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TITLE: Chemical Weapons and Public Health: Assessing impact and responses

Authors: Abdulkarim Ekzayez (MD, MSc)^{1*}, Daniel Flecknoe (RN, MFPH)², Louis Lillywhite (MSc, FFOM)³, Preeti Patel (PhD)¹, Andreas Papamichail (PhD)¹, Hassan Elbahtimy (MD, PhD)⁴

*Corresponding author

1. Research for Health in Conflict in the Middle East and North Africa (R4HC-MENA), Conflict and Health Research Group, Department of War Studies, King's College London, London, UK

2. Derby Teaching Hospitals NHS Foundation Trust, UK; University of Sheffield, UK

3. Centre on Global Health Security, Chatham House, London, UK

4. Centre for Science and Security Studies, Department of War Studies, King's College London, London, UK

Email address for corresponding author:

Abdulkarim.ekzayez@kcl.ac.uk

Email addresses of co-authors:

daniel.flecknoe@nhs.net

LLillywhite@Chathamhouse.org

Preeti.patel@kcl.ac.uk

andreas.papamichail@kcl.ac.uk

hassan.elbahtimy@kcl.ac.uk

Abstract

The recent use of Chemical Weapons in armed conflicts and terror attacks highlights the importance of understanding their full impact in order to inform an effective response. This article argues that while the consequences of CWs on individual health have dominated our understanding of the impact of these weapons, far less attention has been directed to their impact on public health. The article conducts a review of literature on the health impact of CWs and explores two case studies of their use in urban settings - Halabja in northern Iraq in 1988, and throughout Syria's ongoing conflict – in order to demonstrate the importance of considering the long-term health consequences of CW use and their impact on healthcare and health systems. Building on this analysis, the article highlights the importance of generating more evidence to support future research on the topic and proposes a framework for assessing the public health impact of CW use.

Key words: Chemical Weapons, Public health, Halabja, Syria, Global Health, Health systems.

Introduction

'...the very air which he breathes is poison, his chance is gone: he is merely a destined victim for the slaughter' –

A World War 1 Infantry Officer describes soldiers' experiences of gas attacks.¹

Chemical Weapons (CWs) have recently come under the international spotlight. They have been repeatedly used, to tragic humanitarian effect, in the Syrian Civil War. In February 2017, a nerve agent was used to assassinate the half-brother of North Korean leader Kim Jong-un in a Malaysian airport. In March 2018, a chemical agent was used in an assassination attempt targeting Sergei Skripal, a Russian defector living in the UK, and inadvertently poisoned several others. These incidents highlighted the risk posed by CWs and fuelled fears that these weapons are making a comeback on the international stage. This article demonstrates that direct and immediate effects of CWs have long dominated our understanding of their health impacts. It argues that a broader public health approach provides a rich lens to engage with a wider range of consequences of use of these weapons. The article specifically highlights some aspects of the long-term impact of CW use and their impact on health systems, including health workers, and therefore on the provision of health care. The article therefore recommends building on the current available research to assess full impact of CW use on public health.

The article begins with a brief historical overview that highlights the diverse contexts in which CWs have been used. This is followed by a survey of the current state of knowledge about their health impacts. Two short cases are used to highlight aspects of the public health consequences of CW use. The case of Halabja demonstrates the importance of considering some of the long-term consequences of CWs that ultimately impact public health. The case of use in Syria draws attention to the importance of considering how CWs can interfere with and disrupt the operation of vital health systems. Based on examining the academic literature and the cases, the article proposes a framework to examine both the short and long-term public health impact of CWs. In doing so, we aim to highlight the importance of considering impact on public health when a broader assessment of the consequences of CWs is made and, in the process, pave the road for more dedicated research on this topic.

