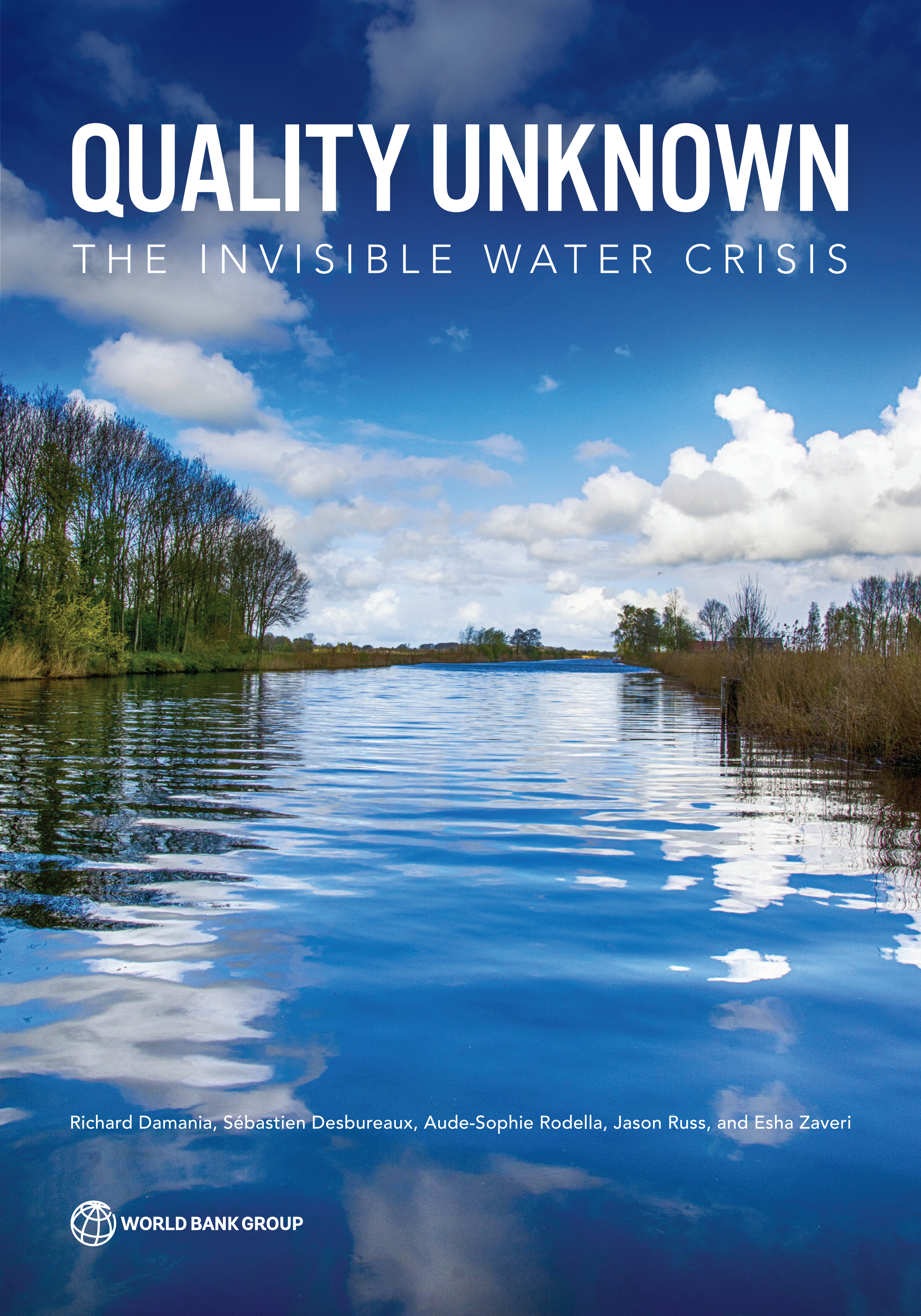
QUALITY UNKNOWN

THE INVISIBLE WATER CRISIS



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1 2 3 4 22 21 20 19

ISBN (paper): 978-1-4648-1459-4
ISBN (electronic): 978-1-4648-1485-3
DOI: 10.1596/978-1-4648-1459-4

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Cover and book design: Studio Grafik, LLC.

