Potential Impacts of Climate Change on Groundwater Quality

October 2023

NJ Department of Environmental Protection

Division of Science and Research

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What was the purpose of the study?

This report is an assessment of hydrogeological and geochemical processes in shallow unconfined aquifers that are likely to be affected by climate change through a variety of mechanisms, including changes in groundwater temperature related to changes in global air temperature, changes in groundwater recharge rates and groundwater levels associated with changes in spatiotemporal precipitation patterns, as well as seawater intrusion.

What was the general approach to the study (methods)?

This report synthesizes existing literature and publications on potential responses of different hydrogeological and geochemical processes to climate change and discusses how these processes would impact groundwater quality based on current scientific knowledge of hydrogeology and geochemistry.

Overall, what did the studies show?

This review suggests that the effects of climate change are likely to cause ephemeral and long-term impacts on groundwater quality driven by modifications of hydrogeological processes, including precipitation, groundwater recharge, discharge, storage, and seawater intrusion. These modifications would influence biogeochemical reactions and the ultimate chemical fate and transport of contaminants and are likely to drive the variability of both anthropogenic and geogenic contaminants.

Below are some specific examples of hydrogeological and geochemical changes and associated groundwater quality changes that are likely to occur as a result of climate change:

1. Climate change is expected to raise groundwater temperature in urban and rural areas. Changes in groundwater temperature would increase mineral solubility and

microbiological activities, which has the potential to elevate concentrations of certain major elements such as silica (Si); potassium (K); fluorine (F); heavy metals including copper (Cu), cadmium (Cd), nickel (Ni), lead (Pb), lithium (Li), and zinc (Zn); redox-sensitive elements including arsenic (As), iron (Fe), manganese (Mn), phosphorus (P); and dissolved organic carbon (DOC) in the shallow groundwater.

2. Groundwater recharge delivers electron acceptors (such as oxygen (O_2^{2-}), nitrate (NO_3^-), ferric iron (Fe^{3+}), sulfate (SO_4^{2-}), organic carbon, and pollutants into the aquifer, which impact existing subsurface geochemical conditions and affects the dissolved concentrations of a wide variety of contaminants, including redox-sensitive trace elements. Rising groundwater levels due to increased recharge would saturate a portion of the normally unsaturated soil layer, reduce oxygen levels, and mobilize natural trace elements and anthropogenic contaminants stored in the unsaturated layer. Therefore, recharge under altered precipitation patterns related to climate change poses increasing threats to groundwater by mobilizing geogenic contaminants (such as As and Mn) and anthropogenic contaminants such as NO_3^-, hydrocarbons, other organic contaminants, emerging contaminants (such as per- and polyfluoroalkyl substances and microplastics), and pathogenic microorganisms into aquifers.

3. Climate change is expected to cause large changes in precipitation frequency and intensity, leading to extreme weather events like more frequent flooding and drought. Flooding can make the surface soil anaerobic and mobilize geogenic contaminants like As, Fe, Mn, P, and other metals such as chromium (Cr), molybdenum (Mo), and vanadium (V) in soils which eventually are transported to shallow aquifers via infiltration and recharge. During droughts, decreased precipitation causes a decline in groundwater recharge and level, which may lead to the mobilization of contaminants such as NO_3, SO_4, and As due to the altered redox condition in the aquifer.

4. In coastal areas, shallow groundwater is expected to respond dynamically to sea-level rise (SLR) leading to seawater intrusion (SWI), rising groundwater levels, and coastal flooding. The increase in salinity by SWI can mobilize metals (As, Cd, Co, Cu, Hg, Pb, Se, V, Ra) from soils/sediments to groundwater through cation exchange and desorption by chloride (Cl) and organic complexes. Similarly, rising groundwater and coastal flooding are likely to affect contaminant concentrations in shallow coastal aquifers.

How will DEP use the data?

This comprehensive review of the literature summarizing and identifying hydrogeological and geochemical processes and their potential to change groundwater quality is an invaluable contribution to our current scientific understanding of the impacts of climate change. Changes in hydrogeological and biogeochemical processes induced by climate change are likely to cause long-term and seasonal variability both in anthropogenic and geogenic contaminants. Given that approximately 33% of the New Jersey public water supply is from groundwater withdrawal and about 13% of New Jersey residents (approximately 1 million people) obtain their drinking water from private wells (Dieter et al. 2018; NJDOH, 2022), this review will be helpful to design and implement necessary groundwater monitoring networks to understand the time scales of change in contaminant concentrations in drinking water wells for contaminant regulation, mitigation, and, eventually, the reduction of human exposure to harmful contaminants in New Jersey.

Furthermore, climate change could impact large numbers of contaminated sites in New Jersey as climate change and the associated extreme weather events can undermine the effectiveness of site remediation efforts. This is due to shifts in hydrogeological and geochemical conditions of aquifers which can affect the contaminant's fate and transport, as well as long-term operations and management of remediation sites. Therefore, it is crucial to understand the response of contaminated unconfined aquifers to climate change for the design and evaluation of effective bioremediation and natural attenuation strategies.

Please review the full report for more detailed information at
https://dspace.njstatelib.org/handle/10929/112368

Who to contact with further questions:

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