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Atmospheric Methane: Natural and Anthropogenic Sources

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Abstract

The analysis is made of natural and anthropogenic sources of methane emission into the atmosphere – one of the important greenhouse gases. New quantitative estimates of methane intake from wetland ecosystems, municipal solid waste landfills, agricultural production, and rapidly developing oil and gas industry are given. The dynamics of oil and gas industry development and possible losses of natural gas are analyzed in the chain: oil and gas exploration – production – transportation – underground storage. Quantitative estimates of methane losses in this chain indicate the leading role of oil and gas industry in the methane dynamics in the Earth's atmosphere over the last 50 years. The ways of reducing methane emission into the atmosphere are suggested.

Keywords: Animal husbandry: Methane emission sources: Methane in the atmosphere: Methanotrophs: Natural gas: Oil and gas industry: Underground gas storage.

Introduction

One of the most serious environmental problems of today is the continuous and significant increase of methane (CH_4) concentration in the atmosphere, which is considered to be a significant potential factor in the global climate changes (methane is the second most important greenhouse gas after carbon dioxide according to the Kyoto Protocol, as it accumulates the energy of infrared radiation 30 times more effectively than carbon dioxide). This simplest saturated acyclic hydrocarbon (colorless and odorless) is the main component of natural (77–99%), associated (31–90%), damp and marsh gases. It is non-toxic and produces narcotic effect only at high concentrations. The danger of its mixture with air is associated with the decrease in the concentration of oxygen. It forms explosive and combustible mixtures with air.

To prevent the growth and reduce the content of methane in the atmosphere, it is important to understand the sources of this phenomenon. However, there is no consensus on this point, in view of the fact that there are a lot of natural and anthropogenic processes with participation of methane. Since agricultural production (ruminant animals and rice sowing) is referred to as the main source of anthropogenic methane in the atmosphere, this paper aims to assess the current supply of methane into the atmosphere from the booming oil and gas industry and specify the ways to reduce the contribution of this factor.

Dynamics of Methane Content in the Atmosphere

Methane is present in the atmosphere in low concentrations (1.58–1.68 ppm), but its atmospheric content increases annually by 1% on average due to imbalance between the production and oxidation (Zavarzin and Clark, 1987; Blake and Rowland, 1988; Galchenko et al., 1989; Kallistova, 2007). Until the 17th century, the concentration of methane in the atmosphere remained almost constant, then it began to grow slowly and in the 1950s notably rapid growth in methane concentration began. Since that time, the rate of methane concentration growth in the atmosphere has almost doubled.

Since the beginning of industrial development the concentration of methane in the atmosphere has increased from 700 to 1775 ppb (Climate…, 2016), changing significantly in the diurnal and seasonal cycles (maximum at night, in autumn and winter). Some researchers noted a slowdown in methane concentration growth in the atmosphere in 2000–2006 (Dlugokencky et al., 2006; Rigby et al., 2008). Nevertheless, a continued growth of methane concentration at a rate of 0.4–1, 45% per year in the territory of Poland was noted in 2008-2011 (Stepnevska, 2012).

The data collected by NASA (see Figure 1) confirm the given variations in the dynamics of methane content in the atmosphere in 1984–2014. From the 1980's to 1992 the amount of methane did not grow more than 12 ppb per year. Then, for about a decade, the growth slowed down and did not increase 3 ppb per year. In 2000–2007 methane concentration in the atmosphere leveled off. Since 2007 it has started growing again, and so far the growth is 6 ppb per year.

The increase in methane concentration in the atmosphere is unambiguously associated with the increase in population (see Figure 2) and human economic activity (Global..., 2016). At the same time, the growth of methane concentration occurs almost twice as fast as the growth of carbon dioxide.

The growth of methane concentration in the atmosphere is countered by the chemical processes of its decomposition; the effectiveness of this process is not high (Bazhin, 2000). Methane leaching from the atmosphere is slow due to its low solubility in water. A more significant role in methane decomposition is played by methane-oxidizing bacteria (methanotrophs), which "work" in the aerated upper soil layers.

