Mineral and Energy Economy Research Institute
of the Polish Academy of Sciences

CO_2 sequestration with the use of fly ash from hard coal and lignite combustion

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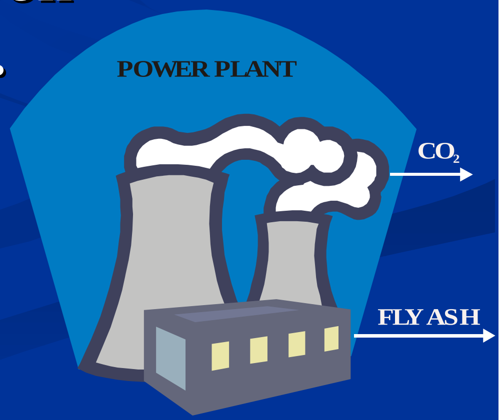
The Polish power industry is based on conventional fuels combustion: hard coal and lignite. This industry is the largest source of carbon dioxide emission in Poland. Power generation process creates considerable quantity of wastes, including fly ash which is used in various other industries. One method of using fly ash in Poland is placing it in a fly ash-water suspensions in underground coal mines. Fly ash in a mixture with water might be used for carbon dioxide fixation in mineral carbonation process.



The CaO and free CaO content decides largely about the usefulness of fly ashes in CO_2 bonding. On the basis of fly ashes analysis from Polish professional power industry, it has been stated that the fly ashes from lignite and fluidized bed boilers are characterized by the biggest CaO contents (10-29,2%). The lowest CaO content amounting to 0,86-6,2% is present in the fly ashes from conventional hard coal combustion.

Fly ashes used for CO_2 fixation need to have high calcium content, which directly reacts with water. As the result of fly ash hydration the $Ca(OH)_2$ and C-H-S phases form, which are reactive with carbon dioxide.

portlandite

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

calcium silicates

$$CaO \cdot nSiO_2 \cdot mH_2O\ (C-S-H) + CO_2 \rightarrow CaCO_3 + SiO_2 + mH_2O$$

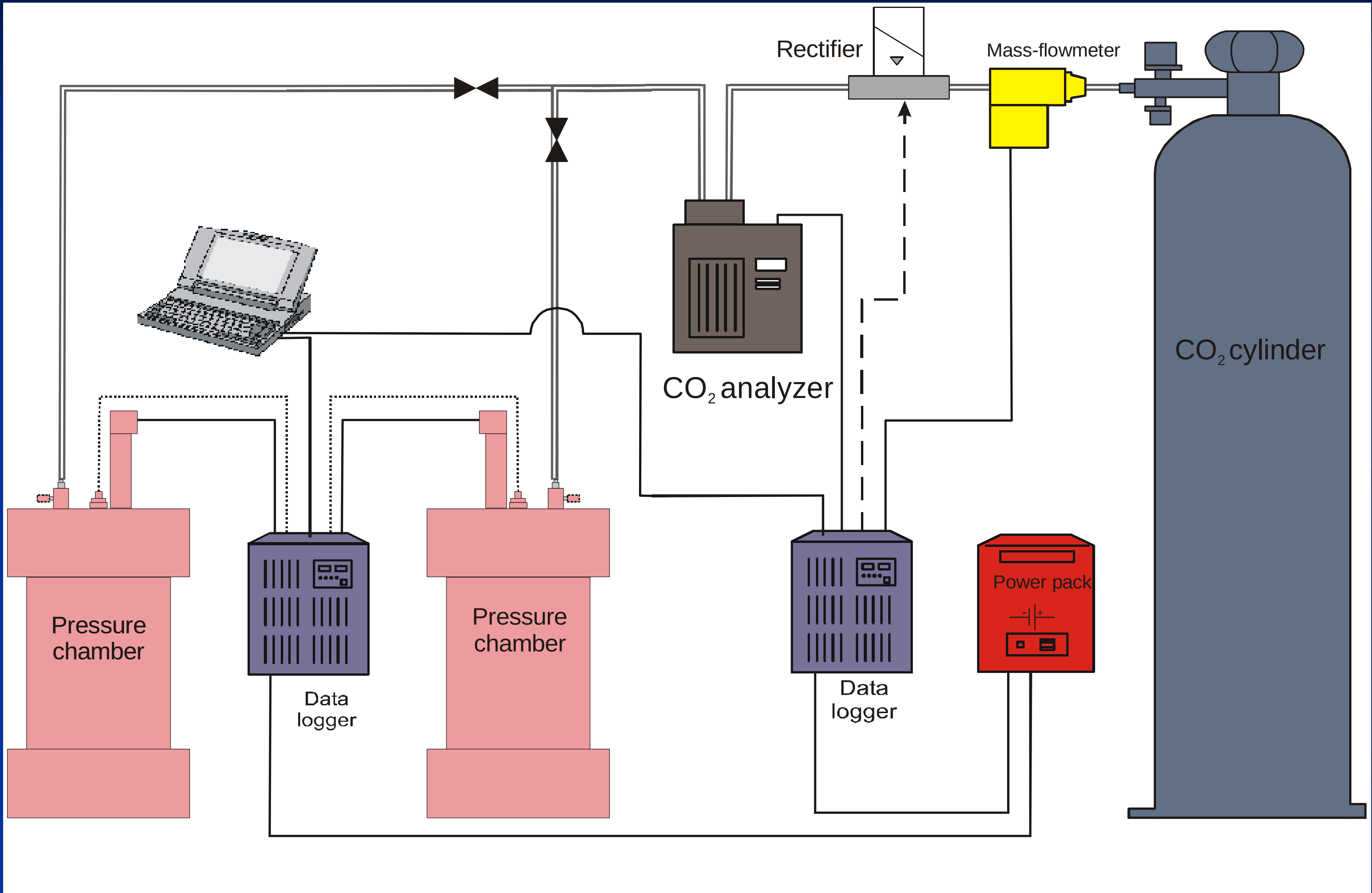
A wide range of research has been carried out in order to determine the applicability of selected fly ash from Polish professional power industry to CO_2 sequestration via mineral carbonation including:

