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Concrete Impacts: Blast Walls, Wartime Emissions, and the US Occupation of Iraq

Benjamin Neimark

School of Business and Management, Queen Mary University of London, London, UK, b.neimark@qmul.ac.uk

Oliver Belcher

School of Government and International Affairs, Durham University, Durham, UK

Kirsti Ashworth

Lancaster Environment Centre, Lancaster University, Lancaster, UK

Reuben Larbi

Division of Health Research, Lancaster University, Lancaster, UK

Abstract: Militaries around the world are a major source of carbon emissions, yet very little is known about their carbon footprint. Reliable data around military resource use and environmental damage is highly variable. Researchers are dependent upon military transparency, the context of military operations, and broader emissions reporting. While studies are beginning to emerge on global militaries and their carbon footprints, less work has focused on wartime emissions. We examine one sliver of the hidden carbon emissions of late-modern warfare by focusing on the use of concrete "blast walls" by US forces in Baghdad over a five-year period (2003–2008). This study uses a Life Cycle Assessment (LCA) to study one of the world's largest military carbon footprints of concrete, an infrastructural weapon in late-modern urban counterinsurgencies. Moving beyond dominant discourses on climate-security and "greening", we present one of the first studies to expose *direct* and *indirect* military emissions resulting from combat.

Keywords: wartime emissions, infrastructure, counterinsurgency, US military, Iraq

Introduction

To say that war is environmentally destructive is to state the obvious. Less obvious, perhaps, are the "hidden" carbon costs entailed in war and military occupation. Recent research has begun to concentrate on the environmental effects entailed in the military use of hydrocarbon fuels for military-grade vehicles, fighter jets, and deployment of troops across the globe (Belcher et al. 2020; Crawford 2022). However, there are multitudinous carbon costs to modern warfare that are difficult to study due to a military's reliance on a "full spectrum" of capabilities not immediately discernible in a battlefield, including the logistical supply chains needed to deliver supplies; the building of various forms of tactical infrastructure (e.g. walls, forward operating bases, development projects) especially as warfare becomes increasingly urbanised; and the gathering and removal of debris. While research exposing the world's militaries' carbon emissions is beginning to emerge (Belcher et al. 2020; Crawford 2022; Parkinson and Cottrell 2022), adequate theoretical and methodological frameworks need to be developed to capture the less "obvious", yet still significant carbon-dimensions of late-modern warfare.

In this article, we focus on one such "hidden" dimension, namely the embedded carbon footprint of concrete blast walls used by the US military during their counterinsurgency campaign in Baghdad, Iraq (2003–2008). Concrete walls and barriers were extensively used by US forces in Baghdad over this five-year period, as well as in other contexts, such as the counterinsurgency operations in Kandahar and Kabul, Afghanistan in 2008–2012 (Belcher 2014). During its occupation of Baghdad, the US military laid hundreds of miles of blast walls as a means of population control in its urban counterinsurgency strategy. Blast walls were used to mitigate against the damage caused by improvised explosive devices (IEDs) planted by insurgents, and to manage civilian and insurgent movements within the city by channelling residents through authorized roads and checkpoints.[1]

Concrete is one of the oldest and most extensively procured materials by the US military, although it is often underappreciated as a weapon in itself (Rubaii 2022). Spencer (2016) has shown how the utilisation of concrete infrastructure by modern militaries constitutes a significant tactic to mitigate the effectiveness of insurgent actors and establish "security" in a variety of contexts, such as Afghanistan (Belcher 2018), Iraq (Izady 2020; Murrani 2016), and Israel/Palestine (Busbridge 2013). Indeed, the instrumentalisation of concrete, particularly blast walls, reflects the urbanisation of warfare in the 21st century (Graham 2010; Kilcullen 2015).

Effective weaponisation of concrete has an extraordinary carbon footprint. It is second only to water as the most consumed material on Earth (Gursel et al. 2014; Huntzinger and Eatmon 2009; Monterio et al. 2017), responsible for 8% of annual global carbon emissions, emitting roughly four billion tonnes of CO_2 on a yearly basis (Cloete et al. 2020; Ostovari et al. 2021). The large carbon footprint comes mainly from the amount of heat and energy in cement production, the main ingredient in concrete. The cement industry is just behind global agribusiness, which contributes roughly 12% of global emissions and more than triple that of aviation fuel at 2.5%. To produce cement, raw materials undergo a chemical process called "kiln-roasting". According to industry reports, the production of one tonne of cement in the Middle East consumes an average of 103 kWh of energy and releases about 703 kg CO_2e (Cement Sustainability Initiative 2019), which translates into 157 kg CO_2e per m^3 of M20 concrete. Emissions in the production process derive primarily from the heating of limestone into lime for further processing into clinker, and the combustion of fossil fuels used in kiln-roasting (Habert et al. 2020). The CO_2 embodied in concrete is heavily dependent on the aggregate materials used, and Marceau et al. (2007) estimated that, at best, range from 112 kg CO_2e to 313 kg CO_2e per m^3 of concrete produced. Even then, carbon pollution involved in concrete production is significant.

Given concrete's well-known significance as a pollutant, what is "hidden" about the carbon costs in the US military's use of concrete? And moreover, what are the conceptual and empirical tools needed to expose carbon emissions and their underlying military climate narratives helping to conceal them? By "hidden" we are focusing on an underexamined dimension of conflict emissions; namely, the difference between *direct* and *indirect* military emissions that result from combat. While the logistical movement of military troops, convoys, *materiel*—supplies, equipment, and weapons—not to mention firepower itself, entails a straightforward, direct carbon cost (e.g. jet propulsion fuel for fighter jets),[2] the *indirect* emissions we interrogate in blast walls are those produced up and down the concrete supply chains that furnishes the US military's most fundamental infrastructural weapon (cf. Denman 2020). Our analysis is concerned with the indirect emissions of concrete blast walls commonly referred to as Scope 2 and Scope 3 emissions (see below). Indeed, an important "hidden" dimension we underscore is a temporal one, i.e. the long-term contribution of conflict emissions to environmental change that result from relatively short-term tactical operations such as walling off a major city like Baghdad, which has been entirely overlooked up to this point (see next section). In other words, we are filling in more detail into the ongoing work that has recently begun to account for the environmental cost of warfare in terms of emissions and climate change (e.g. Crawford 2022; de Klerk et al. 2023).

