



CO₂ Detection Sensitivity, Reporting, and Monitoring Frequency

A primary mode of Carbon Capture and Sequestration (CCS) is geologic sequestration in which carbon dioxide (CO₂) 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 CO₂ injection and that those seals remain leak-proof is difficult since there are not many CO₂ 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.

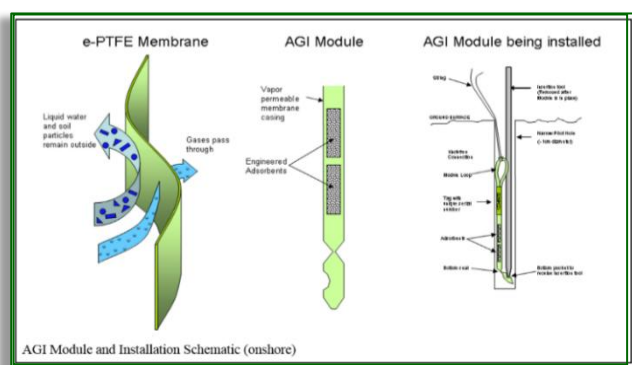


Figure 1.

AGI's proprietary passive compound detection and mapping technology provides a unique ability to detect CO₂ 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 CO₂ monitoring system to be an "On/Off" switch. In other words, you do not want your

monitoring program to detect no CO₂ one moment and then show a substantial leak at the very next survey. **A better approach is to utilize a system that will detect CO₂ 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 ~14 days. This duration allows for concentration of target analytes, enabling low ppb detection levels. Another important factor is that the 14 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 CO₂ detection. Both pipeline and CO₂ 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 CO₂ leak scenario.

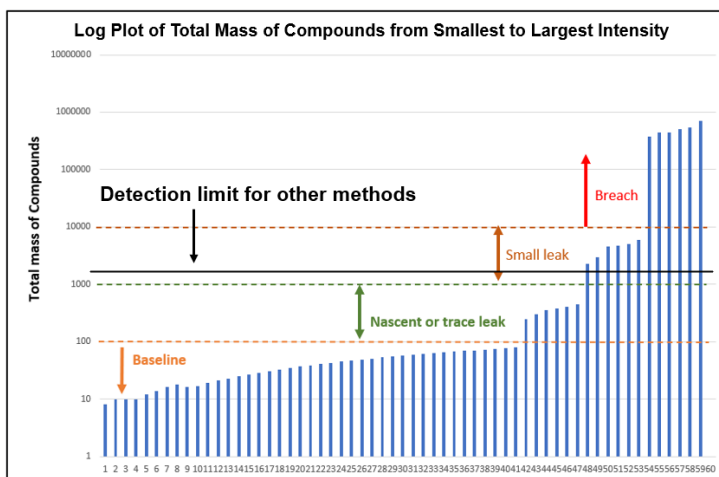


Figure 2.

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

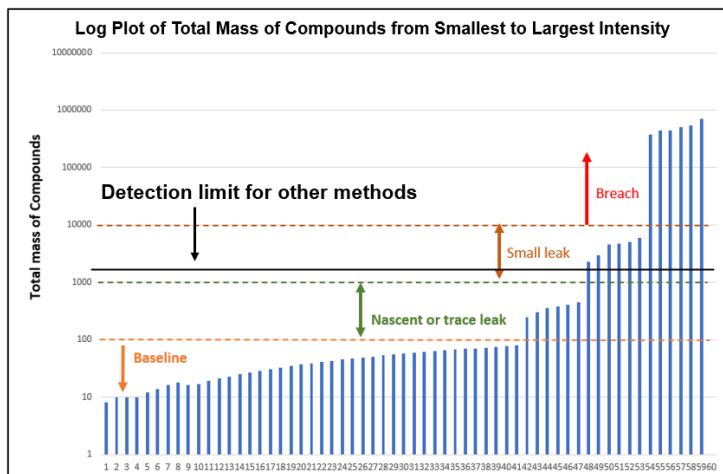


Figure 2.

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 CO₂ methods.**

The ability to detect nascent leaks provides an opportunity to intervene early in the leak process and to increase the CO₂ 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 CO₂ injection rate or stopping CO₂ 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 CO₂ breach. Additionally, **AGI modules are unique in that they can be deployed around CO₂ injection wells, P&A'd wells and orphaned wells, which are common leak points.**

So, how often should a company conduct a CO₂ geochemical monitoring survey?

A geochemical survey should be conducted prior to CO₂ 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 and reservoir seal 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 CO₂ 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 (4 months after CO₂ 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 CO₂ injection.

Survey 4: Geochemical survey 2 years after CO₂ injection.

Survey 5: Geochemical survey 3 years after CO₂ 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 CO₂ 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 **~\$1,200,000**. The geochemical CO₂ monitoring survey costs **~95% less than** a typical 2D seismic program.