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THE INFLUENCE OF METHANE ON CLIMATE CHANGE

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ABSTRACT: The article presents a scientific analysis of the influence of methane on climate change. It has been shown that human influence is one order less than the impact of natural processes among which there is the circulation of the main greenhouse gas, H_2O. The constant amount of H_2O in the atmosphere is maintained by accelerating/decelerating the circulation cycle of water vapor. A similar mechanism of self-regulation has been shown in the article for methane as well. Its content in the atmosphere is adjusted by its natural short-period transformation in the atmosphere. A comparison of the methane impact on the climate based on analyzing the global warming potential and the potential for global temperature changes have shown that the methane equivalence coefficient in relation to CO2 can be estimated as 4-11 instead of 25 as it has been earlier evaluated. The analysis has shown that the methane circulation is a natural global process, and the human-induced egress of methane to the atmosphere has only a small effect on the climate. The influence of the oil and gas sector is 0.1% of the total emissions of greenhouse gases in the global evaluation and the share of methane of the Russian gas industry is 0.004%.

Keywords: Methane, Climate change, Greenhouse gases, Greenhouse effect, Carbon dioxide, Atmosphere.

1. INTRODUCTION

In recent decades, global climate changes have taken their place in the number of global environmental issues posing a serious threat to the future welfare and perhaps even human survival. It should be admitted, however, that two other global environmental issues – the depletion of natural resources and the catastrophic contamination of environment – are no less relevant.

Acknowledging the global climate changes as an urgent issue along with the need to immediately start collective actions to prevent or at least to mitigate the consequences of such changes was confirmed by adopting the United Nations Framework Convention on Climate Change in 1992 (UN FCCC).

An important step on the way to implementing actions provided by the Convention was the adoption and promulgation of the Kyoto Protocol. A significant role in the successful achievement of the goals of the Convention and the Kyoto Protocol is played by Russia. It is enough to remind that if Russia had not ratified the Kyoto Protocol, it would have never become effective.

The Earth's climate is subject to variations on all time scales. The most noticeable variations include the cycle of one hundred thousand years – ice periods when the Earth's climate was primarily cold as compared to the current one, and interglacial periods when the climate was warmer. These cycles were caused by natural reasons. As some scientists believe, we are now moving from one ice period to another one, but the change rate is extremely small being around 0.02 °C for 100 years. Starting with the industrial revolution, the climate changes commenced to occur due to human activity with greenhouse gases emitted to the atmosphere when burning fossil fuels, and also because of the destruction of most forests on the planet that used to absorb gases.

CH_4 is believed to take the second place among greenhouse gases after CO_2. This is contradicted by conclusive evidence testifying otherwise, since the role of the primary greenhouse gas, H_2O, is not estimated. This requires analysis and assessment. We need to assess the role of CH_4 in global climate change, and especially CH_4 of human origin.

Methane is one of the most important representatives of organic substances in the atmosphere [1,2]. It was found a relatively short time ago, in 1947 [2]. Its concentration is small and has stabilized at the level of 1.75 ppm since 1999. For comparison, the CO_2 concentration in the atmosphere is 400 ppm. It is believed that the methane contribution to warming is 28% [3].

The UN report admits that vastly growing herds of cattle are the greatest hazard for the climate, forests and nature. Cattle breeding contributes to 18% of greenhouse gases, which is more than automobiles, aircraft and other means of transport combined. Burning fuels for the production of fertilizers necessary to grow fodders, for meat production and its delivery to consumers, and destruction of vegetation for pastures yield 9% of the total carbon dioxide emission. Cattle's intestinal gases and manure provide for more than a third of methane emission [3,11, 12, 13, 14, and

15].

In the atmosphere, methane is located primarily in the surface layer, in the troposphere that is 11-15 km thick. The methane concentration slightly depends on the height in the interval from the Earth surface to the tropopause, which is conditioned by a high mixing rate with altitude within 0-12 km as compared to the methane life cycle in the atmosphere [1]. The methane concentration in the atmosphere defined by studying the ice cover at the Vostok Station in Antarctica has shown that in the last 150,000 years the concentration varied with a period of 20,000 years, which proves naturality of such variance.