In this article, we account for the carbon emissions entailed in the US military's use of concrete in its deployment of blast walls in Baghdad by utilising a Life Cycle Assessment (LCA) to calculate the emissions embedded in the US military's manufacture and use of these fortifications. As a methodology, LCA is generally used to calculate the flow of materials, energy, and emissions associated with the life of a product from manufacture, to use, to final disposal (Gursel et al. 2014; Kua and Kamath 2014). The specific product of our study is the pre-fabricated T-shaped concrete wall section, whose dimensions are specified by the US Department of Defense, and transported to Baghdad from locally contracted concrete plants (see "Anatomy of a T-Wall" below). We extrapolate the emissions associated with the production of 1 m^3 cement and reinforced pre-cast concrete, to a single walling section, and thence to the total length of blast walls deployed in Baghdad from 2003 to 2008. Our analysis of the Baghdad blast walls, based on available maps of wall layouts, shows the extent of concrete walls in Baghdad *viz.* 412 km (256 miles)—more than the distance from London to Paris. We estimate the production of the necessary sections results in emissions of 200,000 tCO_2e, which is roughly the equivalent to the annual tailpipe emissions from more than 43,000 typical US passenger vehicles—clearly, a significant, albeit small slice of the overall emissions during the Iraq War. Yet, up to this point, these have gone unnoticed within military discussions of climate change.

In the next section, we situate our study within the emerging literatures on geopolitical ecology and wartime emissions to better understand the material-discursive interplay of large geopolitical institutions, like the US military, as a global climate actor (Belcher et al. 2020; Crawford 2022; Selby et al. 2022). As we show, dominant military climate change discourse manifests in two distinct ways; the first, is through a climate-security nexus, where climate change effects pose multiple security risks, and the military sees itself as a sort of "global first responder" to disruptive, unpredictable climate-induced socio-natural hazards (Chaturvedi and Doyle 2015; Dalby 2022; McDonald 2013). The second, is through a "military greening". Here, militaries discuss impacts of climate change through the lens of adaptation and mitigation directives to protect base infrastructure and adapt to challenges of war fighting in a climate-changed world (Belcher 2022; Bigger and Neimark 2017; Depledge 2023). Greening is less about ecological sustainability per se, and more focused on making the military climate resilient. Yet, neither of these two discourses, climate-security and military greening, adequately address the major role militaries themselves play in greenhouse gas (GHG) emissions, and very few, if any, have systematic plans to reduce emissions (cf. Buxton 2015; Wier et al. 2021).[3] The implications here are significant. Our work is not to just simply expose hidden carbon emissions, a task worthy in itself, but also push back on climate-security narratives that seek to normalise green warfare and climate-proof militarism.

In previous work (Belcher et al. 2020; Rajaeifar et al. 2022), we argued that to account for the US military as a global climate actor, one must understand the global logistical supply chain that makes the US military's acquisition, consumption, and attendant environmental damage of resources—particularly hydrocarbons, sand, water, and cement—possible. One cannot understand military supply chains and their "hidden" carbon footprints without taking to account its geopolitical ecology—sites of extraction, purchase, storage, and, in the case of blast walls examined here, constructing a built environment (Bigger and Neimark 2017). It is these supply chain dynamics which significantly contribute to military emissions and though supply chain dynamics that actors, entities, and material can be identified and measured. Therefore, we focus on the more hidden emissions of war, both carbon emissions from concrete and the supply chains of its constitutive parts and underscore the multi-scalar effects—from the object of the blast wall, to the city, to atmospheric emissions—usually overlooked in studies concerning the environmental effects of war and military occupation. Our theoretical and empirical findings contribute to ongoing work on the geopolitics of supply chain studies, by linking it up to some of the largest logistical operations on Earth, the US military (Chua 2018; Cowen 2014; Khalili 2018; Mezzadra and Neilson 2019), while also adding to emerging work on "militarized ecologies" (Bishara 2022) and hidden ecological effects of war (MacLeish and Wool 2022).

In the following sections, we contextualise the instrumental use of walls in Baghdad during the Iraq War, including a look at the so-called 2008 "Battle for Sadr City", where the US military utilised concrete as a weapon to occupy Baghdad to its greatest effect. We show the hidden carbon costs of producing blast wall sections for laying in Baghdad, providing an "anatomy" of different types of blast wall used by the US military, including a detailed explanation of the methods and materials used in our analysis. Finally, we conclude with a call for further independent studies on military emissions, and the need for continued research on environmental damage in contemporary warfare. By identifying the carbon footprint of war for something as mundane as concrete T-walls, this article shows how, from an ecological perspective, there is no such thing as an "effective" or "green" technology or military. We argue that methods of disclosing the hidden carbon costs of war, such as we have developed here, should be further refined to gain a fuller picture of the *de facto* environmental harms of war, often obscured by the immediate horrors of devastation, including how militaries contribute substantially to long-term climate change.

