THE IMPORTANCE OF AGRICULTURE IN GLOBAL WASTE MANAGEMENT

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ABSTRACT

Each year 2-4 billion people dispose of their solid waste by uncontrolled dumping. The majority of these are located in developing countries and generate waste with high organic content, typically 60-80% by weight is putrescible. Whilst some work has been done in the major cities in these countries to manage waste in a controlled manner it has not been possible in the smaller cities Uncontrolled dumping leads to significant emissions of methane and CO_2 as a result of the anaerobic processes in the dumped waste. A series of small community projects in Brazil has demonstrated an appropriate methodology for collecting this waste, composting it and using it in agriculture. These were initially set up to generate income via recycling and the produce a material to enhance soil fertility. Additional aspects which have been realised subsequently are the savings in greenhouse gas emissions (equivalent to more than 20 tonnes of CO_2 per day for a population of 15,000) and the sequestration of the carbon in the soil which also has substantial environmental gains. The Kyoto carbon accounting period for sequestration of 100 years does not reflect the benefits to be gained in shorter sequestration periods in the soil which effectively increase the reservoir of soil organic carbon thus reducing the rate of release back into the atmosphere. If the small communities were able to trade their emissions savings on the international market this could generate substantial income to offset the costs of implementing effective waste management practices.

Keywords: *waste, carbon trading, agriculture, composting.*

INTRODUCTION

In the European Union we value the environment very highly both in a local and a global sense. Our enthusiasm in this area is epitomised by the huge range of legislation designed to both improve and limit damage to the environment. One particular piece of legislation, the Landfill Directive (EC, 1999) is intended to reduce the negative impact on the environment from landfilling of waste: limiting landfill gas generation and controlling its release are key drivers behind the Directive. As a result key features of the Directive are the progressive reduction of the amount of biodegradable waste going to landfill linked to the requirement to control emissions from the landfill.

As we are only part way into the life of the Landfill directive it is difficult to estimate how far we have progressed in making the stringent targets it sets for reducing biodegradable wastes. There is clear doubt as to whether we will make the gas control targets which requires control measures on all new landfills and on most of the existing ones by 2007. An EC report published in 2001 (EC, 2001) showed official estimates for gas control measures in place for Austria (33%), Spain (23%) and the UK(90%). Unofficial estimates for Greece were as low as 10% and up to 90% of the wastes in controlled sites for Germany. Table 1 summarises some of the findings of the EC report in relation to gas control in the EU for 2001.

Since May 2004 a further 10 states have become member of the EU and it is likely that in most cases they come at the lower end of the spectrum in relation to gas controls in place at landfills and waste management generally. Nonetheless the EU with its population of 450 million would be considered in the top division in terms of its environmental management, technologies and practices. If we add this population to that of the other top division members such as the USA, Japan and selected parts of Asia Africa and South America then the population covered is still likely to be less than 2 billion. At a current estimated world population in excess of 6 billion this potentially leaves a great deal of poorly managed waste.

***Table 1**. Some estimated landfill gas control parameters in the EU (EC 2001).*

Parameter	Range (%)	EU average
% of waste in landfill sites with gas control	10 – 90	68 %
Methane collection efficiency	20 - 70	54 %
Landfill gas used for energy	20 - 73	60 %

Things might seem a little desperate in terms of what we do for the other 4 billion with limited resources. There are however several factors which work in our favour:

- labour costs are low;
- soil quality is often poor so any soil improvers, such as compost, are much sought after; and
- the characteristic of waste in developing countries has a high organic fraction

The implication of an increasing population is the growing pressure on land, in 2002 food was needed for an extra 2.2 billion people compared to 1972 (GEO 3, UNEP 2003). In meeting the growing food demand of a growing population, unsustainable agriculture practices have been pursued, leading to the degradation of land and the environment resulting in poor soil quality, pollution of surface water, removal of natural vegetation etc.

With the stringent environmental laws on waste management and atmospheric emissions, agriculture, and specifically agricultural land can be an important element in the global waste management strategy.

EMISSIONS FROM WASTE

There are very few end points for waste and these are principally:

- incineration – gases to atmosphere
  – ash to landfill or reuse
- recycling – avoidance of carbon use
- composting – gas release mainly CO_2
  – carbon sequestrated in soils (short term?)
- landfill – gas release
  – carbon sequestrated in the landfill (long term?)

The systems are normally selected base on economics and public acceptability, however, when viewed in relation to greenhouse gas release the picture is somewhat different. Figure 1 attempts to show the rate at which carbon is released from some of these waste treatment options. Incineration, for example, will release the carbon contained in waste in a matter of minutes, principally as CO_2.