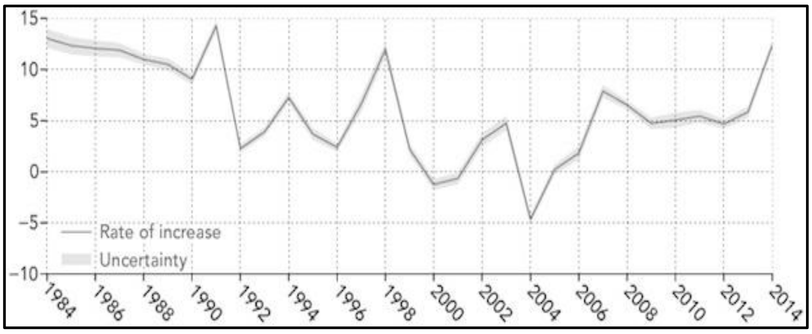

Figure 1. Dynamics of the global annual increase of methane concentration in the atmosphere (ppb/yr) according to NASA (Gismeteo, 2016)

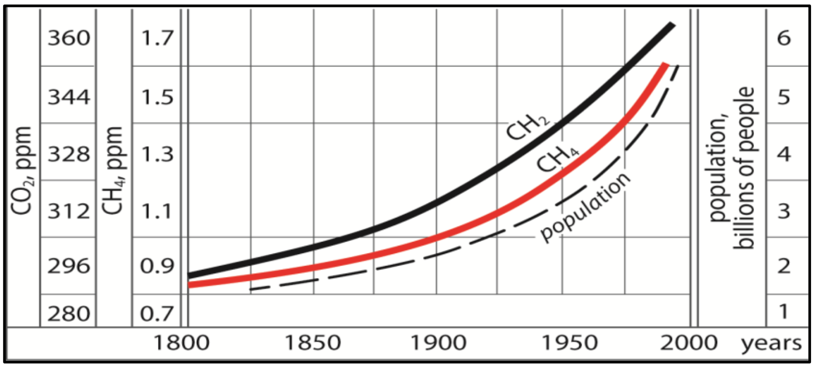

Figure 2. Changes in carbon dioxide and methane content in the Earth's atmosphere and population growth through time (Global…, 2016)

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So far there is no unambiguous answer regarding the specific reasons for methane concentration growth in the atmosphere. Some scientists believe that the tropics have become more humid and, correspondingly, the amount of gas emission has increased. Someone talks about the impact of changes in agriculture. Others point to the rapid growth of gas production in the world, including the rectification boom of natural gas in North America and its periodic leakage.

The global distribution of methane on our planet is shown in Figure 3. Methane concentration is higher in the Northern Hemisphere, due to more powerful natural and anthropogenic sources of methane.

Sources of Atmospheric Methane

Estimates of atmospheric methane emissions from various sources vary considerably. Table 1 shows the estimates of the amount of methane released to the atmosphere from some natural and anthropogenic sources of both biogenic and abiogenic origin, given in the research paper (Barber and Ferry, 2001).

According to (Anderson et al., 2010), the total intake of methane into the atmosphere is 566 million tons per year, among them 37% come from natural sources, of which wetlands prevail (~170 million tons). At the same time, the share of anthropogenic sources is ~357 million tons, which corresponds to estimates of anthropogenic methane emissions of 330–335 million tons given in the publication (Semenov et al., 2018). The main sources of these emissions are ruminants, waste and wastewater, as well as the use of fossil fuels.