Geopolitical Ecology and Conflict Emissions

In recent years, geopolitical ecology has emerged as a rich multidisciplinary framework to analyse complex interactions between political power, institutions, and ecological change. As a framework, geopolitical ecology combines political ecology—which has long accentuated the dialectical relationship between capital, society, and natural environment (Loftus 2020; Ouma et al. 2018; Peet et al. 2010)—with critical geopolitics (Buxton and Hayes 2016; Dalby 2012; O'Tuathail 1996), supplementing political ecology by drawing together the symbiotic connections between geopolitical discourses and ecological concerns (Bigger and Neimark 2017). Much of the work in this vein has emphasised how power dynamics, spatiality, and representation shape environmental policies (Benjaminsen et al. 2018), moving beyond the classical geopolitical focus on resource utilisation and distribution. However, as the world faces unprecedented environmental changes and risks due to climate change, the influence of ecological conditions on state behaviours and international relations has become a pressing matter, best reflected in the burgeoning theoretical and policy-related literatures on environmental security (Albert 2023; Buxton 2015; Dalby 2014, 2022). Yet emerging work shows that within discussions of geopolitics of climate-security narratives, there are also ecological parameters war, such as burn pits and wastewater, which are used as tools of militarised violence, and which play out in material ways within distinct settings (Bishara 2022). Below we make the case for why geopolitical ecology is increasingly becoming a useful conceptual tool for critical scholars to navigate the multifarious and complex relationships between power, conflict, and ecology.

Geopolitical Ecology

As noted above, we situate our study within these emerging literatures in geopolitical ecology, which have developed critical conceptual frameworks for understanding the multifaceted impact of military institutions and other state entities on global environmental processes. The novelty of geopolitical ecology lies in its fusion of the realms of political ecology and geopolitics, affording analytical space for fresh perspectives on the intricate interplay between broader institutional processes and their discursive and material roles in shaping global natural phenomena (Mostafanezhad and Evrard 2018). For our part, we add a twist to these literatures by focusing particularly on the geopolitical ecology of *wartime emissions*, thereby stressing the "inter-carbonic" relations (Selby 2022) between the US military's conflict emissions, the military's extensive supply chains, and climate change, which up to this point has been generally left out of studies on military carbon footprints. We link the upstream supply chain emissions of the extraction and transport of sand, water, and cement to the geopolitical project of occupation and counterinsurgency projected with the tactical use of T-walls as a symbol of power.

In the Iraq War, concrete blast walls were a crucial medium of the US military's environmental impact. It is not merely the geographical obscurity of military contracted concrete production plants in the Kurdistan region of Iraq, or the embedded carbon in concrete production (both discussed below), but the tactical use of blast walls is often obscured within military climate change discourses on military operations, which focus almost exclusively on direct emissions resulting from firepower or vehicle use. The dominant critical narratives on militaries and climate change tend to follow two main discursive threads. The first is a critique of the "climate-security nexus", where climate-security narratives that understand climate change as a "threat multiplier", or, according to the US military, a warming planet will lead to increased threats and deteriorating environmental conditions are rightly criticised (McDonald 2013; Selby et al. 2022). The conventional geostrategic discourse of threat multipliers rooted in climate-security sees climate change as a direct risk to national security across the globe, especially since many of these "threat multipliers" will lead, in the military's view, to increased conflict and war (Dalby 2014, 2018; Gilbert 2012).

The second narrative is that of the "greening the military" as a climate adaptation and part of recent pledges of decarbonisation (Bigger and Neimark 2017; Depledge 2023). A series of recent reports commissioned by the DoD have stated that climate change will have significant implications for US national security and defence (USDoD 2021). In response, the US military have both put forward strategic climate change policy leading to the decarbonisation of militaries and eventual push to contribute to national net zero targets (Rajaeifar et al. 2022). This discourse emanates directly from recent climate hazards to base infrastructure both domestic and international and the DoD's response in rebuilding and reengineering for a climate change-proof military (Crawford 2022). Building on this work, as well as methodologies in political ecology (Brock and Dunlap 2018; Büscher and Fletcher 2018; Geenen and Verweijen 2017), our analysis brings to light the latent materials, pollutants, and emissions consequent to blast wall construction. These environmental implications are discernible only by "deconstructing" the materials involved in blast wall production. In both discourses, there is a strong sense of normalising militarism. We want to stress that our point in examining US carbon emissions is to continue calls for, not a greener military, or one that is more resilient to climate shocks, as seen through a climate-security lens, but less militarisation overall. As we have noted in previous work, the only way to reduce carbon emissions is not tinker around the edges with some sort of military-grade greenwashing, but to "turn down the furnace" (Belcher et al. 2020:75; Neimark et al. 2019). We believe this begins with accounting for many of the hidden direct and indirect emissions militaries emit during wartime.

Wartime Emissions

Wartime emissions represent a critical yet understudied dimension of the broader problem of anthropogenic GHG emissions. These emissions encompass factors ranging from energy consumption entailed in military activities and operations, to infrastructure destruction and mobility of displaced populations in war zones. Recent studies provide a snapshot of the substantial contribution of militaries to global environmental change. For example, Parkinson and Cottrell (2021) show that the carbon footprint of the European Union's 2019 military expenditure was about 24.8 million tCO_2e, the equivalent of the emissions from about 14 million average-sized automobiles. Belcher et al. (2020) estimate the emissions from the US military fuel use in 2017 as 25.4 million tCO_2e, making it one of the largest single institutional carbon polluters in modern history. If the US military were a country, its fuel usage alone would make it the 47th largest emitter of greenhouse gases in the world (Neimark et al. 2019). While a partial picture of global military carbon emissions is emerging, we still know very little about how much GHG global militaries produce (Rajaeifar et al. 2022).

Current studies on military emissions primarily rely on Scope 1 and Scope 2 emissions calculations, defined respectively as the direct emissions (such as burning emissions) and indirect emissions (such as emissions produced from a base drawing electricity from local power grid). There has been very little focus on Scope 3 emissions, such as the emissions produced up and down a logistical supply chain from point of production to delivery. Current estimates of military carbon footprints usually do not account for indirect military consumables, such as water bottles, concrete, and sandbags used at bases and operational field positions. In part, this is due to data related to Scope 1 and Scope 2 military emission being more readily available for researchers.[4] This is where our study aims to fill a gap. By focusing on blast walls, we attempt, in part, to catalyse methodologies accounting for Scope 3 emissions produced by the US military, as well as other militaries. Often, it is the carbon-intensive externalities of war that can have the greatest long-term effects.

