Carbon Sequestration and Global Water
A New Twist on an Old Theme

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It should be no surprise that when we humans needed to dispose of the 21st century's most "inconvenient" contaminant (carbon dioxide), one of the first places we would turn is water. After a century of dealing with environmental, ecological, and human health issues related to our dumping everything from raw sewage to mining wastes into the planet's waters, we still have not overcome the urge to dump our unwanted stuff into water. Carbon sequestration is the euphemistic label applied to the latest fad of disposing that pesky CO_2 into the deep oceans or groundwater, where it will remain undisturbed forever (or at least for the duration of the research grants and initial monitoring phases). Perhaps more importantly, carbon sequestration will permit us to address the CO_2 issue without having to make any real adjustments to our lifestyles. And for those of us who remember similar rhetoric (i.e., "Don't worry, the stuff will remained safely buried with no probable adverse effects.") when it was applied to industrial and radioactive wastes, there is always an option of planting trees to offset the waste gases produced by our behemoth vehicles and aging power plants. After all, what could be more Earth-friendly than contributing to a beautiful tree plantation on some far-away landscape?

After twenty-five years of work in the water quality field, I am witnessing yet another generation of researchers, policy makers, and "think tankers" employ almost the same perception of water and Nature that has accompanied us throughout the Industrialized Age. In an era when thousands of square miles of plastic wastes are still accumulating in the surface waters of the North Pacific Gyre, it is at least ironic that we are about to dump into the deep waters of the Pacific (and other oceans) carbon dioxide generated during the production of such plastics. The purpose of this presentation is to point out some of the more obvious—but too rarely discussed—downsides of specific carbon sequestration techniques and to suggest that we may want to shift our fundamental or underlying views of water before we begin devising any more solutions. Otherwise, we are likely to just perpetuate the current water and environmental crises in a slightly modified form.


Polluted Water, © Jacus (123RF)

Perhaps the most popular of the carbon sequestration techniques includes pumping liquid CO_2 into the deep oceanic depths, where it is predicted to remain as a slowing-dissolving, dense, liquid waste. The term *dense liquid waste* refers to the fact that liquid CO_2 is slightly denser than the surrounding seawater, creating a kind of "carbon dioxide pool" that conforms to whatever deep ocean basin receives it. For the moment, let's overlook the considerable energy demands of capturing the carbon dioxide from its point sources (e.g., the stacks of power plants), transferring it to a facility for cooling and pressurizing into a liquid, loading the liquid CO_2 onto tankers, shipping it to the ocean disposal sites, and pumping it through long hoses to prescribed depths. Even if it were possible to perform all of these tasks without utilizing the very same fossil fuels that generate CO_2, the act of disposing this liquid waste represents an enormous stress on the local deep sea environment, where many biological organisms will be instantly killed and significant changes in the pH and redox chemistry of seawater will rapidly ensue. It is worth noting that the acidification of shallow ocean waters is already occurring as a result of excess atmospheric CO_2 partitioning into seawater and forming carbonic acid. As the pH (acid-base) buffering capacity of the oceans is slowly diminished, rapid changes in seawater chemistry may set the stage for events ranging from the disappearance of coral reefs to the extinction of sensitive marine species.


Red Sea Reef, © Elisei Shafer (123RF)

It is not known if chemical and biological changes will remain localized to the disposal sites or if basin-wide conditions (e.g., temperature) will remain constant in the face of a rapidly changing global climate. Should deep water conditions change just slightly (as has already been observed in some locations), the stability of *gas hydrates* (a type of ice that encases CO_2 and keeps the carbon dioxide pool in place) would be compromised, permitting CO_2 to mix with shallower waters and to reach the atmosphere sooner than anticipated. The behavior of dense, CO_2-saturated, seawater masses is uncertain due to their susceptibility to gravitational forces and to episodic currents affecting the seafloor. Even if the CO_2 were pumped into geologic formations beneath the seafloor, seismic and related activity (perhaps induced by the presence of liquid CO_2 itself) is not uncommon beneath the oceans. Whether or not the sequestered CO_2 ever finds its way back to the atmosphere, its inevitable mixing into oceanic waters is likely to affect conditions in ways that we simply cannot predict. What we do know is that the oceans act as the master controller of the planet's climate and they exert this control through countless processes that are described by scientists as *nonlinear*, meaning that they are practically impossible to predict or to ascribe to specific cause-and-effect relationships.

While the oceans serve as the ultimate repository for all of our wastes, it is the planet's freshwaters that have historically served as humanity's favorite disposal sites—probably because we humans are terrestrial creatures. Surface waters were the early disposal favorites because they were so handy; however, the ramifications of polluting a nearby stream or river quickly encouraged us to look for more out-of-the-way sites. As humans developed the means to drill wells deep into the Earth, groundwater became a preferred disposal site. In keeping with this perception of the subsurface, deep saline aquifers and depleted oil and gas reservoirs (most of which contain a very salty water known as *brine*) have been targeted as just the place to dispose of our excess carbon dioxide.

