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# Natural Processes in Mitigation of $CO_2$ and $CH_4$ Emission

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## 1. Introduction

Both carbon dioxide and methane are responsible for climatic changes, which may negatively impact the Earth's ecosystem. The recommended reduction of these gases aims to prevent unfavourable changes in the environment.

The suggested actions, especially concerning reduction of $CO_2$ emission, focus on substituting carbon-based fuels with carbon-free or low-emission fuels. Undoubtedly, a rational transition from carbon-based fuels to carbon-free or low-emission fuels may significantly influence mitigation of $CO_2$ emissions. The problem consists in that these fuels may simultaneously hamper sustainable development of individual societies (Pawlowski 2009, 2013, Udo and Pawlowski 2010, Liu 2015, Savić et al. 2016, Shindell et al. 2012).

While analyzing IPCC Reports, attention should be paid to the main $CO_2$ fluxes in Earth's ecosystems. The greenhouse effect is induced by an increase in greenhouse gases concentration, mainly $CO_2$ and $CH_4$ (see Fig. 1 and Fig 2) (IPCC 2013, 2014, Soussana 2007, U.S. EPA 2014). For instance, the lithosphere contains approximately 1200 times more $CO_2$ in the form of rocks. However, this part of $CO_2$ virtually does not participate in circulation of $CO_2$ in Earth's ecosystems.

The second largest ecosystem, which contains about 2000 billion tons of carbon, includes soils that comprise carbon mainly in the form of organic compounds. The ecosystem of plants and animals contains roughly 500 biollion tons of $C_{org}$ (in the form of biomass). Permafrost constitutes a significant reservoir of carbon, in the form of methane (1400 biollion tons) (Acharya et al. 2012, Beer et al. 2010, Woodward and Papale 2010). Coal, crude oil, and gas deposits contain approximately 4000 billion tons (Patyńska 2014, IPCC 2013).

Concentration of $CO_2$ in atmosphere is continuously growing (see Fig. 1).

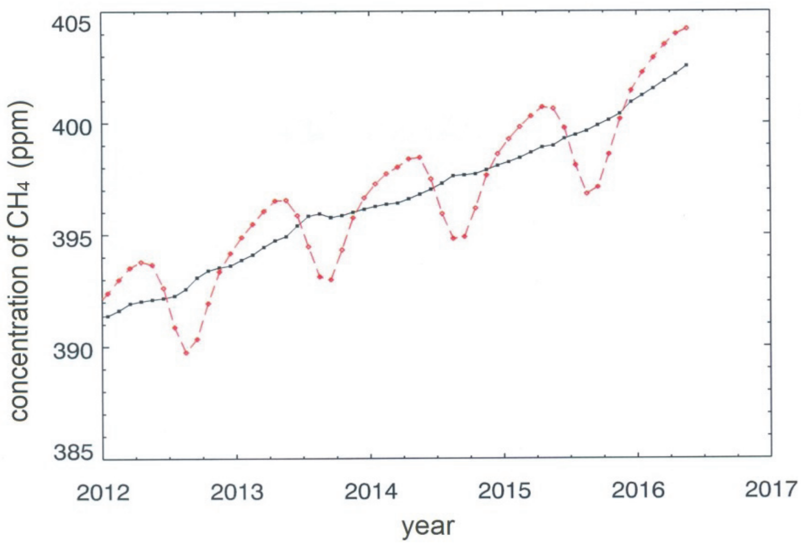


**Fig. 1.** Changes in atmospheric $CO_2$ concentration over time (Kirschke et al. 2013, ESRL 2016)
**Rys. 1.** Zmiana stężenia $CO_2$ w atmosferze w funkcji czasu (Kirschke et al. 2013, ESRL 2016)

Apart from $CO_2$, which corresponds to 65% of the greenhouse effect, methane is the second most important gas, with estimated share of 20%. (Kirschke et al. 2013, ESRL 2016). Concentration of methane in the atmosphere is continuously growing over time (see Fig. 2).

