Environmental Science & Technology

Viewpoint

pubs.acs.org/est

Emerging Challenges for the Drinking Water Industry

Justin D. Brookes,*[†] Cayelan C. Carey,[‡] David P. Hamilton,[§] Lionel Ho,[†,∥] Leon van der Linden,[†,∥] Robert Renner,[⊥] and Anna Rigosi[†]

[†]Water Research Centre, Environment Institute, School of Earth and Environmental Science, University of Adelaide, 5005 South Australia, Australia

[‡]Department of Biological Sciences, Virginia Tech, 1405 Perry Street, Blacksburg, Virginia 24061, United States

[§]Environmental Research Institute, University of Waikato, Private Bag 3105, Hamilton 3240, New Zealand

[∥]Research and Innovation, SA Water Corporation, GPO Box 1751 Adelaide, South Australia, 5001 Australia

[⊥]Water Research Foundation, 6666 West Quincy Avenue, Denver, Colorado 80235-3098, United States

Safe drinking water is a fundamental human right.[1] However, the water industry faces unprecedented demand for drinking water globally as it simultaneously manages climate change and increasing human population.[2] Water utilities will increasingly have to respond to an increased frequency of extreme events (e.g., droughts, floods, fires, storms), altered nutrient loading from catchments, and water quality deterioration.[3] Traditionally, water supplies have been dominated by surface- and ground- water sources; however, yield from these sources is likely to become less reliable, concurrent with rising demand. Investment in alternative water resources is inevitable but exposes utilities to new water quality risks. The water industry thus faces an emerging challenge of how to manage the risks of these threats and make necessary investments to ensure the reliability of future supply.

The use of alternative water sources has increased dramatically over the past three decades, especially toward climate-independent sources. For example, significant investment in desalination has produced ~15000 desalination plants globally. In addition, recycling and bulk transfer of water between catchments are increasingly being used. However, these three alternative water sources present other challenges, including higher infrastructure, operational, and treatment costs, as well as varying levels of community acceptance.

Supplementing water supply with alternative sources changes the risk profile of the water supply system. For example, recycled water increases the risk of occurrences of disinfection byproducts, such as nitrosamine, NDMA, pathogens, and antibiotic-resistant bacteria, potential endocrine-disrupting compounds, and cyanobacterial toxins. The challenge for the water industry is to maintain and enhance the safety of supply from these sources while simultaneously ensuring water security at reasonable prices.

Adaptation to climate change has become paramount.[4] Here, we introduce three principles that are fundamental prerequisites when considering investments in alternative water sources: (1) the reliability of the current water source to meet demand; (2) the thresholds set for water quality standards and regulatory compliance, which vary among water quality parameters and nations/states; and (3) how projected future water quantity and quality will vary from today's conditions (Figure 1).

RELIABILITY

For many regions, climate change will decrease the ability of water utilities to meet demand using catchment-based sources alone, resulting in decreased reliability of supply (Figure 1A) and forcing exploration of alternative water sources.

THRESHOLDS

The level of investment required to ensure water security can be informed by future climate scenarios, including the likelihood of water quality parameters exceeding certain standards (e.g., water quality objectives, regulatory and health standards), and the consequence of exceeding those thresholds. Under future scenarios, increased climate variability is likely to exacerbate the frequency at which thresholds are exceeded (Figure 1B), as increased temperature accelerates many biogeochemical and ecological processes, thereby leading to poorer water quality.

