A farmer-operated system for recycling food waste and municipal sludge to agriculture

Un système gérable à la ferme pour le recyclage de déchets agro-alimentaires et de boues d'épuration en agriculture.

Odd Jarle Skjelhaugen
Agricultural University of Norway, Dep. of Agricultural Engineering,
Box 5065, N-1432 Ås, Norway
E-mail : o.j.skjelhaugen@nlh10.nlh.no

Abstract

To increase the recycling rate of food wastes and domestic septic tank sludge to agriculture, a small-scale system, independent of sewer pipelines and sewage treatment plants, has been developed. The wastes are handled as liquid in a closed system. Food waste and septic sludge are stored in tanks at the homes for a period of one to two years. After being collected, the material is sanitised and stabilised in a thermophilic aerobic reactor. The pathogens are effectively reduced. The treated material is stored until spreading on suitable farm land during the growing season. The processing plant can be located on the farm and can be operated by the farmer who can, therefore, generate an extra income.

Résumé

Afin d'augmenter le recyclage agricole de déchets agro-alimentaires et municipaux (boues), un système à petite échelle indépendant du système de collecte des eaux usées a été développé. Les déchets sont gérés sous forme liquide dans un dispositif fermé. Les déchets agro-alimentaires et les boues sont stockés dans des cuves au domicile pour une durée de un à deux ans. Après la collecte, le produit est hygiénisé et stabilisé en réacteur aérobie thermophile. Les pathogènes sont effectivement réduits. Le produit traité est stocké jusqu'à son épandage lors de la saison de culture. Le système de traitement peut être installé à la ferme et géré par l'agriculteur ce qui lui procure un revenu supplémentaire.

1. Introduction

Deposition of organic wastes in landfills is now forbidden in several European countries. Governments prefer most of the sewage sludge and the organic waste to be recycled to agriculture. This means that the farmers will play an important role in meeting these challenges.
Up to now, the farmers' role in recycling systems has been of a passive character, just receiving, without charge, a waste product from a treatment plant. However, this article presents a solution that might be more attractive, also taking the cash-flow into account. It is a small-scale system, independent of sewer pipelines and sewage treatment plants. The basic idea is to make the farmer an active operator who earns a real income from the environmental business. The operational responsibility is given to that party who has the greatest interest in creating sufficient control routines to ensure the waste quality, that is, the farmer himself.

The solution requires farmland suitable for spreading the processed organic wastes. In high livestock density regions with farmland already heavy loaded with manure, it would be a problem to further increase the nutrient supply. By making the waste business economic attractive, some farmers can replace livestock production with a recycling business.

2. The recycling system

The wastes are handled and treated as liquid in a completely closed system, as shown in figure 1. Food waste and septic sludge is stored in tanks close to the dwellings for one to two years. After collection, the material is sanitised and stabilised in a thermophilic aerobic reactor at a temperature of 55-60 °C. The pathogens are effectively reduced. The treated material is stored until spreading on farmland during the growing season. The processing plant can be located on the farm and can be operated by the farmer who can, therefore, generate an extra income.