Library of Congress Cataloging-in-Publication Data has been requested.

ACKNOWLEDGMENTS

This book was prepared by a team led by Richard Damania and co-led by Aude-Sophie Rodella and comprising Sébastien Desbureaux, Jason Russ, and Esha Zaveri. The book has greatly benefited from the strategic guidance and general direction of Jennifer Sara (Global Director, Water Global Practice) and the management of the Water Global Practice. We also thank Guangzhe Chen (Global and Regional Director, Infrastructure Practice Group) for his support in the early stages of this work.

In addition to research completed by the authors, this work draws on background papers, notes, advice and analysis by a large number of people including the following: John Anderson (London School of Hygiene and Tropical Medicine), Essayas Kaba Ayana (Cornell University), Kelly Baker (Iowa University), Konrad Buchauer (ARAConsult GmBH), Claire Chase (World Bank), Yue Chen (World Bank), Oliver Cumming (London School of Hygiene and Tropical Medicine), Jorge Escurra (World Bank), Florian Heiser (World Bank), Towfiqua Hoque (World Bank), Michael Jermen (University of Oregon), George Joseph (World Bank), Qiong Lu (World Bank), Darwin Marcelo (World Bank), Frédéric Mortier (Université de Montpellier), Léa Noyer (Ecole Polytechnique), Daniel Odermatt (Swiss Federal Institute of Aquatic Science and Technology), Sheila Olmstead (University of Texas), Marcus Poeppke (World Bank), Aditi Raina (World Bank), Giovanna Ribeiro (Center for Learning on Evaluation and Results), Ali Sharman (World Bank), Anshuman Sinha (World Bank), Amal Talbi (World Bank), Michelle van Vliet (Wageningen University & Research), Yoshihide Wada (International Institute for Applied Systems Analysis–IIASA & Utrecht University), Martin Wagner (Norwegian University of Science and Technology), Cheng Xu (George Washington University), Sally Zgheib (World Bank), Jiameng Zheng (University of Texas), and Juan Ignacio Zoloa (National University of La Plata).

The authors received incisive and helpful advice and comments from World Bank colleagues, including Aleix Serrat Capdevila (Senior Water Resource Management Specialist), Genevieve Connor (Practice Manager), Alexander Danilenko (Senior Water Supply and Sanitation Specialist), Marianne Fay (Chief Economist), Martin Gambrill (Lead Water and Sanitation Specialist), Pier Mantovani (Lead Water Supply and Sanitation Specialist), Pratibha Mistry (Senior Water Supply and Sanitation Specialist), Ernesto Sanchez-Triana (Lead Environmental Specialist), Pieter Wallewijn (Senior Water Resources Management Specialist), and Marcus Wijnen (Senior Water Resources Management Specialist).

In addition, the team is greatly indebted to Hartwig Kremer (United Nations Environment Programme) for his advice and support of the research, as well as to Carter Brandon (World Resources Institute), Dustin Garrick (Oxford University), and Bruce Gordon (World Health Organization) for their helpful comments.

The World Bank Water communications, knowledge, and publishing teams, comprising Erin Barrett, Meriem Gray, Martin Hall, Li Lou, and Pascal Saura, provided invaluable support for turning a manuscript into a finalized report.

Finally, Georgine Badou provided impeccable administrative support for which the team is grateful.

This work was made possible by the financial contribution of the Global Water Security and Sanitation Partnership (see https://www.worldbank.org/en/programs/global-water-security-sanitation-partnership) of the Water Global Practice, World Bank Group.

