

Environmental safety in the implementation of carbon dioxide geological storage technologies in the Donbass

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Abstract. The Donbass has the largest potential in Europe for the geological storage of carbon dioxide (CO₂), which needs to be implemented on a large scale to mitigate the effects of global climate change. The environmental risks of CO₂ leaks in the processes of capturing, transporting and geological storage of CO₂ at the enterprises of the energy and industrial sectors of the economy of the eastern regions of Ukraine are analyzed. Geographic information systems have been created in these areas with layers of geological structures suitable for long-term storage of supercritical CO₂. The impact of CO₂ leaks from geological repositories on the environment is estimated. In the proposed CO₂ storage areas, some CO₂ leakage scenarios were analyzed due to the filtering of CO₂ fluids through porous rock layers, through abandoned wells and tectonic faults of the Donbas geological structures. The potential effects of CO₂ leakage on groundwater quality in the region are also assessed.

Current global climate change is caused [1], to a large extent, by an increase in the amount of greenhouse gases in the atmosphere, mainly carbon dioxide (CO₂). The main anthropogenic source of CO₂ emissions is energy and industrial enterprises, which widely use fossil fuel combustion, which causes great environmental risks for the environment [2].

Studies of ways to mitigate the effects of global climate change [3, 4] indicate the need in the near future to significantly reduce CO₂ emissions into the atmosphere through the implementation of CO₂ capture and storage (CCS) technologies. The use of these technologies will ensure by 2050 a decrease in the expected average increase in the global temperature of the atmosphere by 2° C. The large-scale implementation of CCS technologies requires significant material and financial resources, which will lead to an increase in electricity prices by an average of 30% - however, so far there is no other effective way to reduce the amount of CO₂ in the atmosphere and CCS technologies need to be implemented in all countries of the world.

At present, several thermal power plants with installed CO₂ capture units before combustion, during oxygen combustion and after fuel combustion are already under construction and are operating in a number of countries (Australia, Germany, Spain, etc.). The captured CO₂ is then transferred to a liquid supercritical state and transported to the place of geological storage in rocks at a depth of more than 800 m.

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The introduction of CCS technologies in the energy and other industries will temporarily mitigate the effects of climate change before developing climate-friendly energy sources. But when using technologies CCS, there are risks of CO₂ leakage, which can have an adverse effect on humans and the environment.

The territory of Donbass has the most significant potential [5] in Europe (Fig. 1) for geological storage of CO₂ in order to mitigate the effects of climate change [6]. This potential for CO₂ accumulation is estimated at 45.7 to 428.3 billion tonnes, which causes interest in the possibility of using it for the needs of the whole of Europe, but it should take into account the great environmental risks of geological storage of CO₂ for the territory of Donbass.

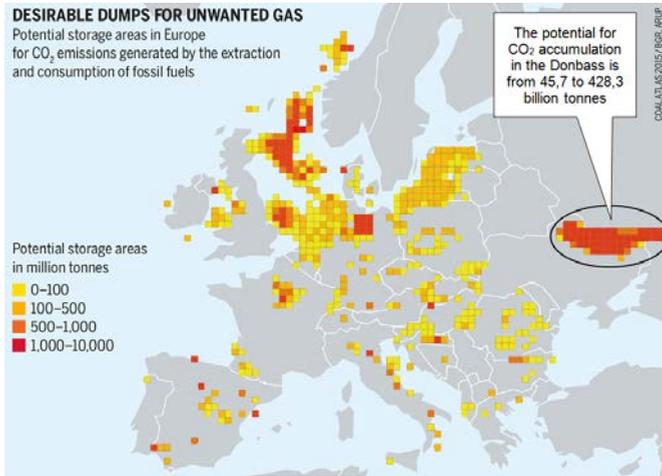


Fig. 1. Potential areas for CO₂ accumulation in Europe [5]

Geological structures of Donbass [7] have been identified previously, suitable for long-term storage of supercritical CO₂, which is transported through the existing gas transmission system with some upgrades, and then pumped into the Paleozoic sediments of Donbass [8] in several promising areas (Fig. 2) that are not contain territories of large settlements, operating coal mines and areas of tectonic disturbances in the form of salt rods.

