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WORLD ECONOMIC FORUM

Antimicrobial Resistance and Water: The risks and costs for economies and societies

BRIEFING PAPER

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Contents

Antimicrobial resistance from water pollution has grown into a major global health concern

Antimicrobial drugs play an essential role in healthcare systems worldwide. Since their discovery, many infectious diseases that were once leading causes of death can now be treated straightforwardly. But they are losing effectiveness due to the development of antimicrobial resistance (AMR), with between 2.4 and 10 million additional deaths yearly by 2050.

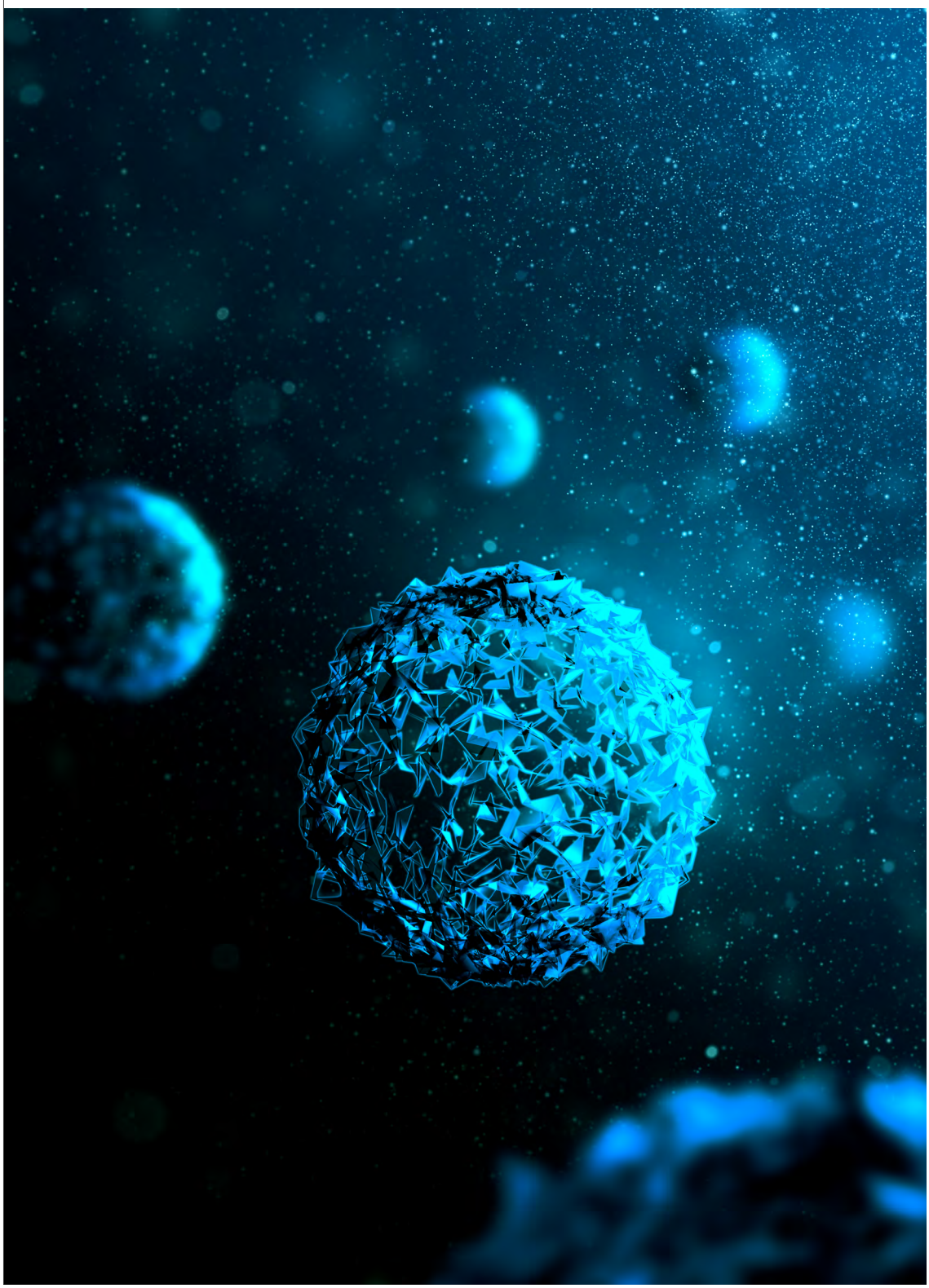
In countries lacking universal wastewater treatment and access to clean water and sanitation, water is a primary vector in the spread of AMR and AMR diseases. Water access and pollution control can have a pivotal effect on AMR development and outcomes.