EXECUTIVE SUMMARY

It was the summer of 1969 and the Cuyahoga River was on fire. This wasn't the first time the river in northern Ohio had burned—it wasn't even the tenth. Every few years, an errant spark would ignite the river, threatening nearby buildings or passing ships. The fire of 1969 was not especially notable for the damage it caused or the duration of its blaze. But it did ignite the tinderbox of environmental unrest that had already been smoldering across the country. Within six months of the fire, the U.S. Congress passed the National Environmental Policy Act, establishing the U.S. Environmental Protection Agency (EPA). One of the first acts of the EPA was to implement the Clean Water Act of 1972, which mandated that all waterways must be of sufficient quality to be safe for swimming and aquatic life by 1983.

Fifty years on, water quality issues remain a challenge. Like the Cuyahoga River in 1969, many other water bodies are on fire—some literally, like the Meiyu River in eastern China or Bellandur Lake in Bangalore, India, which has rained ash onto buildings up to six miles away. Yet most burn imperceptibly, with bacteria, sewage, chemicals, and plastics sucking out the dissolved oxygen much like a raging inferno and transforming water into poison for humans and ecosystems alike. Understanding of this problem has been impaired not just by a lack of information, but also by the complexity of issues that often transcend discipline boundaries—environmental science, health, hydrology, and economics—with each offering different insights.

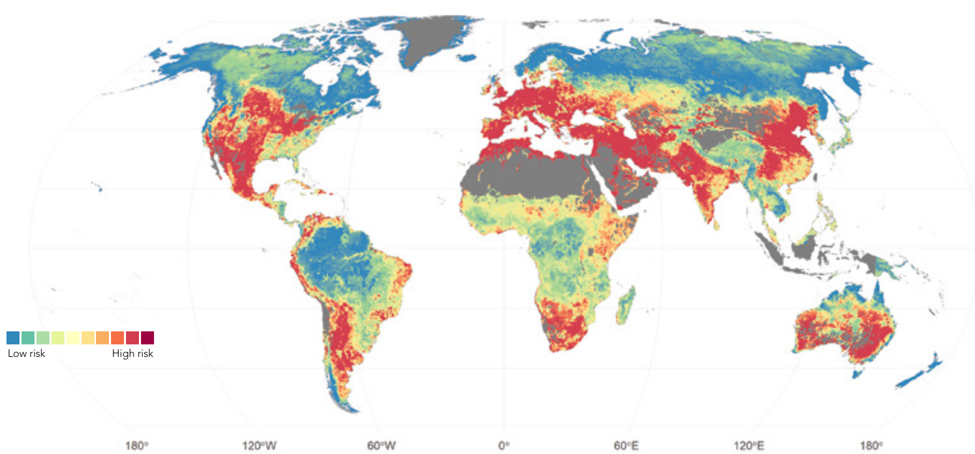
This report brings forth new results that illuminate the impacts of the hidden dangers that lie beneath the water's surface and elucidate strategies for combating them. The main, though not exclusive, focus is on the parameters that are tracked in the water quality Sustainable Development Goal (SDG) 6.3.2, with its focus on nutrient loads, salt balances, and overall environmental health of water bodies. The report demonstrates that the parameters identified in SDG 6.3.2 have impacts that are wider, deeper, and larger than previously known, suggesting the need for a broader focus on water quality beyond indicators of sanitation-related contaminants such as fecal coliforms and *Escherichia coli*. Recognizing the scope of the problem, identifying the magnitude of the impacts, and formulating ways to address these will be critical to improving public health, preserving ecosystems, and sustaining economic growth throughout the twenty-first century.

UNDERSTANDING THE EXTENT OF THE PROBLEM

The complexity of water quality and the multitude of parameters that need tracking are at least partly why global water quality monitoring has proved so troublesome. To shed light on the issue, this study assembled a vast, and perhaps the largest, database on water quality. Data were collected from beneath the surface using information from in situ monitoring stations or samples. Satellites collected data from the sky using remote-sensing techniques. Other data were generated by computer using machine learning models. The latter are particularly interesting because monitoring stations and remote sensing provide data for limited points in space and time, while modeled data can fill gaps to provide a more complete picture of the state of water quality. Harnessing all of this evidence provides some stark insights.

