ANTIMICROBIAL RESISTANCE IN WATER SYSTEMS

A One Health Imperative in Fragile and Conflict-Affected Settings

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TABLE OF CONTENTS

1 INTRODUCTION

This policy brief is intended for decision makers across the water, health, and humanitarian sectors, with particular emphasis on actors operating in fragile and conflict-affected settings (FCAS). Where state authority is functional, national authorities hold primary responsibility for ensuring safe water infrastructure, regulating antimicrobial use, and integrating One Health principles across human, animal, and environmental systems. In FCAS where governance is fragmented, weakened, or collapsed, humanitarian actors including UN agencies, international NGOs, and technical partners often assume operational leadership or work alongside weakened public institutions to deliver WASH and health interventions. Although these actors are not regulatory authorities, their programmes directly influence WASH service safety and related transmission pathways. They therefore play a critical role in mitigating AMR risks even when state systems are absent or severely weakened. This brief encourages context-sensitive action and acknowledges that accountability, legal obligations, and coordination mechanisms shift significantly along the continuum from functioning systems to humanitarian emergencies. By focusing on cross-sectoral interfaces and the institutional realities of FCAS, the brief aims to support more effective, equitable, and realistic approaches to AMR containment in water systems.

Antimicrobial resistance (AMR), defined as the process by which microorganisms (e.g. bacteria) evolve mechanisms to withstand the drugs designed to kill or inhibit them, rendering standard antimicrobial treatments ineffective (World Health Organization, 2023), can accelerate silently through water systems, especially in war zones where broken infrastructure and collapsing health systems help superbugs thrive. Once primarily associated with hospitals and farms, AMR is increasingly identified in water systems, where antibiotic residues, resistant bacteria, and resistance genes circulate across human, animal, and environmental interfaces.

Operating silently, AMR undermines life-saving drugs and poses a direct threat to public health, food security, and ecosystems. In 2019, drug-resistant infections were associated with nearly 5 million deaths worldwide; the UNEP asserts that if no action is taken, this toll could rise to 10 million per year by 2050 (UNEP, 2022). AMR knows no borders, and water has emerged as an important vector that also transcends national boundaries. The situation is even more alarming in fragile and conflict-affected settings, where critical Water, Sanitation and Hygiene (WASH) infrastructure is often damaged, surveillance is limited, and health systems are overwhelmed. Furthermore, such contexts have a severe lack of context-specific evidence and policy guidance (WHO EMRO, 2025). This brief responds to that gap.

Conflict-related damage to water and health infrastructure, combined with climate change and rapid urbanization, is accelerating the spread of resistant pathogens through contaminated water. A large share of the world's wastewater is released without treatment, while up to 90 percent of the antibiotics consumed by people are excreted as active substances into the environment (UNEP, 2022). In fragile and conflict-affected settings, such as Gaza, damaged water and sanitation systems, overcrowding, and the unregulated use of antibiotics, driven by the collapse of healthcare systems, disrupted pharmaceutical supply chains, patient self-medication in the absence of accessible clinical care, and the lack of functioning regulatory and pharmacy oversight mechanisms, together create a perfect storm for the proliferation of AMR in Gaza (Cottrell & Shomar, 2021; Abbara et al., 2025).

The One Health approach, first formally recognized by the international community in the early 2000s and subsequently adopted by the Quadripartite organizations (the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), and the World Organization for Animal Health (WOAH)) as a unifying framework for cross-sectoral health governance, recognizes the interdependence of human, animal, and environmental health. It promotes integrated, cross-sectoral governance to address shared health threats, including antimicrobial resistance (AMR) (FAO, UNEP, WHO & WOAH, 2025). A critical yet often overlooked aspect of antimicrobial resistance (AMR) in water systems is the hidden risk posed by sources that appear microbiologically safe by conventional standards. Water may test negative for standard coliform indicators while still containing antibiotic-resistant bacteria and antibiotic resistance genes at levels that threaten public health. This pattern was documented in Gaza prior to the October 2023 escalation, where resistant strains of Pseudomonas spp. and Staphylococcus aureus were found in water samples that tested negative for Escherichia coli (Abu Shomar, 2023). The problem is further intensified in fragile and conflict-affected settings, where laboratory capacity for advanced resistance testing is often extremely limited.

International humanitarian law (IHL) requires parties to armed conflict to protect objects that are essential for the survival of the civilian population, including water supply infrastructure and sanitation systems. The systematic or incidental destruction of these systems, as documented within the mass destruction in Gaza (Geneva Water Hub, 2024), not only represents a potential violation of IHL but also accelerates the conditions that enable antimicrobial resistance (AMR) to spread far beyond the immediate conflict zone. This brief outlines urgent, cross-sectoral policy actions that can be implemented even in conflict-affected areas to slow AMR propagation and safeguard civilian lives.

2

PROBLEM DEFINITION

2.1 What is AMR in Water Systems?

AMR occurs when microorganisms develop resistance to antimicrobial treatments, such as antibiotics (bacteria, viruses, fungi, parasites) (WHO, 2023). In water systems, it manifests as:

- The presence of antibiotic-resistant bacteria and resistance genes (ARGs) in drinking water, wastewater, and natural water bodies (Alawi et al, 2024).
- Antimicrobial residues from human, agricultural, or industrial activities entering water sources, which exert selective pressure that encourages the growth of resistant strains (UNEP, 2023).
- Transmission pathways which connect contaminated water and wastewater to human use, crop irrigation, veterinary antibiotic use, and animal waste management — and each of which contributes to the spread of resistant microbes across across the human health, animal health, agricultural, and environmental sectors (FAO, 2020).