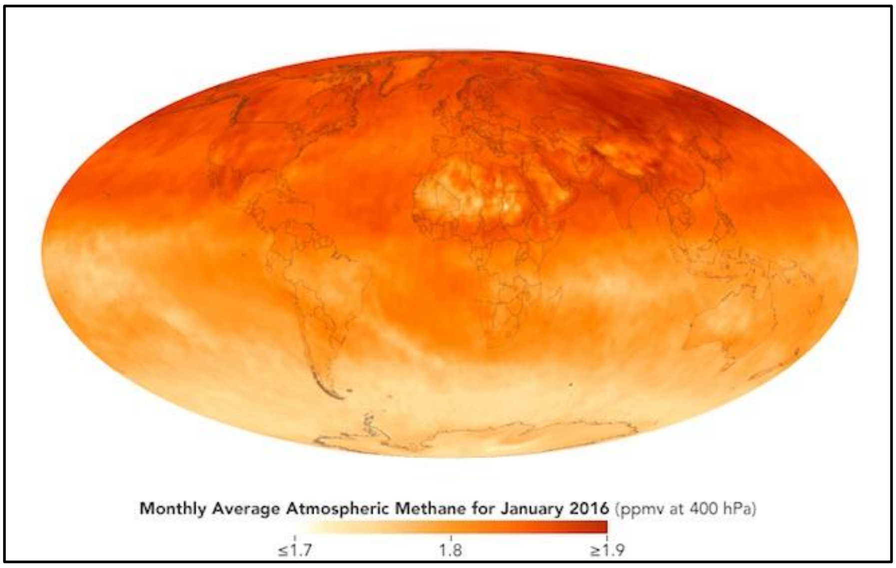

Figure 3. Distribution of methane as of January 2016 in the surrounding airspace at an altitude of about 6 km according to NASA (Strange behavior…, 2016)

Table1. Sources of atmospheric methane

Sourceofmethane	***Annual CH_4 emission, million tons***
Biogenicsources	*302–665*
Wetlands	120–200
Termites	25–150
Oceans	1–20
Tundra	1–5
Ricefields	70–120
Livestockraising	80–100

Landfills	5–70
Abiogenicsources	*48–155*
Methanegashydrates	2–4
Volcanoes	0.5
Coalmining	10–35
Naturalgasleakage	10–30
Industrial losses and leakage from wells	15–45
Biomassburning	10–40
Automobiles&Motorcycles	0.5
Biogenic and abiogenic sources	*350–820*

The main natural sources of methane in the atmosphere are *marsh systems* – up to 30% of all sources of supply by average. However, due to large-scale drainage of bogs, the share of this source in total methane emissions is reduced and cannot be the reason for the observed growth of its concentration in the atmosphere. Thus, nowadays about 60% of the bogs in the woodlands of Russia and Belarus have been drained. Over the past century the area of wetlands in Belarus has decreased from 4.13 to 2.3 million hectares due to their transfer to agricultural lands. In Europe, ~ 20% of marshes have disappeared, and more than 50% do not produce peat. In the Netherlands and Denmark, less than 1% of mire has remained in the natural state, and in Finland 60% of the marshes has been drained for forestry purposes (Vompersky, 2005).

Another participant in the methane migration system in the atmosphere is *gas hydrates* (methane hydrates), huge untapped reservoirs of which are found at great depths in the permafrost zone reservoirs. On the one hand, the formation of gas hydrates can be perceived as methane escape from the atmosphere: on the other hand, taking into account their instability in case of increasing the temperature, they can be considered to be a possible source of methane emission into the atmosphere.

The question of a possible abrupt release of methane from gas hydrate deposits during global warming (the so-called "methane bomb") is under discussion; there is information (Shakhova et al., 2007) on current emissions of methane into the atmosphere in the Arctic Ocean in the form of "methane geysers", the global scale of which is to be clarified.

The main sources of anthropogenic methane supply are solid domestic waste (SDW) landfills, agriculture, and oil and gas industry (fields' development, natural gas transportation, storage and utilization).

A wide range of gaseous compounds is formed at *the solid domestic waste (SDW) landfills*, the main of which is biogas, consisting mainly of methane (40–60%) and CO_2 (30–45%), several percent of nitrogen, and a large number of trace pollutants. Active gas production at the landfill site begins after its closure, usually in a few years, when a balanced methanogenesisis formed, and lasts for 20–30 years, dying out gradually. According to IPCC, methane emissions from the landfills surface are 35–73 million tons per year, which corresponds to 6–12% of the total and 10–20% of anthropogenic emissions of this gas into the atmosphere. In the world practice, systems for biogas extraction and collection are used at solid waste landfills. In Russia, such systems are not implemented even at large landfills, since the use of biogas is restrained by the cost of generated electricity, which is 2–2.5 times higher than electricity produced by burning fossil fuels or at nuclear power plants (Kallistova, 2007).