Composting is a relatively rapid process and a substantial proportion of the carbon is released in a 3–6 month period depending on the process. If the compost is used in agriculture then the remaining carbon will be released over a much longer period of several years. It is unlikely, however, that the 100 year sequestration period used in some models of greenhouse gas emission would apply to any significant fraction of the carbon in waste derived compost.

Landfill has several phases of operation in relation to the biodegradable components of municipal solid waste. During the filling phase both aerobic and anaerobic processes can take place, but when the filling is complete the processes within the landfill itself are entirely anaerobic. The gases produced in the anaerobic process are principally methane and carbon dioxide. Some of the incoming waste, such as lignin, will remain in the landfill for a long period without degrading, essentially becoming long term sequestered carbon.

Figure 2 translates the carbon released into equivalent amounts of CO_2 based on its Global Warming Potential (GWP), which means for example that the CH_4 has an impact approximately 21 times that of CO_2. The illustration in Figure 2 shows the large potential greenhouse gas impact of uncontrolled landfills which are essentially what the majority of the waste dumps are in developing countries.

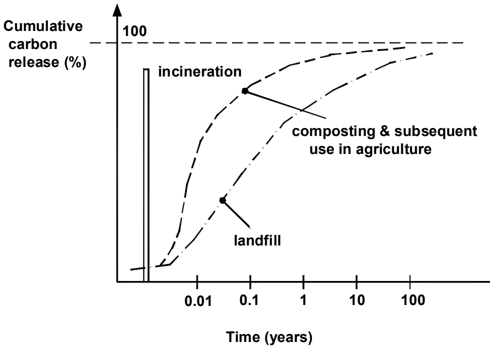

Figure 1. *Release rates of carbon from different waste management methods*

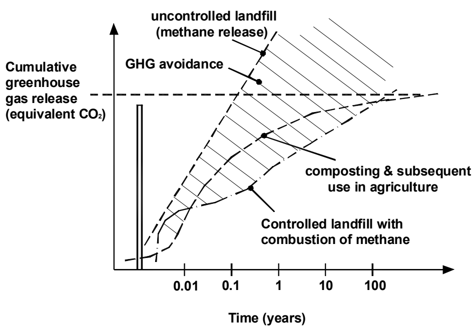

Figure 2. *Cumulative gas release from different management methods - based on methane having 21 times the impact of* CO_2

SEQUESTRATION

In the EC waste report a figure of 8% sequestration has been used on a 100 year basis, but the authors of that report been careful to set out the many variables and report on estimates ranging from zero to 22% for this time horizon. The factors which can affect the long and short term sequestration include:

- type of organic material – lignin likely to remain longer than more degradable components;
- method of application – incorporation below the soil surface facilitates storage as soil organic carbon;
- temperature and moisture in the soil;
- farming practices – decay increases with tillage; and
- availability of clay minerals to form complexes with the humus.

Whilst it can be appreciated why the 100 year period has been used we need to consider whether the use of waste derived composts or other organic wastes in the soil reduces the GHG impact of those wastes. If we consider the case of the burning of biomass to produce energy then we have CO_2 from the atmosphere which has been incorporated into the biomass perhaps over many years in the case of trees. If that CO_2 is released back into the atmosphere within 30 minutes then the atmospheric level of CO_2 must increase by a greater amount than if the CO_2 was released from biomass degrading more slowly over several years in the soil. Even though this carbon was not being sequestered for 100 years by using a slower release mechanism the CO_2

in the atmosphere should potentially be lowered. The carbon not going immediately to atmosphere is used to build up a carbon reservoir in the soil which we can represent it by the following equation:

$$C_t = C_i + C_w + C_a + C_f + C_e + \Delta S \quad (1)$$

Where

C_t = Carbon stored in the soil at time t

C_i = Initial level of carbon in the soil

C_w = Carbon added to the soil with organic waste and/or waste derived compost

C_a = Carbon lost to the atmosphere as a result of biodegradation in the soil

C_f = Carbon removed as a result of farming/cropping

C_e = Carbon lost with the soil as a result of erosion

ΔS = Change in carbon stored in the soil

In equation 1, provided that the value of ΔS is either increasing or is stable, then the effect of adding waste derived composts to the soil will be to reduce the impact of these wastes on green house gas emissions. This assumes that the biodegradation in the soil is aerobic, or if it is anaerobic that any CH_4 formed is oxidised in the soil prior to release to atmosphere. Lal (2004) stressed the importance of soil organic carbon in both improving soil yields and reducing the release rate of greenhouse gases. He makes no reference to the need for a 100 year sequestration period and estimates that by increasing the amount of carbon in the soil (increasing ΔS) it should be possible to offset 5 to 15% of the global emissions. This benefit is only part of the gain as by increasing the organic matter in soil we also improve its productivity.

