# $CO_2$ contents in soil air for needs of carbon dioxide storage monitoring

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*Abstract.* There have been conducted an investigation on $CO_2$ concentration in soil air in the Jastrzabka Stara oil reservoir area, the Carpathian Foredeep in SE Poland, in 2006 - 2007. The reservoir was selected as location of a research $CO_2$ injection installation. Monitoring procedures were executed to define background of $CO_2$ concentration in soil air before injection starts.

Measurements were performed at 24 sampling points located in the SE part of the reservoir, basing on a methodology described in the paper.

Measured $CO_2$ concentration values in the covered area range from 1 to over 5 %. There has been observed a concentration variability depending on sampling point location or seasons. The least concentration was measured in autumn, a bit higher was measured in springtime, both were below 2 % (majority were below 1 %).

The highest $CO_2$ concentrations were logged in summer time, measured concentration values exceeded 5 %. Measurement results display variability of $CO_2$ concentration in soil caused by seasonal biological activity and other natural factors.

They reveal usefulness of further measurements allowing $CO_2$ concentration background estimation in soil air, as reference in underground $CO_2$ injection monitoring procedures.

*Key words:* monitoring, storage, carbon dioxide, soil air measurement

## Introduction

Carbon dioxide geological sequestration requires appropriate monitoring methods proving that the process is run safely and in an effective way. $CO_2$ storage monitoring is performed using various methods: direct (geochemical methods) or indirect (geophysical techniques and other) (Tarkowski et al., 2005).

These techniques allow to register dynamic processes combined with $CO_2$ downhole injection. They are borrowed from: petroleum industry (natural gas storage systems), know-how on hazardous and liquid waste storage in geological formations, underground hydromonitoring, ecosystem research and other (Benson & Myer, 2002; Benson et al. 2002, 2002a).

Direct $CO_2$ concentration measurements in water or ground/soil air make an essential part of the monitoring procedures. It allows to register $CO_2$ concentration in near subsurface ground layers, soil, surface and underground water, injection well vicinity, abandoned boreholes (Strutt et al., 2002).

One of methods used to examine both underground sink and $CO_2$ injection facility tightness is monitoring $CO_2$ concentration in ground subsurface. Atmogeochemical methods hither applied allow to directly detect $CO_2$ in ground air, being both reliable and inexpensive, as well as devices applied being easy to transport and operate.

The results allow to read gas level changes in soil air and to estimate migration tendencies. Majority of techniques applied to $CO_2$ concentration measurement in ground air is based on IR radiation absorbance by that gas. There are two basic types of these apparatuses: non-dispersive IR gas analysers (NSDIRs) and IR diode laser instruments (Monitoring … 2005; Pearce et al., 2005).

The paper presents preliminary measurement results of $CO_2$ contents in soil air in the area of an almost exhausted oil reservoir - the Jastrzabka Stara (Tarnów region, SE Poland). It was chosen as location for an underground $CO_2$ injection research installation (The in-situ researches ..., 2006; Tarkowski, 2007).

Carbon dioxide storage monitoring is to be examined in the location (first three years of $CO_2$ injection operation), combined with estimation of oil recovery enhancement prospects for the reservoir (CO2-EOR response examination). The results displayed cover initial stage of $CO_2$ underground storage monitoring, that is background estimation of ground air $CO_2$ contents.

The measurements started in 2005 and will be run next years (Introductory research…, 2005). The read background will be used as reference in $CO_2$ storage operation monitoring, during injection process as well as afterwards. The gas concentration increase could suggest that there is a $CO_2$ seepage.

## 1. The location and reservoir geology

The Jastrzabka Stara oil reservoir is located in SE Poland, in the Podkarpackie Voivodeship area, within commune of Czarna, 35 kilometers NE from Tarnów. Morphology of the reservoir area is hardly diversed. Rural landscape is filled with scattered buildings, mellow hills, farmlands and green meadows, and the terrain absolute altitude range from 210 do 255 m above see level.

