Waste Management 33 (2013) 2811–2815

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

A Glance at the World

Edited by Giulia Cerminara

This column comprises notes and info not subjected to peer-review focusing on waste management issues in different corners of the world. Its aim is to open a window onto the solid waste management situation in any given country, major city or significant geographic area that may be of interest to the scientific and technical community.

Estimation of potential methane production of agricultural sector in Korea

Biomass is carbon rich materials including all plants, animals, nutrients, excrements and bio-waste from household and industry (Deublin and Steinhauser, 2011). Unused or discarded biomass residues from the agricultural sector have a potential energy resource and they can be a source of greenhouse gas (GHG) emission causing a significant environmental problem. Potential energy production from crop and animal residues is globally estimated to be about 34 EJ out of a total 70.

In Korea, it is estimated that over 50 million tons of organic wastes are produced every year in agricultural sector out of over 80 million tons (MIFAFF, 2010). The interest in biomass in a resource-poor country like Korea is, therefore, increasing rapidly.

Many studies on anaerobic digestion in Korea have focused on pig manure and food wastes such as substrates. Methane, the main product from this process, is a fuel source as well as a greenhouse gas and it can be used as an energy source for electricity and heat generation, which can reduce the cost of treatment and methane emissions into atmosphere. Several studies on the agricultural biomass estimation were also conducted in Korea based on the crop-cultivated area, with an elemental analysis and heating value and in the USA using the dry weight of crops and harvest index followed by the Food and Agriculture Organization (FAO) and the U.S. Department of Agriculture (USDA).

The main objective of this study was to calculate the amount of potential methane production based on total amount of production and characteristics of agricultural biomass in Korea.

Data collection and sampling

In order to make a comprehensive inventory for estimating the potential methane production from livestock waste, agro-industrial waste and crop residues, a field visit was firstly conducted to characterize the waste management systems used and to verify the information collected through other sources by sampling the agricultural biomass. Secondary data including national statistical data was used for estimating the methane yield from Korean Statistics.

Calculation of agricultural biomass inventories

The annual total dry weight of agricultural crop residues was derived from the rural development administration's (RDA) report. Total and volatile dry weights of livestock manure per year were calculated based on the statistics on agriculture and forestry. The average fresh manure productions for cattle, dairy, swine, layer and broiler chickens were 8.0, 24.6, 1.6, 0.15, 0.13 kg/head-day, respectively. The average weights of these animals adopted were 350, 473, 111, 1.6 and 1.3 kg, respectively. The annual total dry weight and volatile dry weight for each type of fresh manure were calculated by multiplying the total annual mass of fresh manure by the average percent solids contents (3.8% for cattle, 3.9% for dairy, 4.1% for swine, and 20.3% for poultry) and by the average volatile solids fraction (2.7% for cattle, 2.8% for dairy, 2.6% for swine, and 19.8% for poultry) according to National Institute of Agricultural Science. The total volatile dry weight for all agricultural manure was used for the calculation of potential CH_4 production for this category. The unit factor including manure, urine, and wastewater for each livestock was obtained from the result of pilot scale experiment conducted in RDA in Korea.

Calculation of potential methane production

Using the Tier 2 method in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, methane potential production for each livestock commodity group (M) and existing manure management system (S) and climate (k) combination are estimated as follows using Eq. 1:

$$CH_{4(M)} = (VS \times H_{(M)} \times 365\ \text{days/yr}) \times [B_{o(M)} \times 0.67\ \text{kg}\ CH_4/\text{m}^3\ CH_4 \times MCF_{S,k}] \quad (1)$$

where $CH^{4(M)}$ = estimated methane potential production from manure for livestock category M, kg CH_4 per year, $VS_{(M)}$ = average daily volatile solids excretion rate for livestock category M, kg volatile solids per animal-day, $H_{(M)}$ = average number of animals in livestock category M, $B_{o\ (M)}$ = maximum methane production capacity for manure produced by livestock category M, m^3 CH_4 per kg volatile solids excreted, $MCF_{(S,k)}$ = methane conversion factor for manure management system S for climate k, decimal.

In order to calculate the methane production from agro-industrial wastes and crop residuals, two different calculation methods

0956-053X/$ - see front matter © 2013 Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.wasman.2013.09.007

Table 1
Population of representative livestock in Korea.

