Supplementing the model of the global biogeochemical carbon cycle

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Abstract. The article considers possible anthropogenic carbon sources and migration ways that were not previously included in the global biogeochemical cycle. Complementing the carbon cycle model is important for clarifying the scenarios awaiting the Earth.

1. Introduction
Life on Earth is based on carbon, all organic compounds include it in their composition. Carbon atoms are constantly migrating in the biosphere, and the global biogeochemical carbon cycle is life-supporting.

The main reserves of carbon on Earth are in the form of carbon dioxide contained in the atmosphere and dissolved in the World Ocean. But when a balanced flux pattern is formed, approximately 27% of the carbon stock from the atmosphere remains unexplained. At the same time, the closedness of the carbon cycle by stocks and sources was 80–85% [1]. This means that the uncertainty in the balance of the global carbon cycle is 15–20%.

The papers of Academician V.I. Vernadsky formed an idea of humanity as a global geological force. He proved that the anthropogenic intensification of the substances migration in the biosphere is a natural process and is in full compliance with the established biogeochemical principles [2]. In the articles it becomes necessary to clarify the biogeochemical model of the carbon cycle in the environment [1; 3-4].

Since the middle of the 20 century, more than 8.3 billion tons of plastics have been produced, which break down into micro- and nanoparticles, that can become one of the carbon reservoirs on the planet. The global biogeochemical carbon cycle is the object of international and national scientific programs as a life-supporting one. Modern balanced carbon cycle models account for anthropogenic carbon emissions but ignore the release of plastics into the environment.

Implemented within the framework of the Global Carbon Project (GCP), the program for controlling carbon flows in the context of the modern civilization development considers anthropogenic emissions of CO₂ and equivalents but neglects the carbon contained in plastics the basis of which is oil [5]. The share of carbon stock in the available models remains unexplained, which greatly reduces the credibility of existing scenarios awaiting the Earth.

Updating the carbon cycle model considering plastic polymers will improve the forecasts accuracy of the processes on the planet.
2. Materials and methods
The description of anthropogenic modifications of all biogeochemical cycles is carried out according to one model. Primarily, the forms of anthropogenic activity that are capable to activate the compounds migration of the key cycle element, in our case, carbon, are quantitatively characterized, and changes in some reservoirs and effluents are also described. The next step is to construct a balance diagram where the main links are the input and output flows of an element in the land-atmosphere-ocean model. Much attention is currently paid to the calculation of anthropogenic CO$_2$ emissions and equivalents. However, the release of plastic particles into the atmosphere, soil and ocean cause a serious problem for the biosphere, as well as adversely affect economic processes.

The volume of plastic production increases with oil production. No reduction in plastic production is foreseen - out of 8.3 billion tons, more than 4 billion tons have been produced over the past 10 years. The amount of materials on the influence of micro- and nanoplastics on environmental components is described in numerous articles and combined in the report of the GESAMP group of the International Maritime Organization (IMO), but the impact on global biogeochemical processes is not currently described. The accumulated data and quantitative characteristics allow to analyze and complement the basic model [8-10].

Between the atmosphere, pedosphere and hydrosphere there is a constant intensive exchange of carbon, which has a self-organizing nature. According to Le Chatelier's principle, the content of mobile carbon in a system tends to a stable ratio of the ratio of the total amount of mobile carbon in the reservoir to the average residence time in the system with a constant characterizing the rate of carbon cycle. If the condition is met, then the release of carbon from the system reservoir is compensated by its input from other reservoirs. Otherwise, uncompensated flows appear in the system.

Spatial and temporal characteristics must be considered to calculate all carbon fluxes. The current level of knowledge allows solving the problem only partially, but by virtue of modern methods of identifying substances in the components of the environment, the model can be refined, thereby reducing the uncertainty interval in predictive models of the future of the Earth.

