



OPEN ACCESS

EDITED BY

Walter E. Grunden,
Bowling Green State University, United States

REVIEWED BY

Lijun Shang,
London Metropolitan University,
United Kingdom
Tatyana Novosiolova,
Center for the Study of Democracy, Bulgaria
Jan-Cedric Hansen,
Centre d'Hébergement et
d'Accompagnement Gérontologique (CHAG),
France

*CORRESPONDENCE

Amy E. Smithson
✉ carolina_aes@yahoo.com

RECEIVED 25 June 2025

ACCEPTED 01 October 2025

PUBLISHED 12 November 2025

CITATION

Smithson AE (2025) Factors in illicit
bioweapons programs: case studies of the
Soviet Union/Russia and Iraq.
Front. Polit. Sci. 7:1654084.
doi: 10.3389/fpos.2025.1654084

COPYRIGHT

© 2025 Smithson. This is an open-access
article distributed under the terms of the
[Creative Commons Attribution License](#)
(CC BY). The use, distribution or reproduction
in other forums is permitted, provided the
original author(s) and the copyright owner(s)
are credited and that the original publication
in this journal is cited, in accordance with
accepted academic practice. No use,
distribution or reproduction is permitted
which does not comply with these terms.

Factors in illicit bioweapons programs: case studies of the Soviet Union/Russia and Iraq

Amy E. Smithson*

Independent Consultant, Washington, DC, United States

Germ weapons can devastate human, animal, and plant populations, and the universe of possible biowarfare agents is expanding with advances such as CRISPR and AI. Political leaders order the development and use of weapons, and they also pass laws and establish regulations and policies to govern their societies. Such political factors can frame the choice of biological agents; the characteristics of research, development, testing, and production programs; and military doctrine for biological warfare. These other factors can be identified, evaluated, and used to inform efforts to detect proliferation. Therefore, this article presents case studies elaborating the sociological context, motivations, organizational structure, level of science, technology, and safety, military doctrine, and visibility of the Soviet/Russian and Iraqi bioweapons programs. The article also contrasts the case studies and draws insights from each.

KEYWORDS

biological weapons, biosafety, verification, inspections, intelligence assessment, comparative studies

1 Introduction

Identifying any type of covert weapons program is no cakewalk, but an illicit bioweapons program exacerbates the task. Worldwide, biological laboratories engage in medical and public health, agricultural, bioremediation, and other research, and fermenters manufacture pharmaceuticals, dairy products, alcoholic beverages, solvents and biofuels, and other commercial goods. The equipment in these laboratories and manufacturing sites could also be used to research, develop, and produce biowarfare agents. Bioweapons facilities have scant exterior visual signatures, which limits the utility of space-based sensors to identify suspect sites among existing facilities. Inside such buildings, differentiating between peaceful and military barely gets easier.

Therefore, many nations conclude that monitoring the 1975 Biological Weapons Convention (BWC), which prohibits the development, acquisition, production, stockpiling, and retention of germ weapons, is not possible. The blinding pace of the current life sciences revolution adds urgency and another layer of complexity to efforts to assess compliance with the treaty (Brenner, 2012). Juxtaposing case histories of illicit biological weapons programs in the Union of Soviet Socialist Republics (USSR) and Iraq fosters better understanding of this predicament, brings relevant factors into sharper relief, and points to ways to identify covert bioweapons programs.

2 Materials and methods

This article examines how the environment in which scientists, technicians, and engineers work can shape a weapons program. The sociological context, motivations, organizational structure, level of science and safety, and military doctrine for weapons use are detailed for the

covert biological weapons programs of the Soviet Union and Iraq. This methodology can be used with any type of weapons program—conventional or unconventional, overt or covert—to glean insights useful for understanding such programs and detecting clandestine programs.

In addition to the factors above, scrutinizing the visibility of covert bioweapons programs informs the improvement of detection capabilities. After the 1990–1991 Gulf War, United Nations Special Commission (UNSCOM) inspectors unmasked a bioweapons program amidst Iraq's dual-use biological facilities despite Iraq's prodigious efforts to mask the program. UNSCOM's efforts compelled Iraq to admit the manufacture and weaponization of biological agents, debunking conventional wisdom that biological weapons inspections cannot work.

These case studies feature sources on the history and sociology of the USSR and Iraq, first-hand accounts of bioweaponers and inspectors, UNSCOM reports, and declassified intelligence data, including Iraqi data captured during the 2003–2011 Gulf War. The author has visited 16 Soviet bioweapons facilities, interviewed over a 100 Soviet bioweapons scientists, a few Iraqi bioweaponers, and dozens of UNSCOM inspectors.

3 Results

3.1 The Soviet/Russian biological weapons program

3.1.1 Sociological context

Following the 1917 Russian revolution, Communist leaders redistributed privately held assets among the people and instituted central planning to push an agrarian country into the industrial age. Propaganda urged workers to meet 5-year productivity goals, which Soviet citizens soon realized were unrealistic. So, they gamed the system, for example, by falsifying production records (Riasanovsky, 1977; Hough and Fainsod, 1979). As corruption and graft became more pervasive, the gap between planned and actual productivity expanded, contributing to the USSR's collapse.

To consolidate power, Communist leaders created the infamous People's Commissariat for Internal Affairs (NKVD) to purge aristocrats and other “undesirables.” Later known as the KGB, the NKVD scrutinized anyone who met with foreigners, traveled overseas, was a Communist Party member, or engaged in activities deemed threatening to the state. Scientists who traveled and communicated with colleagues abroad were easy targets. The NKVD fabricated arrest charges and used torture to force confessions. Millions perished in this witch hunt. The NKVD sent millions more to political prisons and forced labor camps, known as gulags, to power economic development. Propaganda extolled the virtue of reporting anyone disloyal, making fear pervasive and political correctness in the workplace and even at home a necessity (Heller and Nekrich, 1985; Hough and Fainsod, 1979; Riasanovsky, 1977).

To find cures for the diseases that ravaged soldiers and civilians during and after World War I—typhus, tularemia, tuberculosis, brucellosis, anthrax, and plague—the Soviets established scientific institutes. Following a secret 1928 decree, the Red Army opened military biological research institutes and prepared a report on the feasibility of biological weapons (Leitenberg et al., 2012; Bozheyeva

et al., 1999). Many early Soviet military biological researchers were killed during the purges, while others ended up in forced labor or secret research and development labs called Experimental Design Bureaus (Heller and Nekrich, 1985; Kneen, 1984; Leitenberg et al., 2012). After Stalin's death, the Communist Party relied heavily on the *nomenklatura* Party loyalty system. *Nomenklatura* was the gateway to get and keep better jobs, housing, access to Party stores stocked with goods unavailable to other Soviets, and other rewards (Hough and Fainsod, 1979).

Cream-of-the-crop scientists from the USSR's top universities powered the modern Soviet bioweapons program. A few were “read in” from the outset, but most accepted research jobs to study, for example, the pathogenicity of viruses or bacteria. These newcomers found instructions not to interact with scientists in neighboring labs to be odd because shop talk is a lifeblood of science. They also noticed unusual security at nearby buildings, which bolstered suspicions that their research would be applied to weapons, but dared not break the rules or speak openly. The best of these elite scientists found their worst suspicions were true when they were “read in” to the second level of an ultra-secret weapons program. One threw up within minutes (Smithson, 1999).

At the second level, scientists were told their research would be applied only to defend against an aggressive US bioweapons program. At the third level, scientists learned their work was offensive and received an overview of select weapons development efforts. Scientists read into the fourth security level received information about specific weapons programs and some of the connections between them. At every level, scientists signed papers obligating them to the utmost secrecy. Few ever knew the full scope of the work even in their own institute. Almost everyone had similarly compartmented access. Only top staff, like Ken Alibek, a military doctor and the former deputy director of Biopreparat, could access information about the entire program (Hoffman, 2009a; Homeland Defense, with Popov, 2000; Alibek and Handelman, 1999).