- ✓ determination of CO_2 absorption by ‘fresh’ ash-aqueous suspensions
- ✓ determination of CO_2 bonding rate
- ✓ determination of CO_2 influence on leachability of impurities from ash-aqueous suspensions
- ✓ determination of CO_2 influence on properties of ash-aqueous suspensions

Chemical composition of fly ash selected for the purpose of research

Component	Fly ashes from hard coal combustion in conventional boilers	Fly ashes from lignite combustion in conventional boilers	Fly ashes from hard coal combustion in fluidized bed boilers boilers	Fly ashes from lignite combustion in fluidized bed boilers boilers
SiO_2	58.4	41.5	31.4	38.0
Fe_2O_3	4.0	4.5	3.5	4.5
Al_2O_3	14.0	4.8	14.7	28.0
CaO	5.3	30.0	20.0	16.0
MgO	3.0	4.5	2.2	2.0
CaO_{free}	1.3	7.1	6.7	5.0

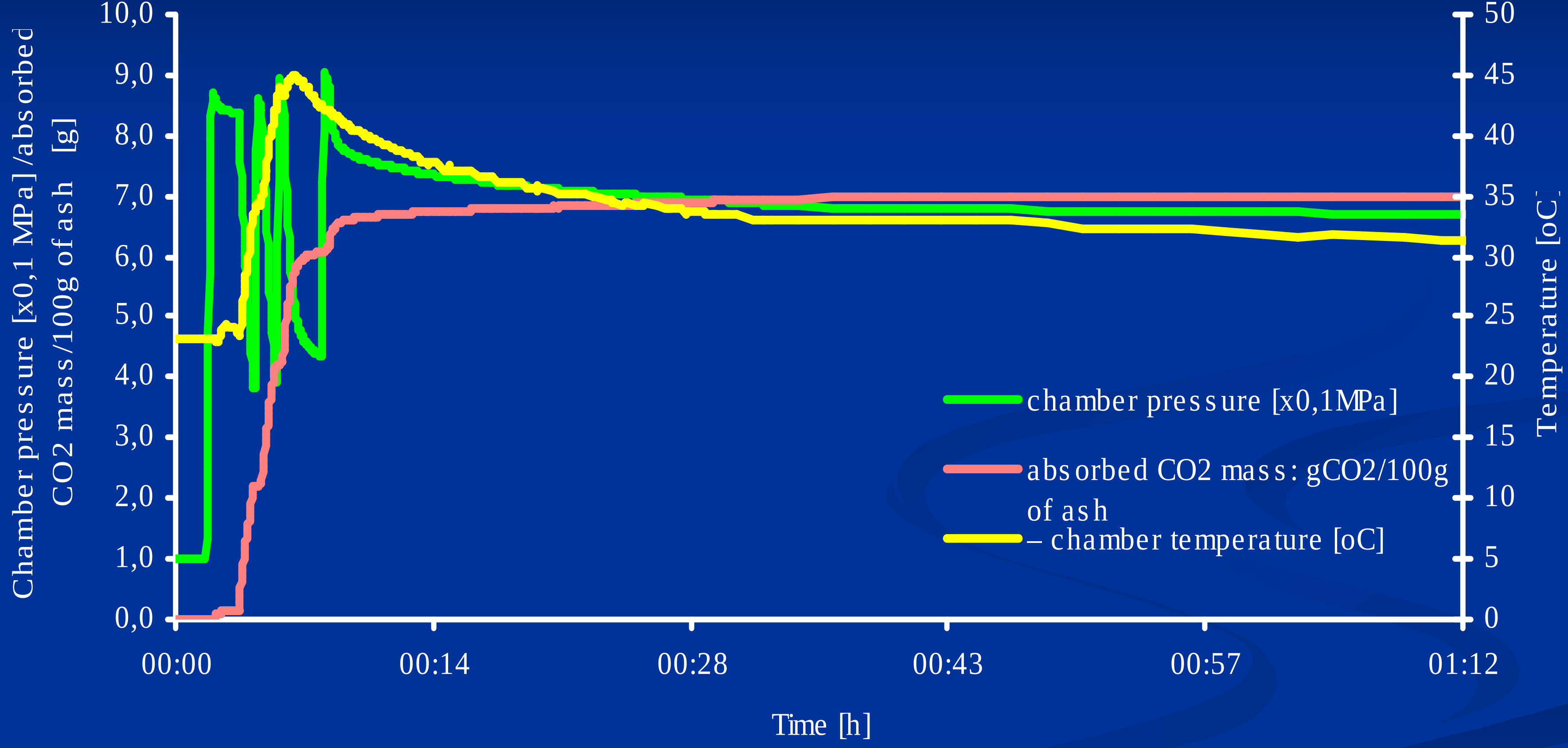
Investigation system to determine the amount of absorbed CO_2