Rich and poor countries alike endure high levels of water pollution. Map ES.1 displays the overall global water quality risk for the three major water quality indicators of SDG 6.3.2: nitrogen (nitrate-nitrite), an outlier pollutant in terms of scale, scope, trends, and impacts; electrical conductivity, a measure of salinity in water; and biological oxygen demand (BOD), a widely used umbrella proxy for water quality. It is clear from map ES.1 that high-income status does not confer immunity from water quality problems. This contradicts what one might assume based on the environmental Kuznets curve hypothesis, which posits that pollution eventually declines with prosperity. Not only does pollution not decline with economic growth, but the range of pollutants tends to expand with prosperity. The United States alone receives notices for the release of more than 1,000 new chemicals into the environment each year—or around three new chemicals per day. Keeping up with such a growing range of risks is difficult even in countries with significant resources and nearly impossible in developing countries.

MAP ES.1: Water Quality Risk for Biological Oxygen Demand, Nitrogen, and Electrical Conductivity



Note: This map shows a water quality index summarizing global predictions for biological oxygen demand, electrical conductivity, and nitrogen. Each value is scaled to a common support for comparability and then summed together. Average values for 2000–10 are displayed. Gray areas have no data for one or more parameters. More details on the construction of the index are presented in the appendix (available at www.worldbank.org/qualityunknown).

WHY IT MATTERS

Results in this report demonstrate the importance of water quality across a range of sectors and how its impacts cut across nearly all SDGs. Water quantity challenges receive a great deal of attention from the development community, but water quality impacts may be equally, or more, important. This report describes results of new analyses that find larger impacts on health, agriculture, and the environment than were previously known. When these sectoral impacts are aggregated, they account for significant slowdowns in economic growth. Well-known pollutants such as fecal contaminants, as well as new pollutants, including nutrients, plastics, and pharmaceuticals, present significant challenges.

Nitrogen is essential for agricultural production but is also volatile and unstable. Frequently more than half of nitrogen fertilizer leaches into water or the air. In water, it may result in hypoxia and dead zones—problems that arise from a lack of dissolved oxygen in water that can take centuries to recover. In the air, it may form nitrous oxide, a greenhouse gas that is 300 times more potent at trapping heat than carbon dioxide. This is why some scientists suggest that the world may have already surpassed the safe planetary boundaries for nitrogen and that it is the world's greatest externality, exceeding even carbon.

Although it is known that oxidized nitrogen can be lethal to infants, this report shows that those who survive its early consequences can be scarred for life—impairing growth and later-life earnings. Nitrogen in water is responsible for fatally inflicting what is known as blue baby syndrome, which starves infants' bodies of oxygen. This report finds that those that survive endure longer-term damage throughout their lives. Infants born in India, Vietnam, and 33 countries in Africa who were exposed to elevated nitrate levels in the first three years of life grew up shorter than they would have otherwise. This result is striking for three reasons: First, it means that nitrate exposure in infancy can wipe out much of the gain in height (a well-known indicator for overall health and productivity) seen over the last half century; second, it suggests that nitrates may have similar or worse impacts on height and other development metrics as fecal coliforms; and finally, impacts are found in even geographies where nitrate levels are below levels presumed safe.

These new findings suggest a stark trade-off between using nitrogen as a fertilizer, where it confers benefits to agriculture, and economizing on its use to protect health. A simple calculation quantifies this trade-off: Globally, an additional kilogram of fertilizer per hectare increases yields by 4–5 percent. However, the subsequent fertilizer runoff and release of nitrates into the water poses a risk large enough to increase childhood stunting by 11–19 percent and decrease later-life earnings by 1–2 percent. A conservative interpretation of this finding suggests that the vast subsidies accruing to fertilizers likely generate damage to human health that is as great as, or even greater than, the benefits that they bring to agriculture.

