Colorado Ground Water Association

Comments on Federal Requirements Under the Underground Injection Control Program for Carbon Dioxide Geologic Sequestration Wells

Proposed Rule – 73 FR 43492,
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The Colorado Ground Water Association (CGWA) is a nonprofit professional society and trade association for the ground water industry in Colorado. Our members include public and private sector ground water scientists, engineers, water well contractors, manufacturers and suppliers of ground water related products and services. The CGWA's vision is to be the leading community of ground water professionals in the State of Colorado and to promote the responsible development, use and management of ground water resources.

While a promising technology for mitigation of CO_2 emissions, geologic storage (GS) of CO_2 also has the potential to impact underground sources of drinking water (USDWs). Even though deep injection of CO_2 has been used for over 20 years to enhance oil and gas recovery and provides a foundation for large-scale use of geologic storage (GS), nothing on the scale of the proposed projects has been implemented. Full-scale projects have the potential to impact an area within a 50-mile radius of the injection well site.

Much of Colorado receives approximately 15 to 20 inches of precipitation yearly, water resources are currently stressed, and significant population increases are expected in the coming decades. Large portions of Colorado's population rely on USDWs and a significant portion of Colorado's agricultural economy relies on the freshwater aquifers for crop irrigation. The CGWA has concerns about the proposed CO_2 GS rule, which will govern not only the injection wells needed for GS but also the siting, operation, monitoring, closure of GS projects and could also govern the post-closure liability of GS project operators. These projects will be implemented on a scale for which there is no analog and will have the potential to impair major water resources in the State of Colorado and elsewhere if the projects are mismanaged.

In response to the U.S. EPA proposed rule on GS (72FR43492), CGWA submits the following comments on thirteen issues relevant to GS:

Issue 1. The proposed regulation has no mechanism for the respective State authority in each state responsible for administration of water resources to remove certain groundwater basins and/or zones with important aquifers from consideration as sequestration repositories.

One of the CGWA's concerns is the siting of CO_2 sequestration projects in major sedimentary rock aquifers, near, or in strata underlying major sedimentary rock aquifers such as those which are the primary source of drinking or irrigation water for large segments of the population or agricultural community. Due to uncertainties in the effectiveness of GS at the project-scales being considered, siting of GS reservoirs in strata underlying "sole-source" or other "important" USDWs, should be avoided, at least until large scale experience validates this methodology. Examples of such aquifers include the Denver Basin Aquifers and the aquifers of the San Luis Valley. Additional examples of aquifers which may be subject to degradation by displaced brines include the alluvial aquifers of the South Platte and Arkansas River Valley where they are in contact with the subcrops of strata which could be used as GS reservoirs. Colorado's reliance in many locations on deep bedrock aquifers should remove potential GS reservoirs from consideration due to the potential for degradation either by migration of CO2 or displacement of CO_2 reservoir brines into fresh water aquifers.

Issue 2. Under the proposed rule, full-scale implementation can begin after finalization.

The EPA is encouraged to consider limiting the scale of projects initially in order to identify issues that may crop up that are currently unanticipated. The early large scale projects should be extensively monitored in order to validate concepts that can be applied to other locations. This early work should include validation of appropriate modeling techniques capable of reliably predicting system responses. This early proof of concept work should also address issues of heterogeneity in reservoir and confining zones.

Issue 3. The proposed regulation currently defines USDWs as zones that contain groundwater with a total dissolved solids (TDS) concentration of less than 10,000 mg/L. This limit should be revised to consider geologic strata with water containing higher TDS concentrations, because these zones may be economic in the future.

The technology for treating high TDS water for use in water supply is improving rapidly, and these high TDS aquifer zones may be needed in the future. In areas with limited water resources water providers are beginning to turn to groundwater sources containing in excess of 10,000 mg/L TDS (Sengebush 2008). It is already conceivable that in the near future sources with up to approximately 20,000 mg/L TDS will be considered viable as water treatment technology advances making such water sources economical. To protect groundwater resources which may be economical in the foreseeable future the rule should evaluate the potential that currently marginal groundwater sources will be usable. The repository zones should be limited to strata containing very high TDS concentrations that siting studies and public input indicate are not likely to be useable in the future, as use of a zone for CO_2 sequestration will likely preclude recovery and use of the groundwater resource in the future.