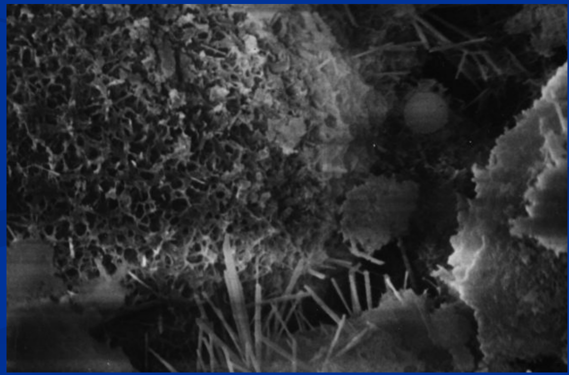
Absorption of CO_2 by ‘fresh’ ash-aqueous suspension

Suspension kind	Ash-water ratio	Seasoning time [h]	CO_2 absorption [g CO_2/100 g]	
			after 24 hours	total
Suspension with fly ashes from hard coal combustion in conventional boilers	1.5	480	1.33	1.83
Suspension with fly ashes from lignite combustion in conventional boilers	2.0	408	4.81	7.88
Suspension with fly ashes from hard coal combustion in fluidized bed boilers boilers	0.6	614	7.85	8.41
Suspension with fly ashes from lignite combustion in fluidized bed boilers boilers	1.0	760	7.03	7.52

