URBAN WARFARE ECOLOGY: A Study of Water Supply in Basrah

MARK ZEITOUN, HEATHER ELAYDI, JEAN-PHILIPPE DROSS, MICHAEL TALHAMI, EVARISTO DE PINHO-OLIVEIRA AND JAVIER CORDOBA

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Abstract

This article assesses the impact of armed conflict on the drinking water service of Basrah from 1978 to 2013 through an 'urban warfare ecology' lens in order to draw out the implications for relief programming and relevance to urban studies. It interprets an extensive range of unpublished literature through a frame that incorporates the accumulation of direct and indirect impacts upon the hardware, consumables and people upon which urban services rely. The analysis attributes a step-wise decline in service quality to a lack of water treatment chemicals, a lack of spare parts, and, primarily, an extended 'brain-drain' of qualified water service staff. The service is found to have been vulnerable to dependence upon foreign parts and people, 'vicious cycles' of impact, and the politics of aid and of reconstruction. It follows that practitioners and donors eschew ideas of relief–rehabilitation–development (RRD) for an appreciation of the needs particular to complex urban warfare biospheres, where armed conflict and sanctions permeate all aspects of service provision through altered biological and social processes. The urban warfare ecology lens is found to be a useful complement to 'infrastructural warfare' research, suggesting the study of protracted armed conflict upon all aspects of urban life be both deepened technically and broadened to other cases.

Introduction

This article assesses the impact of over three decades of armed conflict on the drinking water service of Basrah in order to draw out both its implications for emergency relief programming and its relevance to urban studies. Both aims are important because classical relief interventions, originally designed for acute rural conflicts, are increasingly found by practitioners to be inappropriate for chronic conflict occurring in urban settings, yet there is a lack of critical thought and research dedicated to supporting any progress in that direction (ICRC, 2015a). The roughly 50 million urban residents currently living in such contexts (Dross *et al.*, 2016) stand to gain from even incremental improvements in programming and research.

A discussion on the development of urban warfare ecology is followed by the identification of data gaps and conceptual shortcomings in policy and academic writing on urban infrastructure and armed conflict. A novel frame for gauging impact is developed with the understanding that armed conflict and sanctions permeate all aspects of social and biological ecosystems, with a focus on drinking water services. The frame serves to interpret an extensive set of empirical data found in public and unpublished reports and research articles (from 1978 to 2013), as well as interviews with long-standing Iraqi and expatriate water engineers.<FN1> The sources of vulnerability of the service are then identified, and practical and theoretical implications discussed.

The analysis finds that a step-wise drop in water service quality 'from world class to worst class' has many facets, including a lack of water treatment chemicals (chlorine and aluminium

sulfate), a lack of spare parts (e.g. alum dosing pumps), and, primarily, an extended 'brain-drain' of qualified water service staff. The service is found to be vulnerable to dependence upon foreign parts and people, vicious cycles of direct and indirect impact, and the politics of aid and of reconstruction. The analysis also asserts that, where an urban warfare biosphere has developed, the design of relief programming should replace its assumptions about progress through an RRD model for an acceptance that reality is more accurately described as exacerbations within a chronic conflict. It thus emphasizes sustained and integrated support to local water service operators, for example, and an immediate and minimal goal of avoiding the vicious cycles identified.

In pegging the degradation of the service directly to military or political events, the analysis breaks from the macro-scale journalistic approach that sees cities simply as 'impact points' of warfare (see discussion in Graham 2006: 263). Apart from the practical relevance of an urban warfare ecology reading, then, the detailed 'bottom-up' analysis of *impact* and *services* is also found to be a useful and more focussed complement to the 'top-down' 'infrastructural warfare' work (e.g. Agre 2001, Graham 2005) that emphasizes the intent of belligerents. For reasons discussed herein, furthermore, the urban warfare ecology approach may be considered a political engineering equivalent to 'forensic architecture' work (Weizman 2007, Weizman 2011).

Urban ecology of war and critical urban research

In their study of the impact of protracted war and sanctions in Syria and Iraq, Dewachi *et al*. (2014) found that the health care systems had been both regionalized and militarized, thereby complicating any potential reconstruction—if ever there were to be an end to the conflict. In pressing the point about these changed 'therapeutic geographies', and also tracing the development pathways of multi-drug-resistant organisms in war-wounded in Iraq, Syria and Lebanon (Sahli *et al.* 2016; Abu Sitta, Dewachi and others (2016) suggest the dynamics be interpreted through interdisciplinary analysis referred to as the 'ecology of war'.

The assertion is that a complex biosphere of war develops when armed conflicts alter every element of life-sustaining processes, notably the 'physical infrastructure, and the biological and social environments' (Abu Sitta *et al.*, 2016: 2). A particular set of health needs are generated by the complex interactions that develop as warfare (in all of its forms) incessantly ravages or wears down hospital staff, equipment and infrastructure, and injures and re-injures the bodies and psyches of patients. The authors argue that the discipline of war surgery is ill-equipped to meet such needs, for having grown as a response to acute (and largely rural) conflicts, and any effective 'relief' or 'development' intervention undertaken in such contexts will be done with the understanding that there is no crisis. There is, instead, an enduring and particular biosphere shaped by the protracted armed conflict. As this determines the victims' needs, it should also shape the range of responsive or pre-emptive interventions, and these are likely to be distinct from those developed for temporary emergencies (Abu Sitta and Dewachi, 2016; Abu Sitta, *et al.*, 2016).

The environmental conservation scientific community has also outlined warfare ecology as a field of study that applies ecological theory, methods and empirical studies to the destruction of habitat and disorganization of social systems (Machlis and Hanson, 2008: 730). In a less purely ecological and more politically aware form, warfare ecology has served to assess the 'pervasive and often diffuse effects' of the Israeli occupation of Palestinian territory (Mason, 2011: 11).

Urban warfare ecology, then, is interpreted as the interdisciplinary study of the set of interacting biophysical and social ecosystems that shape all urban space—otherwise known as the 'urban biosphere'. More specifically, urban warfare ecology employs a range of disciplines—from

engineering to medical, environmental and political science—to study the myriad of interdependent institutions, transportation systems, disease transmission routes, ICT flows, social networks and urban services that support life in a city. As the study of Basrah will show, drinking water services are seen as a particularly significant urban ecosystem within the urban warfare biosphere, because of their important connection to so many other services and processes.

Loosely applied as it is here, urban warfare ecology both challenges and builds neatly on programming and academic urban research. Though the current fighting in cities throughout the Middle East is less a novel than a recurrent phenomenon (see e.g. Davis, 2003), the protracted nature of these conflicts has caught the relief industry off-guard, and is eliciting collective reflection on its programming. Perhaps the most blatant deficiency is the enduring assumption that the fighting will end at some point, allowing progression from relief interventions to rehabilitation projects and 'development'<FN2> programmes (see the 'RRD' work of e.g. Duffield, 1994, Keen, 2007, Mosel and Levine, 2014), with agencies specialized in each phase passing an imaginary baton on to the others.

A number of projects (e.g. *Villes en guerre* (Groupe URD), *Conflict in Cities* (the Centre for Urban Conflicts Research, Cambridge University), *Urbanization and Emergencies* (Harvard Humanitarian Initiative), and *Understanding the Tipping Point of Urban Conflict* (University of Manchester) are taking a problem-solving approach to the longer-term urban challenges. These typically consider the influence of basic urban characteristics (such as the large spatial scale of challenges, density of populations, etc. (e.g. BRC, 2013, USAID, 2013) upon different sectors such as wastewater (Bastable and Russell, 2013), energy (Lahn and Grafham, 2015), shelter (Skat-IFRC, 2012), and public health (Patel and Burke, 2012, Rouhani *et al.*, 2012). This body of knowledge recognizes the fundamentally political nature of the challenge, but generally avoids confronting it.

