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A Glance at the World

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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.

National model of methane generation for estimation of methane emissions by solid waste disposal in Ukraine

Municipal waste management in Ukraine is inefficient and in need of reforms. Up to 12 million tons of municipal solid waste (MSW) is generated in Ukraine annually: 96% of wastes are disposed at the landfills and dumpsites and the rest 4% is incinerated, recycled or reused. Amount of collected waste was relatively stable within last six years. The level of reuse and recycling is low; there are no industrial facilities for composting of organic domestic and green solid wastes.

In accordance with National Inventory 1990–2009 the sector's contribution into the total amount of GHG emissions in Ukraine was 9740 thousand tons $CO_{2\text{-eq.}}$ in 2009, that equals 2.4% from the total amount of GHG emissions. Solid Waste Disposal on Land (SWDL) is the most significant GHG source in waste sector of Ukraine. In 1990 methane emission from solid waste was 327.2 thousand tons and it grew up to 414.7 thousand tons in 2009. Waste sector is the only sector in the national inventory that has shown an increase of GHG emissions in the reported period.

Calculation method

In accordance to 2006 IPCC Guidelines for National Greenhouse Gas Inventories there are Tier 2 and Tier 3 methods of emission reduction calculation. Tier 2 method uses the IPCC first order decay (FOD) model with default parameters. Its application requires good quality country-specific activity data on current and historical waste disposal at solid waste disposal sites (SWDS). Historical waste disposal data for 10 years or more should be based on country-specific statistics, surveys or other similar quality sources.

Tier 3 method is based on the use of good quality country-specific activity data and the use of either the FOD method with (1) nationally developed key parameters or (2) measurement derived country-specific parameters. The inventory compiler may use country-specific methods that are of equal or higher quality to the above defined FOD-based Tier 3 method. Key parameters should include the half-life (or methane generation rate constant), and either methane generation potential (L_o) or *DOC* content in waste and the fraction of *DOC* which decomposes (DOC_f). These parameters can be based on measurements.

Experimental study

Recently several studies of LFG generation were executed by Ukrainian companies Scientific Engineering Centre (SEC) Biomass, Renewable Energy Agency in cooperation with the company SCS Engineers from USA (Matveev and Puchnyuk, 2008). Those studies were performed with the support of US EPA Landfill Methane Outreach Program (LMOP), as a part of Methane to Markets Partnership (M2M), an international initiative to assist partner countries to reduce global methane emissions.

Similar pump test program were conducted at several Ukrainian landfills. The objective of the pump tests was to refine the projections of the LFG model generation and recovery model based on LFG flow and methane concentration data. The pump tests consisted of the installation of at least three vertical extraction wells, several monitoring probes, collection piping, and blower powered by electricity. Normally active pumping duration was up to six weeks.

As a result of these activities Ukraine Landfill Gas Model (Version 1.0) was developed by SCS Engineers (Stege, 2009) with support of SEC Biomass. This computer model applying FOD equation, estimates LFG generation and recovery from SWDS for Ukrainian conditions. These results make possible to use Tier 3 with development and application of the national model of methane emissions from SWDS.

National model of methane emission from MSW

The proposed national model of methane emissions from SWDS follows the structure of IPCC model dividing MSW into six separate categories. The FOD equation is used to calculate methane emissions from SWDS. According to this method annual methane emissions from MSW deposited to SWDS during the current and the previous years are calculated as follows:

$$Q(t) = \sum_{j=1}^{m}\sum_{i=1}^{n} A \cdot k_j \cdot MWS_{T,j,i} \cdot MWS_{F,j,i} \cdot L_{0,j,i} \cdot e^{-k_j(t-x)} \quad (1)$$

where $Q(t)$ is the amount of methane generated during the period t, m^3; k_j is the methane generation rate constant of MSW of fraction j; $A = \frac{1-e^{-k_j}}{k_j}$ is the normalizing factor for summation adjustment; MWS_T is the general amount of MSW of fraction j generated in year i, t/year; MWS_F is the portion of MSW deposited at MSWS in year i;

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t is the index of calculation year; o is the period for which input data are to be added, in years; and $L_{0,ji}$ is the potential of methane generation for fraction j in year i, t CH_4/t MSW, calculated by equation:

$$L_{0,j,i} = DOC_j \cdot DOC_F \cdot F \cdot 16/12 \cdot MCF_i \quad (2)$$

where DOC_j is the total amount of organic carbon in year i in fraction j that can be biologically decomposed, t C/t MSW; DOC_F is the portion of carbon participating in decomposition; F is the methane content in biogas; 16/12 is the conversion factor for converting carbon emission in methane emission; and MCF_i is the methane correction factor in year i.