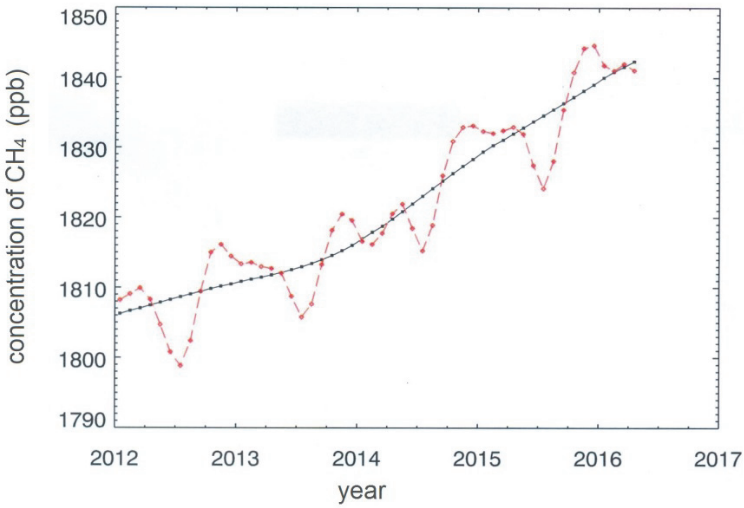


**Fig. 2.** Changes atmospheric $CH_4$ concentration over time (Kirschke et al. 2013, ESRL 2016)
**Rys. 2.** Zmiany stężenia $CH_4$ w atmosferze w funkcji czasu (Kirschke et al. 2013, ESRL 2016)

## 2. $CO_2$ exchange between the main ecosystems of Earth

The highest amounts of carbon flow from the atmosphere to the land vegetation through the process of photosynthesis: 123 ± 8 billion tons $C_{CO_2}$/year (Pan 2011, Philips and Lewis 2014, Gaj 2012, Sauerbeck 2001, Soussana et al. 2004, 2009). Simultaneously, plants and animals living on the surface of the Earth exhale 119 ± 1 billion tons $C_{CO2}$/year. This means that the terrestrial ecosystems remove 2.6 ± 1.2 billion tons $C_{CO2}$/year from the atmosphere (IPCC 2013).

The second largest $CO_2$ fluxes are the ones between the atmosphere and seas and oceans, which absorb 80 billion tos of $C_{CO2}$/year and simultaneously release 78 ± 1 billion tons $C_{CO2}$/year (IPPC 2014, Mota et al. 2010, Trumper et al. 2009, Cao and Cel 2015).

Starting from the year 1750, the $CO_2$ and $CH_4$ emission is constantly on the rise, mainly due to the combustion processes of carbon-containing fuel, as well as due to the mining activity.

In recent years, the emission of $CO_2$ from combustion processes and cement production approximated 9.5 ± 0.8 bilion tons $C_{CO2}$/year (Franay et al. 2013, Peters et al. 2013). This should be supplemented with the emission from changes in land use, i.e. construction of the infrastructure, deforestation, etc., which amounts to 0.8 ± 0.6 billion tons $C_{CO2}$/year (IPCC 2014, Prather et al. 2012, Houghton et al. 2012, Le Quere et al. 2012).

According to the above-mentioned data, the natural fluxes of carbon dioxide are multiple times greater than the emission from anthropogenic sources; therefore, conducting evaluation concerning intensification of carbon dioxide absorption by the ecosystems which are influenced by people to the greatest extent seems relevant. The assessment of $CO_2$ absorption potential was performed on the example of Bielsko County.

## 3. Absorption of $CO_2$ by terrestrial ecosystems on the example of Bielsko County

In order to illustrate the importance of environmental $CO_2$ sequestration, the $CO_2$ absorption by plants will be estimated on the example of Bielsko County.

$CO_2$ sequestration by forests and orchards approximates 9 tons $C_{CO_2}$/year·ha (net). In Bielsko County, forests occupy the area of 21 858 ha, while orchards – 3 423 ha, which amounts to 25 281 ha combined. Therefore, the annual $C_{CO_2}$ sequestration equals 228 000 tons $C_{CO_2}$/rok. Pastures, occupy 4190 ha, with sequestration 4.8 $C_{CO_2}$/year·ha , which adds up to 20 000. $C_{CO_2}$/year (Gaj 2012, Philips and Lewis 2014).

On the other hand, meadows occupy 30 123 ha, with sequestration amounting to 206 tons $C_{CO_2}$/year·ha totals 78 000 tons $C_{CO_2}$ absorbed during a year (Carvajal 2010).

Grains constitute another ecosystem, which occupies 80 260 ha. While analyzing the crop size, it can be assumed that grains can absorb 11 $t\ C_{CO_2}$/year·ha (net) on average, which translates to 883 000 $C_{CO_2}$ per year.

Absorption of $CO_2$ by potatoes equals 13 tons $C_{CO_2}$/year·ha. With 2927 ha, this amounts to 374 000 tons $C_{CO_2}$/year.

