ISSN: 2993-8864
Online Journal of
Ecology & Environment Sciences
DOI: 10.33552/OJEES.2024.02.000526
Iris Publishers

Short Communication

Experimental and Theoretical Approaches to Studying the Earth's Biosphere

SI Bartsev* and AG Degermendzhi

Institute of Biophysics SB RAS, FRC KSC SB RAS, Krasnoyarsk, Russia

Corresponding author: SI Bartsev, Institute of Biophysics SB RAS, FRC KSC SB RAS, Krasnoyarsk, Russia

Received Date: January 19, 2024

Published Date: February 15, 2024

Short Communication

Over the last century the technological power of humanity has reached a level that allows to exert a global influence on the biosphere. The greatest concern is global warming affecting the biosphere-climate system (BCS). In the situation of negative changes in BCS, a comprehensive assessment of possible actions to overcome negative trends is necessary. But it is impossible without an adequate forecast of BCS's reaction to these actions. The forecast can only be built on the basis of adequate mathematical models, representing our understanding the structure of BCS and the mechanisms that ensure its stability. Biophysics is characterized by the construction of conceptual models designed not to accurately reproduce all properties of the original, but only its essential properties that are significant in the context of the research being conducted. The key feature of the biosphere according to V.I. Vernadsky is a high degree of closure of substance flows, which ensures the long-term, and potentially endless, existence of the Earth's biosphere.

The authors of this paper were the first to note [1,2] that due to the positive feedback "greenhouse warming – intensive oxidation of soil organics" and partial disruption of closure, instead of slow increasing global temperature, a catastrophic irreversible process is possible after the transition through the so-called "irreversibility dates". Later, other authors began to discuss a similar possibility [3–5] and the term "tipping points" began to be used. We were also the first to establish a "stepwise" (non-monotonic) increase in global temperature [6-7], the mechanism of which does not yet have a satisfactory explanation [8].

Selecting closure as a key property of the biosphere allows to reduce significantly the severity of general environmental problems - the lack of data and the uniqueness of natural ecosystems, which makes the reproducibility of experiments (the cornerstone of scientific research) impossible. Man-made closed ecological systems (MCES) expand the experimental base of biosphere research, acting as physical models of the biosphere.

MCESs reproduce a key property of the biosphere and the reproduction of a stable cycle in an experiment, and the explanation of this stability by a mathematical model will allow to understand the mechanisms of closure and the stability of the biosphere. In addition MCES provide the opportunity to reproduce or vary experimental conditions to organize repeated experiments with full monitoring of the system state - this is not feasible in natural ecosystems.

It was previously shown traditional mathematical models of the CES with a fixed stoichiometry of nutrient consumption (rigid metabolism models), including more than two nutrients, may not have a non-trivial steady state [9]. In addition in models of rigid metabolism as the number of interacting species increases, the area of stability in the space of model parameters decreases [10], which contradicts observations of natural ecosystems [11] (May's paradox). In addition the Hutchinson's or plankton paradox is known [12,13], when the number of coexisting species in an ecosystem exceeds the number of available resources.

Theoretical and mathematical consideration of CES in comparison with natural ecosystems makes it possible to identify properties of the biosphere that were not previously obvious due to the backdrop of its stunning complexity. For example the very existence of a biosphere closed in matter flows is paradoxical [14]. Considering the closure of the biosphere as the result of its evolutionary development this paradox can be formulated as follows: the closure of the biosphere is not an adaptive trait of an individual (or population). The fact that the closure of the biosphere occurred against the background of natural selection gives grounds to expand the name of this paradox and call it the Vernadsky–Darwin paradox [15].

The models of flexible metabolism proposed by the authors [9,16,17] seem to be an adequate tool for organizing studies of the biosphere using MCES and solving the mentioned above problems of ecology and biospheres. Thus, computational experiments with flexible metabolism models have shown:

1. The patterns of stability growth observed in nature with increasing the number of species are observed (May's paradox);
2. The number of coexisting species is greater than in models of rigid metabolism (plankton paradox);
3. Stationary state of MCES can exist under conditions of complete closure and accounting several nutrients;
4. The Vernadsky-Darwin paradox is almost completely removed [17].

Understanding the closure of substance flows is the necessary condition for the long-term existence of the biosphere makes obvious the incorrectness of applying the "carbon footprint" concept to domestic animals. Organisms that consume organic matter synthesized during photosynthesis and then release CO_2 due to respiration and post-mortem decomposition return carbon to the cycle ensuring the existence of the biosphere. Thus the issue of the carbon footprint of pets, which is discussed in the media and accompanied by calls to reduce their number, makes no sense at all. The carbon footprint of any animal itself is zero, or rather negative.