Academic research that has examined interdependent urban infrastructure from a technical perspective of complex adaptive systems has concentrated on understanding different modes of infrastructure failure. The term 'cascading failure' is of particular relevance to the case studied here, as this is defined to occur when 'a disruption in one infrastructure causes the failure of a component in a second infrastructure, which subsequently causes a disruption in the second infrastructure' (Rinaldi *et al.*, 2001: 22). Efforts at controlling cascading failure emphasize solutions deriving from information technology (Zimmerman and Restrepo 2009) or risk analysis (Little, 2002), and note the particularly challenging complexity of water and wastewater infrastructure (Gillette *et al.*, 2002).

Critical thought and politics are also sidestepped in the otherwise considered body of work on disaster preparedness. Most of this is designed for stable political and institutional situations like the US (AWWA, 2001; CDCP-AWWA, 2012), and is at best tangential to urban areas in the current Middle East. The much more complex hybrid governance arrangements observed in the degrading cities of Iraq, at least, obliges a frame that can test the extent to which armed conflict has distorted pre-conflict urban life, possibly into a significantly different biosphere.

In contrast, critical academic urban studies research often begins with the inherent vulnerabilities of people in densely populated areas to a wide range of issues, including social conflict, predatory governance systems, climate change, and natural disasters (e.g. Pelling, 2003; Loftus and Lumsden, 2007; Satterthwaite, 2013; Shapely, 2013). Urban scholars have recognized technological networks and networked infrastructure to be a constitutive feature of life in cities (Kaika and Swyngedouw, 2000; Graham and Marvin, 2001; Coward, 2009), a source of political power in and of themselves (Meehan, 2014) or a determining element of social control (Mayntz and

Hughes, 1988). While the focus has been primarily on traditional infrastructure systems such as water, energy, and public health, the crucial importance of the people who operate those systems has also been acknowledged (see e.g. Anand, 2005; Barnes and Newbold, 2005). McFarlane and Rutherford (2008: 363), for example, refer to the 'inherently political nature of networked urban infrastructure' to describe the complexities in the web of people employing the same arrangement of systems.

Much of the discussion of disruption of urban infrastructure networks focuses on structural inequalities in terms of access to it (such as McFarlane, 2010), including examination through the concept of metabolism (Silver, 2016), or disruptions induced by natural disasters, or by privatization and neo-liberalism (Graham and Marvin, 2001). Disruptions due to armed conflict have generated only a fraction of the critical attention paid to both the political economic driving forces of war and the effect of the militarization of urban life and 'space' (e.g. Herold, 2002; Graham, 2006; 2012).

The critical urban studies work most relevant to warfare ecology may be that concerned with investigation of the motives of belligerents active in urban areas, namely within thinking on 'infrastructural warfare' (Agre, 2001; Graham, 2005), 'place annihilation' (Hewitt, 1983), and 'urbicide' (Coward, 2008). The research sheds light on how belligerents use urban space to further their military objectives. The US Army's (2008) classified field manual *Intelligence Support for Urban Operations* asserts, for instance, that the selection of targets, objectives and weaponry rely upon solid understanding of networked urban infrastructure and transportation patterns (see also Patterson, 2000).

The work has been built on by studies of 'infrastructural violence' (Jabary Salamanca, 2011), and 'network-centric violence' (Coward, 2009) in the context of armed conflict. Collectively, this 'infrastructural warfare' body of work examines the intentional manipulation, disconnection, and destruction of critical infrastructure as a means of control, repression and demodernization. The top-down approach does not detail the impact on urban *services,* however, which include people and consumables, as well as infrastructure and other forms of hardware. On the whole, furthermore, the research field of urban studies has tended to view the technological aspects of infrastructure as a black box, or as dominated by technical and professional discourses. There thus remains an acknowledged need to 'break down the barriers between a range of largely separated debates about cities, technologies and infrastructure networks' (Graham and Marvin, 2001: 33). There is considerable merit, in other words, in blending the technical and political understanding of urban warfare ecology with the body of critical urban research—in very much the way that the profession of architecture has contributed to the discussion through its bottom-up 'forensic' exploration of destruction (Segal, 2003; Weizman, 2007; 2011).

The cumulative and cyclical impact of armed conflict on urban services

> 'With the changes in military technology and the strategy of warfare, including the capacity to target precisely and destroy a country's infrastructure, there may be many more indirect than direct injuries and deaths.'
> (Harvard Study Team, 1991: 980)

It is perhaps the complexity of war in cities more than any other urban feature that calls classic relief efforts into question. Particularly where there is endemic violence and a lack of collaborative (or existence of coercive) central control—as in IDP camps, or slums—armed conflict

can contribute to the tensions, and possibly fuel the wider war (Norton, 1993; Keen, 2007; IASC, 2011; Pullan, 2011; Moser and McIlwaine, 2014). Tensions can be exacerbated by the allure that cities hold for warring factions on account of their high concentration of valuable economic and political targets (see Gregory, 2010; Pinera, 2011: 92), the advantage of the psychological impact of attacks (Graham, 2004), and the preference of irregular forces engaged in 'asymmetric warfare'. The proximity of urban residents to each other further increases social tensions, by putting the entire population at greater risk of communicable diseases—as with the cholera epidemic in Syria in 2013 (Luff, 2014) and Iraq in 2015 (WHO, 2015a), as well as the outbreaks predicted in Iran (Medact, 2014).

The public health risks are compounded by the large movements of people into cities, as outward fluxes of people fleeing armed combat can occur just before an inward movement of people seeking shelter from fighting in other cities. Both movements can follow years of rural-to-urban migration driven to different degrees by changes in the national economy, drought, or agricultural reform (for the case of the war in Syria, see De Châtel, 2014; Selby et al 2018). The resultant informal settlements are not usually served (or well-served) by the public services typically provided by local government departments, and so the communities self-organize to provide these. As a result, people in different parts of the same urban area have very different levels of service, and the social inequities arising from urban fragmentation, particularly for drinking water services, can increase the chance of tensions with the local authorities or neighbours (Gandy, 2008; MacKillop and Boudreau, 2008).

Such inherent 'urban' complexities are compounded by the previously discussed multiple facets and interdependencies of the services themselves. The treatment and delivery of drinking water, for instance, requires a power supply to run the pumps, chemicals to cleanse the unsafe water, and the people and institutions that manage it all. As will be shown, the 'inherently political nature' (to return to McFarlane and Rutherford's term) of the water service in Basrah is certainly apparent in the construction, reconstruction and re-reconstruction efforts, even if it is not militarized and reorganized to the same extent as public health services in Syria and Iraq.

Those who wage wars clearly do not feel obliged to support the theory that progress develops along the RRD continuum (see Perrin, 2001: p x). Different parts of Beirut suffered continuously from 1982 to 1990 (World Bank, 1983; Nembrini, 1994), for instance, and again in 2006 (GOL, 2006; UNEP, 2007), even if these most recent attacks are sometimes treated in isolation (e.g. Hamieh and Mac Ginty, 2010; Fawaz, 2014; Zeitoun *et al.*, 2014). In Iraq, the experience of prolonged conflict was compounded by the trade embargo imposed on the government by the UN in 1990. Trade sanctions are so common in protracted armed conflict that they should be considered an integral (not distinct) part of them.<FN3> The enduring effect of economic sanctions in Burundi, for instance, has emphasized that problems with electricity and water services 'continue to this day, long outliving the sanctions regime itself' (Bossuyt, 2000: para 79). The impact is felt most directly through restricting the flow of consumables and parts required for routine operations and maintenance, or repairs (see also Hoskins and Nutt, 1997). Cuba's general work-around of US sanctions was similarly challenged when these bit harder in the early 1990s, with a clear impact of reduced funding for water supply, treatment, and sanitation (AAWH, 1997).