BOX 1

Introduction to waterborne antimicrobial resistance

Microbes are tiny organisms such as bacteria, fungi and viruses. While most are not harmful, some can have adverse effects on human health. Antimicrobial drugs work by killing microbes or preventing multiplication. AMR causes such drugs to become ineffective.

AMR can develop and multiply in the environment, including water – acting as a vector in AMR spread and development. In this paper, waterborne AMR refers to microbes and pathogens that have resistant genes and spread through water.



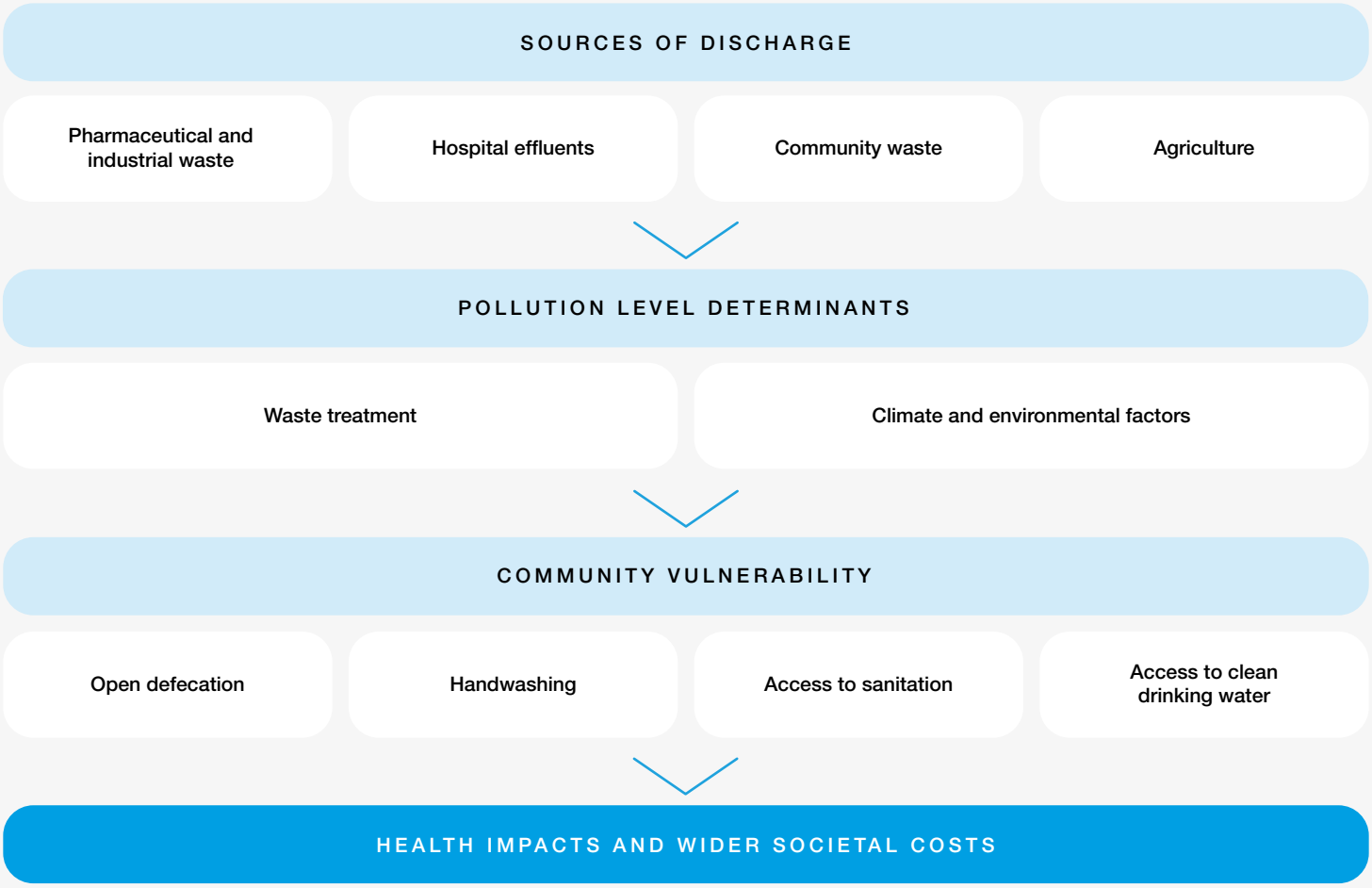
1 Where does waterborne AMR come from?

