PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT
2016, vol. 11, no 1, 173-176

Sustainable Mitigation of Greenhouse Gases Emissions

Zrównoważone przeciwdziałanie efektowi cieplarnianemu

Wojciech Cel*, Aneta Czechowska-Kosacka*, Tao Zhang**

**Faculty of Environmental Engineering, Lublin University of Technology, Lublin, Poland*
***Key Laboratory of Plant-Soil Interactions of Ministry of Education, College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China*
E-mails: w.cel@pollub.pl, a.czechowska-kosacka@pollub.pl

Abstract

The emission and absorption fluxes of CO_2 and CH_4 in the environment have been characterized. It has been pointed out that the anthropogenic emission of CO_2 amounts only to 3% of emissions from the natural sources. It has been also noted that increasing CO_2 absorption of terrestrial ecosystems by 3% could inhibit the increase of CO_2 concentration in the atmosphere. This means that mitigation of global warming by intensifying natural processes is a more sustainable solution than performing expensive changes in energy policy. Lowering the emission of methane, on the other hand, can be accomplished by utilizing fodder additives for ruminants and the process of microbiological methane oxidation in covering soil layers or biofilters.

Key words: greenhouse gases, CO_2 emissions, sustainable development

Streszczenie

W artykule scharakteryzowano strumień emisji i absorpcji gazów cieplarnianych CO_2 i CH_4 w środowisku. Zwrócono uwagę, że antropogeniczna emisja CO_2 wynosi zaledwie 3% poziomu emisji ze źródeł naturalnych. Ponadto zauważono, że intensyfikacja absorpcji CO_2 przez ekosystemy lądowe o 3% mogłaby zahamować wzrost stężenia CO_2 w atmosferze. Oznacza to, że bardziej zrównoważone jest przeciwdziałanie efektowi cieplarnianemu poprzez intensyfikację procesów naturalnych od kosztownych zmian w polityce energetycznej. Natomiast ograniczanie emisji innego gazu cieplarnianego – metanu – można osiągnąć poprzez stosowanie dodatków do paszy dla zwierząt przeżuwających oraz wykorzystanie procesu mikrobiologicznego utleniania metanu w nakładach glebowych i biofiltrach.

Słowa kluczowe: gazy cieplarniane, emisja CO_2, zrównoważony rozwój

1. Introduction

The problems connected with the emission of greenhouse gases are directly associated with the issue of sustainable development. According to reports (IPCC, 2013, 2014), excessive emission of greenhouse gases leads to the degradation of environment, and thus violates the intergenerational equity paradigm of sustainability which requires taking the actions that preserve the non-degraded environment for the future generations.

In the ongoing discussion about greenhouse effect mitigation, costly solutions – which may seriously hinder the inhabitants of less developed countries in the process of going out of poverty – are being recommended. This, in turn, violates the second important paradigm of sustainable development, which requires taking the actions that strive for ensuing equal life standards for all people.

Hence, it is important to seek such methods of inhibiting climate changes which would conform to the paradigms of sustainable development (Cholewa, Pawłowski, 2008; Pawłowski 2019, 2013).

2. Characteristics of the emission of the main greenhouse gases: CO_2 and CH_4

The policy of counteracting the greenhouse effect focuses mainly on mitigating the CO_2 emission from combustion processes. Meanwhile, according to the

data published by Intergovernmental Panel on Climate Change (IPCC 2007), the emission of CO_2 from fossil fuels combustion and cement production equals 7.6±0.6 GT/year, which is a relatively small amount in comparison to the natural fluxes. The emission of CO_2 resulting from the respiration of organisms and plants amounts to 118.7 GT/year, whereas the emission from the surface of oceans equals 78.4 GT/year. This is further supplemented by the emission of CO_2 from volcanic eruptions, approximating 0.1 GT/year and the emission from inland waterways, amounting to 1 GT/year. Changes in land use, which mainly include deforestation, increase the CO_2 emissions by 1.1±0.8 GT/year. Thus, the total CO_2 emission from natural processes equals 198.2 GT/year, while the emissions from anthropogenic sources – 8.7±1.4 GT/year (Falkowski et al., 2000).

