

# The impact of attacks on urban services II: Reverberating effects of damage to water and wastewater systems on infectious disease

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## Abstract

*This article investigates the effects that attacks during armed conflict which damage water and wastewater services have on the outbreak and transmission of infectious disease. It employs a lens of uncertainty to assess the level of knowledge about the reverberations along this consequential chain and to discuss the relevance to military planning and targeting processes, and to the laws of armed conflict. It draws on data in policy reports and research from a wide variety of contexts, and*

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*evidence from protracted armed conflicts in Iraq, Yemen and Gaza. The review finds a strong base of evidence of the impact of attacks on water and wastewater services, and a high level of confidence in information about the transmission of infectious disease. One clear risk identified is when people are exposed to water supplies which are contaminated by untreated wastewater. Obtaining a similar level of confidence about the cause and effect along the full consequential chain is challenged by numerous compounding variables, though there are a number of patterns related to the duration of the armed conflict within which the attacks occur. As the conflict protracts, both the risk of the spread of infectious disease and the evidence base for gauging the reverberating effects becomes stronger, for example. The article concludes that the reverberating effects of damage from an attack can be foreseen in some contexts and can be expected to become more foreseeable over time. The analysis suggests that the most pragmatic path for military institutions and those involved in targeting operations to take this knowledge into account is through a “precautionary approach” which assumes the existence of the reverberating effects, and works them in to the standard information-gathering and planning processes.*

**Keywords:** urban services, water and war, infectious disease, public health, protracted armed conflict, critical infrastructure.

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## The quest to reduce civilian harm

War is the realm of uncertainty; three quarters of the factors on which action in war is based are wrapped in a fog of greater or lesser uncertainty.

— Carl von Clausewitz<sup>1</sup>

The number of dead and injured has been a measure of war for as long as bodies have littered battlefields. As the news and the injured reached home, however, societies realized that the effects of battles reverberate far beyond the combat zone and long after the dust has settled. As Plato is said to have declared: “only the dead have seen the end of war”.

In seeking a better measure of the human cost of war, military and other institutions now seek to gauge “civilian harm”.<sup>2</sup> Along with research, human

1 Carl von Clausewitz, *On War*, Princeton University Press, Princeton, 1976.

2 Frontlines Lab, “Beyond Casualty Counts: Building Dynamic Models to Capture and Foresee Civilian Harm”, *Draft for Comment*, 2020; InterAction, *Building the Evidence Base: Addressing the Reverberating Effects of Military Operations on Civilian Life*, 2 November 2020, available at: <https://www.interaction.org/blog/building-the-evidence-base/> (all internet references were accessed in October 2021); Christina Wille and Alfredo Malaret Baldo, *Reference Framework: Menu of Indicators to Measure the Reverberating Effects on Civilians from the Use of Explosive Weapons in Populated Areas*, United Nations Institute for Disarmament Research (UNIDIR), 2020, available at: <https://unidir.org/publication/menu-indicators-measure-reverberating-effects-civilians-use-explosive-weapons-populated>; U.S. Department of Defense, *Annual Report on Civilian Casualties in Connection with United States Military Operations in 2020*, Washington, DC, 2020.

rights, and humanitarian organizations, they investigate the relative impact of conventional *versus* asymmetric and urban warfare,<sup>3</sup> and of short, intense military campaigns *versus* long, drawn-out ones.<sup>4</sup> Much of the discussion of this collective effort centres around data: what quantitative data is required, how to collect it, how to complement it with qualitative data, and what indicators serve best as proxies for what is not readily measurable.

As the first article in this series discussed, the evidence base required to detail the impact of an explosion upon water or wastewater services can be generated with considerable technical data and institutional or engineering expertise.<sup>5</sup> Considerably more information and skills are required to determine the effect that the damaged water service has on indirect impacts, however – such as a reduction in livelihoods or as a driver of their displacement. This is because of the great number of variables involved; the local economy may have already been in a poor state, for example, and the decision to flee could be more related to security and/or greater opportunities for child education, than concerns about drinking contaminated water.<sup>6</sup> In most cases, and certainly in the protracted urban armed conflicts that this article focuses on, the desired evidence base is not at hand. The process leading to the decision to carry out attacks in these contexts is necessarily based on the best available intelligence, and not on perfect intelligence. This uncertainty is part of the “fog of war” which famously engulfs the options which are perceived to be available to combatants.

This article tackles the challenge of improving the database: first, by detailing how the damage caused by an attack impacts upon the quality of public service delivery; and second, by investigating how and the extent to which that impact translates into further civilian harm. More specifically, it queries the quality of information and evidence base for the impact that attacks in protracted armed conflict have on the quality of water and wastewater services, and the extent to which the effects of the attack on the degraded service reverberate onto the outbreak and transmission of infectious disease. The data reviewed comes from policy and research papers (primarily technical engineering reports), observations and a review of the impact of explosive weapons in Basrah, Yemen and Gaza. These are interpreted within uncertainty theory and discussed in

- 3 David H. Ucko and Thomas A. Marks, *Crafting Strategy for Irregular Warfare*, National Defense University Press, Washington, DC, 2020; John Spencer, “The Eight Rules of Urban Warfare and Why We Must Work to Change Them”, Modern War Institute at West Point, 12 January 2021, available at: <https://mwi.usma.edu/the-eight-rules-of-urban-warfare-and-why-we-must-work-to-change-them/>.
- 4 Charles Pede and Peter Hayden, “The Eighteenth Gap – Preserving the Commander’s Legal Maneuver Space on ‘Battlefield Next’”, *Military Review*, Vol. 101, Issue 2, 2021; U.S. Army, “U.S. Opening Statement”, in *Protecting Civilians in Urban Warfare: Towards a Political Declaration to Address the Humanitarian Harm Arising From the Use of Explosive Weapons in Populated Areas, 3–5 March 2021*, Dublin, 2021, available at: <https://www.dfa.ie/media/dfa/ourrolepolicies/peaceandsecurity/submissions3-5march/Opening-Statement—EWIPA-Mar-3-5-CLEAN.pdf>.
- 5 Mark Zeitoun and Michael Talhami, “The Impact of Explosive Weapons on Urban Services: Direct and Reverberating Effects across Space and Time”, *International Review of the Red Cross*, Vol. 98, No. 1, 2017.
- 6 Yvan Guichaoua and Jake Lomax, *Fleeing, Staying Put, Working with Rebel Rulers*, Institute of Development Studies and the University of East Anglia, July 2013, available at: [https://assets.publishing.service.gov.uk/media/57a08a4940fb64974000510/60719\\_3\\_Yvan\\_FINAL.pdf](https://assets.publishing.service.gov.uk/media/57a08a4940fb64974000510/60719_3_Yvan_FINAL.pdf).

relation to international humanitarian law (IHL), standard military operational planning processes, and intelligence-gathering and decision-making procedures in the midst of armed conflict, including prior to attacks.

The review establishes that there is a strong evidence base of the consequences of attacks using explosive weapons on the functioning of water/wastewater services, and a high level of confidence in information about the consequences of degraded services on infectious disease. Attaining a similar level of confidence in the knowledge of reverberating effects of an attack along this consequential chain (i.e. how sure are we that attack  $x$  has caused disease  $y$ ?) would require a damage assessment of the physical integrity of the infrastructural asset and the impact it has on the delivery of the service, disease monitoring and geo-referenced epidemiological data on non-communicable diseases on the affected population, and a robust method to control for the influence of the great number of compounding factors involved.

Acknowledging that the evidence base is not likely to be of the quality desired when targeting decisions are made, the analysis identifies a number of patterns that may guide and inform the military operational planning and targeting processes. For water/wastewater services in particular, for example, the clearest risk of an outbreak or spread of cholera arises when people consume water which has been contaminated with wastewater (which is referred to as “cross-contamination”). The article also discerns several patterns related to the duration of the conflict within which the attack occurs. For example, as the conflict become protracted, the resilience of the service is expected to degrade, because battle damage accumulates and routine operations and maintenance are no longer carried out; the risk of an outbreak or spread of infectious disease is expected to increase, as exposure to hazards (such as cross-contamination) becomes more likely; and the evidence base for gauging the reverberating effects is expected to improve, as the effects become more visible, familiarity with the systems is gained, and more effort into intelligence gathering can be invested.

The article concludes that, in general, the reverberating or indirect effects caused by attacks on water/wastewater infrastructure can be foreseeable in some contexts and become more foreseeable as the conflict prolongs. The most pragmatic path for military institutions and those involved in targeting operations to take this into account is through a “precautionary approach”,<sup>7</sup> which assumes the existence of the reverberating effects, and which seeks to identify and understand them through intelligence preparation of the operating environment (IPOE), and standard military operational planning processes.

7 As noted later in the article, the “precautionary approach” referred to in this article stems from research and policy on mitigating environmental harm of infrastructure projects, and is distinct from those specific IHL obligations that require parties to conflict to take a range of precautions in attack and against the effects of attacks to protect civilians and civilian objects. See, for example, Protocol Additional (I) to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts, 1125 UNTS 3, 8 June 1977 (entered into force 7 December 1978) (AP I), Arts 57 and 58; and Jean-Marie Henckaerts and Louise Doswald-Beck (eds), *Customary International Humanitarian Law*, Vol. 1: *Rules*, Cambridge University Press, Cambridge, 2005 (ICRC Customary Law Study), Rules 15–24, available at: <https://ihl-databases.icrc.org/customary-ihl/eng/docs/v1>.

## Reverberating effects

Some definitions of the terms are in order, given the complexity of the challenge that has been laid out. Based on their decades of experience, humanitarian water engineers assert that the impact of armed conflict on a service can be measured in terms of direct, indirect or cumulative impact, and can occur on the people, hardware and consumables which keep the service running.<sup>8</sup> The services in question could be health care, education, solid waste removal, financial flows, or the so-called “lifeline services” of electricity, water and wastewater. Most services are dependent on other services for their proper functioning, and some are very highly interdependent (e.g. effective treatment of patients at a hospital typically requires electricity and clean water).<sup>9</sup> The impact of an attack during armed conflict can result in damage to a service, which can be measured in terms of the direct effects and the reverberating effects.<sup>10</sup> Such attacks can take various forms, such as targeting of service provider personnel or supply-lines of consumables, cyber-attacks on infrastructure systems, and the use of explosive weapons on or affecting the service systems (the latter of which is most commonly considered in this article).

In a general sense, the impact of an attack or an explosion is understood in terms of the marked “impression” or “footprint” of an attack, while the effect of an attack refers to the consequences that follow it. Table 1 exemplifies the terms in order to distinguish the differences. Traditionally concerned with the functioning of a particular service, the humanitarian engineering view of the reverberating effects of an explosion or attack are seen to extend to the functioning of other services that the service is dependent on, or which depend on it.<sup>11</sup>

IHL (also known as the laws of armed conflict) obliges those planning or deciding upon attacks to take into account all reasonably foreseeable incidental harm when considering questions of proportionality<sup>12</sup> and precautions in attack.<sup>13</sup> Such “harm” includes both direct effects of an attack (e.g. deaths, injuries, or damage to civilian objects) as well as reverberating effects (also known

8 ICRC, *Urban Services During Protracted Armed Conflict: A Call for a Better Approach to Assisting Affected People*, Geneva, 2015.

9 ICRC, *ibid.*; Emma Lauren Roach and Mohammad Al-Saidi, “Rethinking Infrastructure Rehabilitation: Conflict Resilience of Urban Water and Energy Supply in the Middle East and South Sudan”, *Energy Research & Social Science*, Vol. 76, 2021.

10 The authors acknowledge that the cumulative impact of armed conflict is in many ways more significant than both the direct and indirect impact of armed conflict (ICRC, above note 8), and likely to be more significant than the reverberating effects of attacks. As the effects of attacks often conflate with the cumulative impact of armed conflict, their impact is more readily understood from within the protracted conflict context the attack occurs – particularly in the protracted urban armed conflicts that this article focuses on.

