POLICY BRIEF

Groundwater Quality
A Strategic Approach

Vital but Invisible

Groundwater is central to human development and an essential component of adaptation to climate change. Research has revealed that groundwater contamination is more extensive and harmful than previously thought. In the absence of dedicated action to address this aspect of groundwater management, the capacity of the resource to satisfy current or future demand is increasingly compromised.

Deteriorating Groundwater Quality Threatens Human Development

Groundwater resources are being degraded worldwide, threatening society's ability to provide water for drinking, agriculture, industry, and the environment. The drive to increase food production has polluted many shallow aquifers with nitrate and pesticides. In dry areas, these impacts are aggravated by naturally present salinity and poor land and water management practices. Meanwhile, many urban aquifers have been blighted by a century or more of industrial chemical mismanagement and improper waste disposal. When groundwater is contaminated, either naturally or by human action, the consequences for health, agriculture, and the economy can be immense.

Key Messages

- Groundwater accounts for 97 percent of global freshwater resources and is essential to human and economic development. It supplies drinking water for more than one-third of the world's population, around 40 percent of irrigation water and 25 percent of industrial water (IAH n.d.). As water availability becomes more variable with climate change, groundwater provides a critical buffer in times of water shortage and the importance of aquifers for water storage increases.
- Groundwater quality is central to its utility. When compromised by naturally occurring contaminants or polluted by human activities, the consequences for human health, agriculture, and the economy are far reaching and can span generations, with disproportionately large impacts for the global poor.
- The challenge and cost of cleaning up polluted groundwater or treating it in perpetuity are far greater than protecting it in the first place. The economic costs of these avoidable phenomena are measured in hundreds of billions of dollars.
- Protecting and managing groundwater quality should be a priority for decision makers. Necessary institutional strengthening measures include a well-formulated legislative framework, an adequate budget, and the recruitment of relevant expertise.
- Measurement of groundwater quality is temporally and spatially infrequent and inconsistent. More and better data will enable evidence-based decision-making to ensure groundwater's sustainability today and into the future.

Reducing Anthropogenic Contamination

Risk-based measures can limit the extent of anthropogenic contaminants—those that result from human action—which are incredibly diverse and destructive (see box 1). These contaminants range from petroleum leaks under local fuel stations; to a vast array of industrial chemicals, including polyfluoroalkyl substances (PFAS), a class of 3,500 industrial pollutants (dubbed "forever chemicals") that are highly toxic, persistent, mobile, and bioaccumulating; to pesticides, many of which are known or suspected carcinogens and endocrine-disrupting chemicals (WHO 2019). While most anthropogenic pollution is highly localized, the exceptions are fecal pathogens which contaminate shallow groundwater beneath human settlements, and fertilizer nitrate, which is widely applied and can persist in groundwater for decades, accumulating to high levels as more nitrogen is applied to the land surface every year.

Mitigating Geogenic Contamination

There are fewer known geogenic (naturally occurring) contaminants in groundwater than anthropogenic contaminants. However, increased testing reveals geogenic contaminants are more widespread than initially assumed. They affect hundreds of millions of people, causing crippling and potentially fatal illnesses. In some countries, they contribute significantly to total morbidity (see box 2). Some contaminants,

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BOX 1. Growing Hazards of Anthropogenic Contamination

23% **Share of groundwater bodies in the European Union classified as being of poor chemical status** (Psomas et al. 2021). Although estimating the extent of anthropogenic contamination is difficult because of the legacy of undocumented soil pollution, this study warns of pervasive groundwater contamination, even in countries with strong groundwater protection measures.

1,000 **The number of new chemicals released into the environment in the United States each year**, or about three a day. Pollution does not decline with economic growth, and the range of pollutants tends to expand with prosperity. Keeping up with such a growing range of risks is difficult even in countries with significant resources and is markedly more challenging in those that are underresourced (Damania et al. 2019).

BOX 2. Threat of Natural Contamination to Global Health

150 million **Number of people worldwide affected by arsenic contamination in drinking water** since the 1970s. Arsenic exposure causes a host of debilitating illnesses, including painful skin diseases, the impacts of which cascade beyond health. Adults who are unable to work are subject to social exclusion; many of their children are withdrawn from school and unable to marry. In the mid-1990s, arsenic was discovered to be a widespread natural contaminant in groundwater (Ravenscroft, Brammer, and Richards 2009). An estimated 1 million people died from arsenic poisoning in the two decades since, with excess deaths continuing to this day.