A diverse universe of cases of CWs use

The use of toxic chemicals in warfare is as old as recorded history. Evidence points to the application of poisons, extracted from plants or animals, to spear and arrow tips thought to have been used for both hunting and combat as early as 24,000 years ago.^{2,3} One of the first reported examples of mass chemical warfare is narrated by Thucydides, who stated that in 423 BCE the Spartan army used arsenic smoke during a siege in the Peloponnesian War. In the modern era, toxic smoke and fumes were used as a battlefield tactic on numerous occasions, but it was not until the First World War that the era of CWs truly began.^{4,5}

The first modern chemical weapon (chlorine gas) had its inaugural use on 22nd April 1915 during the second Battle of Ypres. The effects were far greater than had been anticipated by the German military, to the extent that they failed to capitalise on the huge gap in Allied lines which the gas created. As war on the Western Front progressed, both sides employed a variety of CWs, including chlorine, phosgene and mustard gas. By November 1918, CW use had caused an estimated combined toll of 1.3 million casualties including 90,000 dead.⁶ The effectiveness of CWs as a battlefield weapon was at least partly due to their psychological effects. Soldier-poet Wilfred Owen

vividly described the terror of a gas attack in the poem *Dulce et decorum est*, and many WW1 officers testified to the fact that gas was as significant a cause of ‘shell shock’ – an acute and disabling stress reaction - as was actual shelling.⁷

Instances of CW use since the First World War have reinforced their physical and psychological impacts, which are inevitably associated with their insidious and deadly nature. They have been used on a large scale during the Iraq-Iran war,^{8,9} against the Kurds in Halabja and more recently and repeatedly in the context of the Syrian civil war.^{10,11} Their use has not only been confined to the battlefield. They have also been used in non-conflict urban settings as part of terrorist operations or as an assassination tool. In 1995, the Japanese cult organisation Aum Shinrikyo used Sarin gas in a terrorist attack on the Tokyo Subway.^{12,13,14} More targeted examples of CW use can be found in the case of the Russian defector Sergei Skripal in the UK^{15,16} and North Korean Kim Jong-nam in Malaysia.^{17,18} International law, which has not been unanimously adhered to, classifies CWs as illegitimate weapons of war, with the Geneva Protocol (1925), the Biological and Toxin Weapons Convention (1972) and the Chemical Weapons Convention (1993) all banning their use.¹⁹

Methodology

Research for this article commenced with a scoping review of grey literature to inform our search terms and search strategy followed by an academic literature review of sources addressing the health impacts of CWs. We searched the following academic databases: Medline (ovid), Embase, PsycINFO and Global Health for peer-reviewed research reflecting the state of knowledge on health consequences of CWs. This was followed by a targeted search in grey literature to extract more details on public health impacts of CWs, particularly in relation to the two case studies.

We used 10 different search terms referring to CWs such as “chemical warfare”, “Sarin” and “Mustard gas”; 7 different terms referring to health such as “healthcare”, “health”, and “morbidity”; and 5 search terms referring to relationship such as “impact” and effect. The search on the academic databases returned 3940 hits, most of which are related to therapeutic health interventions that use some chemical agents and animal studies. Therefore, we introduced other 7 search terms referring to settings such as “conflict”, “war” and “terrorism”; limited the search to studies on human; and removed duplicates. This returned 464 entries. These entries were then filtered to collect only articles that have the chemical search terms in their titles and in are English. This reduced the outputs to 85 entries whose abstracts were read, based on relevance to our study topic, and the full text of selected entries were read. The full list of the search terms can be seen in the table below.