11 M. Zeitoun and M. Talhami, above note 5.

12 See AP I, Arts 51(5)(b) and 57(2)(a)(iii), and ICRC Customary Law Study, Rule 14. For particular application of IHL to water infrastructure, see Mara Tignino, *Water During and After Armed Conflicts: What Protection in International Law?*, Brill, Leiden, 2016; and Mara Tignino and Öykü Irmakkesen, “The Geneva List of Principles on the Protection of Water Infrastructure: An Assessment and the Way Forward”, *International Water Law*, Vol. 5, No. 2, 2020.

13 See AP I, Art. 57, and ICRC Customary Law Study, Rules 15–21.

Table 1. *Measures of the impact and reverberating effects of an attack classed according to expected distance and duration, with examples from a water treatment plant*

	Damage sustained	Impact on services	Civilian harm
Examples	Physical damage of a water pumping station	Water service: Less or no water in pipe network Health service: Reduced ability to sterilize medical equipment	Increased risk of dehydration/prevalence of diarrhoeal disease. A greater number of wounds are infected
“Engineering” definition	Direct impact	Reverberating effects	Reverberating effects
IHL definition	Direct effect	–	Reverberating effects
Disarmament research definition	1st-level impacts	2nd-level impacts	3rd-level impacts
Distance	Closest ←-----→ Furthest		
Duration	Shortest ←-----→ Longest		

as the indirect consequences).<sup>14</sup> IHL jurists also note that the extent to which the resulting incidental harm can be foreseen depends on, *inter alia*, the circumstances of the attack and the target, and that “*patterns* of incidental harm can be foreseen based on the past effects of urban warfare”.<sup>15</sup> Similarly, the disarmament research community refers to the range as first-level, second-level and third-level impacts<sup>16</sup> – which by definition extend to all interdependent services.

The example of a damaged drinking water service in Table 1 helps to distinguish use of the terms, and further notes how the effects of an attack reverberate in time and across space. The immediate impact of an explosive

14 The reverberating effects of an attack are also commonly referred to as “knock-on” effects: see Michael N. Schmitt, “Wired Warfare: Computer Network Attack and *Jus in Bello*”, *International Review of the Red Cross*, Vol. 84, No. 846, 2002, p. 392; Isabel Robinson and Ellen Nohle, “Proportionality and Precautions in Attack: The Reverberating Effects of Using Explosive Weapons in Populated Areas”, *International Review of the Red Cross*, Vol. 98, No. 1, 2017; or “long-term” effects: Humanity & Inclusion, *Death Sentence to Civilians: The Long-Term Impact of Explosive Weapons in Populated Areas in Yemen*, May 2020, available at: [https://blog.hi.org/wp-content/uploads/2020/06/Study2020\\_Rapport-YEMEN-EWIPA\\_EN\\_Web.pdf](https://blog.hi.org/wp-content/uploads/2020/06/Study2020_Rapport-YEMEN-EWIPA_EN_Web.pdf); ICRC, *International Humanitarian Law and the Challenges of Contemporary Armed Conflicts: Recommitting to Protection in Armed Conflict on the 70th Anniversary of the Geneva Conventions*, Geneva, 2019.

15 ICRC, *ibid.*, p. 18 (emphasis added).

16 C. Wille and A. Malaret Baldo, above note 2.

weapon that detonates near a water treatment plant could result in physical damage to the pumps which push the treated water to consumers. The consequences of the damage to the water service could extend to the health service, if less water is pumped throughout the water network and a nearby hospital is without water in its taps. Some of the consequences of the lack of clean tap water in a hospital include the lack of adequate sterilization of surgical instruments, and (so) a greater number of infections of patients' wounds. Data collection efforts aimed at better gauging civilian harm would class all such consequences as "reverberating effects" (while the number of people infected could also be classed as a "third-level" impact).

The previous article in this series explains how the spatial extent of the reverberating effects of an attack depends primarily on the hierarchy of the component suffering the direct impact (i.e. "upstream" components, e.g. water treatment plants; "mid-stream" components, e.g. water transmission lines supplying water to neighbourhoods; or "downstream" components, e.g. household water piping or rooftop storage tanks).<sup>17</sup> The duration of the reverberating effects depends on the "baseline resilience" of the service before the explosion, which is itself a function of system redundancies and emergency preparedness and response. The baseline resilience of a service is also referred to as the "underlying conditions" or "pre-crisis vulnerability" of a service.<sup>18</sup> In brief, and as [Figure 1](#) shows, the less resilient the service is when the attack occurs, the greater the impact and the reverberating effects are expected to be. As a jab to a boxer in the twelfth round is likely to cause more damage than a jab in the first, an attack on a service that has experienced years of neglect and which is not likely to be rebuilt immediately is expected to cause more disruption than it would on a well-maintained service with full emergency-preparedness measures in place.

## Uncertainty and (pre)caution

Though the examples discussed are straightforward, most reverberating effects are not. Like the tornado caused by the flap of the proverbial and distant butterfly's wings, the reach of the consequences of an attack are almost without limit. As discussed earlier, an assertion that an explosion near a water treatment plant results in mass displacement cannot be made with any confidence, because there are dozens of other reasons which can explain reductions in economic activity or displacement.

The reasoning follows the classic adage of unforeseen consequences: "for the want of a nail, the kingdom was lost". As the number of factors that shape an outcome increase, so does our ability to prove causality decrease. In other words, the longer that the chain of consequences under question is, the less confidence

17 Attacks on upstream components are the furthest reaching. M. Zeitoun and M. Talhami, above note 5.  
18 World Bank, ICRC and United Nations Children's Fund (UNICEF), *Joining Forces to Combat Protracted Crises: Humanitarian and Development Support for Water Supply and Sanitation Providers in the Middle East and North Africa*, Washington, DC, 2021.



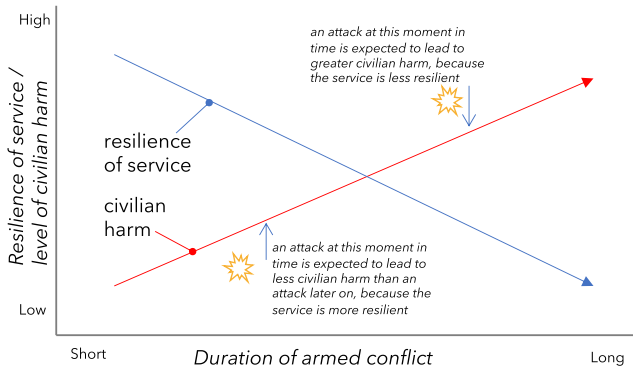


Figure 1. Expected relation between the civilian harm caused by incidental damage to a service, and the baseline resilience of that service, as armed conflict prolongs. The longer the armed conflict and less resilient a service is, the greater the civilian harm is expected to be.

we can have in the information we have about it. Climate scientists refer to this compounding of factors as a “cascade of uncertainty”.<sup>19</sup>

The relevant question generated by uncertainty theory is: if an observed association between factors cannot be proven with confidence, does that mean it does not exist? The related policy question is: If an association is observed but has not been “proven”, should policy be designed to incorporate its possibility, or to ignore it? The range of answers from different institutions will vary from reckless to cautionary, depending mostly on the costs of getting it wrong, and how familiar they are in dealing with the absence of the desired level of knowledge.

It is in this sense that the quest for ever more data about civilian harm is an attempt to reduce uncertainty. With precisely this in mind, simulation models feed on data to quantify risks and probabilities. The logic is compelling: a model could predict the strain that will be placed on Hospital X (measured in terms of the staff and beds) when 5000 civilians who contracted cholera following the bombing of Wastewater Treatment Plant Y compete for health service resources which are already allocated to caring for the 400 combatants who were wounded directly from the fighting. Targeting processes could then assign the wastewater treatment plant a corresponding level of importance. The number of civilian lives that would be spared could be estimated, and the reduction in civilian harm extrapolated accordingly.

Models have their downsides, however, as studies of wargaming and other models have shown.<sup>20</sup> The most well known of these is that the quality of the output

19 Rachel James, Richard Washington, Carl-Friedrich Schlessner, Joeri Rogelj and Declan Conway, “Characterizing Half-a-Degree Difference: A Review of Methods for Identifying Regional Climate Responses to Global Warming Targets”, *WIREs Climate Change*, Vol. 8, No. 2, 2017.

20 See Christopher A. Weuve, Peter P. Perla, Michael C. Markowitz, Robert Rubel, Stephen Downes-Martin, Michael Martin and Paul V. Vebber, *Wargame Pathologies*, CNA Corporation, Alexandria, VA, 2004; Kristin E. Heckman, Michael J. Walsh, Frank J. Stech and Todd A. O’Boyle, “Active Cyber Defense with Denial and Deception: A Cyber-Wargame Experiment”, *Computers & Security*, Vol. 37, 2013;



of the model directly reflects the quality of the data entered into it – regardless of how sophisticated the algorithms and modelling process. “Garbage in, garbage out” is the undeniable if inelegant heart of modelling processes.

Even in the most wealthy, stable and well-ordered societies, public service providers do not have all the information they would like,<sup>21</sup> and so cannot rely fully on modelling. Even as they continue to monitor and collect more information, most institutions develop an approach to policy that is “comfortable” with uncertainty. For example, health, civil engineering and disaster risk-reduction guidelines usually choose to “err on the side of caution” by assuming that any negative impact of their projects will reverberate widely, and then establish measures to prevent or contain them.<sup>22</sup> This manner of developing policy in uncertain operating environments is widely known as the “precautionary approach”.

Military decision making and intelligence gathering follows much the same approach. Because armed conflict in cities is the normal operating theatre of seasoned military institutions, the processes developed to prepare for and to be more effective in battle are designed to make best use of the information that is available. For instance, risks can be calculated and then fed into the targeting procedure, which can then inform the proportionality assessments and weaponizing decisions.<sup>23</sup> The US military, for example, reduces the uncertainty of a complex operating environment by identifying, assessing and controlling risks arising from or during military operations throughout the targeting cycle (e.g. find, fix, track, target and engage)<sup>24</sup> and as part of the IPOE.<sup>25</sup> In the sense that the term is used here, such procedures are “precautionary”.

The measures taken by military institutions through these procedures puts them in a stronger position to achieve military objectives with less civilian harm, as

Yuna Huh Wong, Sepastian Joon Bae, Elizabeth M. Bartels and Benjamin Michael Smith, *Next-Generation Wargaming for the U.S. Marine Corps: Recommended Courses of Action*, RAND Corporation, Santa Monica, CA, 2019; Susan Bryant and Tom Nagle, “Wargaming for the New Great Game”, Modern War Institute at West Point, 2021, available at: <https://mwi.usma.edu/wargaming-for-the-new-great-game/>.

- 21 See Jim W. Hall, Alexander Otto, Adrian J. Hickford, Robert J. Nicholls and Martino Tran, “A Framework for Analysing the Long-Term Performance of Interdependent Infrastructure Systems”, in Jim W. Hall, Martino Tran, Adrian J. Hickford and Robert J. Nicholls (eds), *The Future of National Infrastructure: A System-of-Systems Approach*, Cambridge University Press, Cambridge, 2016.
- 22 See, e.g., Bernard Haemmerli and Andrea Renda, “Protecting Critical Infrastructure in the EU”, Centre for European Policy Studies (CEPS), Brussels, 16 December 2010, available at: <https://www.ceps.eu/ceps-publications/protecting-critical-infrastructure-eu/>; Public Safety Canada, *Risk Management Guide for Critical Infrastructure Sectors*, Ottawa, 2010, available at: <https://www.publicsafety.gc.ca/cnt/rsrsc/pblctns/rsk-mngmnt-gd/rsk-mngmnt-gd-eng.pdf>; U.S. Department of Defense, *DoD Policy and Responsibilities for Critical Infrastructure*, Washington, DC, 2012; Michael N. Schmitt and Michael Schauss, “Uncertainty in the Law of Targeting: Towards a Cognitive Framework”, *Harvard National Security Journal*, Vol. 10, 2019.
- 23 See, e.g., Joint Chiefs of Staff, *Joint Targeting*, Department of the Navy, U.S. Department of the Army, Department of the Navy – Marine Corps, Department of the Air Force, U.S. Coastguard, 2013.
- 24 See Joint Chiefs of Staff, *Joint Targeting School Student Guide*, Joint Targeting School, Dam Neck, VA, 2017.
- 25 Other militaries also follow a similar procedure, with different terminology (e.g. NATO employs decide, detect, track, deliver and assess); see Giulio Di Marzio, “The Targeting Process... This Unknown Process (Part I)”, *NRDC-ITA Magazine*, 2009, available at: <https://www.nato.int/nrdc-it/magazine/2009/0911/0911d.pdf>. See Joint Chiefs of Staff, above note 23.

well as compliance with the principles of IHL. As previously noted, however, such compliance rests on gauging the extent to which reverberating effects are “reasonably foreseeable” in the sense that they “may be expected” (Art. 51(5)(b) of Additional Protocol I).<sup>26</sup> The task for those who seek to better gauge (and, so, minimize) civilian harm is thus to map out the extent to which the reverberating effects of an attack may be expected.