2.2 Why It's Growing: Globally and in Fragile Settings

The global rise of AMR in water systems is largely driven by the overuse or misuse of antibiotics and the failure to manage human and animal waste safely. These problems are amplified in fragile and conflict-affected settings such as Gaza, Syria, and Sudan, where regulatory enforcement is weak and infrastructure often non-functional. Healthcare and pharmaceutical facilities frequently release wastewater containing antibiotics or resistant bacteria, and inadequate or collapsed sanitation infrastructure enables these contaminants to spread unchecked. Water supplies become key transmission pathways when untreated sewage, hospital effluent, and runoff from unregulated livestock production enter surface and groundwater sources used for drinking, cooking, and hygiene. Global estimates suggest that up to 80 percent of wastewater is untreated. In many FCAS, this figure approaches 100 percent. In 2015 alone, about 35 billion doses of antibiotics were used, the majority of which ended up in the environment due to poor governance and regulation. In FCAS, these governance gaps are often severe. Major contributors to this issue include untreated sewage, waste from hospitals and drug manufacturers, runoff from farms (including manure and fertilizers) (UNEP, 2022), and discharges from livestock and fish farms, all of which help resistance take hold and spread.

Climate-related pressures, such as flooding in South Sudan or water scarcity in Yemen, further accelerate the environmental spread of resistant pathogens. When governance collapses, the basic checks on antibiotic use, water quality, and infection control also collapse. These are the conditions under which AMR spreads fastest and furthest. Attacks on or neglect of civilian water systems, wastewater treatment plants, and drainage infrastructure disrupt containment measures. When governance fails, antibiotic stewardship, environmental regulation, and sanitation oversight often collapse simultaneously, allowing AMR to spread unchecked across human, animal, and environmental interfaces (Zeitoun et al., 2021; Abbara et al., 2025).

2.3 How It Spreads Across Sectors in Conflict-Affected Settings (One Health Perspective)

Antimicrobial resistance spreads through interconnected pathways that link human, animal, and environmental health; a concept known as the One Health approach (WHO, 2023). When a resistant microbe appears in one domain (human, animal, or environment) it can quickly cross over into the others through water. This brief applies the One Health approach to conflict-affected settings; highlighting how disrupted environmental, human, and animal systems accelerate AMR.

- **Human exposure**: People can contract drug-resistant infections from contaminated sources due to inadequate sanitation and hygiene, or coming into direct contact with floodwaters or soil that contains resistant microbes. In areas without safe water or toilets, fecal bacteria, possibly carrying resistance genes, can easily spread between individuals (Bürgmann et al, 2018).

- **Animal and food chain**: The direct use of antibiotics in animals, whether for treatment or growth promotion, also contribute to resistance. Livestock and wildlife can ingest resistant bacteria through contaminated water or feed. These resistant microbes or genes can then return to humans via the food supply, for example, through undercooked meat or vegetables irrigated with polluted water, or via runoff from farms into the environment (Manyi-Loh et al, 2018).

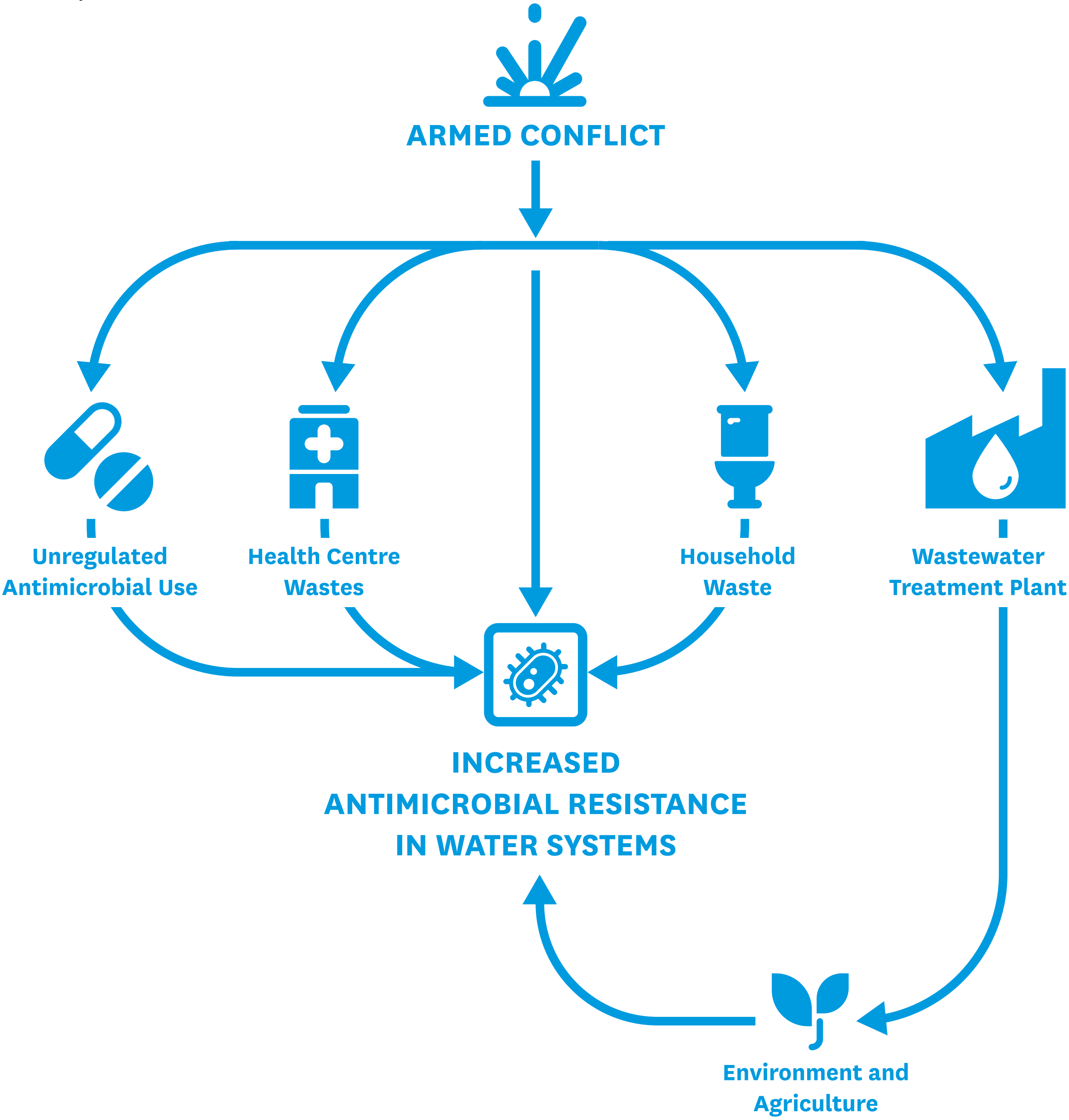
- **Environment as reservoir**: Water bodies, soil, and sewage act as reservoirs and breeding grounds for resistance. Bacteria, and even free-floating DNA carrying resistance traits, can survive and exchange genes in rivers, lakes, and sewage systems. This makes the environment a key pathway that allows resistant bacteria to travel between hospitals, communities, farms, and wildlife. For instance, resistant bacteria from hospital wastewater can enter a river and end up in irrigation systems or wells downstream (UNEP, 2023).