Received: January 16, 2014
Accepted: January 24, 2014
Published: January 31, 2014

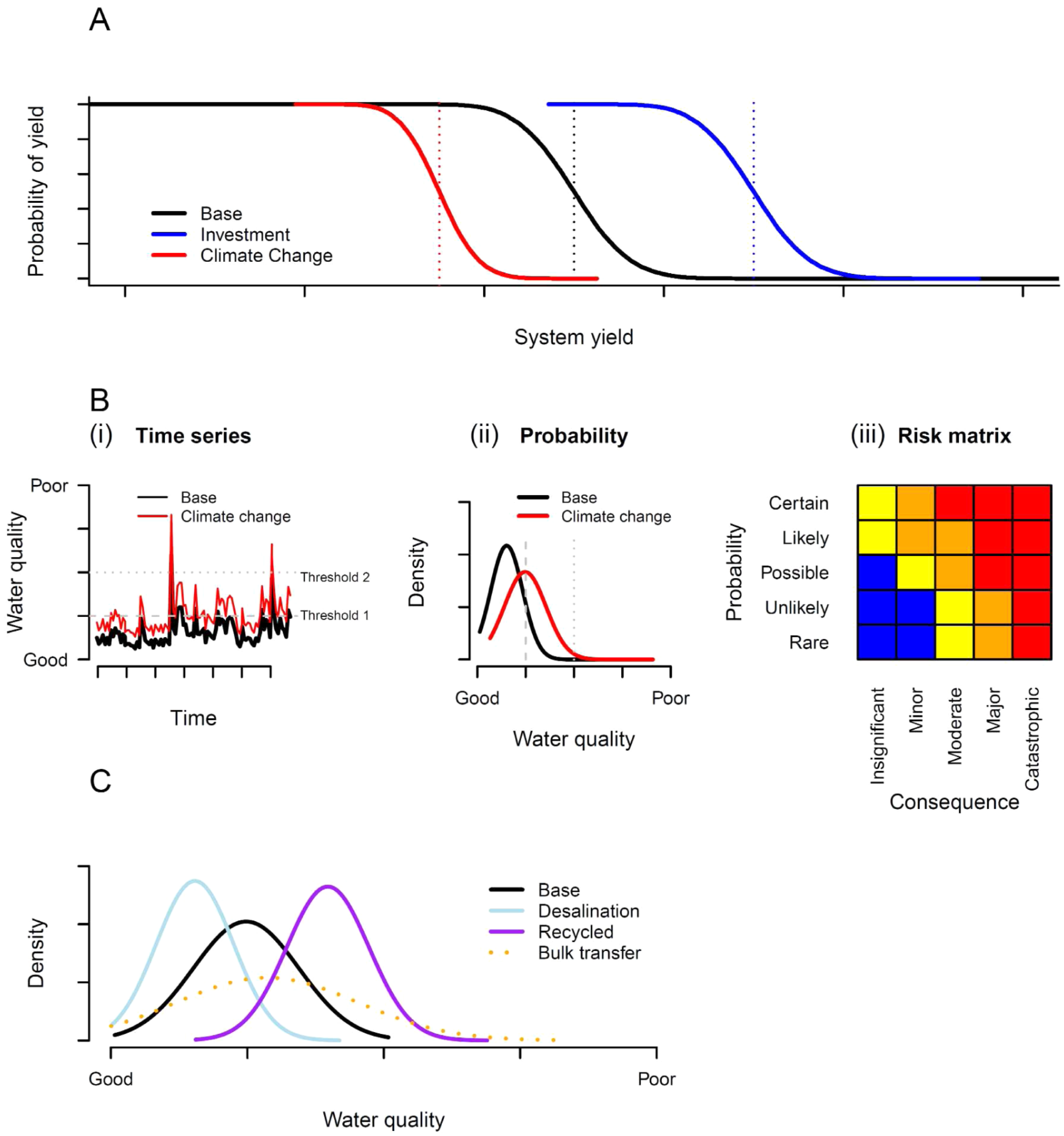

Figure 1. Climate change is likely to decrease surface water yields relative to current yields while investment in alternative sources may increase yield (A). The likelihood of a hazard and the consequences dictate the necessary actions to mitigate the risk and avoid noncompliance (B(iii)). Alternative source waters vary in quality and so present different risks which changes the probability density of achieving a particular water quality (C).