For example, consider the opening days of Russia's invasion of Ukraine in March 2022, where images showed a 40-mile-long Russian convoy stalled for days outside Kyiv. One was left wondering if, during that time, the Russian military vehicles were turned off, idling, or stop-starting. Both situations highlight carbon-based externalities often overlooked in studies on the relationship between war and environmental change and impact. It is important to note the asymmetrical emissions production of the actors involved in late-modern wars. Since the United States' war in Vietnam, most conflicts have been between "advanced" militaries in the Global North engaging in conflicts in the Global South, against insurgent actors whose methods of war are a fraction of the carbon cost when compared to the heavy vehicles and artillery of, say, the US military's campaigns in Iraq and Afghanistan. Yet, mirroring the general problem of the "advanced economies" historically driving climate change through industrialisation with unequal consequences for communities and ecosystems in the Global South—particularly island nations—the environmental damage and *sites* of carbon-intensive warfare also take place nearly always in postcolonial contexts (Iraq and Afghanistan, among others), with Ukraine being the exception rather than the rule.

Concrete is the Weapon

In March 2003, the United States and allied forces (the "Coalition of the Willing") invaded Iraq, deposing Saddam Hussein's Ba'athist regime from power in a little over three weeks. By the first week of April, US-led forces held Baghdad, with US General Tommy Franks occupying the Presidential Palace and commanding forces across Iraq. On 1 May 2003, US President George W. Bush infamously declared the "end of combat operations" from the deck of the USS Abraham Lincoln aircraft carrier, and the Coalition Provisional Authority (CPA) headed by Presidential Envoy Paul Bremer assumed control of the country.

On 23 May 2003, ten days after his appointment, Bremer made perhaps the most consequential decision of the Iraq War when the CPA issued an order disbanding Saddam Hussein's Iraqi military, security, and intelligence infrastructure in a policy called "De-Ba'athification". Overnight, Ba'athist party members were isolated and banned from working in government institutions. Although a secular party, Ba'athists were invariably identified by US authorities in religious terms, as "Sunnis". The policy of De-Ba'athification thus had the insidious effect of fragmenting and isolating the population along ethnic lines—Sunni vs. Shia vs. Kurd (Rosen 2010). Combined with the wholesale destruction of public works infrastructure by US bombings, this created the unstable conditions for the insurgency and civil war that raged in Southern and Western Iraq from 2004 to 2008 (Dodge 2013).

In response to the growing insurgency against the American-led occupation in Iraq, the US Department of Defense adopted a counterinsurgency strategy (Clemis 2009), which has a long and dubious track-record in American military history (McClintock 1992). Mainstream advocates of counterinsurgency often present the doctrine as a method for "winning hearts and minds" by investing heavily in security and development projects which, they argue, directly benefit the occupied population (US Army 2007). In Iraq, initiatives such as USAID's Community Stabilization Program were designed to improve governance and create services and employment, and thus disincentivise young men from joining the insurgency (Attewell 2023; Belcher 2018). Kilcullen (2010:43), a major influence on contemporary US counterinsurgency doctrine, once described counterinsurgency as "armed social work". The everyday reality of American counterinsurgencies in Iraq, and Afghanistan, was very different than that presented by its proponents, with security prioritised over development projects, and "population control" given pride of place in daily military operations (Belcher 2015).

In Baghdad, where sectarian violence was most acute, the US military adopted three tactical approaches during the occupation to stem the insurgency and secure Baghdad. First, in daylight hours, US Marines and Army personnel were deployed *en masse* outside of the Green Zone in foot and vehicle patrols. Patrols served the dual purpose of policing the population and ensuring that American soldiers were a highly visible presence. Second, after dark, US commanders deployed Special Forces on night raids into homes of suspected insurgent operatives and leaders—often summarily arresting or "eliminating" military-aged men (Niva 2013). While commanders praised the efficacy of night raids for gathering intelligence (Gregory 2006), the violent practice often had the effect of terrorising

Figure 1: Top—Images of emplacing [i] Jersey walls (far left), [ii] Alaska blast walls (centre), and [iii] guard towers used at checkpoints (far right) in Iraq 2008. Image credit: Senior Airman Eunique Stevens, US Air Force; Staff Sgt. James Selesnick, US Army (source: Spencer 2016). Bottom—the US military's tactic of lining every major road with T-walls. Image credit: Spc. Kiyoshi Freeman, US Army (source: Spencer 2016).

and alienating the very population that military personnel were trying to "win" over through the daytime patrols. Finally, and most consequentially, the US military divided the city into a labyrinth of checkpoints, barbed wire, and high concrete walls, often strategically placed around Sunni neighbourhoods (Gregory 2008). Between 2003 and 2008, 412 km of such blast walls, often called "T-walls", due to their shape, or "Bremer Walls", after CPA proconsul Paul Bremer, were placed around Baghdad (see Figure 1).

Concrete walls quickly became the city's distinguishing feature. The tactical use of blast walls as a means of separating populations was widely implemented in

Israel, where similar structures were utilised in 2003 for the Separation Wall between Israeli urban areas and the Palestinian territories (Niva 2008; Weizman 2007). The practice was rapidly adopted by the US military, and put to great effect not only in Baghdad, but across urban areas in Iraq and Afghanistan.

These three counterinsurgency tactics—daily foot and vehicle patrols, night raids, and concrete barriers—developed within a context when the US military was more broadly recalibrating its military doctrine to long-term occupations in Iraq and Afghanistan, and other potential guerrilla-style insurrections in a more urbanised world (Davis 2006; Kilcullen 2009).