## Cause and effect between attacks, water, wastewater and disease

The extent to which the reverberating effects caused by attack play out on water/wastewater services can be gauged first by determining the level of confidence in information about the impact on the services, and the subsequent influence on the outbreak and transmission of infectious diseases.

### Links between water and wastewater, and disease

The evidence base supporting the importance of clean drinking water for reducing the risk of outbreak or rate of transmission of infectious disease is by now so well established that it is no longer questioned very much. One of the greatest concerns is when wastewater contaminates drinking water. The spread of the Spanish flu through the mud, faeces and wastewater which lined the trenches of the First World War is considered to have killed more people than both world wars combined, for example. Similarly, the lack of clean water and adequate wastewater evacuation in the refugee camps of the Democratic Republic of Congo is blamed for the epidemics of dysentery and cholera which claimed over 40,000 people from Rwanda in 1994. In fact, the outbreak and transmission of cholera was linked to bugs in the water more than a century earlier, through pioneering efforts to contain the spread in London.<sup>27</sup> While the orthodox scientific knowledge of the day held that cholera was spread through the air, those who persisted in sampling drinking water prevailed, and the study of the ways that pathogens and environmental contaminants travel (epidemiology) was born. Chlorine was quickly found to be the best way to kill these pathogens; its addition to Tokyo’s drinking water service led to a drop in the infant mortality rate of 18,000 per year in 1915 to less than 1000 by 1998, for example.<sup>28</sup>

26 Ellen Nohle and Isabel Robinson, “War in Cities: The ‘Reverberating Effects’ of Explosive Weapons”, in *Humanitarian Law & Policy*, ICRC, 2 March 2017, available at: <https://blogs.icrc.org/law-and-policy/2017/03/02/war-in-cities-the-reverberating-effects-of-explosive-weapons/>.

27 Steven Johnson, *The Ghost Map: The Story of London’s Most Terrifying Epidemic – and How it Changed Science, Cities, and the Modern World*, Penguin Books, London, 2006.

28 Satoru Ueda and Mohammed Benouahi, “Accountable Water and Sanitation Governance: Japan’s Experience”, in Vijay N. Jagannathan, Ahmed Shawky Mohamed and Alexander Kremer (eds), *Water in the Arab World: Management Perspectives and Innovations*, International Bank for Reconstruction and Development/World Bank, Washington, DC, 2009.

Like other diarrhoeal diseases, cholera and dysentery originate from a number of sources, are usually contracted by contaminated water or food, and are readily spread in water and wastewater,<sup>29</sup> and are just as deadly. The World Health Organization (WHO) estimates that they caused over 1.5 million deaths of children under the age of 5 years in low- or middle-income countries in 2002.<sup>30</sup> Indeed, children under the age of 5 years are “more than 20 times more likely to die from diarrhoeal disease linked to unsafe water and sanitation than violence in conflict”.<sup>31</sup>

The transmission routes of these and related diseases are very well known. As in [Figure 2](#), the cross-contamination of wastewater and drinking water is in fact just one of several potential routes of disease transmission (diarrhoeal or otherwise). Just some of the variables that compound the complexity – and, so, reduce certainty about the main drivers – include the presence of a new strain of disease in inward-migrating people, pathogens transmitted by flies or animals, and direct physical contact with contaminated surfaces.

Policy and operational responses designed to tackle the water-related transmission and exposure routes focus on interrupting them, through, for example, chlorination and handwashing, or prevention. The cardinal rules that humanitarian water engineers follow to avoid an outbreak of infectious disease is to chlorinate, so that the pathogens are eliminated, and to ensure that drinking water pipes and raw wastewater systems are kept physically separate (i.e. to prevent cross-contamination). Such interventions are effective. A systematic review of over 2000 interventions to prevent diarrhoea found that all of them<sup>32</sup> reduced the risk.<sup>33</sup> However, cholera and the more common forms of diarrhoea persist. In rural areas, the risk of cross-contamination arises from buckets dipped into an unprotected (and unchlorinated) village water well. In urban areas, the concern is when the wastewater is not treated adequately (because the treatment plant has been run down), a malfunctioning pumping station means the wastewater is not evacuated from a built up area, or when leaks from wastewater drainpipes seep into drinking water sources – particularly if the chlorination of the latter is below par.

29 See also Paul R. Hunter, Alan M. MacDonald and Richard C. Carter, “Water Supply and Health”, *PLOS ONE*, Vol. 7, No. 11, 2010; Paul R. Hunter, Denis Zmirou-Navier and Philippe Hartemann, “Estimating the Impact on Health of Poor Reliability of Drinking Water Interventions in Developing Countries”, *Science of the Total Environment*, Vol. 407, No. 8, 2009.

30 The figure is more than the sum of deaths from the “big three” of malaria, tuberculosis and HIV/AIDS combined: Jamie Bartram and Sandy Cairncross, “Hygiene, Sanitation, and Water: Forgotten Foundations of Health”, *PLoS Medicine*, Vol. 7, No. 1, 2010. See also Annette Prüss-Ustün, Jamie Bartram, Thomas Clasen, *et al.*, “Burden of Disease from Inadequate Water, Sanitation and Hygiene in Low- and Middle-Income Settings: A Retrospective Analysis of Data from 145 Countries”, *Tropical Medicine & International Health*, Vol. 19, No. 8, 2014.

31 World Bank, ICRC and UNICEF, above note 18.

32 At least for the forty-six of 2120 publications which met the stringent requirements of the systematic review.

33 Lorna Fewtrell, Rachel B. Kaufmann, David Kay, Wayne Enanoria, Laurence Haller and John M Colford Jr, “Water, Sanitation, and Hygiene Interventions to Reduce Diarrhoea in Less Developed Countries: A Systematic Review and Meta-Analysis”, *Lancet Infectious Diseases*, Vol. 5, No. 1, 2005.

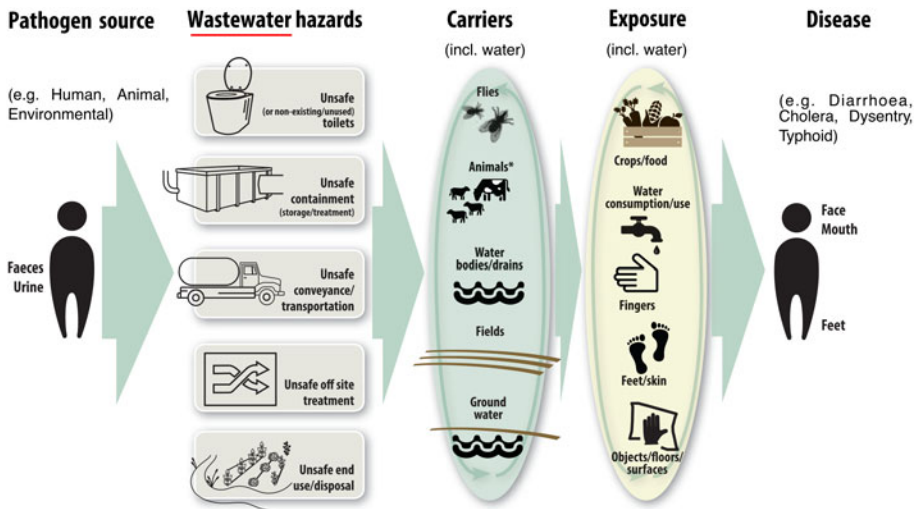


Figure 2. Some infectious disease transmission routes. Pathogens which develop in humans and wastewater hazards can be carried through water bodies (and other carriers) until exposed to humans, causing disease.<sup>34</sup>

### The impact of attacks affecting water and wastewater services

Of course, different types of attacks affect water and wastewater services in different ways. A cyber-attack that aims to disrupt the services’ operating system may inflict damage that is much less visible than an air-to-surface missile attack on an isolated component of the infrastructure, for example. Explosive weapons employ low- and high-explosive substances to create blast, and commonly fragmentation, in order to achieve a particular effect. The damage caused by the use of explosive weapons in protracted urban armed conflicts, where population density and foot traffic are high, is not only a result of the blast itself, but also of the fragmentation and heat which are produced by the detonation. These three mechanisms can also cause extensive harm to civilians and infrastructure through penetration, ground shock, cratering, secondary fragmentation and fire.

Researchers and humanitarian water engineers have documented such damage from armed conflicts that have taken place all over the world, the latter usually as an internal reporting requirement for the institution which employed them or as a means to request a pause in hostilities in order to ensure safe access for the operation, maintenance or repair of infrastructure.<sup>35</sup> The dozens of reports detailed in Table A in the Annex cover a very wide range of impact and follow no common methodology. Read collectively, however, they do reveal a number of

34 Adapted by the authors from WHO, *Guidelines on Sanitation and Health*, Geneva, 2018.

35 See, e.g., Volodymyr Kalinin, “Key Pipelines Damaged by Shelling”, WASH Incident Report No. 283, 8 May 2021, available at: [https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/wash\\_incident\\_report\\_no283\\_-\\_080521.pdf](https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/wash_incident_report_no283_-_080521.pdf).

patterns which offer a snapshot of the “working knowledge” which backs the authority they have developed on the topic over the decades of their careers.<sup>36</sup> Each of the reports documents the extent of direct damage to water infrastructure, at a minimum – possibly because this form of damage is the most visible and easiest to repair. The quality of the service prior to the attack may be inferred from this direct impact, particularly when the documentation spans a number of attacks, or when the same case is revisited years later by the same author (or a new author with access to the prior reports). The measures of this “baseline resilience” are defined generally by the level of inherent infrastructure redundancies in the systems, by the existence of an emergency preparedness plan (EPP), and the capacity of the service personnel to execute the EPP (or simply to maintain or restore the service in face of long-term degradation or short-term interruption).<sup>37</sup> The evidence base of Table A further reveals patterns of deterioration of wastewater treatment plants (which are usually prone to partial or total failure because of the lack of sophisticated replacement parts on the open market, as in Kabul, Monrovia, Brazzaville and Grozny) and malfunctioning chlorination systems (which often fail to lack of sophisticated replacement parts or chlorine gas, tablets, or liquid on the open market, as in Dilli, Huambo, Novi Sad and Baghdad). The concern for cross-contamination of wastewater and drinking water can be inferred in each of the engineers’ reports, and is prevalent in several. The concern is most notable where sewage ponds develop in public areas (and surrounding drinking water pipes) after drainage lines back up when booster pumps fail (Kabul, Beirut, Basrah, Mogadishu, Novi Sad). A further pattern that can be gleaned from the reports which is of direct relevance to the topic at hand is that the concern shown for degraded water and wastewater systems stems not from evidence but from assumptions that the public health risks increase accordingly. Data is collected from within the “silos” of professional expertise; humanitarian engineers and health workers rarely mix, and even less frequently with munitions experts and epidemiologists.

### The chain of consequences that reverberate from damage to water and wastewater services and infectious disease

To summarize findings to this point: over a century of epidemiological study of transmission routes has developed a robust scientific body of knowledge that infectious diseases can spread through water and wastewater, and a more recent body of knowledge has documented how attacks can damage water and wastewater services in ways which facilitate cross-contamination between the two.

It is when seeking causation along the attack–water/wastewater service–infectious disease chain of reverberating consequences that the uncertainty begins to cascade. Indeed, a systematic review of nearly 4000 research articles (published

36 Comprehensive documentation on the effects of armed conflict on water infrastructure is to be found, for example, in P. Giorgio Nembrini’s *Thirsty Cities in War* collection – see Table A in the Annex.