An important source of methane in the atmosphere is *agricultural industry*. Primarily, it is *animal husbandry* (livestock), since the life-sustaining activity of many animals (food fermentation by cattle, sheep, camels, pigs) is accompanied by the release of methane. For example, a hundred liters of methane per day can be formed in the gastrointestinal tract of a cow. *Rice growing* is another source of methane. In the conditions of waterlogging during a significant part of the season a swamp gas is formed at paddy-fields under anaerobic conditions similar to bog systems. According to the estimates given in Table 1, these two processes together contribute approximately 150–220 million tons of methane per year.

Another important anthropogenic source of methane emissions into the atmosphere is *oil and gas industry* developing rapidly in recent decades. Global natural gas production is continuously growing (see Figure 4). Since 1950 it has grown more than 18 times! The reason for this is the high environmental friendliness of this energy source: natural gas is 75% more favorable than diesel fuel and 50% – than gasoline, the exhaust gases of methane engines are less harmful to humans and practically do not contain carcinogenic components.

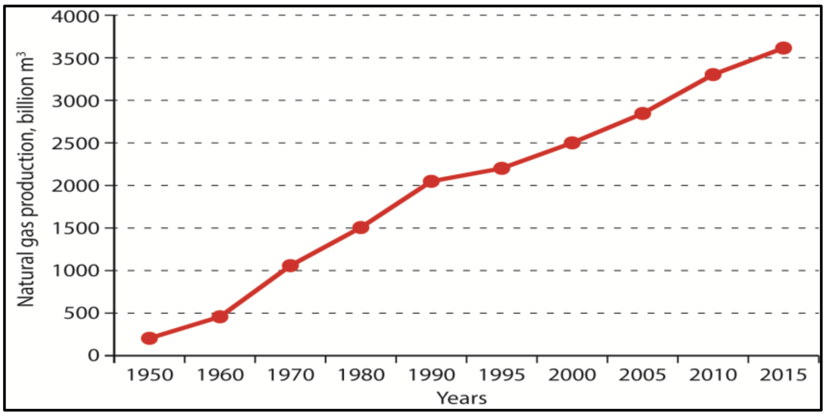

Figure 4. Global natural gas production dynamics, billion m^3

In the course of drilling, transportation of oil and gas, removing and incomplete burning of associated gases, leakage from underground gas storage facilities (UGSs), and in emergency situations a huge amount of natural gas enters the atmosphere. Table 1 shows that in total oil and gas industry delivers 25–75 million tons of methane into the atmosphere annually (i.e. about 9% of total discharge).

However, let us consider this source in detail.

Methane in the Atmosphere and Development of Oil & Gas Industry

According to some authors (Shishko, 1991) annually about 83 % of all the produced gas goes into pipelines, i.e. up to 17% of sour gas (or 440 million tons) escapes. And this is only the beginning of gas supply chain!

The methane production cycle begins with ***geological exploration***, which can sometimes lead to emission of significant quantities of natural gas into the atmosphere as a result of process losses and accidents (see Figure 5).

As a rule, the emergency situations are of a one-time nature and probably do not contribute much to the emission of methane into the atmosphere. For all the uncertainty of this source of methane, we can agree with the data given inTable 1 indicating that the losses amount to 15–45 million tons per year.

Figure 5. Well Darvaz or "Door to the Underworld" (crater diameter ~ 60 m, depth ~ 20 m) – man-made landmark of modern Turkmenistan. It was formed in 1971 as a result of a failure during a faulty drilling of an exploration well, and since then, the ignited natural gas is continuously burning day and night (Darvaz…, 2016)

At the stage of ***oil production and treatment*** the so-called associated gas (AG) appears, up to 2/3 consisting of methane. Depending on the production area, 1 ton of oil produces from 25 to 800 m³ of associated gas. With global oil production of about 4.4 billion tons per year (2015), the estimated amount of associated gas is up to 1.3 billion tons per year. To meet the required standards the associated gas (AG) is separated from oil and is subsequently either disposed or burned (see Figure 6).

Figure 6. Typical AG flaring

According to the data provided by the Ministry of Energy of the Russian Federation (2016), the norms for losses of associated gas (AG) produced in the country were reduced from 1.14% in 2010 to 0.33% in 2016. Minimum estimates of current global methane losses in the composition of AG are about 10 million tons of methane a year.