There is a wide variation in waste composition between countries and within countries so in looking at a global picture it is difficult to making very many general statements about global waste. However, if we consider Table 2 we can see that although there are many differences between the EU and typical developing economies the proportion of biodegradable carbon in the waste (principally in kitchen, garden and paper waste, with a proportion in the 'other' fraction) comes within the same banding.

Table 2. *Comparison of domestic waste composition in the EU and developing economy countries (% by weight - source EC 2001, Jaramillo 2002 and PAHO-WHO 1998).*

Waste type	**EU**		**Developing economies**		**LAC** [e]
	Range	**Average**	**Low income**	**Med income**	
Food/garden [a]	21 - 47	31	40 - 85	20 - 65	27 – 71
Paper [b]	16 - 44	29	1 - 10	15 - 40	6 – 25
Plastic [c]	3 - 18	8	1 - 5	2 - 6	3 – 20
Glass	5 - 22	11	1 - 10	1 - 10	1 – 10
Metal	2 -8	5	1 - 5	1 - 5	1 – 10
Other [d]	3 - 29	15	1 - 40	1 - 30	1 - 32

Notes:(a) contains a mixture of readily degradable and more resistant carbon which affects the duration of sequestration (b) medium/low degradation rate so potential for longer term sequestration (c) long term sequestered carbon, if not incinerated - mostly from oil sources (d) depending on the source and location this can either be highly organic or contain substantial amounts of ash making it difficult to generalise about degradation rates.(e) LAC = Latin American and Caribbean countries

EMISSIONS TRADING SCHEMES

Most of the developing countries in the world are not amongst the major producers of greenhouse gases,. In general the industrialised countries are responsible for the current and historical GHG emissions from sources such as fossil fuels. The United Nations Framework Convention on Climate Change in acknowledging this, divided countries into Annex 1 and non-Annex 1. The Annex 1 countries are the industrialised and OECD countries, which have contributed most to GHG emissions but are also the countries with a greater financial and institutional capacity to address climate change. The convention places non-legally-binding constraints on greenhouse gas emissions on Annex 1 countries, so that they substantially reduce their own emissions to the 1990 levels. The Kyoto protocol was introduced to review the commitments and set legally-binding targets to all Annex 1 countries which ratified the Protocol. In order to allow countries to effectively meet these emission reduction targets without jeopardising national economic growth, the Protocol introduced flexible mechanisms aimed at cutting the cost of emission reductions schemes. These mechanisms are the ***joint implementatio***n, the ***clean development mechanism*** and ***emissions tradin***g. For example, if a particular industrialised country is committed to reducing its greenhouse gas emissions and is unable to achieve its Kyoto targets by in-country changes it can purchase "allowances" on the international market. Whilst this market is not as yet fully developed there is some limited trading going on and the rates are based on one tonne of CO_2 or the gases equivalence.

In relation to the waste industry, one of the most common examples of this is in the management of landfill gas. The majority of the gas is a mixture of methane and carbon dioxide. In order to estimate the impacts of emitted gases they are often referred to in terms of their global warming potential (GWP). The baseline used is carbon dioxide and the GWP of other gases is referred to in terms of the equivalent CO_2 impact. For example one kg of methane has 21–23 times the GWP of one kg of CO_2 over a 100 year time period.

In relation to a landfill by collecting and burning the methane, either flaring off or using it for power generation, the majority of the carbon release to the atmosphere is as CO_2. A site operator who sets up a gas management scheme on a particular site is then able to sell the GWP he has saved by releasing only CO_2 after combustion and not methane with its much higher GWP.

Table 3 shows the GWP for different gases commonly released in the waste and agricultural industries. It is interesting to note the differentiation between biogenic CO_2 (from renewable resources) and CO_2 from fossil fuel sources or products from it, such as plastics made from oil.

Table 3. *Global warming potential (GWP) of gases commonly associated with biodegradable wastes (taken from EC 2001).*

Emission	Origin	Trend	GWP (100 yrs)
CO_2 – fossil source	Combustion of plastics	Increasing	1
CO_2 – short cycle	Combustion and respiration of biomass	Stable	0
CH_4 – short cycle	Anaerobic decomposition of biomass	Increasing	21
N_2O	Combustion processes and N metabolism in soils	Increasing	310

WASTE COLLECTION AND DISPOSAL IN DEVELOPING COUNTRIES

A large proportion of the waste in many developing countries is readily biodegradable (see Table 2), however a substantial proportion of it is never formally collected and even that which is collected is not properly disposed of. As an example if we look at South America some of the system characteristics can be summarised as in Table 4.

