Best Practices in Monitoring CO_2 at Krechba Field-Algeria AGI CO_2 Tracer Gases Detection Technique

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Abstract. This paper outlines the CO_2 monitoring in general and focuses on the AGI technique to detect CO2 tracer gases as a new technology used in the CO2 monitoring at Krechba field. The In Salah Gas project (ISG) is performing the monitoring for safe geologic CO2 storage under the Kyoto protocol. The success of CCS project in Krechba saline aquifer is a key role in future onshore storage site over the world to fulfil the COP21 Paris agreement targeting a global warming around 1.5 °C to tackle climate change and reducing the CO2 emissions. The monitoring is divided into two categories surface and subsurface techniques, in total six techniques are executed regularly as a best practice to store safely the CO2 underground. Due to the long-term uncertainty in the CO2 sequestration below monitoring techniques are subject to normalization by DNV to transfer a standard technology to future similar CCS projects over the world.

Keywords: AGI · CCS · DNV · CO2 Monitoring · Saline aquifer

1 CO2 Monitoring History, Overall Design, and Implementation

1.1 Introduction and Objective

The CO2 monitoring at Krechba site under the in Salah project has as a first objective to provide a useful international standard for CCS project development and in particular an agreed standard for site selection and monitoring requirements, based on a real world project the following points will be tested on a learning-by-doing basis:

- Demonstration of the technical viability of CCS projects
- Development of the concept of project boundary definitions
- Demonstrate the efficacy of storage site monitoring procedures, address legal matters around storage sites and liability in the short, medium and long-term

The In Salah project in Algeria is an industrial-scale CO_2 storage project that has been in operation since 2004. CO_2 from several gas fields, which have a CO_2 content of 1–10%, is removed from the production stream to meet the sales gas export

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specification of 0.3% CO_2. Rather than vent the separated CO_2 to atmosphere (as was normal industry practice for such gas plants), BP and its Joint Venture (JV) partner, Sonatrach, invested incremental capital of $100 million in a project to compress, dehydrate, transport and inject that CO_2 into a deep saline formation. Monitoring techniques were set up in 2005 to secure the CO_2 storage process using a variety of geochemical, geophysical and production techniques. The CO_2 was injected into the Aquifer leg of a 20 m thick carboniferous sandstone reservoir from which the Krechba field produces CO_2 rich gas. The reservoir has porosities ranging from 10–18% and permeability averaging around 10 md while the injection depth is between 1850–1950 m underground. The injection reservoir is sealed by around 950 m of a mixed sequence of carboniferous mudstones (Fig. 1) that are overlain by approximately 900 m of a mixed cretaceous sequence of sandstone and minor mudstones. There are currently three long (1300–1500 m), horizontal, state of the art injectors at Krechba, that have injected up to 50 mmscfd of CO_2 in total. Over the life of the project it is planned to store up to 17 million tonnes of CO_2, while to date, some 3.9 million tonnes of CO_2 have been injected. This has principally been into the two northern injectors, KB-502 and KB-503 where approximately 75% of the CO_2 has been injected.

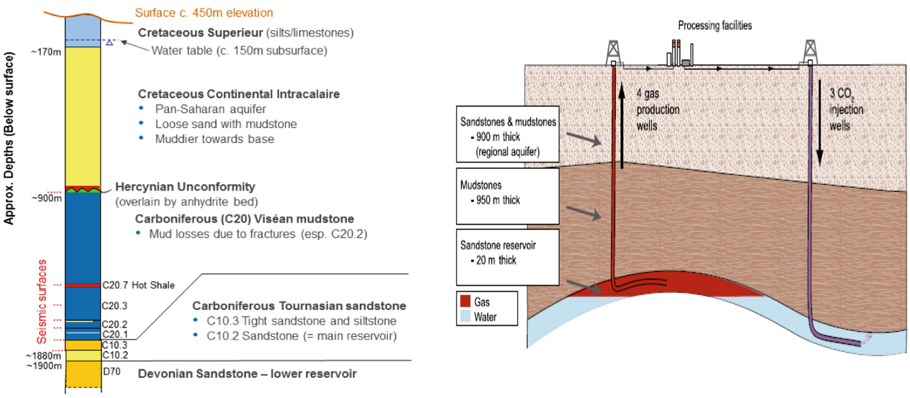


Fig. 1. Simplified krechba geology

1.2 Why Monitor CO2 AT Krechba?

The In Salah Gas (ISG) is monitoring the CO2 to know where it is moving and be able to communicate safety aspects to the public, there are three scenarios which are not mutually exclusive that require us to monitor the CO_2 in Krechba:

- CO_2 ingress to the local aquifer
- CO_2 being recycled through a production well
- CO_2 leaving the permit area in which ISG can legally operate/monitor problems and leakage from wellbores or wellheads.

1.3 The Monitoring Program

The technologies deployed for monitoring and verification of storage at Krechba consist of surface and subsurface techniques as illustrated in below table.