*Table 1 Combination of $CO_2$ concentration measurement results (%) for given time intervals*

| Well number | 5 min | 20 min | 30 min | 60 min | 120 min | 240 min | 360 min | 480 min |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.34 | 1.68 | 1.78 | 1.85 | 1.81 | 1.89 | 1.87 | 1.84 |
| 2 | 1.34 | 1.6 | 1.73 | 1.73 | 1.7 | 1.81 | 1.75 | 1.73 |
| 3 | 1.87 | 1.79 | 1.95 | 1.9 | 1.9 | 2.13 | 2.11 | 2.02 |
| 4 | 1.62 | 1.89 | 1.82 | 1.93 | 2 | 2.04 | 2.04 | 2.02 |

The reservoir is located in the Carpathian Foredeep that is filled up with autochtonic Miocene sediments, lying on a bedrock formed of Jurassic and Cretaceous rocks. Within the Upper Jurrasic formations, in calciferous-marls Senonian complex, occur three sandstone reservoir levels bared with hydrocarbon accumulation.

The reservoir is tightened by younger Jurrasic strata in the central part, the peripherals being eroded and therefore tightened by Tertiary rocks. Hydrocarbon accumulation in the area of Jastrzabka Stara oil reservoir is combined with an anticline structure of NW-SE length. Nowadays seven wells (Jastrzabka Stara 6, 7, 8, 12, 15, 20 and 21) are operational there and produce oil.

## 2. Ground air $CO_2$ concentration measurement methodology

Ground air $CO_2$ concentration measurements were performed in SE part of the reservoir, within area around and between JSt-12 and JSt-8 wells that are 1 200 m distant each other. The JSt-12 well is selected to be an injection well while the least distant neighbouring well (JSt-8) is chosen to be the monitoring one (The in-situ researches...., 2006; Tarkowski, 2007).

In the area there were defined 24 sampling points. The point grid definition is combined with $CO_2$ injection prospects, therefore likely closest seepage locations. The sampling points are defined in farmlands and meadows, ground there occurring is sandy, sometimes sand loamy.

Measurements of $CO_2$ contents in ground air consisted in:

- sampling point tracking down by a GPS device
- hole of 4 cm diameter boring down to 80 cm depth with a hand-driven sounder
- the borehole insulation from atmospheric air by plugging
- measurement of soil air $CO_2$ concentration at bottom of the borehole, after at least 2 hours, using a gas sounder and a MultiRaePlus IR detector of maximum $CO_2$ threshold of 5 %.

The time gap between sampling borehole drilling and measurement was determined experimentally (Tab.1). There were performed about 160 measurements of $CO_2$ contents in these sampling points, in springtime, summer and winter season in 2006-2007. In some cases measurement was not possible due to borehole inundation during the time gap or some other reason.

## 3. Results of $CO_2$ concentration measurements

Results of ground air $CO_2$ concentration measurements are displayed in diagrams (Figs. 1 - 3). They display gas concentration changes at the sampling points in different seasons.