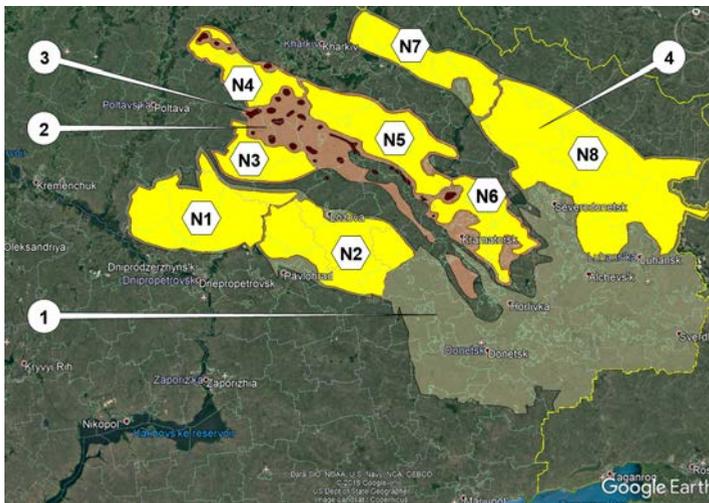


Fig. 2. Localization of promising zones and areas of CO₂ geological storage in the Donbass

- 5 - rocks of deeper geological layers, located deeper than CO₂ storage areas;
- 6 - well for injection of supercritical CO₂ into its storage area;
- 7 - zone of distribution and storage of fluid CO₂ under the impermeable rock-cap.

Positions 8, 9 and 10 in Fig. 3 correspond to the implementation of the first scenario of CO₂ leakage due to the lack of tightness of the rock-tire. Estimates of CO₂ leakage volumes in this scenario are carried out by numerical simulation of thermo-hydrodynamic and mechanical-chemical processes [9], taking into account the real parameters and composition of rocks located above the CO₂ storage area. These processes (8) proceed very slowly (it may take 100 or 1000 years until the product of the processes reaches the groundwater or surface), but it is extremely dangerous for humans and the environment (supercritical CO₂, both liquid and two-phase, is a very effective solvent of rocks and products of such chemical reactions may be toxic). And getting into the groundwater (9) such toxic products can significantly impair their quality. Then these products and gaseous CO₂ reach the surface (10) and can adversely affect humans and the environment.

The second scenario of CO₂ leakage can be realized in the area of developed and existing oil and gas fields. There are many such deposits in the Donbass, some of which continue to be exploited [10], and some are conserved or abandoned, although hydrocarbons still remain there. In order to increase oil and gas recovery from seams, you can use CO₂ injections as part of projects on the implementation of CCS technologies in the Donbass.

Positions 11 and 12 in Fig. 3 correspond to this scenario of CO₂ leakage from geological storages, while in the process of raising CO₂ to the surface through abandoned and operating wells (11), it can be dissolved in groundwater (12), which will affect their quality.

Since the abandoned and operating wells are located near or on the territory of oil and gas fields, it is possible to estimate the risks of CO₂ leakage in this way by comparing the areas of fields and areas of prospective geological storage of CO₂.

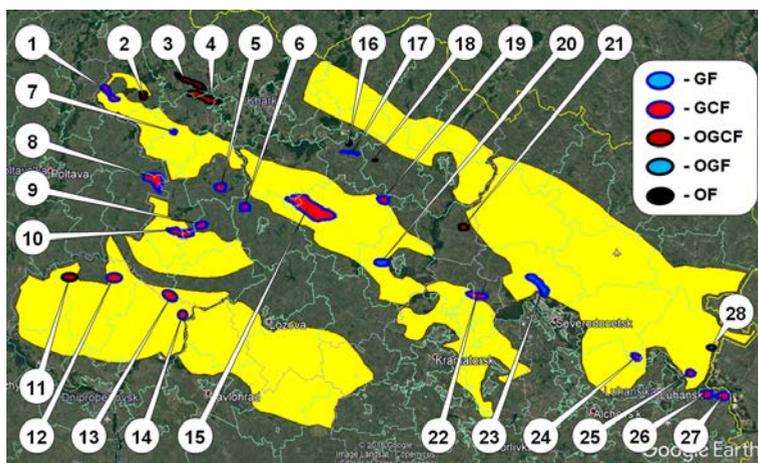


Fig. 4. Localization of gas (GF), gas condensate (GCF), oil and gas condensate (OGCF), oil and gas (OGF) and oil (OF) fields

