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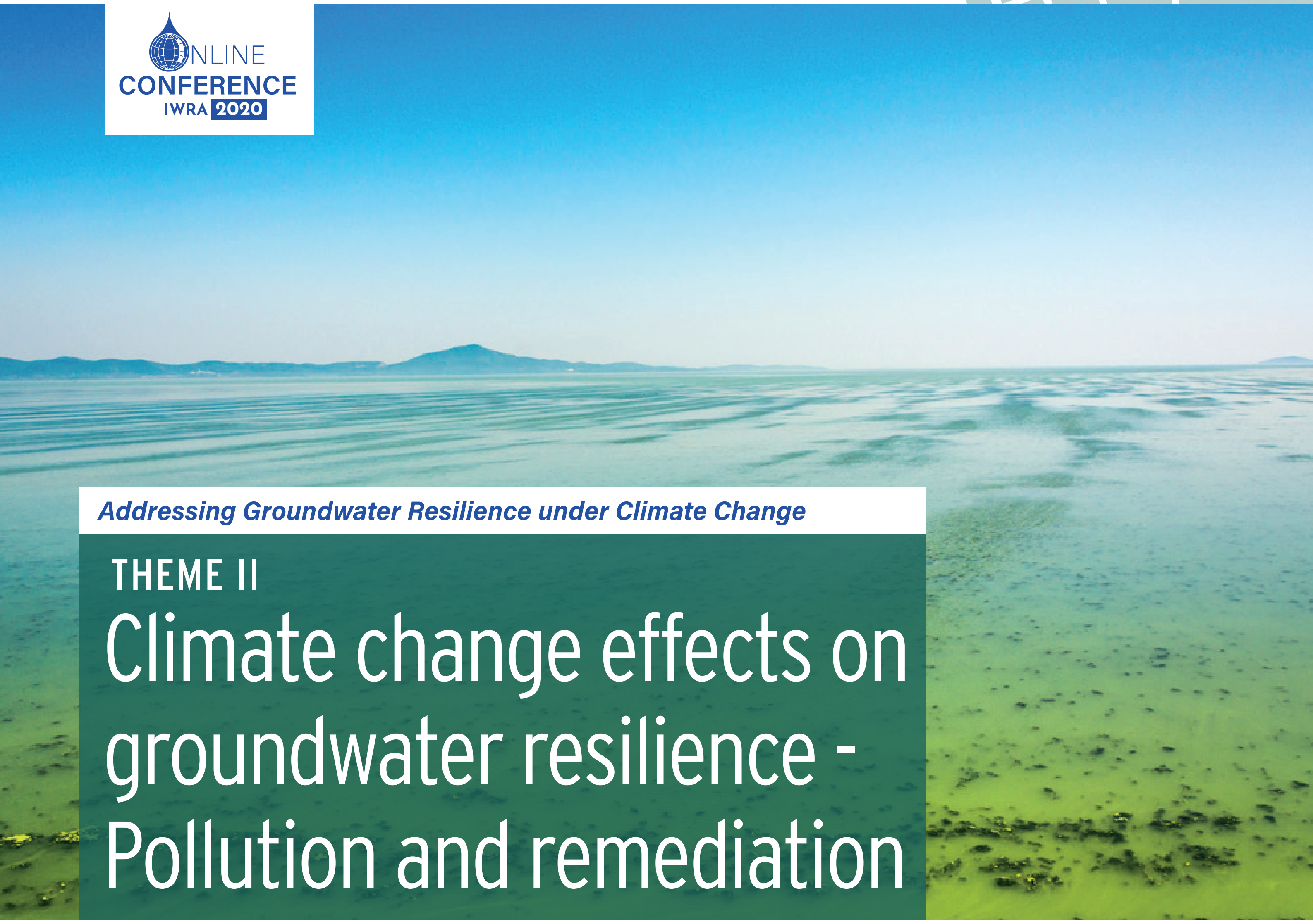

Addressing Groundwater Resilience under Climate Change

THEME II

Climate change effects on groundwater resilience - Pollution and remediation

Ukrainian river covered by Cyanobacterias
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KEY POLICY MESSAGES

- Climate change and growing water demand mandate creative, targeted, and scientifically-informed interventions to protect groundwater.
- Monitoring networks and models are crucial for understanding hydrological and hydrogeochemical processes related to groundwater quality.
- Passive remediation can be effective for point-source contamination and in areas facing water scarcity.
- Managed Aquifer Recharge can support groundwater resilience but requires context-sensitive design and robust regulation of water quality.