Table 1. Monitoring and verification technologies applied at Krechba

Monitoring Technology	Risk to Monitor	Action/Status
BGS Soil Gas Survey	Surface seepage	No anomalies today
Wireline Logging / sampling	Subsurface characterization	Overburden samples and logs Geomechanical and geochemical modelling
Shallow aquifer wells	Caprock Integrity	5 wells drilled to 350m – one beside each injector, one remote and one between KB-5 and KB-502.
	Potable aquifer contamination	No anomalies noted to date
Wellhead / annulus samples	Wellbore integrity Plume migration	2 monthly sampling since 2005
Tracers	Plume migration	Different perfluorocarbon tracers into each injector Implemented 2007
Surface Flux / Soil Gas	Surface seepage	Initial survey pre-injection Two surveys in 2009 around key risk wells No anomalies to date

2 AGI Modules (Tracers Monitoring)

2.1 Executive Summary

Amplified Geochemical Imaging, GmbH (AGI) from Ottobrunn, Germany was contracted by ISG (Algeria) to conduct a pilot geochemical survey to detect three different perfluorocarbon tracers injected in the Krechba CO2 storage, to allow, in case of leakage, identification of the source and pathway of leakage. To perform Krechba CO2 detection survey, 179 AGI samplers have been sent to the field in total, including 10 transport calibration samplers and 5 extra samplers. The field work was conducted between July 26 and August 15, 2015. Samplers were deployed at 500 m spacing and at 100 m around three injector wells. The AGI samplers have been installed for an exposure period of 15 days which is ample time for the sampling agent to reach equilibrium with the soil gas in the surrounding ground. After retrieval of samplers, they were shipped back to AGI's laboratory in Newark, Delaware, USA, for analysis.

Fig. 2. AGI modules field implementation

All AGI geochemical samplers were analyzed via automated thermal desorption, gas chromatographic separation, mass selective detection (ATD-GC/MS). None of the field samples were found to contain Perfluoromethylcyclohexane, Perfluoroethylcyclohexane and n-Propylperfluorocyclohexane compounds. All sampler analyses were accompanied by calibration samples including several classes of quality control blank samples. The survey data were certified as acceptable for processing and interpretation, through the application of several quality control tests. Ten outlier samples were identified in the data set. These signatures have anomalously high response for n-alkanes from C10 to C18 and may reflect field contamination.

2.2 AGI Objective

Introduction

A geochemical survey for detection of three different perfluorocarbon tracers was conducted for ISG in CO2 storage Krechba field. Carbon dioxide was injected for long-term Krechba storage as a greenhouse gas reduction initiative as part of the overall In-Salah-Gas (ISG) development project (Mathieson et al. 2010).This survey involved the geochemical sampling of soil gases in the shallow subsurface of Krechba, and mapping of the distribution of chemical components with emphasis on detection of perfluorocarbon tracers used by ISG. The survey employed the use of AGI samplers exposed to the soil for 15 days period. The AGI sampler is a passive soil gas sampling device incorporating selected adsorbents which are effective at retaining ambient volatile and semi-volatile organic compounds. A general description of this geochemical technique is included in Appendix A, “AGI Surveys for Exploration”. All geochemical samplers were analysed after an appropriate exposure period in the ground. Analysis was accomplished using gas chromatography – mass spectrometry (GC/MS), for perfluoromethylcyclohexane, perfluoroethylcyclohexane and n-propylperfluorocyclohexane based on reference standards, and for a range of hydrocarbon compounds from hexane (C6) to octadecane (C18), also including pristane (C19) and phytane (C20). Geochemical data are evaluated for the presence of these three gas tracers and other thermogenic hydrocarbons, indicative of other thermogenic hydrocarbons, which may issue from the storage structure at depth. Likely petroleum reservoir areas. In order to optimize the system for perfluorocarbon detection the light hydrocarbon gases were not captured. Typically, the geochemical results of survey samples are compared to calibration sample data collected around the injection wells.

Objective of Survey
The main objectives of using the AGI Modules™ are:

- Take measurements around and near the injector wells to detect any leakage of CO2 on the surface.
- Take measurements around the old wells in the context of check the well integrity.

2.3 Geochemical Survey Information

Survey Location and Design
The survey consists of sample locations selected by AGI GmbH within Krechba CO2 storage field in Algeria, in order to identify CO2 leakage by detection of injected tracer gases. The location of the survey area is shown in Fig. 1. Nearly 4 Mt of CO2 were injected by three wells (KB-501, KB-502 and KB-503), between 2004 and 2011. Figure 2 (Ringrose et al. 2013) shows the locations of the injector (blue) and gas-producing (orange) wells. The CO2 was injected into the ~20 m thick downdip water leg of the gas reservoir at ~1.9 km depth (Mathieson et al. 2010). Schematic illustration of the geology of the Krechba field is shown in Fig. 3. Gas is produced from and the CO2 is injected into a ~20 m thick reservoir at 1850–1900 m depth. The reservoir is overlain by ~950 m Carboniferous mudstones, siltstones, and limestones which are in turn overlain by Cretaceous sandstone deposits (Ringrose et al. 2009). This thickness of caprock should make it a good site for CO2 storage (Stork et al. 2015). The response of the reservoir to CO2 injection has been observed using geophysical techniques: InSAR (Interferometric Synthetic Aperture Radar), 3D seismic surveys and micro-seismic. Surface deformation of up to several cm was observed above the injection wells by InSAR.