Table 1 List of search terms

Chemical weapons	Health	Relationship	Settings
Chemical warfare	Health care	Impact	Conflict*
Chemical weapon*	Health*	Effect	War*
Chemical attack*	Morbidity	Association	Armed conflict
Sarin	Mortality	Correlation	Insurgency*
Mustard gas	Health system	Relation*	Atrocity*
Chlorine	Health service*		Terror*
Nerves agent*	Public health		Humanitarian*
Blistering agent*			
Choking agent*			
Blood agent*			

(Search terms with asterisks refer to truncation used in the search)

The paper then employed two case studies, which were chosen based on field experience, to highlight public health consequences that are under-studied in the literature. For the case studies, we used descriptive analysis of secondary data and direct observations in addition to the desk review. The direct observations are drawn from the experience of one author (AE) who was involved in the medical response to CWs incidents in Syria, and another (DF) who worked for an aid organisation in areas of Iraqi Kurdistan that still bear the scars of such attacks in the 1980s.

For the Syria case study, we relied on a dataset developed by Human Rights Watch that collated reported allegations of CW use in Syria from 2013 to 2018. The data set draws from the following seven data sources: Human Rights Watch, the Organization for the Prohibition of Chemical Weapons–United Nations Joint Investigative Mechanism, the United Nations Commission of Inquiry, the OPCW Fact-finding Mission in Syria, the United Nations Mission to Investigate Allegations of the Use of Chemical Weapons in Syria, Amnesty International, and Bellingcat (an open source investigative organization). Considering the sensitivity of such information in an active conflict, it is difficult to find a one reliable source, which is why we relied on this dataset which allows for cross checking and triangulation from seven sources reporting incidents over the same timeframe. When sources provided a different estimate of casualties and deaths, an average number was used.

Current knowledge on the health impact of CW

Each group of CWs is associated with different sets of health problems that also depend on the mode of exposure (quantity of agent and route of exposure) as well as the health conditions of exposed victims. A widely accepted grouping of chemical agents classify them into four groups; nerves agents such as Sarin, which interfere with neural transmission through inhibiting the enzyme acetyl cholinesterase, leading to neural over-stimulation or paralysis;²⁰ blistering agents (also known as a “vesicants”) such as Sulphur Mustard, which cause cell death through the irreversible alkylation of DNA, RNA and proteins;²¹ choking agents such as Chlorine, which primarily affect the respiratory tract through pulmonary irritation;²² and blood agents such as Arsine, which attack red blood cells and prevent the body from transporting oxygen.²³

Most studies reviewed (see figure 2) emphasised immediate and mid-term consequences of CWs on individual health focusing on clinical presentation and health response and treatment guidelines. The clinical presentation varies with different chemical agents. For example, blistering agents are associated with skin burns, painful erythema, and blepharospasm (involuntary closure of the eyelids) in the case of eye exposure; nerves agents are associated with neurological symptoms such as miosis, headache and convulsions; and choking agents are associated with chest tightness and breathlessness.²⁴ Also, health response received attention through developing relevant treatment protocols, and decontamination and protection guidelines.

In addition to the focus on individual health in the short term, the reviewed studies also highlight some of the mid and long-term health effects, mainly on morbidity and quality of life. In particular, CW exposure has been linked to chronic health problems such as respiratory, dermatological and eye problems.²⁵ Organophosphate nerve agents are specifically thought to cause difficulties in intellectual functioning and flexibility of thinking, difficulties in simple motor skills, fatigue, visual disturbances, Post-Traumatic Stress Disorder (PTSD), and sleeping disorders. A study on the Tokyo Sarin incident in 1995 found associations with lower psychomotor performance, fatigue and PTSD 6-8 months after exposure to the gas.²⁶ We found a larger number of studies providing evidence related to the long-term effects of Mustard gas, probably because of the longer and more widespread history of its military use. Those effects include respiratory and skin cancers, chronic skin problems, chronic respiratory disease such as asthma, chronic eye disease, and PTSD.