Operation Gold Wall

In April 2008, the United States military launched Operation Gold Wall on the edge of Sadr City, a large district in the northeast of Baghdad with nearly two million residents (see Figure 2). Originally called Al-Thawra, the district was built in the late-1950s under Prime Minister Abdul Karim Qassim to address housing shortages among the urban poor and has a long history of labour struggle. During the era of Arab nationalism, "secular" working-class movements fought for better labour conditions and housing for the neighbourhood's residents (Cockburn 2008).

Immediately preceding and following the overthrow of Saddam Hussein's regime, Shia leaders long residing in the district harnessed the history of labour

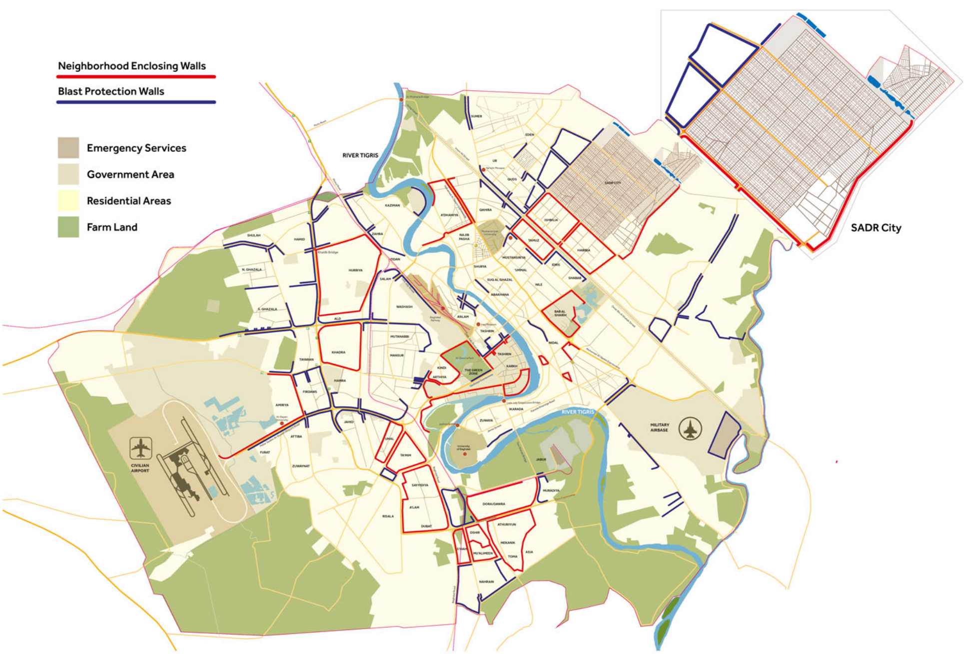

Figure 2: Map of neighbourhood separation and blast walls in Bagdad 2003–2008 (the map was adapted from previous research conducted by Dr Michael Izady, "Atlas of the Islamic World and Vicinity", Columbia University Gulf 2000 Project: 2006–present: https://gulf2000.columbia.edu/maps.shtml).

grievances into a political-religious movement led by Muqtada al-Sadr to demand greater representation of impoverished residents in national politics, as well as an end to the American occupation (ICG 2006). It was Muqtada al-Sadr's father, Mohammad al-Sadr, a prominent Shia religious leader who openly challenged Hussein during the Iran–Iraq War, for whom the district was unofficially renamed to "Sadr City" (replacing "Saddam City") after the fall of Baghdad in 2003.

Unlike the rest of Baghdad, Sadr City lies on a grid system reminiscent of mid-century modernist urban design. This made the neighbourhood particularly vulnerable to the US military's Operation Gold Wall initiative. The pretext for Operation Gold Wall was the continuous firing of rockets into the Green Zone from the district throughout 2007 and 2008. Militias and Iranian-backed "special groups" operated in Sadr City during the American occupation, firing rockets and laying IEDs throughout Baghdad to disrupt Coalition patrolling operations. The groups ranged from criminal elements trafficking weapons and equipment between Iran and Iraq, to paramilitary militias allied with Jaysh al-Mahdi, the armed wing of Muqtada al-Sadr's political party, Sadrist Trend (Cochrane 2008). According to Cochrane (2008:11), "[n]early 700 rockets and mortars were fired at the Green Zone during late March and early April; more than 80% of these attacks originated in Sadr City".

The trigger for Operation Gold Wall was a particularly audacious attack on 24 March 2008, when nearly two dozen rockets and mortars struck the Green Zone, including the area around the US Embassy, in a brazen attack that killed 15 people and injured many others (Goode 2008). On 25 March, Iraqi Prime Minister Nouri al-Maliki ordered a curfew in Baghdad, and targeted Sadrist sympathisers in the southern city of Basra in retaliation for the 24 March attack. Muqtada al-Sadr responded by calling for a "day of civil disobedience". In the following month, US and Iraqi forces initiated Operation Gold Wall to cordon-off and isolate Sadr City in a bid to disrupt the insurgent network operating in the district.

Our focus here is not to assess the operational impact of Gold Wall, which has been extensively covered elsewhere (Johnson et al. 2013:71–82). Rather, our concern is the *environmental* impact of the segregation of Sadr City, as a sample within the larger context of the US military walling-off large swathes of Baghdad. A fortnight after establishing checkpoints around Sadr City on 5 April, the US military began constructing a wall along Al-Quds Street, on the northern edge of the Jameela and Tharwa neighbourhoods (Cochrane 2008; see Figure 3).