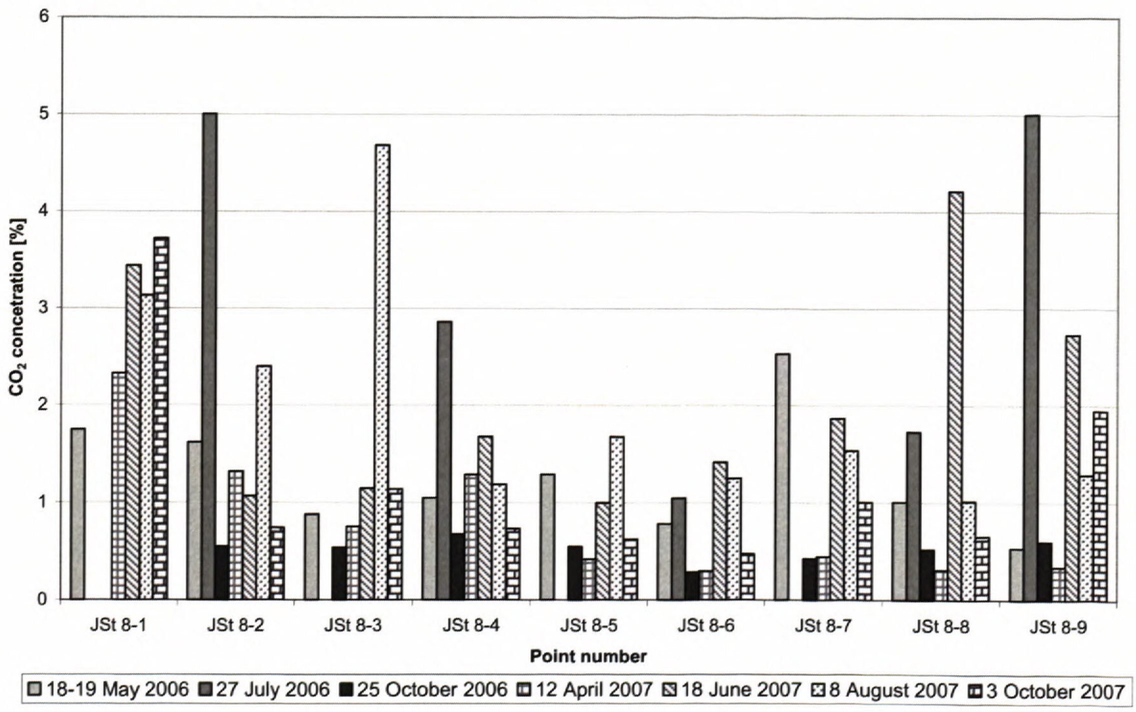


*Fig. 1 Soil air $CO_2$ concentration around the JSt-8 production well in the Jastrzabka Stara reservoir area (2006-2007)*

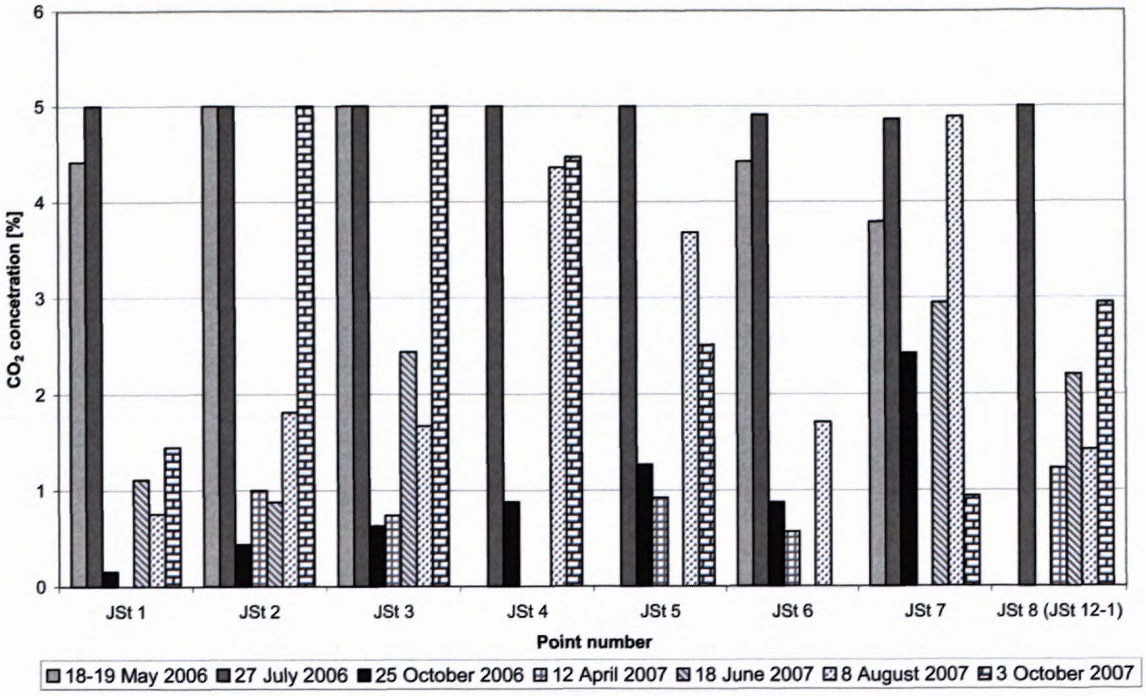


*Fig. 2 Soil air $CO_2$ concentration by a lane between JSt-8 and JSt-12 production wells in the Jastrzabka Stara reservoir area (2006-2007)*