Nevertheless, no evidence was found for any cause-specific mortality related to non-lethal mustard gas exposure as reported by a fifty-year cohort study on veterans who participated in mustard gas chamber tests during World War II.²⁷

We found relatively few studies about the wider public health impacts of CWs. A pilot study on only 30 Vietnamese women provided some evidence for CWs effects related to reproductive health outcomes such as miscarriage, premature birth and congenital malformation.²⁸ Also, the association between CWs exposure and psychological disorders could potentially have effects on community and social health outcomes. Some studies propose environmental impacts of CWs (based on animals and plants experiments) through ecosystem disruption resulting in economic and food production deficits.²⁹ A report by the World Health Organization discussed potential public health impacts of CWs including carcinogenesis, mutagenesis, disruption of the ecosystem, and reduction in both the quality and quantity of food supplies.³⁰

In order to identify the CWs incidents, agents and effects that received more attention in the literature, we conducted basic bibliometric analysis of the identified 91 studies. For incident-specific studies, the Iranian-Iraqi war (1980-1988) was on the top of list with 18 studies, followed by the terrorist attack on Tokyo subway with 5 studies, Syria with 2 studies, and one study per incident for each of Halabja, Vietnam war, WWI and WWII; whereas the majority of the studies (52/91) had no geographical focus. In relation to types of effects, 29 studies focused on short term consequences, 31 on mid and long-term morbidity, 10 on security effects, and 5 on environmental and public health impacts. In terms of agent-specific studies, 21 studies were on Mustard Gas, 12 on nerve agents (mainly Sarin), and 8 on Chlorine. Most studies were published either in the US (34 studies) or in the UK (24 studies). However, when it comes to the location of the first author, the US remains first with 21 studies followed by Iran with 15 studies. The following figures summarises some of this basic bibliometric analysis.

[Figures 1, 2 and 3 here please]

Long term health consequences: CWs use in Halabja

In March 1988, Saddam Hussein's military forces bombed the city of Halabja in Iraqi Kurdistan with CWs, resulting in approximately 5,000 immediate deaths and thousands more injured.³¹ Based on the recorded symptoms of survivors, the bombs are thought to have contained a combination of mustard gas and the nerve agents Tabun, Sarin and VX gas.³² These deadly, heavier-than-air munitions were preceded by hours of conventional bombardment that forced the population into underground bomb shelters, which subsequently became gas chambers when the CWs were dropped.³³ The attack was part of the explicitly genocidal 'Anfal' campaign against the Kurdish population of northern Iraq (which resulted in approximately 100,000 deaths in total), and caused significant long-term public health impacts for the local population.^{25,32}

One might think that the immediate effects were bad enough as recalled by a survivor who returned to her village after the attack:

*"Dead bodies—human and animal—littered the streets, huddled in doorways, slumped over the steering wheels of their cars. Survivors stumbled around, laughing hysterically, before collapsing... Those who had been directly exposed to the gas found that the symptoms worsened as the night wore on. Many children died along the way and were abandoned where they fell."*³³

However, more than 30 years later, the population of northern Iraq still suffers from the effects of the Anfal campaign. The social and economic impact of those killed or displaced by the atrocity is significant. The demographic structure of the region changed dramatically after the campaign with conflict-related emigration of up to 75% of Halabja citizens and severe environmental impacts which damaged the local agrarian economy.³⁴ CWs are strongly suspected to be the cause of the increased population burden of respiratory, dermatological, ophthalmic and neurological problems, as well as congenital malformations and cancers in the local area.^{25,35} The environmental impacts of the CWs used have also affected the local ecosystem, thus magnifying the impact on agriculture and the economy of the region.³⁴

Impact on healthcare and health system: CWs use in Syria

The Syrian Civil War, which started in 2011 and continues at the time of writing in 2019, has seen the most recent large-scale use of chemical warfare.³⁶ A recent report by the Global Public Policy Institute (GPPi) suggests that the use of CWs in Syria is significantly higher than has been reported, and that 98% of incidents can be attributed to the Syrian government.³⁷ Meanwhile, analysis of the dataset we collated for CWs incidents in Syria shows that from March 2013 to February 2018, 85 reported incidents took place causing a total of 1,385 deaths and 6,568 injuries.