Therefore, the total $C_{CO_2}$ sequestration by the most important crops in Bielsko County approximates 1.583 million tons $C_{CO_2}$/year.

This means that agricultural crops are one of the main $CO_2$ absorbers.

## 4. Exchange of $C_{CH_4}$ between main ecosystems of Earth

Methane is the second most important greenhouse gas emitted into the atmosphere. Its share in the greenhouse effect is estimated at 20% (Kirsche et al. 2013, Ghosh et al. 2015). The total methane emission in 2015 amounted to 771 million t/year, including 131 million t/year from combustion processes and 200 million t/year from agriculture and waste management. This translates to 331 million t/year, i.e. 43% from anthropogenic sources. The remaining 57% constitutes emissions from natural processes (Dlugokencky et al. 2011, EPA 2011, European Commission; Ghosh et al. 2015).

Methane emissions from landfills in selected countries in million tons of $C_{CO_2}$ eqilivalent is depicted in Table 1. (Data for 2010)

**Table. 1.** Emission of methane in selected countries for 2010
**Tabela 1.** Emisja Metanu w wybranych krajach w 2010 roku

| | |
|---|---|
| Global Emissions | 799 |
| United States | 130 |
| China | 47 |
| Mexico | 38 |
| Russian Federation | 37 |
| Turkey | 33 |
| Indonesia | 28 |
| Canada | 21 |
| United Kingdom | 19 |
| Brazil | 18 |
| India | 16 |
| Poland | 10 |

It is predicted that the emission of methane from anthropogenic sources will increase to 430 million t/year in 2030, and 680 million t/year in 2050. Landfills constitute an important source of methane emissions.

The share of landfills in methane emissions from anthropogenic sources equals 6% (Bogner et al. 2008, Bagner and Matthews 2003, EPA 2014, Staszewska and Pawlowska 2011). Limiting the human impact on the environment constitutes one of the important problems for environmental engineering.

## 5. Mitigation methods of methane emission

Mitigation of methane emissions is one of the important tasks related to prevention of climatic changes. Utilizing landfill gas as a source of energy is the most favourable solution (Matthews and Themelis 2007, Ahmed et al. 2015, Bagner i Matthews 2003, Themelis et al. 2002). Another interesting method is intensifying the process of methane production by introducing municipal sewage sludge to a landfill (Pawlowska and Siepak 2006). Landfill gas contains about 50% of $CO_2$. Removing $CO_2$ through, for instance, leaching with water greatly improves the energetic value of landfill gas.

From the point of view of mitigating methane emission, eliminating residual landfill gas emission to the atmosphere is an important issue. This emission is relatively low; hence, it is not profitable to utilize this gas as a source of energy. In this case, employing natural microbiological methane oxidation processes under a special cover is a more favourable solution (Pawlowska 2008, 2014, Pawlowska and Stepniewski 2005). This cover acts as a natural filter removing methane from residual landfill gas. Utilizing microbiological filter with forced landfill gas flux is a more advanced solution. Special layers are formed in such a biofilter. Methanotrophic bacteria, which can oxidize methane, develop on their surface. These methods employ the natural methane oxidation process by methanotrophic bacteria (Stepniewski and Pawlowska 1996, Bogner et al. 2008, Czepiel et al. 1996, Montusiewicz et al. 2008, Pawlowska 2008).

The presented information show that there are multiple possibilities of utilizing natural processes for mitigation of the main greenhouse gases, i.e. carbon dioxide and methane.

## References

Acharya, B.S., Rasmussen, J., Eriksen, J. (2012). Grassland carbon sequestration and emissions following cultivation in a mixed crop rotation. *Agriculture, Ecosystems & Environment, 153*, 33-39.

Ahmed, S.I., Johari, A., Hashim, H., Mat, R, Lim, J.S., Ngadi, N., Ali, A. (2015). Optimal landfill gas utilization for renewable energy production. *Environmental Progress & Sustainable Energy, 34(1)*, 289-296.

Beer, C. et al. (2010). Terrestrial gross carbon dioxide uptake: global distribution and covariation with climate. *Science*, *329(5993)*, 834-838.

Bogner, J. et al. (2008). Mitigation of global greenhouse gas emissions from waste: conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation). *Waste Manag. Res.*, *26,* 11-32.

Boogner, J., Matthews, E. (2003). Global methane emissions from landfills: New methodology and annual estimates. *Global Biogeochem. Cycles*., 17(2), 1065-1083.

