%)	348,510 (0.7%)	45,845 (0.1%)	131,130 (0.3%)

Source: Grant, N. et al 2005, Powelson, et, al 2008, Walsh (Ed) and Jones, (Ed) 2001, Woodenergy.ie , 2006 & Sassine et al, 2005.

²⁰ Of final material. The rest made up of hydrogen and oxygen in humus.

Collection

An example family of two adults and two children may deposit 21.3kg²¹ of excreta in their home compost toilet a week. These excreta would be combined with 17.3 kg of cover material, producing 38.6 kg of material to be collected a week. This would need a receptacle with a holding capacity of about 40 litres. Figure 4 shows a suitable collection device that could be wheeled to the refuse collection vehicle. This material could be taken to municipal facilities or participating farms for composting, together with other organic waste.

Figure 4. Commercial compost toilet.



Source: Jenkins, 2005

²¹ In this estimate, two children produce the equivalent of one adult. One quarter of the excreta are estimated to be deposited elsewhere: work, school etc.

Compost in agriculture

Previous studies

Studies by WRAP have shown that composts provide SOM and slow release fertilisers. Nitrogen mineralises slowly minimising leaching. 5 - 10% released in the first year. Potassium builds in the soil with repeated applications and one application lasts 1 to 3 years. Fifteen percent of phosphorus is available in the first year and the rest released over the rotation. Other nutrients such as Sulphur, and trace elements are provided (2008).

In 2003 100 farmers in England were working in partnership with local authorities to compost municipal green waste. Sheepdrove organic farm composts 12,000 tonnes of organic material a year and applies 10,000 tonnes of compost across the farm.

Application rates are 14 - 25 tonnes per hectare every 3 to 4 years. The farm had severely degraded soils after decades of continuous intensive production. The compost is improving the structure and SOM content (Forum for the future, 2005).

Compost trials at Park Farm found the increase in SOM caused long-term improvements in soil structure and workability. Application rates were 30 tonnes ha⁻¹ (WRAP, 2008).

Figure 5. Improvements in SOM and crumb over a seven-year period of compost application at 30 tonnes ha⁻¹.

Before



After



Source: WRAP, 2008

Trials by the organic resource agency have shown a steady increase in soil Potassium and Phosphorus due to compost application. Crops yields improved. (WRAP, 2008)

Total available

Nearly fifty million tonnes of excreta and cover material could be collected annually, at the correct C:N ratio to undergo composting. With a reduction in size of fifty percent this mixture could yield nearly 25 million tonnes of compost with 1.2%²² nitrogen, 0.2% phosphorus and 0.6% potassium similar to the 0.8%:0.3%:0.6% NPK content of commercially available compost (WRAP, 2008). Combined with the 12.250 million tonnes of compost that is available from the composting of garden and food waste, a total of 37,500,000 tonnes of compost would be available per year.

Application

Currently the chemical NPK fertiliser applied in the UK is split roughly evenly between the 4,583,439²³ hectares of tillage crops and 12,494,115 hectares of grassland (DEFRA, 2008). A very small proportion of UK farmland is organic. For example only 1.1% of wheat is organic (DEFRA, 2009). See appendix 3.

Table 13. Proportion of chemical fertilisers applied to tillage and grazing land

	Nitrogen	Phosphorus	Potassium
Crops and Bare fallow (tillage)	48.3%	53.2%	54.8%
Grasses and rough grazing	51.7%	46.8%	45.2%

Source: Defra, 2008

37,250,000 tonnes of compost split evenly between tillage and grazing could be applied at rates of 4.1 and 1.5 tonnes per hectare respectively. This is lower than the rate of artificial fertilisers as show in table 14. If the compost was only applied to the tillage the phosphorus and potassium would compare favourably with those supplied by artificial fertilisers. Nitrogen would still be a little low.

Table 14. Nutrients provided by compost at rates that would cover all UK rough grazing

²² Allowing for 15% nitrogen losses

²³ Bare fallow comprises 192,000 hectares (4%) of tillage land (Office for National Statistics, 2009).

and tillage compared to nutrients supplied by chemical fertilisers.