Conflict zones face compounded risks, the attacks on WASH infrastructure and interrupted WASH services means that untreated sewage flows openly into living areas and natural systems, exposing communities to dangerous pathogens and antimicrobial-resistant organisms. For instance, in Gaza, even prior the 7th of October 2023, more than 100 million liters of mostly untreated wastewater are dumped into the sea every day due to damaged treatment facilities (Cottrell & Shomar, 2021). Hospitals in these areas struggle with infection control, and displaced people often live in overcrowded, unhygienic conditions. Antibiotics can be available without prescriptions and used indiscriminately due to limited access to healthcare. These conditions -collapsed WASH systems, lack of antibiotic regulation, and weak oversight -create the perfect environment for dangerous, drug-resistant "superbugs" to emerge (WHO EMRO, 2025; Abbara et al, 2025). Figure 1 shows the potential transmission pathways contributing to AMR spread in war-affected regions.

2.4 Why Conflict Settings Magnify AMR Risks

While AMR is a growing concern worldwide, fragile and conflict-affected settings face amplified risks due to structural and governance breakdowns that disrupt every line of defense. In stable environments, antibiotic use is more controlled, health systems are functional, and sanitation infrastructure limits environmental exposure. In contrast, conflict zones are marked by weak or absent regulation, collapsing WASH infrastructure, overwhelmed or fragmented healthcare services, and overcrowded living conditions. In Gaza,

Figure 1: Potential transmission pathways contributing to AMR spread in war affected regions (Zeitoun et al.,2021).



the ongoing war has systematically degraded water and health infrastructure, producing cascading health crises (Geneva Water Hub, 2024), that include rising antimicrobial resistance and waterborne disease risks. In armed conflict settings, poor infection prevention, limited lab capacity, and unregulated antibiotic access lead to both unchecked resistance and under-reported AMR-related deaths. The displacement of people and animals further accelerates environmental exposure and transmission. These compounding vulnerabilities make AMR not only more likely to emerge, but also more likely to cause preventable illness and death—yet remain largely invisible in mortality estimates.

2.5 The Health, Ecological, and Economic Risks

Health: Drug-resistant infections lead to longer illnesses, higher healthcare costs, more complications and more deaths. Common conditions like wound or urinary tract infections become harder, more expensive, or even impossible, to treat, even in infants. Essential procedures such as surgeries or chemotherapy carry greater risk when effective antibiotics aren't available. Without these medicines, even minor injuries or routine operations could once again become life-threatening, particularly in conflict settings (WHO EMRO, 2025;