Cao, Y., Cel, W. (2015). Sustainable Mitigation of Methane Emission by Natural Processes. *Problemy Ekorozwoju/Problems of Sustainable Development, 10(1)*, 117-121.

Carvajal, M. (2010). Investigation into $CO_2$ absorption of the most representative agricultural crops of the region of Murcia. *CSIC Report*, http://www.lessco2.es/pdfs/noticias/ponencia_cisc_ingles.pdf

Czepiel, P.M., Mosher, B., Crill, P.M., Harriss, R.C. (1996). Quantifying the effect of oxidation on landfill methane emissions. *Journal of geophysical research: Atmospheres, 101 (D11),* 16721-16729.

Dlugokencky, E.J., Nisbet, E.G., Fisher, R., Lowry, D. (2011). Global atmospheric methane: budget, changes and dangers. *Phil. Trans. R. Soc. A, 363*, 2058-2072.

European Commission, Joint Research Centre/Netherlands Non-$CO_2$ Environmental Assessment Agency. Emission Database for Global Atmospheric Research (EDGAR) (VERSION 4.2) http://edgar.jrc.ec.europa.eu

EPA (2011). Environmental Protection Agency. Global Athropogenic Non-$CO_2$ Greenhouse Gas Emissions: 1990-2030.

EPA (2014). Climate Change Indications in the United States: Global Greenhouse Gas Emissions. www.epa.gov/climatechange/indicators.

EPA (2014). Global Methane Emissions and Mitigation Opportunities. EPA's Global Anthropogenic Emissions of Non-$CO_2$ Greenhouse Gases: 1990–2020 (EPA Report 430-R-06-003), www.epa.gov/climatechange /economics/international.html.

ESRL (2016). Trend in Atmospheric Methane. www.esrl.noaa.gov.

Gaj, K. (2012). Pochłanianie $CO_2$ przez polskie ekosystemy leśne. *Leśne Prace Badawcze/Forest Research Papers, 73(1),* 17-21.

Ghosh, A. et al. (2015). Variations in global methane sources and sinks during 1910–2010. *Atmos. Chem. Phys., 15*, 2595-2612.

Houghton, R.A. et al. (2012). Carbon emissions from land use and land-cover change. *Biogeosciences, 9,* 5125-5142.

IPCC (2013). Climate Change 2013: The Physical Science Basis, Cambridge University Press, Cambridge.

IPCC (2014). Intergovernmental Panel on Climate Change. Climate change 2014: Mitigation of climate change. Working Group III contribution to the IPPCC Fifth Assessment Report. Cambridge, United Kingdom: Cambridge University Press. www.ipcc.ch/report/ar5/wg3.

Kirschke et al. (2013). Three decades of global methane sources and sinks. *Nature Geosci., 6*, 813-823, doi:10.1038/ngeo1955.

Le Quare et al. (2013). The Global Carbon Budget 1995-2011. *Earth Syst. Science Data, 5,* 165-168.

Matthews, E., Themelis, N. J. (2007). Potential for reducing global methane emissions from landfills, 2003-2030. *Eleventh International Waste Management and Landfill Symposium*, Sardynia 2007.

Montusiewicz, A., Lebiocka, M., Pawlowska, M. (2008). Characterization of the biomethanization process in selected waste mixtures. *Archives of Environmental Protection, 34(3),* 49-61.

Mota, C. et al., (2010). Absorption of $CO_2$ by the Most Representative in the Region of Murcia Crops. *Report SCIC*.

Liu, H. (2015). Biofuel's Sustainable Development under the Trilemma of Energy, Environment and Economy. *Problemy Ekorozwoju/Problems of Sustainable Development, 10(1),* 55-59.

Pan, Y. et al. (2011). A Large and Persistent Carbon Sink in the World's Forests. *Science, 333(60450),* 988-993.

Patyńska, R. (2014). Methodology of Estimation of Methane Emissions from Coal Mines in Poland. *Studia Geotechnica et Mechanica, 36(1),* 89-101.

Pawlowska, M. (2008). Reduction of methane emission from landfills by its microbial oxidation in filter bed. Management of Pollutant Emission from Landfills and Sludge Book Series: *Proceedings and Monographs in Engineering Water and Earth Sciences*, 3-20.

Pawlowska, M. (2014). Mitigation of landfil gas Emission. *Publisher: CRC Press- Taylor & Francis Group*, 6000 Broken Sound Parkway NW, Ste 300, Boca Raton, FL 33487-2742 USA.