Methane disappears from the atmosphere primarily in reaction with the OH radical. If the methane concentration in the atmosphere does not grow, it means the methane arrival to the atmosphere equals its egress from the atmosphere. Unlike CO_2, methane that cherishes hope for forests and other drains is self-destroyed if its amount exceeds the amount required for the equilibrium in the atmosphere. The nature of methane formation in such sources as swaps, lakes, rice fields, ruminant animals, insects, dumps, is approximately equal: fermentative processing of cellulose [5,16].

The issue of the balance in the atmosphere is not studied. The concept of noospheric balance [6] is especially applicable to the main greenhouse gas of H_2O. The noospheric balance is necessary to be applied to the CH_4 balance since panic appeals [7] having no scientific grounds, unfortunately, find a response in political and social circles. A reasonable approach to analyzing processes is extremely important to solve global environmental issues [8]. The role of methane in the overall picture of the greenhouse problem must be considered together with the role played by the human factor in climate [9] considering not only the prevailing point of view.

The discussion concerning methane and climate still continues. N.A. Yasamanov writes [10]: "Methane, which comes to the atmosphere from various sources, is primarily guilty of the current global warming". At the same time, he points that it is not easy to check this by direct observations, "since the speed of its movement in the atmosphere is high, and the life cycle is small".

2. AIMS AND TASKS

The urgency of the topic is caused by the fact that resolving the global environmental issues, one of which is global climate change, is the most important scientific task. Defining the actual role of methane in global processes is one of the most urgent scientific tasks in solving the global problem in general.

The study aim is to define the actual role of methane in the global climate change with respect to its balance in the atmosphere against the overall balance of greenhouse gases and, first of all, H_2O, and to define the role and relevance of methane of human origin.

The study tasks include the following:

1. To analyze the natural and human factors of climate change;
2. To study the balance of greenhouse gases in the atmosphere and the actual role of methane in them;
3. To define the role of methane of human origin and its share in the overall balance of greenhouse gases.

3. METHODS

The methodology is based on the fundamental and applied aspects of methane origin and balance in the overall balance of greenhouse gases and their effects on the climate change. There are sufficient data for quantitative balance indicators for each of the greenhouse gases to make a systemic analysis of their share in global processes. The main methodological tool is, therefore, a systemic analysis of the methane impact on climatic changes. To define the methane contribution to the global temperature change, it is necessary to compare two methodologies defining the degree of impact: based on the global warming potential (GWP) and the global temperature change potential (GTP).

4. RESULTS AND DISCUSSIONS

The analysis of methane sources shows [1] that source No. 1 is swamps (21%), the second place is taken by rice fields (20%). These are merely man-made swamps. This source can be eliminated, but this solution will cause even more pressing food problem. The same picture is observed with cattle (15% of the total methane emission), followed by biomass burning (10%), coal mines, dumps (7%). Methane hydrates that have been blamed on methane emission yield only 1%. Methane of coal mines (7%) damages people and adds the products of coal burning, which is a significant contribution to greenhouse gas emissions. By the way, this 7% must be included in the coal carbon footprint and the next step must be a prohibition of coal underground mining. Nature used to hide carbon for millions of years and the humanity, knowing that it brings harm, continues mining coal introducing it into the atmosphere natural balance as a continuous CO_2 concentration growth that has reached 400 ppm.

According to the IPCC estimate reports [20, 21, 22, 23, and 25], the overall methane emission from natural and human sources is given in Fig. 1.