Waterborne AMR is the product of discharges into water and socio-economic vulnerability (Figure 1).

Discharges into waterbodies result from human consumption of antimicrobial drugs in healthcare systems and the community, animal consumption in agriculture, and antimicrobial drug manufacturing.

Vulnerability reflects the rate at which AMR propagates, the rate at which humans are exposed to it and the effect this has on health. Key vulnerability factors are environmental, such as the temperature and quality of receiving water bodies, and societal, notably population density and the efficacy of wastewater treatment and water, sanitation and hygiene (WASH) in mediating human contact with waterborne AMR.

FIGURE 1 **Sources of discharge and vulnerability**



Note: Discharge includes waterborne AMR and waterborne drivers of AMR, all of which promote the development of resistant genes.

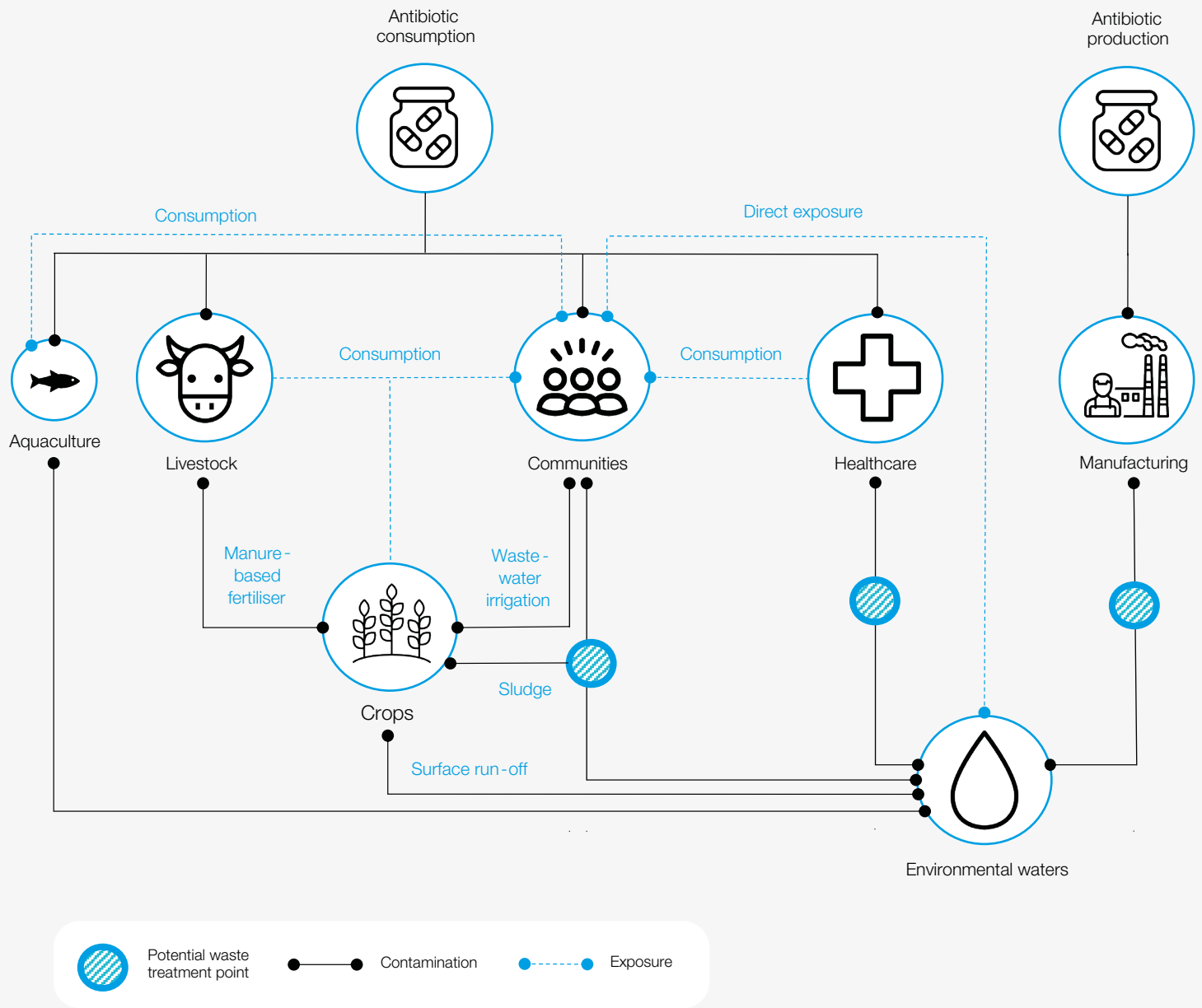
Source: Vivid Economics

Sources of discharge

Hospital and community waste, agricultural run-off, and by-products from antimicrobial manufacturing are the main sources of waterborne AMR and drivers of AMR in waterways (Figure 2).

The relative importance of each channel in causing exposure is poorly understood globally and across regions due to a lack of monitoring.

FIGURE 2 **Waterborne AMR and sources of human and animal exposure**



Note: Adapted from Bürgmann, Helmut, "Antibiotic Resistance as an Emerging Environmental Contaminant, Swiss Federal Institute of Aquatic Science and Technology.

Source: Vivid Economics

Hospital and community wastes