The US Army 3rd Brigade worked 24 hours per day, seven days per week to lay a 4.6 km wall along Al-Quds Street using 12-foot-high concrete barriers. During that time, Jaysh al-Mahdi incessantly attacked the construction teams, but were unable to prevent wall's construction which was completed on 15 May. On 11 May, al-Sadr announced a ceasefire, and the Iraqi Army was patrolling the district by 18 May (Johnson et al. 2013). Rocket attacks from the district were dramatically reduced from hundreds to fewer than two per day (Fussman and Sills 2009). However, as we show below, the operational "successes" of Gold Wall from the perspective of the US military and Iraqi government, did not come without a substantial environmental cost.

Figure 3: Map of Sadr City walls and the US military's Operation Gold Wall, April–May 2008 (the map was adapted from an Institute for the Study of War and Weekly Standard report [Cochrane 2008]).

Anatomy of a T-Wall

While the concrete barriers used by the United States military in theatres of war vary in height according to primary use, they share the same cross-section, and are precast in 2.5 m lengths for installation in location and must meet a minimum compressive strength of 20 MPa, commonly referred to as M20 grade concrete. M20 is composed of a specific mix of constituents conforming to Section 03300 of the cast-in-place concrete standard specifications of the US Department of State Bureau of Overseas Buildings Operations (USDoD 2006). We do not include the transportation of raw materials or finished sections due to the lack of reliable data on the locations of raw material extraction or production facilities of the suppliers of concrete barriers. This lack of data is due to the hasty procurement of blast walls during this period, highlighting the difficulties of calculating carbon emissions and data gaps.

Three heights of wall were used in Baghdad: Jersey, Texas, and Alaska (see Table 2). Jersey barriers are the smallest at ~0.9 m in height and were used for checkpoints and traffic control (Finoki 2008; Obaid 2014), in a way familiar to

Table 1: CO_2 emissions inventory to produce 1 m^3 of concrete

Constituent or process	Quantity (kg)	Emission factor (kg CO_2e / kg)	Total emissions (kg CO_2e)
CEM 1 Ordinary Portland Cement	224	0.912	204.29
Sand	831	0.00747	6.21
Crushed stones	1127	0.00747	8.42
Water	141	0.000344	0.05
Steel reinforcement	100	1.55	155.00
Pre-casting	2423	0.01419	34.38
Total	**2423**		**408.44** $\pm$ **20.19**

drivers in many world regions. The largest, Alaska barriers, are ~6 m high, and were used to segregate communities and for the protection of US military bases. By far the most common wall deployed in Baghdad, as elsewhere, was the Texas barrier. These, standing ~3.6 m high and weighing 900 kg, were colloquially referred to as "T-walls" or "Bremer walls", and were routinely installed for the protection of key commercial and public buildings, such as hotels, banks, restaurants, and places of worship. Texas barriers provided vital protection for diplomatic and military installations in the "Green Zone" against IEDs, rockets, and mortar-fire (Izady 2020). Operation Gold Wall relied almost entirely on Texas barriers for the segregation or containment of communities (Fussman and Sills 2009).

Carbon Emissions Embodied in Precast Wall Segments

Here, we use a Life Cycle Assessment to estimate the carbon embodied in the concrete walls emplaced in Baghdad by US and allied militaries. The scope of our analysis, however, is confined to the production of the cement and reinforced pre-cast concrete required for construction of the ~412 km of concrete walls installed in Baghdad during the occupation. As previously noted, we do not include the transportation of the materials or finished concrete barriers in the analysis due to lack of reliable data on the locations of raw material extraction or suppliers of concrete barriers.

Concrete is made from a mix of cement, sand, crushed stones, and water, each of which is associated with a different magnitude of CO_2 emissions, in proportions depending on the required compressive strength (Monteiro et al. 2017). Here we consider the production of M20 concrete with components as stipulated in the 2007 report of the Portland Cement Association (Marceau et al. 2007). The US Overseas Building Operations code Section 03300 further specifies that "Ordinary Portland Cement" should be used for supply of T-walls (USDoD 2006). We therefore assumed that all blast walls were produced using CEM 1 Ordinary Portland Cement, comprising 94% clinker, 5% gypsum, and 1% minor additional constituents (BS EN 197), which is the main type of cement produced in Iraq (Cement Sustainability Initiative 2019). Concrete T-walls are reinforced with steel to enhance the tensile strength, and we account for CO_2 embodied in the steel. The total mass of input materials consisting of aggregates, cement, water, and steel for a cubic metre of concrete is 2,432 kg (ICE 2019).

We calculated the CO_2 emissions resulting from the production of 1 m^3 concrete, conforming to this specification, in Iraq during the period of occupation. Emission factors for each constituent were taken from the Inventory of Carbon and Energy (ICE) version 3.0 (ICE 2019) and are shown in Table 1. The ICE emission factors encompass Modules A1 to A3 of the European Union sustainability of construction works and services standards EN 15978 and EN 15804 (Building Research Establishment 2013). These cover CO_2 emissions associated with both stationary and mobile combustion of fossil fuel to extract, process, and transport constituent to the factory gate (IPCC 2006a) as well as process-based emissions arising from the crushing of stones and fuel combustion for kiln-roasting of raw materials for cement. We also included emissions resulting from pre-casting the wall sections, which involves batching, mixing, and pouring concrete into moulds and compaction using high-frequency external vibrators to ensure the optimum density (ICE 2019).