The Fig. 4 shows following oil and gas fields of Donbass [10] are shown: 1 - Berezovskoe GCF; 2 - Sakhalinskoe OGCF; 3 - Skvortsovskoe OGCF; 4 - Yulievskoe OGCF; 5 - Melikhovskoe GCF; 6 - Efremovskoe GCF; 7 - Kolomakskoe GF; 8 - Zap.-Krestischenskoe GCF; 9 - Kegichevskoe GCF; 10 - Kobzevskoe GCF; 11 - Kremenovskoe OGCF; 12 - Proletarskoe GCF; 13 - Bogatoyskoe GCF; 14 - Leventsovskoe GCF; 15 - Shebelinskoe GCF; 16 - Sev.-Korobochkinskoe OGF; 17 - Korobochkinskoe GCF; 18 -

Gashinovskoe OF; 19 - Vishnevskoe GCF; 20 - Spivakovskoe GF; 21 - Drugelyubovskoe OGCF; 22 - Drobyshevskoe GCF; 23 - Evgenyevskoe GF; 24 - Trekhizbenskoe GCF; 25 - Kondrashevskoe GCF; 26 - Olkhovskoe GCF; 27 - Markovskoe GCF; 28 - Lvovskoe OGF.

The estimate of the probability of CO₂ leakage through the wells of existing fields is defined in Table 1, where areas of promising areas of CO₂ geological storage and areas of oil and gas deposits are taken into account, it is considered that there are a large number of abandoned and operating wells in the fields, and the shafts and drifts of coal mines were previously excluded from areas of promising areas of CO₂ geological storage.

Table 1. The probability of CO₂ leakage through the wells of existing fields

Site number for CO ₂ geological storage	1	2	3	4	5	6	7	8
The area of the prospective site, km ²	4425	4373	1630	1594	3311	1995	2712	9641
The area of fields on the site, km ²	65,7	-	47,3	45,1	212,9	16,0	-	90,3
The probability of leakage of CO ₂ , %	1,5	-	2,9	2,8	6,4	0,8	-	0,9

Positions 13, 14 and 15 in Fig. 3 conditionally reflect the third scenario of CO₂ leakage through existing faults and cracks in mountain formations (13), where gaseous CO₂ rises along tectonic structures of a given area to groundwater (14), affecting their quality, and going to the surface (15), affecting vegetation, animals and humans.

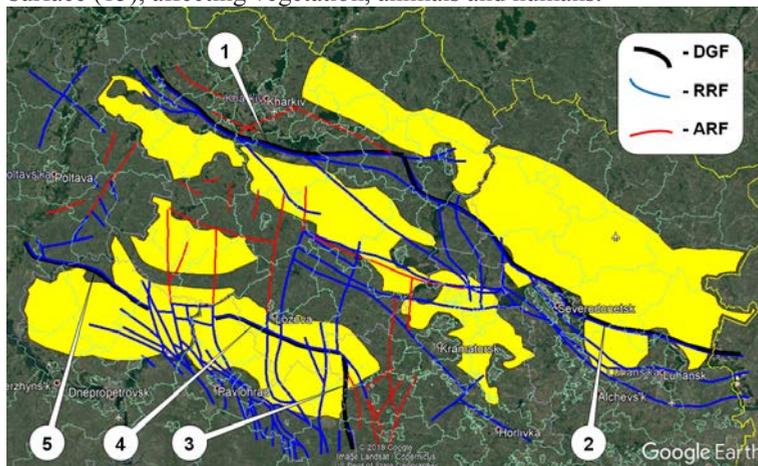


Fig. 5. Localization of deep geological (DGF), reliable (RRF) and alleged regional (ARF) faults