'Dual-use' restrictions are particularly problematic for restoring water services. The impact in Gaza of the Israeli denial of a vast range of material deemed to serve military as well as civilian purposes is well-known to those agencies attempting emergency and development efforts there (see PTFP, 2012; OGB, 2017). There are other, less considered, effects of sanctions necessitated by

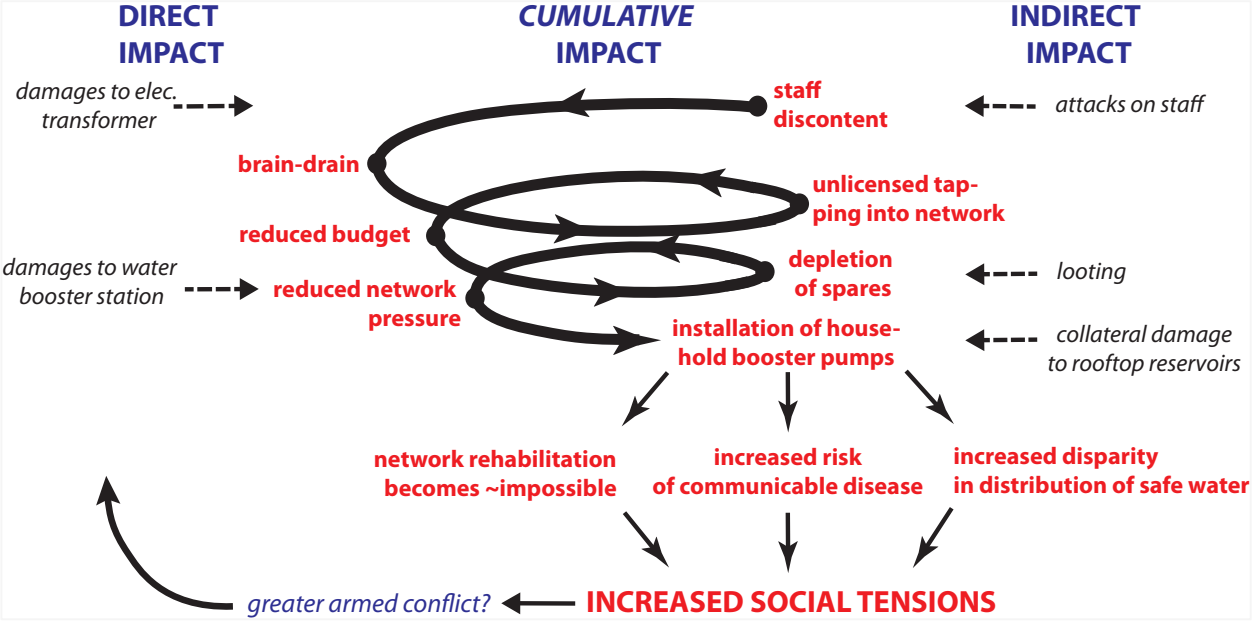
an assessment of an urban water system's vulnerability. These include the degradation associated with the very poor quality of those commodities that do make it past the sanctions, and the discouragement of creative coping mechanisms by the brakes put onto private commerce (personal communication from Jeremy Loveless, 13 December 2013). For example, traders of higher-quality goods (and lending banks such as Barclays<FN4>) that break embargoes were fined a total of US$1.7 billion between 2008 and 2012 (Standard Bulletin, 2012).

Because of increased exposure to hazards, death and disability due to the 'indirect and lingering effects' of armed conflict can be greater than that caused directly by hostilities or immediately after their cessation (Ghobarah *et al.*, 2003, see also Butala *et al.*, 2010). Yet, distinguishing between these types of effects and more direct impact is not straightforward. In developing a basic 'skeleton' framework with which to examine different types of impact for an early Basrah case study, for instance, Barakat (1993: 33) acknowledged that 'there is no clear distinction between the immediate impact of war, the side-effects of that impact and the long-term effects', suggesting attempts to develop a comprehensive frame would be futile.

In order to define the distinction, the *direct impact* of protracted armed conflict here refers to immediate and (usually) physical impact directly from the armed conflict, such as the deaths of water workers or looting of spares stores. *Indirect impact* is understood to mean the impact upon an associated component of a system, usually in the short to medium term, such as the 'brain-drain' that occurs following demotivation of staff, or shortages in spares due to a lack of funds to replace them. Borrowed from thinking on environmental impact assessments, *cumulative impact* is that 'which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions' (Canter and Sadler, 1997: 69). This includes the lack of planning that results from insufficient staff over the long term, or the damaging 'repairs' made to machinery running with poorly calibrated or poorly fitting parts.

While there is considerable literature on the direct impact of armed conflict upon water infrastructure (see e.g. Nembrini, 1994; Nembrini *et al.*, 2003; Nembrini and Moreau, 2009; Pinera and Reed, 2011; Pinera 2012) indirect and cumulative impacts remain wholly understudied. Any combination of direct, indirect or cumulative impacts may affect any of the people, hardware, or consumables that make up the water service, yet this remains insufficiently conceptualized. In much the same way that interdependent or networked infrastructure is prone to 'cascading failure' (to return to Little, 2002; Zimmerman and Restrepo, 2009), the links that exist between the different types of impact can in some urban warfare biospheres create effects that are irreversible. The economic sanctions on Gaza, Iraq and Cuba, for instance, have led to a reduction of funds being transferred from the central government to the water and sanitation sectors (US DIA, 1991; AAWH, 1997; Doyle, 2003; COHRE, 2008). Insufficient funding leads to lack of infrastructure maintenance, which, in turn, leads to more water leaks and lower pressure in the distribution networks—and so higher public health risks associated with the cross-contamination with sewage (EWASH 2012). Considered alongside the interdependencies that exist between the different components of drinking water services, this interdependent pathway can be conceptualized as a vicious cycle of cumulative impact—as in Figure 1.

Figure 1. A vicious cycle of cumulative impact in drinking water service, the result of incremental direct and indirect impacts upon the personnel, hardware, and consumables that make up the service. The accumulation of impact ultimately affects public health, and may contribute to the very conflict which created it. As such, the cycle of impact sits within the cycles of conflict that characterize complex emergencies. Examples from cases documented in Dushanbe (Roberts 2000) and various Afghani cities (Pinera 2011). Based on (ICRC 2015b).



Based on cases documented in Dushanbe (Roberts, 2000) and various Afghani cities (Pinera and Reed, 2011), the figure demonstrates how direct and indirect impact can become nearly permanent. A reduction in staff levels followed attacks upon several members, making follow-up of unlicensed tapping into the water network difficult. This results in reduced cost recovery by the municipality (and may be exacerbated by reduced funding from the central authorities), leading to shortages in spare parts. The resultant reduced pressure in the network leads people to install household-level booster pumps—a negative coping mechanism that could result in serious health problems due to the risk of cross-contamination of the drinking water with contaminated soil water. The decline in service also reduces the bill-collection rates, and dashes hopes of relatively straightforward network repairs, if and when the fighting stops. After some (undefined) point, the cumulative impact is thus not readily reversible, and may, furthermore, increase social tensions leading to the urban violence and armed conflict that originally drove it (though this issue is not considered further here).