The amount of methane generated in year t is obtained by summing up the results for all years of the period x. After subtracting the methane that was recovered during the year t and taking into account oxidation factor, the amount of methane emitted into the atmosphere during the year can be obtained:

$$Q(t)^{em} = [Q(t) - R] \cdot (1 - OX) \quad (3)$$

where $Q(t)$ is the methane emissions, t; R is the recovered methane, t; and OX is the methane oxidation factor.

The MWS_T value is determined based on the reported total amount of MSW and organic industrial waste (OIW) amount deposited to MSWS and available data for waste composition in Ukraine. National methane generation rate constant (k_j) recommended for the model is determined using the maximum correlation criterion with the Ukraine Landfill Gas Model (Stege, 2009).

For 1990–2010 GHG Inventory amount of MSW deposited at MSWS was taken directly from the statistical data provided by Ministry for Regional Development, Construction, Housing and Communal Services of Ukraine. For example, in 2010 amount of MSW deposited at MSWS equals to 10,561st tons. Information about industrial waste generated by agriculture and food industries was also taken from official statistical documents. These data are available in the country from 1994. Three waste streams were taken into the account: MSW collected and reported, agriculture and food treatment waste deposited at the MSWS and unregistered waste delivered to the unauthorized landfills. The latter was assumed as 10–15% from reported MSW.

Methane correction factor reflects the conditions of waste decomposition (aerobic or anaerobic ones). In the controlled or managed landfills disposal must comply with the modern technology of waste management (disposal layer by layer, compacting, coverage, landfill gas (LFG) recovery and utilization, leachate treatment). Several Ukrainian landfills could be considered as managed one. The share of waste deposited at those landfills was evaluated as 25.9% in 2010. Solid waste streams were divided in three categories: managed landfills (MCF = 1.0), unmanaged deep landfills (MCF = 0.8) and unmanaged shallow landfills (MCF = 0.4).

To implement the IPCC methodology using a national model for calculating methane emissions from MSW it has been proposed to divide MSW into six separate categories, each of which has its own combination of methane decay, rate constants k_j, and degradable organic carbon DOC_j. These parameters were defined for each of six waste categories, as presented in Table 1.

Morphological composition of MSW delivered to MSWS in Ukraine has variable character. It depends on the structure of population employment and income rate, settlement size as well as season of the year. It is obvious that certain long-term trends present in the input of individual fractions, however careful assessment of these trends require good quality data for long periods of time. To use the multi-component models of LFG generation is necessary to allocate an appropriate number of waste fractions, each of which may have individual combinations of the parameters DOC and k. It should be mentioned that for slow degraded fraction an information regarding long time periods are needed. For example, using the values of k = 0.024 is necessary to use time-series of at least three half-lives, the half-life in this case is 29 years, and the duration of the series should not be less than 87 years. Thus, the transition to multi-component model has led to the need for restores data on amount and morphology of solid waste in Ukraine since 1900.

Table 1
MSW categories, corresponding methane decay rate k_j and DOC_j.

	MSW categories	*k*	*DOC*
I	Wood	0.024	0.43
II	Paper & cardboard	0.048	0.40
III	Food waste	0.110	0.15
IV	Textiles waste	0.048	0.24
V	Garden and park (green) waste/other organic waste	0.070	0.20
VI	Nonorganic waste	0.00	0.00

Several waste composition studies were executed during 1990–2010 in Ukraine. Historical trends of waste composition were investigated with use of available publications.

Results and discussion

The comparison of the methane emissions estimations for 1990–2010 (Bereznytska et al., 2012) by national model of methane emissions with the previous results obtained by FOD IPCC method (Tier 2), showed that the difference in methane emission by two inventory versions lies in the range 3–9%. The national model of methane emission provides possibility to increase accuracy and to decrease uncertainty of methane emission estimation for purposes of GHG inventory.

Analysis of the methane emission sources shows that there is a big potential for methane emissions reduction in Ukraine. There is a strong need to increase the level of reuse and recycling as well as energy recovery from MSW in Ukraine. The typical existing practice is that source waste separation is typically not carried out. Some cities in Ukraine have installed experimental separate waste collection, which is mainly aimed at dividing waste into two fractions – recyclables and "gray" residues, but the total percentage of waste recycling is still very low.

Several scenarios of methane emissions reduction from anaerobic decomposition of organic matter at Ukrainian SWDS were considered. The most efficient way to reduce emissions from SWDS is prevention of waste. Simple reduction of landfilled waste by one per cent per year leads to the 25% emission reduction in 2050 in comparison with 2010. Increasing of production of bioenergy from organic-based waste before landfilling could provide 10–18% of emission reduction in 2050. Efficient source separation, increasing reuse and recycling of paper and cardboard could lead to 3–6% of emission reduction in 2050.

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