AMPLIFIED GEOCHEMICAL IMAGING LLC

CO_2 Detection Sensitivity, Reporting, and Monitoring Frequency

A primary mode of Carbon Capture and Sequestration (CCS) is geologic sequestration in which carbon dioxide (CO_2) is injected into underground geologic sinks. Critical to the success of geologic sequestration is the need to ensure that underground storage sinks have adequate seal and do not leak to pose a potential threat to human health and the environment.

However, the ability to determine if these subsurface structures have adequate seal prior to CO_2 injection and that those seals remain leak-proof is difficult since there are not many CO_2 monitoring technologies available to provide adequate sensitivity and coverage for underground sequestration. However, ultrasensitive passive geochemical sorbers at the surface **provide the ability to monitor leakage over reservoirs, faults, as well as natural fractures**.

The Amplified Geochemical Imaging (AGI) passive geochemical sampler contains specially engineered polymeric adsorbents encased in a microporous membrane (**Figure 1**). Membrane pores are small enough to prevent soil particles and water from entering, but large enough to allow vapors to pass through and concentrate on the adsorbents within.

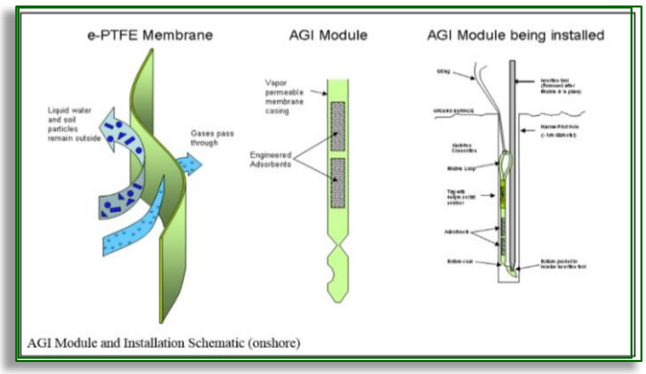

Figure 1.

AGI's proprietary passive compound detection and mapping technology provides a unique ability to detect CO_2 and hydrocarbons at parts per billion (*ppb*) levels, **which is 1,000 times more sensitive than traditional geochemical methods**.

While this may sound impressive, why is it important? You don't want your CO_2 monitoring system to be an "On/Off" switch. In other words, you do not want your monitoring program to detect no CO_2 one moment and then show a substantial leak at the very next survey. **A better approach is to utilize a system that will detect CO_2 leakage at the nascent stage** (i.e. at trace levels) long before a catastrophic breach occurs.

AGI samplers are typically left in contact with the survey matrix (i.e. soil, cores, or seabed sediments) for ~21 days. This duration allows for concentration of target analytes, enabling low *ppb* detection levels. Another important factor is that the 21 day residence time allows for the sampler to come into adsorptive equilibrium with the matrix. This results in a time integrated signature that reflects average compound concentration instead of variable concentrations at one specific moment in time.

AGI has been utilized for leak detection for many years along natural gas pipelines. There are many similarities between pipeline leakage detection and injected CO_2 detection. Both pipeline and CO_2 leaks can start as small volume breaches (nascent leaks), that can build over time resulting in serious breaches at percent level concentrations.

Figure 2 illustrates the mass range in nanograms that have been detected near pipeline leaks, which should also reflect a CO_2 leak scenario.

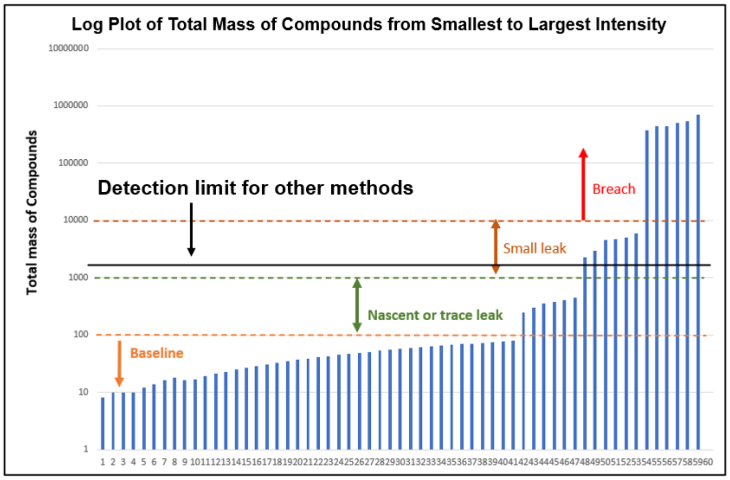

Figure 2.