The view of the biosphere as a CES is perfectly consistent with the features of ecology as a science, which is characterized by:

1) an integrated approach (it is necessary to take into account as fully as possible interrelations taking place in nature);

2) mandatory consideration of long-term consequences.

Based on this idea an approach to an integral assessment of the environmental harm of implemented technologies was proposed [18,19]. By this approach was shown the introduction of electric vehicles ultimately does not provide benefits in terms of CO_2 emissions, and moreover will have a significant negative impact on natural ecosystems.

We do not at all claim the problem of climate change and its consequences does not exist. On the contrary we have written since 2005 that the consequences of burning fossil fuels can have the most catastrophic consequences [1,2,19]. The problem of climate change is very serious; it requires comprehensive research to formulate an adequate strategy to overcome the threat of these changes. No electric cars or solar panels will save us; a radical restructuring of technology and the formulation of the principles of a "circular" economy are required.

Acknowledgements

The study was funded by State Assignment of the Ministry of Science and Higher Education of the Russian Federation (project No. 0287-2021-0018).

References

1. Bartsev SI, Degermendzhi AG, Erokhin DV (2005) Global Minimal Model of Long-Term Carbon Dynamics in the Biosphere. Doklady Earth Sciences 401(2): 326-329.
2. Bartsev SI, Degermendzhi AG, Erokhin DV (2008) Principle of the worst scenario in the modelling past and future of biosphere dynamics. Ecological Modelling 216(2): 160-171.
3. Lenton TM, Held H, Kriegler E, et al. (2008) Tipping Elements in the Earth's Climate System. PNAS, 105(6): 1786-1793.
4. Steffen W, et al. (2018) Trajectories of the Earth System in the Anthropocene. PNAS, 115(33):8252-8259.
5. Wunderling N, Staal A, Sakschewski B, Jonathan F Donges, Henrique MJ Barbosa, et al. (2022) Recurrent droughts increase risk of cascading tipping events by outpacing adaptive capacities in the Amazon rainforest. PNAS, 119(32): 11 p. e2120777119.
6. Belolipetskii PV, Bartsev SI, Degermendzhi AG (2015) A Hypothesis about Double Surging Climate Change in the 20th Century. Doklady Earth Sciences 460(1): 46-49.
7. Belolipetsky P, Bartsev S, Ivanova Y, Saltykov M (2015) Hidden Staircase Signal in Recent Climate Dynamic. Asia-Pac J Atmos Sci 51(4): 323-330.
8. Bartsev S, Belolipetskii P, Degermendzhi A (2017) Multistable states in the biosphere-climate system: towards conceptual models. IOP Conf. Series: Materials Science and Engineering 173: 012005.
9. Bartsev SI (2004) Stoichiometric constraints and complete closure of long-term life support systems. Adv Space Res 34: 1509-1516.
10. May RM (1971) Stability in multi-species community models. Mathematical Biosciences 12:59-79.
11. Ives A.R., Carpenter SR (2007) Stability and diversity of ecosystems. Science 317:58-62.
12. Hutchinson GE (1961) The paradox of the plankton. The American naturalist 95(882):137-145.
13. Levine JM, HilleRisLambers J (2009) The importance of niches for the maintenance of species diversity. Nature 461: 254-257.
14. Barlow C, Volk T (1990) Open systems living in a closed biosphere: a new paradox for the Gaia debate. BioSystems 23(4): 371-384.
15. Bartsev SI, Degermendzhi AG, Sarangova AB (2019) Closure of Earth's Biosphere: Evolution and Current State. Journal of Siberian Federal University. Biology 12(3): 337-347.
16. Saltykov M Yu, Bartsev SI, Lankin Yu P (2012) Stability of Closed Ecology Life Support Systems (CELSS) models as dependent upon the properties of metabolism of the described species. Adv. Space Res., 49(2): 223-229.
17. Bartsev S, Degermendzhi A (2023) The Evolutionary Mechanism of Formation of Biosphere Closure. Mathematics, 11(14), Article number 3218.

18. Bartsev SI, Degermendzhi AG, Okhonin VA, Saltykov MY (2012) An Integrated Approach to the Assessment of an Ecological Impact of Industrial Products and Processes. Procedia Environmental Sciences, 13: 837-846.

19. Bartsev SI, Degermendzhi AG, Sarangova AB (2017) Stability of the Biosphere and Sustainable Development: a Challenge to Biospherics. Journal of Siberian Federal University. Biology 10(2): 134-152.