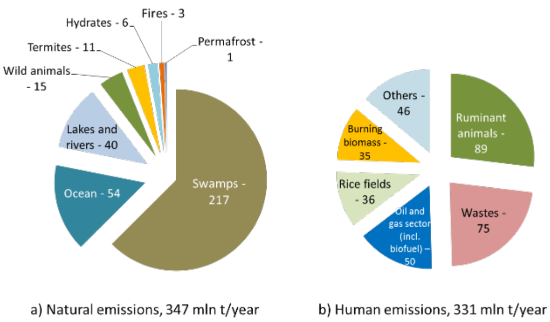

Fig 1. Sources of methane emission to the atmosphere, mln t/year

In this manner, emissions from natural and human sources are distributed approximately in the ratio of 50/50. Considering the short-term life of methane and its concentration as low as 1.75 ppm as compared to 400 ppm of CO_2, it should be expected that even for an equivalent coefficient of 25 tons of CO_2/ton of CH_4, its impact is 11 times lower than that of CO_2, and the impact of human methane is 24.4 times lower, respectively.

The impact of methane should be considered based on the overall balance of greenhouse gases. However, it should be noted that the climate change is of no human nature. This is indicated by the correlation of the CO_2 content in the atmosphere and temperature variations for the last 500,000 years (Fig. 2).

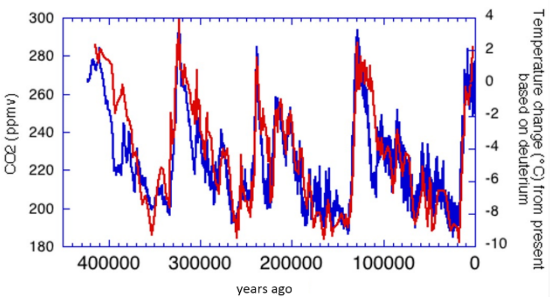

Fig 2. Temperature changes and changes in the carbon content in the atmosphere

Source: U.S. National Oceanic and Atmospheric Administration

The studies of climatic changes for the previous thousand years show that paleoenvironmental records based on ice cores, tree rings, lake bottom deposits, coral reefs allow reconstructing the climate in the past. Many million years ago, in the time of dinosaurs, the climate was much warmer, averagely by 7 °C across the planet in general. Then the climate became colder, and there were many abrupt changes in the Earth's history (cold periods, primarily) when the mass extinction of living organisms occurred.

Since the last glacial retreat from Central Europe, two stages of incredibly fast natural warming were observed. The first one took place about 15,000 years ago, late in the last ice period, the second one was observed about 3,000 years ago. In general, for the last 10,000 years, the average global temperature has slightly decreased due to high volcanic activity and other natural reasons, followed by its increase in the 20th century.

As the systemic analysis of the issue shows, the natural reasons for climate change include:

1. A shift in the Earth's orbit and incidence angle;
2. A change in solar activity;
3. Volcanic eruptions and a change in the quality of atmospheric aerosols.

The analysis shows that during the last million years, ice and interglacial periods changed depending on the Earth's orbit position. Smaller orbit perturbations were observed for the last 10,000 years and the climate became stable. However, in any case, orbit perturbations are an inertial phenomenon, which is principally important within the scale of one thousand years.

Due to the changes in the elliptical orbit position, the energy flux from the Sun changes. The change of the solar activity is related to the Solar system COG offset (SSCOGO) from the Sun's center. According to the Central Aerological Observatory (Moscow), the variations of the solar energy flux received by the Earth are ±24 W/m^2 of solar energy. The human-induced strengthening of the greenhouse effect received by the Earth as a result of that is +2.3 W/m^2 according to the IPCC reports.

Let us compare ±24 W/m^2 and +2.3 W/m^2. The difference is –20.7 W/m^2. This is not warming. The effect of human impact is one order less than that of natural variations. The SSCOGO has a quasi-period of 178 years. In November 2013 in Moscow, the temperature of +14.8 °C was recorded. The previous record was registered in 1838 (14.5 °C).

Volcanic activity and aerosol emission is the third important factor of the natural causality of climate changes.