Simultaneously, absorption of CO_2 from the atmosphere takes place. Plants absorb 123 GT/year during photosynthesis, 80 GT/year is absorbed by oceans, and 0.3 GT/year is absorbed through the erosion of rocks. According to the above-mentioned data, out of the anthropogenic emissions amounting to 8.7±1.4 GT CO_2/year, 5.0 GT CO_2/year is absorbed in natural processes. The remaining 3.7 GT CO_2/year contributes to the increase of CO_2 concentration in the atmosphere. Therefore, if the absorption of CO_2 in natural processes was enhanced by 3.7 GT CO_2/year, the increase of CO_2 in the atmosphere would be inhibited. In such context, the approach of J. Szyszko, Polish Minister of Environment, deserves attention. Instead of costly changes in energy policy, he proposes to take an interest in the sequestration of CO_2 by forests.

Methane is another important greenhouse gas. According to the data published by IPCC (IPCC, 2013), 87-94 MT of methane us emitted by animal husbandry, 33-40 MT/year is emitted from rice cultivation, 85-105 MT/year from fossil fuel extraction and processing, 67-90 MT/year from landfills, and 32-39 MT/year from biomass combustion, which in total amounts to 304-368 MT/year (Uliasz-Bocheńczyk, Mokrzycki, 2015).

Moreover, the emission of CH_4 in natural processes comprises: 2-9 MT/year from hydrates, 177-284 MT/year from swamps, 8-73 MT/year from surface waters, 2-22 MT/year by termites, and 33-75 MT/year from geological reservoirs, which amounts to 222-463 MT/year when combined. The total annual emission of methane from both anthropological and natural sources amounts to 676-1080 MT/year.

Natural processes of methane removal occur in the atmosphere: 16-84 MT/year of methane is oxidized by OH^- radicals in the stratosphere, whereas in the troposphere – the oxidized amount ranges 454-617 MT/year. Moreover, microorganisms in soil annually remove 9-47 MT of CH_4 through oxidation.

Hence, the methane content in the atmosphere increases by 184-305 MT/year.

3. Sustainable mitigation of CO_2 and CH_4 emissions

Vast majority of efforts aimed at mitigating the greenhouse effect focuses on limiting the CO_2 emissions, mainly by eliminating usable energy from fossil fuels, with coal in particular. Such approach, as pointed out by Lindzen (2010) leads to a substantial increase in the cost of energy. Additionally, there are concerns whether alternative energy carriers exist in sufficient amounts to ensure smooth functioning of the human civilization (Pawłowski, 2009). It seems that the role of natural processes occurring in the environment remains underappreciated.

According to the CO_2 balance given in the introduction, out of 8.7±1.4 GT/year produced through anthropogenic emission, 5.0 GT/year is absorbed in natural processes, mainly in photosynthesis and by dissolving in oceans, and only 3.7 GT/year is emitted to the atmosphere, contributing to the increasing CO_2 concentration in the atmosphere.

The CO_2 absorption capacity of seas and oceans is limited, as the symptoms of acidification are already becoming apparent, leading to a reduced CO_2 solubility in water. Attempts are being made to increase the CO_2 absorption capacity in sea water through artificial intensification of algal growth, carried out by means of fertilization with ferric ions (IPCC, 2007; Boyd et al., 2000; Coale et al., 1996; Aumont and Bopp, 2006). However, this method raises certain concerns (Allsopp et al., 2007). On the other hand, absorption of CO_2 by terrestrial ecosystems remains underappreciated. While comparing the annual CO_2 emission from the anthropogenic sources – which equal 3.7 GT/year – with the level of CO_2 absorption occurring in terrestrial ecosystems through photosynthesis, it is becomes obvious that raising the photosynthesis intensity merely by 3.0% could completely inhibit the increase of CO_2 concentration in the atmosphere. This could be achieved, e.g. by a proper silviculture (Oren et al., 2001; Garbulski et al., 2008; Gorte, 2009; Uliasz-Bocheńczyk, Mokrzycki, 2005; Olejnik et al., 2011; Gaj, 2012; Dubey et al., 2015).

Polish Minister of Environment noticed this possibility, showing that CO_2 sequestration by forest ecosystems is very beneficial and profitable. Sequestrating 1 MT of CO_2 would cost approximately €4 (Szyszko, 1015). Silviculture in Poland occupies 9.5 million ha. The absorption of CO_2 by forests ranges from 9 to 21 MT of CO_2/ha per year. Thus, it is easy to calculate that Polish forests absorb 86.5-199.5 MT of CO_2 annually. In 1990, 387.3 MT of CO_2 was emitted in Poland, whereas in 2014 – 316.8 MT of CO_2, i.e. the emission was cut by 18.1% (B.P, 2015). According to the above-mentioned data, Polish forests remove 27.3-63.3% of CO_2 emitted by the Polish industry. Therefore, proper silviculture is the most sustainable method of reducing CO_2 emissions, and not only in Poland.