Among all the factors affecting the redistribution of carbon on the planet, currently, the most important role can be distinguished as the transfer of carbon by meteogenic waters and human economic activity. Due to the first former, excess carbon on the continents comes from the meteogenic waters below the earth's surface [1].

The formation of large sedimentary basins occurs more often in the faults of the earth's crust. The presence of faults, on the one hand, facilitates the penetration of meteogenic waters under the Earth's surface, and on the other hand, facilitates the discharge of these waters from the carbon transported by them [3]. This fact indicates that the carbon cycle cannot be studied in isolation from the water cycle.

Considering the above assumptions, the general scheme of the carbon cycle can be taken as a basis to optimize carbon fluxes and reduce the uncertainty in the balance of the global cycle [7].

3. Results
The model of the global cycle of plastic hydrocarbons in the atmosphere – hydrosphere – land – biota system reflects carbon exchanges at the boundaries of the atmosphere with the earth's covers, water areas and biota (figure 1).

Plastic hydrocarbon flows $C_i$ are functions of temperature, geographic coordinates and other environmental characteristics.

The main sources of plastic in the environment are short-lived consumer products, synthetic fabrics, agricultural mulch films, sludge, and tire abrasion.

A significant part of plastic pollution is made up of fragments of synthetic fabrics that enter water bodies after washing and into the atmosphere when worn, particles of rubber car tires contained in city dust, and solid household waste.
4. Discussion
Microparticles of plastics entering the atmosphere can act as condensation nuclei. Condensation on nuclei with radii of the order of $10^{-7} - 10^{-5}$ m occurs without significant oversaturation. Particles of plastics are stable compounds that can be contained in aerosols for a long time, transported by air currents over long distances and enter soils and water bodies with precipitation. Plastic particles from the surface layers of the atmosphere can undergo aerobic oxidation by microorganisms.

In soils, particles with a size of $10^{-9} - 10^{-7}$ m are included in colloidal systems. Colloidal impurities from atmospheric precipitation are very small aggregates; due to their large specific surface area, they have significant surface energy and high adsorption capacity. Microplastic particles are able to adsorb many pollutants on their surface thus accumulating them. This fact negatively affects both the growth and development of vegetation and the pedofauna [8-9].

Soil formation without living organisms, especially mesofauna, which performs a very important function of crushing organic matter and converting it into humus, is not possible. In the event of a decrease in the number of earthworms, for example, the soil will gradually collapse, lose humus, and reduce the yield.

Microplastics from soils are transferred to groundwater and surface waters. Marginal filters in the mixing zones of river and sea waters at river mouths flocculate and coagulate a significant part of
dissolved (colloidal) and suspended solids. In addition to sedimentation and sorption, bioassimilation and biofiltration take place. By virtue of the marginal filter, up to 95% of suspended and about 40% of colloidal substances of river runoff including microplastics are deposited in this zone [10]. In the oceans, plastics are concentrated in the photic layer above the thermocline, gradually degraded, and migrating through the deep layers reaches the bottom layer. Plastics accumulate in bottom sediments.

Microparticles of plastic have a wide range of size groups and low density, as a result of which many actively feeding living organisms perceive them as a food source, and organisms with a passive type of food, for example, filter feeders, are forced to absorb plastic from the environment. Since the plastic is not broken down by their enzymatic system, ingesting the plastic itself is dangerous and can be fatal. Of particular concern is the adsorption capacity of plastics and the intake of high doses of pollutants with particles into the body. Studies also indicate a high probability of assimilation and migration of microplastics along the trophic chains, including humans [11].

5. Conclusion
In conclusion, it should be noted that the closure of carbon flows in the environment should take into account the migration of plastic particles. Modeling opens the possibility for further targeted studies of the biogeochemical carbon cycle, taking into account the impact of the plastic particles release into the atmosphere, soil, ocean and biota. The development of a model structure that considers an additional anthropogenic carbon source will allow the more accurate characterization of carbon flows between reservoirs.

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