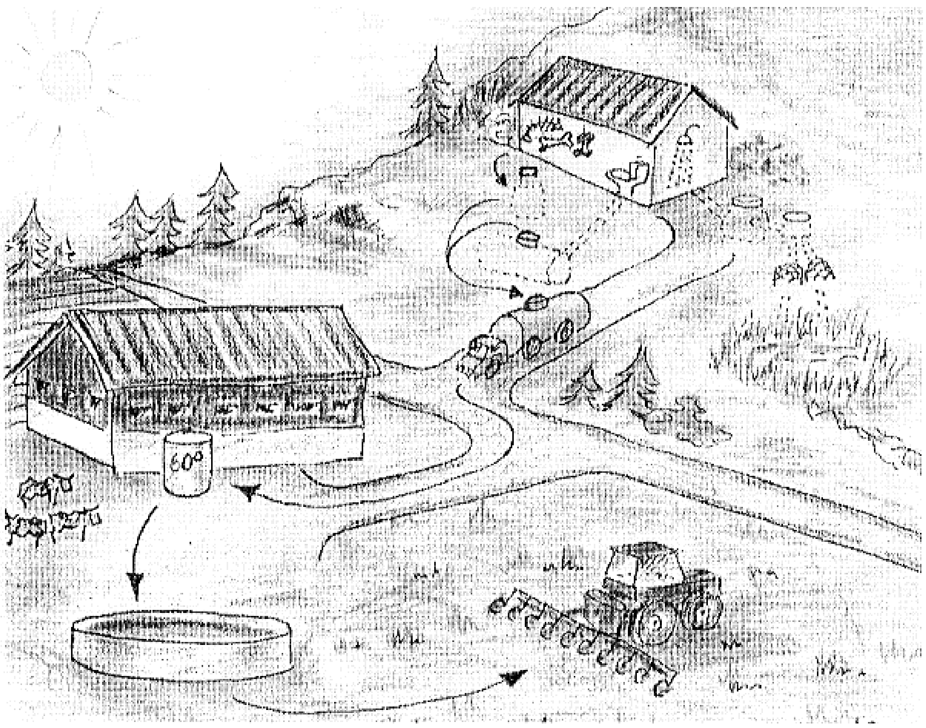

Figure 1.
A farmer-operated system for recycling food waste and septic tank sludge to agriculture. The wastes are handled as liquid. They are transported from the dwellings to a processing plant located at the farm and applied to farm land during growing season.

<u>Food waste</u>

The food waste has to be sorted in the homes. In Norway, the food waste from private households is not used as feed for pigs, due to its low nutrient value and risk of health problems caused by fungal toxins. Instead, it is considered as a source of plant nutrients and a soil improver. Commonly, the food waste is handled as solids by collecting it in a bag in the kitchen, carrying the bag to a bin outside, and waiting for the refuse collection truck to pick up the bags once a week during summer, and once every second week during winter. (Figure 2). The frequent collection of small amounts of waste is necessary due to odour problems.

To improve the logistics and user acceptance, whilst reducing transportation costs and loss of nutrients, a liquid route is now being developed in a collaborative project between the Agricultural University of Norway and Vera Miljø Ltd. By storing food waste in a closed, sub-surface tank, the biomass produces acids that decrease pH to below 5, thereby conserving the waste. (Figure 2). Very little degradation takes place, and gases such as hydrogen sulphide and methane are not produced. A one-year trial demonstrated that there were no problems with freezing, odour, flies, and other vectors. The biomass was emptied by a tanker (Sæther, 1996).

Since the food waste is stored at the source for a long period (one to two years), source control–analysing the tank content before emptying–might be introduced without causing a high annual cost. If the stored waste is contaminated, it must be handled via the "hazardous waste route" at a much higher cost to the householder than with the "agriculture route".

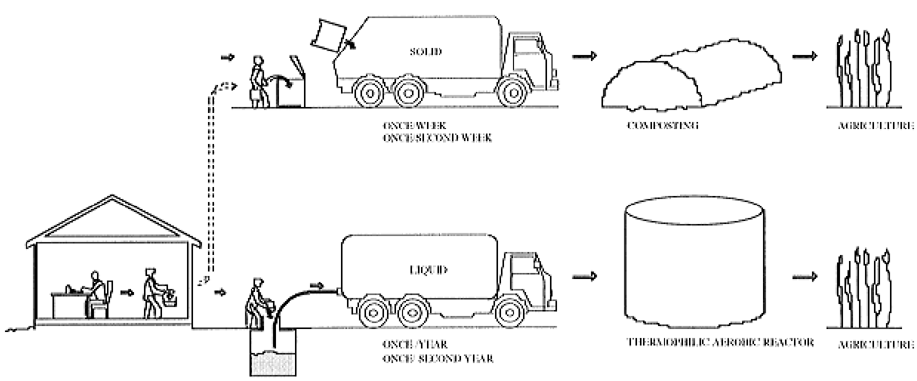

Figure 2.
Food wastes–solid or liquid? The liquid route improves the logistics, reduces transportation cost, reduces loss of nutrients, and improves user acceptance.

Sanitation and stabilisation in a thermophilic aerobic reactor

The Norwegian regulations require municipal sludge to be sanitised and stabilised before spreading onto farmland. This treatment can be undertaken in a thermophilic aerobic reactor. Such a reactor has been developed in a collaborative project between the Agricultural University of Norway and Alfa Laval Agri Ltd. (Skjelhaugen, 1998). The operating parameters are: semi-continuous treatment of liquid with TS from 2 to 10%, hydraulic retention time of 7 d and processing temperature of 55 to 60 °C. In its commercial form the reactor has been made in two sizes, with capacities of 2.5 and 4.5 m^3/d, respectively. No ammonia or odour is released from this one-stage, fully insulated reactor, and no energy is added for heating the biomass. The reactor is especially suitable for small and localised plants, and is often operated by farmers. (Figure 3).