Waterborne AMR in contaminated faecal matter enters waterways through community or hospital wastewater. Between 30% and 90% of oral antibiotic doses consumed are excreted as active substances.[1] With inadequate wastewater treatment, close contact with polluted waters can result in a consumption-excretion cycle.

Experts expect discharges through community and hospital waste to grow in line with antibiotic consumption, which they expect to increase by 28% by 2030. Antibiotic consumption remains highest in developed countries where access to medicines is more widespread but is growing fastest in lower- and middle-income countries (LMICs). This reflects increased basic healthcare service coverage; it also reflects healthcare system weaknesses, where clinicians lack diagnostic capabilities, are incentivized to over-prescribe, or lack control over antibiotic distribution (over-the-counter availability or through unlicensed outlets).[2,3]

Food production

Agriculture and aquaculture practices contribute to waterborne AMR through four pathways:

- **Use of antimicrobials in livestock** to prevent infection and enhance feed conversion and growth.[4,5] Such livestock can excrete 90% of the dose as an active substance, which can enter waterways through surface run-off.[6]
- **Use of antimicrobials in crops** to treat and prevent infection, which releases antimicrobials into waters through surface run-off.
- **Use of wastewater and sludge** that may contain AMR and drivers of AMR to irrigate fields or as a fertiliser, with at least 10% of the global population consuming food irrigated by wastewater.[7]
- **Use of antimicrobials in aquaculture**, which now supplies more than half of all seafood.[8] This is particularly likely to facilitate development of AMR in freshwater-based aquaculture systems, where bacteria are more widespread.