Salt, the most elementary contaminant that has plagued the world since antiquity, is on the rise in soils and bodies of water throughout the world. This report presents new research that documents the extent of the impact of salt on agricultural production. Sumer, the civilization that gave us the wheel, plough, and written language, was also the first to pioneer irrigated agriculture. In doing so, it led to an accumulation of salts that destroyed agricultural potential and led to the eventual decline of the great civilization. Today, saline waters and soils are spreading throughout much of the world—especially low-lying coastal areas, irrigated drylands, and around urban areas—with large impacts on agricultural yields. This report quantifies the effects on yields and finds they fall almost linearly with salt concentrations in water. Overall, enough food is lost each year because of saline water to feed 170 million people, or a country the size of Bangladesh.

Saline drinking water is harmful for human health, particularly in the vulnerable phases of the life cycle—infancy and pregnancy—compromising human development. In Bangladesh, where saline water is widespread, it is responsible for up to 20 percent of infant mortality across the most affected coastal areas. Pregnant women exposed to high amounts of salt are more likely to miscarry and are at a greater risk of preeclampsia and gestational hypertension. But new research finds visible effects even in areas with lower levels of salinity than in Bangladesh, where fetal deaths are found to rise by as much as 4 percent in saline regions. When babies exposed to high salinity levels survive, they are at higher risk of health complications. Despite this, there are no health-based drinking water standards for salt.

Pollutants of emerging concern such as microplastics and pharmaceuticals exemplify the complex nature of water quality issues: multifaceted, with no immediate or obvious solutions. The usefulness of plastics and pharmaceuticals is immeasurable, and yet the unintended by-products have consequences that are widespread and difficult to quantify and contain. Microplastics, the broken-down product of consumer goods, plastic bags, and other polymeric materials, are ubiquitous throughout the world. Although there is uncertainty about the extent of the problem, some studies have detected them in 80 percent of global freshwater sources, 81 percent of municipal tap water, and even 93 percent of bottled water. Although there is growing concern that ingesting microplastics and nanoplastics can be harmful to human health, there is still limited information about where safe thresholds might lie. Removal of plastics, once in water, is difficult and costly. Voluntary approaches to reduce, reuse, and recycle plastic, though popular, can only go so far and will not resolve the problem without the right mix of regulations and incentives. Prevention is therefore key, as is a better understanding of these hazards and the need for standardized methods for exposure and hazard assessments.

Given the range of contaminants, is it possible to determine the total economic cost that bad water quality has on economic activity? The multitude of contaminants, the complexities of measurement, and the uncertainty of impacts leave that question unanswered. However, it is possible to provide an indication of the relationship between upstream water quality and downstream economic activity using several recently available, spatially disaggregated data sets on economic activity, measured by gross domestic product (GDP), water quality, and other parameters of relevance.

The release of pollution upstream acts as a headwind that lowers economic growth in downstream areas, reducing GDP growth in downstream regions by up to a third. Although many water quality parameters may affect growth, BOD is perhaps the most appropriate measure to use to test the relationship between upstream water quality and downstream GDP, given its ability to proxy a wide array of pollutants. When the BOD level of surface water is at a level at which rivers are considered heavily polluted (exceeding 8 milligrams per liter), GDP growth in downstream regions is lowered by a third. This is yet another stark indication that there are often trade-offs between benefits of economic production and environmental quality, and that the externalities generated by economic production can be circular, reducing growth downstream.