Soviet bioweaponers were physically isolated in remote, closed cities that were not marked on maps. Once they began working with pathogens instead of surrogates, scientists received multivalent vaccines to prevent laboratory-acquired infections with harsh side effects. The toll on the scientists' health was both physical and mental. Pushed to work long hours, bioweapons scientists were frequently exhorted to develop better, stronger weapons than America's. On top of good pay, the ability to shop at Party stores and vacation in special locations, top scientists received awards and promotions. Only a handful of the most trusted bioweapons scientists could travel overseas. Many conscientiously objected to their work but felt they could not quit without extreme consequences (Wolfiger, with Popov, Nova Online, 2001). Though economically privileged, they were psychologically jailed.

Conscientious objectors within the USSR's biological weapons program had nowhere to turn. The concept of whistleblower protection was as unfathomable as truth in the Soviet newspaper *Pravda*. In 1922, the Party established Gavlit, a censorship wing of the Department of Agitation and Propaganda, to review all print, radio, and television content before publication. Gavlit censors also worked in the Ministry of Defense, KGB, and the Academy of Sciences (Hough and Fainsod, 1979; Vladimirov, 1972). Reverting to the past, Russia now bans and blocks all independent media, which are declared foreign agents or “undesirable organizations.” Reporters Without

Borders ranks Russian press freedom 171st out of 180 countries ([Reporters Without Borders, 2024](#)).

The Supreme Soviet, a two-chamber parliament composed of Communist Party members, rubber-stamped pre-approved Communist policies. In 1985, Freedom House rated the USSR as “not free,” due largely to Moscow’s suppression of many of the USSR’s 184 nationalities, the repression of individual opinion via arrests and exiling, the use of political trials, state control of the media, and the large number of political prisoners in jails or insane asylums ([Gastil, 1986](#)). Bioweaponers, in short, could not seek redress by telling a reporter or a Duma member about their work. Not until 1989 did a high-level defector escape this tightly controlled environment. In 2025, Russia is rated a consolidated authoritarian regime that is “not free” with regard to civil liberties and political rights ([Freedom House, 2025](#)).

3.1.2 Program motivations

Not long after the Soviets began developing biological weapons in 1928, the USSR’s leaders fell for Trofim Lysenko’s pseudoscientific methods to increase agricultural productivity. Lysenko strenuously opposed Mendelian inheritance genetics. As the director of the Institute of Genetics, Lysenko allied with the NKVD and quashed opponents of his costly, later disproven theories. Lysenko’s reign gutted Soviet life sciences for decades, including within the Soviet bioweapons program ([Hough and Fainsod, 1979](#); [Heller and Nekrich, 1985](#); [Kean, 2017](#); [Gordon, 2012](#)). Nonetheless, by 1938, Soviet Minister of Defense Kliment Voroshilov publicly declared the Red Army “fully prepared” to use bacteriological and chemical weapons “against aggressors on their own soil” if any nation used such weapons against Soviet troops ([Duranty, 1938](#)).

As World War II waned the Red Army gained detailed practical knowledge from the captured bioweaponers of Japan’s Unit 731 at Pingfan. The Soviets learned that Japan contaminated Soviet water sources and planned more biological sabotage, including the dispersal of plague-infested fleas. American publications about the potential usefulness of biological weapons, followed by Moscow’s discovery that the Canadians, Americans, and British collaborated on bioweapons development during World War II motivated the USSR to ramp up its biological weapons program ([Harris, 1994](#); [Leitenberg et al., 2012](#)). As Soviet nuclear weapons capabilities became well-established in the late 1960s, Soviet military leaders considered biological weapons less important.

Yuri Ovchinnikov, a prominent biochemist, changed that perspective. Well connected to the Kremlin’s political and military hierarchy, Ovchinnikov authored an influential paper highlighting the need to use the latest biotechnology to develop weapons. In 1971, the Central Committee and Council of Ministers issued a classified joint decree to initiate the modern Soviet bioweapons program. The Soviet Union, the United Kingdom, and the United States became the charter members of the BWC in 1972. That same year, the Soviet Council of Ministers created a secret interagency committee beneath the Soviet Academy of Sciences, the Interagency Science and Technology Council on Molecular Biology and Genetics, to advise and supervise all bioweapons work. In 1973, a joint decree of the Council of Ministers and the Central Committee established The All-Union Production Association Biopreparat, the civilian industrial cover to execute this interagency council’s decisions ([Leitenberg et al., 2012](#); [Alibek and Handelman, 1999](#)). In a Cold

War arms race with America, Moscow embraced biological weapons a surprise advantage that was pennies on the dollar compared to other weapons, according to Biopreparat’s director, Yuri Kalinin ([Hoffman, 2009a](#)).

3.1.3 Organizational structure

While a sole member of the Politburo was responsible for all defense industry and military matters, Soviet General Secretaries received briefings on the biological weapons program and authorized key directives about “special problems,” the euphemism for the bioweapons program. In the winter of 1987, General Secretary Mikhail Gorbachev signed off on a billion dollar 5-year plan to develop new biowarfare agents, to build two production facilities for viral and bacterial agents, and to enhance the USSR’s capacity to make smallpox. The Interagency Council and the Ministry of Defense managed and strategically directed the bioweapons program. All other ministries involved had one or more specific directorates, offices, and internal planning committees to segregate top-secret biowarfare work from everything else ([Alibek and Handelman, 1999](#); [Tucker, 1999](#)).

The bioweapons program encompassed 40–50 research and development, testing, production, mobilization, and special weapons facilities that employed about 65,000 scientists, engineers, and technicians. Just under 40 facilities in Biopreparat, also known as P.O. Box A-1063, reported to the Medical and Microbiological Industries Ministry. Many Biopreparat facilities masked their military purpose by also making veterinary and pharmaceutical products for domestic markets and export. Roughly 30,000 of Biopreparat’s staff were part of the bioweapons program ([Alibek and Handelman, 1999](#); [Rimmington, 1996](#); [Tucker, 1999](#)).

The Chemical and Biological Weapons Department funded all program facilities.

At the Ministry of Defense, the 15th Directorate funded Biopreparat, supplied most of its staff, supervised Biopreparat’s work, and also coordinated it with a dozen or so military institutes engaged in bioweapons research, development, testing, production, and mobilization. The Ministry of Defense developed Lassa fever as a weapon and operated the open-air test site at Vozrozhdeniye Island, where anthrax, botulinum toxin, brucellosis, plague, Q fever, typhus, smallpox, and Venezuelan equine encephalitis were tested against rodents, sheep, donkeys, horses, and monkeys. Roughly 15,000 personnel of the 15th Directorate engaged in bioweapons work ([Alibek and Handelman, 1999](#); [Bozheyeva et al., 1999](#); [Leitenberg et al., 2012](#)).

Domestic resources mainly fueled the Soviet biowarfare program, but the Ministry of Trade also covertly purchased equipment and animals for it. Also, the KBG procured exotic pathogen strains and other substances of interest to the program and provided intelligence on possible bioweapons programs overseas. The KGB’s Third Main Directorate secured the entire complex and spied constantly on its workers ([Alibek and Handelman, 1999](#)).