Livestock treatment comprises the bulk of antimicrobial use by volume. China, the United States and Brazil consume the most antimicrobials for agriculture. Livestock consume 70% of antibiotics sold in the US. In 2013, Chinese agriculture consumed more than eight times the volume in the US and more than 12 times the volume in Brazil.[9]

Antibiotic consumption by livestock is expected to increase by ~50% globally by 2030 relative to 2013 levels,[10] particularly in LMICs, due to population growth and changes in dietary preferences.

Antimicrobial manufacturing

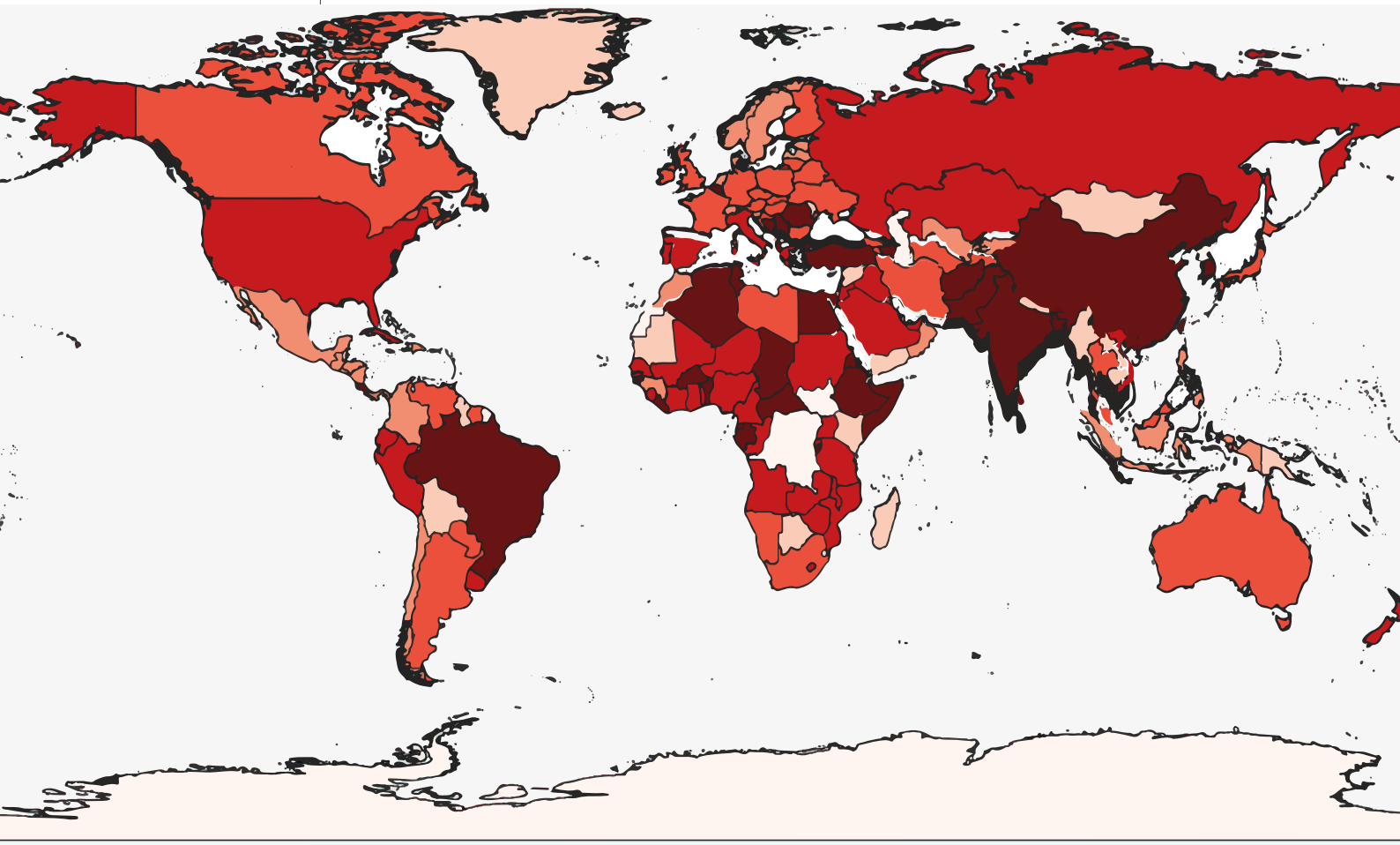
Antimicrobial manufacturing processes can release effluents directly into local waterways, resulting in localised hotspots with high waterborne AMR levels.[11] China and India manufacture between 80% and 90% of the world's antibiotics, supplying large domestic markets and around 70% of global exports.[12] Investigations have revealed evidence of dumping, while localised AMR hotspots in rivers near manufacturing sites are well documented[13] and are associated with the development of superbugs. **Recent trends suggest that China and India will constitute the bulk of antimicrobial manufacturing**.