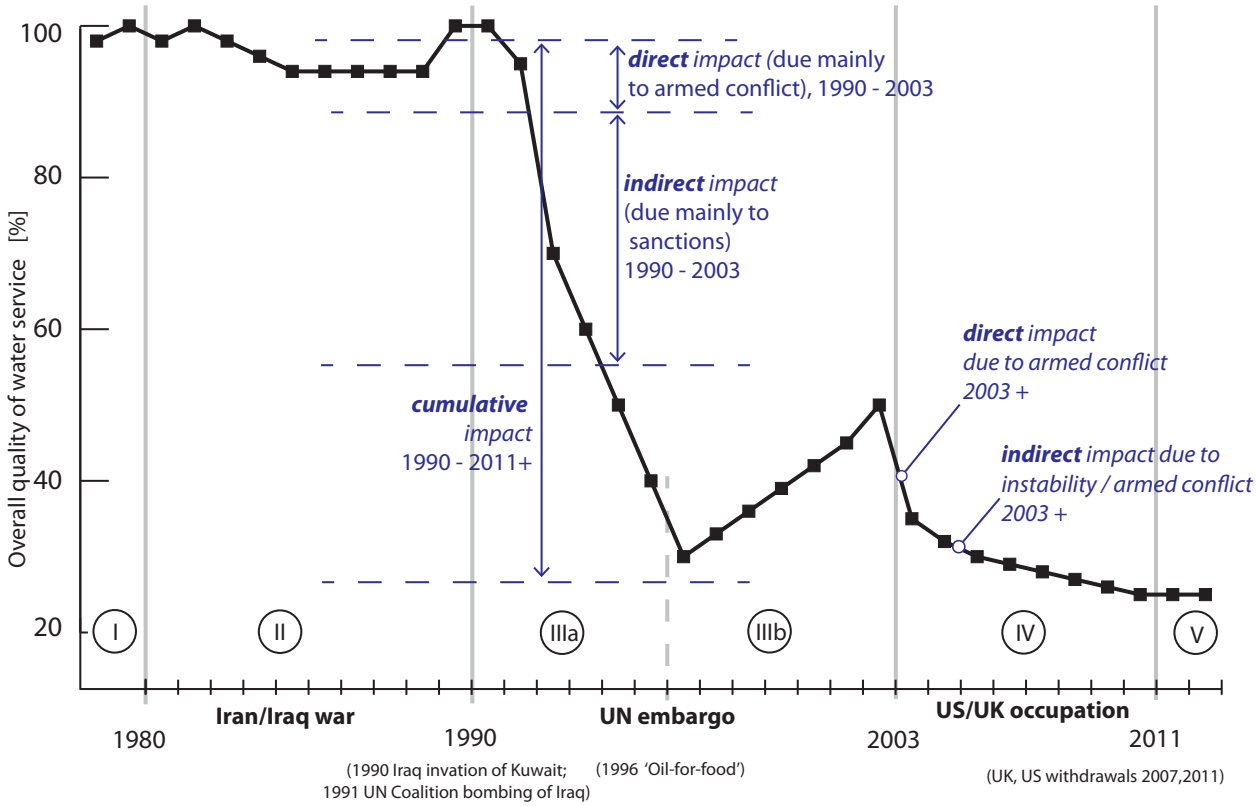
The impact of protracted armed conflict and sanctions on the drinking water service ecosystem in Basrah

The impact of protracted armed conflict and sanctions upon drinking water services in Basrah<FN7> over the 36-year period from 1978 to 2013 is presented in Figure 2. The assessment of quality of service is a composite of the quantity and quality of the water provided, and interpreted within the frame of direct, indirect, and cumulative impact upon hardware, consumables, and people.

The state of drinking water services throughout the period under consideration was very closely pegged to the military and political events shown in Figure 2. The phases defined by the events start with the 'baseline' period prior to the Iran–Iraq war (Phase I); and are followed by the 1980–1988 Iran–Iraq war (II); the UN Security Council-imposed sanctions ('the embargo') from 1990 to 1996, beginning just after the Iraqi invasion of Kuwait in Aug 1990 and before the UN Coalition attacks on Iraq (Jan–Feb 1991) (IIIa); UN Security Council Resolution 986 (the 'Oil-for-food' programme), from 1996 to 2003 (IIIb); the US/UK invasion and occupation 2003 – 2011 (IV); and the ongoing internationalized civil unrest (V).

The baseline used for this analysis is the latter part of the period of political stability (and political oppression), from 1968 to the start of the Iran/Iraq war, in 1980. Numerous reports depict a country that had essentially completed at least the urban parts of its 'hydraulic mission' (see e.g. Swyngedouw (1999) and Allan (2001)), to deliver water to all of its citizens. Drinking water meeting international quality standards was available throughout most cities at a rate ranging from 250 to 450 litres/person/day (Harvard Study Team, 1991; WHO/UNICEF, 1991: 17; Khogali *et al.*, 1996: 3; SIGIR, 2010: 7).

Figure 2. Relative quality of water service delivery in typical urban centres in Iraq (modelled after *Basrah*), 1978 to 2013. The step-wise decline in relative quality reflects the significant political or military events shown, and is attributed to inter-connected direct, indirect, and cumulative impact upon staff, consumables, and hardware. The overall quality of water service is a composite of quantity and quality of water provided.



The type and magnitude of the impact of the conflict upon the quality of drinking water services is expected to reflect the nature of each military and political phase. Standing armies faced

each other during Phase II through aircraft, surface-to-air and surface-to-surface missiles (and, earlier, tank battles and hand-to-hand combat), with the bulk of the fighting and damage suffered in Iran. The UN Coalition bombing of Iraqi forces at the start of the embargo period was focused on southern Iraq. Though the bombing did not directly affect Basrah, the 1991 uprisings against the government there elicited first violent then negligent responses from the Ba'ath government until its downfall in 2003. The UN trade embargo outlawing the import of anything other than 'essential needs' was imposed in 1990, and purportedly eased in 1996 under the 'Oil for food' programme (UNSC Resolution 986). International armed conflict during the embargo period comprised primarily one US bombing campaign of Baghdad in 1998. The US/UK-led 2003 invasion was conducted initially through aircraft, surface-to-air and long-range surface-to-surface missiles, and the ensuing occupation was shaped by the rule of the Coalition Provisional Authority (CPA). At some point prior to the UK withdrawal from Basrah in 2007 and the US withdrawal from Iraq in 2011, the violence turned to asymmetric warfare between US, UK, Iraqi army and other troops, and Iraqi insurgents. The internationalized armed conflict continues to this day, with the rise of ISIS and other militant groups.

The impact of the sustained violence upon the drinking water system itself is but an indicator of the extent the people suffered from the degraded service.<FN6> The US Defense Intelligence Agency (1991) and Harvard Study Team (1991) both reported concern, for instance, about outbreaks of water-quality-related cholera, typhoid and hepatitis. While the effect of the Iraqi conflict on health is better documented in medical research journals (Pellett, 2000; Salvage, 2002: Table 2; Medact, 2003; WHO, 2003; Al-Naseri *et al.*, 2008), it is notoriously difficult to isolate associations solely with water quality issues induced by disrupted services. As Hunter (2009) shows, a single short disruption in drinking water service (lasting, say, a day or week), can greatly increase the probability of infection with endemic diseases, if the quality of the service was previously reliable. The concern of the US DIA report may be overstated (or underinformed) in this regard, in the sense that it gives little credence to the capacity of Iraqi people to cope<FN7> (see Int Doc 006 1991). In any case, by 2005 less than one quarter of the people in Basrah governorate rated their water or wastewater services as 'good to very good' (US GAO 2005: 18). By 2014 the figure had dropped to 6% (Takechi 2014), and a genuine outbreak of cholera (with at least 60 cases confirmed in Basrah governorate) came in 2015 (WHO 2015b).