According to the Ministry of Natural Resources and Ecology of the Russian Federation, out of 55 billion m^3 (about 39 million tons) of annually produced AG in Russia, only 26% (14 billion m^3) is recycled, 47% (26 billion m^3) *is used for the oilfield needs or is written off as technological losses* and 27% (15 billion m^3) is burned in flares. It is not known what part of the 26 billion $m^3$of AG is released into the atmosphere; if 50% of the given value is taken as a basis, then the estimate is 13 billion m^3, or about 10 million tons per year only for Russia. It is important to note that the level of AG beneficial use has increased significantly in the recent years (see Figure 7).

In this case it is necessary to take into account the incomplete flaring of gas, which in addition to unburned methane, gives off a whole complex of dangerous pollutants (active black, carbon monoxide, etc.). The volume of soot emissions during the AG flaring is approximately estimated as 0.5 million tons per year (Associated petroleum…, 2010). According to the executive authorities, the fraction of flare units equipped with AG measuring devices in Russia is about 50%. At the same time, in some regions less than 20% of flare units are equipped with AG measuring devices (Knizhnikov et al., 2015).

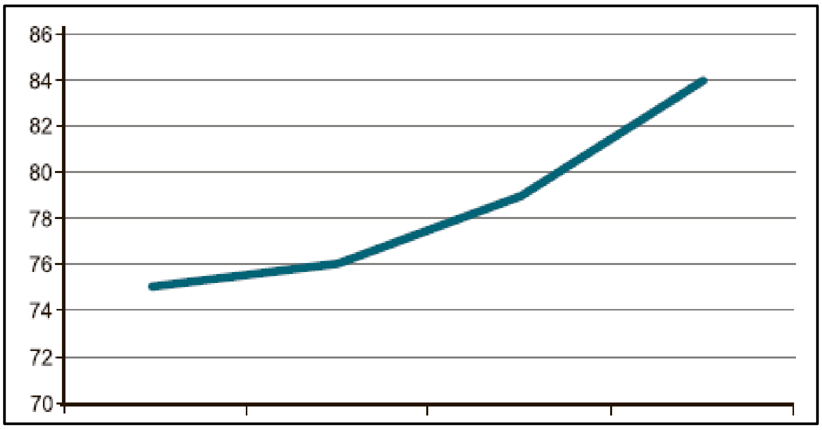

Figure 7. The level of AG beneficial use as a percentage of total AG resources in Russia in dynamics for 1911-2014 according to the Ministry of Energy of the Russian Federation (Knizhnikov et al., 2015)

It should be noted that AG flaringhas risen to such a level that it has become an important factor in light pollution (see Figure 8), as it can be observed in Western Siberia and the Sinai Peninsula (Egypt).

Figure 8. Combined space images of the Earth light pollution at night according to NASA, 2012. The arrowsshow a light spot in Western Siberia and Sinai in places of intensive oil production (Nighttime lights…, 2014).

In the near future, the planned production of gas hydrates will become an additional source of methane emission into the atmosphere. For instance, Japan Oil, Gas & Metals National Corp. (Jogmec) announced the beginning of trial operation of an underwater gas hydrate field (Smirnov, 2013); while the full-scale development of the field is planned after the development of production technology suitable for industrial use.

Natural gas losses during transportation (in pipelines). Significant losses of natural gas occur during the operation of transport gas mains equipment. It is the technological expenditure of gas occurring during the gas units' adjustment and testing, equipment installation and repair, various emergency situations. Part of the gas is lost due to imperfection of technological equipment or methods used in gas hubs. At the same time, gas expenditure and losses can be conditionally divided into explicit and implicit ones (Shishko, 1991).

Explicit losses can be detected by the sound, noticed due to manifestation of secondary characteristics, directly measured or calculated, knowing the parameters of corresponding technological process. The primary explicit losses in the linear part of the main gas pipeline are: gas leakage through fistulas, micro cracks, shut-off valves; losses during gas bleeding and blowing of pipes during the connection of bends, jumpers, pulse tubes and other technological lines; losses during periodic cleaning of gas pipelines' internal cavity; emergency losses and losses during the repair work associated with the pipeline sections' discharge.