Five research institutes of the Soviet Academy of Sciences conducted biowarfare research. In the Ministry of Agriculture’s Directorate of Scientific and Production Enterprises, another 10,000 or so staff at six facilities performed anti-crop and anti-livestock research, development, and testing. The Ministry of Health charged roughly a dozen research and anti-plague institutes with finding pathogens that might be useful germ weapons. Special courts, judges, and lawyers in the Ministry of Justice handled any legal matters related

to the bioweapons facilities and personnel (Alibek and Handelman, 1999).

3.1.4 Level of science, technology, and safety

In 1975, the Interagency Council approved Igor Domaraski's proposal to create more effective weapons by genetically engineering pathogens in five different ways, launching an avalanche of Soviet military research that repudiated Lysenko's claim that genes did not exist (Hoffman, 2009a; Domaradski and Orendt, 2003). The USSR's genetic engineering of pathogens, large-scale production and weaponization, and apocalyptic doctrine for use shattered all ethical boundaries previously associated with biowarfare. What Alibek, Serguei Popov, and other scientists who worked in the program have revealed is summarized below, but much more detail is available (Alibek and Handelman, 1999; Preston, 1998; Homeland Defense, with Popov, 2000; Wolfinger, with Popov, Nova Online, 2001; Leitenberg et al., 2012; Rimmington, 1996; Tucker, 1999).

Soviet weaponeers continued to develop warfare agents from exotic viruses like Russian spring–summer encephalitis, Japanese encephalitis, yellow fever, the Argentine and Bolivian hemorrhagic fever viruses, Machupo, and Ebola. In programs code-named Factor, Bonfire, Metol, Hunter, and Flute, the Soviets also genetically engineered classic warfare agents to make them more lethal, more stable, resistant to antibiotics and vaccines, and able to cause unexpected symptoms. For example, scientists engineered strains of tularemia, melioidosis, and glanders to make them resistant to 7 or 8 antibiotics. A vaccine-resistant anthrax strain was developed, and Alibek created an anthrax strain that was resistant to 10 antibiotics.

Scientists gave classic agents “new properties” by synthesizing small DNA chains for a toxin gene or a biologically active peptide or protein, then inserting the chains into the genome of a classic agent. These new properties were often antigenic structures that would make it difficult to diagnose and/or treat a virus or bacterium. Anthrax, plague, and smallpox strains were apparently modified with peptide genes to make the body's immune system attack itself. Genes from *Bacillus cereus*, which causes gastrointestinal problems, were inserted into *B. anthracis*, and a diphtheria toxin was spliced into *Y. pestis*, the causative agent of plague. The Soviets also coated a tularemia strain with Protein A—a staphylococcal protein that blocks the immune system.

Soviet weaponeers tried to make viruses with exotic genes in the 1980s. They successfully combined the whole genomes of viruses and crossed viruses with bacteria to create completely new pathogens with characteristics that essentially rendered attempts at protection and treatment useless. Genes from Ebola, encephalomyelitis, and smallpox viruses were inserted into the plague bacteria. Anyone infected with these engineered plague strains would be given antibiotics to knock out the bacterial infection, but a viral infection would explode a few days later. Soviet researchers also sought to create strains to suppress the human immune system and to transform nonpathogenic microorganisms into lethal ones. In addition, the Soviets developed agents to alter human moods and behavior. These studies focused on bacterial and viral expression of bioregulators and biopeptides like endorphins, neuromodulators, and enkephalins to cause the nervous system or the brain to foster symptoms like aggression or insomnia.

Soviet scientists crossed Venezuelan equine encephalitis with smallpox, creating a Veepox that was tested in monkeys. Of the development of chimera agents, Vector's director, Lev Sandakhchiev,

conceded only that “we developed vaccinia-virus recombinants with VEE viruses and some others” (Preston, 1998). A Blackpox cross of smallpox and Ebola may have also been achieved. The Soviets also engineered pathogens to produce toxins inside the host. The host's immune system will prompt the body to clear the USSR's engineered *Legionella* strain, but it will have already secreted peptides that will catalyze a host's immune cells to destroy the myelin of nerve cells, causing paralysis and then death. The infective dose of this engineered *Legionella*, which was tested against guinea pigs, is only a few cells. Alibek recalled Popov's presentation and its accompanying video at a fall 1989 meeting held at Obolensk. The proof-of-concept aerosol test showed the animals developed symptoms of one illness, then another, becoming paralyzed.

Under a program codenamed Ecology, the Soviets also developed a significant capability to wage economic germ warfare against cattle, pigs, and fowl, and against wheat, rice, corn, and rye (Millet and Whitby, 2000; Alibek and Handelman, 1999).

Though morally appalled, Western scientists who visited Biopreparat facilities could not help but marvel at such technical achievements. Soviet laboratories often lacked the most sophisticated equipment, yet through ingenuity and years of painstaking research the USSR's best and brightest scientists made novel bioweapons breakthroughs (Preston, 1998; Western industry experts, interviews with Smithson, 2004).

The USSR's concentration on how to prepare, manufacture, store, and effectively disperse pathogens as aerosols would ultimately be key to any battlefield success. The Soviets also conducted periodic tests of techniques, equipment, and facilities to ensure their readiness for short-notice manufacturing. This work began before the 1970s and continued until the USSR's collapse (Hoffman, 2009b). The Soviets hardened warfare pathogens against multiple environmental vulnerabilities that degrade their effectiveness, such as desiccation, heat, ultraviolet rays, and shear forces. Soviet manufacturing advances included a standardized cell culture production technique that yielded 10,000 L of smallpox and large-scale production methods for drying Marburg (Alibek and Handelman, 1999; Leitenberg et al., 2012).

The antibiotic-resistant strains of plague and anthrax were weaponized, as may have been the case with a plague strain enhanced with a diphtheria toxin. In 1991, the Soviet economy went into freefall. Funding cuts hit even the bioweapons program, essentially halting work before the novel and chimera agents were produced (Homeland Defense, with Popov, 2000; Smithson, 1999).

The USSR employed physical barriers and operational procedures, known collectively as biosafety, to prevent accidents that could harm workers or the public. In addition to the use of biosafety cabinets for bench research with pathogens that can cause disease in humans, many bioweapons facilities had high-level biosafety containment suites with submarine doors for entry airlocks, negative air pressure, personal protective gear with individual air supplies for the workers, high-efficiency air filters, autoclaves, safety showers, and isolation medical units. Specialized treatment facilities processed wastes from these units (Smithson, 1998/1999/2003/2004).

Nonetheless, biosafety failures occurred. A July 1971 smallpox outbreak in Aralsk, Kazakhstan resulted from outdoor smallpox test on Vozrozhdeniye Island (Tucker and Zilinskas, 2002). In April 1979, about 100 g of dried anthrax leaked from Compound 19 at The Center for Military Technical Problems when a ventilation filter was not replaced. Dozens downwind in Sverdlovsk were killed

(Alibek and Handelman, 1999; Meselson et al., 1994). A March 1980 Defense Intelligence Agency assessment detailed the accounts of four Soviet tipsters, the most crucial being a physician who spoke with other doctors also treating patients whose symptoms were inconsistent with ingestion of anthrax or exposure through a cut in the skin. Four days after a loud bang at the military complex, 7 or 8 military reservists who were inside the complex at the time of the accident died of pulmonary anthrax several hours after entering a nearby hospital. Ten days after the incident, the Soviet cover story took shape when a district epidemiologist told local hospital doctors that consumption of contaminated meat had caused an anthrax outbreak. All anthrax casualties in local hospitals were taken to a vacated military hospital. Local residents were ordered to be vaccinated. The dead were decontaminated, not allowed to be cremated, and no one could attend their funerals. After decontamination, large parts of the military complex were bulldozed or covered with new asphalt, and wider decontamination efforts began. Local dogs and wild animals were destroyed (Defense Intelligence Agency, 1980; Hoffman, 2009a).