As a result of eruptions, significant volumes of suspended particles are emitted into the atmosphere, such as aerosols, that are spread by tropospheric and stratospheric winds and do not let pass a share of incoming solar radiation. However, these changes are not long-term, since particles sediment quickly. A large volcano eruption on the island of Santorini in the Mediterranean around 1600 B.C. significantly cooled down the atmosphere, which was seen by tree rings.

The eruption of the Tambora Volcano in Indonesia reduced the average global temperature by 3 °C. The following year saw no summer in Europe and North America, but everything restored for several years. As a result of the Pinatubo Volcano eruption in 1991 in the Philippines, so much ash was brought to the altitude of 35 km that the average solar radiation level reduced by 2.5 W/m^2, in other words, this change was almost equal to the entire human impact (2.3 W/m^2 according to the IPCC reports). An eruption of a single volcano excels the human-induced impact.

The analysis, therefore, shows that natural reasons affect the climate one order more than human factors. But politicians and community do not notice this.

Not only natural reasons for climatic changes are ignored but also those factors that naturally compensate for the human impact on the climate. When the temperature grows, the H_2O evaporation increases, along with cloudiness and Earth albedo, which compensates the human impact.

The Earth atmosphere contains gases and various admixtures (dust, aerosols, water drops, ice crystals). The gas concentration is almost constant except for water and carbon dioxide: N_2 – 78.084%, O_2 – 20.946 %, Ar – 0.9340 %, CH_4 – 0.00018 %. CO_2 is estimated to be 0.0407%, but it has been constantly growing recently. Water is constantly moving (recirculating between the ocean and dry land) referred to as a hydrological cycle. 12-14,000 km^3 of water take part in the hydrological cycle (1/2 of Baykal). 45 cycles occur annually. Their duration is 7-10 days. Participation and evaporation are equal (577,000 km^3 per year).

This is a natural regulator of processes in the atmosphere. Those who do not admit H_2O as the main greenhouse gas say that its concentration is constant. It does not change only because it participates in the regulation of global processes: when it grows warmer, evaporation increases, and the recirculation cycle accelerates.

The H_2O contribution to the greenhouse effect is estimated as 36-72%, CO_2 – as 9-26%, and CH_4 – as 4-9% [12-18], e. g., the above-given result by 24.4 times coincides with the estimates of contributions of various gases into warming. The water balance along with the energy balance is the primary factor of global stability.

Furthermore, it should be taken into account that methane is a short-lived greenhouse gas (8-12 years). We can see that the focus on measures to reduce emissions of short-lived greenhouse gases has no long-term trend of impact by long-lived greenhouse gases (CO_2) on the Earth's climatic system. This is politically motivated to demonstrate easy and quick results as measures to mitigate emissions of short-lived greenhouse gases are less expensive and permit demonstrating faster-rated reduction of CO_2-eq emissions.

The change dynamics of methane concentration in the atmosphere are indicated above and in the 5th Assessment Report [19-23,25]. Variations sometimes take negative values (Fig. 3).

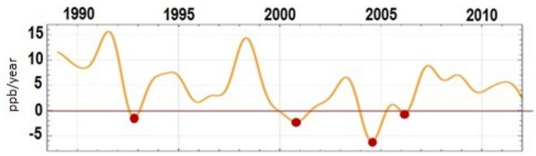

Fig 3. Dynamics of atmospheric methane concentration growth/reduction

The total content of methane in the atmosphere is about 5 bln tons, and annual changes estimated as 592-785 mln tons are almost equal to the emissions (542-852 mln tons). The variation mechanism has its own nature and is similar to the vapor balance regulation mechanism.

Comparing greenhouse effect assessment methodologies according to the results of the 5th Assessment Report shows that there is no unified system of indicators to precisely compare all consequences. The global warming potential GWP is based on the total radiation impact for a specific time interval. Up to the 4th Assessment Report, it was the most common metric indicator. Uncertainty rises with a time horizon, and for a 100-year potential of well-mixed greenhouse gases, uncertainty can reach up to 40%.