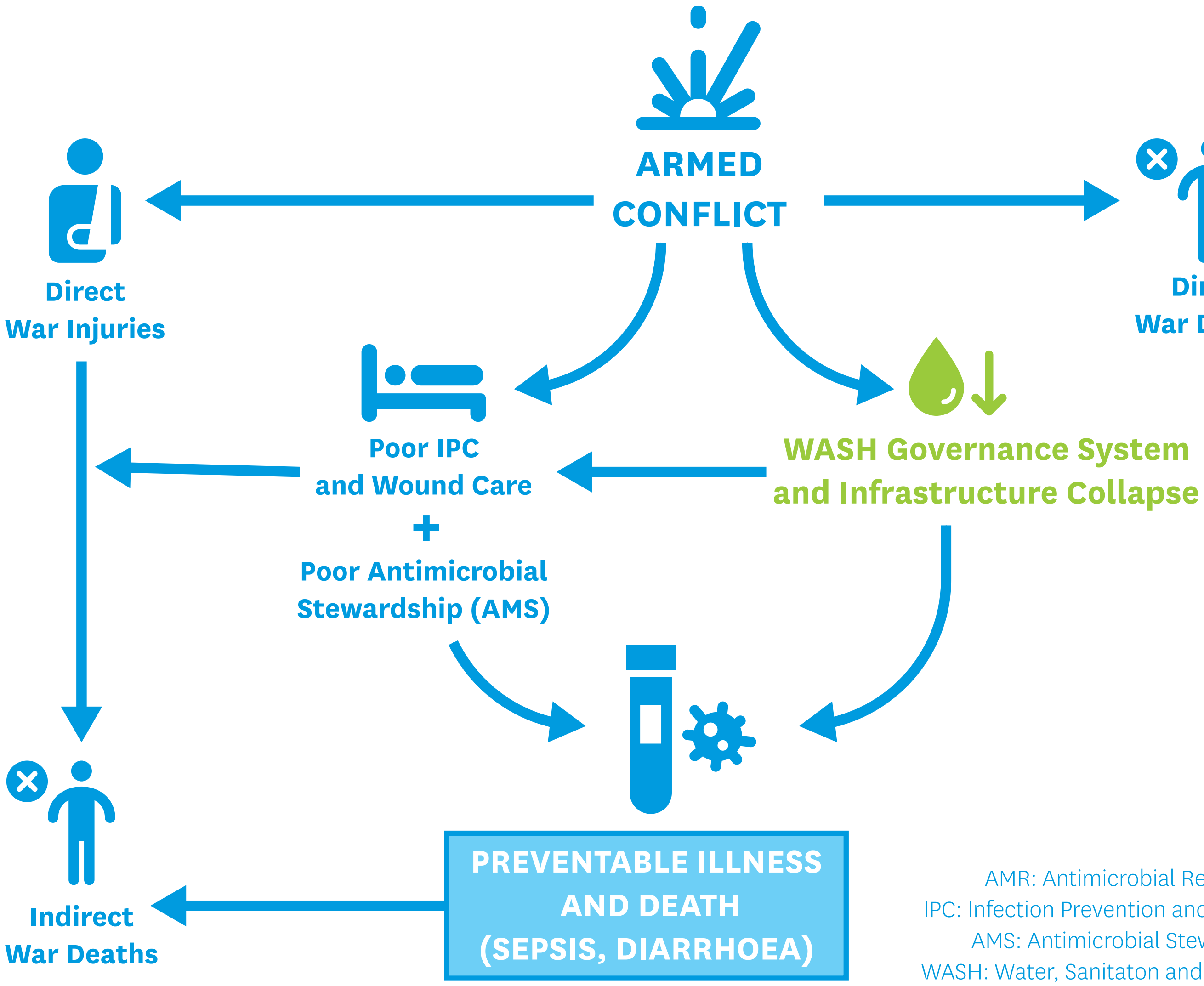
AMR Drivers	Stable Settings	Conflict-Affected Settings
Antibiotic use regulation	Prescription controls, stewardship programs	Over-the-counter sales, weak or no regulation and enforcement
WASH infrastructure	Functional systems with regular monitoring	Collapsed or absent infrastructure, untreated sewage spills, contaminated water supplies
Healthcare access	Available and structured	Fragmented, under-resourced, overwhelmed facilities, hosting displaced patients and companions, sometimes under direct attack
Infection prevention and control (IPC)	Training, protocols, and supply chains	Scarcity of personal protective equipment (PPE) and sterile supplies, overcrowding, lack of emergency IPC programs, protocols or training tailored to conflict settings
Surveillance systems	National AMR and mortality reporting	Weak or absent systems, limited laboratory capacity, under-reporting of AMR-related deaths
Environmental exposure pathways	Treated wastewater, controlled discharge, safe water supplies, water safety plans in place	Raw sewage, unregulated waste dumping, direct exposure via floodwaters, contaminated water resources
Displacement impact	Minimal	Crowded camps, hygiene breakdown, increased human–livestock contact

UNEP, 2022; Abbara 2025). Damage to urban water systems in war zones not only disrupts essential services but creates long-term reverberating effects on infectious disease transmission, compounding the burden of AMR (Talhami & Zeitoun, 2020).

The figure below illustrates the indirect AMR related health toll from WASH collapse in war zones, leading to poor infection prevention and spread of antimicrobial resistant bacteria (Figure 2). The result is a rise in preventable illnesses (e.g., sepsis, diarrhea) and deaths that often go unrecorded in conflict mortality counts.

- Ecological: The spread of antibiotic-resistant bacteria (ARB) and resistance genes (ARGs) disrupts natural ecosystems. Wastewater carrying antibiotics and resistant bacteria changes the makeup of microbial life in rivers and coastal waters. These resistant pathogens can infect wildlife like fish and birds, while the antibiotics themselves may build up in aquatic life or cause ecological harm. The rise of tough, drug-resistant strains can destabilize ecosystems critical for clean water and healthy soil.
- Economic: AMR places a massive financial strain on economies. Treating resistant infections requires longer hospital stays and more expensive drugs, often with more complications, driving up healthcare costs. Productivity drops as people, and livestock, remain sick for longer. The World Bank warns that if left unchecked, AMR could slash over $3 trillion from global GDP annually by 2030, and by 2050, force up to 24 million people into extreme poverty. Health spending could rise by $1 trillion per year by 2050. In low-income countries (WHO, 2023), these effects deepen poverty and push already overstretched healthcare systems to the brink.

Figure 2: WASH and AMR in conflict settings-the indirect health tool



AMR: Antimicrobial Resistance
IPC: Infection Prevention and Control
AMS: Antimicrobial Stewardship
WASH: Water, Sanitaton and Hygiene

In fragile states, the above risks compound, undermining development. The spread of untreatable diseases through water can erode trust in services and exacerbate humanitarian crises. AMR in water is not just a health issue – it threatens social stability and economic recovery, particularly in vulnerable regions.

Gaza city, Al Aqsa hospital damages caused by shellings. @ICRC

3 POLICY ACTIONS: COORDINATED INTERVENTIONS UNDER A ONE HEALTH FRAMEWORK IN FCAS SETTINGS

Tackling AMR in water systems requires coordinated efforts that bring together the health, water, environmental, and infrastructure actors. The three policy actions outlined below form a unified strategy to limit the spread of AMR and build long-term resilience. In fragile and conflict-affected settings, where public governance is often weakened or fragmented, these interventions must be adapted to on-the-ground realities. Each action is accompanied by practical recommendations for implementation in FCAS, emphasizing feasibility, institutional constraints, and humanitarian-operational relevance. Because AMR risks intensify in such settings, a One Health approach is especially critical: progress in one domain reinforces others, and cross-sector coordination becomes both more challenging and more necessary. A strong, context-aware commitment to these measures can have transformative impact, even in settings of insecurity and crisis

3.1 Enhancing WASH Infrastructure and Safe Water Management

Why it matters: Reliable access to clean water, sanitation, and hygiene (WASH) is the cornerstone of preventing the spread of AMR bacteria and other waterborne diseases. Safe water and proper waste disposal interrupt the chain of infection, reducing illnesses and the need for antibiotics. In contrast, poor access to WASH fuels disease outbreaks, which in turn drive antibiotic use. Upgrading WASH infrastructure and wastewater management is critical to stopping infections before they start and limiting the spread of resistant bacteria and genes in the environment (World Health Organization [WHO], Food and Agriculture Organization of the United Nations [FAO], & World Organisation for Animal Health [OIE], 2020). Simply put, improving WASH removes the conditions that allow AMR to grow and spread in communities (WHO, 2020).