Note the intensity range of baseline signatures range from 10 – 100 ng. Nascent leaks are 3X the intensity of baseline signatures, ranging from approximately 300 – 500 ng, making it easy to differentiate the two.

Monitoring Frequency

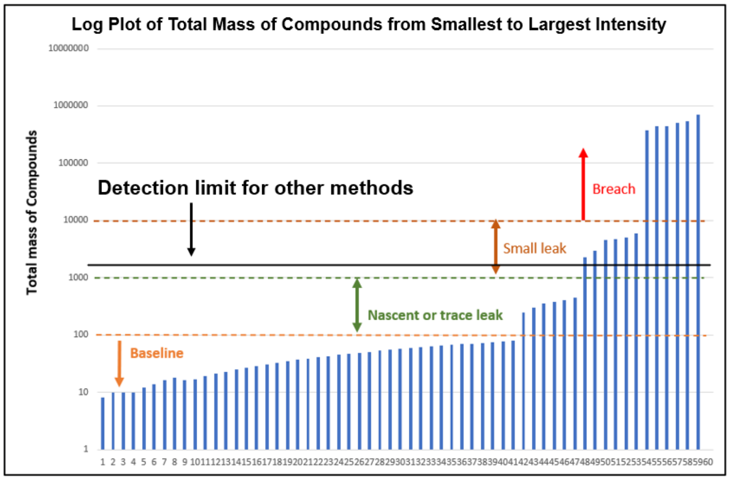

Figure 2.

As indicated by the black horizontal line in **Figure 2**, **AGI's baseline and nascent leak concentrations are below the normal detection limits of most other CO_2 methods.**

The ability to detect nascent leaks provides an opportunity to intervene early in the leak process and to increase the CO_2 monitoring frequency, to determine if leakage can be mitigated effectively.

AGI's technology also provides the ability to detect small to moderate leaks, ranging from 1,000 – 10,000 ng. Again, the effectiveness of immediate corrective actions, such as reducing the CO_2 injection rate or stopping CO_2 injection all together, can be assessed by subsequent monitoring.

To summarize, whatever the scale of leakage, when properly deployed, this technology provides early warning for corrective actions and thereby helps to avoid a catastrophic CO_2 breach.

So, how often should a company conduct a CO_2 geochemical monitoring survey?

A geochemical survey should be conducted prior to CO_2 injection to assess seal integrity and to provide baseline data for comparative purposes throughout the life of the project.

It is important to conduct this initial geochemical survey as early as possible since the data can inform the end user whether the proposed reservoir is suitable for sequestration purposes.

Assessing reservoir seal integrity, or the lack thereof, **can save a client millions of dollars in seismic survey and stratigraphic well costs** at locations not suited for sequestration purposes.

As an example, consider the following conceptual scheme for AGI baseline and monitoring surveys:

Survey 1: Baseline geochemical data acquisition prior to CO_2 injection, followed by seismic survey and stratigraphic well if the geochemical survey indicates a competent reservoir seal.

Survey 2: Short-term post-injection geochemical survey (5 months after CO_2 injection) to assess leakage proximal to the injection as well as near the injection well to monitor leakage up the well bore.

Survey 3: Geochemical survey 1 year after CO_2 injection.

Survey 4: Geochemical survey 2 years after CO_2 injection.

Survey 5: Geochemical survey 3 years after CO_2 injection, possibly followed by a seismic survey.

The program can be extended annually to monitor for nascent leaks, with seismic imaging once every three or four years. The details and timing of such a monitoring program would be approved by the appropriate regulatory agencies.

The estimated cost of an onshore AGI CO_2 monitoring survey for 1 mile plume radius **ranges from \$85,000 - \$125,000**, while a typical 2D seismic survey for 1 square mile coverage is **~\$2,100,000**. The geochemical CO_2 monitoring survey costs **~95% less than** a typical 2D seismic program.

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