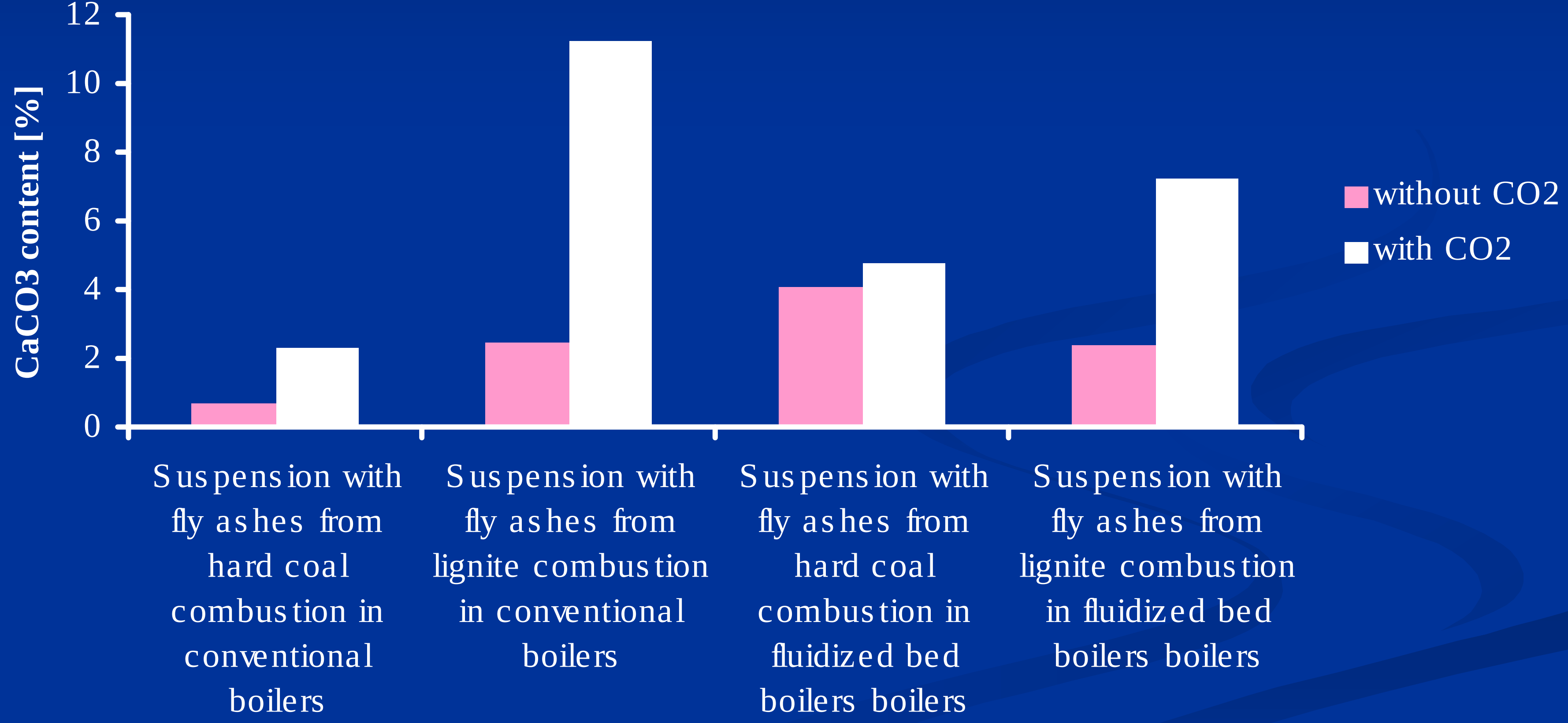
Example chart of absorption



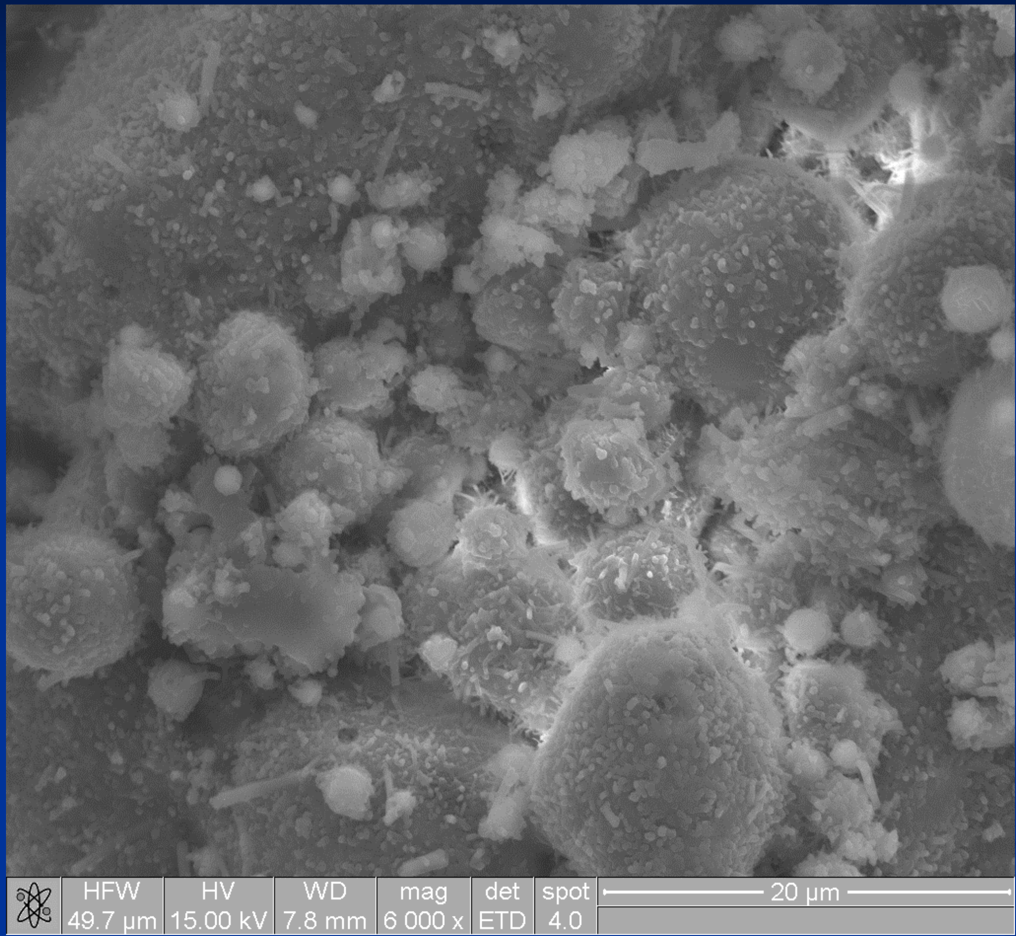
In order to confirm CO_2 bonding by ash-aqueous suspensions, that is the ongoing processes of mineral carbonation, their phase composition has been examined by means of roentgenographic method, calcium carbonate content – thermogravimetry method and supplementary, the microstructure has been examined with the use of a scanning microscope. In the studies the presence of calcite and its content has been of a particular interest, which is the elementary product of mineral carbonation and phases – the products of ash hydration undergoing carbonation. Determination of phase composition helps to state whether carbonation will proceed.



