CO_2 Sequestration in Thin and Shallow Coal Beds: Eastern Kansas

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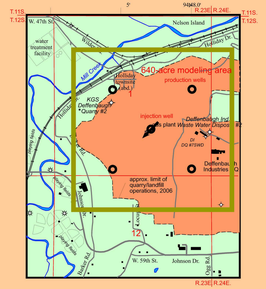
JOHNSON COUNTY LANDFILL - KANSAS CITY

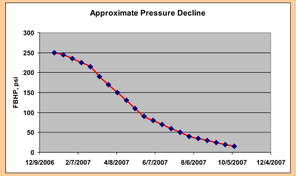


The Johnson County Landfill covers about 1 square mile (2.4 sq. km) and serves much of metropolitan Kansas City.

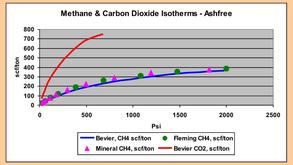
Large trash cells are created by quarrying. These trash cells are lined with plastic and gravel and then filled by several layers (called "lifts") of trash and shale. Note the size of the pickup truck in comparison to the size of the

Approximately 2.2 million cubic feet per day (mmcfd) of LFG are gathered from wells augered into the landfill a few weeks after the waste cells are covered by shale and topsoil. LFG is collected in a gathering system (approximately 7 miles [11.25 km] of polyethylene pipe up to 22" [56 cm] diameter) that services about 150 augered wells. This LFG is upgraded at a gas plant on site. The CO_2 is vented to the atmosphere and the residual CH_4 is compressed and sold to a nearby natural gas pipeline.

CRITICAL INPUTS - SIMULATION STUDY OF ECBM & CO_2 SEQUESTRATION



CBM operators in the Deffenbaugh area unload their wells gradually so that fines do not migrate under rapid drawdown. Lacking data, all modeled wells were unloaded gradually over the course of 1 year to approximate field conventions.

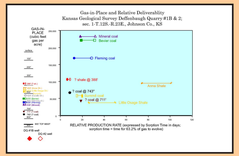


Laboratory-measured adsorption isotherms were carried out on representative samples from the 3 major coal seams below the Johnson County Landfill. The CH_4 adsorption profiles for all the 3 coals appear similar. As expected, the coals have a significantly greater affinity for CO_2 than CH_4.

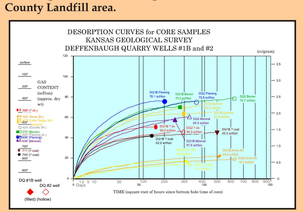
	Layer	Thickness, ft	Ash %	Net/Gross
Bevier	1	1.54	11.4	0.89
Fleming	2	1.25	15.6	0.84
Mineral	3	1.75	27.9	0.72

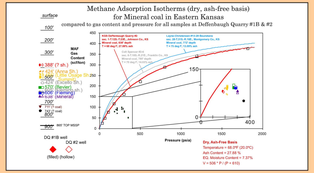
	Layer	Frac. Phi	CH4 desorb, days	CO2 desorb, days	Pr Mat, psi	Gas Content, scf/ton	Pr Frac, psi
Bevier	1	0.0371	25.24	25.24	136	74.5	267.5
Fleming	2	0.0534	20.62	20.62	113	75.9	284.0
Mineral	3	0.0409	25.20	25.20	80	59	299.8

Fracture porosity was estimated from difference in weights of wet and air-dried samples for respective coals. Sorption times (to desorb 63.2% of gas content) were measured for each of the coals. The matrix pressure in each coal was estimated using the measured gas content and the respective adsorption isotherm.



The crossplot above simultaneously displays the potential quantity (scf/acre) and quality (sorption time) of CBM production from respective coals in the Johnson County Landfill area.



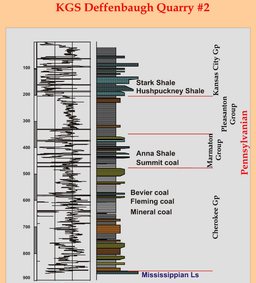


An isotherm expresses the saturated gas content of a coal at a given temperature (usually reservoir temperature), but with varying pressure. This curve is derived experimentally using the coal after it has desorbed its gas. Isotherms from Mineral coals in two localities in eastern Kansas are compared to an isotherm from this coal at the Johnson County Landfill. The subsurface pressure (based on hydrostatic gradient and depth) and the gas content of the coals at the Johnson County Landfill show that all are undersaturated, and the degree of undersaturation increases with depth.