In May 1988, Vector scientist Nikolai Ustinov was wearing only two layers of thin gloves while injected guinea pigs with Marburg in a biosafety level 3 suite. Not wearing the usual thick mitts employed for work with animals was a fatal error. Ustinov pricked himself with a tainted needle. He died because Vector did not have a supply of Marburg antiserum. In 1990 the Ministry of Defense approved the more powerful Marburg strain harvested from Ustinov's organs, named Variant U in his honor, for use in the USSR's germ arsenal. The pathologist who conducted Ustinov's autopsy also reportedly died from exposure as well (Alibek and Handelman, 1999).

3.1.5 Military doctrine

In 1969, the Central Intelligence Agency (CIA) believed the Soviet military was skeptical about biological weapons because the general population was vulnerable to their use and their effects were unpredictable and delayed. The CIA assessed that the Soviets maintained biological defenses and had some bioweapons capability to retaliate in kind. If being forced to withdraw from territory, the CIA believed front-line Warsaw Pact commanders might be authorized to use biological weapons. The CIA wrote: "[P]olitical considerations would weigh very heavily against Soviet initiation of the use of BW" (Central Intelligence Agency, 1969). This analysis informed President Richard Nixon's 25 November 1969 decisions to renounce the use of biological weapons that "either kill or incapacitate," to destroy the US stockpile, and to submit the Geneva Protocol to the US Senate for ratification (Nixon, 1969).

The CIA was far off the mark. In a total war, Soviet military doctrine called for attacks on some American and North Atlantic Treaty Organization targets with biological *and* nuclear weapons, while a second category of targets would be hit with nuclear *or* biological weapons. In 1989, Alibek and the general in charge of the 15th Directorate updated the list of agents stipulated for three use categories:

- 1 Smallpox and plague, both lethal and contagious, were strategic weapons. Initially designated for delivery in single-warhead missiles, a 1988 decision upgraded these agents to the multiple-warhead SS-18. A single SS-18 could release enough biological bomblets to kill half the population of a city of eight million.
- 2 Glanders, Venezuelan equine encephalomyelitis, and tularemia were operational weapons to incapacitate military reinforcements and other rear services located 62 to 93 miles behind the front lines. The USSR stationed Illyushin-28 medium-range bombers in the Volga region, equipped with 500-kilogram cluster bombs or two-ton spray tanks that could cover 1,850 to 2,486 square miles with agent.
- 3 Anthrax and Marburg hemorrhagic fever were designated strategic-operational weapons for both types of targets, using precise delivery including heavy cruise missiles.

A missile would release its warhead to parachute over a target and deliver non-kinetic payloads by jettisoning over 100 oval-shaped bomblets that separate and reconverge for a criss-cross dispersal of agent at heights of 650 to 80 feet above the ground. In total war, the Illyushin bombers could also carry anti-crop and anti-livestock agents to wipe out the enemy's food supplies. Brucellosis and Q fever fell off the operational and strategic operational weapons lists, respectively, in 1989 (Alibek and Handelman, 1999; Tucker, 1999; Preston, 1998; Leitenberg et al., 2012).

Soviet bioweaponer Vladimir Pasechnik indicated the USSR's military doctrine may have also included the concept of covert dispersal of biowarfare agents in cities, allowing for plausible deniability. A subsequent Russian Foreign Intelligence Service report also described scenarios for covert economic warfare with anti-livestock and anti-crop agents (Leitenberg et al., 2012). According to Alibek, Russia maintains an offensive program because it views biological weapons as effective in mountainous territory and for certain high-intensity or low-intensity conflict situations (Alibek and Handelman, 1999).

Some Biopreparat and military facilities continuously produced agents and filled the delivery systems kept on standby. For example, the Soviets annually made about two metric tons of antibiotic-resistant pneumonic plague and 20 tons of liquid smallpox grown in eggs. Refrigerated bunkers stored the bulk smallpox, which had a 6 to 12-month shelf life, and also contained filling lines for munitions and spray tanks. The CIA and US Department of Defense concluded Alibek exaggerated the amount of agent the USSR could or did produce annually and but on-site visits to production facilities like Stepnogorsk under the Cooperative Threat Reduction Program revealed astonishing production capacities (Hoffman, 2009b; Alibek and Handelman, 1999; Leitenberg et al., 2012). The Corpus One building of The State Scientific Center of Applied Microbiology at Obolensk contains 42-story tall fermenters, separated into different biosafety containment zones, to make plague and other agents (Preston, 1998; Smithson, 2004). Building 221 at The Scientific Experimental and Production Base at Stepnogorsk housed 10 four-story-high, 20,000-liter fermenters and could make 300 metric tons of anthrax in 10 months. Other production lines at Kurgan, Penza, and Sverdlovsk could add hundreds more tons to the USSR's prodigious capability to make biowarfare agents and fill munitions on short notice (Davis, 1999; Bozheyeva et al., 1999; Leitenberg et al., 2012).

3.2 Iraq's biological weapons program

3.2.1 Sociological context

Since gaining formal independence in 1932, Iraq has been politically volatile and often rife with violence. Saddam Hussein ruled

Iraq ruthlessly until 3 April 2003, when he fled Baghdad for his hometown of Tikrit. Saddam was a member of the then upstart Ba'ath Party, which seized power in 1968. In a sign of things to come, Saddam attended Cairo's Law School and Baghdad Law College, but rather than sit for the bar exam in 1969 he menaced his examiners with a pistol and his bodyguards, effectively hijacking his law degree. By that time, Saddam was already murderer and former convict. Rising through the Ba'ath party ranks, Saddam proved to be a shrewd politician who formed and ran the party's first internal security service. On 16 July 1979, Saddam became Iraq's fifth president (Coughlin, 2002; Karsh and Rautsi, 1991; Scovel, 1991).

Saddam undercut the military's ability to unseat him by reassigning and retiring some uniformed political opponents while jailing or executing others. He established parallel military, intelligence, and internal security structures to further consolidate his power. Overlapping responsibilities between organizations kept everyone uncertain of when, how, or even if they had made an error that might cost them their job or their life. With all government organizations reporting to Saddam or his most trusted allies, Iraqi citizens, including Saddam's inner circle, cowered (Al-Marashi, 2002; Hashim, 2003; Duelfer Report I, 2004c). As an extra security policy, Saddam established personal militias like the Al Quds and Fedayeen Saddam, which reported to Saddam's son Uday. A renowned death squad, the Fedayeen also engaged in smuggling and other illegal activities (New York Times, 2003; British Government Assessment, 2002).

Many of Saddam's relatives from Tikrit were in his inner circle (Al-Marashi, 2003). For example, in 1979 Saddam named his brother, Barzan al-Tikriti, chief of the Mukhabarat internal intelligence service. Barzan, a brutal enforcer against anyone who dared to oppose Saddam, ate grapes while watching the torture he ordered (Parsons, 2007). In a 1983 book, Barzan claimed Saddam had already survived seven assassination attempts. Attempts were made on Saddam's life, but Barzan stretched the number to glorify his brother, just as Saddam often exaggerated his bravery (Reuters, 1983; Makayi, 1998).

Iraq was the world's fourth largest oil producer when Saddam seized the Iraq Petroleum Company's assets, nationalizing Iraq's oil industry on 1 June 1972 (Stork, 1975; New York Times, 1973). Saddam redirected Iraq's oil profits to strengthen Iraq's armed forces, underwrite weapons of mass destruction programs, and build grand monuments, like Baghdad's Victory Arch, swords and Grand Festivities Square. While honoring Iraq's victory in the 1980s War, the underlying purpose of these public works was to enlarge Saddam's reputation as a leader. Saddam also constructed dozens of grandiose palaces featuring gold lavatories, marble and mosaic trim, zoos, nuclear bunkers, swimming pools, and lavish gardens. Eight of Saddam's compounds alone had over 1,000 luxury mansions, garages, office buildings, guest villas, and warehouses (Vince, 2016).

