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POLICY BRIEFS

Chemical contamination of drinking water: Emerging risks and latest concerns

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KEY MESSAGE

Chemical contamination of drinking water is a significant water security challenge for developed and developing economies. Chemical contamination is prevalent in many drinking water sources, leading to multiple health concerns. Contaminants can be hazardous, persistent and accumulative. However, the emerging field of water metallomics can advance our understanding of the extent of drinking water contamination and associated health risks through interdisciplinary analysis. More attention needs to be paid to pollution from multiple contaminants, the impacts of climate change in water quality and quantity, and multiple stressors of watershed degradation. Collaboration between water companies, regulators, governments, scientists and local communities is needed to seek context-appropriate solutions.

DEGRADED WATER THREATENS 2030 SUSTAINABLE DEVELOPMENT GOAL TARGET

The Sustainable Development Goal (SDG) 6 on clean water and sanitation is unlikely to be met globally by 2030. SDG target 6.1 promotes universal and equitable access to safe and affordable drinking water. However, currently one in every four people still lack access to safe drinking water. More than half of the rivers located in Africa, Asia and Latin America are suffering from significant degradation in river water quality caused by increased biological, nutrient and salinity pollution with poor wastewater management and treatment.[1] Similarly in Europe, more than half of the region's rivers do not achieve good ecological status. This degradation is mainly caused by nutrient overload from intensified agriculture.[2]

Water pollution results from dumping of organic and inorganic sediments, chemical compounds from agricultural fertilizers and pesticides, as well as heavy metals from manufacturing processes and mining operations.[3,4] Heavy metals such as arsenic, lead and iron could directly pollute a water body by entering through different point or diffused pollution sources. Uncontrolled and diffused input of mercury is a major problem in more than 40% of European waterbodies.[5] Alternatively, heavy metals can indirectly impact drinking water quality by leaching or corroding from old or defective distribution or storage water systems. [6]

Exposure to chemical contamination can lead to acute and chronic health effects ranging from increased cancer risk to numerous non-carcinogenic health problems. Health effects include damage to the immune and nervous systems as well as endocrine disruption, cardiovascular and gastrointestinal diseases, reproduction issues and birth defects and dermal related problems. Specifically, arsenic has been associated with lung and skin cancer, while lead has been linked to neurological issues.[6] In the environment, chemical contamination can impair aquatic life and this exposes people to concentrated levels of toxins as they bioaccumulate up the food chain.[7] Moreover, the problem of water pollution is not an equal one, as it can exacerbate existing socio-economic inequalities, placing disproportionate burdens on marginalized communities and putting them at more risk of using or drinking contaminated water.[8]