It should be noted that admixtures such as superplasticisers, air entrainment, and accelerators are widely added to concrete to enhance its properties (Gursel et al. 2014). However, they constitute less than 1% of the mass of concrete and produce relatively negligible emissions (Marceau et al. 2007), and are therefore not included in our analysis, although materials such as slag, fly ash, and silica fume are now regularly used as part-replacement for cement in concrete to reduce the embodied carbon (Ahmad et al. 2021).[5]

Estimation of Uncertainty

The main sources of uncertainty in our estimation of the carbon embodied in precast concrete blast walls are the composition of the concrete used in the barriers, and the emissions factor associated with each. The IPCC methodology recommends the use of country-specific emission factors wherever possible (IPCC 2006b), in which case the uncertainty relating to default carbon emission factors for fossil fuel combustion sources is quite low (5–10%). However, we used emission factors based on UK data (ICE 2019) due to lack of country-specific data for Iraq, hence assuming the maximum, i.e. 10%, uncertainty to these figures. Due to the similar technologies used across the world (Weidema and Wesnaes 1996), we assign an uncertainty of 1% for quantity of inputs for m^3 of concrete. We conducted a Monte Carlo analysis of 100,000 iterations for the carbon embodied in a cubic metre of concrete (Table 1) and each walling scenario (Table 3). This simulation returns a mean and standard deviation of the distribution. M20 concrete is stipulated to have a density of 2,423 kg m^3 (USDoD 2006). Using the proportions of each constituent specified by USDoD (2006), our best estimate of the total carbon emissions embodied in the production of 1 m^3 of DoD-regulation concrete in Iraq during the 2003–2008 occupation is 408 kg CO_2e.

Carbon Emissions of Blast Walls in Baghdad

We estimate the total emissions associated with the M20 concrete barriers produced and emplaced in Baghdad by the US and allied militaries between 2003

Table 2: Type of concrete barrier and embodied carbon (figures are for illustration only and are not to scale)

Barrier	*Jersey*	*Texas*	*Alaska*
			
Volume of concrete (m^3)	0.96	3.02	4.78
Embodied carbon (kg CO_2e)	392.10	1,233.49	1,952.34

Table 3: Scenarios of walling and resultant embodied carbon

Walling scenario	Length of barrier (km)			Number of sections of barrier			Total embodied carbon (kt CO_2e)
	Jersey	Texas	Alaska	Jersey	Texas	Alaska	
S1	0	412	0	0	164,648	0	203.0 ± 11.6
S2	0	412[6]	0	0	253,924	0	313.2 ± 17.9
S3	63	286	63	25,124	114,400	25,124	199.9 ± 11.5

Scenario 1 (S1): All blast and neighbourhood walls are formed of Texas barriers.
Scenario 2 (S2): All blast and neighbourhood walls are formed of Texas barriers. However, blast walls are assumed to be a "composite wall of two rows of T-walls with HESCO bastions or a similar soil barrier [that] would provide the needed blast and fragment protection for the minimum footprint with available materials" (USDoD 2006), as described in a US Department of the Army memorandum on blast wall requirements for use against vehicle-borne IEDs in Iraq.
Scenario 3 (S3): All blast walls are formed of Texas barriers. Neighbourhood walls are an equal mix of single-layer Jersey, Texas, and Alaska barriers.

[6]Blast walls consist of a double layer of Texas barriers.

and 2008 by extrapolating the emissions per unit to the total volume of concrete used. We start by calculating the total carbon embodied in a 2.5 m pre-fabricated section of each of the Jersey, Texas, and Alaska barriers used in Baghdad. The volume of concrete required for one section of each is approximately 0.96, 3.02, and 4.78 m^3 based on the approved dimensions of a Texas barrier (USDoD 2006), resulting in emissions of 392, 1,233, and 1,952 kg CO_2e, respectively (Table 2).

The total length of each blast and neighbourhood wall was extracted using Fiji ImageJ software (Schindelin et al. 2012) from an infographic of concrete walls in Baghdad developed by Izady (2020) for the Gulf 2000 Project at Columbia University, a repository of infographics and maps of demographic and socio-political indicators of the Gulf Region (see Figure 1), cross-checked against other sources (Murrani 2016). We estimate ~412 km of blast walls, comprising 164,648 sections of 2.5 m standard barriers, were emplaced in Baghdad by the end of 2008.

However, information regarding which size barrier was used in each location in Baghdad is not available. While more than half (54%) of the total length of walls in Baghdad are recorded as "blast walls", which were most usually Texas barriers, other barrier types were used for "neighbourhood walls". We therefore formulated three scenarios to estimate the total volume of concrete in the walls. In each, all blast walls were taken to be Texas barriers, but the neighbourhood walls comprised different proportions of the three types of concrete barrier.

The estimated 412 km of concrete walling therefore embodies between 200 kt CO_2e and 313 kt CO_2e. We consider the last scenario, S3, which includes the use of different heights of neighbourhood walls, the most likely and therefore take this to be the best estimate of emissions.[6] The total carbon embodied in the production of the concrete required to install blast walls in Baghdad during 2003–2008 is therefore ~0.2 million tonnes CO_2e. This is equivalent to the annual tailpipe emissions from more than 43,000 typical US passenger vehicles.[7] In 2008, Iraq's total carbon emissions were ~ 25 million tonnes (Earth System

Science Data 2022), making the carbon from walls emplaced by occupying forces in Baghdad equivalent to nearly 1% of Iraq's annual carbon footprint.[8]

Total Gold Wall Emissions

Operation Gold Wall saw the construction of a 4.6 km wall along Al-Quds Street using 12-foot-high concrete slabs, i.e. Texas barriers, which is typified by walling scenario S1 as discussed above. This length equates to about 1,840 single units of 2.5 m-long concrete wall sections and therefore represents about 2.27 $\pm$ 0.13 kt CO_2e of carbon. The use of concrete walls in this single military intervention, therefore emitted as much carbon as 500 average-sized passenger vehicles on the road for a year.

Conclusion

In this work, we studied one aspect of the massive carbon emissions of the US military force Iraq (2003–2008)—its use of concrete as a weapon of war. Promoted by military planners as being one of the most effective counterinsurgency weapons used in Iraq, the hundreds of miles of concrete walls and barriers laid to secure safe areas in Baghdad had a more enduring legacy—namely, the carbon emissions embedded in concrete blast walls, which have remained up to this point, out of sight, and unreported (Fisch-Romito 2021).