The disposal of carbon dioxide in underground waters is a bit trickier than pumping it into the ocean depths due to the physical and chemical characteristics of the *media* (e.g., sands or rocks) surrounding the pore spaces where CO_2 is actually sequestered. Carbon dioxide not only reacts with and changes the properties of groundwater (as it does with seawater), it also reacts with the rocks in ways that may permit it to be trapped as a solid mineral complex, to block the pore spaces, or to alter the chemistry of an entire reservoir. While these may not sound like monumental incidents, they could result in the blowout of injection wells, the leakage of CO_2 and other greenhouse gases (e.g., methane) to the atmosphere, the subsiding or uplifting of the ground surface, the initiation of shallow seismic activity (e.g., earthquakes), and the contamination of adjacent (perhaps drinking water) aquifers. The slow release of carbon dioxide gas from an underground aquifer or reservoir would simply nullify the carbon sequestration effort; however, the rapid release of carbon dioxide could be lethal to humans and animals if its dilution in atmospheric air did not result in a CO_2 concentration below 10%.

Even if none of the catastrophic consequences of pumping carbon dioxide into aquifers and subsurface reservoirs ever occurs, there are still the questions of how a devastated microbiological community, a tainted hydrological fluid, and an altered geochemical environment will impact seemingly unrelated natural systems. We have repeatedly learned that there is no such thing as an "isolated" environmental compartment, where we can dump our wastes into a localized natural system without also affecting other systems. However, when our ignorance and short-term memory finally give way to our arrogance and desperation, we predictably treat the natural world as a global-scale laboratory—and when things go unexpectedly awry, we are offered yet another chance to perceive water and our world differently. Whereas a few global problems may require a human solution, most global problems require an Earth solution that incorporates an innate wisdom more profound than anything we can grasp with our intellect. Paradoxically, Earth solutions are often implemented in ways that we do not recognize (primarily because they are too slow or subtle); hence, we unintentionally override them in our zeal to attain a quick fix and, at the same time, carry on with the activities that create the problems.

Another water-related activity included under the heading of carbon sequestration or "carbon offsets" is the planting of trees in tropical and subtropical regions, many of which have lost much of their biomass to logging or slash-and-burn activities during the last century. So-called high biomass tree plantations have been shown to be a poor substitute for virgin forests in a number of significant ways. Monoculture plantations disrupt local hydrologic regimes (e.g., substantially reducing surface water flows and increasing the salinity or acidity of soils), increase the susceptibility of trees to disease, and essentially constitute a swap of carbon credits for water losses. Presently, the Kyoto protocol offers incentives for reforestation and tree plantations, but not for protecting virgin forests, which are significantly more efficient in stabilizing global climate regimes, preserving biodiversity, and maintaining a viable ecosystem. In essence, tropical farmers have an incentive to cut down the virgin forests and then to create plantations. Virgin forests are more than just endless rows of trees—whether or not we acknowledge it.


Meandering River, © West Marrin

The oceanic counterpart of tree plantations includes fertilizing surface waters with a soluble form of iron (a limiting nutrient for the ubiquitous phytoplankton) to stimulate photosynthesis and convert near surface CO_2 into plant biomass that supposedly sinks into the abyssal depths. Local "ironing" not only alters the most fundamental level of a highly complex ecosystem, it affects a number of physical and chemical properties at the sea surface, which is critical to both oceanic and atmospheric phenomena. Moreover, the extent to which the biomass is sequestered, rather than metabolized by marine bacteria near the ocean surface and converted back into CO_2, depends on a vast array of ocean properties that can vary substantially. Whereas many marine ecologists have cautioned against such large-scale manipulations, a number of entities are engaging in this practice for the purpose of making money in the lucrative carbon credit market.

The carbon credit market is characterized as rewarding the wealthiest nations and the high-volume polluters, frequently to the detriment of the global climate and the poorer nations of the world. The present system of trading carbon credits has been repeatedly demonstrated as flawed in a number of ways (e.g., firms receiving credits for performing routine practices and generating cash for doing nothing). Although carbon sequestration is normally recommended as only one of several solutions implemented for reducing atmospheric carbon dioxide levels (others include curtailing energy consumption, using available energy more efficiently, and switching to renewable energy sources), it remains a popular one because the technologies can be implemented immediately, can work with no substantial changes in lifestyles or infrastructure, and can sometimes turn a profit—at least a monetary one. A difficulty with most cost-benefit analyses is the underestimation of costs (particularly non-economic ones) arising from unanticipated problems that are due to mistaken assumptions about the interaction of technologies with natural waters. As much as I respect science and its understandings of the natural world, predicting the effects of large-scale manipulations on complex earthly systems is very difficult.

The global water cycle and the planetary carbon balance are interwoven so tightly that a shift in one necessarily affects the other. In fact, water vapor is the only greenhouse gas that can reverse the global warming trend on a short-term basis, and seawater is the major regulator of atmospheric CO_2. Similarly, the subsurface combination of groundwater and biogenic/petrogenic gases is critical in maintaining the integrity of at least some geologic formations and in determining the kinds of microorganisms and geochemical processes that prevail. As we begin to relocate massive volumes of carbon dioxide into intricately-balanced natural systems (e.g., in accordance with a February 2007 international law that permits the oceanic burial of CO_2), it may be well worth reflecting on our rudimentary understanding of how Nature maintains these systems and our dismal record for burying other types of wastes either in the oceans or beneath the ground. Although we claim to have learned much from our experiments with earthly systems, one of the things we have not gained is true respect and reverence for the Earth and "her" ability to both detoxify and recover from our inadvertent, but cumulative, assaults if we would change our focus from fixing to minimizing them.

Selected Readings

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