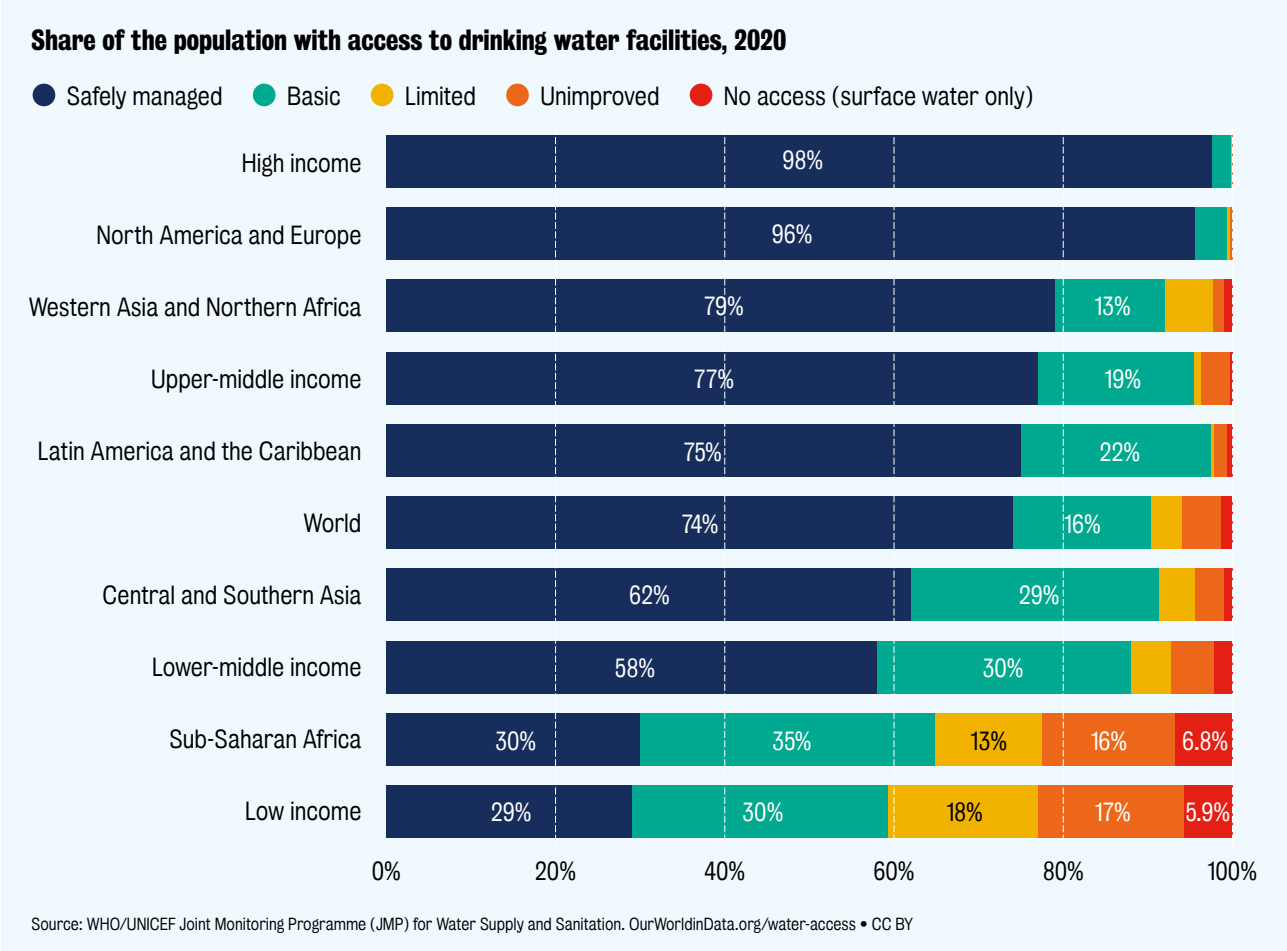

Figure 1: *Share of the global population with access to drinking water facilities by region, 2020. Source: Ritchie H. The world is making progress on clean water and sanitation, but is far behind its target to ensure universal access by 2030. Our World in Data. Published July 1, 2021.*

NEW THREATS FROM PHARMACEUTICALS, PESTICIDES, AND MICRO-PLASTICS

Anthropogenic activities are the primary causes of water quality degradation. Water over-abstraction, in addition to hydro-morphological changes to water bodies and diffused sources of pollution, make the contamination harder to trace or manage.[5] Agriculture, urbanisation, and industrialisation have contributed to increased waste discharge and run-off. Chemical contaminants from pharmaceuticals, pesticides, and disinfectants, as well as micro-plastics pose emerging threats to people and the environment. Many of these contaminants are becoming an urgent issue to control in developed economies. For example, new limits have been posed on drinking water in the United States for per- and polyfluoroalkyl substances (PFAS), or 'forever chemicals' that break down slowly but are found in everyday items such as food packaging and cosmetics. These new threats expose challenges in tackling hazardous, persistent and accumulative contaminants. Pollution from multiple contaminants requires comprehensive examination to fully grasp its causes and extent.

WATER METALLOMICS: A CRUCIAL EMERGING FIELD

Water metallomics is an emerging field which can shed light on the quality of drinking water. Metal ions and metallome are an essential component of life, which play fundamental biological roles in enzyme and ribosome catalysis. Metallomics is an integrated biometal science that analyses the role metal ions have in biological systems, complementing other fields such as genomics. Even small traces of metals can be of significant consequence to the human body, which makes it all the more important to study when so much of our water sources are contaminated with metals. Advances in metallomics have underscored the importance of elements appearing in quantities so minute in the human body that up until now have alluded accurate detection – and attention. Now, these minute traces of metals can be measured with state-of-the-art instrumentation.

Better understanding of the metallome in drinking water would allow insight to many health implications. It can be useful in cases of environmental effects of disused mines and increase of e-waste that bring about new concerns of metal contamination and challenges for monitoring. Exposure to certain metals and metalloids, such as lead, cadmium, mercury, chromium and arsenic have been linked to a range of health problems, including neurological damage, kidney failure, immunity issues, developmental delays, and cancer.[9] From metallomics, metals and the interaction of metals in tissues, fluids, or diseases now can be studied more effectively. Investigations have demonstrated the feasibility of biomarker discovery for disease to assist in screening for exposures to disease-causing metal contaminants. For instance, since nickel exposure can lead to allergy or carcinogenesis, it is worthwhile to explore the nickel proteome and its impact in more depth.