The 3D seismic survey in 2009 concluded that injection has activated a deep fracture zone extending NW of KB-502 by several hundred meters, and reaching about 150 m above the reservoir (Rutqvist 2012). The fracture zone is aligned parallel to the dominant NW-SE fracture orientation and perpendicular to the minimum compressive principal stress (Iding and Ringrose 2010; Rutqvist 2012). As reported by Stork et al. 2015 during periods of high injection rates the degree of anisotropy increases slightly and then falls back to original values when injection rates fall. This implies that CO2 is opening pre-existing fractures which then close as pressure decreases. In 2007, high concentrations of CO2 were measured in KB-5 well to the north (an old appraisal well drilled in 1980 into the Carboniferous aquifer and not cemented across that interval when suspended). This well is located 1.4 km to the NW of the KB-502 injector. Tracer analyses confirmed that the CO2 detected at KB-5 came from KB-502. The KB-5 well has now been successfully fully decommissioned and injection in KB-502 restarted in November 2009, (Mathieson 2010). An AGI survey was put in place to evaluate if CO2 tracer gases reach surface via fault leakage or through microseepage.

One of the driving factors for microseepage may be increased pressure within the reservoir as result of CO2 injection. For this evaluation AGI provided one hundred seventy nine (179) samplers, which were sent to the field for installation in the ground. The shipment included 10 quality control trip blanks and 5 extra samplers. Samples were installed in a semi-regular grid pattern with 400 to 500 m sample interval. Three injection wells were available in the area. Each well was spiked with a different perfluorocarbon tracer, to allow for identification of the source and pathway in case of leakage. Survey coverage was based on observed uplift of surface elevation as result of CO2 injection, mainly above the horizontal portion of injection wells. Each injection location was sampled with five modules around its vertical location, as leakage during the injection was observed at one well. A sample transect near KB-502 extends SW into the producing gas field. Another transect was designed along direction of most prominent elevation change (NW – SE) from KB-503.

Summary of injection wells:

KB-501: 7.5 kg of perfluoromethylcyclohexane (PMCH) was injected 1st June 2007;
KB-502: 8.5 kg of perfluoroethylcyclohexane (PECH) was injected 1st June 2007;
KB-503: 9.5 kg of n-propylperfluorocyclohexane (n-PPCH) was injected 1st June 2007.

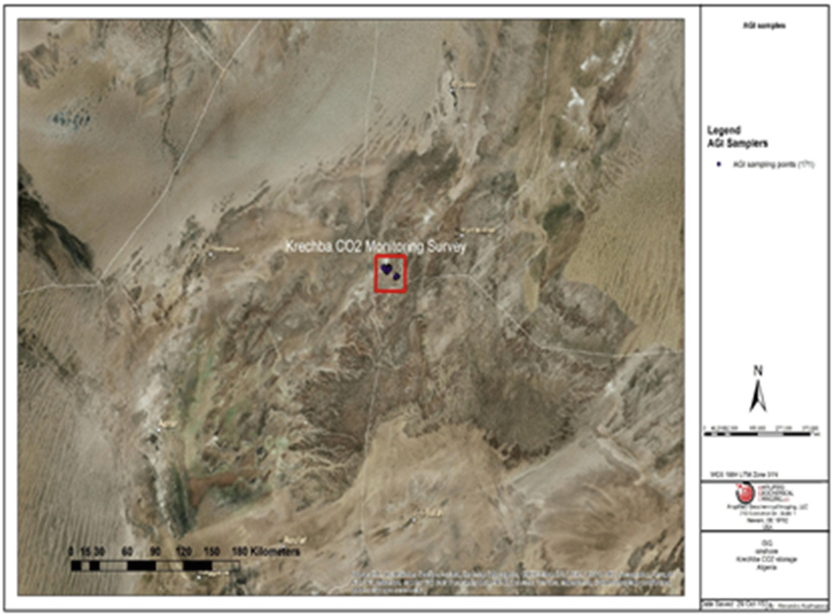


Fig. 3. Location of Krechba CO2 Monitoring Survey polygon in Algeria

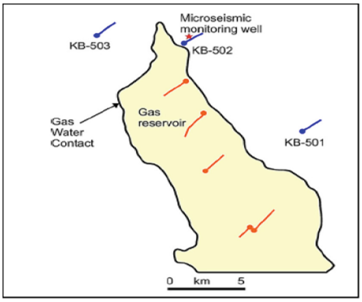


Fig. 4. Schematic illustration of the Krechba field

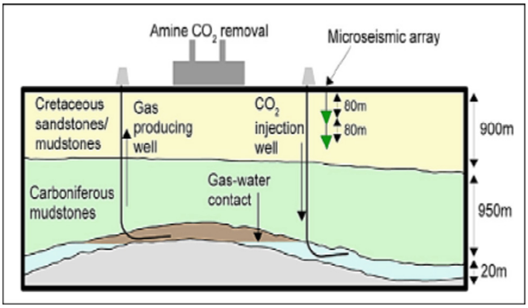
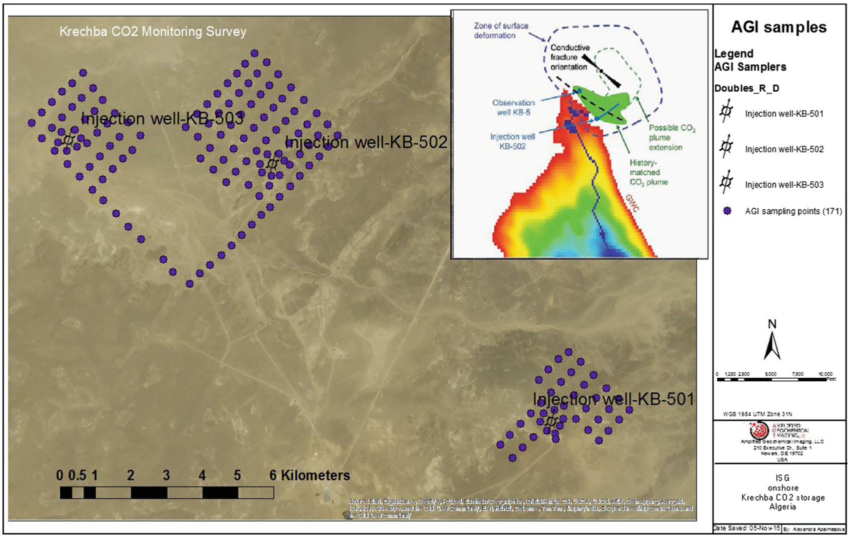