Key Actions

- Restore, upgrade and expand wastewater treatment facilities in conflict-affected areas, with a focus on high-risk discharges like hospital waste. Even basic sewage treatment can significantly reduce the spread of harmful microbes in downstream water. Where possible, deploy decentralized or mobile systems for treating healthcare and industrial waste in fragile settings, especially when centralized systems are inoperable (UNEP, 2022).

- Ensure access to safe drinking water in conflict zones by deploying emergency-compatible disinfection and treatment technologies. In hospitals and densely populated areas, install on-site water treatment systems (like filters, UV, or chlorination) to kill pathogens. Make sure water is stored and distributed safely to avoid contamination after treatment.

- Prevent contamination of water sources with human and animal waste in war-affected regions. This includes repairing leaking sewage systems, sealing latrines and septic tanks, and managing farm runoff. Keeping groundwater and surface water clean from fecal matter helps stop resistant bacteria and genes from entering the water supply.

- Adapt treatment strategies to crisis contexts. In stable settings, centralized water and wastewater treatment plants offer efficiency, scale, and stronger regulatory oversight. However, in fragile and conflict-affected areas where infrastructure is damaged or inaccessible, decentralized systems, such as mobile treatment units, modular filtration plants, or point-of-use disinfection, can provide more resilient and practical solutions. These systems are quicker to deploy, easier to maintain, and more adaptable to shifting conditions, particularly when managed at the community level. Supporting flexible, context-specific approaches to water treatment can help ensure safe access in both emergency and recovery phases.

- Integrate WASH into health, humanitarian, and development programming with a crisis lens. Treat water and sanitation projects as essential health interventions. Urge donors and governments to prioritize WASH infrastructure as part of their national AMR strategies. For instance, climate-resilient and conflict-adapted water systems can reduce disease outbreaks and, in turn, lower the reliance on antibiotics.

Benefits

- Less disease, less antibiotic use: With fewer infections, there's less need for antibiotics that means a lower risk of resistant strains developing. Clean water and proper sanitation break the cycle of fecal-oral diseases, which are often treated unnecessarily with antibiotics (like diarrhea) (WHO, 2023).

- Environmental improvements across sectors: Strong WASH systems don't just protect health, they also clean up the environment (World Bank, 2025). Cleaner rivers, safer beaches, and healthier ecosystems support agriculture, boost tourism, and improve overall quality of life. These gains also support global goals like the Sustainable Development Goals focused on water and health.

- Tangible benefits drive support and investment: Infrastructure like new treatment plants or public toilets provides clear, immediate benefits that communities and donors can see. Every dollar spent on water and sanitation can save multiple dollars in healthcare costs, improve productivity and have broader social benefits (SDG knowledge Hub, 2014, UNICEF, 2021, WHO, 2025).

Challenges

- High costs and slow progress: Building or upgrading water and sewage systems is expensive and time-consuming. In low-income or conflict-affected countries, funding is limited, and these large projects can take years to complete. Political instability and urgent crises often shift focus away from these long-term but vital investments (UNOPS, 2024; UN-Water, 2024).

- Ongoing maintenance and weak governance: Infrastructure is only part of the solution, keeping systems running is just as important. Treatment plants need electricity, spare parts, and trained personnel. When operations break down due to poor maintenance or lack of resources, the whole system can fail. Ensuring long-term sustainability also depends on strong local institutions, which may be missing in fragile or unstable regions. Inequitable access: Big infrastructure projects often benefit urban areas or easy-to-reach populations, leaving behind remote, rural, or marginalized communities. If improvements aren't evenly distributed, neglected areas will continue to suffer from poor WASH services, driving the spread of AMR. Reaching informal settlements and conflict zones remains a major challenge for inclusive service delivery (UNOPS, 2024; UN-Water, 2024).

Feasibility in Conflict and Fragile Settings

Under IHL, parties to armed conflict are prohibited from attacking objects indispensable to the survival of the civilian population, which explicitly includes water supply and sanitation infrastructure (Additional Protocol I, Article 54; Additional Protocol II, Article 14). Recognizing this legal framework is essential for humanitarian advocacy and for establishing accountability mechanisms when water infrastructure is deliberately targeted. Humanitarian WASH programming must document infrastructure damage to support legal accountability and post-conflict reconstruction planning (United Nations, 1977, Protocol I, Article 54 & United Nations, 1977, Protocol II, Article 14).

While major infrastructure projects are difficult to implement in conflict zones due to insecurity, funding gaps, and damaged facilities, smaller and more flexible WASH solutions can still make a big difference, even in unstable environments where human protection must be prioritized particularly for workers, displaced populations, and vulnerable groups who are at high risk and often neglected.

For instance, mobile water treatment units and solar-powered pump systems can be deployed in remote or high-need areas to ensure access to clean water. Humanitarian agencies can also run emergency WASH programs (like distributing water filters, building basic latrines, or trucking in water) and connect these to long-term improvements by training local staff and using durable technologies.

In prolonged crises, small-scale fixes (such as repairing broken pipes, setting up sterilization systems in hospitals, or adding chlorine to water trucks) can have a major impact. Partnerships between NGOs, U.N. agencies, and local governments are essential to link emergency efforts with national WASH development plans.

3.2 Establish Integrated AMR Surveillance in Water and the Environment

Why it matters: Effective AMR governance is predicated on the availability of robust, cross-sectoral surveillance data. Without systematic detection and monitoring, targeted intervention remains impossible. Environmental surveillance for AMR provides an early warning function and generates the evidence base required to guide technically sound, cost-efficient policy responses.