Impact on staff: the 'natural brain drain'

Iraq was, of course, not spared the 'brain drain' so commonly seen in war economies (see Burnham *et al.*, 2009). Many skilled workers critical to the drinking water supply services left immediately after the start of embargo in 1991, and often those with 'middle'-qualifications (e.g. water maintenance technicians), joined the private sector for the better wages offered (ICRC Focus Group, 2014).

The shortage of skilled staff was most acute in the smaller urban centres and villages—where it was not uncommon to have no maintenance staff whatsoever (Int Doc 063 1996)—though it became noticeable in the larger governorates by 1995, and was felt across most water boards by 1997 (ICRC Focus Group, 2014: 13). Even during the time of the UN's Oil for Food Programme, the lack of (or very low) salaries of service workers remained an issue, with public sector water technicians earning US$5 per month (Int Doc 053 1996: 2), and fewer (though unquantified) staff reporting to work (Int Doc 052 1991; Int Doc 071 1993: 15; Khogali , *et al.* 1996: 6, Nembrini *et al.*, 2003: 26). There were only seven engineering staff in Basrah's Department of Water in 2001, for

instance, down from hundreds before (Remote interview with Basrah water engineer, December 2013). By 2008 there were approximately 70 engineers earning US$300 per month, though with fewer qualifications (Int Doc 158 2008: 8).

The lack of qualified staff has been exacerbated by what has been called a '*natural* brain drain' (ICRC Focus Group, 2014: 14) over the two and half decades under consideration, as the qualified people who remained in service eventually reach their retirement age. The intricate knowledge these skilled workers had of the patchy systems that had been created is not replaceable, or easily transferrable to younger, less well formally trained staff (ICRC Focus Group 2014: 14).

As was the case for retrofitting the sewage-lifting stations of Basrah (Int Doc 053 1996), the effect of poorly trained or motivated or overworked staff meant that, in some cases, there were no staff on hand to install the new equipment that did make it through the embargo. Equipment and spares imported into Basrah were just as easily misused or mistakenly broken (Int Doc 039 1992; Int Doc 099 1992: 3; Int Doc 132 2003; Int Doc 142 2004). Irregular payment of the salaries of technicians and other support staff continued through 2003 (Int Doc 122 2003; Int Doc 134 2003; US GAO, 2005: 27), at least through 2010 (Int Doc 158 2008; SOCMD 2010: 9). The CPA's policy of exchanging the Iraqi civil service ('de-Ba'athification'), furthermore, compounded the exodus at a point when it might have been slowed.

The impact of such personnel issues throughout Iraq is confirmed in an internal ICRC assessment of 92 of its water projects from 2011 to 2014 (ICRC, 2014). The extent of the influence of the personnel issues is difficult to untangle from those related to consumables and hardware, because of the importance of adequate maintenance. Underqualified or inexperienced staff would often order parts through the embargo with incorrect dimensioning, or were unable to properly install the spares, and it is generally felt that the majority of the problems related to spare parts stems from their improper installation (ICRC Focus Group 2014: 24.).

Impact on hardware: problems with spare parts

The water treatment plants within Basrah have long relied on a single source over 200km away on the Euphrates River (Etienne and Nembrini, 1995, Nembrini *et al.*, 2003). The UN coalition bombing in early 1991 targeting national electrical power production thus had an indirect and immediate impact on water treatment (and, so, drinking water quality) and distribution particularly in Basrah (as well as Baghdad) (Int Doc 025 1991: 3; WHO/UNICEF, 1991: 17; SIGIR, 2010: 10). Some disruptions to water services (at al Qurna and Basrah city) were also attributed to damage to bridges in 1991 and in 2003, which prevented the access of maintenance staff (Int Doc 039 1992: 4, Nembrini *et al.*, 2003: 7).

The 2003 US/UK invasion also resulted in hundreds of leaks in the distribution pipes of Basrah's water network (direct impact), hundreds of illegal household connections (indirect impact), and the reduction of water produced for some neighbourhoods to 30–40% of full capacity (Nembrini *et al.*, 2003: 14–20). Meanwhile, over 1000 water tankers and wastewater evacuation trucks were denied entry into Iraq, on the grounds that their stainless steel linings might have 'dual use' (Gordon, 2010: 71), as was the stainless steel required for wastewater treatment plants (Remote interview with Basrah water engineer, December 2013).

Though diesel fuel and petrol remained readily available for electrical generators to run water treatment plants, booster stations, and sewage lifting stations, difficulties importing spare parts for these made water treatment and supply throughout the rest of the 1990s intermittent and

unreliable, at best (Int Doc 025 1991; Int Doc 044 1992; Etienne and Nembrini, 1995). In hindsight, most hardware-related disruptions to the service were caused by the lack of availability of spares, due to the embargo and/or looting. In particular, shortages of aluminium-sulfate dosing equipment<FN8> reduced the quality of water treatment (Int Doc 025, 1991, Int Doc 032 1992; Etienne and Nembrini, 1995), and broken chlorination pumps led to 'haphazard' treatment (Int Doc 032 1992: 17).

The poor quality of spares that the ministries, municipalities and international organizations managed to get through the embargo may have been as much a problem as their lack of availability. From very small chlorine- and alum-dosing pumps to very large water booster pumps, reliable treatment and delivery of drinking water requires equipment that is designed and built to standards that fit the rest of the system that they are part of. The pre-1990 heavy reliance of the Iraqi water authorities upon top-quality European parts (filters from the Netherlands, for example, or pumps from Germany and Scotland (Int Doc 061, 1991)), thus ensured they were vulnerable to the embargo (Int Doc 059 1998). Chinese and Iranian companies proved more willing than their European counterparts to supply parts that others could bring in around the embargo, but the host of spares available in these markets (sometimes at one thirtieth the cost) would rarely match the micromillimetre tolerances required of finely machined parts, and so could not be finely calibrated (Remote interview with Basrah water engineer, December 2013; ICRC Focus Group, 2014).

Though over 100 European chlorine-dosing devices were repaired to high standards in Baghdad (and at a much lower cost than imports) (ICRC 029 2000), the once sizeable local manufacturing industry is considered to have been 'on its knees' by the mid-1990s (ICRC Focus Group, 2014: 15). This poor situation with spare parts also led to their 'cannibalization', a term used to describe the removal of functional equipment from a lower-priority part of a water system to a higher-priority part. Predicted to occur early on (US DIA, 1991), the practice ensured sustained water supply to hospitals and health centres in Basrah and elsewhere, at least through 1991 (Int Doc 025 1991). Cannibalization of equipment was compounded by looting immediately after the 2003 invasion (Int Doc 134 2003: 4; Nembrini *et al.*, 2003: 26), and beyond (Int Doc 147 2004; Int Doc 158 2008; Remote interview with Basrah water engineer, November 2015), leading to further deterioration of the electrical power supply, and a renewed reliance on electrical generators (Int Doc 128 2003). Though revenues from oil began flowing to the CPA in the years that followed, spending remained unevenly distributed throughout the country. International donors began to fund hardware for new projects, but not always its installation, or its operation and maintenance costs (ICRC Focus Group, 2014: 6–7). British authorities installed many short-lived Compact Units<FN9> in the villages, for example, while US plans to replace the main canal feeding Basrah with a large-diameter transmission pipe never materialized (Remote interview with Basrah water engineer, November 2015).