Fig. 5. Geology of the Krechba field



CO2 Plume Development. Ringrose, 2009

Fig. 6. Site location map. Locations sampled for this CO2 Monitoring Survey

Sampling Operations

Sarl Petroleum Industry Engineering personnel started the field work in Krechba area in Algeria on 25th July 2015. Field work was supported by ISG vehicle and labor. In order to perform the survey at Krechba, 179 AGI samplers have been sent to field in total, including 10 transport calibration samplers (trip blanks) and 5 extra samples. These 10 trip samplers must be kept sealed, but in fact 14 samplers have not been opened. The field team installed 164 AGI samplers at about 40–50 cm below ground. Survey design was developed by AGI and ISG collaboratively. The grid samplers were spaced 500 m apart, and were exposed in ground for 15 days. In general, the surface in Krechba is hard and stony with exposed limestone. The hard ground required a more powerful drill with portable Genset – arranged by ISG (verbal comm., Zeboudj Fayçal, ISG Petroleum Engineer). Around injection wells 501 and 503 there is flat land, but the area surrounding injection well 502, where most samples were placed (78 points), is mountainous. The field work was conducted between July 26 and August 15, 2015. Upon field work completion, all samples were shipped back to AGI's facility in Newark, Delaware for analysis. AGI Survey for Exploration features passive geochemical sampling, incorporating engineered adsorbent to collect organic compounds from C6 to C20, and equilibration with such compounds in soils and sediments over a specified period of time. After arrival at the laboratory, samples were then randomized with a few other quality control blanks, and prepared for analysis. One sampler was labeled as damaged in field and did not contain location coordinates. Prior to the onset of analysis, all geochemical samplers were inspected and sample acquisition documentation was reviewed to determine the allocation and status of every sampler (sample reconciliation step). Relevant field notes and documented sampler conditions for this survey were reviewed as part of the reconciliation. All samples have been accounted for. A summary of the reconciliation and a full accounting of all samples is given in Table 1. Analysis of these samplers was started on September 11th and completed by September 24th, 2015.

2.4 AGI Modules: GRID Pattern, Installation

AGI uses a patented passive diffusion sampler called the AGI® Module formerly known as the AGI-SORBER® Module for sampling air, soil gas, and water in its environmental, petroleum exploration, and mineral exploration markets. The AGI sorber design facilitates easy installation and retrieval, along with sample identification, storage and testing, while providing protection from soil and water.

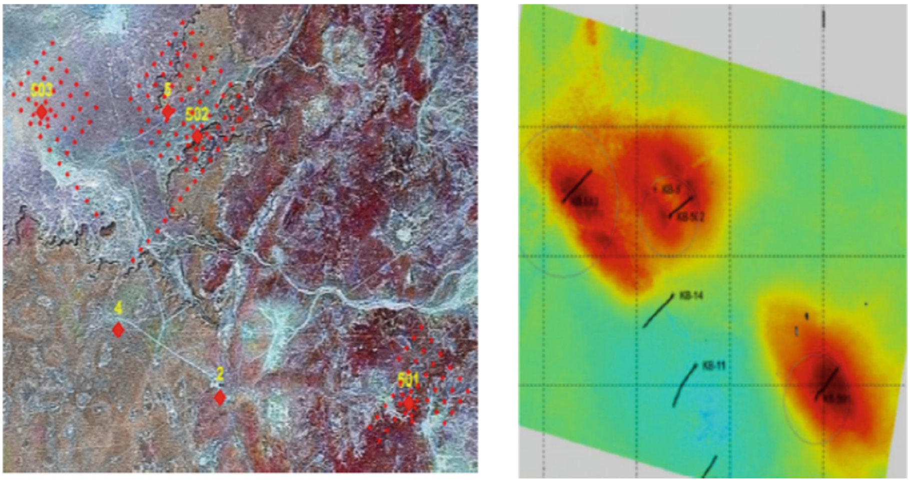


Fig. 7. AGI Modules coordinates installation

Inside each module is an adsorbent structure engineered by AGI to be hydrophobic and to collect a wide variety of volatile inorganic and organic compounds ranging from C_2 (Ethane) to C_{20} Phytane. Each module and its jar are labelled with a unique serial number. An adhesive device attached to the jar and lid will indicate if it has been opened.