Wastewater treatment

Wastewater treatment practices mediate how much AMR or other drivers of resistance reach waterways. Modern waste treatment processes are designed to remove conventional pollutants, not antimicrobials.[14] While all available technologies can significantly reduce AMR contamination, none eliminate it entirely.[15] Without advanced wastewater treatment, pollutants can enter and spread through waterways.[16]

The risk map in Figure 3 shows countries with the highest waterborne AMR risk.

FIGURE 3 | **Clinical use, agricultural use and manufacturing determine waterborne AMR risk; whether wastewater treatment systems are in place mediates it [2020]**



DISCHARGE SCORE [0 - 100]

Missing | 0 - 2 | 2 - 12 | 12 - 19 | 19 - 25 | 25 - 53

Note: The waterborne AMR risk score combines a country's average ratings across discharge sources and connections to wastewater treatment.

Source: Vivid Economics

AMR vulnerability

Aquatic environment and socio-economic features determine the risk associated with AMR discharge.

Environmental factors

The volume, temperature and quality of water into which AMR or AMR drivers are discharged can all affect the spread of AMR. Warmer, more concentrated bodies of water that contain additional pollutants are thought to be more amenable environments for AMR to develop.[17]

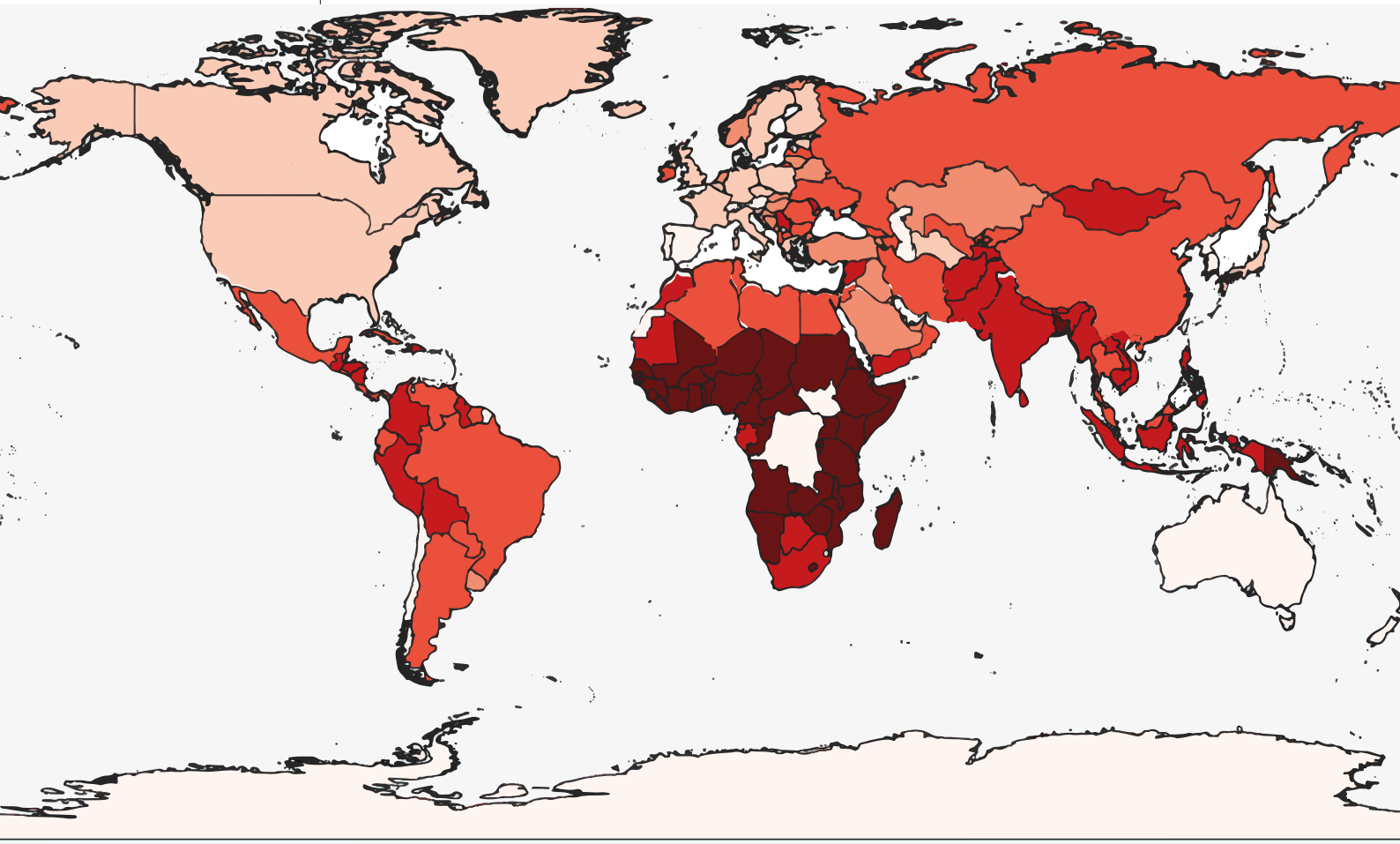
Economic and climatic trends are expected to increase environmental vulnerability factors. Water availability is expected to become more volatile due to increasing competing demands; water temperatures increase as climate change takes hold. Economic activity will equally increase wastewater flows.