Saddam liked science, particularly what science could do for his military (Duelfer Report I, 2004c). Scientists, like all Iraqis, sought favor. To advance in the Ba'ath Party and secure research funds, Iraqi scientists pitched pet projects to officials who may not have understood the science they green-lighted. Iraq lured the top graduates from its medical, science, and veterinary universities into its 1970s-era biological weapons program with prized incentives, such as graduate study and overseas travel. By the mid-1980s, however, Ba'ath Party loyalty surpassed high grades and sharp technical skills as a prerequisite to work in the bioweapons program. Early in the

1980s, Mustansiriyah University Professor Nassir Al Hindawi proposed to develop anthrax as a tactical and strategic weapon and a botulinum toxin-like nerve agent as a tactical weapon. The Presidential Diwan forwarded Hindawi's proposal to the State Establishment for Pesticide Production at Al Muthanna, Iraq's main chemical weapons facility (Duelfer Report III, 2004a). Hindawi's proposal energized Iraq's bioweapons program by the mid-1980s.

Navigating daily life in Iraq was no easy feat. Iraqi citizens feared falling out of favor or worse, torture or execution (Salbi and Becklund, 2006; British Government Assessment, 2002). Even Saddam's closest allies were not spared his wrath. Saddam's first cousin and husband of his daughter Raghda, Lt. Gen. Hussein Kamal Hassan was probably the second most powerful man in Iraq when he defected to Amman, Jordan, on 7 August 1995 with some of Iraq's unconventional weapons secrets in hand. Kamal's subordinates scrambled to place blame for Kamal's defection elsewhere so that they might avoid retribution (Ekeus, 2023; Smithson, 2011; Smithson, 2013). Kamal was summarily executed when he returned to Iraq in February 1996 (Williams, 1996, p. 8).

In its 1986 report, Freedom House described Iraq as a military dominated, socialist one-party state, rating it "not free" because a small minority faction was in control, the Ba'ath party screened candidates for election, political opponents were frequently jailed, books and movies were censored, and media outlets were either government monopolies or closely controlled (Gastil, 1986). In 2025, Iraq remained an unstable country. Freedom House ranks Iraq as "not free" and Reporters without Borders placed Iraq 155th out of 180 countries for journalistic freedom (Freedom House, 2025; Reporters Without Borders, 2024).

3.2.2 Program motivations

Although Iraq's early efforts to develop biological weapons were sputtering by the late-1970s, Iraqi leaders turned to bioweapons as a strategic alternative after Israel's 7 June 1981 F-16 strike on the Tammuz 1 nuclear reactor at Osirak (Battle and Burr, 2021). Iraq assessed that Israel, an undeclared nuclear weapons possessor, began a biological weapons program in 1948 (Eisenstadt, 1990; Cohen, 1998; Cohen, 2001). Saddam repeatedly stated that Israel had every kind of unconventional weapon (Smithson, 2013). Iraq thus sought unconventional weapons to deter Israel and, if necessary, to use in conflict (Duelfer Report I, 2004c; Duelfer Report III, 2004a).

Still, Saddam considered Iran to be Iraq's foremost foe (Duelfer Report I, 2004c). In August 1983, Iraq began using chemical weapons to hold back Iran's human wave offensives, starting with tear and mustard gas and graduating to nerve agents (Burke and Floweree, 1991; Duelfer Report II, 2004b; Ali, 2001; Hiltermann, 2007). Saddam viewed chemical weapons as the reason Iraq "won" this war, and he found them useful to suppress domestic opposition. The 16 March 1988 massacre of Halabja civilians with mustard gas, sarin, tabun, and VX capped a campaign against the Kurds in northern Iraq. On 7 March 1991, Iraq also deployed MI-8 helicopters armed with sarin-filled R-400 bombs to quell a Shi'ite uprising near Karbala. Iraq's "success" with chemical weapons also sparked the rejuvenation of its bioweapons program (Human Rights Watch, 1994; Duelfer Report I, 2004c).

Saddam's belief that Israel and Iran would use unconventional weapons spurred his quest for and use of those weapons. In 1981, he stated: "Baghdad will be attacked chemically, atomically, and by

germs" (Smithson, 2013). In 1984, Saddam explained intimidation and deterrence to his military officers: "[S]ometimes what you get out of a weapon is when you keep saying, 'I will bomb you,' [and] it is actually better than bombing him. It is possible that when you bomb him the material effect will be 40 percent, but if you stick it up to his face the material and the spiritual effect will be 60 percent, so why hit him?" said Saddam. "Keep getting 60 percent!" (Smithson, 2013) Like all bullies, Saddam bragged: "We have superiority in the chemical and in the biological weapons. In the world, there are only two countries on our level or maybe one or maybe none in regards to the quality and quantity. We have biological weapons that can kill even if you step on it forty years later" (Smithson, 2013). Saddam's "forty years" jargon described anthrax, which, in sporulated form, can survive for decades in the soil. Lastly, Saddam understood the psychological aftershocks of unconventional weapons use. Poison gas "exterminates by the thousands," he said, and it also "restrains [those gassed] ... from leaving the city for a period of time until it is fully decontaminated—nothing; he cannot sleep on a mattress, eat, drink or anything. They will leave [inaudible] naked" (Smithson, 2013).

Obsessed with his legacy, Saddam thought of himself a great Arab leader, a modern-day Nebuchadnezzar (Duelfer Report I, 2004c). Possession of unconventional weapons confirmed his great stature, helped ensure his regime's survival internally, and deterred Iraq's enemies.

3.2.3 Organizational structure

Iraq restarted its biological weapons program in 1983, the same year that Saddam's son-in-law Kamal became director of the Special Security Organization (SSO) (United Nations Monitoring, Verification, and Inspection Commission, 2006). A year later, with a newly minted British PhD in microbiology, Rihab Rashid Taha took the helm of the biological research team at Al Muthanna. Lt. Gen Nizar Al Attar, Al Muthanna's director, reportedly told Taha that he "did not want research to put on a shelf. He wanted applied research to put in a bomb" (Duelfer Report III, 2004a). Iraq's 1986 five-year plan aimed to weaponize biological agents. In mid-1987, Taha's research group transferred to the Forensic Research Department at Salman Pak and began reporting to the SSO's Technical Research Center. Afterwards, the scope of Iraq's developmental work on viruses, bacteria, and toxins increased under the guise of agricultural research (United Nations Monitoring, Verification, and Inspection Commission, 2006; Duelfer Report III, 2004a).

Saddam chaired Iraq's top decision-making body, the Council of Revolutionary Leadership, and made Iraq's critical security decisions. In 1987, Saddam made Kamal the chair of the Military Industrialization Commission. Lt. General Amir Al Sa'adi Kamel, a chief science advisor to Saddam, was Kamal's assistant at the Commission and the SSO. Al Sa'adi also steered the bioweapons program. The Technical Research Center's chief, Ahmad Murtada, worked closely with Kamal. Taha reported to Murtada, but she also briefed Saddam on important bioweapons matters (Duelfer Report I, 2004c; Duelfer Report III, 2004a; Smithson, 2011). Thus, a handful of people were key decisionmakers in Iraq's bioweapons program. Approximately 500 Iraqi scientists, engineers, and technicians worked on research, production, and delivery of biowarfare agents (Author's estimate from interviews with UNSCOM inspectors and para. 83, United Nations Monitoring, Verification, and Inspection Commission, 2006).