The data also shows that the majority of reported incidents used three particular chemical agents: Sarin, Sulphur Mustard and Chlorine. Sarin was associated with the highest number of casualties reaching approximately 1,117 deaths in the Ghouta attack of August 2013. The second highest was Sulphur Mustard that was used in Aleppo on 21 August 2015 resulting in 85 deaths. Reported uses of Chlorine gas have not resulted in any recorded fatalities.

Furthermore, the injury numbers mentioned above refer only to physical injuries, and the psychological impacts of these attacks remains inadequately reported by health and security actors. Reports by journalists, human rights groups and international organisations all depict widespread confusion, anxiety and a sense of helplessness and entrapment amongst victims. This can be in part attributed to widespread bereavement due to loss of family and community members, and in part to the terror caused by the impact of CWs. Those psychological effects, such as PTSD, could last years. For instance, some internally displaced persons coming from Ghouta to Idlib in 2018 were still experiencing mental health issues associated with the Sarin attack in 2013. The terror caused by the Ghouta attack in 2013 is described thus by a doctor:

*'The fear and horror in people's eyes were more difficult than death.'*³⁸

In addition to these direct effects, CWs attacks in Syria have had indirect effects on the health system. Reports from international organisations and testimonies from medical staff indicate that the health services struggled to effectively deal with the chemical attacks and were repeatedly overwhelmed with numbers of casualties. This was exacerbated by the debilitated nature of health care facilities in Syria during the conflict which were starved of resources and staff and frequently directly targeted in the fighting. One report by a local NGO shows that as a result of the Sarin attack on Ghouta three out of four medical units in the town of Zamalka had to shut down.³⁹ Moreover, CWs attacks far exceeded the capacity of the health facilities to respond and compromised their ability to attend to other health needs of the community. Meanwhile, when they had the capacity to respond, the lack of protective equipment for medical staff made them prone to contamination and even death.³⁹ This is on top of the acute psychological trauma that paralysed some medical staff from responding and had long-term effects on other staff who experienced anxiety and fear. Those effects, compounded by many other challenges such as 'conventional' bombardment and difficulties

of day to day living, are thought to have pushed some of the medical staff to flee the country. The wider social, economic and environmental effects of CWs use in Syria seem to be considerable and to have a profoundly negative influence on population health.

Discussion

Based on our literature review, some of the wider public health impacts of CW use seem to have been overlooked. While the available literature emphasises the immediate, mid and long-term impact of CWs use on individual health, it often fails to provide an evidence-based examination of public health impact including long-term consequences and impact on health systems. Therefore, we argue that research into chemical weapons needs to reconceptualise the health impacts of such weapons and generate more evidence that could influence related practice, policies and accountability measures.

The two case studies presented in this article demonstrate how the impact of CWs extends far beyond immediate effects. In the Halabja case, studies 30 years after the exposure are still showing detrimental health outcomes on both individual and community levels. In the Syria case, CWs caused further disruption to the already shattered health system particularly in opposition-held areas where the majority of attacks took place.

In assessing the impact of use of CWs on public health, this article highlights the importance of considering both direct and indirect effects thereof. Direct health impacts can be physical due to exposure to the toxic agents, but also psychological due to the panic, stress, bereavement and anxiety that are associated with use of CWs, particularly when applied on a large scale or against unprepared civilians. Use of CWs can also have an impact on health services, as first responders or medical professionals can become exposed either directly or through cross contamination. Chemical attacks can often result in mass casualties that overwhelm medical infrastructure and systems, effectively curtailing their ability to attend to all victims or to other health needs of the wider population. This effect can be particularly aggravated if medical facilities are already debilitated or compromised as a result of an on-going conflict. Moreover, indirect impact of CWs could be extended to include environmental, social and economic effects.