Impact on consumables: alum, chlorine, cholera

The relative importance of hardware and consumables is put firmly into perspective in the Harvard Team's report: 'Direct physical damage, either from the bombing or looting during the civil uprisings, was found to be only a minor factor in the impairment of water and wastewater systems. The primary rate-limiting factors are lack of spare parts and supplies of chlorine and erratic electric supply' (Doleh and Piper, 1991: 1). The consumables most directly affected by the protracted conflict and embargo in Iraq were the chlorine and aluminium sulphate (more commonly referred to as 'alum') required for water treatment, particularly in Baghdad and Basrah. There was an acute

shortage of these following the imposition of the embargo (Int Doc 043 1991; CARE International, 1997) and they were recognized as a major limiting factor shortly after the UN Coalition's bombing (Int Doc 041 1991; Int Doc 032 1992; Int Doc 044 1992).

Iraqi-produced alum was low in quality (CARE International, 1997; ICRC Focus Group, 2014: 25), meaning the sediment suspended in the muddy water of the Tigris, Euphrates or Shatt al Arab rivers could only be poorly flocculated, making the water much more difficult to disinfect effectively with chlorine. The good-quality chlorine produced in Basrah that once supplied the entire country was in severe shortage by 1993 (Int Doc 031 1996; Remote interview with Basrah water engineer, November, 2015). The Chinese-imported chlorine supplied by the Iraqi water authorities throughout the country contained impurities, leading to blockage of the chlorine-dosing pipes and thus further increasing the need for the ever-decreasing maintenance or replacement of the pipe (CARE International, 1997).

In a somewhat perverse beneficial relationship, there were no chlorine shortages during the worst periods of armed conflict, as very few water treatment plants still operated, creating little demand for it (Doleh and Piper, 1991). Shortages in chlorine dioxide gas began soon afterwards, however, with treatment plant operators in Basrah obliged to replace chlorine with bleaching powder, a practice also observed in Nassiriah, Najaf and Kerbalah (Int Doc 114 1991). As neither the operators nor the treatment plants were prepared to work with bleaching powder, any improvements in water quality are judged as marginal (Int Doc 025 1991, Int Doc 032 1992).<FN10>

The resumption of chlorine gas delivery to Basrah in 1992 is credited with a general improvement in the level of domestic water services (in contrast to the situation in Baghdad (CARE International, 1997: 8)). Along with alum and alum-dosing equipment, higher-quality chlorine was one of the first requests made by the various water boards under Resolution 986 (Int Doc 020, 1997). As a result, chlorine shortages appeared to subside from 1998, even if the gas cylinders were not handled safely on site by underqualified staff (ICRC Focus Group, 2014: 24).

Chlorine and alum shortages re-emerged following the US/UK invasion (Int Doc 122 2003, Int Doc 134 2003), and reliable and quality supplies were still wanting in 2008 (Int Doc 158 2008). By 2015 there was essentially no chlorine treatment of any of Basrah's piped drinking water, meaning the overall microbiological quality of the drinking water (and, by extension, the service) was lower than the previous low at the start of the embargo period (Remote interview with Basrah water engineer, November 2015). While the quantity of water produced in 2015 was generally sufficient, its high salinity meant that all those who could afford to purchased bottled water. Those who could not afford bottled water continued to rely on the unchlorinated piped water, which, when cross-contaminated with sewage water, was blamed in part for the 2015 cholera outbreak (WHO, 2015b).

Vulnerabilities of the drinking water service ecosystem in Basrah

Though the perseverance of Iraqi water workers at times slowed or reversed the step-wise decline of the Basrah drinking water service, every improvement was curtailed by the enduring effect of the trade embargo or renewed fighting. Any relapse into overt violence—or return to a sanctions regime—is likely to quickly reverse any gains made in what appears to be a substantially altered urban biosphere. The precariousness of the drinking water ecosystem is credited to at least three vulnerabilities: dependence on foreign parts and people, the accumulation of impact, and the politics of aid and reconstruction.<FN11>

Vulnerability induced by dependence upon foreign parts and people

The technical qualifications of engineers in ministries, consulting bureaus and construction firms throughout Iraq was very high in the 1980s, yet most of the large water treatment stations had been constructed, operated and maintained with considerable involvement of foreign expertise. This left drinking water systems particularly vulnerable to the predictable departure of such staff, as, for instance, during the 1991 UN bombing campaign (Int Doc 032 1992, Int Doc 044 1992). Water treatment plants built at the end of the 1980s were fitted with high-technology equipment (Int Doc 025 1991), which, furthermore, required highly skilled foreign operators who were in short supply even before the Iraqi invasion of Kuwait. Always a disadvantage to a country suffering a war, the phenomenon affected the modern, tertiary-level Basrah sewage treatment plant, a planned upgrade of which was 90% complete at the start of the fighting—at which point the (Indian) contractors fled. The dependence continues, with a Turkish company taking over the upgrade in 2009 but unable to complete its work due to mismanagement (Remote interview with Basrah water engineer, November 2015), which led to the Japanese International Cooperation Agency's plans to rehabilitate the city's entire drinking water system (Takechi, 2014).

Apart from the effect of abandoning projects during bombing campaigns, Iraq's reliance on foreign expertise also created a 'technological dependence' which became difficult to escape (Int Doc 044 1992: 13). It was rarely possible to bring enough foreign technical know-how into Iraq to tackle complex technical difficulties, and training programmes only ever managed to reach dozens of the thousands required (Int Doc 132 2003, US GAO, 2005: 26). New projects or repairs that required such expertise were typically abandoned (Int Doc 032 1992), at least during the early phases under consideration here. The ability of the occupying forces or international organizations and NGOs to help fill this gap proved very limited indeed, in part because expatriate engineers were never committed to long missions (Int Doc 027 1996, WICRC 024, 1998).

Vulnerability induced by *cumulative* impact

The step-wise decline in the quality of the drinking water service in Basrah has been read as the result of an accumulation of combined, incremental direct and indirect impacts of war and embargo on service people, hardware and consumables. Much of this is related to the degraded electrical power system (Int Doc 059 1998) and failing economy, and is evident in the demotivation and other opaque manifestations that occurred in step with the degradation of the general warfare ecology. At some point during the protracted conflict, water service staff were caught in emergency or response mode and stopped planning altogether. With most of the qualified people who had not left the country now retired, the messy patchwork of systems that made up the water service proved too complicated to operate or upgrade. Though water still filled the distribution pipes in 2015, its very poor microbiological quality meant that it was drunk only by those who could not afford to purchase bottled water (Remote interview with Basrah water engineer, December 2013). The published advice on disaster preparedness is of little use when a system has been transformed so completely from world-class to worst-class, and from safe to dangerous.

A large part of this system's vulnerability stems from the predictable and justifiable responses of the service operators, such as the cannibalization of parts. In situations where good-quality spares are impossible or very lengthy to procure, however, the activity is the first step down a slippery path. Not only are the systems that the parts are cannibalized from never likely to operate again, relaxation of the pressure to render the higher-priority system operational can tend to reduce efforts to seek replacements—and thus lead to an inevitable repeated failure of the more important

system. Throughout Iraq, the accumulating impact of the war and sanctions ultimately led to a drop in design criteria from national standards (based on British Standards) under a new operating logic of 'semi-sustainability' (Etienne and Nembrini, 1995). The rationale for this suboptimal design was based on an acknowledgement that the regular delivery and installation of spares required by any complex system was not achievable. It may thus have appeared more pragmatic to maintain minimal operations capacity for an interim period in the hope that a return to 'normal' was imminent, i.e. that the embargo would be lifted (Int Doc 044 1992: 7; ICRC Focus Group, 2014: 7). In situations where sanctions are not lifted or that are, in effect, just a return to chronic crisis within a warfare biosphere, however, pragmatic efforts can have little enduring positive effect.