To assess the likelihood of the implementation of the third scenario of CO₂ leakage from promising areas of CO₂ geological storage in Donbass, you can combine the location of deep and regional faults [10] with geological sites (Fig. 5), which show the following deep geological faults: 1 - South-Kharkiv fault; 2 - Krasnoresky fault; 3 – Krivoy-Rog-Pavlovsky fault; 4 - Yurievsky fault and 5 - Golubovsky-Mikhailovsky fault, as well as other reliable and suspected regional faults in promising areas of CO₂ geological storage. If we assume that the zone of CO₂ leakage through geological faults is on average 1 km wide, then an estimate of the probability of such a CO₂ leakage can be presented in Table 2.

Table 2. The probability of CO₂ leakage through geological faults

Site number for CO ₂ geological storage	1	2	3	4	5	6	7	8
The area of the prospective site, km ²	4425	4373	1630	1594	3311	1995	2712	9641
Area of possible CO ₂ leaks, km ²	310	439	80	5	262	150	9	142
The probability of leakage of CO ₂ , %	7,0	10,0	4,9	0,3	7,9	7,5	0,3	1,5

As an example, assessing the impact of CO₂ leaks on groundwater quality is compatible (Fig. 6) the contour of the promising area of geological storage of CO₂ N8 (1) with a hydrogeological map of Ukraine (first from the surface of aquifers) [11] showing aquifers: in the Eocene, Oligocene and Miocene (2); in the fracture zone of the Marl-Cretaceous stratum of the Upper Cretaceous (3); in the upper and modern estuary sediments (4); in the deposits of the Jurassic (5); in Triassic sediments. Also in Fig. 6 shows the bed of the Seversky Donets River (7) and its tributaries (8). At the same time, 46.7% of the horizon 2, 43.0% of horizon 3, and 40.9% of horizon 4 fall within the territory of section N8, which indicates a significant impact on all aquifers of possible CO₂ leaks in section N8.

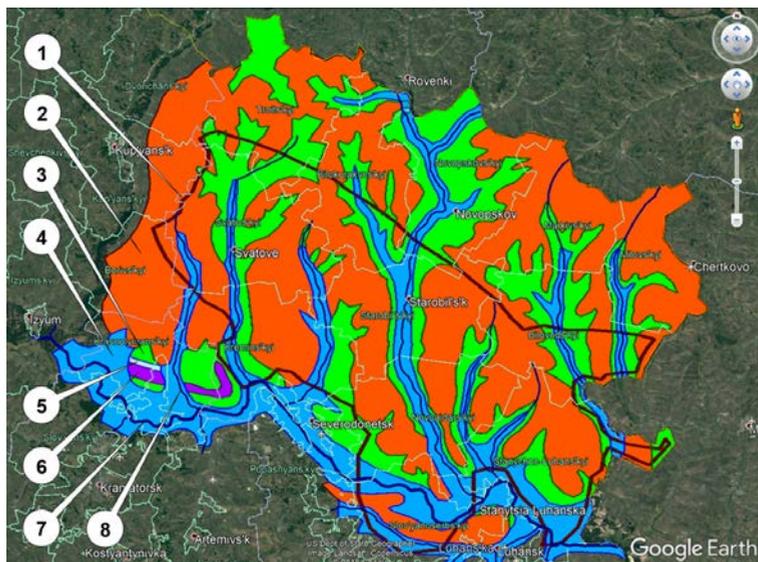


Fig. 6. The first aquifers from the surface in the territory of a promising area of storage of CO₂ N8

Similar estimates for the first aquifers in the territory of other promising areas of the geological storage of CO₂ (N1-N7) can be made on the basis of data from this map [11].

A study of the scenarios and risks of CO₂ leakage during its geological storage in the Donbass area will allow for measures to be taken to comply with environmental safety measures when implementing carbon dioxide capture and storage technologies to mitigate the effects of global climate change.

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