We looked to fill that gap. Theoretically, we provide a foundation by which to study large geopolitical organisations and their environmental damage during war. Geopolitical ecology has been shown to be an effective conceptual framework for analysing the role of large institutions, such as the US military, in environmental change. Our focus on US military supply chains sheds light on the institution's longstanding war on the climate (Belcher et al. 2020). Through an examination of the "inter-carbonic" relations (Dalby 2022; Selby 2022) between the US military, the environment, and climate change, we hope that this work also helps others contextualise the discursive-material interplay coalescing large geopolitical institutions. If anything, scholars can use this work as a point of departure calling out wide-ranging efforts by large geopolitical institutions who continually hide their massive carbon emissions and wider environmental damage of war, "out of sight", and obfuscated through new "greening" discourse and under the guise of national security.

Empirically, our calculations show the sizeable length of concrete walls in Baghdad to be roughly 412 km (256 miles), with 203,000 tCO_2e—roughly equivalent to the total emissions of a small island nation. This output, however, is just a single, albeit important, sample of the enormity of carbon emissions emanating from US military interventions during that time. We argue that concrete is an ideal case study to illuminate the enormity of military emissions. It is an extremely important material in military defence, used historically in bunker and base construction, and as noted above in particular the use of concrete in the Operation Gold Wall, it is an important tool for occupation forces for counterinsurgency and security control of civilian populations. Most noteworthy, the rapid construction and extensive laying of blast walls throughout the city of Bagdad not only changed the social and cultural fabric of the city (Izady 2020; Murrani 2016), but it also came with a large carbon cost.

At a moment when governments are pledging net zero commitments to keep global temperatures below the 1.5°C target, the world's largest militaries are still given a "free pass" to release carbon emissions without any accountability or concern. Much of this has to do with previous exceptions granted to many of the militaries in not having to account for their greenhouse emissions in international climate agreements (Buxton 2015; Rajaeifar et al. 2022). Yet, these emissions can no longer go hidden from view. And while independent research is emerging exposing the world's militaries' massive carbon emissions, less of this work specifically addresses carbon emissions during war. Our study contributes to these independent studies of military GHG emissions, and future studies that look at calculations of carbon pollution during wartime. Again, it is important to note that we understand that it is not enough to just call out militaries on their carbon footprint, but to support calls of de-scaling the military overall and reduce operations, when possible.

For instance, impacts of war are generally calculated in terms of military and civilian casualties, property damage, and economic costs. As Neta Crawford et al. (2021) at the Watson Institute's Costs of War Project estimated, between 184,382 and 207,156 civilians and 4,572 US military personnel died from direct war related violence during the US Iraqi conflict from 2003 to 2019. The economic costs are astounding as well, as they found that the Iraq War cost US taxpayers close to US$2.2 trillion (Crawford 2019). Yet, within the human and economic calculations, the US military's carbon footprint remains out of sight and rarely discussed by policymakers or academics.

Moving forward, we believe that these calculations of the costs of war need to include the GHG and wider environmental footprints. We are not naive to think that any major military is going to hold back on engaging in military intervention because of its environmental or carbon emissions. However, up to this point, there is very little evidence given any contemporary research that they do. Like that of human rights of civilian casualties (e.g. due to collateral damage of drone strikes), environmental damage, and more noteworthy, carbon emissions, should also be part of the military calculations to waging war. This environmental exceptionalism must end. We advocate for more efficient accounting by both militaries themselves to begin adhering to their obligations at COP in Paris to voluntary report their GHG emissions alongside their national inventories to the UNFCCC. Militaries are themselves waking up to the effects of climate change and their own carbon footprints. After COP26 in Glasgow, the United States and NATO members all made commitments to reduce their GHG emissions in line with national net zero targets (Depledge 2023; Goodman and Katarina 2022; Rajaeifar et al. 2022; US Army 2022). However, as stated above, to meet these goals, much more needs to be done in terms of transparent reporting and research to hold global militaries accountable, not just to expose their massive carbon emissions, but also against increasingly dominant and normalising narratives surrounding of the greening of war.

Data Availability Statement

The data that support the findings of this study are openly available in Lancaster University: at https://www.research.lancs.ac.uk/portal/en/datasets/search.html.

Endnotes

[1] Although also described as T-walls, for this article, we use the name "blast wall" as a description of their original use to protect against IEDs and other explosives. However, as Rubaii (2022) explains, the uses of T-walls in Iraq and elsewhere have been adopted well beyond their blast-proof functions—mainly for population control and to quell political dissent.

[2] See Dalby's (2018) enlightened discussion on the complex relationship between climate geopolitics, combustion, and firepower.

[3] For more on the lack of military emissions reporting, see "The Military Emissions Gap", a collaboration between Concrete Impacts (a UKRI-Economic Social Research Council funded collaboration between Queen Mary, Lancaster, and Durham Universities and the Conflict and Environment Observatory https://militaryemissions.org/). See also Scientists for Global Responsibility (https://www.sgr.org.uk/).

[4] See Crawford (2022:295–312) for an overview of the methodologies utilised for calculating military emissions, as well as issues of data reliability within such methodologies.

[5] These are relatively recent introductions and there is no evidence that these were in use in 2008 in Iraq or elsewhere.

[6] We classified the walls as blast protection and neighbourhood enclosing walls based on data from the Gulf 2000 Project (Izady 2020). Scenario 3 (S3) assumes that all blast walls are formed of Texas barriers, and neighbourhood walls are an equal mix of single-layer Jersey, Texas, and Alaska barriers. We therefore consider the S3 as the most likely scenario. The height of the wall determines volume of concrete it is made of, and hence the amount of carbon it embodies.

[7] The US Environmental Protection Agency estimates that a typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year (USEPA 2023).

[8] Although this is not a routine source of carbon during peace time, and thereby do not believe that is attributable to the annual carbon accounting in Iraq.

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