■ FUTURE PROJECTIONS

Finally, using the same assessment criteria, we provide hypothetical but plausible scenarios of water quality for three alternative water sources: recycled water, desalination, and bulk water transport (Figure 1C). In general, recycled water (before treatment) has poor but less variable quality; desalination source water provides more reliability and has higher quality but requires high energy costs; and bulk water transport will have a quality that reflects the original source, but may have unknown reliability and is dependent on trans-national or trans-regional politics. In summary, alternative sources may be more predictable in terms of water quantity, but the risk profile and hazards (i.e., water quality and economic risks) vary widely among sources.

Developed countries that have experienced severe water shortages have already invested heavily in alternative sources. We provide case studies of four major Australian cities that have been severely impacted by droughts and floods and have invested differently in water supply infrastructure to increase water security.

The city of Perth experienced a 15–20% decrease in rainfall since the 1970s, leading to a 40% decline in reservoir inflows/recharge during a period of rapid population growth. In response, Perth invested in two desalination plants, which provided sufficient water to meet demand, even during the worst drought on record in 2010. This has increased resilience but has significantly increased cost. By comparison, both Sydney and Adelaide invested in desalination plants after major drought; however, their completion coincided with increased rainfall and a reduced need for full-scale water production in the immediate future. These cities now have insurance against future variability in surface water supplies; however, they also have the legacy of ongoing infrastructure maintenance and higher water prices without full utilization of these assets. Likewise in 2008, after a prolonged drought, Brisbane invested in recycled water infrastructure to treat wastewater for indirect potable reuse. Recent high rainfall has prompted politically and economically based decisions to reduce reliance on the reclaimed water. In each of these cases, investing in alternative sources was deemed necessary, but may be tenuous if traditional water sources rebound for the short-term.

While it is possible to invest in a combination of these alternative sources, most countries lack the resources to do so. For example, Singapore (area = 710 km^2; population = 5.3 million) has invested heavily in local catchment runoff, desalination, and recycling to make its water supply self-sufficient and less reliant on bulk water transfer from Malaysia. In contrast, most developing nations have minimal water infrastructure and lack the resources to invest in conventional water technology, let alone alternative water sources. It is in these regions that the greatest risk of water-based conflict is likely to occur.[5] The lack of water infrastructure in developing countries may have global implications that could influence human migration patterns, especially to nations with greater water security.

Optimization models for treatment, delivery cost, and water volume will be valuable in creating a vision for the future security of water supplies; however, climate change, human demographics, and customer acceptance/perception are harder to quantify, cost, and incorporate in a model. Ultimately, while cost may dictate which water projects are viable, modeling of reliability, thresholds, and future projections of water quantity and quality will help determine which alternative sources are worth the investment.

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: justin.brookes@adelaide.edu.au.

Notes

The authors declare no competing financial interest.

■ REFERENCES

(1) UN Resolution 64/292. United Nations General Assembly, July 2010. General Comment No. 15. The right to water. UN Committee on Economic, Social and Cultural Rights, November 2002.

(2) Vörösmarty, C. J.; McIntyre, P. B.; Gessner, M. O.; Dudgeon, D.; Prusevich, A.; Green, P.; Glidden, S.; Bunn, S. E.; Sullivan, C. A.; Reidy Liermann, C.; Davies, P. M. Global threats to human water security and river biodiversity. *Nature* **2010**, *467*, 555−561, DOI: 10.1038/nature09440.

(3) *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Averyt, K. B.; Tignor, M.; Miller, H. L., Eds.; Cambridge University Press: New York, NY, 2007).

(4) Brookes, J. D.; Carey, C. C. Resilience to blooms. *Science* **2011**, *334*, 46−47, DOI: 10.1126/science.1207349.

(5) *Climate Change and Transboundary Water Resource Conflicts in Africa*; Woldemichael, D. T., Ed.; Institute for Security Studies, 2009.