Tonnes ha ⁻¹	M ³ ha ⁻¹ ²⁴	Depth (cm)	Carbon ha ⁻¹ (Kg)	Nitrogen ha ⁻¹ (Kg)	Phosphorus ha ⁻¹ (Kg)	Potassium ha ⁻¹ (Kg)
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Compost

Grassland	1.25	2.1	0.21	146	12	2	4
Tillage	4.1	6.8	0.68	475	38	5	14
Tillage only	8.1	13.5	1.35	951	76	10	29

Artificial fertiliser

Grassland	34	4	12
Tillage	114	10	26

Perhaps the compost could be applied at higher rates to the most degraded tillage soils in the first instance. Or the compost could be applied at 24.38 tonnes ha⁻¹ every three years, which would be similar to the higher rate applied at Sheepdrove farm.

²⁴ Compost density of 0.6 tonnes per cubic metre (Environment Agency, 2007)

Conclusion

Summary of the case made

Collecting and composting all organic wastes including human excreta, could supply the same amount of phosphorus and potassium to tillage land that is currently applied by chemical fertilisers. Alternative sources of nutrients need to be applied to grassland.

There would be insufficient compost to apply at the rates used on experimental farms trials (30 tonnes ha⁻¹) but sufficient to match the rates used commercially on Sheepdrove organic farm. Nitrogen would be supplied in lower quantities to chemical fertilisers, however, it would, together with phosphorus and potassium, be in a slow release form. SOM would increase and soil structure improve wherever compost was applied. Phosphate and potassium resources would be conserved and there would be energy savings by not manufacturing nitrogen fertilisers.

Thirty-five percent less domestic potable water would be needed and a major stream of pollution would be eliminated.

Critically, soil carbon loss would be reversed.

Existing Orthodoxy

Farmers are sometimes described as 'guardians of the countryside' and UK agriculture considered highly efficient. However since the end of Second World War energy intensive farming practices such as the regular application of chemical fertilisers have stripped UK soils of organic matter, leaving the soil a lifeless medium dependant on further regular inputs of chemicals.

The water-based sewerage system is regarded as hygienic and the use of human excreta for growing crops a disease risk. Compost toilets are considered primitive and only suitable for those seeking alternative lifestyles.

In reality the UK sewerage system takes two valuable resources, potable water and nutrient-rich excreta, mixes them together with heavy metals, household chemicals

and agricultural and industrial run-off turns it into one large stream of pollutant: sewage.

Limitations of the essay

The adoption by the general public of a dry excreta management system was not considered. Neither were the logistics of retrofitting domestic properties and the practicalities of municipal authorities collecting the material.

Collection from public places (e.g. pubs) was not explored.

Averages were taken for nutrient content and volume of excreta and cover material.

Variation would exist.

The flow of NPK within the system was not accurately modelled, in particular nitrogen losses during composting.

Calcium, sulphur and the obligatory micronutrients were not considered.

The composting of animal slurries, with their requirement for additional cover material was not investigated.

The fate of the remaining grey water in the sewerage system was not considered.

Neither were the consequences on the ease of composting and nutrient levels if urine was separated out.

Further research

A full life cycle analysis to evaluate carbon emissions from a human excreta-collection and composting operation should be performed.

The carbon, moisture and nutrient contents (including micronutrients) of materials should be measured before and after composting using a range of composting techniques. Faeces and urine should be composted together and separately with a range of cover materials.

Several long-term practical studies should be conducted around the UK to evaluate changes in SOM with repeated applications of compost, varying the initial soil type and SOM content and the application rates of compost.

The savings in farm irrigation water due to improved soil structure due to composting should be measured.

A study should be made into the use of bioaccumulating plants to harvest phosphate and potassium out of the soil for use in composting.