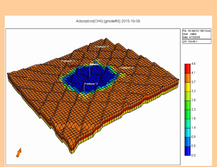
DEFFENBAUGH QUARRY #2 CORE HOLE & STRATIGRAPHY

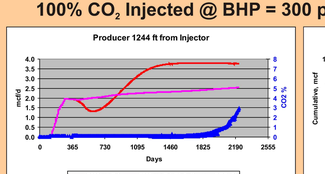
The Kansas Geological Survey wire-line rig cored two wells in the Johnson County Landfill to investigate the presence and thickness of coals in the Pennsylvanian rocks that underlie the landfill, and to ascertain their gas content by desorption measurements.

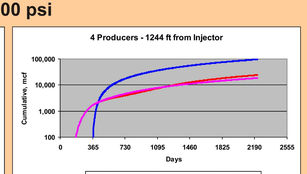
The core holes reached total depth at the top of the Mississippian carbonate section at approximately 870 ft (265 m) depth. Three major coals (Bevier, Fleming, and Mineral) were encountered between 570 and 640 ft (175 to 195 m).



5 Spot in 640 acres - 1 Injector & 5 Producers (1244 ft apart)
100% CO_2 Injected @ BHP = 300 psi







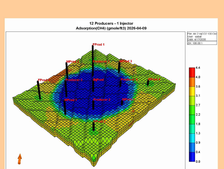
Total CO_2 sequestered = 97 mmcf
CH_4 produced (CO_2 Inj) = 24.3 mmcf
CH_4 produced (No Inj) = 18.7 mmcf
Incremental CH_4 (CO_2 Inj) = 5.6 mmcf

CO_2 breakthrough at producers ≈ 6 years

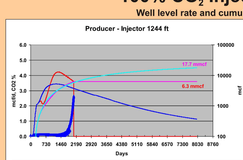
The producers are shut-in upon CO_2 breakthrough (<3%, as per local pipeline requirements).

There is an initial decline in CH_4 production after onset of CO_2 injection because it takes a critical mass of CO_2 for it to be adsorbed by the coal. It is only after the injected CO_2 starts to adsorb in the coal that CH_4 gets desorbed from the coal and ends up being produced as enhanced gas production. Before onset of adsorption of the injected CO_2, the fracture pressure in the cleats increase and this reduces CH_4 production.

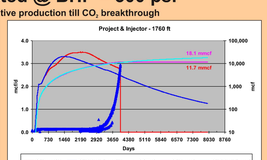
Injector & Producers at Varying Distances in 640 acres
100% CO_2 Injected @ BHP = 300 psi
Well level rate and cumulative production till CO_2 breakthrough



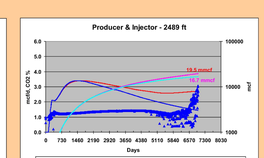
The injector is centrally located in 640 acres with producing wells located at varying distances. Producing wells are shut-in when the percentage of CO_2 in produced gas exceeds 3%.



With producer-injector spaced 1244 ft apart, CO_2 injection results in immediate CH_4 rate increase followed by CO_2 breakthrough. Cumulative CH_4 recovery is greater with no CO_2 injection as a result of quick breakthrough followed by stoppage of injection when CO2 percentage in produced gas exceeds 3%.



With producer-injector spaced 1760 ft apart, CO_2 injection results in an increase in CH_4 production rate after 5 years and continues till the 11 year when the producer has to be shut-in due to CO_2 breakthrough. Cumulative CH_4 recovery is greater with no CO_2 injection as compared to that with CO2 injection.



With producer-injector spaced 2489 ft apart, the cumulative CH_4 recovery with and without CO_2 injection becomes nearly equal. Thus, for maximum CO_2 sequestration and CH_4 production, distance between injector and producer has to be > 2500 ft. CO_2 breakthrough at these far wells takes after 22 years.