These adsorbents are protected by a sealed durable micro porous tube of polytetrafluoroethylene or AGI-TEX® Membrane. This inert membrane has pores 1000 times larger than the molecules to be collected and an open area of over 80% making it essentially transparent to the gas molecules. Yet these hydrophobic pores are small enough to reject soil and water to a depth of over 50-60 cm keeping the adsorbents clean and eliminate water contact. As a result, these AGI-Sorbers can be used in air, soil, saturated sediments, or directly in water. When placed in water, compounds will partition across the membrane following Henry's Law and be adsorbed almost instantaneously. In November 2009 a sample of the perfluorocarbon tracers were sent to Gore (now is AGI) for analysis in their Mary-land laboratories and after several tests Gore confirmed they were comfortable reporting values for perfluorocarbon tracers as low as 5ng. This indicates the method is viable for tracer detection in the shallow subsurface at Krechba with the advantage of being able to cover large areas with accuracy.

2.5 Deployment and Retrieval (Data Acquisition)

The data is acquired by the AGI Module 'soaking' up the free moving gases in the shallow subsurface. If there is any leakage of the injected CO_2 in the area of the module, the tracer Associated with the injected CO_2 should be captured in the textile of the AGI Module. The full length of the module is approximately 220 mm.

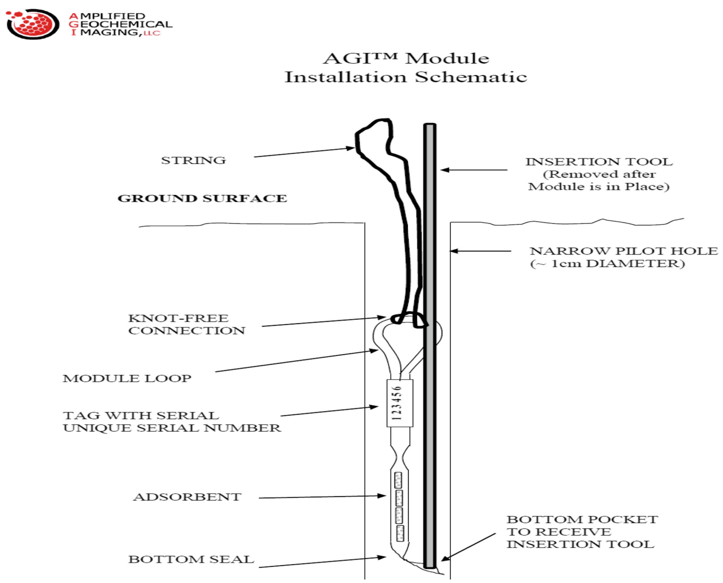


Fig. 8. Schematic showing deployed AGI Module

3 Geochemical Data Evaluation

3.1 Sample Analysis

All geochemical modules were analyzed via automated thermal desorption, gas chromatographic separation, mass selective detection (ATD-GC/MS), at the AGI laboratory. All module analyses are accompanied by instrument calibration samples for all compounds on the analytical list of this method. In addition, several classes of quality control blank samples are included for analysis with the field modules of the project. The types and numbers of quality control and instrument calibration samples for this project are listed in Table 1. The various classes of quality control sample are defined in Sect. 3.2.2 below. As an aggregate, quality control and instrument calibration samples constitute ~ 42% of all modules analyzed for this survey. As a percentage of samples analyzed for a project, the quality control measures of the AGI Survey represent a significant effort, and are demonstrative of AGI's commitment to quality control.

Typical compounds included in the AGI Survey method are listed in Table 2. There are 86 organic compounds and the three perfluorocarbon compounds (perfluoromethylcyclohexane, perfluoroethylcyclohexane and n-propylperfluorocyclohexane), for a total of 89 compounds evaluated for this project. Reference standards for the volatile tracer gases were added to the analytical method for this project. The analytical detection limit for the compounds by this method is about 1 nanogram (1 billionth of a gram). The target compound list includes several distinct types of organic compounds, including several hydrocarbon types (aliphatics – alkanes, alkenes, cycloalkanes – and aromatics and polyaromatics). The diversity of compounds is intended to better characterize the geochemical environment, and provide an unbiased data set for studying petroleum emanation and related changes in the soil zone. Many of the compounds included in the

Table 2. Analytical Compound List by Compound Class.