POLICIES TO TAME THE WICKED PROBLEM

Water quality is a problem that is growing in complexity as prosperity expands and new contaminants emerge. The increasing range of pollutants varies by sector, geography, and development level. There are still deep uncertainties about safe levels and the size and type of impacts on humans and ecosystems. Not only is there no silver bullet solution to solve the water quality problem, but even coming up with a typology of appropriate responses is challenging. Measuring, understanding, and regulating water quality combines the ingredients of a "wicked problem," a term coined by design theorists Horst Rittel and Melvin Webber to describe complex matters for which there are no optimal solutions.

Faced with these wicked challenges, there are three approaches available to policy makers: a passive approach of inaction, a proactive approach of prevention, or a reactive approach that treats contaminants (figure ES.1). Policy inaction is common in low-income countries or where there is uncertainty about the effects of pollutants. Responses to perceived hazards are then left to individuals, who may, for instance, relocate to a safer area or

FIGURE ES.1: Three Main Approaches to the Wicked Problem

circumvent the effects through private avoidance actions. Where regulatory capacities are higher, policy makers can be proactive and seek to prevent or reduce pollution at the source. Alternatively, they may be reactive and attempt to treat the toxic discharges, typically through investments in various types of water treatment facilities.

The way forward requires a mix of these approaches, tailored to reflect the specificities of the water quality challenges at hand. First, it requires obtaining more information about the scale and scope of the problem and making it available to affected parties in an open and transparent manner. Next, it requires better incentives to prevent pollution from entering the environment. As the adage goes, an ounce of prevention is often better than a pound of cure, and given the high uncertainty in regard to impacts, prevention is often the safest alternative. Finally, because it is cost prohibitive to prevent all pollution, smart investments must be made to effectively treat pollution. Each of these pathways is described in figure ES.2, which summarizes a ladder of interventions that begin at relatively lower effectiveness but are more easily implementable and then increase in complexity and impact.

Improving the measurement of water quality is a critical first step. Few developing countries adequately monitor water quality. New technologies and techniques have made measurement more feasible and reliable. Recent trials have demonstrated that multilayered monitoring systems involving several parties can improve the reliability of data collected. These in turn can be complemented with remote sensing and machine learning to provide an additional and independent layer of verification. Blockchain technologies, though still in the experimental stages of use in the water sector, can offer a promising added layer of verification and transparency at low cost and with increasing reliability with the inclusion of newly collected data.

Information disclosure is a vital part of the policy mix. In contexts in which there is significant uncertainty, information has high economic value. As analysis in this report suggests, there is considerable uncertainty about the safe thresholds of key water pollutants that are pervasive across the world. In such circumstances, the provision of clear and understandable guidelines about the existing evidence and uncertainties involved would equip consumers with the ability to make better choices. One of the most powerful outcomes of information disclosure is its ability to inspire social movements and create the support needed for policy improvements. Citizens cannot act if they are uninformed or unaware of the situation. Encouraging and enabling this information is fundamental to the social contract that exists between the governed and the governors and is critical to getting this wicked problem under control.

Measurement is only effective if it is coupled with well-designed regulations that provide incentives for firms and individuals to adhere to water quality guidelines. But the longer the pipeline of regulations, the greater the opportunities for leakage, rent seeking, and corruption.

FIGURE ES.2: Ladder of Policy Interventions

Passive		Proactive		Reactive		
Information		**Prevention**		**Investments**		
Trans-parency	**Monitoring systems**	**Enforce-ment**	**Legislative framework**	**Financing**	**Treatment**	
Publish data online and in regional/ global data-bases, as well as in schools and health centers	Establish water quality monitoring for major water sources (surface and groundwater)	Codified laws and regulations in place that incentivize the reduction of point and nonpoint source water pollution with clear jurisdictions for enforcement and sufficient levels of devoted resources		Treatment is publicly financed	100% of drinking water is treated (SDG 6.1.1)	STAGE ONE
Overlapping systems with remote sensing or alternative monitoring infrastructure	Systemati-cally monitor water quality in all sources of surface and ground-water	Smart contracts and automatic monitoring	Command and control structure	Incentives are put in place to attract private sector investors	100% of wastewater is safely managed (SDG 6.2.1)	STAGE TWO
Third-party or disaggregated publishing and verifica-tion system such as blockchain	Remote sensing or overlapping systems and early warning	Costs of water pollu-tion are fully internalized by polluters	Economic incentives (taxes, permits, payment for services schemes, etc.)	Treatment is financed through a blend of private sector financing and tariffs levied on polluters	Tertiary treatment of drinking and wastewater for denitrifi-cation	STAGE THREE

