Югорский государственный университет, Ханты-Мансийск
Институт почвоведения и агрохимии СО РАН, Новосибирск
Институт лесоведения РАН, Москва
Университет Орлеана (Франция)
Национальный исследовательский Томский государственный университет

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METHANE EMISSION FROM LANDFILLS OF KHANTY-MANSIYSK REGION

A.F. Sabrekov[1,2,4], M.V. Glagolev[1,2,3,4**], I.E. Terentieva[1], O.R. Kotsyurbenko[2,5]*

[1]Tomsk State University, Tomsk, Russia
[2]Yugra State University, Khanty-Mansiysk, Russia
[3]Moscow State University, Moscow, Russia
[4]Institute of Forest Science (Russian Academy of Sciences), Moscow region, Russia
[5]Faculty of Biology, Moscow State University, Moscow, 119992, Russia
e-mail: * sabrekovaf@gmail.com, ** m_glagolev@mail.ru

Introduction. Atmospheric methane (CH_4) has multiple anthropogenic sources with high uncertainties, including rice production, ruminant animals, natural gas leakages, biomass burning, and landfills. According to global estimates, annual landfill CH_4 emissions constitute 1-2% of total anthropogenic greenhouse gas emissions. In both developed and developing countries with a history of landfilling, inventory estimates indicate that landfills can be nationally significant sources of atmospheric CH_4, for example, in the U.S., landfills are currently the third largest anthropogenic source of CH_4, after natural gas systems and ruminant animals (Spokas et al., 2011).

Russian landfills in boreal climate are investigated sufficiently less than landfills in USA and Scandinavia. Moreover, only chamber measurements of methane emission were conducted on Russian landfills while in USA, Sweden and Denmark micrometeorological remote sensing techniques were used for landfill methane flux estimates. It is important because flux chamber measurements are not feasible for landfills due to temporal and spatial heterogeneities in surface gas emissions across the site and the occurrence of several significant individual gas emission sources (Nozhevnikova et al., 2003; Terentieva et al., 2017). To our knowledge our study is the first attempting to estimate methane flux from Russian landfills using space averaging approach (Eulerian inverse modelling) in a cold season. Using this technique methane emission in municipal solid waste landfills of Khanty-Mansiysk region of two cities – Surgut and Khanty-Mansiysk – were investigated in the end of October 2016.

Site description. Two sections (of 3) of Khanty-Mansiysk municipal solid waste landfills (20 km to the east from Khanty-Mansiysk) were investigated: closed (i.e. waste deposition was finished in 2015, than section was covered with 20-50 cm soil layer) section (KM3) and active (KM2). Active section KM2 has area about 1.7 ha and height about 15 m. There is no vegetation; heavy mechanical graders distribute refuse on the roof of the section providing relatively flat surface. KM3 section has area of 1 ha and height about 15 m too. Surgut municipal solid waste landfill (8 km to the north-east from Surgut) has area 26.2 ha, total area of waste deposition sections is 12.9 ha. Two sections (of 3) were investigated: closed re-cultivated section (S1) and closed but not re-cultivated section (S2). Section S1 has area of 8 ha and height 25-30 m. After the end of waste deposition (in 2007) it was covered by 50 cm sandy soil layer and aeration tubes were installed into the roof of section (1 tube per 0.2 ha). In 2013 willow was planted on the roof of the section to prevent soil erosion. In 2016 summer section was covered by 50 cm layer of organic soil to provide intensive plant growth. Section S2 has area of 4 ha and height 25-30 m. After the end of waste deposition in 2013 it was covered by 20-50 cm layer of sandy soil, vegetation is absent. All sections were partly covered by snow, maximal depth of snow cover was 5 cm. Upper layer (10-30 cm) of landfill soil cover was frozen, while deeper horizons have positive temperature (in °C).

Methods. Eulerian inverse modelling was used for methane flux calculation (Глаголев и Сабреков, 2012; Terentieva et al., 2017). As an input data methane concentration on two heights (1.6 m and 5.7 m), frictional velocity and Monin–Obukhov length were determined with 10 min time step. Methane concentration was measured using gas chromatograph "Kristall-5000"

(CHROMATEC, Russia), equipped with flame ionization detector. Meteorological parameters were measured by 3-D sonic anemometer “WindMaster” (Gill Instruments, UK). Size of calculation domain was defined according to a GPS coordinates of each tower and satellite images of each landfill. For monitoring of surface methane concentration optical sensor Testo 316-Ex was used.

