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11. Conclusions and Recommendations

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Despite the fact that since 25 July 2011 the Slovak Act on underground storage of CO_2 has been in force, (No.258/2011 of the Code), certainly a considerable amount of time is needed until this important legislative instrument will be applied in the practical sphere.

The monograph has assessed depleted hydrocarbon deposits, local and regional aquifers, and mafic and ultramafic rocks that may be suitable for CO_2 storage.

All the objects that could be considered are included in the database, which provides the essential parameters that are available, including an estimate of storage capacity.

In terms of performance criteria the most appropriate are depleted hydrocarbon deposits. However, within the West-Carpathians territory they do not represent significant objects in terms of sufficient capacity. Those structures with calculated capacity which we could assign to "effective" ones allow some objects to be used for the purposes of the pilot project (Stretava, Ptrukša, Láb, Marcelová), but storage of industrial importance (annual volume of injected gas 500 kt - 1 (Mt) with a lifetime of 15-20 years cannot be considered except the Marcelová site.

The Marcelová structure should provide effective capacity for storing 70 Mt of CO_2 while extracting highly-mineralized brine containing economically interesting amounts of iodine and bromine. The highly-mineralized water exploitation (90 $g.l^{-1}$) could reduce to a certain extent the costs for CO_2 storage. Even if the estimated amount is too optimistic (based on the calculation of reserves of mineral waters), it is still interesting for capacity reasons and what is important from the point of security, the location in a seismically active area does not affect tightness of the reservoir. The CO_2 behaviour in the reservoir was predicted using hydrogeochemical modelling.

The sufficient storage capacity appears to have the deposit Vysoká - Zwerndorf in the Vienna Basin, shared by Slovakia and Austria. At the Slovak territory the deposit is depleted and flooded. According to our calculations 11.7 Mt of CO_2 can be stored at the Slovak side within so-called 'g' sand (base of Middle Badenian), which already produces reflections at industrial scale (pilot project could be implemented in the overlying horizons). At this point we would like to emphasize that at the Austrian side we can assume by the size of the deposit virtually doubled storage space. Non-negligible are residual methane reserves in the deposit, which could be exploited after mastering the EGR technology; but still this will definitely take several years of research.

Larger capacity estimates we assume within the Danube Basin, but here we are dealing with local storage in aquifers of identified small gas deposits. Although the estimated capacities are of the order of about 10 Mt, despite our very "sober" assessment, we must remember that these are "theoretical" capacities that require further work, which results in terms of capacity pyramids usually lead to diminished capacities. From the point of view of capacity the deposit Báhoň could be considered; of course, further work is needed to define the volume of the aquifer in detail.

In the case of the deposits of natural gases Križovany nad Dudváhom (CO_2) and Cífer (N_2) which are included among underground methane reservoirs, the question is where the original gases will be deposited (or used?), if they will be replaced by methane (e.g., the Križovany structure contains about 6 Mt of CO_2).

Since CCS is very costly, it is useful if the costs incurred could be at least partially covered by added value.

Similarly considered could be the Lipany site, where geothermal water from the Fatricum unit is planned to be exploited for recreational purposes. However, it contains a high amount of natural CO_2 to be disposed of. We suggest to store the carbon dioxide potentially in the overlying aquifer, situated near the base of the Inner Carpathian Palaeogene, with the possible additional exploitation of small deposits of methane and its use for the purpose of recreational facilities. The site has the features of potential industrial storage, but this requires further technical verification work.

Similarly interesting capacity has the Zlatá Baňa area in the Slanské vrchy Mts. The intention to store CO_2 within porous products of rhyolitic volcanism is not common, the implementation, however, requires a number of additional data.

At the Zboj site in the north-easternmost tip of Slovakia, we deduced a number of conclusions based on the interpretation of newly identified magnetic anomalies. In addition to the findings, leading to fundamental issues of geological setting, it is possible to deduce conclusions leading to the application sphere and not only to the prob-

lems of CO_2 storage, but also to metallogenetic sphere. In any case the result may "provoke" potential candidates for business plans in hydrocarbon and metallogenetic issues.

The aforementioned structures are in our opinion the most significant findings in the framework of the research and we stress them because they have (except the Zboj site) very close affinity to the real situation.

Another interesting achievement is certainly the fact that we tried to estimate the amount of natural CO_2 released into the atmosphere from 1708 recorded mineral springs in Slovakia. We came to the result of 3.6 Mt/year, which is the approximate amount that produces the third largest CO_2 emitter in Slovakia - thermal power plant Nováky.

We emphasize that the work has dealt with "***selected*** structures suitable for CO_2 storage" and therefore we do not assume that we have exhausted all possibilities for this purpose, which provides complicated geological setting of the Slovak territory. We have focused on structures that are close to current reality.

In addition to the above sites we address the issue of permanent CO_2 storage in suitable petrographic types of rocks. This method is not usable in every country because it requires the existence of ultramafic rocks. The results are as follows:

We have come to the finding that an unparalleled potential to absorb CO_2 have the samples of the serpentine group, where levels of magnesium component vary between 34.75 to 39.73 %. They are followed by amphibole-chlorite and talc serpentines; the least potential have the samples of the amphibolite and basalt. On average, 1 t of CO_2 could be stored in 2.6 tonnes of amorphous serpentine rocks. In the present methodology in operational stage this method of carbonatization can be suitable complement to the sites with hydrodynamic storage regimes. Its advantage is the acquisition of raw materials and contribution to improving the environment.

Thus, if in the future Slovakia plans to reduce the negative effects of climate change by CO_2 storing, the first necessary step would be a pilot project as a necessary intermediate stage prior to industrial application. In the research we have identified a number of structures - depleted hydrocarbon deposits, both in Vienna and Transcarpathian Basins, which would meet the criteria for a pilot project. The prospects of the pilot project depend on the overall situation and the need to make a step forward in that sphere.

Note: In cooperation with Nafta Bratislava a.s. we have proposed in the scope of the project CGS Europe (Czernichowski-Lauriol at al., 2010) for ZEP (Zero Effective Platform – EC advisory body) 4 sites of pilot projects (Láb, Marcelová, Ptrukša a Stretava).

However, we can conclude that, if necessary, the Slovak Republic has available appropriate structures for both the pilot as well as industry imposition of the carbon dioxide. Of course, all designed sites will require further technical work and build the infrastructure and based on the results of this forthcoming work will be possible to launch industrial CO_2 storage.

The intended technology comes to conflicts of interest mainly with the sources of mineral and geothermal waters. An important role will play economic possibilities, including fees for emissions because CCS technology is challenging not only operationally, but it is also costly. The further development will depend on the overall situation in the field of global climate change, economic and energy opportunities and the resulting political decisions. We cannot omit the public attitude, which tends to be very important input into this type of issues. Therefore, the upcoming developments will show whether the methodology of CCS in Slovakia finds practical application in the future.

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