37 M. Zeitoun and M. Talhami, above note 5.

between 1980 and 2014) on the effectiveness of water and sanitation interventions to improve health outcomes in “humanitarian crises” found the evidence base to be “extremely limited”.<sup>38</sup> Only six papers found interventions to produce change that was significant enough to be counted.<sup>39</sup>

The bulk of investigations into the consequences of the attack–water/wastewater service–infectious disease chain remains associative, and very tricky to untie from the effects of the armed conflict within which they occur. Studies have shown, for example, how outbreaks of hepatitis A during the 1990s war in Bosnia are attributed – in part – to the virtual collapse of “the hygienic [read water and wastewater] infrastructure which was intended to protect against enteric disease”.<sup>40</sup> The outbreak was followed by “staggering” (and relatively well-documented) rates of diarrhoea and dysentery. In a similar vein, the impact of the US/UK invasion of Iraq on public health was considered to work its way “through specific diseases and conditions” such as AIDS and cancer.<sup>41</sup> Epidemiologists blame water-related pathogens (like *Vibrio cholerae*, which results in cholera) for 85% of the 50,000 deaths after the sudden influx of nearly one million refugees from Rwanda into the Democratic Republic of Congo in 1994,<sup>42</sup> though do not link it with attacks on water and wastewater services. And while there is clear association between periods of high-intensity armed conflict, damage to water and wastewater systems, and spikes in diarrhoea in Aleppo and Idlib (Syria), “multiple confounders” mean that no direct co-relation can be drawn.<sup>43</sup> Interpreting such associations as consequential chains with any certainty requires the deeper understanding provided by case studies.

38 Anita Ramesh, Karl Blanchet, Jeroen H. J. Ensink and Bayard Roberts, “Evidence on the Effectiveness of Water, Sanitation, and Hygiene (WASH) Interventions on Health Outcomes in Humanitarian Crises: A Systematic Review”, *PLOS ONE*, Vol. 10, No. 9, 2015.

39 The review discusses the factors required to robustly evidence causation (especially during the conduct of hostilities): a good “control” case to compare against, agreed health indicator definitions, age-specific, water quality records, seasonal changes in water or wastewater quality, and the confounding variables that make up the “cascade of uncertainty”. See D. Blum and R. G. Feachmen, “Measuring the Impact of Water Supply and Sanitation Investments on Diarrhoeal Diseases: Problems of Methodology”, *International Journal of Epidemiology*, Vol. 12, No. 3, 1983; B. T. Kerridge, M. R. Khan, J. Rehm and A. Sapkota, “Conflict and Diarrheal and Related Diseases: A Global Analysis”, *Journal of Epidemiology and Global Health*, Vol. 3, No. 4, 2013; M. A. Connolly, *Communicable Disease Control in Emergencies: A Field Manual*, WHO, Geneva, 2005; Máire A. Connolly, Michelle Gayer, Michael J. Ryan, Peter Salama, Paul Spiegel and David L. Heymann, “Communicable Diseases in Complex Emergencies: Impact and Challenges”, *Lancet*, Vol. 364, No. 9449, 2004; A. Ramesh *et al.*, above note 38, Discussion, p. 14.

40 Jonathan Mann, Ernest Drucker, Daniel Tarantola and Mary Pat McCabe, “Bosnia: The War against Public Health”, *Medicine & Global Survival*, Vol. 1, No. 3, 1994, p. 139.

41 Hazem Adam Goharrah, Paul Huth and Bruce Russett, “Civil Wars Kill and Maim People – Long After the Shooting Stops”, *American Political Science Review*, Vol. 97, No. 2, 2003, p. 189.

42 A. Ramesh *et al.*, above note 38, p. 2; Goma Epidemiology Group, “Public Health Impact of Rwandan Refugee Crisis: What Happened in Goma, Zaire, in July, 1994?”, *Lancet*, Vol. 345, No. 8946, 2005.

43 Aula Abbara, Omar Zakieh, Diana Rayes, *et al.*, “Weaponizing Water as an Instrument of War in Syria: Impact on Diarrhoeal Disease in Idlib and Aleppo Governorates, 2011–2019”, *International Journal of Infectious Diseases*, Vol. 108, 2021.



## Reverberating effects of attacks in protracted armed conflict

This section reviews public-domain literature on Iraq, Yemen and Gaza to gauge the extent of confidence in information about the attack–water/wastewater service–infectious disease chain. Because of the importance that the “baseline resilience” of any service (Figure 1) plays in determining the extent of civilian harm, attacks are considered within the protracted armed conflict in which they occur.

### Water/wastewater and cholera in Basrah, Iraq

As shown in Figure 3, the decades-long decline of Basrah’s drinking water system from world-class to “worst-class” has been attributed mostly to the accumulation of indirect impact of armed conflict,<sup>44</sup> rather than to by parties to armed conflict *per se*. As attacks precipitated each degradation, their reverberating effects should be considered, particularly for links with the thousands of cases of cholera and other water-related disease in 2015 (if not the “water riots” three years later).<sup>45</sup>

Even when it was of top quality, Basrah’s drinking water system was vulnerable to disruption due to its heavy reliance on a single source and means of delivery – the al-Bada’a water canal which brought freshwater hundreds of kilometres from the Euphrates River to a large reservoir that then supplied raw water to a series of treatment plants where the water was cleaned and pumped into the network in Basrah. This source was developed after the raw water quality in the original source (the nearby Shatt al-Arab river) had started to deteriorate (mainly due to salinization, as far back as the 1980s).<sup>46</sup> The canal and related distribution pipes were damaged by

44 The bulk of the negative impact was indirect, and accumulated over time – manifesting itself most importantly in the lack of qualified staff: Mark Zeitoun, Heather Elyadi, Jean-Philippe Dross, Michael Talhami, Evaristo de Pinho-Oliveira and Javier Cordoba, “Urban Warfare Ecology: A Study of Water Supply in Basrah”, *International Journal of Urban and Regional Research*, Vol. 41, No. 6, 2017. For example, the staff either did not show for work because of security reasons, eventually left the country (“brain drain”), or – over the decades since 1990 – simply retired. The biggest impact on hardware was felt in the depletion of spare parts, due both to looting of stores or to the prohibition of importing spare parts: P. Giorgio Nembrini, C. Generelli, A. Al-Attar, *et al.*, *Basrah Water Supply During the War on Iraq*, Geneva Foundation and International Committee of the Red Cross, Geneva, 2003; Int Doc 039, “Report on Sanitation Activities in Basrah”, Internal Technical Document of the International Committee of the Red Cross, Baghdad, 23rd June 1991; Int Doc 099, “ICRC Sanitation Activities in Basrah Area”, Internal Technical Document of the International Committee of the Red Cross, Baghdad 29 January 1992. The quality of water treatment was reduced due in particular to shortages of aluminium sulphate-dosing equipment, unavailability of the preferred type of chlorine, and broken chlorination pumps: Yves Etienne and P. Giorgio Nembrini, “Establishing Water and Sanitation Programmes in Conflict Situations: The Case of Iraq During the Gulf War”, *International Journal of Public Health*, Vol. 40, No. 1, 1995; ICRC 029, “Water Treatment”, Baghdad, ICRC News Bulletin, ICRC Iraq, No. 7, March 2000; Int Doc 142, “Wathab General Meetin [sic], on 23.03.2004”. Internal Technical Document of the International Committee of the Red Cross, Baghdad, 6 April 2004.

45 Azhar Al-Rubaie, Michael Mason and Zainab Mehdi, *Failing Flows: Water Management in Southern Iraq*, LSE, London, 2021.

46 United Nations Development Programme, “UN Joint Programme Document: Response to Basra Water Crisis – Iraq”, 2020, available at: [https://info.undp.org/docs/pdc/Documents/IRQ/JP%20Document\\_Proposal\\_final%20-Basra%20water%20project%204.NOV.2020%20UNICEF%20signed\[2\].pdf](https://info.undp.org/docs/pdc/Documents/IRQ/JP%20Document_Proposal_final%20-Basra%20water%20project%204.NOV.2020%20UNICEF%20signed[2].pdf).



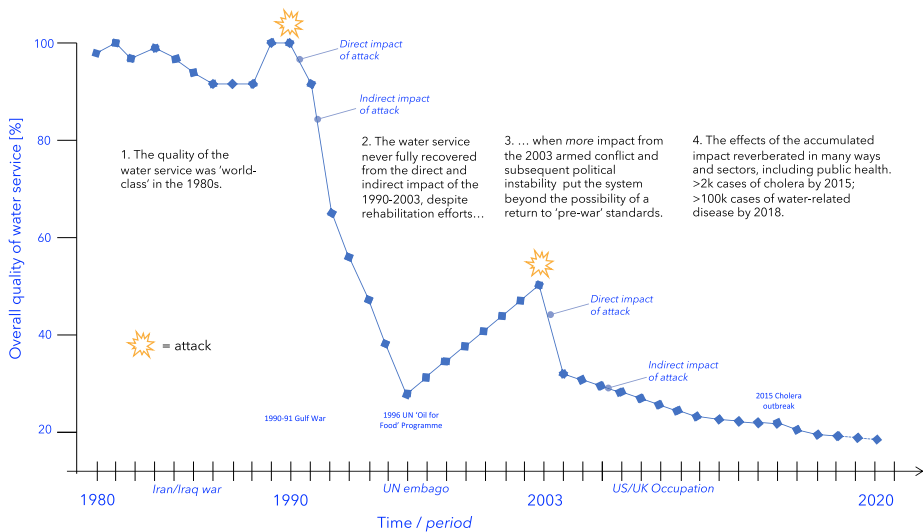


Figure 3. The long and predictable decline of the quality of the drinking water service in Basrah. Draft based on Zeitoun *et al.* 2017.<sup>49</sup>

attacks in 2003,<sup>47</sup> thereby setting off a heavy reliance on locally desalinated and unregulated water supply services.<sup>48</sup> Over 4500 cases of cholera were reported in Iraq in 2007, primarily in Baghdad.<sup>50</sup> The baseline resilience of the wastewater service was compromised to a greater extent as the wastewater treatment plant was never completed (because construction was halted as the foreign contractors fled the instability that followed hostilities in 1991).<sup>51</sup> The sewers and wastewater pumping stations that had been completed on the very flat city filled up, and, as a result, standing wastewater puddles have been present in populated areas for decades.<sup>52</sup>

As the quality of the water and wastewater services declined, the risk of both contamination of the water and public exposure of untreated wastewater in populated areas increased. By 2015, the water authorities were obliged to return to the extremely salty Shatt al-Arab river as an alternative source. Water engineers who faced the challenges were certain of cross-contamination of the wastewater and drinking water,<sup>53</sup> and many were warning of the possibility of an

47 P. G. Nembrini, C. Generelli, A. Al-Attar, *et al.*, above note 44.

48 World Bank, ICRC and UNICEF, above note 18, Figure 3.2.

49 M. Zeitoun, C. Generelli, A. Al-Attar, *et al.*, above note 44.

50 J. M. Khwaif, A. H. Hayawi and T. I. Yousif, "Cholera Outbreak in Baghdad in 2007: An Epidemiological Study", *Eastern Mediterranean Health Journal*, Vol. 16, No. 6, 2008. For longer-term national trends, see also A. M. Hussain and R. K. Latfa, "Trend of Cholera in Iraq in the Time of Unrest", *Mustansiriya Medical Journal*, Vol. 18, No. 1, 2019.