Issue 4. The proposed regulation is ambiguous on the issue of tectonic stress release (earthquakes).

The proposed regulation should specifically address the issue of triggering tectonic stress releases, to avoid problems, such as the generation of earthquakes that resulted from deep waste injection at the Rocky Mountain arsenal in the 1960s and in other locations such as the Paradox Valley, Colorado (Ake, et al, 2005). From 1962 through 1966 the Rocky Mountain Arsenal injected a volume of approximately 165 million gallons of waste, or roughly 35 million gallons annually. This volume would be dwarfed by the injection volumes proposed on the three billion gallons of supercritical CO_2 annually. While the proposed rule states that the potential for induced seismicity is low, the magnitude of the volumes proposed for injection indicate that this issue has the potential to present a significant risk to occupants within a GS project Area of Review AoR.

Issue 5. The regulations should specifically address the potential for migration of injected CO_2 in different types of groundwater reservoirs.

The proposed rule lacks specificity with respect to the manner in which a proposed operation will demonstrate that there is a suitable geologic trap for the injected CO_2 and that the integrity of that trap will be perpetual. Demonstrating a pre-existing geologic structure capable of trapping CO_2 and demonstrating that the complex geochemical reactions in and adjacent to the GS reservoir will not compromise the reservoir's integrity are critical. However, the rule simply presumes such a demonstration can be made and provides no methods or criteria to be met in developing the demonstration.

Supercritical CO_2 is essentially a light non-aqueous phase liquid (LNAPL) capable of dissolving into water and also into which water can dissolve. A porous medium, such as the strata comprising a GS reservoir, is about eight times as permeable to supercritical CO_2 as to water due to the low viscosity of the supercritical CO_2. The supercritical CO_2 will rise through a water-bearing reservoir as a buoyant fluid, independent of injection pressure gradients. When the supercritical CO_2 reaches an impermeable stratum, that buoyancy will cause it to continue to move updip along that stratum until it encounters a stratigraphic or structural trap or permeability change sufficient to preclude further migration, i.e., a trap. The CO_2 will continue to migrate into that trap, displacing the native water. If the injected volume is greater than the trap's available volume the excess CO_2 will "spill" from the trap and continue to migrate laterally and vertically along the upper confining stratum until it either finds another trapping configuration or reaches temperature and pressure where it reverts from supercritical to gaseous CO_2.

Finding trapping structures in the subsurface is a non-trivial exercise. Every dry oil or gas exploration hole was drilled because a geologic investigation appeared to establish presence of a trap for buoyant hydrocarbons. While some dry holes may result from a missing source of petroleum, overwhelmingly the cause is that the postulated trap did not exist, either because the trapping structure was absent or due to natural leaks through the confining units through which the oil or gas escaped. These technical problems associated with finding petroleum LNAPL traps are directly analogous to finding traps capable of holding CO_2 in perpetuity. There are, however, major issues for CO_2 sequestration not borne by hydrocarbon exploration.

One issue is geologic trap integrity. Drilling can verify the postulated trapping geometry for either activity. If the confirmed configuration does not contain petroleum, the configuration is likely to be leaky. There is no corresponding way to establish the integrity of the seals in the case of exploration for CO_2 traps.

Another issue relating to GS reservoir siting evaluation is economics inherent in the process. There is significant financial incentive to find the petroleum-bearing trap, and that incentive can bear the burden of multiple failures. For the operator of a large point-source of CO_2, sequestration of CO_2 is a cost to be minimized as it does not result in a profit opportunity. Without detailed, explicit rules establishing how to prove a trap before attempting GS, the existence of functional traps will be simply presumed until lack of their existence or integrity is proven by failure.

The problem of finding and proving a sequestration trap for CO_2 can be minimized by requiring sequestration in depleted petroleum traps, however there may not be enough depleted oilfields to contain a significant amount of CO_2 and the presence of unsuitably constructed or abandoned wells can compromise integrity of a GS reservoir.

Issue 6. Buffer Zone monitoring wells need to be addressed in the regulation.