At compressor stations the explicit gas losses occur mainly: in the course of bleeding and blow down of compressor piping during gas pumping units (GPA) start-ups and stops; during the purging of condensate collectors, dust collectors, pulse tubes of instrumentation and automation; losses in the system of seals of GPA superchargers and other equipment.

Quantitative ratios of the main types of losses in the main gas transport can be seen in Table 2, which proves that more than half of the gas losses (54–56%) occur due to a breach of tightness of the structures, and therefore this is the part of methane loss that enters the atmosphere. Totally, these losses amount to 894–988 million m^3, or taking into account the methane density (~0.72), to 644–711 million tons per year.

Table 2. The main types of natural gas losses during its transportation through the main gas pipelines (Harris, 2015)

Main causes of gas losses	***Losses, mlnm^3***	***Losses, %***
Gas losses during the repair of linear part	7–8	
Losses during the gas pipelines' rupture and destruction	170–180	18–19
Losses due to the gas pipeline leakage	80–90	
Losses due to the leaks in piping	340–350	35–40
Losses during the start-ups and stops	17–18	
Gas losses in dust collectors	200–250	22–25
Total	*894–988*	

Implicit (latent) losses and gas expenditure are difficult to detect and measure; their quantity can be determined only indirectly: by over-consumption of fuel gas at compressor stations while reducing the hydraulic efficiency of gas pipelines' linear sections; by deviations of GPA modes from optimal; fuel gas expenditure in the presence of overflows of compressed gas in the pipelines of injection and input communications of gas pumping units and compressor stations (CS); gas losses as a result of phase transformations in the gas pipeline (formation of the liquid phase and hydrates); leakage due to condensate and water formed in the gas pipeline during the cleaning and degassing in waste heaters; losses during the operation of regenerative GTUs at CS.

Approximately 24–27% of gas losses take place in the course of technological operations at compressor stations. The largest gas losses during the main gas pipelines' transportation occur when compressing the fuel gas (about 80% of this gas is burned in combustion chambers – these are productive losses, the remaining 20% is the unproductive expenditure of commercial gas). Reduction of such losses is a specific task and requires the development of special technologies.

Natural gas losses during the underground storage. At the beginning of 2016 680 underground gas storage facilities (UGS) with a total working capacity of 413 billion cubic meters operated in the world, which corresponds to 12% of global gas consumption in 2015 (Vinogradova, 2016). About 15% of natural gas is consumed from UGS in Russia, 20% –in Germany, 26%– in Italy, 29% –in France, 40% –in Ukraineand up to 70 % in Latvia (Polohalo, 2009).

As of 01.01.2010 in Russia the number of underground gas storage facilities in operation was 25 with the commercial gas volume – 64.0 billion m^3; the potential daily production at the beginning of the selection season (2009–2010) was 620 million m^3/day (Aksyutin, 2010).

During the UGS operation methane escapes through untight technological assemblies, through wells' construction elements, through leaky geological rocks overlapping the UGS, and also in the course of emergency procedures. For example, on October 23, 2015 a leak occurred in one of the 115 wells connected with huge underground natural gas storage in California in Aliso Canyon, the fifth largest in the US. Because of the accident 11 thousand people were evacuated; every day so much gas was in the air that one could fill a ball of the size of a football stadium. At the time of gas emission maximum activity the rate of methane emissions in the entire Los Angeles County doubled. The leak was closed on February 18; by that time almost 100 thousand tons of methane escaped into the atmosphere (Gismeteo, 2016).

Data on gas technological losses during its underground storage are inconsistent. There is some tentative information about the losses of 1.5–3% of active storage volume (Elizarova, 2011). At the same time, it is believed that geologic and technological structure of reservoir losses and gas expenditure at the UGS depends on the geological and field type of storage and its operation scheme. The most significant reservoir losses are typical for UGSmade in an aquifer of a flat-lying deposit, which may amount to about 50% of the total gas volume. For storages made in aquifers of anticlinal traps, the losses can amount to 30% of the total gas volume (Iskhakov, 2013). In this regard, the error in calculating the volume of gas in the reservoir by balance and volume methods, depending on the specific characteristics of the object, can amount to 20% of the total gas volume.