51 Al Janoob, personal communication, "Remote Interview with Basrah Water Engineer, 23 December 2013", anonymized, 2013.

52 Mark Zeitoun, "More Bombs and Bread", Opinion, *The Jordan Times*, 2003.

53 Al Janoob, personal communication, "Remote Interview with Basrah Water Engineer, 3 November 2015", anonymized, 2015.

outbreak of communicable disease. Over 2000 cases of cholera were reported soon afterwards.<sup>54</sup> By 2018 over 110,000 cases of diarrhoea, vomiting and other ailments were reported.<sup>55</sup> These have been attributed to a combination of ageing filtration media for water treatment, failing pumps (indirect impact) and the temporary discharge of wastewater to the Shatt al-Arab river (which had by that time become a source of drinking water).<sup>56</sup>

## Wastewater and cholera throughout Yemen

Subject to armed conflict since 2015, the worst outbreaks of cholera globally this century have occurred in Yemen.<sup>57</sup> Over two million cases and 3500 deaths were reported during the identifiable waves of 2016 and 2017.<sup>58</sup> While some have attributed this to changes in rainfall,<sup>59</sup> most concur that the outbreaks are due to failures in the water and wastewater services, which are a result of the destruction of and damage to critical infrastructure that enables these services.<sup>60</sup>

In response to the outbreak, humanitarian actors have stressed the importance of improving the “underlying conditions” (read “baseline resilience”) of the health and safe drinking water, sanitation and hygiene (WASH) sectors.<sup>61</sup> The country does not have much water to draw on in the first place,<sup>62</sup> with coastal cities suffering from saltwater intrusion<sup>63</sup> and cities in the highlands, such as Ta’iz, famously running out of drinking water in 1996.<sup>64</sup> Only about 50 to 60% of people in the country had access to safe piped water services before the hostilities.<sup>65</sup> Indeed, well before the start of the current hostilities, one of the main actors in the development of Yemen’s water sector was advocating the importance of alleviating the effects of the earlier crisis in 2011. Gesellschaft für Internationale

54 WHO, “Cholera-Iraq”, *World Health Organization – Disease Outbreak News*, 12 October 2015; Al Janoob, personal communication.

55 Human Rights Watch, “Basra Is Thirsty: Iraq’s Failure to Manage the Water Crisis”, 22 July 2019, available at: <https://ceobs.org/hrw-basra-is-thirsty-iraqs-failure-to-manage-the-water-crisis/>.

56 UNICEF, *Water Scarcity Crisis in Basra*, 2019.

57 For longer-term trends and comparison with other countries, see [knoema.com/infographics/xknpzhh/cholera-outbreak-in-yemen](http://knoema.com/infographics/xknpzhh/cholera-outbreak-in-yemen).

58 REACH, *Secondary Desk Review on WASH Assessments in Yemen*, May 2020, available at: [https://reliefweb.int/sites/reliefweb.int/files/resources/reach\\_yem\\_report\\_wash\\_secondary\\_desk\\_review\\_may\\_2020.pdf](https://reliefweb.int/sites/reliefweb.int/files/resources/reach_yem_report_wash_secondary_desk_review_may_2020.pdf).

59 Anton Camacho, Malika Bouhenia, Reema Alusufi, *et al.*, “Cholera Epidemic in Yemen, 2016–18: An Analysis of Surveillance Data”, *Lancet Global Health*, Vol. 6, No. 6, 2018.

60 For example, Fekri Dureab, Khalid Shibib, Yazoumé Yé, Albrecht Jahn and Olaf Müller, “Cholera Epidemic in Yemen”, *Lancet Global Health*, Vol. 6, No. 12, 2018.

61 OCHA, *Humanitarian Needs Overview: Yemen*, February 2021, p. 22, available at: [https://yemen.un.org/sites/default/files/2021-05/yemen\\_hno\\_2021\\_final\\_version\\_1.pdf](https://yemen.un.org/sites/default/files/2021-05/yemen_hno_2021_final_version_1.pdf).

62 NWSSIP, *National Water Sector Strategy and Investment Programme, 2005–2009*, Final Draft 17 December 2008; Leslie Morris-Iveson and Ahmed Alderwish, “Experiences with Local Water Governance and Outcomes for Vulnerable Communities in the Tihama Region of Yemen”, *Water Alternatives*, Vol. 11, No. 3, 2018.

63 World Bank, *Yemen Dynamic Needs Assessment: Phase 3 (2020 Update)*, Washington, DC, 2020.

64 Yasir Mohieldeen, *Responses to Water Scarcity: Social Adaptive Capacity and the Role of Environmental Information. A Case Study from Ta’iz, Yemen*, 1999, available at: <https://www.soas.ac.uk/water/publications/papers/file38366.pdf>.

65 Humanity & Inclusion, above note 14.

Zusammenarbeit GmbH (GIZ) notes that the hostilities in Ta'iz city led to a sharp decrease in water supply (from 80% in 2014 to 38% by 2017) and wastewater services (from 70% in 2014 to 38% in 2017).<sup>66</sup> This kind of deterioration does not bode well in a country where cholera is endemic. The same report also notes that water consumption in twelve out of seventeen governorates in Yemen had fallen below 50 litres per person per day by 2016, which is the level of access required to maintain health concerns at “low” levels,<sup>67</sup> coupled with a rapidly collapsing health system. Compounding the pressure, roughly 270,000 Yemenis had fled to Ta'iz governorate by 2017, some of whom may have carried different strains of the disease.<sup>68</sup> It is therefore not surprising that Ta'iz was among the governorates that reported the highest suspected cholera cases (over 31,000 as of 3 August 2017 for the period between 27 April 2017 to 3 August 2017).<sup>69</sup>

The very many routes through which the resilience of the drinking water systems in Yemen was compromised are shown in Figure 4. This emphasizes how specific elements of the water and energy infrastructure and other aspects of the service were vulnerable on one level to armed conflict, and at a second and even more profound level to the adaptations undertaken by individuals and service providers in order to continue to benefit from water or electricity.

Figure 4 suggests that private water vendors may be filling an essential need, but also unwittingly spreading cholera – because of the distribution of untreated (and possibly cholera-contaminated) water.<sup>70</sup> The baseline sanitation conditions also do not help. Fewer than half of Yemenis had access to the soap so crucial to interrupt disease transmission routes.<sup>71</sup> Only the major cities are served by wastewater treatment plants,<sup>72</sup> and less than half of the homes have “adequate” sanitation.<sup>73</sup> The resilience of both water and wastewater services are known to be linked to the electrical power supply.<sup>74</sup> When fuel shortages spiked during the economic blockade, operation of

66 GIZ, *Yemen Water Sector: Damage Assessment Report of Twelve Water Supply and Sanitation Local Corporations (LCs) and their Affiliated Branch Offices and Utilities – Stage III, Part 2: Situation Assessment Report and Development of Technical Assistance and Investment Plans for the Infrastructure Rehabilitation of Water Supply and Sanitation Services*, Annex 2: Technical Assessment Report for Aden LC, 2018.

67 WHO, *Domestic Water Quantity, Service Level and Health*, Geneva, 2013.

68 International Organization for Migration/United Nations High Commissioner for Refugees, *Task Force on Population Movement (TFPM), 13th Report, March 2017*, available at: [https://reliefweb.int/sites/reliefweb.int/files/resources/draft\\_tfpm\\_13th\\_report\\_feb2017\\_v4.pdf](https://reliefweb.int/sites/reliefweb.int/files/resources/draft_tfpm_13th_report_feb2017_v4.pdf).

69 KfW, *Technical Needs Assessment Report*, 2015.

70 World Bank, above note 63, p. 120.

71 OCHA, above note 61, p. 94.

72 Republic of Yemen, *National Report for the Third UN Conference on Housing and Sustainable Urban Development – Habitat III*, Sana'a, 2016.

73 REACH, above note 58; Adel A. S. Al-Gheethi, M. O. Abdul-Monem, A. H. S. Al-Zubeiry, A. N. Efaq, A. M. Shamar and Ramzy M. A. Al-Amery, “Effectiveness of Selected Wastewater Treatment Plants in Yemen for Reduction of Faecal Indicators and Pathogenic Bacteria in Secondary Effluents and Sludge”, *Water Practice & Technology*, Vol. 9, No. 3, 2014.

74 Christopher Ward, Sabine Beddies, Khaled Hariri, Souad Othman Yaffie, Anwer Sahooley and Barbara Gerhager, *Yemen's Water Sector Reform Program – A Poverty and Social Impact Analysis (PSIA)*, World Bank, Washington, DC, 2007; Gerhard Lichtentahler, *Political Ecology and the Role of Water: Environment, Society and Economy in Northern Yemen*, Ashgate Publishing Ltd, Aldershot, 2002;

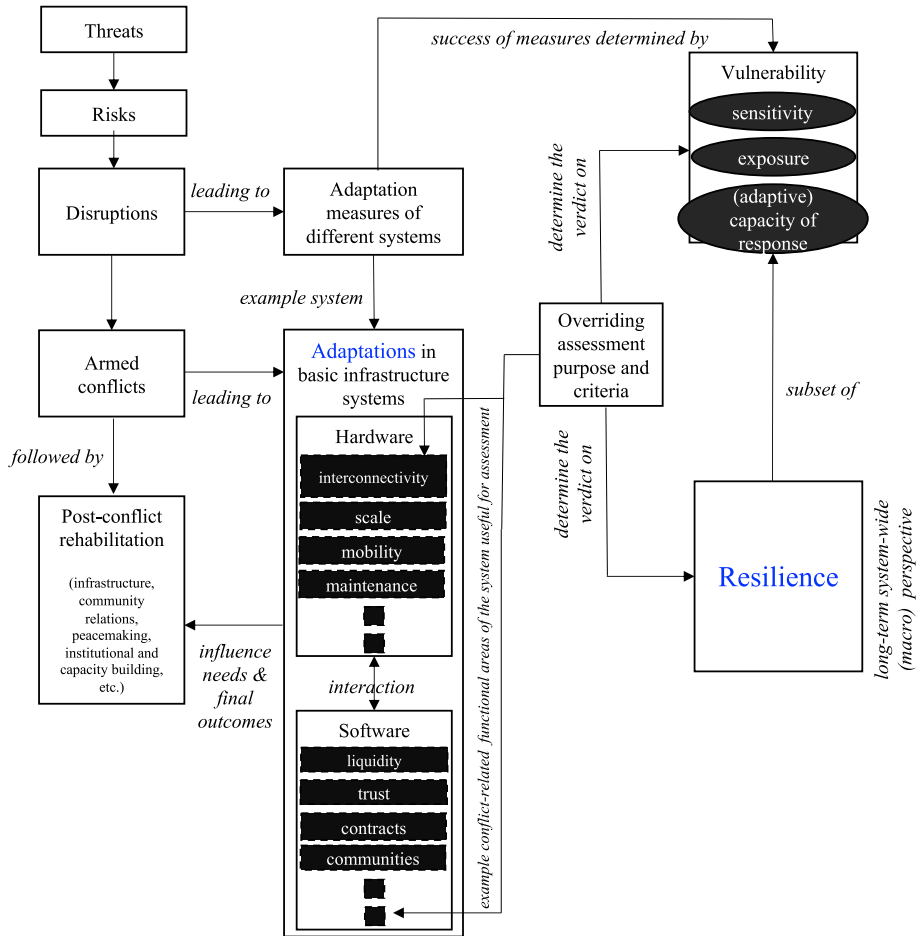


Figure 4. Framework of vulnerability and resilience of water systems in Yemen.<sup>75</sup>

water and wastewater, health and many other services was undermined.<sup>76</sup> To make matters worse, there was a lack of cholera vaccine stockpiles.<sup>77</sup>

By 2019 over 145 airstrikes on WASH facilities had been recorded.<sup>78</sup> By 2020, ten of the country’s thirty-three water treatment plants and five of the

Gerhard Lichtentaehler, “Water Conflict and Cooperation in Yemen”, in *Middle East Report*, Middle East Research & Information Project, Washington, DC, 2010, pp. 30–6.

75 Adapted by the authors from Mohammad Al-Saidi, Emma Lauren Roach and Bilal Ahmed Hassen Al-Saeedi, “Conflict Resilience of Water and Energy Supply Infrastructure: Insights from Yemen”, *Water*, Vol. 12, No. 11, 2020.

76 M. Al-Saidi, E. L. Roach and B. A. H. Al-Saeedi, *ibid.*; World Bank, above note 63, p. 148.

77 Frederik Federspiel and Mohammad Ali, “The Cholera Outbreak in Yemen: Lessons Learned and Way Forward”, *BMC Public Health*, Vol. 18, No. 1, 2018.