***Table 4**. Some data on waste management in Latin America and the Caribbean countries (PAHO-WHO 1998)*

Collection coverage	70–85% in large cities 50–70% in medium and small cities
Landfilling	Majority of collected waste goes to open dumps (>70%) Few landfills with any form of gas control
Uncontrolled dumping	Includes domestic, hospital and hazardous waste
Waste scavengers	An estimated 200–300,000 people 10 – 30% being children
Living on waste sites	Approx. 45,000 in Brazil alone Many cases food scavenged from waste

WASTE COMPOSTING AND RECYCLING IN DEVELOPING COUNTRIES

In situations where there is no management of the municipal solid waste the normal practice is for it to be either burnt or dumped in an uncontrolled manner where the organic material degrades anaerobically. Realising the potential health hazards associated with waste and also the potential benefits of its proper reuse schemes have been set up to properly manage various waste streams. An example of this is the work developed at the University of Vicosa in Brazil by Professor Pereira-Neto in the early 1990s which focused specifically on small cities with populations up to 10-15,000 and has been implemented it in over 100 cities since that time (Pereira-Neto 2001). This particular system puts the emphasis on:

- involving the city council and local communities in the development and implementation of the scheme;
- composting the organic fraction of the waste (50-70% by weight of the waste);
- separating and recycling components of value, e.g. paper and metal;
- employing local people at the plant – often those who used to scavenge on the waste dump – with minimum need for mechanical equipment.

By moving to this type of system there are several gains both locally and globally which include:

- improved collection coverage for the city – often close to 100%
- the aerobic composting system which does not produce methane associated with the previously used anaerobic dumping sites;
- compost is available for agricultural use to increase the soil carbon and improve production;
- income is generated to offset some of the operating costs; and
- there are reduced health risks with the closing of the uncontrolled dumps.

The original driver behind schemes such as the example given for Brazil was to improve waste management and reduce the health risks associated with the days of uncontrolled dumping. However, it is realised now that by switching from a system of anaerobic dumps to one of aerobic composting there has been a substantial saving in terms of greenhouse gas emissions by going from emitting CH_4 (GWP = 21) to emitting mostly CO_2. This has perhaps provided us with an additional advantage of this type of management scheme which may also generate external funding through emissions trading.

A fundamental underlying requirement for schemes such as these is the need for a market for the compost, which in most cases will be agriculture. We mentioned previously the global gains to be had from sequestering carbon in the soil but this will not generate a local market for the materials. The local market relies on local farmers seeing the benefits in terms of improved soil structure and productivity and the experience in Brazil is that these improvements are relatively easy to demonstrate.

FUNDING WASTE MANAGEMENT SCHEMES THROUGH EMISSIONS TRADING

One of the problems in establishing waste management systems, even the low cost ones like the example given for Brazil, is obtaining funding for what is generally the lowest priority infrastructure provision after water supply and sanitation. However, if it was possible to trade the emissions saved by implementing schemes in small communities then this could perhaps generate some financial support. The only small schemes reported for South America are concerned with the planting and preservation of forest areas. Currently most of the emissions trading with developing economies related to wastes covers the control of landfill gas emissions either flaring the gas or generating power from it, and these are all schemes in medium to large cities which require large investments. For small scale investments there needs to be clearer methodologies and legal frameworks to promote smaller emission trading schemes.

If we consider a city of 15,000 people in Brazil as an example then based on the expected generation rate for biodegradable waste and a GWP factor for methane of 23 we could expect to save between 20 and 40 tonnes of CO_2 equivalent per day. On the basis of a trading rate around €10 this could generate a substantial income for the community without taking any account of the possible sequestered carbon following compost use in agriculture. There would of course need to be validation processes in place and a certain level of in-country bureaucracy to contend with which would take some of the funding but it could still leave substantial amounts for local use. Given that in many of these areas the basic salary is often less than €100 per month then the low cost systems advocated by researchers such as Pereira-Neto (2001) could be readily paid for by income from this source.

CONCLUSIONS

Current practices of uncontrolled waste dumping release considerable quantities of methane to the environment because of the degradation which takes place anaerobically. By composting this waste and releasing mostly CO_2 it should be possible to substantially reduce the impact of poor waste management practices on greenhouse gas emissions.

It is unrealistic to look at a 100 year sequestration horizon when dealing with organic waste as the different management practices can make a major difference on the release rate of these gases which is important in the shorter term. In addition it is beneficial to both the atmosphere and soil productivity if we build up the levels of soil organic content to a level significantly higher than exists at present in many parts of the world. The commitment of agriculture in using composted organic wastes is a key requirement for the success of this practice.

It should be possible by changing waste management practices in developing countries to trade the savings in greenhouse gas emissions on the international market. This should generate sufficient funds to offset some, if not all the costs of establishing and running the new systems.

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