Hence, implementation deficits are especially large in developing countries with limited regulatory capacity. Fortunately, new technologies can be harnessed to improve enforcement in these circumstances. For instance, smart contracts—rules written in computer code that are embedded in a blockchain and automatically execute when the conditions are met—could be used to automatically enforce payments from polluters. Such automatic execution adds a level of transparency that is often missing in enforcement. For prevention to be effective, the monitoring system needs to be tamper proof, and it should not be possible to evade the sanctions for violations. With appropriate attention to incentives and design, such systems can galvanize polluters into action.

Long-standing assumptions about wastewater treatment infrastructure need to change—investments must be scaled up but also need to become more effective. More than 80 percent of the world's wastewater—and more than 95 percent in some developing countries—is still released into the environment without treatment. There is therefore an urgent need for greater investment in wastewater treatment plants, especially in heavily populated areas. But this report finds that at times, investments in wastewater treatment facilities lead to little measurable improvement in water quality, representing a waste of scarce public funds. The clear implication is that investments need to be accompanied by appropriate incentive structures that monitor performance, penalize profligacy, and reward success. Moreover, the large gap in public sector resources suggests the need for new models that attract private investments.

Finally, better land use policies and smart spatial planning are critical for protecting water supplies. Forests and wetlands act as natural buffers that absorb excessive nutrients that would otherwise pollute waterways. This report finds that globally, land extensification—from both urban expansion and agricultural land expansion—is one of the biggest threats to environmental water quality. It sharply increases the risk of hypoxia and anoxia (dead zones), which is a great threat to ecosystems and human health alike. Land use policies that preserve critical forests, wetlands, and natural biomass, particularly in the vicinity of high-value water resources, are therefore key to protecting water supplies.

Action is needed: water quality needs to be politically prioritized, and it should be treated as an urgent concern for public health, the economy, and ecosystems. The findings from this report show that long-term costs have been underestimated and underappreciated. The threats that poor water quality presents are largely imperceptible, and as a result, policy inaction and procrastination are often convenient responses to an invisible problem. But this means that populations are subjected to hazards without their knowledge or their consent. With water scarcity expected to increase as populations grow and the climate changes, the world cannot afford to waste and contaminate its precious water resources.

Water quantity—too much in the case of floods, or too little in the case of droughts—grabs public attention and the media spotlight. Water quality—being predominantly invisible and hard to detect—goes largely unnoticed. *Quality Unknown: The Invisible Water Crisis* presents new evidence and new data that call urgent attention to the hidden dangers lying beneath water's surface. It shows how poor water quality stalls economic progress, stymies human potential, and reduces food production.

Quality Unknown examines the effects of water quality on economic growth and finds that upstream pollution lowers growth in downstream regions. It reveals that some of the most ubiquitous contaminants in water, such as nitrates and salt, have impacts that are larger, deeper, and wider than has been acknowledged. And it traces the damage to crop yields and the stark implications for food security in affected regions.

An important step toward tackling the world's water quality challenge is recognizing its scale. The world needs reliable, accurate, and comprehensive information so that policy makers can have new insights, decision making can be evidence based, and citizens can call for action. The report calls for a paradigm shift that emphasizes safer, and often more cost-effective remedies that prevent pollution by combining smarter policies with newer technologies. A key message of *Quality Unknown* is that such solutions exist and change is possible.

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ISBN 978-1-4648-1459-4
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9 781464 814594
SKU 211459