Socio-economic factors

Socio-economic factors determine the impact of waterborne AMR on human populations.

- **WASH access:** Limited WASH access can exacerbate antibiotic consumption, excretion, contact and further consumption cycle. Open defecation or use of pit latrines means pollutants enter waterways used by households for drinking and washing and by farmers for irrigation.
- **Density and formality of settlements:** Dense settlements such as informal settlements, intensify consumption, exposure and spread through a larger population.
- **Trade and mobility:** People and animals serve as reservoirs for AMR, meaning outbreaks of resistant disease can transmit globally through travel, trade and even wildlife migration patterns.[18]
- Other factors, including **healthcare system performance** and the **availability of novel antimicrobial drugs** can contribute to the spread of AMR.

FIGURE 4 **Overall WASH gaps are starkest in sub-Saharan Africa but remain in South Asia and South America too [2020]**



SANITATION SCORE [0 - 100]

Missing | 0 - 2 | 2 - 8 | 8 - 23 | 23 - 64 | 64 - 100

Note: The sanitation score is based on the worst-performing sanitation indicator – a sanitation system is only is strong as its weakest component. The indicators included are access to handwashing facilities, prevalence of open defecation, access to basic sanitation, and access to clean water.

Source: Vivid Economics

2 AMR risks and the cost of inaction

While the Global South is expected to see the greatest AMR risks over the next 10 years, it will remain a global phenomenon (Table 1). This reflects a number of trends:

- **Sustained growth in human and agricultural use of antibiotics will drive increased discharge globally**. Clinical use of antibiotics is projected to grow 28% by 2030, while agricultural use rates are expected to increase 50% from 2013 to 2030. Manufacturing growth is expected to remain concentrated in India and China.
- **Variable progress in increasing access to WASH and wastewater treatment services means many countries will remain highly vulnerable**.
- **Broader economic and environmental trends are expected to exacerbate risk**. Migration to urban areas and increasing water stress, most rapidly in the Global South, raise risks. Global trade and mobility will continue to transmit infections across borders, ensuring that risk remains a global phenomenon.[19]
- **The development of novel, last-resort antimicrobial drugs remains slow**, as manufacturers regard them as unprofitable.