Typical Petroleum Constituents *Carbon number in ( )*			
Normal Alkane: 17 compounds	**Iso-alkane: 11**	**Cyclic Alkane: 15**	**Aromatic and PAH: 17**
Ethane (2)	2-Methylbutane (5)	Cyclopentane (5)	Benzene (6)
Propane (3)	2-Methylpentane (6)	Methylcyclopentane (6)	Toluene (7)
Butane (4)	3-Methylpentane (6)	Cyclohexane (6)	Ethylbenzene (8)
Pentane (5)	2,4-Dimethylpentane (7)	cis-1,3-Dimethylcyclopentane (7)	m,p-Xylenes (8)
Hexane (6)	2-Methylhexane (7)	trans-1,3-Dimethylcyclopentane (7)	o-Xylene (8)
Heptane (7)	3-Methylhexane (7)	trans-1,2-Dimethylcyclopentane (7)	Propylbenzene (9)
Octane (8)	2,5-Dimethylhexane (8)	Methylcyclohexane (7)	1-Ethyl-2/3-methylbenzene (9)
Nonane (9)	3-Methylheptane (8)	Cycloheptane (7)	1,3,5-Trimethylbenzene (9)
Decane (10)	2,6-Dimethylheptane (9)	cis-1,3/1,4-Dimethylcyclohexane (8)	1-Ethyl-4-methylbenzene (9)
Undecane (11)	Pristane (19)	cis-1,2-Dimethylcyclohexane (8)	1,2,4-Trimethylbenzene (9)
Dodecane (12)	Phytane (20)	trans-1,3/1,4-Dimethylcyclohexane (8)	Indane (9)
Tridecane (13)		trans-1,2-Dimethylcyclohexane (8)	Indene (9)
Tetradecane (14)		Ethylcyclohexane (8)	Butylbenzene (10)
Pentadecane (15)		Cyclooctane (8)	1,2,4,5-Tetramethylbenzene (10)
Hexadecane (16)		Propylcyclohexane (9)	Naphthalene (10)
Heptadecane (17)			2-Methylnaphthalene (11)
Octadecane (18)			Acenaphthylene (12)
Byproduct and Alteration Compounds *Included in this method to provide a comprehensive inventory of the geochemical system in the surface soil zone*			
Alkene: 10	**Alteration/Byproduct: 3**	**Biogenic: 4**	**Nitrogen/Sulfur/Oxygen Compounds: 9**
Ethene (2)	Octanal (8)	alpha-Pinene	Furan
Propene (3)	Nonanal (9)	beta-Pinene	2-Methylfuran
1-Butene (4)	Decanal (10)	Camphor	Carbon Disulfide
1-Pentene (5)		Caryophyllene	Benzofuran
1-Hexene (6)			Benzothiazole
1-Heptene (7)			Carbon Dioxide
1-Octene (8)			Carbonyl Sulfide
1-Nonene (9)			Dimethylsulfide
1-Decene (10)			Dimethyldisulfide
1-Undecene (11)			

analytical list for this method are minor constituents of typical oils, or simply not found in oils (aldehydes, for example). Such compounds help to better discriminate between petroleum emanation and geochemical background influences, and thus help to delineate prospective regions more reliably. The inclusion of such compounds is one of the features that distinguish this surface geochemical method from others. CO2 tracer gas compounds were manually reviewed. No hits were found, for the tracer gases, in any of the samples. The analytical data for this geochemical survey is included in Appendix B.

3.2 Data Quality

Several steps have been taken during the processing of the geochemical data to ensure proper data quality. These include steps to evaluate sample data in order to remove statistical outlier samples.

Samples are placed in randomized order prior to analysis, to avoid loss of samples due to potential instrumental mishap, and to remove potential bias due to sample manufacturing.

Data quality steps taken during data processing include canonical variants analysis. This quality control effort follows in step with the stringent quality procedures instituted by AGI's laboratory staff, during preparation and analysis of the samples.

3.3 Sample Outlier Definition

Field sample data were visually and statistically inspected to determine the potential for outlier samples. Field sampler data were clustered using Hierarchical Cluster Analysis (Fig. 5). The cluster at the bottom of the dendrogram plot represents samples which have relatively high levels of hydrocarbons compared with the rest of survey samples. As a method of evaluating the data in a completely unbiased manner, and in order to categorize the samples into groups of geochemical similarity, this step of hierarchical clustering was undertaken. This process will group the samples together based on geochemical similarity, but is somewhat subjective in that the separation of the cluster groups may not focus on petroleum system differences from the survey area. The x-axis of the dendrograms include each of the input organic compounds in elution time order with the more volatile compounds to the left and the higher molecular weight compounds to the right. Each compound is represented as a column of color-coded squares, according to the relative abundance of the compound (column) for every sample (row) of the survey. Blue color indicates low mass response (below the mean), grey color indicates mass response at the mean for the whole data set, and red color indicates high response (above the mean) (Fig. 9).

After that the outliers locations were plotted to investigate spatial pattern distribution of the outliers (Fig. 6). The outliers build the line feature at the northern border of KB-502 survey polygon. Geochemical signature plots of the selected outliers have been examined to evaluate which compounds have elevated response (Fig. 7). For these plots, the y-axis is given in nanograms (log base 10 transformed). Observed signature levels for heavy range compounds exceeds typical levels for microseepage, and may indicate field contamination or macroseepage of hydrocarbons. Macroseeps are usually associated with faults and fractures, so the anomalies follow to regional

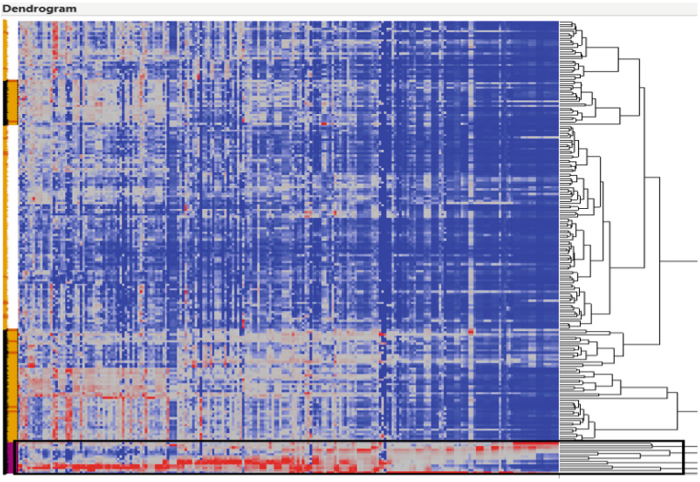


Fig. 9. Outliers cluster in the dendrogram, outlined in black

tectonic trend. No typical surface expression of macroseepage was documented in the field. High intensity of heavy range n-alkanes C10 to C18 were noted in nine outliers only. In addition, sample #759970 contains moderate abundance of heavy n-alkanes C15 +. In total, ten samples may be considered outliers of this survey (Figs. 10 and 11).