The global temperature change potential GTP is based on the change in the mean global surface temperature at the selected point in time, and also with respect to the change caused by the reference CO_2 gas, and thus takes into account the climate response along with radiation efficiency and atmospheric lifetime. At present, GTP is increasing.

The results for various methodological approaches are given in Fig. 4.

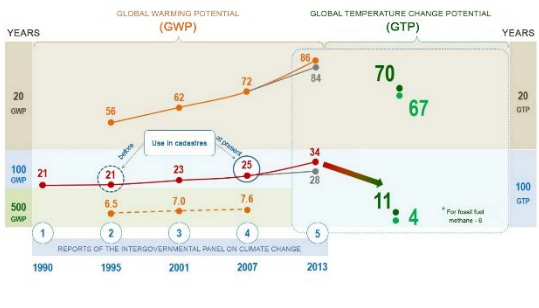

Fig. 4. Comparison of the t CH_4/t CO_2 calculated ratio based on different methodological approaches to the role of methane in climate change

These results allow assessing the degree of methane impact on the climate. Currently, the most cited are the conclusions of the Exergia consulting company made in the Study "On Actual GHG Data For Diesel, Petrol, Kerosene And Natural Gas" [19] published in 2015. This study says that methane has the highest emission coefficient for greenhouse gases (25-34 times higher than CO_2).

Currently, GWP – indicator that allows experts to compare methane impact on the climate with its very well studied peer CO_2 – is discussed. The global warming potential is based on the cumulative radiation impact over a specific time interval and it has been considered as the most widely spread indicator until the 4th Estimate Report of the IPCC.

Currently, the GTP is being increased, which is based on the changes in the average global surface temperature at the selected point of time. In other words, this indicator is intended to answer the following question: what will the temperature change be in year X as a response to the radiation impact of specific emissions of greenhouse gases? According to the IPCC report, the global temperature change potential better suits for the goal-setting policy that is promoted by the Paris Climate Agreement.

In case of using the global temperature change potential, the CH_4/CO_2 ratio is 4-11 against 25 being used currently when calculating the global warming potential.

An alternative point of view was for the first time given in the IPCC 5th Assessment Report "The Physical Science Basis" that was an internationally admitted "Climatic Bible". We should not forget that the IPCC has been awarded the Nobel Prize for this study in the area of combating climate change. The IPCC declares that various indicators can be used to compare the impact of emissions of various substances on the climate. The most suitable indicator and the time range are selected based on specific aspects of climate change that must be assessed. Neither indicator can be regarded as a perfect one and can precisely compare all consequences of various emission types. All indicators have their limitations and uncertainty that may reach ±40%.

Furthermore, the IPCC declares another peculiar feature: measures to mitigate human methane emission to the surface layer with ozone are defined as a mutual gain, they can result in both climate cooling and warming.

To solve the climatic problem, it is very important to focus on the long-term effects of climate changes and pay more attention to long-lived gases such as CO_2.

On the opposite, methane is a short-lived gas: a methane molecule is oxidized and transformed into water and carbon dioxide in 12 years. When we shift our attention from CO_2 to CH_4, we substitute the trend of global temperature change. The strategy to mitigate methane emissions with no respect to the long-term effect of CO_2 emissions gives a fast and cheap result, but it does not bring us closer to fulfilling ambitious goals of the Paris Climate Agreement.