78 UNICEF, *Water under Fire*, Vol. 3: *Attacks on Water and Sanitation Services in Armed Conflict and the Impacts on Children*, New York, 2021.

country's twelve wastewater treatment plants had been damaged or destroyed.<sup>79</sup> Access to safe water at the household level dropped in every governorate.<sup>80</sup> The general paucity of electricity and fuel for generators is judged to have seriously undermined the quality of the water and sanitation services.<sup>81</sup> As such, the potential for untreated wastewater to cross with drinking water was high,<sup>82</sup> and the spread of cholera was entirely predictable.<sup>83</sup> As a United Nations Children's Fund (UNICEF) employee stated, "we are just one airstrike away from an unstoppable epidemic".<sup>84</sup>

Though humanitarian agencies mobilized, the cholera outbreak still came, in no small part because – as in Basrah – of the mixing of untreated wastewater and drinking water. "(T)he accumulation of stagnant water in the streets due to frequent sewer backups are precipitating the spread of diseases such as cholera, vector-borne diseases, and parasites."<sup>85</sup> Indeed, the greatest number of cases appear to have come from the areas where wastewater treatment plants were not functional,<sup>86</sup> and were also associated with increased incidence of diarrhoea.<sup>87</sup>

### Wastewater and diarrhoea in Gaza (before May 2021)<sup>88</sup>

Subject to numerous episodes of armed conflict since 1948, and to full territorial closure and naval blockade since at least 2006, Gaza is notoriously bad both in terms of public health<sup>89</sup> and of quality of drinking water.<sup>90</sup> There furthermore appears to be a strong association between the incidence of diarrhoea and the attacks carried out during the "summer war" of 2014 (see [Figure 5](#)).

79 Indirect impacts of the longer-term aspects of the war were felt on the water providers' governance systems, bill-collection rates and staff: GIZ, above note 66. The impact on staff was due in part to the lack of salaries paid and also because of brain drain: World Bank, above note 63.

80 REACH, *Access to Improved Water Sources in Yemen: Secondary Data Review*, July 2017, available at: [https://reliefweb.int/sites/reliefweb.int/files/resources/reach\\_yem\\_situation\\_overview\\_access\\_to\\_improved\\_water\\_sources\\_july\\_2017\\_final\\_0.pdf](https://reliefweb.int/sites/reliefweb.int/files/resources/reach_yem_situation_overview_access_to_improved_water_sources_july_2017_final_0.pdf); see also Erika Weinthal and Jeannie Sowers, "Targeting Infrastructure and Livelihoods in the West Bank and Gaza", *International Affairs*, Vol. 95, No. 2, 2019.

81 World Bank, above note 63.

82 M. Al-Saidi, E. L. Roach and B. A. H. Al-Saedi, above note 75.

83 GIZ, *Yemen Water Sector: Damage Assessment Report of Twelve Water Supply and Sanitation Local Corporations (LCs) and their Affiliated Branch Offices and Utilities – Stage III, Part 2: Situation Assessment Report and Development of Technical Assistance and Investment Plans for the Infrastructure Rehabilitation of Water Supply and Sanitation Services*, 2018.

84 UN News Service, "Yemen: Attacks on Water Facilities, Civilian Infrastructure, Breach 'Basic Laws of War' Says UNICEF", 1 August 2018, available at: <https://news.un.org/en/story/2018/08/1016072>.

85 World Bank, above note 63, p. 72.

86 Naif Abu-Lohom, Dambudzo Muzenda and Yogita Upayda Mumssen, "A WASH Response to Yemen's Cholera Outbreak", *The Water Blog of the World Bank*, 13 December 2018, available at: <https://blogs.worldbank.org/water/wash-response-yemen-s-cholera-outbreak>.

87 Charbel El Bcheraoui, Aisha O. Jumaan, Michael L. Collison, Farah Daoud and Ali H. Mokdad, "Health in Yemen: Losing Ground in War Time", *Globalization and Health*, Vol. 14, 2018.

88 The documentation and analysis was completed before the May 2021 hostilities in Gaza.

89 Sophie Arie, "Gaza is Running Out of Medicines as Egypt Limits Movement Through the Rafah Crossing", *British Medical Journal*, Vol. 347, 2013; John Zarocostas, "Quality of Medical Services is in Decline in Gaza, Says UN Official", *British Medical Journal*, Vol. 340, 2010.

90 Palestinian Water Authority (PWA), *Water Safety for Public Health Status Joint Report*, Gaza, 2019; PWA, *Water Resources Status Report*, Gaza, 2018.

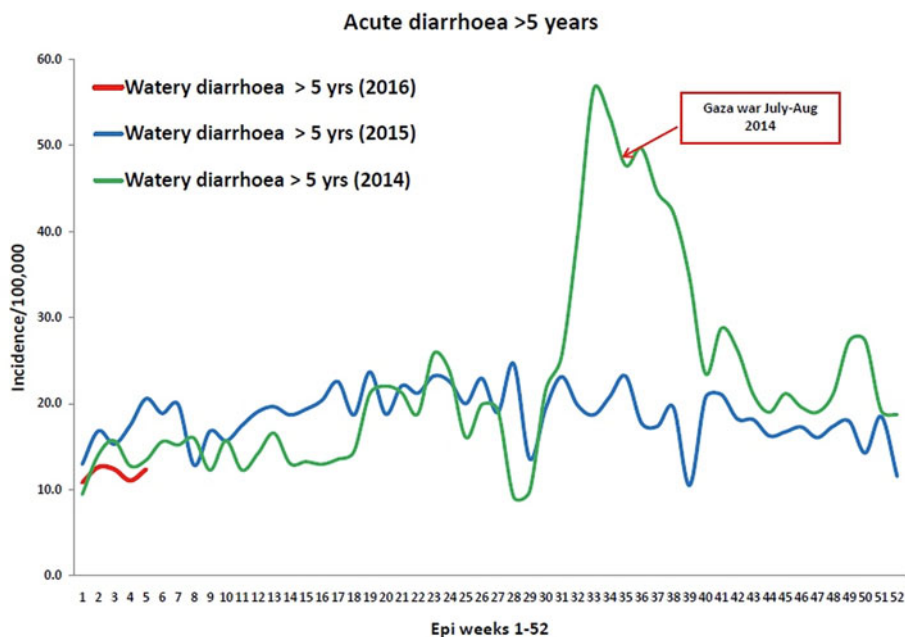


Figure 5. Comparison of reported cases of acute diarrhoea, for 2014 (including the July “summer war”) and 2016.<sup>91</sup>

The “underlying conditions” of water and wastewater services in Gaza are as well studied as they are concerning.<sup>92</sup> Over 90% of the drinking water supplied by the municipality exceeds WHO drinking water guidelines for nitrates (and 79% for chlorides).<sup>93</sup> Roughly 40% of water sampled at taps from two hospitals was found to be biologically contaminated in 2020.<sup>94</sup> This is not surprising, considering how rife the conditions for cross-contamination with wastewater are.<sup>95</sup> Less than half of the

91 United Nations Relief and Works Agency (UNRWA), *Epidemiological Bulletin for Gaza Strip*, Gaza City, 2016. See also PWA, *Baseline Study on Water Quality & Public Health in the Gaza Strip: Final Report*, Gaza City, 2015.

92 Oxfam, *Still Treading Water: Reviewing Six Years of the Gaza Reconstruction Mechanism and the Dire Water Situation in the Gaza Strip*, Oxfam, Oxford, 2021.

93 PWA, *Water Resources Status Report*, above note 90.

94 Reem Shomar, *Anti-Microbial Resistant Bacteria in Health Care Facilities in Gaza: Exploring Links with WASH. Final Report of a Pilot Study Conducted Under the GCRF/UK Academy of Medical Sciences Networking Grant* Networking Grant GCRFNGR4\1490, Gaza City, February 2021.

95 A separate line of enquiry finds that roughly one-quarter of the diseases in Gaza are water-related: World Bank, *West Bank and Gaza: Assessment of Restrictions on Palestinian Water Sector Development Sector Note April 2009*, International Bank for Reconstruction and Development, Washington, DC, 2009, and are compounded by the additional threat of the spread of anti-microbial resistance: R. Shomar, *ibid.*; Abdelraouf A. Elmanama, Philippe Hartemann, Kamal J. Elnabris, *et al.*, “Antimicrobial Resistance of *Staphylococcus Aureus*, Fecal Streptococci, Enterobacteriaceae and *Pseudomonas Aeruginosa* Isolated from the Coastal Water of the Gaza Strip-Palestine”, *International Arabic Journal of Antimicrobial Agents*, Vol. 6, No. 32, 2016.

wastewater is routinely treated,<sup>96</sup> and most regularly seeps into the sea<sup>97</sup> or into Gaza's main source of drinking water: the aquifer located between one and fifty metres below the sand surface.

The direct impact from the hostilities in 2008–2009, 2012, and even more extensive damage caused in 2014 seems likely to have contributed to the conditions required to communicate disease. One of the anaerobic ponds of the Gaza City wastewater treatment plant was hit in 2009, for example, thereby creating a small flood (over 55,000 square metres) of partially treated wastewater in the surrounding fields.<sup>98</sup> Alongside damages to a considerable amount of water and wastewater infrastructure, the nearly completed North Gaza wastewater treatment plant was damaged in 2014.<sup>99</sup>

Any evaluation of the likely risk of cross-contamination should also consider the (likely greater) risk of exposure from the great extent of degradation of the water and wastewater services. Routine operations and maintenance become neglected,<sup>100</sup> as the water authorities struggle to get people to pay their bills,<sup>101</sup> fuel shortages are chronic, spare parts are very difficult to import past the blockade<sup>102</sup> and administrative buildings themselves are attacked.<sup>103</sup> Like the water services, the quality of the health services is furthermore clearly tied to the (poor) levels of electricity available.<sup>104</sup> As state-supplied power cuts are scheduled, hospital and wastewater treatment plants use diesel-driven electrical

96 World Bank Group, "Securing Water for Development in West Bank and Gaza", in *Water Global Practice – Sector Note*, International Bank for Reconstruction and Development/World Bank, Washington, DC, 2018.

97 Mads Gilbert, *Brief Report to UNRWA: The Gaza Health Sector as of June 2014*, UNRWA, Tromsø, 2014.

98 United Nations Environment Programme, *Environmental Assessment of the Gaza Strip Following the Escalation of Hostilities in December 2008–January 2009*, Nairobi, Kenya, 2009, available at: <https://www.unep.org/resources/report/environmental-assessment-gaza-strip-following-escalation-hostilities-december-2008>; see also EWASH, *Gaza Emergency Wash Cluster Weekly Situation Report 24 January 2009*, 2009, available at: [https://reliefweb.int/sites/reliefweb.int/files/resources/33D83908349E91CCC12575610042BF06-full\\_report.pdf](https://reliefweb.int/sites/reliefweb.int/files/resources/33D83908349E91CCC12575610042BF06-full_report.pdf); Oxfam International, *Rebuilding Gaza: Putting People before Politics*, June 2009, available at: [https://oi-files-d8-prod.s3.eu-west-2.amazonaws.com/s3fs-public/file\\_attachments/bn-rebuilding-gaza-0906\\_9.pdf](https://oi-files-d8-prod.s3.eu-west-2.amazonaws.com/s3fs-public/file_attachments/bn-rebuilding-gaza-0906_9.pdf); Palestinian Hydrology Group, *Rapid Community Based Water and Sanitation Needs Assessment from the Impact of the Israeli Offensive on Gaza between 27th Dec. 2008 and 17th Jan. 2009*, Gaza City, East Jerusalem, 2009.

99 Coastal Municipalities Water Utility (CMWU), *Damages Assessment Report: Water and Wastewater Infrastructure (Gaza Strip; 7 July–14 August 2014)*, Gaza City, 2014, available at: [https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/assessments/Damage\\_Assessment\\_Report\\_War%202014%20%28%20REV%201%29.pdf](https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/assessments/Damage_Assessment_Report_War%202014%20%28%20REV%201%29.pdf); see also EWASH, *Gaza Water Disaster: Damages to Water Infrastructure*, 2014; E. Weinthal and J. Sowers, above note 80.