Pawlowska, M., Siepak, J. (2006). Enhancement of Methanogenesis at a Municipal Landfill Site by Addition of Sewage. *Environmental Engineering Sciences*, *23(4)*, 673-679.

Pawlowska, M., Stepniewski, W. (2005). Biochemical reduction of methane emission from landfills. Conference: Conference of Pathway of Pollutants and Mitigation Strategies for Their Impact on the Ecosystems Location: Kazimierz Dolny, POLAND Date: SEP 04-07, 2005*, Environmental Engineering Science, 23(4)*, 666-672.

Pawlowski, A. (2009). Theorethical Aspects of Sustainable Development Concept. *Rocznik Ochrona Środowiska*, *11(2),* 985-994.

Pawlowski, A. (2013). Sustainable Development and Globalization. *Problemy Ekorozwoju/Problems of Sustainable Development, 8(2)*, 5-16.

Peters, G.P. et al. (2013). The challenge to keep global warming below 2°C. *Nature Climate Change, 3*, 4-6.

Philips O.L., Lewis S.L. (2014). Evaluating the Tropical Forest Carbon Sink. *Global Change Biology*, *20*, 2039-2041.

Prather, M.J., Christopher D.H., Hsu J. (2012). Reactive greenhouse gas scenarios: Systematic exploration of uncertainties and the role of atmospheric chemistry. *Geophysical Research Letters*, 2012.

Sauerbeck, R.D. (2001). $CO_2$ emissions and C sequestration by agriculture – perspectives and limitations. *Nutrient Cycling in Agroecosystems*, *60(1),* 253-266.

Savić, D, Jeremić, V., Petrović, N. (2016). Rebuilding the Pillars of Sustainable Society Index: a Multivariate Post Hoc I-distance Approach. *Problemy Ekorozwoju/Problems of Sustainable Development, 12(1)*, 125-134.

Shindell, D. et al. (2012). Simultaneously mitigating near-term climate change and improving human health and food security. *Science*, *335,* 183-189.

Soussana, J.F. et al. (2004). Carbon Cycling and Sequestration Opportunities in Temperate Grasslands. *Soil Use and Management, 20*, 219-230.

Soussana, J.F. et al. (2007). Full Accounting of the Greenhouse Gas ($CO_2$, $NO_2$, $CH_4$) Budget of Nine European Grassland Sites. *Agriculture, Ecosystems, and Environment*, *121*, 121-134.

Soussana, J.F. et al. (2009). Mitigating the Greenhouse Gas Balance of Ruminant Production Systems Through Carbon Sequestration in Grasslands. *Animal, 4(3),* 334-350.

Staszewska, E., Pawlowska, M. (2011). Characteristics of emissions from municipal waste landfills. *Environment Protection Engineering, 37(4),* 119-130.

Stepniewski, W., M. Pawlowska, (1996). A possibility to reduce methane emission from landfills by its oxidation in the soil cover.*Chemistry for the Protection of the Environment 2, 51*, 76-92.

Themelis, N.J., Kim, Y.H., Bredy, M.H.(2002). Energy recovery from New York City municipal solid wastes. *Waste Manag. & Res., 20(3),* 223-233.

Trumper, K. et al., (2009). *The Natural Fix? The Role of Ecosystems in Climate Mitigation.* A UNEP rapid response assessment. United Naions Environment Programme. UNEP-WCMC. Cambridge, UK.

Udo, V., Pawlowski, A. (2010). Human Progress Towards Equitable Sustainable Development: A Philosophical Exploration. *Problemy Ekorozwoju/Problems of Sustainable Development, 5(1),* 23-44.

U.S. EPA (2014). Global Anthropogenic Emissions of $CO_2$, Greenhouse Gasses. EPA Report 430-R-06-003.

# Procesy naturalne redukujące emisję $CO_2$ i $CH_4$

## Streszczenie

W pracy scharakteryzowano emisję $CO_2$ i $CH_4$ oraz ich wpływ na efekt cieplarniany. Omówiono przepływy pomiędzy ekosystemami Ziemi. Szczególna uwagę zwrócono na naturalne metody usuwania $CO_2$ przez uprawy rolnicze na przykładzie powiatu bialskiego.

Omówienie redukcji ograniczono do redukcji jego emisji z wysypisk.

**Słowa kluczowe:**
ditlenek węgla, metan, emisja, absorpcja

**Keywords:**
carbon dioxide, methane, emission, absorption