$CaCO_3$ content

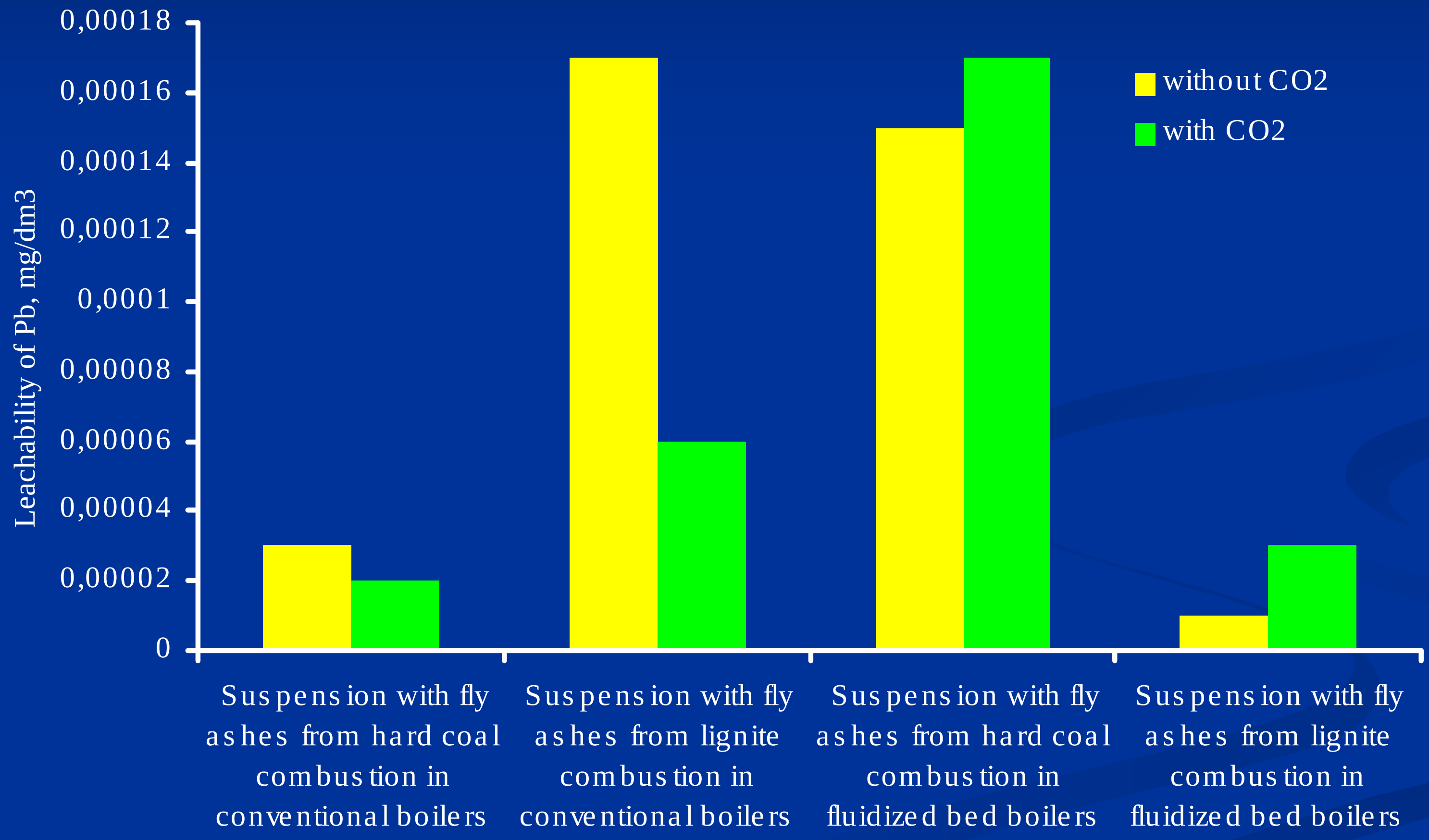


Ash-aqueous suspension with the inserted CO_2

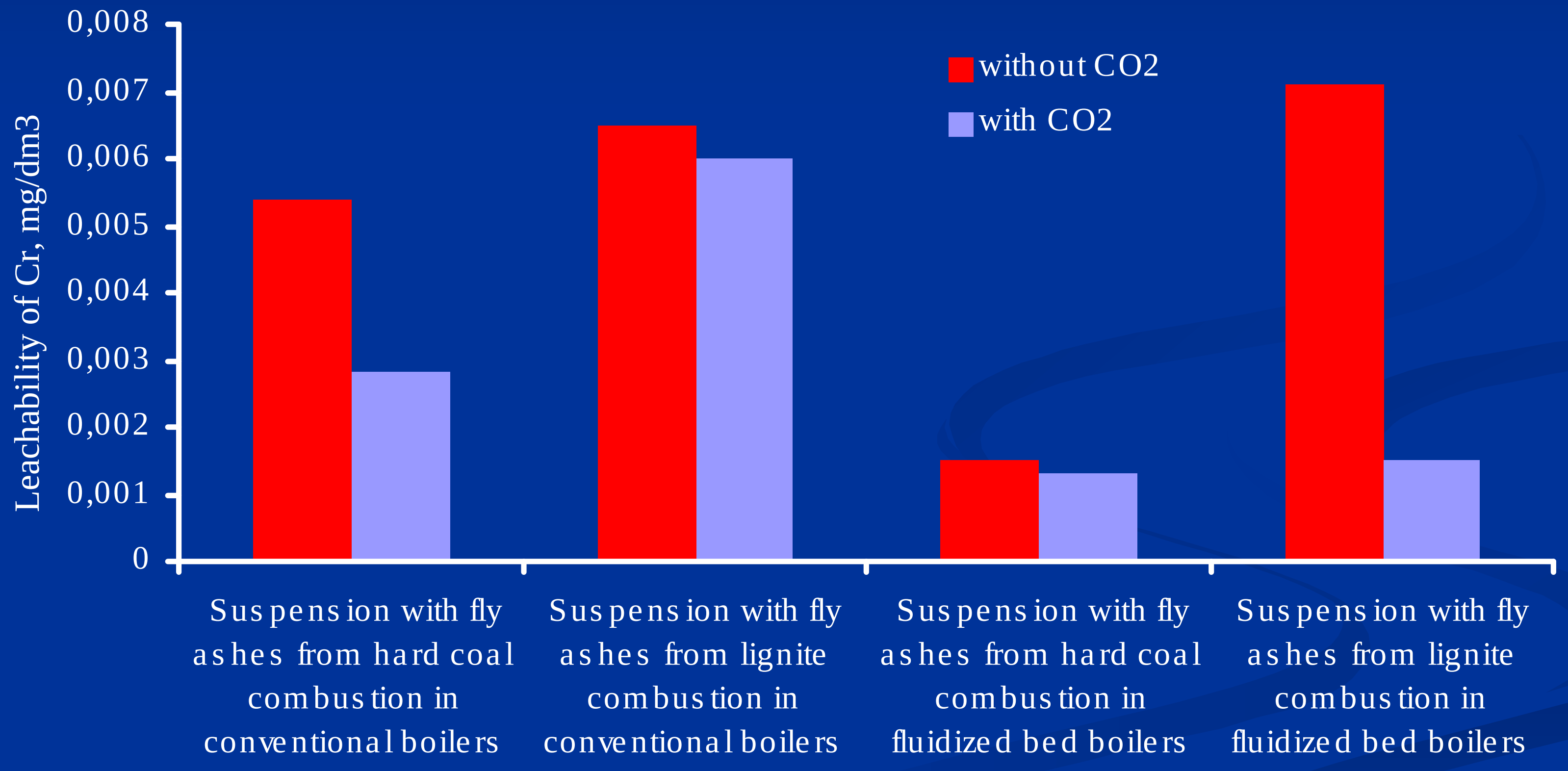


Noticeable ash grains covered with