Monitoring water for resistant bacteria and genes helps identify hotspots (like a polluted water source or a failing sewage plant) before they spark wider outbreaks. When water surveillance is combined with data from human and animal health systems, it brings the One Health approach to life. For example, detection of the same drug-resistant organism in hospital patients, livestock, and wastewater effluent can pinpoint the likely source of transmission, for instance a community lacking functional sanitation infrastructure or adequate wastewater treatment, and

European hospital. View of a European hospital corridor, Gaza Strip. Due to rain, flooding or the high influx of patients, it is difficult to maintain an adequate level of cleanliness. Photo by Thomas Glass @ ICRC.

direct targeted remediation efforts accordingly (WHO, 2023).

Surveillance also supports stronger policy decisions. It provides the solid evidence governments need to justify investments in clean water infrastructure or to enforce pollution control rules. There's now broad agreement that tracking AMR in the environment, not just in healthcare facilities, is a critical part of the solution (Franklin et al., 2024). By expanding surveillance scope to include water bodies and soil, states, humanitarian agencies, and environmental regulators increase the likelihood of detecting emerging resistant strains before they disseminate across sectors and geographic boundaries.

Key Actions:

- Set up cross-sector monitoring systems that routinely test drinking water, wastewater, and environmental sources like rivers, costal water, and groundwater. This should be integrated within the existing health surveillance systems; ideally linking into national AMR programs. Countries can integrate this into their broader AMR action plans to build a unified approach (FAO, UNEP, WHO & WOAH, 2025).
- Test for resistant bacteria, resistance genes, and antibiotic residues at carefully chosen sites. These might include hospital wastewater outlets, public water taps in crowded urban areas, effluent points from livestock farms, and locations upstream and downstream of treatment plants. Simple indicators, like E. coli with known resistance genes, can serve as a good snapshot of the AMR situation in water. However, E. coli alone is not sufficient (as the context matters). For example, in Gaza, resistant strains of Pseudomonas spp. and Staphylococcus aureus have been detected in water samples that tested negative for E. coli, highlighting the need for broader microbial surveillance. Advanced tools like PCR and gene sequencing can strengthen traditional testing methods to detect resistance more precisely.
- Connect surveillance data to national and global platforms. Environmental AMR data should feed into systems like WHO's Global Antimicrobial Resistance Surveillance System (GLASS), which has traditionally focused on clinical data. Some pilot programs, like the WHO Tricycle project, already collect environmental, human, and animal data together. Sharing this information with health ministries and global networks ensures a more complete understanding of AMR risks (Franklin et al., 2024).
- Promote open data sharing and coordination across sectors. Establish mechanisms for health, environment, water, and agriculture ministries to routinely exchange AMR surveillance data through joint inter-ministerial platforms aligned with national AMR action plans. Internationally, the Quadripartite organisations (WHO, FAO, UNEP, WOAH) provide technical guidance, standardised methods, and shared reporting frameworks. In humanitarian and conflict-affected settings where national structures are absent, inter-agency AMR working groups convened by UN agencies, the ICRC, or cluster mechanisms can serve this role. Trend analyses from these platforms should inform national policy and humanitarian planning. Publicly accessible outputs, such as maps of AMR hotspots in water sources, can raise awareness and help direct resources to priority areas.

Benefits

- Informs smarter policies: When officials have clear data showing where and how resistance is spreading through water, they can take targeted action (e.g. upgrading a failing sewage plant or stopping illegal antibiotic dumping). Surveillance pinpoints priority areas and helps track the success of policies over time. It also helps rally support: when communities see clear evidence of contamination, they're more likely to demand improvements.

- Catches problems early: Monitoring water allows for early warning. For instance, if a town's well suddenly shows high levels of drug-resistant bacteria, that could alert authorities to a sewage leak or poor waste management, before it becomes a full-blown health crisis. In this way, surveillance serves as an early warning system, helping detect hidden threats in the environment before they escalate.

- Builds collaboration across sectors: Creating an integrated surveillance system naturally brings together diverse groups such as: health, laboratories, water utilities, veterinarians, and environmental agencies. This promotes a culture of teamwork essential to the One Health approach. Regular data sharing builds trust and understanding between professionals like doctors and environmental engineers. Over time, these relationships can help launch broader cross-sector health initiatives beyond surveillance alone.

Challenges

- Limited resources and technical capacity: Setting up labs and field teams to test water for AMR requires specialized equipment, chemicals, consistent supply chains and trained personnel, resources that many low-income or conflict-affected regions simply might don't have. In places where even basic lab facilities are lacking, advanced testing is often out of reach. Environmental surveillance often takes a backseat to more immediate health needs, making funding scarce. And long-term programs, needed to track trends over time, are hard to sustain without consistent budgets and training.

- No action from data: There's a real risk that surveillance ends up being just a report-writing exercise if it's not tied to concrete policy changes. Publishing data on AMR in water won't make a difference unless that information is used to enforce laws or allocate resources. Turning surveillance findings into real-world action (closing the feedback loop) is a major hurdle.

- Inconsistent methods and data sharing barriers: Collecting samples is just the first step, interpreting and comparing data is another challenge. If different agencies use different testing methods or track different indicators, their data may not align or be usable together (Franklin et al., 2024). Data sharing can also be a problem due to concerns about confidentiality or fear of exposing poor water quality. Setting up common standards and a shared data system is especially tough in fragile settings where coordination is weak or fragmented.

Feasibility in Conflict and Fragile Settings

Even in conflict areas with limited financial and technical resources, it's possible to roll out AMR surveillance gradually. One practical strategy is to use what's already available; for example, university labs can act as starting points by testing a few water samples each month. Simple, low-cost methods like growing bacteria on antibiotic-treated plates can give a basic snapshot of resistance without needing high-tech equipment.

International support and collaboration can help make this work. Organizations like WHO, UNEP, and academic networks often provide test kits, portable lab tools, and remote training or data analysis (Franklin et al., 2024). Cloud-based platforms allow local staff to upload test results and get help from experts abroad.

Importantly, surveillance can begin on a small scale, just monitoring a few strategic locations like a hospital outflow, a rural well, or a river near livestock can prove the concept. As stability improves or funding increases, the system can grow.