To systematically assess the broader public health impact of CWs, the following three levels are key:

1. Individual health: which could be either physical or psychological effects;
2. Community health: through indirect effects on health systems and socio-economic impacts;
3. Environmental effects: through direct contamination of water, food and livestock, and indirect effects on the ecosystem.

Based on these three levels, we have developed a framework for conceptualising the public health impacts of CWs (see Figure 4).

[Figure 4 here please]

This approach requires consideration of the whole of the patient pathway for those affected, including potential long-term health impacts on the casualties and psychological impacts on others. Because of the wide area impact of CWs, the need for decontamination of casualties, non-casualties, equipment and the environment, and their impact on ecosystems, this requires a multi-sectoral approach as well as the establishment of systems for long-term follow-up.

Therefore, we believe that an effective health systems preparedness approach to address these consequences is necessary and needs to take the following considerations into account:

- (1) An appropriate system of triage, both at the point of exposure and throughout the health system. The triage should be informed by ethical guidance developed in collaboration with the local communities.
- (2) Medical personnel and auxiliary staff should have proper individual protection against CWs in relation to availability of equipment as well as training on how to use them.
- (3) A monitoring service, both to identify immediate threats and for long term monitoring and assessment of the exposure.
- (4) Epidemiological approaches to identify public health impacts including the likely distant hazard of a chemical plume.
- (5) Clinical guidance on best practices of dealing with different types of chemical agents. This includes decontamination, medication, respiratory support, and managing agent-specific symptoms.
- (6) An appropriate system of documentation and information management.

As CWs are banned under various protocols and conventions of international law, and as their use constitutes a war crime, collecting evidence becomes important for attribution and accountability. The same goes for the use of chemical weapons outside of conflict, where health actors in collaboration with local police and with the Organisation for the Prohibition of Chemical Weapons should take into account forensic aspects when collecting, recording and labelling data and evidence in the aftermath of CWs incidents. The need to collect evidence that will stand up in a Court of Law imposes requirements which might be frustrated by the clinical emergency and there thus needs to be advanced co-ordination and subsequent co-operation between the health and police or security services.

Conclusion

While the bulk of historical CWs stockpiles have been destroyed,⁴⁰ their recent use in intra-state armed conflicts, targeted assassinations and terror attacks highlights the importance of understanding the full impact of CWs use. This understanding contributed to preparedness and the ability of health systems to deliver an effective and comprehensive response. The effects on individuals vary according to the levels of protection available, the mode of exposure, as well as the vulnerability of the targeted population such as babies, elderly, and people with pre-existing morbidity. Indirect effects on public health highlight the need for incorporating CWs preparedness plans into designing health interventions in conflict settings. This includes emergency and contingency planning, training for medical staff, and community awareness. Thus, based on the recent use of CWs, and considering their wider health impacts, we argue that health systems need to be better prepared to deal with incidents of this nature.

The recent use of CWs has caused widespread condemnation but also triggered questions about the adequacy of international verification and accountability measures. Furthermore, their use in an on-going protracted conflict imposes limitations on access for weapons inspectors, humanitarian workers and health professionals to targeted areas. This raises the importance of understanding the full impact of their use and increasing the level of preparedness to deal with the individual but also the public health consequences of such use when it occurs. By demonstrating the importance of the public health consequences of CW and proposing a framework for their assessment, this article emphasises the importance of dedicated studies to generate new empirical data on the topic that can inform effective health, humanitarian, legal and security responses to chemical weapons use.

Declarations

Ethical approval and consent to participate

Not applicable

Availability of data and material

All data used on chemical incidents in Syria are publicly available online.

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Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

The literature search, thematic analysis, conceptual framework, initial drafting of the article, and multiple rounds of edits were carried out by AE. DF and HE helped designing the study, contributed substantial amount of content, and drafted some sections. LL helped design the study, added further literature and contributed to various sections. PP and AP helped conceptualise the study and contributed to the editing rounds. All authors read, edited and approved the final manuscript.

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