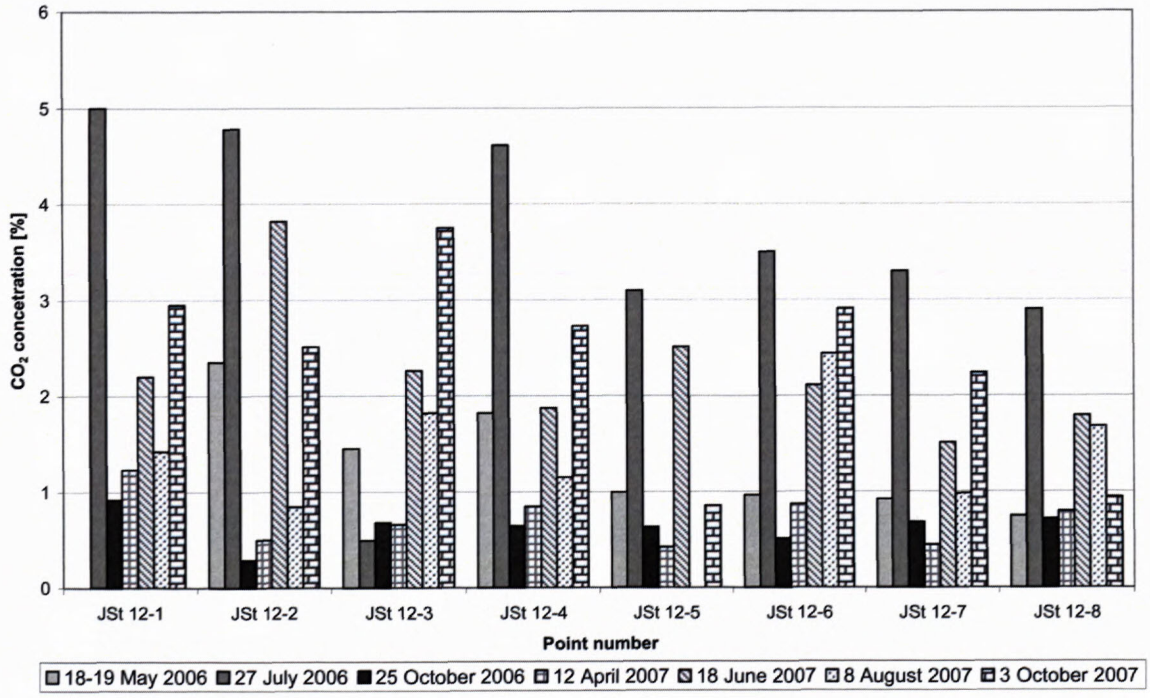


*Fig. 3 Soil air $CO_2$ concentration around the JSt-12 production well in the Jastrzabka Stara reservoir area (2006-2007)*

For the investigation period measured $CO_2$ concentrations have only thrice exceeded 5 % in the JSt-8 well vicinity, in JSt 8-2, JSt 8-7, JSt 8-9 sampling points, all in July. It has been remarked that measured $CO_2$ concentrations in all sample points are generally similar to each other for a given month of investigation. Anomalous, elevated $CO_2$ concentration appear in the JSt 8-1 sampling point located by the JSt-8 well. However it is obvious that in April and October $CO_2$ concentration was the least.

$CO_2$ concentration measurement results measured between JSt-8 and JSt-12 production wells (Fig. 2) are far higher than those obtained for sampling points around the wells. For a dozen of points concentration reaches or exceeds 5 %, in summertime (July, August). In early springtime and late autumn observed $CO_2$ concentrations were the least.

Carbon dioxide concentration around the JSt-12 production well (Fig. 3) has only twice exceeded 5 % for investigation period, in JSt 12-1 and JSt 12-5 sampling points, just in summer months (July, August). High stability of measurement results is observed for springtime and autumn months when concentration does not exceed 2 % and usually is below 1 %.

The results obtained so far display clear impact of cycle of the seasons on the $CO_2$ concentration in $CO_2$ in ground air. The gas concentration clearly depend on the season when measurements took place. The dependence read from results having been obtained for the last two years follows such outline: July (the highest concentrations observed) < June< August< May< April< October (the least concentrations observed).

Variable weather conditions (air temperature) and flora activity probably impact results the most, considering such factors as soil humidity and fertility as well.

It has been perceived that high $CO_2$ contents variability in the investigated area might be impacted some other way. Possible impact factors might be natural like: geological structure, kind of local bed and ground, terrain morphology (the JSt- 8 production well is situated higher – 243 m above see level while the JSt- 12 production well is situated lower – 229 m above see level).

It is to stress that read $CO_2$ concentrations in ground air are much higher than those observed in other areas (Ciężkowski et al., 2002).

## Conclusions

Obtained results display the first, interesting image of the $CO_2$ concentration diversity in ground air being impacted by cycle of the seasons and natural environmental conditionings. These results indicate purposefulness of further investigations, run also in winter (regarding mild winters), as well as they indicate necessity to observe various parameters that might impact measurement results. Longer investigations would allow to read ground air $CO_2$ concentration background more reliably as a reference for the gas underground injection and storage process monitoring.

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