3.3 Promote Antimicrobial Stewardship and Environmental Controls Across Sectors in FCAS settings

Why it matters: Reducing the overuse and misuse of antimicrobials, and preventing their entry into the environment through inadequately treated waste streams, are foundational to any One Health AMR response. When antimicrobials persist in water systems, they exert continuous selective pressure on microbial communities, accelerating the evolution and dissemination of resistance. National governments, supported by international regulatory bodies and humanitarian organizations, must enforce responsible antimicrobial use across the human health, animal health, and environmental sectors, and mandate pre-discharge treatment of antibiotic-containing waste from healthcare facilities, pharmaceutical manufacturers, and large-scale agricultural operations (UNEP, 2023).

In practical terms, this means improving antibiotic stewardship, using antibiotics responsibly in both healthcare and animal farming, and putting tighter controls on how antibiotic waste is managed. These efforts need to be coordinated across sectors so that hospitals, farms, pharmacies, and factories aren't working in silos. For example, limiting antibiotic use in hospitals won't help much if farms are still releasing manure full of antibiotics into rivers.

A One Health approach makes this coordination possible. It expands stewardship beyond hospitals to include veterinarians, agriculture, and industry. The goal is to treat antibiotics as critical medicines (not as over-the-counter remedies or growth enhancers for animals) and to make sure waste containing antibiotics is treated before it enters the environment.

This approach doesn't require huge infrastructure investments. It relies more on smarter policies and changing behaviors, making it affordable and practical, even in low-resource settings.

Key Actions

- Enforce prescriptions for antibiotics in humans: Governments should make sure antibiotics are only available with a prescription from a qualified healthcare provider. This includes cracking down on over-the-counter sales at pharmacies and informal markets. Hospitals and clinics should also run stewardship programs, like prescription audits, treatment guidelines, and training, to ensure antibiotics are only used when absolutely necessary.

- Regulate antibiotic use in farming and aquaculture: Stop using antibiotics to promote growth in animals. Instead, require that their use is approved and monitored by licensed veterinarians, and only for real treatment needs. Encourage better animal husbandry practices, like vaccinations and hygiene. to prevent disease in the first place. In aquaculture (like fish and shrimp farming), limit the routine mixing of antibiotics into feed or water.

- Mandate pre-Treat high-risk waste before it hits the environment: Facilities like hospitals, pharmaceutical manufacturers, and large-scale farms must treat their wastewater before releasing it. Simple treatment systems (such as disinfection units, settling ponds, or specialized filters) can dramatically cut down on harmful discharges (UNEP, 2022). Pharmaceutical waste in particular should be treated as hazardous and never dumped untreated into water systems.

- Improve how unused antibiotics are disposed of: Set up systems for the safe disposal of expired or leftover medicines, like take-back programs at pharmacies or proper incineration. Ensure drug manufacturing waste is managed responsibly. Support innovation in "green pharmacy" practices that create more eco-friendly drugs with less environmental impact.

Benefits

- Targets the root cause of resistance: Reducing unnecessary antibiotic use and preventing antimicrobial compounds from entering the environment directly diminishes the conditions that drive resistance development (UNEP, 2022). This means fewer new "superbugs" over time, and helps protect both people and animals from hard-to-treat infections.
- Affordable and effective: Unlike large infrastructure projects, many stewardship efforts—like regulating antibiotic sales or training health workers are relatively low-cost. Yet they can have a major impact. Countries that have adopted these policies have already seen declines in some types of resistance. Similarly, treating waste at the source is far cheaper than trying to clean up polluted rivers or fix the health damage later on.
- Protects antibiotics for the future: Antibiotics are life-saving but finite medical resources. Once existing agents lose efficacy, replacement options are neither readily available nor guaranteed. Stewardship helps extend the useful life of existing antibiotics, ensuring they remain effective for future generations. This benefit is priceless.

Challenges

- · Lack of enforcement: In many unstable regions, laws may exist on paper but are rarely enforced. Governments may not have the capacity to monitor thousands of pharmacies, farms, or clinics. In conflict zones, the central government may have no control at all in some areas.
- Pushback from stakeholders: Some groups might resist change. Small farmers may fear losing their livestock to disease if antibiotics are restricted. Drug manufacturers might object to the cost of treating their wastewater. Some doctors or pharmacists may continue overprescribing or selling antibiotics for profit. Changing these practices will require negotiation, education, and sometimes support (such as training or financial incentives).
- Low public awareness: Many people don't understand the connection between antibiotic misuse and environmental health. For instance, a farmer may not realize that dumping animal waste into a river contributes to human disease, or a patient might throw antibiotics in the trash without thinking twice. Without awareness, even the best policies may be ignored.

Feasibility in Conflict and Fragile Settings

Even where government oversight is weak, community-driven stewardship efforts can still take root. For example, humanitarian organizations running clinics can implement safe antibiotic use policies and train staff. Local professional groups, like pharmacists or veterinarians, can promote voluntary codes of conduct.

Public education campaigns (via radio, schools, or community leaders) can also raise awareness about responsible antibiotic use and disposal. In areas without strong law enforcement, donors could require antibiotic stewardship as a condition for funding health programs. They can also help control supply chains to block counterfeit or substandard drugs.

On the environmental side, even basic waste controls can help. A hospital might build a simple disinfection unit, or a farm could compost manure instead of dumping it. By integrating these practices into ongoing humanitarian and health efforts, we can make real progress—saving lives today while laying the groundwork for stronger systems in the future.

Synergistic Impact under One Health

These three policy actions; improving WASH systems, strengthening AMR surveillance, and promoting responsible antibiotic use don't just work in isolation. When combined, they reinforce each other and create a powerful defense against antimicrobial resistance.

- Cleaner and safe water systems reduce the spread of infections, meaning fewer people and animals need antibiotics in the first place.
- Surveillance data helps track where resistance is rising and shows whether WASH upgrades or stewardship efforts are working.
- Better antibiotic stewardship and waste controls help ensure that resistance doesn't keep re-entering the environment and undoing progress.