Figure 3.
A commercial plant in Meldal community for processing septic tank sludge and source separated food waste before applying it to farmland.
It consists of a covered pre-storage tank, a thermophilic aerobic reactor, and a post-storage tank. The plant is located on a farm.

Application to agricultural land

A slurry application technology, developed by the Agricultural University of Norway and Moi Ltd., injects liquid wastes directly into the ground. By creating a pressure of five to eight bars and shooting small volumes of liquid into the ground, the injector ensures that the material is not exposed to air. Instead, it is placed directly into the plant root zone in the soil. Hence, low amounts of ammonia are released into the atmosphere (Morken and Sakshaug, 1996). The spreader can be connected to a flexible rubber pipe for direct transport of the liquid from the storage tank, if it is located near the farm land. This gives high spreading capacity, and low soil compaction.

3. The economy

The economy for a local farmer-operated system is given in table 1. Labour needed for operation and spreading is about 400 h/year, or one day a week. The gate fees for the waste to be processed are critical for the economic balance. Fees less than NOK 150/m^3 sludge make a negative profit, but the profit rises very quickly as the fees increase. The fertiliser value of the processed biomass contributes to the profit, but is less important than the fees. The most profitable option is based on source separation of both household wastewater and food waste, see tables 1 and

2. Such solutions might become more common in the future, as they are especially profitable with respect to environmental aspects (Refsgaard 1997).

Investments					
Covered pre-storage 200 m^3		180			
Thermophilic aerobic reactor with a capacity of 4.5 m^3/d		540			
Post-storage 1500 m^3 (one year storage capacity)		280			
Pump, strainer, sieve, instruments, etc.		200			
Spreading equipment		100			1,300
Annual costs					
Depreciation 20 years		65			
Interest 6%		39			
Maintenance and service		30			
Energy consumption 35 kWh/m^3 biomass, NOK 0.5/kWh		26			
Analyses		15			175
Annual income (gate fee examples)	*Gate fee*		*Option 1*	*Option 2*	*Option 3*
Income from sludge and blackwater	0.2/ton		300	274	273
Income from food waste	0.4/ton		0	50	55
Fertiliser value	0.007/kg N		11	15	53
Income			311	339	381
Salary for operation and spreading (income - cost 175)			136	164	206

Table 1.
The economic balance for a farm operated recycling system for household wastewater sludge, source separated blackwater and source separated food waste, based on treatment in an thermophilic aerobic reactor, NOK 1000. Options 1, 2, and 3 refer to table 2.

In addition to processing and spreading, the farmer can transport the waste materials from the dwellings to his farm. Typically the annually income for such a service is about NOK 200,000, based on an emptying fee of NOK 300 to 500 per dwelling. With an investment of about NOK 250,000 and annual capital and running costs of about NOK 50,000, the payment for labour is NOK 150,000. About half a man year is needed per year.

4. Contamination risks

Inorganic contaminants such as heavy metals are not removed in the aerobic process. Therefore they must be kept outside the recycling system. However, several analyses indicate that normal food waste, blackwater, and septic tank sludge contain low concentrations. As shown in table 3, the contents in food waste and blackwater was below the strict limit values for class I waste (Ministry of Environment 1996), which can be applied in amounts up to 4000 kg TS/ha. Septic tank sludge was acceptable for application rate of 2000 kg TS/ha (class II). It is important that the recycling system includes a means of source control, to ensure the quality of the waste to be used for new food production. Contaminated material has to be excluded from the agriculture route.