200 million **Number of people at risk of disease from fluoride exposure in drinking water** (EAWAG 2015). Fluoride contamination can cause dental and skeletal fluorosis in humans, which may lead to chronic pain and damage to joints and bones (Fawell et al. 2006). It primarily affects poor communities that rely on untreated and perhaps untested water supplies. Knock-on effects can trap households into multigenerational cycles of poverty.

100 million **Minimum number of people estimated to be exposed to manganese contamination**, which impairs intellectual development of children (Bouchard et al. 2011; Khan et al. 2012). However, some countries do not test for it or are practically unaware of the health impacts.

such as arsenic, threaten the sustainability of irrigated agriculture, which has important implications for food security. Although geogenic contaminants cannot be removed, they can be prevented from causing harm to humans through treating contaminated supplies or developing alternative supplies.

Legacy of Polluted Groundwater

Regardless of the source of pollution, contaminants may travel slowly through the ground for years until intercepted by a pumping well. By this time, the stores of contaminants in the soil are significant and can pollute aquifers and abstraction wells for decades, even after the original source of pollution has stopped. Likewise, some health impacts may take time to appear. For example, cancers induced by contaminants (such as arsenic) may develop decades after exposure ceases. The legacy effects of contamination can impact multiple generations by suppressing economic growth (see box 3).

Responding to Contamination Events

Large-scale anthropogenic contamination (such as nitrate and pesticides from agriculture and pathogens from inadequate sanitation) requires government support and a community-level

BOX 3. Economic Impact of Polluted Groundwater

–30%	**Share of reduced economic growth because of a lack of clean water.** When water pollution crosses a certain threshold, gross domestic product growth drops by as much as one-third because of impacts on health, agriculture, and ecosystems. (Damania et al. 2019).

BOX 4. Mitigation and Remediation Costs

US$1.23 billion	**Amount spent on water treatment, blending, and replacing water sources in the United Kingdom between 1975 and 2003** to address deteriorating water quality affecting almost half of the groundwater used for public supply (UKWIR 2004).
US$150 billion to US$750 billion	**Cost of cleaning up known contamination** of groundwater from industrial and municipal wastes in the United States (USEPA 2001).

response to change practices and gradually reduce contaminant inputs. Localized pollution, such as from industrial sites and urban landfills, can often be stopped through improved operations or other preventive measures.

The best way to limit the damage from pollution, however, is to stop it from happening in the first place. The basic approach is to delineate source protection zones around abstraction points linked to the planning process so planners can identify where hazardous activities should be prohibited or permitted only with special precautions.

While some pollution is inevitable, its severity can be greatly reduced by following groundwater management best practices. These include mandatory groundwater monitoring (allows early detection), participatory management of groundwater, maintenance of an active register of new chemicals (to enable an adaptive response), and a regulatory regime that encourages voluntary remediation. This requires effective site characterization and collaboration between the site owner and the regulator. Placing these actions in a risk-based approach will prioritize action when it is likely most effective in reducing harm and avoid unnecessary expenses associated with blanket responses. The difficulty and time necessary to remediate aquifers is why groundwater protection and monitoring is so important. The groundwater crisis worsens when there are long gaps between the start of pollution, its discovery, and the start of remediation (see box 4).

Practical Actions to Prioritize Groundwater Monitoring and Protection

Prioritizing groundwater protection and management provides benefits to managers, policy makers, and budget holders. When groundwater quality monitoring is supported by the right regulatory framework, proper groundwater management reduces vulnerability to increased water scarcity while optimizing investments in water supply infrastructure and systems.

Improving Groundwater Quality Monitoring

Improved monitoring is a precondition for all other actions and should be a top priority. Key actions:

- Develop a conceptual model to characterize the aquifer that illustrates groundwater flow and quality, its uses, and its interaction with the surface environment and mapped pollution hazards.
- Establish a baseline to define the initial state of the aquifer and so measure the effectiveness of interventions or identify the presence of contaminants so they can be mitigated before harm occurs.
- Commission an external review of groundwater monitoring and management to identify reforms that align with international best practices.

Reforming Legislation

Precise requirements should be developed to fit the national context through a regulatory review. Key actions:

- Administer environmental impact assessments that consider groundwater quality impacts.
- Build risk assessments into the regulatory process to enable a targeted and proportionate response.
- Establish groundwater protection measures as part of legally binding planning and land use controls.