The study [24] "The Global Biogeochemical Cycles of Methane Concentration Increase in the Atmosphere: Growth in 2007-2014 and Isotope Shift" given by fifteen influential institutes of the United Kingdom, the USA, New Zealand, Canada and the RSA has shown that the globally averaged molar share of methane in the atmosphere increased by 5.7 ± 1.2 parts per billion (bln^{-1}) per year from 2007 to 2013. At the same time, the indicator of $\delta^{13}C_{CH4}$ ($^{13}C/^{12}C$ carbon isotope ratio in methane) has substantially shifted to negative since 2007. An extremum value of growth by 12.5 ± 0.4 bln^{-1} was recorded in 2014, and a further shift towards more negative values was observed in most latitudes. The presented isotope evidence shows that the methane growth is mostly affected by significant growth of biogenic methane emissions, especially in the tropics, for example, in relation to expanding areas of tropical swampy soils in years with abnormally high amount of atmospheric precipitation or due to the increased amount of methane emission sources from agriculture, such as ruminant animals and rice fields. The changes that are similar to changes in methane removal rate from the atmosphere in reactions with the OH radical have not been found in other tracers from the atmospheric chemical composition and, as we see, they do not explain short-term variations of methane concentrations. While there is the possibility of growth of emissions from burning fossils, stable shift to low values of ^{13}C isotope and its significant interannual variability as well as increased methane share in tropical areas and in the Southern Hemisphere after 2007 show that emissions from burning fossils have not become the primary reason for methane concentration growth.

Though the emissions from fossils have reduced as a part of the total methane budget, the results [26] may not exclude emission increase in absolute terms, especially if the initial gas has been isotopically poor in ^{13}C to a great extent. Based on the analysis by latitudes and by isotope restrictions [23-28], the Siberian gas has been excluded as a cause for methane growth. In this manner, isotope studies prove that methane concentration in the atmosphere depends on natural factors and not on the produced natural gas.

Analyzing this topic, it becomes more evident that today's politicians and regulators consider short-lived contaminants, such as methane, an easy way to shift the focus of the current climatic discussion from main obstacles to reducing CO_2 emissions to the issue of methane emissions which will actually evaporate on a long-term scale. This issue has no effect on general climatic goals, but politicians find it easier to join the trend that methane emissions during last years from the oil and gas sector have been constantly reducing both in Europe and Russia. Consequently, the issue of short-lived contaminants will have low effect on warming that will be endured by future generations, with the community focus shifted from CO_2, which is a much more dangerous greenhouse gas.

Finally, the share of methane from the oil and gas sector is 0.1% for a global scale and 0.004% for Russia. With the generally insignificant effect of methane on the climate, the impact of the man-induced methane emissions from the gas sector in both Russia and the entire world, in general, is small and has no effect on the climate.

5. CONCLUSIONS

Based on the above study, the following conclusions can be drawn.

The impact of methane on the climate is 24.4 times lower than the impact of CO_2. The man-induced impact on the climate in general that is one order less than natural one (deviation of the Earth's orbit, changes in solar activity, volcanic phenomena with aerosol emissions) is compensated by natural processes of restoration and self-regulation (natural balance) in the atmosphere.

When assessing the methane influence on climate, it should be considered that its share in the overall picture of climate impact by greenhouse gases is 4-9% whereas that of vapor is 36-72%. Vapor maintains the heat balance and is a natural regulator of processes in the atmosphere. The analysis of the role of each greenhouse gas proves the conclusion that the impact of methane is 24.4 times weaker than that of CO_2 and in case of natural regulation of vapor and short life of methane in the atmosphere, its impact on the climate can be deemed as insignificant.

Comparing greenhouse effect assessment methodologies for various substances has shown that there is no unified system of indicators to precisely compare all consequences. Assessing the role of methane using existing GWP and GTP methodologies shows differences, but in general, testifies an insignificant role of methane in the climate change. The methane equivalence coefficient currently recognized as 25 under the GTP methodology is reduced to 4, which is proved by radioisotope studies.

The analysis of methane emissions in the gas sector shows that the share of emissions of greenhouse gases from the global oil and gas sector is 0.1%, the share of the Russian gas sector is 0.004%. This makes it possible to conclude on its insignificant impact, and the emissions of the Russian gas sector in the overall picture should be deemed as totally irrelevant.

The analysis of changes dynamics for methane concentration in the atmosphere shows that methane emission is approximately equal to its egress from the atmosphere. This process has natural causes and is similar to the natural regulation of heat balance through the vapor circulation cycle.

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