It is mentioned in one of the sources that at one of the gas storage facilities natural gas losses amounted to 1.5 billion m^3 over a 30-year period of operation (Bukhgalter et al., 2002). It means that annually 0.036 million tons of methane escaped from one UGS facility! At such rate, annually 24 million tons of methane will escape globally from 680 UGS. And probably, this is not the maximum value.

However, estimation of these losses is associated with great difficulties, since it is impossible to determine with sufficient accuracy the volume of gas in the storage. The total amount of gas losses in the storage system may not be revealed for a number of years until it becomes noticeable.

When seeping through the cover rocks not all methane directly enters the atmosphere, because some of it is oxidized by methanotrophic bacteria in the soil horizon. Calculations of methane leakage from artificial gas deposits prove that 6–10% of methane is retained by the soil mantle (Bukhgalter et al., 2017).

The activity of methane bacterial oxidation by soil is dynamic over time: oxidation does not occur in spring, it is maximum in summer, it decreases in autumn. The amount of methane emissions depends on hydrothermal conditions and on season, it also varies in dry and wet years. According to some researchers (Glagolev, Filippov, 2011), estimations of methane absorption by soil have very poor accuracy, which clearly indicates poor knowledge of the problem of absorption of soil methane. Nevertheless, it is believed that annual absorption of methane by soil in Russia is about 3.6 Mt/year, which falls within the estimates made by various authors.

The fact of methane emission through the rocks overlapping UGS is proved by the results of isotope studies of carbon in gases extracted from water samples taken from water wells near the Inchukalnskoe underground gas storage facility (Latvia). The calculations showed the availability of 40–75% of anthropogenic methane in different samples, i.e. the methane that was pumped into the UGS (Prasolov, Sergeev, 2005).

Summing up the results of the analysis, we can approximately estimate the amounts of methane (natural gas) entering the atmosphere as a result of oil and gas industry activities (excluding emergency situations). The data given in Table 3 show that the emission of methane (natural gas) into the atmosphere as a result of losses from global oil and gas complex can amount to 693–790 million tons per year, which is much higher than the values given in Table. 1. And this is without taking into account the emergency situations occurring over and over again in different countries!

Table 3. Estimation of methane (natural gas) emission into the atmosphere as a result of oil and gas industry activity

The main causes of losses	***Losses, mlntons/year***
Geologicalexplorationwork	15–45
Associatedgaslosses	10
Losses of natural gas during transportation (pipelines)	644–711
Loss of natural gas from underground storage facilities	24
Totallosses	*693–790*

Estimates of possible methane emission into the atmosphere as a result of oil and gas industry activity given in Table. 3 prove that we are facing the most powerful source of atmospheric methane replenishment, far exceeding all the biogenic natural sources combined.

Ways to prevent the growth of methane concentration in the atmosphere. *Non-productive methane losses during transportation* can be decreased by using modern equipment and special technologies: minimizing emergency gas losses at the linear part of main gas pipelines (MG) and compressor stations (CS); applying modern technologies for utilization of gas emissions from gas mains system; applying the technology of dusting the parts of pipeline systems without blowing into the atmosphere, reducing the consumption of fuel gas in off-design modes by optimizing the parameters of compressor station equipment; excluding the over-expenditure of fuel gas due to physical deterioration of equipment through reconstruction of compressor stations and modernization of gas compressor stations; improving the quantitative gas estimation, applying reliable methods of measuring the MG productivity.

Therefore, the primary task is to reduce large losses of gas through leaks during production operations, both in the compressor stations' piping and in gas pipelines' linear sections. To this effect, it is necessary to improve the design of the units in order to improve the tightness, as well as to seek methods and develop special instruments for locating gas leakages and their subsequent elimination.

To reduce natural gas losses it is important to use associated gas, which in Russia is largely due to the activities of SIBUR holding company, the largest producer in petrochemical industry. The decision of the RF Government No. 7 of 08.01.2009, which calls for bringing the level of associated gas utilization to 95%, contributes to the promotion of this initiative. In the US, Canada, France and other countries the laws have been passed prohibiting oil production and treatment without utilization of associated gas.