Strengthening Relevant Institutions

Most countries have developed water resource institutions to deal with quantitative issues of surface water and require reform to better accommodate groundwater and water quality more broadly. Measures relating to groundwater quality include the following actions:

- Provide budgetary allocations for groundwater quality monitoring.
- Create an independent auditor to examine networks and records.
- Implement a policy of public reporting.
- Facilitate citizen science.

About the Policy Brief

This policy brief highlights the key messages for policy makers from the World Bank report "Seeing the Invisible: A Strategic Report on Groundwater Quality" (Ravenscroft and Lytton 2022a). This report and "A Practical Manual on Groundwater Quality Monitoring" (Ravenscroft and Lytton 2022b) describe the types of contaminants in groundwater, tools and resources for their measurement and long-term monitoring, and techniques to protect the resource from being contaminated in the first place.

References

Bouchard, M. F., S. Sauvé, B. Barbeau, M. Legrand, M.-E. Brodeur, T. Bouffard, E. Limoges, D. C. Bellinger, and D. Mergler. 2011. "Intellectual Impairment in School-Age Children Exposed to Manganese from Drinking Water." *Environmental Health Perspectives* 119 (1): 138–43.

Damania, Richard, Sebastien Desbureaux, Aude-Sophie Rodella, Jason Russ, and Esha Zaveri. 2019. *Quality Unknown: The Invisible Water Crisis*. Washington, DC: World Bank. doi:10.1596/978-1-4648-1459-4.

EAWAG (Swiss Federal Institute of Aquatic Science and Technology). 2015. *Geogenic Contamination Handbook: Addressing Arsenic and Fluoride in Drinking Water*, edited by C. A. Johnson and A. Bretzler. Dubendorf, Switzerland: EAWAG.

Fawell, J., K. Bailey, J. Chilton, E. Dahi, and Y. Magara. 2006. *Fluoride in Drinking-Water*. WHO Drinking-Water Quality Series. Cornwall: IWA Publishing.

IAH (International Association of Hydrogeologists). n.d. "Groundwater: More about the Hidden Resource." https://iah.org/education/general-public/groundwater-hidden-resource. Accessed February 17, 2022.

Khan, K., G. A. Wasserman, X. Liu, E. Ahmed, F. Parvez, V. Slavkovich, D. Levy, J. Mey, A. van Geen, J. H. Graziano, and P. Factor-Litvak. 2012. "Manganese Exposure from Drinking Water and Children's Academic Achievement." *Neurotoxicology* 33: 91–97.

Psomas, A., G. Bariamis, S. Roy, J. Rouillard, and U. Stein. 2021. *Comparative Study on Quantitative and Chemical Status of Groundwater Bodies*. Study of the Impacts of Pressures on Groundwater in Europe. Copenhagen: European Environment Agency.

Ravenscroft, P., H. Brammer, and K. S. Richards. 2009. *Arsenic Pollution: A Global Synthesis*. Chichester, UK: Wiley-Blackwell.

Ravenscroft, P., and L. Lytton. 2022a. "Seeing the Invisible: A Strategic Report on Groundwater Quality." World Bank, Washington, DC.

Ravenscroft, P., and L. Lytton. 2022b. "Practical Manual on Groundwater Quality Monitoring." World Bank, Washington, DC.

UKWIR (UK Water Industry Research). 2004. *Implications of Changing Groundwater Quality for Water Resources and the UK Water Industry: Phase 3: Financial and Water Resources Impact*. London: UKWIR. https://ukwir.org/eng/reports/04-WR-09-8--/67216/Implications-of-Changing-Groundwater-Quality-for-Water-Resources-and-the-UK-Water-Industry-Phase-3-Financial-and-Water-Resources-Impact.

USEPA (United States Environmental Protection Agency). 2001. *Cost Analyses for Selected Groundwater Clean-up Projects: Pump and Treat Systems and Permeable Reactive Barriers*. Washington, DC: EPA. https://www.epa.gov/remedytech/cost-analyses-selected-groundwater-cleanup-projects-pump-and-treat-systems-and-permeable.

WHO (World Health Organization). 2019. *Preventing Disease Through Healthy Environments Exposure to Highly Hazardous Pesticides: A Major Public Health Concern*. Geneva: WHO. https://apps.who.int/iris/handle/10665/329501.

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