Waste source	Processing plant	Application to agricultural land
Option 1. Recycling septic tank sludge from tanks with overflow		
From **750 dwellings** - with septic tanks of 4 m^3 which are emptied every second year without dewatering the sludge. The overflow from the tank, and thereby some N and K, flows to the ground.	Capacity per year: **1500 m^3 septic sludge** Septic sludge with 1.7% TS (Sæther 96) and nutrient content, % of TS: N 6.2; P 1.4; K 2.6 and nutrient content, kg/m3: N 1.1; P 0.2; K 0.4 TS is near the lower limit for successful processing. A small supply of other organic wastes is recommended.	To be incorporated into the soil on land for growing cereals or grass, to be included in fertilising plans. Norwegian sludge regulations allow up to 2000 kg TS/ ha year, i.e., **12.8 ha** spreading area. Application rate per ha: 117 tonnes sludge, 128 kg total-N, 23 kg P and 47 kg K.
Option 2. Recycling septic tank sludge from tanks with overflow and source separated food waste		
From **685 dwellings** - with septic tanks of 4 m^3 which are emptied every second year without dewatering the sludge. The overflow from the tank, and thereby some N and K, flows to the ground. - with source separation of food waste. 70 kg/person year, 2.5 person/dwelling and volume weight 0.95 makes 0.18 m^3 waste/dwelling year	Capacity per year: **1370 m^3 septic sludge** **126 m^3 food waste** Septic sludge with 1.7% TS (Sæther 96) and nutrient content, % of TS: N 6.2; P 1.4; K 2.6 Food waste with 28% TS (Norin 1996) and nutrient content, % of TS: N 2.1; P 0.5; K 1.1 Mixture with 3.9% TS and nutrient content, kg/m^3: N 1.4; P 0.3; K 0.7	To be incorporated into the soil on land for growing cereals or grass, to be included in fertilising plans. Spreading based on 2000 kg TS/ha year. Farmland for application: **29.3 ha**. Application rate per ha: 51 tonnes sludge and food waste, 71 kg total-N, 15 kg P and 35 kg K.
Option 3. Recycling source separated blackwater from closed tanks and source separated food waste. Observe.: new toilet with very low water consumption.		
From **757 dwellings** - with source separation of wastewater. Blackwater is stored in closed tanks and emptied yearly. No nutrients are lost to the ground. 0.73 m^3/person year, 2.5 person/ dwelling makes 1.8 m^3/dwelling year (Sæther 1997) - with source separation of food waste. 70 kg/person year, 2.5 person/dwelling and volume weight 0.95 makes 0.18 m^3 waste/dwelling year.	Capacity per year: **1363 m^3 blackwater** **137 m^3 food waste** Blackwater with 3.4% TS (Sæther 1997, use new toilet) and nutrient content, % of TS: N 14.4; P 2.1; K 1.9 Food waste with 28% TS (Norin 1996) and nutrient content, % of TS: N 2.1; P 0.5; K 1.1 Mixture with 5.6% TS and nutrient content, kg/m^3: N 5.0; P 0.8; K 0.9	To be incorporated into the soil on land for growing cereals or grass, to be included in fertilising plans. Spreading based on 2000 kg TS/ha year. Farmland for application: **42.3 ha**. Application rate per ha: 35 tonnes sludge and food waste, 177 kg total-N, 28 kg P and 32 kg K.

Table 2.
Key-data for a farmer-operated recycling system based on processing 4.5 m^3/d in a thermophilic aerobic reactor. Three options with different combinations of domestic wastewater sludge and food waste are given. They represent a step-by-step implementation of the system.

Metal		Limit values *)		Food waste		Septic tank sludge	Balckwater	
		cl.I	cl.II	1)	2)	1)	3)	2)
Copper	Cu	150	650	13	48	367	101	42
Zinc	Zn	400	800	24	141	611	351	260
Cadmium	Cd	0.8	2	0.1	0.3	1.4	0.6	0.2
Mercury	Hg	0.6	3	0.1.	0.1	2.7	<0.8	0.4
Nickel	Ni	30	50	2.2	10	32	4.6	2.4
Lead	Pb	60	80	10.6	26	25	7.2	5.2
Chrome	Cr	60	100	2.6	53	13	5	2.6

*) Ministry of Environment 1996, class I allows application of 4000 kg TS/ha, class II 2000 kg TS/ha
1) Sæther 1996 (Norway); 2) Norin 1996 (Sweden); 3) Sæther 1997 (Norway)

Table 3.
Content of heavy metals in source separated food waste, septic tank sludge, and source separated blackwater from private households, mg/kg TS.

5. Conclusion

The results so far can be summarised as :

- *The wastes are converted to a hygienic and stable liquid product.*
- *No nutrients, including ammonia, are lost on their way from households to farm land.*
- *Odour is not a problem.*
- *The product is well suited as organic fertiliser for cereal production.*
- *Source control is possible at the level of the individual house.*
- *Quality control of the reused materials is made by the farmer himself.*
- *The farmers labour payment for treatment and spreading is NOK 100,000 - 200,000 a year, from about 750 dwellings. In addition, similar payment can be generated from transport service.*
- *The recycling business can replace livestock production, and thereby reduce the nutrient supply to farmland without reducing the farmers' income.*

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