microcrystalline silicates hydration, distinguishable calcite

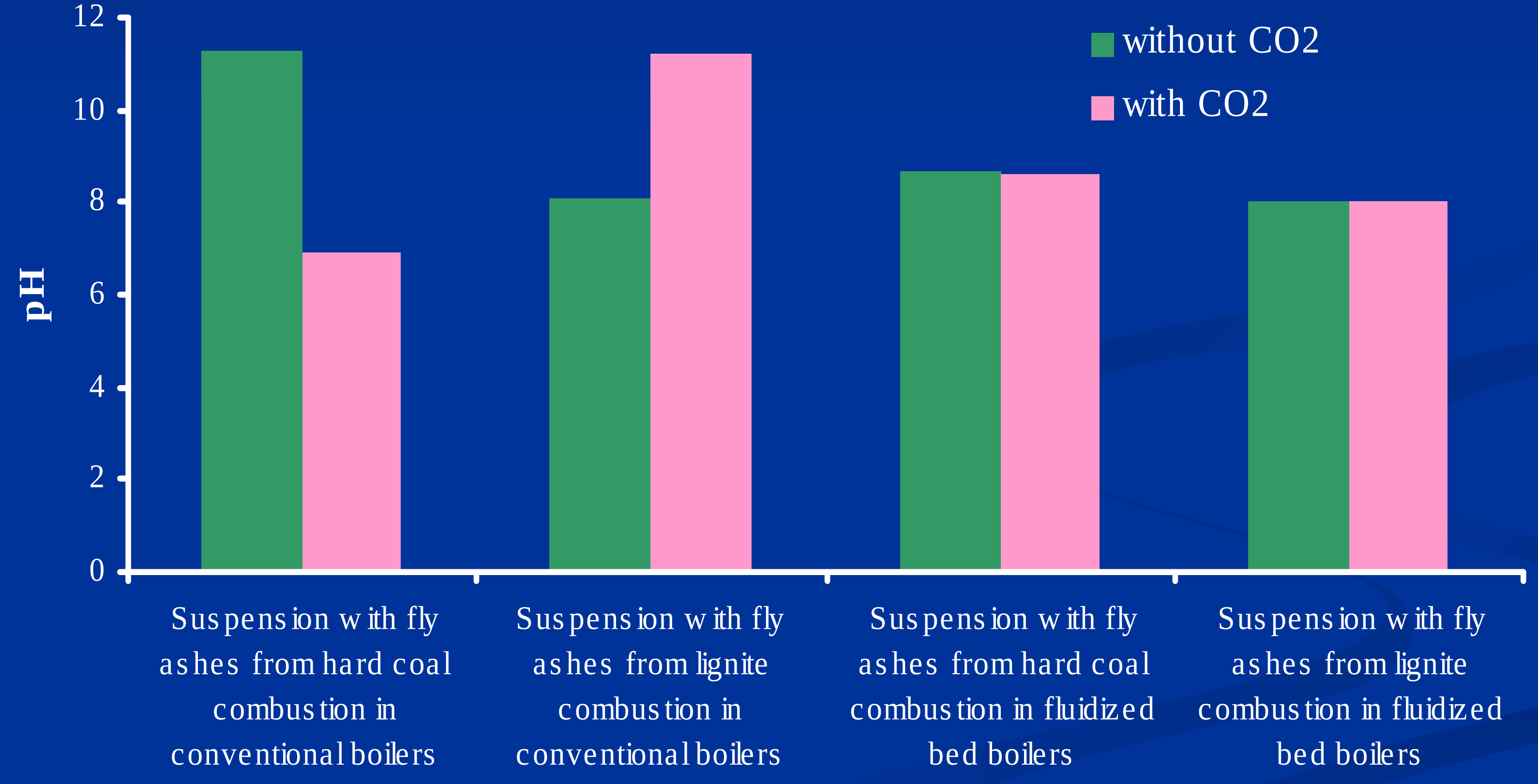
Pb contents in leachates from ash aqueous suspensions ‘pure’ and with the inserted CO_2