Kamal piloted the bioweapons program by selecting warfare agents and delivery systems. Kamal also tapped Iraq's military

industries to provide the program resources, such as delivery systems. In 1990, he ordered the Agriculture and Water Resources Center to make aflatoxin and Al Daura Foot and Mouth Disease Vaccine Facility to switch to production of botulinum toxin. The Ministry of Defense was apparently an end-user but not an active supervisor of Iraq's bioweapons program (Duelfer Report III, 2004a; Smithson, 2011).

The Technical and Scientific Materials Import Division of the Ministry of Trade procured key assets for the bioweapons program, such as aerosolization chambers, fermenters, spray driers, filling machines, and 39 tons of growth media. Cover stories aided these purchases. For example, Ministry of Health facilities were to use the growth media, and the filling machines were for biopesticide production at Salman Pak (Duelfer Report I, 2004c; Central Intelligence Agency, 1997; Smithson, 2011).

Beneath the Technical Research Center, the program's organizational structure correlates with the function of the facilities involved:

- Research and development: Baghdad and Al Mustansiriya Universities, the Al Hasan Ibn-al-Haytham Institute, Al Muthanna, Al Daura;
- Biological weapons testing: Al Muhammadiyah, Jurf al Sakr Proving Ground, Khan Bani Saad Airfield, Abou Obeidi Airfield;
- Biological agent production: Al Fudhalliyah Agricultural Research and Water Resources, Al Taji, Al Hakam, Al Daura, Salman Pak; and,
- Biological weapons filling: Salman Pak, Al Hakam, Al Muthanna (Central Intelligence Agency, 1997)

3.2.4 Level of science, technology, and safety

One of Taha's initial acts was to cue a literature survey on prospective biowarfare agents based on Stockholm International Peace Institute publications. In 1985, Taha began ordering pathogen strains of interest from culture collections overseas for bench research. Taha, who recommended pursuing Brucella as a warfare agent, required her scientists to work first with simulants for different agents to minimize safety hazards during research and testing. Program scientists then learned how to grow pathogen strains, which guided the selection of biowarfare agents. Animal toxicology studies began in Al Muthanna's inhalation chambers and continued after the 1987 move to Salman Pak, followed by pilot-scale production (United Nations Monitoring, Verification, and Inspection Commission, 2006; Duelfer Report III, 2004a).

In May 1988, mycologist Imad Dhiyab joined the bioweapons program to lead a fungal toxin research team. Dhiyab's team researched and tested tricothecene mycotoxins in 1990. Iraq's acceptance of Dhiyab's proposal to weaponize aflatoxin, which can take 40 years to cause liver cancer, bewildered UNSCOM inspectors. The inspectors also considered Dhiyab's aflatoxin production method, which required the daily rotation of glass flasks stacked inside incubators, environmental chambers, and modified ovens to be a biosafety fiasco (Smithson, 2011). Iraq tested wheat smut spores as a possible carrier for aflatoxin (Duelfer Report III, 2004a).

Two employees of Iraq's bioweapons program, Abdul Rahman Thamer and Professor Nassir Al Hindawi, attended an August 1988 British conference on progress to combat the disease anthrax hoping to interact with scientists from Britain's biodefense institute. Iraq shopped with governments and companies for components for its bioweapons program. The Pasteur Institute sent Iraq two anthrax

strains, the Sterne strain employed for vaccine and the A-2 strain from Spanish sheep. The American Type Culture Collection sent Iraq seven anthrax strains, including two Vollum strains used in the shuttered U.S. and British bioweapons programs, six strains each of *C. botulinum* and *C. Perfringens*, and an *F. tularensis* strain (Lynch and Warrick, 2001). During UNSCOM's first inspection the Iraqis turned a pathogen list and 75 ampoules containing seed cultures over to inspectors (Smithson, 2011).

Iraq's shopping spree included a 1988 purchase of 40 tons of growth media from the British company Oxoid to Iraq's Ministry of Health. Upon arrival in Iraq, Taha's crew received this growth media to make anthrax and botulinum toxin. Fluka also sold Iraq growth media, Karl Kolb inhalation chambers, Chemap fermenters, and Niro Atomizer a fine-particle spray device. Iraq paid a small German company suitcase full of cash for a possible dispersal device (Smithson, 2011). The CIA reported that in the late 1980s foreign scientists went to Iraq "to provide BW assistance," sharing technology related to smallpox and anthrax (Central Intelligence Agency, 1997). In mid-1995, Iraq negotiated with a former deputy director of Biopreparat—who knew nothing about making single-cell protein—to purchase two large fermentation lines to make that product. An Iraqi delegation went to Russia to examine the 50,000-liter fermenters designed to make *Yersinia pestis*. Russia did not, however, grant an export license (Tucker, 1999; Duelfer Report III, 2004a).

Uncertainties remain about how far Iraq progressed on work with some agents. Iraq developed and produced *Yersinia pestis* but apparently could not overcome its dispersal challenges. Iraq's bioweapons program and the Iraqi Intelligence Service were interested in and produced small quantities of ricin (Central Intelligence Agency, 1997; Duelfer Report III, 2004a). Iraq had tularemia strains but Iraqi officials never admitted developing this agent. However, Iraq conceded early research exploring influenza, polio, and Crimean Congo hemorrhagic fever viruses. In mid-1990, Iraq asked virologist Hazem Ali to lead renewed research on viruses, including Enterovirus 70, rotavirus, and camelpox, a smallpox surrogate. The Minister of Agriculture signed an order to commandeer the Veterinary Service Center in Irbil, an animal vaccine plant, to scale-up camel pox production in eggs using the chorioallantoic membrane method. Iraq also reportedly studied increasing the effectiveness of biowarfare agents by mixing them with chemicals like dimethyl sulfoxide, mustard gas, and tear gas (Central Intelligence Agency, 1997; Duelfer Report III, 2004a).

Iraqi virologists who were not known to be associated with the weapons program had experience with vaccinia virus and genetic engineering. Scientists at the Tuwaitha Agricultural and Biological Research Center, which developed Iraq's growth media and dry biopesticide technology, also engaged in genetic engineering research. No evidence of Iraqi use of genetic engineering to enhance biowarfare agents was found (Central Intelligence Agency, 1997).

Like the United Kingdom and the United States, Iraq weaponized the Vollum strain of anthrax. Taha may have modeled Iraq's program on the former US program (Smithson, 2011). In 1988, Iraq quickly constructed Al Hakam as a dedicated facility to produce biowarfare agents. Unable to procure large-scale fermenters and spray driers overseas, Iraq transferred equipment from a veterinary vaccine plant at Al Kindi and a single-cell protein plant at Al Taji to establish Al Hakam's production lines (UNMOVIC, 2005).

Iraq began conducting live-agent field tests with animals in 1988. Iraq field tested several delivery systems using water with various

additives and anthrax simulants. Other field tests involved live botulinum toxin, wheat cover smut, and aflatoxin. LD-250 and R400A bombs, 155 mm artillery shells, and 122 mm multi-barrel rockets. Also, the Zubaydi device, a pesticide sprayer fitted with overlapping mesh screens, was mounted on a helicopter for field tests (Central Intelligence Agency, 1997; Duelfer Report III, 2004a). As the air war began in January 1991, the Iraqis were flight-testing 2,200-liter fuel tanks modified into sprayers on Mirage-1 jets and on remotely piloted fixed-wing aircraft. Given the mixed results of these flight tests, UNSCOM inspectors concluded Iraq was years away from mastering important technical parameters to disperse biowarfare agents, such as the correct particle size and agent concentration (Duelfer Report III, 2004a; United Nations Monitoring, Verification, and Inspection Commission, 2006; Smithson, 2011).