As methane is a useful fuel, the most advantageous solution is to recover it for energy production. If the concentration of methane is sufficiently high, it can be used as a fuel. However, lower concentrations are problematic. In the case of air obtained from bituminous coal mine shafts ventilation, attempts have been made to combust it in a reactor equipped with a catalytic converter (Gosiewski et al., 2010).
Regulating natural processes in the case of methane is significantly more difficult. The highest amounts of methane are emitted by ruminants. The studies performed (Boadi et al., 2004) have shown that the addition of ionophores probioties, acetogens, bacteriocins, archaeal viruses and organic acids can reduce generation of enteric methane.
Utilizing natural processes of microbial oxidation of methane allows to reduce the emission of methane. One of the simplest methods is the oxidation of methane in covering soil layers or biofiltres (Stępniewski, Pawłowska, 1996; Bogner, 2003; Streese, Stegmann, 2003; Pawłowska, 2008; Scheutz et al., 2009; Montusiewicz at al., 2008; Staszewska, Pawłowska, 2011; Zdeb, 2015).

Conclusions

To sum up, effective employment of CO_2 absorption by terrestrial ecosystems consisting in the intensification of photosynthesis – which additionally increases the production of biomass – constitutes an example of implementing sustainable development principles in the mitigation of greenhouse effect.
Mitigation of methane emissions is possible by utilizing fodder additives for ruminants and employing a microbiological methane oxidation process in specially formed covering soil layers or biofilters.

References

1. ALLSOPP M., SANTILLO D., JOHNSTON P., 2007, *A scientific critique of oceanic iron fertilization as a climate change mitigation strategy*, report GRL-TN-07-2007.
2. AUMONT O., BOPP L., 2006, Globalizing results from ocean in situ iron fertilization studies, in: *Global Biogeochemical Cycles*, vol. 20, p. 2017-2032.
3. B.P., 2015, *Statistical World Energy Review*, http://www.bp.com/statisticalreview/ (10.08.2015).
4. BOADI D., BENCHAAR C., CHIQUETTE J., MASSE D., 2004, Mitigation strategies to reduce enteric methane emissions from dairy cows: Update review, in: *Canadian Journal of Animal Science*, vol. 84, no 3, p. 319-332.
5. BOGNER J., 2003, Global methane emissions from landfills: New methodology and annual estimates 1980-1996, in: *Global Biogeochemical Cycles*, vol. 17, no 2, p. 1065-1072.
6. BOYD P.W. et al., 2000, A mesoscale phytoplankton bloom in the polar Southern Ocean stimulated by iron fertilization, in: *Nature*, vol. 407, p. 695-702.
7. CHOLEWA T., PAWŁOWSKI A., 2009, Sustainable Use of Energy in the Communal Sector, in: *Rocznik Ochrona Środowiska/Annual Set Environment Protection*, vol. 11, p. 1165-1177.
8. COALE K. et al., 1996, A massive phytoplankton bloom inducted by an ecosystem-scale iron fertilisation experiment in the equatorial Pacific Ocean, in: *Nature*, vol. 383, p. 495-501.
9. DUBEY G. et al., 2015, Carbon dioxide metabolism and ecological significance of enzyme complex systems in terrestrial ecosystem, in: *Current Life Sciences*, vol. 1 (2), p. 35-45.
10. GAJ K., 2012, Carbon dioxide sequestration by Polish forest ecosystems, in: *Forest Research Papers*, vol. 73, p. 17-21.
11. FALKOWSKI et al., 2000, The Global Carbon Cycle: A test of our knowledge of earth as a system, in: *Science*, vol. 290, no 5490, p. 291-296.
12. GARBULSKY M.F. et al., 2008, Remote estimation of carbon dioxide uptake by a Mediterranean forest, in: *Global Change Biology*, vol. 14, p. 2860-2867.
13. GORTE R. W., 2009, Carbon Sequestration in forest, in; *Congressional Research Service*, 7-5700, http://www.crs.gov, RL31432 (10.08.2015).
14. GOSIEWSKI K., PAWLACZYK A., JASCHIK M., 2010) Utylizacja metanu z powietrza wentylacyjnego kopalń węgla kamiennego w termicznym reaktorze rewersyjnym, in*: Inż. Ap. Chem*, vol. 49, p. 37-38.
15. IPCC, 2007, *IPCC Fourth Assessment Report: Climate Change, Working Group III: Mitigation of Climate Change*, http://www.ipcc.ch (10.08. 2015).
16. IPCC, 2013, *Report 2013, Carbon and other Biochemical Cycles*, http://www.ipcc.ch (10.08. 2015).
17. IPCC 2014, *Report 2014, Carbon and other Biochemical Cycles*, http://www.ipcc.ch (10.08. 2015).
18. LINDZEN D., 2010, Global Warming: The Origin and Nature of the Alleged Scientific Consensus, in: *Problemy Ekorozwoju/Problems of Sustainable Development*, vol.5, no. 2, p. 13-28.
19. MONTUSIEWICZ A., LEBIOCKA M., PAWŁOWSKA M., 2008, Characterization of the biomethanization process in selected waste mixtures, in: *Archives of Environmental Protection*, vol. 34, issue 3, p. 49-61.
20. OLEJNIK J. et al., 2011, *Oszacowanie strumieni dwutlenku węgla wymienianymi pomiędzy ekosystemami leśnym a atmosferą, Raport z projektu badawczego zleconego przez DGLP za okres styczeń 2008- grudzień 2011*, Warsaw.