100 Office of the Quartet, *Report to the Ad Hoc Liaison Committee*, Jerusalem, June 2020.

101 Karim Nashashibi and Yitzhak Gal, *Gaza: The Water–Energy–Governance Nexus – a Plan of Action for Saving What Has Been Achieved*, 2019, available at: <https://www.kas.de/documents/268421/8457122/Gaza+The+Water-Energy+Governance+Nexus.pdf/43b30628-9635-e74f-a975-a5c3329aac88?version=1.0&t=1583501742254>.

102 S. Arie, above note 89.

103 CMWU, *Damage Assessment Report for CMWU Main Building & Al Nusirat Pump Station*, Gaza City, 2011.

104 Office of the Quartet, above note 100; ICRC, *Israel and the Occupied Territories: Concept Note for Helping to Build People's Resilience to the Humanitarian Consequences of Chronic Difficulties in the Gaza Strip*, Geneva, 2019; K. Nashashibi and Y. Gal, above note 101.



generators for power in between.<sup>105</sup> When there is not enough diesel to operate the generators, several of the municipal or hospital wastewater treatment plants discharge over the surrounding soil – and into the aquifer or the sea.

The conditions for cholera are so rife and predictable that journalists and think-tanks have drawn attention to the risks faced by Israel.<sup>106</sup> The decline in the baseline resilience of water and wastewater services in Gaza creates a system-wide vulnerability such that if any single point of failure is rendered inoperable, the entire service risks collapse, while coping mechanisms to safeguard public health are largely inadequate in face of the lack of safe alternatives.

## Consequences and implications

Considered together in [Table 2](#), the review of policy and research papers, observations, and the impact of explosive weapons in the protracted urban armed conflicts in Iraq, Yemen and Gaza reveals several conclusions that may be drawn about how effects reverberate from an attack on water/wastewater infrastructure through to the outbreak and transmission of infectious diseases. As previously noted, any conclusions drawn should be done from within the context of the protracted armed conflict in which they occur.

Amongst a considerable amount of other findings, a comparison of the cases reveals a clear association between the risk of cross-contamination between drinking water and wastewater, and the observed outbreak or transmission of infectious disease. There was significant information in each of the cases about the degradation of the baseline resilience of the water and wastewater services, and, in the case of Basrah, this is detailed to a considerable extent.

The pattern is reflected in the blue lines of [Figure 6](#), which plots a typical pattern of degradation of water and wastewater services against much more general trends of increasing risk of cross-contamination, risk of outbreak or transmission of disease, and quality of the evidence base about the reverberating effects. The trend of increased risk of cross-contamination (shown in blue) is not detailed because of the very many potential determinants which are not related to an attack (e.g. the lines were not separated by design, the materials used were faulty, etc.). The increased risk of transmission of infectious disease (shown in red) is directly related to the risk of cross-contamination. Further detailing of this trend would require controlling for the previously discussed non-attack-related variables (such as endemic pathogens, new strains introduced to a population, environmental factors, etc.).

105 ICRC, *Towards More Effective Humanitarian Operations in Urban Protracted Armed Conflicts: Lessons from the Application of the “Operational Resilience Approach” and “Institutional Learning” in Gaza*, Geneva, 2021.

106 Shira Efron, Jordan R. Fischbach, Ilana Blum, Rouslan I. Karimov and Melinda Moore, *The Public Health Impacts of Gaza’s Water Crisis: Analysis and Policy Options*, RAND Corporation, Santa Monica, CA, 2018; Michelle Malka Grossman, “Gaza Sewage Crisis is a Ticking Timebomb for Israel”, *The Jerusalem Post*, 17 March 2016, available at: <https://www.jpost.com/arab-israeli-conflict/gaza-sewage-crisis-is-a-ticking-timebomb-for-israel-448335>.

Table 2. Parsing of the cases in the “Reverberating effects of attacks in protracted armed conflict” section, in relation to establishing the level of confidence of the knowledge about reverberating effects along the attack–water/wastewater service–infectious disease chain

Case	Relevant direct impact	Underlying conditions/ baseline resilience of water/wastewater services	Associated reverberating effects on disease transmission	Level of confidence in the attack–water/ wastewater service– disease consequential chain	Expected changes in level of confidence in the consequential chain
Basrah (1991– 2020)	2003: Damages to main drinking water supply channel; leaking transmission pipes	Water scarcity, water quality low, lack of alternative sources of water, safe wastewater treatment low, inadequate electricity supply, ageing infrastructure, and health system low. Cholera is endemic  Baseline resilience: Low Risk of cross-contamination between wastewater and water: High	Cholera outbreaks 2007 – over 4500 cases 2015 – over 2000 cases in Basrah Governorate. Over 100,000 cases of diarrhoea and vomiting	The decline of WASH services over decades is very well documented. The cholera outbreaks were predicted. The high rate of diarrhoea is very well documented	Level of confidence is expected to increase. The transmission of cholera ceased/greatly decreased when crucial repairs were carried out
Yemen (2011– 2020)	Damage or destruction of wastewater and drinking water supply infrastructure throughout the country	Water scarcity, lack of proper wastewater collection and treatment, unreliable and intermittent electricity supply, lack of alternative sources of water. Compounded by unregulated alternative	Cholera outbreaks 2016, 2017 > 2 million cases	Once cholera had broken out the first time, and following battle damage assessments of the conditions of WASH services, the further spread of cholera	Level of confidence is expected to increase. Current levels of documentation are much greater now than at the beginning of the hostilities

*Continued*

TABLE 2.  
Continued

Case	Relevant direct impact	Underlying conditions/ baseline resilience of water/wastewater services	Associated reverberating effects on disease transmission	Level of confidence in the attack–water/ wastewater service– disease consequential chain	Expected changes in level of confidence in the consequential chain
		sources of water. Weak health system. Cholera is endemic Baseline resilience: Low Risk of cross-contamination between wastewater and water: High		(which occurred) was predictable, and indeed, predicted	
Gaza (2001–2020)	Damage or destruction to water supply and wastewater infrastructure throughout the territory	Water scarcity, water quality low, lack of alternatives, safe wastewater treatment low, inadequate electricity supply, and health system low Baseline resilience: Low Risk of cross-contamination between wastewater and water: High	Cases of diarrhoea seen to triple during hostilities in 2014	The decline of WASH services and spread of diarrhoea is well documented	Level of confidence is expected to increase. Even prior to the hostilities of 2021, Ministries and international non-governmental organizations (NGOs) have been documenting the reverberating effects of previous rounds of hostilities

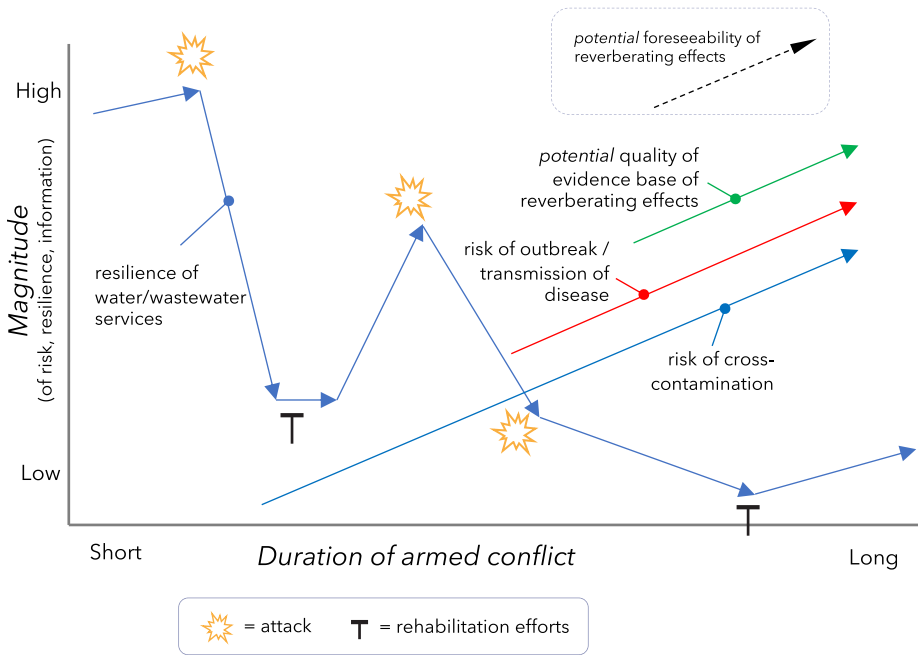


Figure 6. Compounded figure based on the review of Yemen, Gaza and Basrah showing the trends between the baseline resilience of water and wastewater services, the risk of cross-contamination, and the associated consequences in terms of infectious disease. The combination of rehabilitation of infrastructure (which restores service delivery) and emergency preparedness planning (e.g. identification of alternative sources to be used as a backup if the primary source fails) together help to strengthen the resilience of the services. The confidence in knowledge about the degradation of the baseline resilience is high, relative to the confidence in the knowledge of the likelihood of cross-contamination and its cause of infectious disease, for the reasons explained in the text. The figure also shows that the quality of the evidence base and the foreseeability of reverberating effects can increase over time, subject to intelligence-gathering efforts.

As such, establishing a cause-and-effect relationship along the attack–water/wastewater service–infectious disease consequential chain with a high degree of certainty would oblige tests that controlled for the influence of these other variables on the outcome observed (as this would allow judgement of the extent to which the variable in question is significant).

Indeed, this article’s analysis suggests that more research can be done to factor in the specific characteristics and vulnerabilities of civilian infrastructure and services in order to mitigate civilian harm during conduct of hostilities.<sup>107</sup> As just one example, the analyses required to feed into targeting procedures should seek to identify the visible infrastructural laydown of water and wastewater

107 To complement Sahr Muhammedally, “Preparedness in Urban Operations: A Commander’s Planning Checklist to Protect Civilians”, *Humanitarian Law & Policy Blog of the ICRC*, 11 May 2021, available at: <https://blogs.icrc.org/law-and-policy/2021/05/11/preparedness-in-urban-operations/>.

services. These could be mapped as part of an IPOE or prior to an attack using geospatial and systems mapping techniques, and specify a range of points of particular hazard (including single points of failure as well as upstream and mid-stream infrastructure) which if rendered inoperable would affect the largest part of the population in the service area. Taken as part of the IPOE, the information of critical civilian infrastructure in the area of operations would be improved through enhanced stand-off recognition (remote sensing techniques, satellite imagery) or directly from allied/local forces or from local authorities.

The effort could be complemented by improved systems-level understanding obtained by involving the relevant engineering expertise and using other open-source information which could help to identify the population served by specific ground-level objects (i.e. water treatment plants) and sub-surface objects (transmission lines under main roads, or bridges). Carried out prior to an attack, the effort can inform weapons selection (usage and restrictions), identification of restricted targets, and the development of a no-strike list. A similar effort would be expected if planning multiple attacks during a protracted armed conflict, since infrastructure condition and use changes with time. Routine ISR (intelligence, surveillance, and reconnaissance) data collection procedures would have to be prioritized and augmented when in the midst of hostilities, to accommodate for the suspected reverberating effects.

Because of the greater level of knowledge that it is possible to acquire, as well as the general awareness that existing services are very likely to be degrading due to reduced operations and maintenance, the quality of the evidence base can increase as the conflict prolongs. This is shown by the green line of [Figure 6](#). What the local health services and humanitarian actors know about the cholera outbreaks in Yemen in 2021 is much better than what was known when they occurred in 2018, for example.

With the importance of understanding the underlying conditions/baseline resilience of any service in mind, the patterns revealed show that reverberating effects of an attack can be expected, to an extent (dashed line of [Figure 6](#)). It would not be unreasonable to expect an outbreak of infectious disease if a wastewater treatment plant were damaged, and if its proximity to drinking water sources or infrastructure meant there was a high risk of cross-contamination, for example. It follows that the extent of measures that parties to armed conflict must take to avoid or at least minimize such reverberating effects also increases as the conflict prolongs.

In short, it is possible to establish the same level of confidence in the three-element (attack–water/wastewater service–infectious disease) consequential chain as in the double-element links between them, through a suite of robust epidemiological and damage assessment studies. The effort required to obtain this level of confidence is very much easier to specify than it is to execute, however. Combatants, lawyers, policy-makers and humanitarian organizations alike will thus inevitably be obliged to answer the earlier theoretical and practical questions about uncertainty. For the topic at hand, the question will be some variant of: if robust epidemiological and damage assessment studies cannot prove an outbreak of

cholera was due primarily to the incidental damage inflicted by an attack on a wastewater treatment plant, does that mean that they are not linked?

