Potential Water Quality Challenges Posed by Human Responses to Climate Change

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Abstract

During this period of rapid global climate change, there are a wide variety of measures that have been proposed to reverse or mitigate recent trends. Questions regarding the efficacy of these measures and the extent to which they could inadvertently affect other environmental processes or compartments are currently debated. Water and its planetary cycle are often cited as being susceptible to the unintended effects of remediation technologies (e.g., carbon sequestration) that address the major causes of climate change and intervention technologies (e.g., solar radiation management) that address the results of climate change. Rather than storing inorganic carbon in geologic formations or ocean basins, perhaps this carbon can serve as a component of usable products such as cement. Similarly, reducing the particulate matter in snow instead of increasing the area of snow cover, or burying biochar instead of establishing monoculture tree plantations, could assist us in confronting climate threats without the use of controversial measures.

Keywords: water, carbon, sequestration, geoengineering, alternatives

Introduction

Climate change may affect water quality in diverse ways, such as the mobilization of pollutants during extreme runoff events, the increase of pathogens in warmer source waters, and the salination of coastal aquifers due to sea level rise. Consequently, there has been considerable discussion about probable shifts in infrastructure and treatment technologies required to address the altered water quality. Less attention has been placed on water quality changes that may result

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from anthropogenic responses (e.g., geoengineering or carbon sequestration) to climate change. For example, sequestering CO_2 in saline aquifers or depleted petroleum reservoirs could impact potable groundwater aquifers via the introduction of soluble pollutants and localized changes in pH and redox chemistry. Similarly, the cultivation of monoculture tree plantations has been demonstrated to impact the quality of surface and shallow groundwater, primarily through changes in soil acidity and nutrient loading. Additionally, cloud seeding (or whitening) and the release of various airborne particles to reflect sunlight and cool Earth's surface could affect the chemistry of surface waters and the global water cycle itself.

Whereas the implementation of geoengineering will likely depend on several different factors, this presentation identifies some of the potential impacts on water quality and suggests possible ways to reduce them. Mitigation measures may include implementing the technologies under a restricted set of spatial and temporal hydrologic conditions or concurrently implementing measures to counteract the undesired water quality impacts. Substituting mega-scale techniques with ones designed to mimic the more subtle, sustainable, or small-scale characteristics of water and watersheds has been proposed as an alternative approach to climate issues (Marrin 2011).

Carbon Sequestration

One of the most popular carbon sequestration techniques includes pumping liquid CO_2 into deep oceanic basins, where it is predicted to remain as a slowing-dissolving, dense, liquid waste (Fer and Haugen 2003). One of the major drawbacks of this oceanic sequestering is the considerable energy required to capture CO_2 from point sources, cool and pressurize it into a liquid, ship it to ocean disposal sites, and pump it to the prescribed depths. Moreover, disposing this liquid waste represents an enormous stress on the local deep sea environment, where marine organisms are instantly killed and rapid changes in seawater pH and redox chemistry rapidly ensue. Additionally, 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. An alternative involves creating CO_2 gas hydrates, which are a type of ice that encases CO_2 and keeps it in place, because they are relatively stable and mimic a natural form of CO_2 and CH_4 storage in the ocean depths. However, if deep water conditions change appreciably as a result of shifts in climate or ocean currents, the stability of gas hydrates could be compromised.

An interesting natural response to the elevated CO_2 levels and acidity of the world's ocean is illustrated by a study that indicated some species of crabs and lobsters build thicker shells in response to these conditions (Ries et al. 2009). Whereas localized nutrient levels in seawater influence the ability of marine organisms to uptake inorganic carbon, some species appear to remove a portion of the excess inorganic carbon that the oceans have absorbed.

The geologic disposal of CO_2 in saline aquifers or abandoned petroleum reservoirs seems to be currently favored over pumping it into the ocean depths due to the stabilizing physical and chemical characteristics of the media (e.g., sands or rocks) surrounding the pore spaces where CO_2 is actually sequestered. Nonetheless, carbon dioxide can react with and alter the properties of groundwater or petroleum residues in ways that can result in the blowout of injection wells, the leakage of greenhouse gases back to the atmosphere, the subsidence of land surfaces, or the contamination of adjacent potable aquifers (Damen et al. 2006).

The aforementioned ability of marine organisms to sequester inorganic carbon in their shells has prompted several suggestions for the land-based sequestration of carbon. The first is reacting CO_2 with magnesium- or calcium-containing minerals to form stable carbonate rocks, similar to those found in natural sedimentary formations. Instead of pumping CO_2 into geologic formations, magnesium and calcium silicates could be mined, grinded, and then mixed with CO_2

under controlled conditions in above-ground reactors. As an offset to the energy requirement of these reactors, a number of scientific and entrepreneurial entities have suggested that a viable product, cement, be produced and sold as a byproduct (Biello 2008). Carbonate cements are an eco-alternative to the conventional ones that require more energy and water to produce.