Livestock	Populations (heads)					Increase rate (%)
	2005	2006	2007	2008	2009	
Cattle	1,818,549	2,019,516	2,200,573	2,430,389	2,634,705	44.9
Dairy	478,865	464,056	453,403	445,754	444,648	−7.1
Swine	8,961,505	9,382,039	9,605,831	9,087,434	9,584,903	7.0
Poultry	109,627,646	119,180,640	119,365,107	119,783,943	138,767,543	26.6

were used based on data availability. When information on the ultimate analysis was available, theoretical methane production was adapted for calculating the methane production. Otherwise, Eq. 3 from IPCC guideline was used for calculating the methane production.

$$C_aH_bO_cN_d + \left(\frac{4a-b-2c+3d}{4}\right)H_2O \rightarrow \left(\frac{4a+b-2c-3d}{8}\right)CH_4 + \left(\frac{4a-b-2c+3d}{8}\right)CO_2 + dNH_3 \quad (2)$$

For crop residuals, the calculation method from IPCC guideline was adapted because information available for carrying out an element analysis of crop residuals was lacking.

$$CH_4\ Emission = \Sigma_i(M_i \cdot EF_i) \cdot 10^{-3} - R \quad (3)$$

where CH_4 Emission = total CH_4 emissions in inventory year, Gg CH_4, M_i = mass of organic waste treated by biological treatment type i, Gg, EF = emission factor for treatment i, g CH_4/kg waste treated, i = composting or anaerobic digestion, R = total amount of CH_4 recovered in inventory year, Gg CH_4.

For the emission factor of anaerobic digestion, wet weight basis emission factor, 1 g CH_4/kg waste treated was used. In addition, two assumptions were made to calculate the methane production with crop residuals. In Korea, the rice straw was collected at 2257 thousand tons (42%) of total yield and then used for feeding forage to cows. If this is used for alternative energy production, it might be assumed as follow; first, 50% of total production of each crop residual is collectable from the field, and second, the utilization rate of crop residuals for anaerobic digestion ranges from 10% to 30% of collectable crop residuals.

Results and discussion

From 2005 to 2009, the number of cattle, swine, and poultry increased by about 44.9%, 7.0%, and 26.6%, respectively, from 2005 to 2009 while the number of dairy cattle gradually decreased during this period across the (Table 1).

The amount of calculated waste from livestock manure was 37,521 thousand t/y. Among the waste types, swine waste produced the highest amount of waste at the level of 17,881 thousand t/y, accounting for 47.7% of the total waste amount. The waste produced from cattle occupied 28.4%, 10,674 thousand t/y of the total amount followed by dairy with 14.1%, 5303 thousand t/y of the total waste amount. The least amount of waste was calculated with poultry because of the lower unit factor compared to other livestock.

In rice and barley categories, the estimated total biomass was 4,186,427 and 24,904 t/y for rice and common barley, respectively. In the pulses category, the biomass related with soybeans and peanuts was investigated for each province in Korea, and summed together to calculate the total amount (Table 2).

Estimated total biomass for soybeans was 128,071 t/y and 12,296 t/y for peanuts. In the vegetable category, four vegetables such as watermelon, carrot, garlic, and green onion were investigated to estimate the organic biomass amount. The estimated total biomass was 10,444 t/y for watermelon, 1165 t/y for carrot, 60,899 t/y for garlic, and 33,518 t/y for green onion. Among them, it was shown that biomass of garlic was the highest. Estimated total biomass for sweet potatoes was 62,960 t/y, and 36,118 t/y for potatoes. Three different oil seed crops such as sesame, perilla seeds, and rapeseed were investigated to estimate the biomass amount. It was estimated that the total biomass amount was 103,190 t/y for sesame, 112,758 t/y for perilla seeds, and 4338 t/y for rapeseed.

Table 2
Summary of total organic waste from agro-industry wastes and crop residuals.

Sources		Organic waste amount (Thousand t/y)	References
Rice barley	Rice	4,186	NAAS (2007)
	Common barley	25	"
Pulse	Soybean	128	"
	Peanut	12	"
Vegetables	Watermelon	10	"
	Carrot	0.4	"
	Garlic	22	"
	Green Onions	13	"
Potato	Sweet potato	63	"
	Potato	36	"
Oil-seed	Sesame	103	"
	Perilla seed	113	"
	Rapeseed	4	"
Sub-total		4715	"
Agro-industrial wastes		844	MOE (2007)
Total		5559	

Total methane potential production from agricultural waste was estimated at 435,511 t/y. Among the three categories, estimated methane production from animal manure showed that the highest amount occupying 71% of total methane production, and this was followed by 28% of agro-industrial wastes. Methane emission from crop residuals showed the least amount because of the level of recyling efficiency for animal feeding stock.

Conclusion

Potential methane production in Korea was estimated in the agricultural sector. The total of generated waste from livestock, agro-industrial waste and crop residues was 43,080 thousand t/y in Korea. Estimated potential methane production from animal manure in 2007 totaled 309,154 t/y.

Among them, poultry generated the highest methane potential production with total estimated methane production of 256,149 t/y followed by 138,378 t/y from diary waste. For crop residues and agro-industrial wastes, estimated methane production was calculated as 707 and 125,650 t/y, respectively. The total methane potential production was estimated at 435,511 t/y for livestock, crop residues and agro-industrial waste in Korea.

The results of this study suggested that methane emission from livestock manures occupied the highest portion in the agricultural