However, health risks associated with metal contamination continue to present uncertainties for policymakers. The extent of contamination and the associated risks are still unclear in some cases, as for example, the effects of long-term exposure to low levels of these metals are not well understood.[10] Synergistic effects between different metals, or between metals and other pollutants further complicate the challenge.[11] Since metallomics can integrate research of chemical structures and transformations, as well as the physics of nanomaterials, with toxicology, pharmacology and nutrition research, the field has the potential to shed light on some of these emerging unknowns.

BOX 1: AN INSIGHT INTO UK DRINKING WATER

In the United Kingdom, water pollution is a key concern for water security. Extensive industrial, agricultural and urban development activities are constantly creating new risks for surface and ground water contamination. Half of England's polluted waters are caused by the excessive use of pesticides and herbicides. Water companies also contribute to water pollution as well, with frequent sewage spills and illegal sewage discharge increasingly viewed as a major problem. In a 2019 analysis of water quality in England, none of its river stretches achieved a good chemical status.[12]

Concerns are growing regarding undetected water toxins making their way to consumer taps.[13] Nearly half of surface water protected areas marked for drinking purposes are considered at risk of chemical pollution from pesticides, herbicides, agrochemicals, pharmaceutical and industrial chemicals.[14,15] Many metals and metal compounds are also not completely removed within existent treatment facilities. For drinking water quality, raw water purification is a priority. Water from both surface and groundwater water bodies requires stringent treatment. Water utilities are required to comply with the 2016 Water Quality Regulations to ensure water wholesomeness before reaching consumer taps. However, some chemicals can surpass conventional treatment and require advanced purification stages.[16,17,18] Furthermore, contaminants such as lead, nickel, iron, and manganese can leech into drinking water through the interior lining of old pipes and plumbing systems. Tracking the source of water degradation is required during and post-treatment but may be challenging.

Storm overflows and sewage flooding left unmanaged by water companies also pose a major problem for ensuring water quality. These occurrences, if left unresolved, can deposit heavy metals into the water environment.[19] Catchments in London are polluted and Thames Water, which services almost 15 million customers, reported more than 600 overflow incidents in 2021 alone.[20,21] In light of water pollution by water companies, regulatory bodies, the Environmental Agency (EA) and Ofwat, have launched the largest investigation to date to determine whether water utilities have breached permits or engaged in serious environmental offenses. The EA aims to enforce tighter regulations on companies to ensure compliance on treating and managing storm water and wastewater discharges.[22] Proposed sanctions range from issuing warnings to accruing monetary penalties and executing criminal prosecutions.[23]