Another carbon offset includes the planting of trees in tropical and regions that have lost much of their biomass to slash-and-burn activities. High biomass tree plantations appear to be a poor substitute for virgin forests in several ways (Niesten et al. 2002). Monoculture plantations disrupt local hydrologic regimes (e.g., substantially reducing surface water flows and increasing soil salinity or acidity), increase the susceptibility of trees to disease, and diminish surface water flows. A potential alternative to clearing additional tropical forest land for agriculture (primarily because forest soils are quickly depleted of minerals and nutrients) is the use of biochar.

Biochar is a type of carbon-rich charcoal created by burning plant wastes—including food crops—under low oxygen conditions (Bruges 2009). It has been added to soils to increase fertility, enhance water retention, and sequester carbon. Among carbon sequestration techniques, biochar is unique inasmuch as it has been practiced for centuries, has small-scale applicability, requires minimal energy, and has not been linked to catastrophic events. The major objection to biochar production seems to be its possible takeover by corporate agriculture for purposes of generating commercially valuable oils in lieu of essential food crops.

Geoengineering

Geoengineering is loosely defined as an attempt to modify or manipulate aspects of the Earth's climate in order to lessen the effects of rapid global climate change. Geoengineering is often divided into remediation technologies (e.g., carbon sequestration) that address the causes of climate change and intervention technologies (e.g., solar radiation management) that address the results of climate change (Greene et al. 2010). There appears to be an underlying assumption that, through continued discussion and debate, the world community will eventually agree upon ways to implement and monitor geoengineering. The validity of this assumption is unknown, as is the assumption that potential effects of large-scale geoengineering projects are likely to be less catastrophic (at least to humans in the industrialized world) than are those of climate change. The projects are as diverse as spraying seawater aerosols into the air to whiten clouds and releasing aluminum or sulfate particles into the upper atmosphere to reduce incoming solar radiation.

As a major greenhouse gas, water vapor’s conversion to a liquid or solid (as enhanced by artificial processes) has been proposed as a possible means to slow down global climate change. One difficulty is that cooling the air in locations where water vapor concentrations are highest requires energy. In addition, the condensed water must be sequestered from the air so that it does not evaporate back into the atmosphere. Only a fraction of airborne water vapor ever condenses into the tiny droplets or ice crystals that comprise clouds and produce rain.

The tiny particles around which water vapor condenses (including airborne bacteria and sea salt), the amount of air turbulence, and the size of water droplets all contribute to a cloud’s probability of producing rainfall (Bruintjes 1999). The practice of seeding clouds with dry ice or silver iodide seeks to augment local rainfall, although regional-scale results have been mixed. Increasing local precipitation may be an unexpected and inadvertent consequence of reservoirs, which have been assailed for their costs, evaporative losses, and destruction of ecological and human habitats. However, the question of whether direct water evaporation from large reservoirs increases local rainfall and alters the frequency or intensity of precipitation events is one that has been explored, but not yet fully resolved. Nonetheless, there is evidence that large dams do affect water’s liquid-vapor phase change and local rainfall patterns (Hossein et al. 2009).

Similar to cloud seeders, geoengineers have devised a scheme to introduce sulfur dioxide or silicon chips into the upper atmosphere in an attempt reflect sunlight and, therefore, mitigate recent global warming. Potential effects of this shading scheme on water dynamics in the upper atmosphere, let alone on Earth's water cycle, are currently unknown. However, the surprisingly reasonable costs (at least on a global basis) and technical feasibility of this technology make it a viable option for reducing incoming solar radiation. Alternatively, a major process responsible for keeping the planet's surface cool is the reflection of sunlight (up to 85%) by snow. Increasing snowfall via seeding clouds or converting liquid water to snow using the kind of blowers that are routinely employed on ski slopes could locally increase snow cover, but the energy requirements are huge. Interestingly, the tiny airborne particles created by burning diesel fuel, coal, and wood reduce the amount of sunlight reflected by snow (Grenfell et al. 2009). Keeping these particles out of the air may be a more efficient means of increasing the amount of reflected sunlight than attempting to influence the total area of snow cover.

Previous examples have involved the physical, chemical, or dynamic properties of water in its liquid phase; however, scientists also have an interest in processes that involve water's solid and vapor phases. The practice of growing glaciers, also known as glacier grafting, has been practiced for centuries by villagers in the mountains of Asia to augment their water supply (Douglas 2008). Ice or snow relocated to the foot of a glacier is subsequently seeded with rocks, sawdust, and charcoal that can trap and shield the frozen water during its growth down the mountain over a period of several years. Whereas these grafts could never be mistaken for a naturally-formed glacier, they can grow to lengths exceeding one hundred meters and provide a reliable source of water for local communities without implementing the large-scale technologies that are most often associated with geoengineering.

Conclusion

As a true water planet, the fate of Earth's climate will be largely determined by its oceans, which absorb and store the majority of heat and CO_2 that are measured in the atmosphere. Water evaporated from subtropical oceans has even been identified as "the mediator of rapid global climate change." One question we might ask ourselves before implementing grandiose schemes of unknown efficacy and, perhaps, unintended consequences is whether we could be interrupting or nullifying natural planetary responses that are already in effect. Adapting to a changing planet may require strategies that go beyond our trying to recreate recent climate regimes.

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