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Appendices

Appendix 1. Average statistics for urine and faeces

	Per Adult per day					Per person per year (g)	UK population ²⁵ (Tonnes per year)
	Faeces	Faeces Mean	Urine	Urine Mean	Total	Total	Total
Approximate quantity	135 – 270g/ day wet weight	202.5g	1000 – 1,300g/ day	1150g/ day	1352.5	493,663	30,169,298
Approximate composition	35 – 70g/ day dry weight	52.5g	50 – 70g/ day dry weight	60g	112.5	41,063	2,509,461
Moisture	66 – 80%	73%	93 – 96%	94.5%			

% dry basis:

Nitrogen	5.0 – 7.0%	6.0%	15 - 19%
P ₂ O ₅	3.0 - 5.4%	4.2%	2.5 - 5.0%
K ₂ O	1.0 - 2.5%	1.75%	3 - 4.5%
CaO	4.0 - 5.0%	4.5%	4.5 - 6.0%
Carbon	40-55%	50%	1%

Total Dry Basis

P ₂ O ₅	2.21g	2.25g	4.46g	1,626g	99,375
K ₂ O	0.92g	2.25g	3.17g	1,157g	70,683
CaO	2.36g	3.15g	5.51g	2,012g	122,964
Nitrogen	3.15g	10.20g	13.35g	4,873g	297,789
Phosphorus ²⁶	0.96g	0.98g	1.94g	709g	43,327
Potassium ²⁷	0.76g	1.87g	2.63g	960g	58,667
Calcium ²⁸	1.69g	2.25g	3.94g	1,439g	87,919
Carbon	26.25g	0.60g	26.85g	9,800g	598,925
C:N Ratio	8.33:1	0.06:1	2.01:1		

²⁵ 61,113,205

²⁶ Phosphorus pentoxide (P₂O₅) × 0.436 = Phosphorus (P)

²⁷ Potassium oxide (K₂O) × 0.83 = Potassium (K)

²⁸ Calcium oxide (CaO) × 0.715 = Calcium (Ca)

Appendix 2. Total and available nutrients in sewage Sludge

Nutrient	Availability (%)	Digested cake Dry Matter 25%		Equivalent weight of dry solids ²⁹		UK total	
		Total (kg/tonne)	Total Available (kg/tonne)	Total (kg/tonne)	Total Available (kg/tonne)	Total (tonnes)	Total Available (tonnes)
Nitrogen	15%	7.5	1.125	30	4.5	43,980	6,597
Phosphate	50%	9	4.5	36	18	52,776	26,388
Elemental Phosphorus	50%	3.924	1.962	15.696	7.848	23,010	11,505
Potash / Potassium	N/A	Trace	Trace	Trace	Trace	Trace	Trace

1,465,993

Source: DEFRA Fertiliser recommendations for agricultural and horticultural crops

(2000), UK Water, 2006.

²⁹ Digested cake dry matter * 4.

Appendix 3. Organic land by type 2008

	In conversion	Fully organic	Total	Total crop area at June 2008	Organic area as % of total crop type
Total cereals	9,923	47,316	57,239	3,272,075	1.70%
Wheat	4,512	17,812	22,324	2,080,463	1.10%
Barley	3,135	12,410	15,545	1,031,960	1.50%
Oats	1,092	11,525	12,617	134,664	9.40%
Other cereals	1,184	5,569	6,753	24,989	27.00%
Other crops	2,486	8,675	11,161	991,894	1.10%
Sugar beet	35	152	188	119,654	0.20%
Fodder, silage and other crops	1,810	6,174	7,984	73,183	10.90%
Other crops	641	2,349	2,990	799,058	0.40%
Fresh vegetables	1,835	14,651	16,486	271,566	6.10%
Potatoes	205	3,065	3,270	143,317	2.30%
Fruit & nuts	374	1,510	1,884	32,912	5.70%
Herbaceous & ornamentals (a)	586	4,922	5,508	12,866	42.80%
Temporary pasture	31,048	98,808	129,855	2,058,362	6.30%
Permanent pasture (inc. rough grazing) (c)	96,022	398,294	494,316	8,897,334	5.60%
Woodland	2,709	3,176	5,885	716,163	0.80%
Other	3,916	13,995	17,911	n/a	n/a
Total organic land area	149,103	594,413	743,516		

Source: DEFRA Organic Statistics, 2009