On Kamal's orders, in 1990 Iraq embarked on a crash program to produce and weaponize biological agents. Al Hakam, which began making *Clostridium botulinum* in 1989, added anthrax and *Clostridium perfringens* production in 1990. The Iraqis converted seven fermenters at Al Daura in September 1990 to enable anaerobic production of *Clostridium botulinum* (Duelfer Report III, 2004a; Smithson, 2011).

In November 1990, Kamal decided to use Iraq's chemical delivery systems for biowarfare agents, initiating a rush to convert chemical rockets, bombs, missile warheads. Iraqis painted the interiors of 1-centimeter-thick R-400 bombs with blue, acid-resistant, epoxy so they could carry wet anthrax and botulinum toxin payloads (Duelfer Report III, 2004a; Smithson, 2011). Just before the January 15th deadline requiring Iraq's withdrawal from Kuwait, Iraq filled 157 R-400 bombs and 25 Al Hussein missile warheads with anthrax, botulinum toxin, and aflatoxin. Equipped with ground-impact fuses, these weapons would probably have killed the agent or dispersed it inefficiently and ineffectively. The commander of Iraq's surface-to-air missile force considered Iraq's biological missiles to be weapons of terror, not weapons of military utility. Before 15 January 1991, Iraq hid these weapons at two air bases, the Tigris Canal, and the Mansuriyah railway tunnel and began moving containers with the remaining bulk agent from place to place. When war erupted, Iraq was testing biological cluster bombs and trying to buy hundreds of parachutes to improve its delivery of biological payloads via cluster bombs and perhaps Al Hussein warheads (Duelfer Report III, 2004a; Central Intelligence Agency, 1997; Ekeus, 2023).

After the 1991 war, Iraq went to extensive efforts to conceal its bioweapons program and preserve key assets to be able to restart the program after UNSCOM departed. Saddam ordered Kamal to destroy the weapons and bulk agent before UNSCOM inspectors arrived. In May 1991, Kamal ordered Murtada to destroy the biological arsenal, who then delegated the destruction to Taha. The Iraqis chemically deactivated the agent with potassium permanganate and formaldehyde and then blew up the munitions at Zaghareet, Al Azziziyah, and Al Nabae (Central Intelligence Agency, 1997; Duelfer Report III, 2004a; Duelfer Report I, 2004c). Following a briefing by Taha, in April 1991 Saddam authorized Al Hakam's conversion to produce biopesticide and single-cell protein as cover stories. Kamal directed large, ongoing efforts to hide key assets and documents, scrub facilities, and put the cover stories in place. In the late summer of 1991, Taha required the bioweapons scientists at Salman Pak and Al Hakam to sign a legal document stipulating they would be executed if they revealed anything about Iraq's progress in the development and weaponization of biowarfare agents (Duelfer Report III, 2004a; Smithson, 2011;

Smithson, 2013). From the first biological inspection, some UNSCOM inspectors recognized that Iraq was not telling the truth. With doggedly persistence, UNSCOM inspectors eventually uncovered evidence that forced Iraq to admit in 1995 that Iraq produced biowarfare agents and had probably weaponized them (Smithson, 2011; Crossette, 1995; Ekeus, 2023).

After encountering trouble importing growth media in 1990, Iraq created an indigenous capacity to produce it so that Iraq could sidestep sanctions and covertly revive its mothballed bioweapons program. Although Iraq conducted research on growth media for *Clostridium botulinum*, *Brucella*, and perhaps *Clostridium perfringens*, this initiative focused on growth media for bacteria since anthrax was Iraq's key biowarfare agent. Dr. Al Mādhihi at the Tuwaita Agricultural and Biological Research Center developed a process to make nutrient media that relied on inexpensive local resources such as whey, cornstarch, simple salts, corn steep liquor, and plants. Tests proved Iraq's growth media for bacteria to be effective with the biopesticide *B. thuringiensis*, a well-known anthrax simulant (Duelfer Report III, 2004a).

Prior to 1991, Iraq produced only liquid warfare agents, which Taha knew would not remain potent for long. From 1992 until Al Hakam's 1996 destruction, Al Hakam made roughly 40 tons of biopesticide a year by spraying liquid *B. thuringiensis* onto bentonite. The Iraqis used bentonite, provided by a Ministry of Industry and Minerals mining company, because they deemed use of acetone for drying too costly. The process, also developed by Dr. Al Mādhihi, resulted in a dry, 1–10 micron particle size, which is ideal for biowarfare applications. Iraqi farmers disliked this biopesticide because they had to sprinkle it by hand atop individual plants. Production of this biopesticide allowed Taha's group to learn how to dry anthrax. UNSCOM learned that Iraq conducted a couple of tests with freeze dried anthrax on sheep (Duelfer Report III, 2004a; Smithson, 2011).

Al Hakam's chief technician claimed the *B. thuringiensis* biopesticide production line at Al Hakam could be converted to produce anthrax within a week. The technician was aware of the safety hazards of using this line's spray dryer, which lacked containment, to dry anthrax (Duelfer Report III, 2004a). UNSCOM inspectors, accustomed to modern biosafety, could hardly believe Iraq produced biowarfare agents and filled munitions in buildings that lacked physical containment barriers (Smithson, 2011). In fact, Kamal told Saddam that Iraqis involved in developing and producing biological agents had been exposed to them (Smithson, 2013).

3.2.5 Military doctrine

Whether Iraq established a military doctrine for the use of biological weapons is unclear. In January 1991, Saddam stipulated Tel Aviv and other Israeli cities as biological attack targets. If US-led Coalition forces used unconventional weapons against Iraq, Saddam planned to retaliate with biological weapons. Saddam also put Jeddah and Riyadh on Iraq's biological target list. When Kamal asked Saddam to choose which of Iraq's three weaponized agents he wanted to use, Saddam selected "the many years kind," his description for anthrax. From Iraq's delivery options of missiles and aircraft sprayers and bombs, Saddam ordered "all the methods" used. Kamal tried unsuccessfully to persuade Saddam that spraying biological agents "like a crop plane" would be "a thousand times more effective," but Saddam insisted that Iraq not "depend on one option. The missiles will

be intercepted and the planes, at least one will crash." Clearly, Saddam had modest expectations for a successful biological attack. He stated: "[W]henver the missiles or planes fall down over the enemy land, then I consider the goal to be achieved and the mission fulfilled" (Duelfer Report III, 2004a; Smithson, 2013). Saddam insisted that "all the orders about targets [be] sealed in writing and authenticated" in case something happened to him (Duelfer Report III, 2004a). Iraq planned to follow an initial conventional bombing run of Riyadh with a second run with the modified drop tanks to spray biowarfare agent. The first mission was shot down, so the Iraqis cancelled the second (Central Intelligence Agency, 1997).

Iraq used the term "special munitions" to cover both chemical and biological payloads. Iraqi troops had chemical defensive gear and operational experience using chemical weapons but none with biological weapons. Iraq used letters to designate different biological agents, and UNSCOM inspectors found markings on some munitions. Iraqis conceded the markings indicated biological fills. The letter codes were A for anthrax, B for botulinum toxin, and C for aflatoxin also changed to A for botulinum toxin, B for anthrax, and C for *Clostridium botulinum*. Iraq filled bombs with black stripes with anthrax or botulinum toxin, but bombs containing aflatoxin had no distinguishing marks (Ekeus, 2023; Smithson, 2011). Iraqi commanders may have had a key code for the biological bombs and warheads deployed in early 1991, but the distinctions between chemical and biological weapons may not have been incorporated into Iraq's military doctrine. In short, Iraqi troops may not have had any instruction in biological defense or knowledge about the risks of handling biological agents. Iraqi troops who handled, transported, guarded, and disposed of Saddam's biological weapons also may not have understood those weapons had biological, not chemical fills. UNSCOM's inspections and destruction of Al Hakam and key biological materials in the late 1990s effectively ended Iraq's bioweapons program (Duelfer Report III, 2004a; Smithson, 2011).