The regulations do not specifically identify the need for monitoring to verify performance of the repository. Monitoring wells to detect potential migration from the repository need to be incorporated into the proposed rule. Early implementation of GS should incorporate the concept of multiple barrier zones. This allows implementation of monitoring in zones below a USDW that can serve as a guard zone. These are critical in a zone between the repository and USDWs to allow for the early detection of a problem while mitigation is still an option. Even highly effective monitoring of GS reservoirs for failure may only inform operators after “the horse has left the barn.” In addition to buffer-zone monitoring, pressures in confining units should be monitored to provide allow detection of failure of the GS reservoir.

Issue 7. The fate of displaced brines is not sufficiently addressed.

The regulations need to be more specific on assessing the fate of displaced brines in the repository. Large volumes of CO_2 will increase reservoir pressures and will displace brines laterally and potentially vertically. Based on 2005 CO_2 production rates for Colorado power plants (CCS, 2007) and adding 30% additional carbon resulting from the parasitic load, power plants in Colorado can be expected to produce an average of 5.5 million metric tons annually. This production rate results in a year-round injection rate of approximately 5,500 gallons per minute of supercritical CO_2 for a medium-sized power plant. Assuming a reservoir thickness of 300 feet with 10% porosity available to the supercritical CO_2, this quantity would result in displacement of the brine from approximately 0.5 square miles of reservoir annually, or from approximately 25 square miles over an assumed 50-year project lifetime. A large power plant, such as the Craig plant, would displace brine completely from approximately 65 square miles of such a hypothetical reservoir. Additionally, the volume calculations presented here assume the supercritical CO_2 will occupy the entire thickness of the reservoir, while in reality, the supercritical CO_2 can be expected to float to the top of the reservoir and spread laterally, migrating approximately 8 times the velocity of groundwater flow. In the event CO_2 were to migrate into portions of the reservoir where pressure is insufficient to maintain the supercritical state, substantial volume increases could occur which could drive brines into shallow portions of the reservoir strata used for drinking water sources. The applicants will need to address the fate of these displaced brines.

Issue 8. The risks associated with the presence of old wells in depleted oil and gas fields are not adequately addressed in the proposed regulation.

The use of depleted petroleum reservoirs poses a significant problem. Depleted petroleum traps are generally the oldest oilfields and there are the problems of record keeping and are likely subject to outdated and inappropriate technologies during their development and the subsequent abandonment of the wells. Oil fields initially are characterized by pressures that are higher than depth-equivalent water bearing zones. However, as the fields are developed, those excess pressures are relieved, and the field becomes hydrostatically pressured or even underpressured. The result is that as the field ages and the reservoir becomes under pressured, well construction and abandonment integrity become less and less critical

Undertaking CO_2 sequestration in a depleted oil or natural gas field reverses the process of depressurization in the reservoir. Pumping CO_2 (or any fluid) increases the pressure of the reservoir substantially and every old production and exploration bore hole becomes a potential route of failure. Well and borehole abandonment configurations, even if fully compliant with requirements in place at the time of the abandonment, may not be capable of containing the pressures of the GS reservoir. Even if the reservoir is allowed to fill passively to the spill point, there will be excess pressure relative to formation hydrostatic pressures at the confining layer. The magnitude of the excess pressure will be directly proportional to the density contrast with the formation brine and the thickness of the CO_2 lens. Wells appropriately sealed against hydrostatic pressures present in the depleted oil field may fail catastrophically when subjected to pressures that result from CO_2 storage in the trap. Here too, the rule needs to add specificity to what needs be performed in the way of finding and recompleting the abandonment of all pre-existing wells and boreholes to configurations consistent with the reservoir conditions expected after CO_2 sequestration, not the conditions that exist at the time the field was abandoned or the project is initiated. There is no discussion in the USEPA materials supporting this rule that acknowledges or discusses the implications of the equivalent of an oil-field blow out. The catastrophic failure of a plugged or abandoned well would create an open conduit for the expulsion of supercritical CO_2 to the ground surface, potentially miles from any injection infrastructure.

Issue 9**.** Use of models to assess area of review is only briefly discussed in the proposed regulation.