21. OREN R. et al., 2001, Soil fertility limits carbon sequestration by forest ecosystem in a CO_2 – enriched atmosphere, in: *Nature*, vol. 411, p. 469-472.
22. PAWŁOWSKA M., 2008, Reduction of methane emission from landfills by its microbial oxidation in filter bed, in: *Management of Pollutant Emission from Landfills and Sludge*, eds. Pawlowska M., Pawlowski L., Taylor & Francis Group, London, 2008, 3-20 (ISBN 978-0-415-43337-2).
23. PAWŁOWSKI A., 2009, Teoretyczne uwarunkowania rozwoju zrównoważonego, in: *Rocznik Ochrona Środowiska/Annual Set Environment Protection*, vol. 11(2), p. 985-994.
24. PAWŁOWSKI A., 2008, How many dimensions does sustainable development have?, in: *Sustainable Development*, vol. 16, no 2, March-April, p. 81-90.
25. PAWŁOWSKI A., 2013, Sustainable Development and Globalisation, in: *Problemy Ekorozwoju/Problems of Sustainable Development*, vol. 8, no 2, p. 5-16.
26. SCHEUTZ C, KJELDSEN P., BOGNER J.E., DE VISSCHER A., GEBERT J., HILGER H. A, HUBER-HUMER M., SPOKAS K., 2009, Microbial methane oxidation processes and technologies for mitigation of landfill gas emissions, in: *Waste Manage Resources*, vol. 27, no. 5, p. 409-455.
27. STASZEWSKA E., PAWŁOWSKA M., 2011, Characteristic of emissions from municipal waste landfills, in: *Environment Protection Engineering*, vol. 37, issue 4, p. 119-130.
28. STĘPNIEWSKI W., PAWŁOWSKA M., 1996, A possibility to reduce methane emission from landfills by its oxidation in the soil cover, in: *Chemistry for the Protection of the Environment 2, Book, Series Environmental Science Research*, vol. 51, p. 75-92.
29. STREESE J., STEGMANN R., 2003, Microbial oxidation of methane from old landfills in biofiltres, in: *Waste Management*, vol. 23, issue 7, p. 573-580.
30. SZYSZKO J., 2015, *Information* on *Nowy Przemysł, http:// www.wnp.pl* (10.08.2015).
31. ULIASZ-BOCHEŃCZYK A., Mokrzycki E., 2015, Biomasa jako paliwo w energetyce, in: *Rocznik Ochrona Środowiska/Annual Set Environment Protection*, vol. 17, p. 900-913.
32. ULIASZ-BOCHEŃCZYK A., E. MOKRZYCKI E., 2005, Przegląd możliwości utylizacji ditlenku węgla, in: *Wiertnictwo, Nafta, Gaz*, vol. 22, p. 373-381.
33. ZDEB M. Redukcja emisji metanu i węglowodorów aromatycznych ze składowisk odpadów w biofiltrze – badania polowe, in: *Rocznik Ochrona Środowiska/Annual Set Environment Protection* vol. 17 (2), p. 1053-1073.