Vulnerabilities related to the cumulative impact upon the people running the service stem from both the brain-drain and the reliance on foreign workers. It would be difficult to exaggerate the benefit of the constant presence of devoted local staff who are intimate with the particularities and idiosyncrasies of any service, particularly one that has been patched up as often as that of Basrah. The retirement of such staff over the duration of prolonged conflicts (the so-called 'natural' brain-drain) may be even more damaging than the exodus of skilled labour out of the country, in the sense that their knowledge is irreplaceable and cannot be recovered by a sudden influx of skilled Iraqi (or foreign) labour, or the typical capacity-development programmes discussed in the previous section.

Vulnerability enhanced by the politics of aid and reconstruction

Just as the impacts of the protracted conflict have been shown to reflect the conflict's nature across different phases, reconstruction efforts very much reflect the preferences and commitment of the ruling authorities of the time. This is the 'inherently political' side of interdependencies of urban infrastructure during wartime (McFarlane and Rutherford, 2008) and arguably present in any urban warfare biosphere. The Ba'ath government's response to the UN-imposed embargo, for instance, clearly privileged certain cities and regions over others (generally disadvantaging Basrah city and governorate). Reconstruction efforts by the Coalition Provisional Authority were also asymmetrically distributed, as the poor security situation disfavoured areas in the centre and south of the county (US GAO, 2005), and favoured the predominantly Kurdish areas in the north. Nearly two billion dollars targeted by the US authorities for water and sanitation was later reallocated to security, justice, and employment-development sectors (US GAO, 2005; SIGIR, 2013: 59), furthermore, the bulk of the US$500M of water projects implemented during the occupation were judged to have had major or minor deficiencies (SIGIR, 2013: Fig 1.2).

While it is clearly difficult to gauge reconstruction needs at any particular point in an extended armed conflict, knowledge of the context certainly helps. A 2003 US government strategy document heaps all of the blame for the 'outdated … and badly dilapidated' state of Iraq's drinking water systems on the Ba'ath government, for example, and none for the effects of the UN embargo (USAID, 2003: 1). Convinced that progress passes through phases of relief, rehabilitation, and development, the same report and other needs assessments (e.g. UN-World Bank, 2003; US GAO, 2005; Baker and Hamilton, 2006) suggest that the reconstruction phase was to shift into long-term development planning in 2004. But in many parts of the country a 'recovery' phase was certainly delayed, and arguably never really entered into. The British armed forces in Basrah left little more behind than dozens of short-lived Compact Units, and new village water networks that are still waiting for an adequate water source (Remote interview with Basrah water engineer, November 2015). An ICRC report of the same time was more realistic, foreseeing a lag before the re-activation

of the former Oil-for-Food supply pipeline would be possible, and expecting that lack of quality spare parts would remain an issue until the reconstruction funds that had been committed began to flow (Int Doc 122 2003: 6).

The glut of implementing agencies following the 2003 US invasion exposes the opportunistic character of some actors in the industry, with very few NGOs active towards what turned out to be the end of the sanctions period. The general failure of the UN's Oil for Food Programme to reduce the suffering of people throughout Iraq (particularly those punished by the contemporary Iraqi government (Joyner, 2003)) furthermore exposes the invalidity of the self-financing assumptions upon which Iraqi 'reconstruction' efforts were based. The same may be said for the dashed US hopes that a combination of oil wealth and a more open marketplace would help the country's systems off their knees (as early as 2004, in some estimates) (ICRC Focus Group, 2014). Despite the wealth, the country generally has not managed to return to pre-1980 conditions, and neither, certainly, has the drinking water service in Basrah.

Learning from the urban warfare ecology reading

To summarize the urban warfare ecology reading of the impact of armed conflict on the drinking water service of Basrah: the degradation may be traced to the brain-drain (in the immediate, short and long-term), the lack of good-quality spare parts (where cannibalization of parts eventually led to a deterioration in planning, and poor-quality spares led to a patchwork system), and the limited availability of the treatment chemicals alum and chlorine. The evidence clearly shows that the poor quality of drinking water service that residents currently receive has its roots in the previous decades of armed conflict and sanctions (see ICRC, 2014). Conceived as a slide down the vicious cycle of cumulative impact, the main initiating factor was the indirect impact caused by the violent conflict and the UN trade sanctions, and chiefly the economic aspects of the latter. The service has been shown to be vulnerable to dependence upon foreign parts and people, sensitivity to vicious cycles of direct and indirect impact, and the politics of aid and of reconstruction.

Implications for relief programming

The analysis implies that relief programming in urban warfare biospheres should seek first and foremost to avoid the predictable vicious cycles. One path towards this is the reduction of vulnerabilities induced by reliance on foreign parts and people, or by the politics of aid and reconstruction. Most relevant to local municipalities, agencies and ministries, the former suggests that strengthening national capacity in all regards (e.g. technical or social knowledge, industrial production, construction capacity, etc.) will render urban services more resilient. This is, of course, much easier said than done for communities and institutions beset by protracted conflict, but highlights the importance of low-risk capacity-building and training programmes.

Addressing the vulnerability induced by the politics of aid and reconstruction in urban warfare biospheres obliges us to question the way that the relief industry is structured, including the duration of its commitment and its founding assumptions (see e.g. ICRC, 2016). Even the few international organizations that have maintained a long-term presence in Iraq (e.g. Unicef and the ICRC) have not been able to plan more than one year ahead, and this has also been the case for those that rushed in after 2003. Short-term planning reflects the donor preference (or industry standard) for distinguishing between emergency and 'development' assistance—the 'post-war'

thinking based on a hope that the armed conflict will end within a predictable and manageable period of time. The classic humanitarian time-bound funding sources which limit the NGOs dependent on them to six-month funding cycles (see e.g. Olsen *et al.*, 2003) seems excessively and myopically short, in this regard. Using such funding models to address the challenges of urban warfare biospheres can be read as negligent of so-called humanitarian ideals, and the people most affected. Longer-term and more flexible funding (as by the UK's Department for International Development (DFID) in Yemen—see McElhinney, 2014) will likely support better programming, though it would necessarily entail less stringent monitoring of spending.

Rethinking the RRD paradigm in urban ecologies of war is key for operational staff, as well. In their call for a shift from that paradigm, the ICRC (2015) suggested that international agencies improve their logistical and technical capacity in order to better support local water service operators—a point made by several others, on different foundations (e.g. Duffield, 1994; Smirl, 2009; Mosel and Levine, 2014). That capacity is typically constrained by short-term contracts and staff with managerial—rather than technical—experience and expertise. Effective long-term programming throughout the exacerbations of chronic crises obliges external relief workers to get into the full detail of proper service delivery, beyond disaster preparedness and prepositioning of stocks, to understanding and addressing the classic 'development' issues of e.g. financing, innovative technology and asset management (see e.g. Verhoeven *et al.*, 2015), and technical support to the very large and complex systems that the local operators manage.

Relevance to urban studies

More effective relief programming will also benefit from pushing the envelope that constrains our collective understanding—through a more appropriate research base, for instance. In short, this means more critical and innovative policy-oriented research to support the shift in paradigm, as well as critical research that is more engaged with those delivering and funding the service.