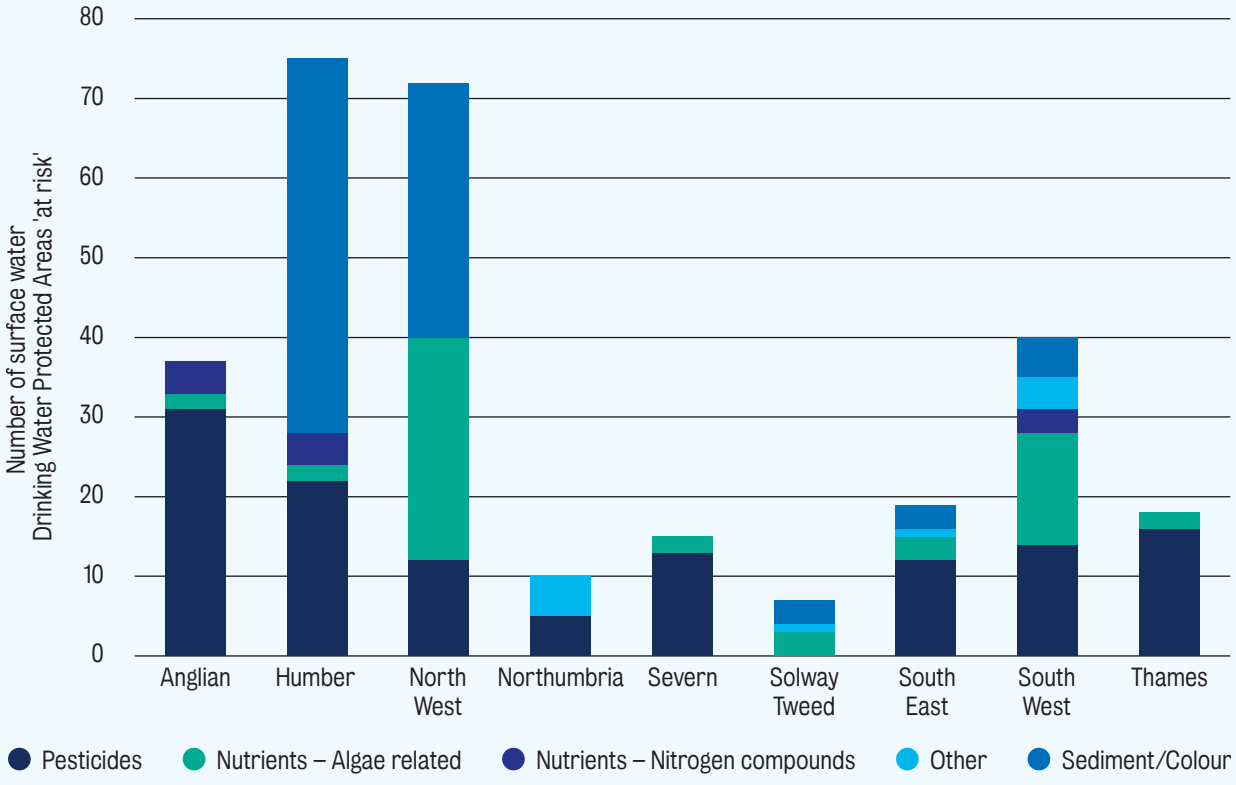

Figure 2: *Reasons for surface water being 'at risk' in England, grouped by substance type and river basin district. Source: GOV.UK. Drinking water protected areas: challenges for the water environment, page 7. Published online August 15, 2022.*

WATER AVAILABILITY COMPOUNDS BOTH QUANTITY AND QUALITY

Water shortages due to climate change will also make it more challenging to manage water quality. In water scarce regions, water bodies tend to have a higher concentration of pollution build-up, which further deteriorates water quality from polluted flow returns.[24] Since water quality is measured by parameters such as salinity and temperature, this can differ when water sources are under stress from competing uses such as for manufacturing, agriculture and for domestic use. More than a third of the world's population will experience water scarcity if temperature is included as a quality parameter in the assessment of scarcity.[25] In places like the UK, temperature rise due to climate change may affect how chemicals behave in the water environment. Climate change and intensified economic activity driving scarcity will require enhancing water quality whilst addressing water availability.

TACKLING MULTIPLE STRESSORS AT THE SAME TIME

Chemical contamination exposes a systemic challenge in utilising the same water resource for numerous purposes. Multi-purpose water use introduces various stressors that degrade water quality with diffused contamination. Changes to the physical and hydrological qualities of water are considered to be the most prominent.[26] In European freshwaters, nearly half of waterbodies are negatively impacted by a mix of stressors rather than just one. The interactive properties of stressors pose an increased risk when present in the same environment.[27] For example, some stressors in conjunction can have cumulative impacts (i.e an additive influence) or synergetic impacts (i.e a magnified influence), while other stressor combinations can interact antagonistically by cancelling each other out.[28] Nevertheless, traditional water management approaches usually target single stressors. In the case of an antagonistic interaction, for example, using a single stressor treatment may render the influence of other stressors more pronounced. The combined effect of stressors should be identified and prioritised through a 'multi-stressor approach' to understand the most effective way to enhance water quality.[29] Knowledge regarding this topic is nascent, offering further avenues of research.

ADDRESSING WATER QUALITY PROBLEMS FOR A JUST SOCIETY

Chemicals are ever-present in modern day life, from small-scale household uses to large-scale industrial and agricultural processes. Minimising the levels of exposure and risk from water contamination for people and the environment will require a comprehensive approach. Ensuring drinking water wholesomeness requires consideration of the type, source and pathway of contamination, the state of provisional services provided, and the efficiency of toxin removal techniques, as well as new management approaches and governance policies.[6,30] One approach to address the issue is to invest in improved monitoring and surveillance systems. Such intervention could help to identify the sources and extent of contamination, as well as to track changes over time.[31]

Effects of water toxicity not only have health and environmental dimensions but also socio-economic ones. This is because those most impacted are often financially disadvantaged and usually reside close to polluted rivers in densely populated cities.[32] This is true of places such as London, where across the country inspection rates have been declining. Governments can also implement more effective regulatory and monitoring measures. Stricter limits on metal concentrations or more frequent testing requirements need to be considered.

Above all, solutions will require engagement across a range of stakeholders, including various government agencies, water utilities, multi-disciplinary research bodies, industry partners as well as local communities. To ensure that effective measures are put in place, solutions to contamination must be suitable to local contexts. Factors such as geographical region, climate, water supply, water service systems, and regulatory measures can affect the level of exposure and risk posed by various contaminants. As the impacts of contamination are multiple, interdisciplinary approaches are needed to fully consider the health, socio-economic, and ecological measures required to effectively address the issue.

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King's Water Centre works to incubate, elevate, and empower the best science and innovation to tackle the world's water problems. We are curiosity-driven, interdisciplinary, and solutions-focused. Based in the heart of London, King's Water Centre brings together scholars and practitioners for a just and sustainable water future.

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