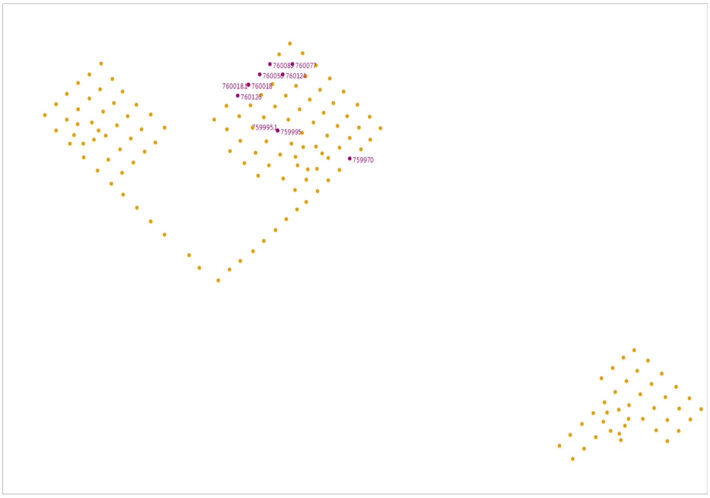


Fig. 10. Outliers areal distribution

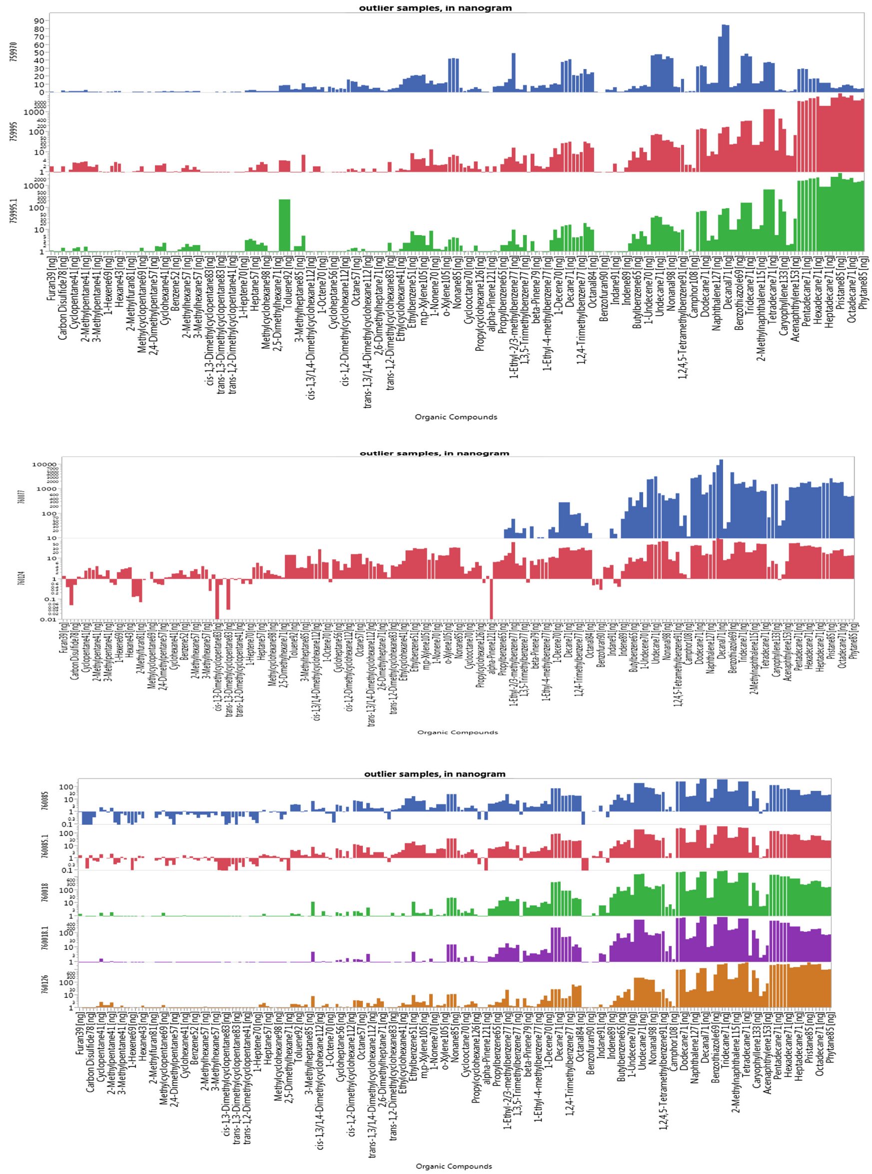


Fig. 11. Geochemical signatures of the outliers

3.4 Canonical Evaluation

The relationship between survey samples (including model samples, if any) and quality control blank data is evaluated using Canonical Variants Analysis (CVA). CVA is a procedure for evaluating the relationship between sets of variable measurements, such as the physical measurements made on two or more genetic groups of items. The purpose of this evaluation is to determine whether there are obvious geochemical differences between the geochemical sample data and quality control blank data with respect to measured organic compounds of this method. Differences between geochemical sample data and quality control sample data point to the equilibration of geochemical samplers to in situ geochemical influences, and signify that field data interpretations are not biased by inherent sampler signatures. Figure 8 shows a plot of the survey data in canonical variates space, with samples distinguished by class (field samples and quality control blank samples). Canonical scores are linear combinations of the measured compound response values, and are relative to a coordinate system of "variants" which span the survey data space. The variants are calculated as orientations, which maximize the separation of defined sample classes (such as the various blank classes).