TABLE 1 **Growth and changes in risk by 2030**

	Hospital & community use		Agricultural use		Sanitation services	
Country	DDD/1m	2030 growth	Tonnes /100ht	2030 growth	Access gap	2030 gap
Bangladesh	4.1		2.20		52%	
Brazil	6.8		2.73		12%	
China	3.1		14.80		15%	
Ethiopia	-		1.21		93%	
India	5.0		1.47		40%	
United States	10.3		2.34		0%	

Note: For hospital and agricultural use, red cells indicate growth of >10% and green cells indicate growth of < -10%. For sanitation services, red cells indicate a gap in access of >10% and green cells indicate a gap in access of <5%.

Expected human and economic costs will be severe if trends continue unchecked.

- **Impact of increased disease burdens on the duration and quality of life of those who suffer infection:** Waterborne AMR leads to 15 million disability-adjusted life years (DALYs)[20] yearly, equivalent to 25% of the total global burden of malaria and tropical diseases or economic impacts of $340 to $680 billion annually.

- **Costs to healthcare systems:** Waterborne AMR costs $1 to $5 billion per year in additional healthcare expenditures and is expected to increase as resistance develops further and populations grow. The costs of managing the disease burden associated with waterborne AMR are concentrated in the Global South and are in many cases unaffordable.

- **Costs to the wider economy due to reduced labour supply:** Disease burdens result in worktime and productivity losses.[21] Globally, waterborne AMR leads to 3.5 million additional sick days yearly, at a cost of $300 million.

- **Waterborne AMR could cost the agricultural sector up to $6 billion per year**. Antimicrobials play an important role in controlling infection in industrialized agricultural production. Resistance could increase animal mortality rates by 1 percentage point, an equivalent loss of $13 billion in livestock value ($3 billion of which is attributed to waterborne AMR) and $3 billion in aquaculture value.[22]

3 An AMR-driven epidemic

Cholera, a waterborne disease primarily spread through contaminated drinking water, causes up to 143,000 deaths annually.[23] There were more than 300 cholera epidemic events between 2011 and 2017,[24] including resistant strains in Africa and Asia.

Bangladesh is a potential hotspot for a waterborne AMR epidemic. Only 35% of the population has access to handwashing facilities at home and 48% have access to basic sanitation services – many in dense urban areas. Endemic cholera already causes 100,000 cases in Bangladesh annually.

An adverse but treatable outbreak might infect 350,000 and kill 5,000 people. A resistant strain could double caseloads, as untreated infections are prolonged and secondary infections – propagated through lack of WASH – extended.[25,26] Moreover, resistance can significantly raise fatality rates. Based on statistics, a doubling of average annual cases and a case fatality rate of 20% – is therefore a plausible outcome for a resistant cholera epidemic[27] – resulting in 700,000 cases and 140,000 deaths. Doubling the costs, in line with its extended duration, would lead to a $4 billion cost to the economy.[28]

4 Conclusion

The scale and interconnectedness of waterborne AMR calls for a comprehensive, multi-sectoral response, including interventions addressing discharges and vulnerability, and enhanced data collection and research:

- Expanded wastewater treatment and improved access to WASH are critical to reducing AMR vulnerabilities. While the costs of meeting global targets are substantial, estimated at $13-$47 billion annually, the benefits are large and pervasive, including reduced AMR risk, thus safeguarding the health of people, in particular most vulnerable populations, and building a more resilient economy.

- Regulatory and incentive measures to promote the prudent use of antimicrobials and encourage responsible manufacturing practices would also reduce AMR risk and vulnerabilities.

- Improved data would enhance monitoring and understanding of risk and attribution to its sources.

- Further scientific research into poorly understood risk aspects, such as when AMR mixes with other pollutants and the effects of AMR on the natural environment, would also be important to addressing AMR. An informal coalition between academic and research institutions with the private sector would be valuable in sharing existing knowledge and identifying gaps where research and collaboration are needed.

This briefing paper summarizes the technical report.

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