Together, they form an interconnected safety net that protects people, animals, and ecosystems. This is what the One Health approach is all about: recognizing that the health of humans, animals, and the environment are tightly linked—and acting on that insight in a coordinated way.

In fragile settings, this kind of integrated strategy is especially powerful. Finacial and technical resources may be limited, so every intervention needs to count. By combining these efforts, namely improving water safety, promoting responsible antibiotic use, and strengthening environmental monitoring, far greater impact can be achieved than through piecemeal, sector-specific interventions.

Gaza, South Remal waste water pumping station was damaged during bombings. Photo by Ann Paq @ ICRC

The ICRC and the Coastal Municipalities Water Utility (CMWU) are trucking in domestic and drinking water for displaced peoplein Deir al-Balah, Gaza Strip. @ ICRC.

4 RECOMMENDATIONS

To put all these strategies into action, here's what decision-makers and partners can do next:

- Adapt One Health coordination to fragile and conflict-affected contexts: Where formal interministerial task forces are not feasible due to conflict or weak governance, One Health coordination on AMR and water safety should be embedded within existing humanitarian and emergency response systems. In many conflict settings, national authorities still exist in a limited capacity. Coordination should therefore involve both these authorities where possible, alongside key humanitarian actors. Health, WASH, livestock, and environmental agencies, such as WHO, UNICEF, FAO, and humanitarian NGOs, can collaborate through humanitarian clusters and technical working groups.

- Secure dedicated AMR financing within humanitarian and development funding streams. Bilateral donors, multilateral development banks, and UN agencies should establish earmarked funding lines for AMR-WASH integration within existing humanitarian response plans and national AMR action plans. Governments should allocate domestic budget resources for cross-sectoral AMR surveillance and WASH infrastructure maintenance, consistent with the financing architecture recommended by the Quadripartite organizations and the World Bank (World Bank, 2025). In low-income FCAS, emergency health funding should include explicit AMR-WASH components.

- Launch a low-cost AMR surveillance pilot: Begin with targeted, small-scale monitoring in high-risk settings like a hospital or IDP camp. Use basic, available methods (e.g. selective culturing for resistant E. coli, Pseudomonas, and Staphylococcus aureus) and rely on existing public or NGO labs. Sampling drinking water and wastewater outflow monthly over one year can provide a useful risk map. Surveillance tools need to be portable, adaptable, and not dependent on grid electricity or internet.

- Prioritize emergency wash repairs in AMR hotspots: Focus resources on repairing critical WASH infrastructure where breakdowns fuel AMR, especially in hospitals, health posts, and camps. Short-term, high-impact fixes may include repairing water tanks, sealing sewer leaks, or installing chlorine dosing systems. Where possible, integrate simple, lowuntech solutions that reduce microbial contamination and can function off-grid.

- Introduce stewardship measures through existing channels: In resource-limited settings, integrate basic antibiotic stewardship into existing humanitarian health programs. Train frontline health workers to document prescriptions and avoid unnecessary antibiotic use, especially in primary clinics and mobile units. Collaboration with veterinary officers andlocal councils can promote safer animal treatment practices and hygiene standards. Where formal regulatory frameworks are absent or non-functional, private sector pharmacies should be engaged as key implementation partners, given their role as primary points of antibiotic dispensing in many FCAS contexts, alongside community leaders who can support public awareness initiatives on responsible antibiotic use and safe disposal practices.
- Build up local skills and simple shared data tools: Prioritize hands-on training for lab technicians, field engineers, and WASH officers on recognizing AMR risks and testing for indicators. Use simple digital tools to share data between sectors. When possible, embed AMR awareness into existing trainings (e.g. WASH, IPC, veterinary health) rather than creating new programs from scratch. Encourage donor support for staffing, mentorship, and basic supplies- not just equipment.
- Engage the public and local stakeholders: Use simple messaging and promote success stories. Involve community health volunteers, women's groups, or teachers to spread awareness. Highlight stories of local efforts that improved hygiene and reduced illness. Informed communities are powerful allies in sustaining long-term change. Encourage local activities like reporting pollution.

Gaza Strip, Al-Jama'at street. Gaza's coastal municipalities and water authorities repairing the water supply infrastructure.
Photo by Ahmed Waheidi @ ICRC

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ABOUT THE PARTNER INSTITUTIONS

The Geneva Water Hub (GWH) is a Center of Competence on Water for Peace based out of the University of Geneva and the Geneva Graduate Institute. Established in 2015 by the Swiss Agency for Development and Cooperation (SDC), the GWH pursues the roadmap laid out in the report of the Global High-Level Panel of Water and Peace “A Matter of Survival”. The GWH’s mission is to advance the use of water for peace in humanitarian, development, and peacebuilding efforts. Our experience has shown that when water is shared equitably, and spared from war and pollution, peace can prevail.

The United Nations University Institute for Water, Environment and Health (UNU-INWEH) is one of 13 institutes comprising the United Nations University (UNU), the academic arm of the United Nations. UNU-INWEH specializes in addressing critical global security and development challenges at the intersection of water, environment, and health. Through research, capacity development, policy engagement, and knowledge dissemination, the institute bridges the gap between scientific evidence and the practical needs of policymakers and UN member states, with particular attention to low- and middle-income countries.

Tripoli, Lebanon, Nahr el Bared Palestinian camp Gineen reservoirs rehabilitation. Photo by Jordi Raich @ ICRC.

Photo credits.

Cover photo: Flooding and sewage intrusion in displacement shelters. Makeshift shelter for displaced persons in Deir al-Balah Gaza. A twelve-year-old boy and his younger brother empty the dirty, sewage water that has seeped into their tent following a severe cold and rainy. Photo by Ahmed Waheidi @ ICRC.

P.4: Gaza, Khuza'a. A man is fetching water from a water tank in one of the most damaged areas by the bombing, notably of water towers. Photo by Marco Yuri Jimenez Rodriguez @ ICRC

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