The regulation specifies the use of mathematical models to assess the AoR and potential impacts. Prior to beginning modeling to evaluate the suitability of a potential reservoir, applicants should be required to collect sufficient field data from the reservoir and over-and underlying formations to evaluate the effects of the project on not only the area of review but also nearby locations where groundwater resources are present, even if not used widely. In modeling of proposed GS projects, multi-phase geologic models should be used coupled with solute transport modeling to evaluate the anticipated impacts. Additionally, models which can evaluate the geomechanical stresses upon the geologic materials within the AoR should be used to determine the potential for induced seismicity. Prior to modeling, site characterization should be performed with an adequate number test boreholes and wells to allow a statistically-valid characterization of issues within the AoR. In addition, the models should simulate the entire project lifespan and a substantial amount of time in the post-closure phase to provide insight into, support mitigation of, potential failure mechanisms.

Issues to be evaluated in reservoir modeling should include but not be limited to:

- Rock mechanics and susceptibility to fracture/failure,
- Water quality within the AoR including strata above and lateral to the proposed GS reservoir,
- Reservoir and aquifer properties,
- Potential for CO_2 migration into overlying strata via faults and improperly sealed boreholes,
- Potential water quality impacts on USDWs due to the pressure field developed under project scale injection,

- Mechanical and hydraulic properties of low-permeability units anticipated to serve as barriers to migration of the CO_2 and,
- The effects of fluids that will be displaced from zones between the GS reservoir and USDWs.

Ongoing collection of verification data for these models is important and should be performed on an interval that will be sufficient to allow identification and mitigation of potential failure mechanisms. Use of any model must be combined with calibration, where field observations should be replicated in the model. Any models that are used must be fully documented, with assumptions and methodology provided. A 5-year review interval is suggested over the course of the project life. Models alone, without sufficient field data collected prior to and during operation, are not protective of the public safety or resources.

Issue 10. Well construction and well conversion issues are not adequately addressed in the proposed regulation. The conversion of wells from enhanced oil recovery (EOR) or hazardous waste injection to CO2 injection is vague.

Well construction and potential well conversion issues need to be addressed in the regulations. All materials with the potential to come into contact with the injectate and/or the formation fluids should be designed and tested to insure the materials' integrity will be maintained and they will prevent movement of the injectate into a potential USDW zone. Materials that will not come into contact with the injectate and/or formation fluids in the zone of injection are not as critical, but sufficient design review should be performed to insure that proper materials are used for all well construction. All wells used for injection and monitoring should be operated according to a periodic maintenance schedule similar to other wells in the UIC program.

Conversion of existing oil and gas wells and/or EOR wells to CO_2 injection wells should be evaluated on a detailed case-by-case basis. Review should include all well construction records, performance of well evaluation and mechanical integrity testing and cement bond logging, and in the event the well is retained, workover should be performed.

While detailed geologic modeling is planned, monitoring wells should be installed into the injection zone, and into buffer zones above the injection zone, including fluid bearing zones below any potential USDW zone. In addition, pressure sensors should be installed in the confining units above the GS reservoir. The data collected from the monitoring wells and pressure monitoring points can be used to confirm the accuracy of a model and to monitor the zone above the injection zone for CO_2 leakage. Monitoring wells should be installed into the buffer zone to provide early detection in the event CO_2 or the associated pressure front begins to migrate into zones above the proposed injection zone. All monitoring wells should be designed to similar standards as injection well and will need pressure shut-in equipment.

Clustered monitoring wells should be considered to allow a single borehole to be used to monitor several different vertically discrete zones. For example, there is a potential that the injection zone, one or more buffer zones, and the USDW zone could be monitored from clustered monitoring wells installed into a single borehole. In the event such technology is used, equipment should be installed, maintained, and tested on a designated frequency to prevent migration of fluids between zones.

Issue 11. The post-closure operator liability timeframe of 50 years should be considered a minimum and should be extended in the event monitoring and modeling data indicate potential failure may require mitigation.

Issue 12. The timeframe of Area of Review Reevaluation should be revised to require more frequent reevaluation during the beginning of a project implementation and then less frequent reevaluation as the GS reservoir is shown to maintain integrity.

The AoR should schedule be reevaluated annually during the first five years, biannually during the five to 10-year period and then on a 5-year schedule afterwards until closure. Following closure, reevaluation should be performed on a 10-year frequency until the operator is released from liability.

Issue 13. The proposed rule should consider mitigation options for large-scale failure of a mature GS reservoir.

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