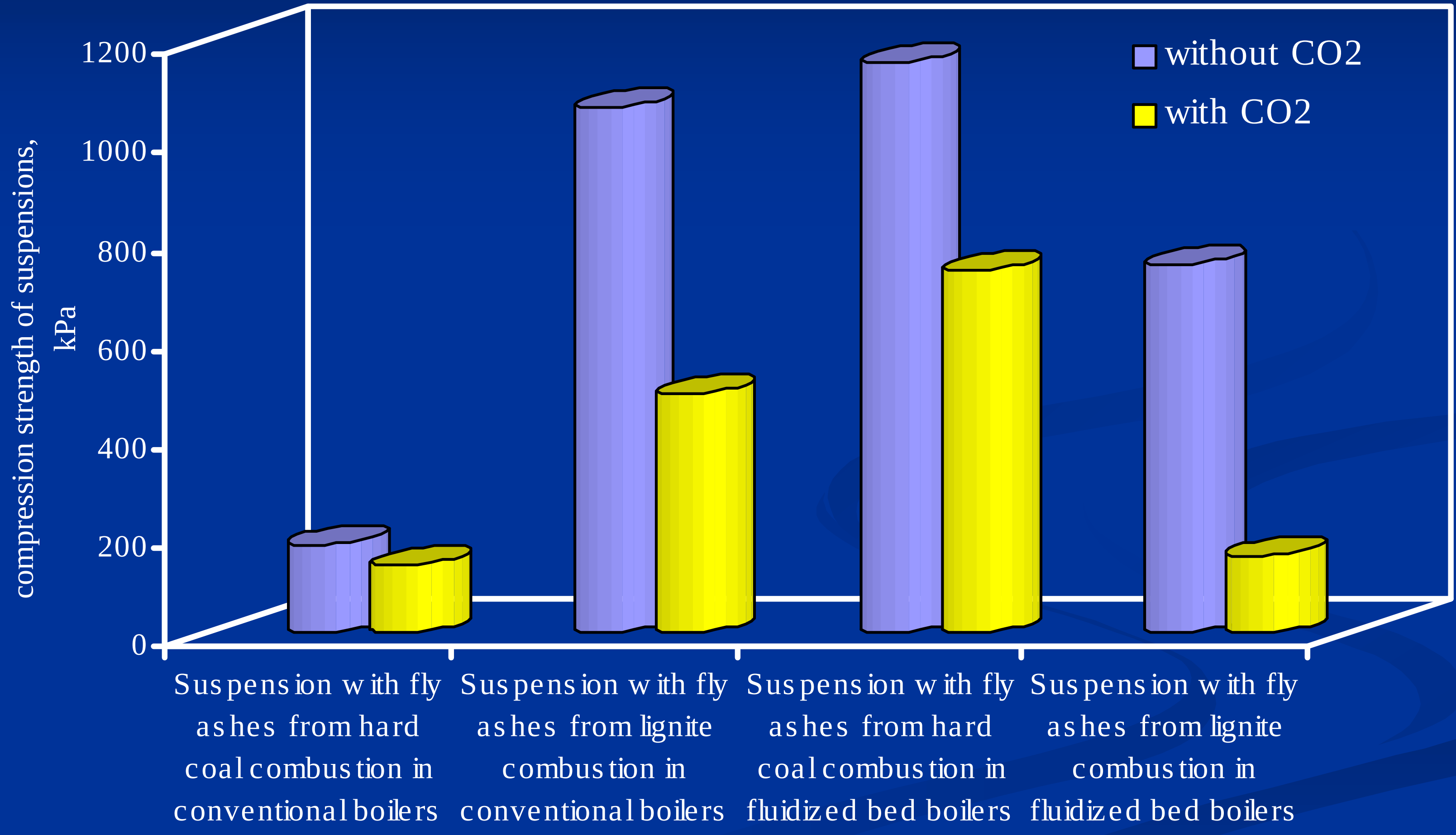
Cr contents in leachates from ash aqueous suspensions 'pure' and with the inserted CO_2