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Taking samples determine level contamination pollution.
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Contaminants pose significant challenges to the sustainability of groundwater resources worldwide, particularly those in water-stressed regions. Nature contaminates in a few cases but human activities constitute the most common and most addressable challenge. New technologies for monitoring and modeling groundwater systems can help mitigate contamination and, more broadly, support efforts to build resilience against climate change.

GO BELOW THE SURFACE TO IDENTIFY GROUNDWATER THREATS

Among anthropogenic sources of groundwater contaminants, agriculture accounts for a major share. For example, recycled water is often laced with pharmaceuticals, farm chemicals (e.g., fertilizers and pesticides), and other toxins. When this water is used to irrigate crops, pollutants can leach into the groundwater. For example, a study in North-Eastern Tunisia found pharmaceutical compounds present in treated wastewater and in groundwater below irrigated crops. The presence of antibiotics in the groundwater of western Catalonia, Spain, was linked to aquifer hydrodynamics, demonstrating the ability of groundwater flow to disperse pollutants. Further, heavy rainfall has been associated with increased levels of antibiotic compounds in groundwater, illustrating the importance of focused recharge as a vehicle of transport, which can be more frequent under climate change.

Groundwater recharge must account for threats posed by a variety of contamination sources. While recharge – through natural or managed processes – bears the threat of leaching large contaminant loads into groundwater, it may also promote dilution, whereas weak or absent recharge can also contribute to contamination by allowing pollutant concentrations to rise. For example,

Groundwater recharge must account for threats posed by a variety of contamination sources.

Human activity above ground directly impacts.
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a Portugal-based study found that subsoils retain and accumulate contaminants in times of droughts, illustrating that inadequate recharge is a measurable threat. As such, policymakers must be aware that both concentrated heavy rainfall and droughts (increasingly frequent under climate change scenarios) can exacerbate the degradation of groundwater quality.

MODEL AND FOLLOW THE FLOW

Models of groundwater flow can fill knowledge gaps and support governance mechanisms for addressing pollution challenges. Water resource managers and policymakers can use these models to identify groundwater reserves with high or fluctuating pollutant concentrations, observe the movement of contaminants across subterranean regions, and evaluate aquifer resilience under various climate change, extraction, and management scenarios.

Monitoring and modeling also helps researchers and analysts track the state of contaminant plumes and ensure the protection of essential source areas, such as those providing potable water. Such efforts also require the establishment of capacities to trace the evolution of groundwater conditions and contamination dynamics over time. Once correctly calibrated with monitoring data, such models can further help evaluate water management and climate change scenarios.

ENSURE THAT MAR DOES MORE GOOD THAN HARM

The prospect of groundwater depletion mandates innovative solutions that enable water demand to be met while preventing aquifer depletion. One such solution is

Human activity above ground directly impacts, but is also reliant on, water systems below ground.

managed aquifer recharge (MAR), in which surplus water from runoff or treated wastewater infiltrates the ground through natural processes or is pumped into the ground using reverse wells and other means. A principal aim of MAR is to ensure the quality of recharged water as a means to avert deterioration of groundwater quality. For example, a study in Tunisia identified pollutants in an aquifer traced to a MAR system that used treated wastewater. At the same time, pollutant concentration values in the examined groundwater were one-tenth of concentrations in the treated wastewater, suggesting the effectiveness of absorption processes and natural "passive" attenuation.
Countries around the world have implemented various regulations to manage the quality of groundwater replenished through MAR systems. More universal understandings about and regulation of MAR processes would facilitate comparative studies for use in applied research. Consistency in regulation can be achieved in part through shared terminology and more fine-grained measurements of the effectiveness of differing MAR techniques and sources (such as rainwater, river runoff, and treated wastewater). MAR regulations should be designed to fit governance as well as geological context.

THE VICIOUS CYCLE HAS TO BE BROKEN - URGENTLY

In considering groundwater contamination and efforts to mitigate it, we must realize the interconnectedness of systems that impact groundwater quality. Human activity above ground directly impacts, but is also reliant on, water systems below ground. This endogenous relationship suggests that something must eventually give; human activity that relies on groundwater cannot also be the cause of its unsustainable depletion or deterioration in quality. Exacerbating these dynamics is climate change, with extreme wet or dry weather events visiting harmful effects on groundwater resources.

Groundwater systems are both seen and unseen, requiring substantial efforts to map, monitor, and model. They must be observed also in the context of human systems and broader ecological conditions. Policymakers and other decisionmakers, many of whom are not water experts or engineers, must acknowledge this urgent reality, enable and promote monitoring, enact robust regulations on activities that impact groundwater, and provide resource support for applied research and extension programs.

ADDRESSING GROUNDWATER RESILIENCE UNDER CLIMATE CHANGE
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