In case of *underground gas storage* an important factor for reducing the risk of losses is proper selection of UGS locations with a view to minimize reservoir losses, to prevent leakage of pipelines and production units, and application of the method of equipment purging without gas emission into the environment.

To prevent the risk of methane contamination resulting from UGS operation, specialists of Energodiagnostika LLC offered to use methanotrophs – bacteria that live on methane (Vlasov et al., 2015; Snakin et al., 2014). The patent "Method of ensuring environmental safety of underground gas storage facilities" (RU 2591118 C 2 dated 06.03.2014) was received. The substance of the proposal is to remotely monitor the methane content in the near-the-ground atmosphere and in the zones of piping assemblies. Based on the results of the monitoring, zones with high concentration of methane are treated with a suspension of methanotrophic bacteria in saline solution. Methanotrophic suspension is also pumped cyclically under a certain pressure and temperature into the critical zones of piping assemblies. This method allows lowing the concentration of methane and thereby reducing not only the risk of ignition, but also the pollution of the atmosphere taking advantage of one of the most effective greenhouse gases. Further development of this proposal can become a significant contribution to implementation of the World Pact to Stop Global Warming, approved on December 12, 2015 in Paris by 195 countries.

At the same time, the main task is to increase the efficiency of methanotrophic bacteria by activating the methanotrophs in natural conditions, as well as changing the ratio in their species composition in favor of methanotrophs that efficiently "work" at low temperatures.

Preliminary experiments with natural methanotrophs extracted from soil near the Inchukalnskoe UGS (Latvia) proved that the potential annual methane-oxidizing capacity of soil layer ~ 0.5 m is about 150 t/ha of methane. The analysis of methane-oxidizing ability of soils has proven the possibility of increasing the activity of natural methanotrophs, which undoubtedly can improve the environmental situation at the underground storage facilities by preventing methane emission into the atmosphere (Snakin et al., 2017).

Conclusion

The study of methane concentration dynamics in the Earth's atmosphere shows its steady growth, especially in the latest half a century, which results in an unreasonably high content of one of the most dangerous greenhouse gases in the atmosphere.

There are no natural sources of methane emission into the atmosphere (bogs, volcanoes, wild animals), that could be responsible for the observed growth in methane content in the atmosphere. Moreover, the role of these sources in methane formation is steadily declining.

At the same time, the dynamics of methane concentration in the atmosphere is obviously synchronous with the increasing human activity. Agricultural activity (livestock and rice growing) and oil and gas industry are among the main anthropogenic sources of methane.

The analysis of losses of methane (the main component of natural gas) at various stages of oil and gas industry activity proves that *total losses of natural gas associated with the possibility of methane emission into the atmosphere* amount to about 700 million tons per year (without taking into account emergency situations), which far exceeds all other sources of methane emission into the atmosphere.

Planned production of methane hydrates can also become the source of additional methane emission into the atmosphere.

It is quite natural that we are talking about the approximate estimates, taking into account the multivalued nature of the loss factors and sometimes the impossibility of their accurate calculation. But these estimates prove the growth of methane concentration in the atmosphere over the last 50-70 years with the steadily growing natural gas and oil production.

The decrease in the intensity of methane concentration in the atmosphere observed at the beginning of the current century can be fully explained by several reasons: the steady increase in the use of associated gas, the improvement of pipeline transport, and a slight decrease in the rate of gas production.

Nevertheless, there is much to be done in reducing the environmental risk associated with the growth of methane concentration in the atmosphere, which is largely due to the need to tighten the control of natural gas losses in main pipelines and piping assemblies, as well as the prospects for using methane-oxidizing bacteria (methanotrophs) in the places of uncontrolled emission of methane, especially in case of undergroundgas storage.

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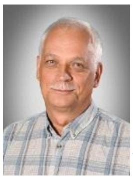*Valeriy V. Snakin* – Dr. Sci (Biol.), professor of Lomonosov Moscow State University, Head of Landscape Ecology Laboratory of Institute of Fundamental biological problems of Russian Academy of Science; head of Ecology Department of LLC «Energodiagnostika» (Moscow, Russia); snakin@mail.ru;zhizn_zemli@mail.ru

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