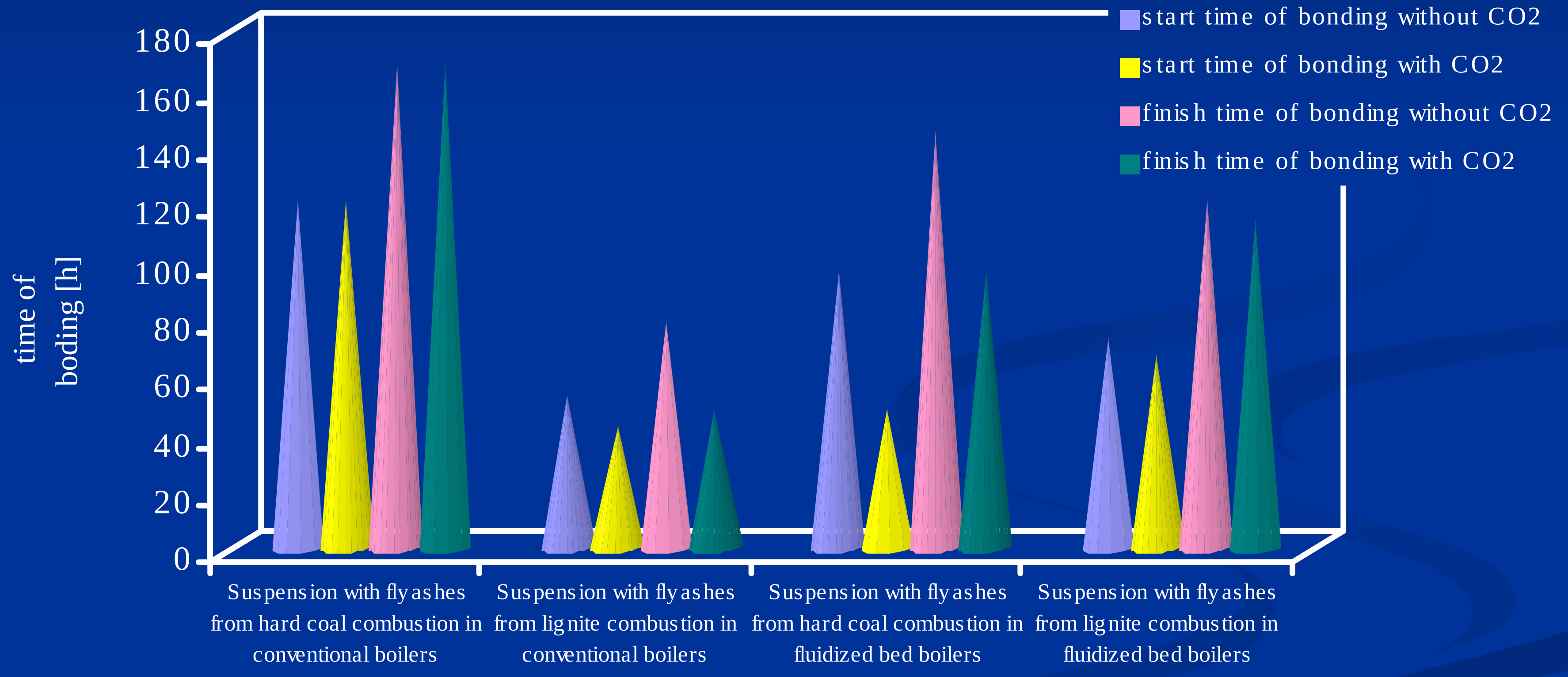
Impact of CO_2 on pH leachates from ash aqueous suspensions



Impact of CO_2 on the compression strength of suspensions



Impact of CO_2 on the time of bonding of suspensions



Conclusions

Fly ash may be the material used for CO_2 sequestration. Regardless of a low extent of absorption, as for example in suspensions based on fly ash from hard coal combustion, waste is worth considering for CO_2 sequestration, because of its great amounts.

An important aspect of ash-aqueous suspensions use for CO_2 bonding is their subsequent economic usage, that will be limited by CO_2 influence on leachability of impurities and the impact on technological properties of 'fresh' and hardened suspensions.

Literature:

1. Uliasz-Bocheńczyk A., Mokrzycki E., Piotrowski Z., Pomykała R., 2007: The underground storage of CO_2 with ash-water suspensions. Edit. MEERI PAS, Krakow, 142 p. (in Polish).
2. Uliasz-Bocheńczyk A., Mokrzycki E., 2006: Fly ashes from Polish power plants and combined heat and power plants and conditions of their application for carbon dioxide utilization. Chemical Engineering Research and Design. Vol. 84, Issue: A9, p. 837-842.
3. Uliasz-Bocheńczyk A., Mokrzycki E., 2008: CO_2 sequestration with use of fly ash from hard coal and lignite combustion. Slovak Geological Magazine, special issue, 2008, p. 19-22.
4. Wacławska I., 2007: Investigation of Bond CO_2 in fly ash-water suspensions. Arvieve of MEERI PAS, Krakow (in Polish).