Those seeking to quantify and reduce civilian harm during the conduct of hostilities must therefore decide how they will deal with uncertainty. The decision taken may matter little to humanitarian practitioners and those tasked to stabilize infrastructure and service delivery, considering how humanitarian work continues unabated by any equivocalty.<sup>108</sup> The answer matters considerably for those involved in the conduct of military operations and, in particular, the targeting process, on the other hand, because they are compelled by their own targeting procedures to reduce the complexity of their operating environment and ensure compliance with the laws of armed conflict/IHL.

In the absence of the preferred level and quality of information, those who seek to reduce civilian harm should follow a “precautionary approach” which assumes the causal links and chains, and which is readily adapted to standard military operational planning process and targeting procedures.

## **Annex: Literature on the effects of war on WASH systems**

Table A presents an incomplete list of documentation, mostly by humanitarian water engineers charged to repair water and sanitation systems damaged by military attacks. Read collectively, the reports reveal patterns about the influence of the resilience of the service before the attack occurs (or “baseline resilience”), cross-contamination between wastewater and drinking water, and, to a lesser link, observed links with outbreak or transmission of infectious diseases.

108 Indeed, the assumption that improved and sustained levels of public health relies on good WASH services is the foundation for most humanitarian and development programmes, whether humanitarian, “development” or military.

Table A. *Published and unpublished literature on the effects of war on WASH systems*

Location	Approximate year	Reference	Topics covered/summary
<b>First tier: Documentation of direct impact</b>			
Beirut	1989/1990	109	Description of infrastructure directly damaged by hostilities
Aden	1994	110	
Baghdad	1991	111	
Kigali and Butare	1994	112	
Sarajevo and Srebrenica	1992–1994	113	
Grozny, Chechnya	1995–1998	114	Description of the relief effort, including graph of number of people served water
Donbass	2017	115	Description of infrastructure directly damaged by hostilities, and number of people affected
<b>Second tier: Documentation of direct and indirect impact</b>			
Mogadishu and Kismayo	1991/1992	116	Documentation of damage to physical and institutional components
Dilli	1999	117	
Huambo	1985+	118	

*Continued*

109 Pier Giorgio Nembrini, “Lebanon: Water Supply Problems during the 1989 and 1990 Wars”, in ICRC, *Water and War: Symposium on Water in Armed Conflict, Montreux, 21–23 November 1994*, Geneva, 1994.

110 Aloys Widmer, in ICRC, *ibid.*

111 Riccardo Conti, in ICRC, above note 109.

112 Riccardo Conti, in ICRC, above note 109.

113 Markus Baechler, in ICRC, above note 109.

114 Robert Hodgson and Alain Oppliger, “After the Battle of Grozny”, in ICRC, *War and Water*, Geneva, 1999.

115 Mark Buttle, Volodymyr Kalinin and Stas Dymkosvskyy, *Incident Analysis January–June 2017*, 2017, available at: [https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/9\\_wash\\_cluster\\_alert\\_bulletin\\_issue\\_9.pdf](https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/9_wash_cluster_alert_bulletin_issue_9.pdf).

116 P. Giorgio Nembrini and Riccardo Conti, “In a Town Scarred by War”, in ICRC, *War and Water*, Geneva, 1999.

117 P. Giorgio Nembrini, “Cities in War: Thirsty Cities – Dili (East Timor)”, Geneva, August 2000, available at: <https://www.thirstycitiesinwar.net/>.

118 P. Giorgio Nembrini, *Huambo (Angola): Water Supply in a War Torn Town: Evolution and Impact of the Different Interventions Since 1985*, Occasional Paper No. 3, Cities in War: Thirsty Cities, Geneva Foundation, Geneva, 2001.



TABLE A.  
Continued

Location	Approximate year	Reference	Topics covered/summary
Novi Sad	1999	119	
Monrovia	1990+	120	
Kabul	1992–1994	121	
Jenin	2002	122	
Basrah	2003	123	
Southern Lebanon	2006	124	Documentation of village-level water infrastructure (e.g. water reservoirs); development of analytical frame of water and armed conflict
Gaza	2008–2009	125	Documentation of damage to physical and institutional components
Gaza	2008–2009	126	

Continued

- 119 P. Giorgio Nembrini, *Novi Sad (Republic of Yugoslavia): How the Water Supply of the Town Was Affected by the Nato Campaign of 1999*, Occasional Paper No. 5, Cities in War: Thirsty Cities, Geneva Foundation, Geneva, 2001.
- 120 P. Giorgio Nembrini, C. Smith, A. Petters, *et al.*, *Cities in War: Thirsty Cities – Monrovia (Liberia). Water Supply for Monrovia During and after the Civil War*, Occasional Paper No. 4, Cities in War: Thirsty Cities, Geneva Foundation, Geneva, 2001.
- 121 P. G. Nembrini, P. Jansen, J. F. Pinera, R. Luff, O. Bernard, M. Weber and M. J. Elliot, *Kabul Water Supply: Evolution Since the 1992–94 Civil War*, Occasional Paper No. 7, Cities in War: Thirsty Cities, Geneva Foundation, Geneva, 2002.
- 122 Mark Zeitoun, “Conflict and Water in Palestine – the Consequences of Armed Conflict on Drinking-Water Systems in Jenin, West Bank”, in Imad Khatib, Karen Assaf, Dominique Claeys and Ayman Al Haj Daoud (eds), *Water Values and Rights*, Palestine Academy Press, Ramallah, Palestine, 2005.
- 123 P. G. Nembrini, C. Generelli, A. Al-Attar, *et al.*, above note 44.
- 124 Mark Zeitoun, Karim Eid-Sabbagh and Jeremy Loveless, “The Analytical Framework of Water and Armed Conflict: A Focus on the 2006 Summer War Between Israel and Lebanon”, *Disasters*, Vol. 38, No. 1, 2014.
- 125 Pier Giorgio Nembrini and A. Moreau, *The Gaza Strip: The Last “Ghetto”: An Organized Deprivation and a Denied Urban Development*, Occasional Paper No. 9, Cities in War: Thirsty Cities, Geneva Foundation, Geneva, 2009.
- 126 P. Giorgio Nembrini, *The Gaza Strip: The State of the Water Supply after the 2008–2009 War*, Occasional Paper No. 10, Cities in War: Thirsty Cities, Geneva Foundation, Geneva, 2010.

TABLE A.  
Continued

Location	Approximate year	Reference	Topics covered/summary
<b>Third tier: Documentation of cumulative impact and/or reverberating effects</b>			
Kabul	2001	<sup>127</sup>	Condition of public and private water and wastewater services, pre- and post-war; impact of armed conflict on water infrastructure, water authority, buildings; assessment of humanitarian interventions (especially regarding partnerships) by different actors
	1985–2003	<sup>128</sup>	Impact of protracted conflict on civilian population and municipal authorities; reconstruction efforts by several NGOs
Jaffna	1990–2006	<sup>129</sup>	Condition of public and private water and wastewater services, pre- and post-war; impact of armed conflict on water infrastructure, water authority, buildings; assessment of humanitarian interventions (especially regarding partnerships) by different actors
Monrovia	1992–2003	<sup>130</sup>	
Béni	1994–2003	<sup>131</sup>	
Port-au-Prince	1986–2004	<sup>132</sup>	
Port-de-Paix	1986–2004	<sup>133</sup>	
Grozny	1994–2005	<sup>134</sup>	

*Continued*

127 Jean-François Pinera and Robert Reed, “A Tale of Two Cities: Restoring Water Services in Kabul and Monrovia”, *Disasters*, Vol. 33, No. 4, 2009; Jean-François Pinera and Robert Reed, “Restoring Services, Rebuilding Peace: Urban Water in Post-Conflict Kabul and Monrovia”, *Water International*, Vol. 36, No. 2, 2011.

128 Stephan Magnaldi and Jessica Patera, “Kaboul, de la destruction à la reconstruction”, in François Grünewald and Eric Levron (eds), *Villes en guerre et guerres en villes*, Editions Karthala, Paris, 2004.

129 Jean-François Pinera, “Urban Armed Conflicts and Water Services”, *Waterlines*, Vol. 31, Nos. 1 and 2, 2012.

130 J.-F. Pinera and R. Reed, above note 127.

131 J.-F. Pinera, above note 129.

132 Jean-François Pinera, *Cities, Water and War: Looking at How Water Utilities and Aid Agencies Collaborate in Cities Affected by Armed Conflicts*, Lambert Academic Publishing, Loughborough, 2011.

133 *Ibid.*

134 *Ibid.*

TABLE A.  
Continued

Location	Approximate year	Reference	Topics covered/summary
Huambo, Angola	1998	<sup>135</sup>	Collaboration between a “development” NGO and ICRC on an emergency rehabilitation water project
	1961–1990s	<sup>136</sup>	Impact of protracted conflict on civilian population and municipal authorities; reconstruction efforts by several NGOs
Dushanbe and Kulyab, Tajikistan	1992–1996	<sup>137</sup>	Explanation of cross-contamination of sewage and drinking water; effects of economic decay on water systems
Mogadishu, Somalia	1980s+	<sup>138</sup>	Measuring of groundwater quality (e.g. salinity) to trace impact of informal water provision and well-drilling
Gaza	2008–2009	<sup>139</sup>	“The Goldstone Report”. Forensic analysis complemented by health records and testimonies of victims; documentation of damages to a well field and Gaza City wastewater treatment plant
Gaza	2008–2009	<sup>140</sup>	“Forensic architecture” approach to interpreting damaged infrastructure

Continued

<sup>135</sup> Mary Daly and Christoph Langenkamp, in ICRC, above note 109.

<sup>136</sup> Jean-Paul de Passos, “Huambo, une capitale provinciale au cœur de la guerre civile”, in F. Grünewald and E. Levron, above note 128.

<sup>137</sup> Les Roberts and Katayon Faramusova, in ICRC, above note 109.

<sup>138</sup> Pier Giorgio Nembrini and Riccardo Conti, in ICRC, above note 109.

<sup>139</sup> United Nations Human Rights Council, *Human Rights in Palestine and Other Occupied Arab Territories: Report of the United Nations Fact-Finding Mission on the Gaza Conflict (the “Goldstone Report”)*, New York, 2009.

<sup>140</sup> Eyal Weizman, *The Least of All Possible Evils*, Verso, London, 2011.

TABLE A.  
Continued

Location	Approximate year	Reference	Topics covered/summary
Donbass	2015–2017	<sup>141</sup>	Detailed investigation of many interlinking services. UNICEF includes risk analysis
Aden/Yemen	2011–2019	<sup>142</sup>	Documentation of damage to WASH, agricultural, energy, health services
West Bank and Gaza	2006–2017	<sup>143</sup>	
Various	Multiple	<sup>144</sup>	Review of over 700 pieces on water and war. Identification of knowledge and conceptual gaps

141 Organization for Security and Co-operation in Europe (OSCE), *Access to Water in Conflict-Affected Areas of Donetsk and Luhansk Regions*, September 2015, available at: <https://www.osce.org/files/f/documents/0/6/183151.pdf>; OSCE, *Hardship for Conflict-Affected Civilians in Eastern Ukraine*, February 2017, available at: <https://www.osce.org/files/f/documents/4/0/300276.pdf>; UNICEF, *Risk Assessment of the “Voda Donbasu” Water System*, October 2020, available at: <https://www.unicef.org/ukraine/en/reports/VD-risk-assessment-2019>.

142 Jeannie Sowers and Erika Weinthal, “Humanitarian Challenges and the Targeting of Civilian Infrastructure in the Yemen War”, *International Affairs*, Vol. 97, No. 1, 2021.

143 E. Weinthal and J. Sowers, above note 80.

144 Juliane Schillinger, Gül Özerol, Şermin Güven-Griemert and Michiel Heldeweg, “Water in War: Understanding the Impacts of Armed Conflict on Water Resources and Their Management”, *Wiley Interdisciplinary Reviews: Water*, Vol. 7, No. 6, 2020.