The evidence reviewed through the urban warfare ecology approach suggests ways in which the degradation of services may be linked with 'infrastructural warfare' research into the intentional destruction of infrastructure as a means of social control. The motives of those who created the direct (and, also, the indirect and cumulative) impacts were not examined, however, and the effects not gauged in terms of repression. The analysis has emphasized that it is the *cumulative* impact of the UN trade sanctions that is most concerning, suggesting that the drinking water services are more a victim than a target of conflict (in the case of Basrah, at least). The point requires contextualization, first because conclusions drawn about the drinking water services of one city (Basrah) do not hold for the interdependent infrastructure in the same city, or in other cities. Second, and perhaps more importantly, the devastating consequences of the degradation of the service are similar, whether the damage is intentional or not. The findings thereby oblige consideration of the drivers of the violence that initiated the degradation. Targeted research into the geopolitics of the sanctions would help situate this article's analysis more accurately, as would investigation of the awareness and intent of the belligerents involved. The way that water services may serve as a tool of conflict (Jaubert *et al.*, 2014) or contribute to existing tensions (as in Figure 2, and CinC, 2012) would be especially useful, in this regard.

In Basrah, the alteration of the social and biological processes that make up the drinking water service has led to the development of short-term coping mechanisms and long-term adaptive practices, and, likely, an increased incidence of communicable diseases (though that has not been

studied here). But there are also distinctions to be made with the 'changing therapeutic geographies' that Dewachi *et al*. (2014) noted with respect to the public health services in Iraq and Syria. Within Basrah's warfare biosphere, the protracted armed conflict and trade sanctions have transformed the drinking water service ecosystem in a number of ways. Internal and transnational supply lines have been established, interrupted, dissolved, and created anew; much less qualified staff deal with a much more complex and complicated system; and coping mechanisms at every level have altered the once highly central and hierarchical management of the sector to one of overlapping hybrid governance (see e.g. Shapely, 2013). On the whole, however, the drinking water service of Basrah has not been militarized or reorganized to the extent that public health services have been, for reasons that merit further investigation.

There are parallels to be drawn between this insight into damage to complex engineering systems and the ballistics analysis of the damage—as in 'forensic architecture' work (Weizman, 2011). It follows that a blend of technical engineering awareness of the functioning of water services with ballistics expertise and sharp social/political science will serve to move us closer to the roots of the problem.

The analysis's focus on indirect and cumulative impact further draws attention to the extension in space and in time of armed conflict. Even relatively precise attacks on military targets can cause knock-on effects along the vicious cycle identified here, well beyond the direct impact zone of the explosive and long after the dust has settled. Such 'reverberating effects' of weaponry are the subject of debates about military targeting and proportionality in International Humanitarian Law (ICRC, 2015b: 5; Robinson and Nohle, 2017; Zeitoun and Talhami 2017), and are attracting campaigns against the use of wide-area explosives in populated areas (e.g. Brehm and Borrie, 2010; Rappert *et al.*, 2012).

Examination of the impact of armed conflict through interdisciplinary urban warfare ecology has not only allowed sight of the extent of one aspect of a greater urban transformation, it also shines a spotlight on the very mechanisms of the transformation itself. Application of the frame to other services (e.g. solid waste, energy, health) and other urban warfare biospheres (e.g. Aleppo, Beirut, Donetsk, Gaza, Ta'iz) will reveal yet more of the enduring and otherwise hidden impacts of war.

Mark Zeitoun, School of International Development and UEA Water Security Research Centre, University of East Anglia, Norwich, Norfolk, NR4 7TJ, UK, m.zeitoun@uea.ac.uk

Heather Elaydi, independent, Amman, Jordan, heather.elaydi@gmail.com

Jean-Philippe Dross, Water and Habitat Unit, International Committee of the Red Cross, 19 Avenue de la paix, 1202 Geneva, Switzerland, pdross@icrc.org

Michael Talhami, Water and Habitat Unit, International Committee of the Red Cross, 19 Avenue de la paix, 1202 Geneva, Switzerland, m.talhami@icrc.org

Evaristo de Pinho-Oliveira
Water and Habitat Unit, International Committee of the Red Cross, 19 Avenue de la paix, 1202 Geneva, Switzerland, eoliveira@icrc.org

Javier Cordoba
Water and Habitat Unit, International Committee of the Red Cross, 19 Avenue de la paix, 1202 Geneva, Switzerland, jcordoba@icrc.org

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<NUMBERED FOOTNOTES>

<FN1>The limits of this article's analysis are bounded primarily by the extensive empirical data analyzed. The bulk of this derives from unpublished reports from relief agencies active in the sector in Iraq, and individual or group interviews with employees of the same agencies (but not those on recent, direct fieldwork). Among the many important issues and methods thus excluded are the coping mechanisms developed by people; the intent of the belligerents; and ballistics analysis of damage.

<F2>The corresponding limitations of capacities and operational modes developed for much smaller-scale and less complex rural settings has been well noted (see Janneck*, et al.*, 2012, Sanderson*, et al.,* 2012, Lucchi, 2013, Bryant and Campbell, 2014).

<F3>It is next to impossible to separate the impact of the sanctions from the impact of armed conflict and neglect. The visible results in Iraq have been cumulative, a combined effect on a time continuum over 30 years of multiple crises and bad management (ICRC Focus Group, 2014).

<FN4>Other banks and companies include ABN Amro, Lloyds TSB, Chevron and DHL (for trading with Iran, Lybia, Syria, Sudan, Cuba, Burma, Liberia).

<FN5>The experience of Basrah is considered to be broadly representative of large urban centres throughout Iraq, with the notable exceptions of Baghdad and cities in the northern Kurdish parts of the country during the sanctions period (1990 to 2003). Both sets of urban centres fared better than Basrah during this period, the former because the Iraqi government favoured it, and the latter because it was beyond its reach. The population of the city of Basrah was roughly 2.7 million in the 1980s, and 3.4 million by 2015.

<FN6>This article's analysis remains focused on disruptions to services, and so does not seek to gauge the impact of the war directly upon people.

<FN7>Coping mechanisms are not discussed further here, but have been identified by the ICRC Focus Group as including: illegal connections; installation of household booster pumps (at least 1.5 million around Iraq (!)); compact-unit water treatment plants; bottled water; private, neighbourhood-level reverse osmosis (desalination) plants; imports from Kuwait; generators at household or neighbourhood level; leaving the country; rooftop storage reservoirs.

<FN8>The equipment is used to deliver the alum, which facilitates the removal of sediment suspended in the muddy river water

<FN9>These self-contained compact water treatment plants, which can be dropped in by trailer and so appear to be quick-fix solutions, were very popular as a relief intervention (there were 91 compact units around Basrah in 1991, and 430 by 2015 (Al Janoob, 2015). Because of their sophisticated technology, reliance on chemicals, and poor ability to deal with turbid water, these compact units have proven very ill suited for southern Iraqi villages.

<FN10>In some cases (e.g. Ninevah), there was a shortage even of bleaching powder (CARE International, 1997).

<FN11>A fourth source of vulnerability may derive from interdependence with other systems. The internal documentation demonstrates the clear relation between electricity and water (without the former there is none of the latter). With the failure of the national electricity grid and very low cost of diesel fuels, most water systems became reliant upon electrical generators, though these have proven very difficult to maintain (Int Doc 059, 1998). Transportation (e.g. of treatment chemicals) and the reaction of some international companies fearing the consequences of breaking the embargo are further sources of vulnerability arising from interdependence.

Appendix

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