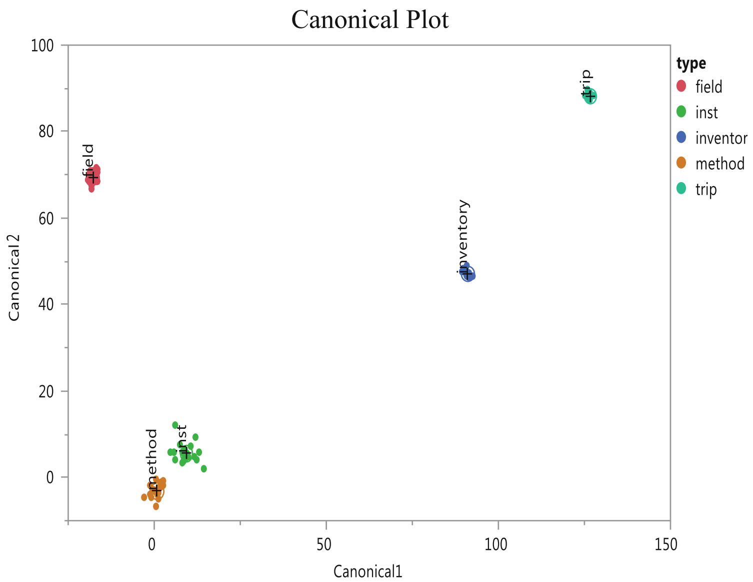


Fig. 12. Canonical Plot showing separation of various samples classes.

While the weights of the measured chemical responses to each of the scores are useful information, the analysis of canonical scores is not the purpose of this exercise; hence, the composition of the scores is not discussed. The objective of this exercise is to demonstrate chemical differences between the various sampler classes, as verification that geochemical sampler data are not a product of any manufacturing or analytical process effect. Chemical differences are apparent whenever subsets of samples are distinct in the canonical variants plot. Five types of quality control blank samples are included in this exercise: instrument blanks, method blanks, inventory blanks, trip blanks and field blank. The instrument blank class data represents analytical data recorded with no sample inserted in the GC/MS instrument, and should show the inherent instrument condition. The method blank class records the analysis of clean, isolated AGI Samplers, and should demonstrate analytical process conditions. Instrument and method blanks should be similar in signature, plotting in the same region of canonical score space. Inventory blanks are AGI Sampler that have been manufactured from the same lot as those that were sent to the field, except they are held in reserve at the laboratory until the other samples return from the field. The trip blanks are also AGI Sampler that were sent to the field, but they are not opened at any time during transit, and ideally the chemical signature from these trip blanks should appear to be look very similar to that of the inventory blanks.

Figure 8 shows significant separation between sample classes. It is concluded that instrument and method blank samples are sufficiently distinct from field samples, to indicate that the survey data are not a function of instrumental conditions or laboratory effects. Furthermore, the inventory blank class and the trip blank class are in the same general region of this cross plot, which indicates there is not likely to have been significant impact to the samplers in transit. To summarize, field samples have acquired chemical signatures not related to instrumental or analytical conditions, nor are the field samples affected by any transit-related contamination.

As a result of this analysis, the survey sample data are evaluated as fundamentally fit for use in further processing and interpretation.

4 Conclusions and Recommendations

The objective of the survey is to detect CO2 tracer gases over the Krechba CO2 storage reservoir in Algeria, as indication of potential leakage from the reservoir. Quality control procedures have determined the data as "fit for use", ten outlier samples were identified in the data set, signatures of these samples show anomalously high response for heavy n-alkanes from C10 to C18, and may reflect field contamination or possibly macro seepage from the subsurface. None of field samples detected perfluoromethylcyclohexane, perfluoromethylcyclohexane or n-propylperfluorocyclohexane – the tracer gases injected with CO2 into the reservoir, these compounds have been detected in the analytical standards included during analysis of survey samples. Thus, based on this survey result no evidence for the CO2 leakage from the gas storage to the surface or around injection wells has been observed. Survey sample coverage was very specific and does not span the entire structure or range of faults known from time of injection. It is assumed that tracer gases still reside within the reservoir, but this is not known as no samples of current reservoir gas showing still-present tracers are available. In other words, if the tracers have already leaked out prior to the survey, there would now be no indicators of leakage to detect.

AGI recommends future surface geochemical surveys over Krechba storage be considered, if additional CO2 injection with tracer gases is undertaken. If possible, the period between injection of such tracers with CO2 and the conduct of the geochemical survey should be much less than the interval of this project ($\sim$100 months). The shorter the period between injection and survey, the less uncertainty there would be that tracers are still present to be detected.

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