Results and Discussion. Results of seven measurement sessions are shown in the Tab. Obtained methane flux values varied from 0.5 to 3.8 $gCH_4 \cdot m^{-2} \cdot h^{-1}$. Spatial distribution of methane fluxes from different sections, obtained in October 2016 shows the same pattern as fluxes, obtained in August 2015 (Terentieva et al., 2017): flux from KM3 < flux from S1 < flux from KM2 < flux from S2. The only exclusion was found for measurements in KM2 section. Emission from this section was higher than from S2 section in August 2015 (Terentieva et al., 2017) but was less than emission from S2 section in October 2016. For all investigated sections emission in October 2016 was less than August 2015. It is in contradiction with idea about increasing of emission due to decreasing of the methanotrophy caused by cooling of surface soil layer. Decreasing of the emission can be explained with two hypotheses. First of them – methane flux can decrease because on frozen upper soil layer transport of methane is much slower. Snow and ice can lock pore space and cracks preventing methane migration from deeper layers. Second – cooling of upper layers can be strong enough to decrease methanogenesis in upper refuse layers. To proof this hypotheses temperature profile measurements are necessary.

Monitoring of near surface methane concentration showed that concentration on the cliffs of section are about one-two orders higher (depending on microtopography) than on flat surface of the section roof. Most probably it can be explained by overcompaction of the soil on the sections roof and shows that during cold season, when roof surface of the section is frozen, cliffs of the section can be stronger source of methane than roofs. In general, obtained values of methane emission are in good agreement with values, given in literature for landfills, situated in temperate and boreal climate zones (Mønster et al., 2015).

Limitations of inverse modelling approach. Basic idea of this technique is to deduce source information from measured concentrations at any height inside in the surface layer (Flesch et al., 2005). Flux determination is based on fitting of the calculated (using atmospheric transport model for current conditions) concentration values to measured concentration values. Our measurements showed that when turbulent mixing is strong (i.e. when frictional velocity and Monin–Obukhov length (by absolute value) are high enough), difference between predicted and observed concentrations is relatively stable and varies in the same narrow interval. When turbulent mixing becomes weak difference between predicted and observed concentrations becomes less stable and varies in wide interval. It can be explained by increasing influence of emission heterogeneity when turbulence is weak in the surface layer of the atmosphere. Plumes from hot spots of methane emission do not have enough time to be well mixed. It leads to unpredictable stochastic dynamic of methane

Methane fluxes from landfills of Khanty-Mansiysk region in 2016

Section	Tower coordinates	Date	Area, ha	Wind speed (at height 2 m), m/s	CH_4 flux, $gCH_4 \cdot m^{-2} \cdot h^{-1}$
KM2	61.04834° N, 69.37367° E	27.10	1.7	1.95	2.5 ± 0.3
KM3	61.04876° N, 69.37185° E	25.10	1.0	1.86	0.60 ± 0.1
		27.10		1.50	0.45 ± 0.1
S1	61.28425° N, 73.65005° E	28.10	7.9	1.40	1.0 ± 0.3
		29.10		3.17	0.80 ± 0.2
S2	61.28413° N, 73.64454° E	28.10	3.9	1.03	3.8 ± 0.7
		29.10		2.47	3.2 ± 0.4

concentration, which is not explained by atmospheric transport, and increases the uncertainty of flux calculation. Therefore, it allows to give a recommendation: very accurately use data obtained during periods of weak turbulence (when frictional velocity is less than 0.10-0.15 m/s (Massman and Lee, 2002)).

Regional flux estimate. If we suppose that half of all landfills of Khanty-Mansiysk Autonomous Okrug emits methane like old closed re-cultivated landfills while the other half like landfills with continuing waste deposition, according to our 2015 (Terentieva et al., 2017) and 2016 (this study) flux measurements total methane emission from landfills of Khanty-Mansiysk Autonomous Okrug can be estimated as 0.04 ± 0.02 $MtCH_4$/year. It is about 5% of total methane emission from West Siberian north and south taiga wetlands. Therefore even in the region with relatively low population density and extremely high wetland extension (30-40% of the total area, and wetlands are the main natural source of methane), contribution of landfills into regional methane emission can be substantial.

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