4 Program visibility

4.1 The Soviet/Russian program

According to a 1965 US intelligence report, post-World War II German intelligence files that indicated that Vozrozhdeniye Island was a bioweapons test site. In 1957, overhead imagery confirmed the island's infrastructure and security were consistent with a military facility, indicated a biological test site, and noted that top Soviet military leaders occasionally "boasted they have the means to rebuff a U.S. military attack with nuclear, chemical, and biological weapons." Although towers and one or two buildings were visible at five test sites, the report did not categorize the island as a bioweapons test site because the "apparent 'grid systems' were small, ill-defined as to configuration and purpose, and not comparable to the Soviet CW proving ground and U.S. CW-BW proving grounds." The island also lacked "a sophisticated airstrip" and was located three miles downwind from an inhabited island with 35 buildings (Lexow and Hoptman, 1965). A 1986 Defense Intelligence Agency booklet identified the island as a "candidate BW test and evaluation installation" (Defense Intelligence Agency, 1986).

A 1969 US National Intelligence Estimate assessed that the Soviets had a research program exploring how to make pathogens more

virulent, sustain that lethality, and delay the deterioration of aerosols. The Soviets had aerosolized botulinum toxin and were testing the use of non-traditional vectors for dispersal and the infectivity of non-endemic diseases (Central Intelligence Agency, 1969; Leitenberg et al., 2012). When the BWC entered into force in 1975 entry a Soviet diplomat professed the USSR had no biological weapons and was not engaged in any treaty-prohibited activity (Hoffman, 2009a).

In 1982, the U.S. government publicly questioned the origins of the 1971 Sverdlovsk anthrax outbreak. Soviet officials brushed the outbreak off with the contaminated meat cover story (Hoffman, 2009a). Other evidence of an aerosol release included the heavy military presence in Sverdlovsk after the accident, aerial decontamination spraying and other heavy decontamination efforts, and incongruity in public Soviet data regarding the incidence of anthrax throughout the USSR versus the Sverdlovsk accident. In 1986, a Defense Intelligence Agency booklet asserted that a pressurized system preparing dry anthrax at a Sverdlovsk military institute probably exploded, releasing 10 kg of dry anthrax and causing the outbreak. This booklet also stated the Soviets had developed anthrax, cholera, plague, tularemia, botulinum toxin, enterotoxin, and mycotoxins as biowarfare agents. Moreover, due to heavy Soviet investment in biotechnology beginning in 1974 that could enable “new and more effective” biowarfare agents, including more virulent, antibiotic- and vaccine-resistant agents, the USSR was “rapidly incorporating biotechnological developments into their offensive BW program to improve agent utility on the tactical battlefield” (Defense Intelligence Agency, 1980).

Other 1980s US intelligence reports said at least seven military facilities were part of the program and pegged the Interagency Science and Technology Council’s role overseeing the Soviet bioweapons program. Literature reviews indicated the possible involvement of other ministries in the program and resulted in a consensus that the USSR was pursuing a new class of biowarfare agents and attempting to genetically engineer pathogens (Leitenberg et al., 2012). Doug MacEachin, the CIA’s Chief of Arms Control, said these estimates “never had a whole lot of credibility. They went beyond the evidence too many times” (Hoffman, 2009a).

Imagery, literature reviews, and communications and human intelligence would have informed 1980s-era assessments. Synthetic aperture radar allowing two-dimensional images of objects also became available in the late 1980s (Tspis et al., 1986). Pages 22 to 24 of a report on former Soviet bioweapons facilities in Kazakhstan puts the challenges facing imagery analysts past and present into perspective (Bozheyeva et al., 1999). Although the bunkers were identifiable, otherwise the outside of Stepnogorsk buildings does not belie the huge bioweapons factories inside, much less the laboratories in Building 600. The Soviet empire covered over 8,140,000 square miles, which made it a challenge for human imagery analysts to identify suspect bioweapons facilities.

In October 1989, Vladimir Pasechnik, the director of the USSR’s Institute of Ultra Pure Biopreparations defected to the United Kingdom. Pasechnik’s description of the Soviet program resoundingly disproved the British and US view that nuclear weapons possessors would forego biological weapons (Hoffman, 2009a, Smithson, interview with Kelly, 2002a). To feign transparency and allay Western suspicions, the Politburo approved a plan to invite British and US visits only to meticulously scrubbed Soviet facilities. In a separate document, Gorbachev stipulated that bioweapons

development and production resume after these visits. Gorbachev thus led President George H.W. Bush and Prime Minister Margaret Thatcher to a Trilateral Agreement to exchange site visits. At sites on the list for visits, Soviet staff memorized cover stories and hid movable incriminating evidence (Alibek and Handelman, 1999; Hoffman, 2009a; Moodie, 2001). In 1991, 1993, and 1994, US and British experts nonetheless got an eyeful at seven Soviet research, development, and production facilities—the State Scientific Center of Applied Microbiology at Obolensk, the Institute of Immunological Studies at Lybuchany, The Institute of Molecular Biology (Vector) at Koltsovo, the Institute of Ultrapure Preparations in Leningrad (later St Petersburg), the All-Union Scientific Research Institute of Veterinary Virology at Pokrov, the Chemical Plant at Berdsk; and the Chemical Plant at Omutninsk. Western Trilateral inspectors were told that research was being conducted with smallpox, and they also saw unique milling equipment, explosive and dynamic aerosol test chambers, excessive biosafety containment for the activity being described, and hardened (bermed) facilities. They also concluded the Soviets were misrepresenting their research on plague (Kelly, 2002b; Smithson, 2004; Tucker, 1999). Nonetheless, the United Kingdom and the United States did not subsequently exert sufficient political or economic pressure to force the program’s closure.

The Soviet team’s first Trilateral visit to US facilities began in December 1991. The USSR foundered before the Soviet team returned home, where Moscow’s military leaders asked Alibek and other senior bioweaponers to prepare reports to support the case for Russian President Boris Yeltsin to keep and conceal the biological weapons program (Tucker, 1999). Instead, in January 1992 Yeltsin conceded that the USSR’s violation of its BWC obligations, pledged to close the program, and initiated severe budgetary cuts (Yeltsin, 1992; Hoffman, 2009a). On 14 September 1992, Deputy Foreign Minister Gregory V. Berdennikov stated the USSR “was violating this convention [BWC] and was running a program in the sphere of offensive biological research and development ... from 1946 until March of 1992” (US State Department, 2020). Then, Alibek’s 1992 defection gave the CIA vast detail about the USSR’s genetic engineering prowess, chimera agents, weaponization, production, and mobilization capacity, and military doctrine for biological weapons.

Insider opposition to Yeltsin’s disarmament decree quickly became apparent. Russia’s 1992 voluntary BWC declaration asserted that the Soviet bioweapons program never achieved anything militarily significant because of the program’s subpar methodology, equipment, and materials (Federation, 1992). Russian diplomats also reverted to the cover story that contaminated meat caused the 1979 Sverdlovsk anthrax outbreak (Leitenberg et al., 2012). Now known as Yekaterinburg-19, a series of decrees have charged this site, Sergiev Posad-6, the Kirov Institute, and the Volgograd Institute with “biopreparedness” missions. Moscow has also spent billions rejuvenating these sites. Russian President Vladimir Putin retained the generals who led the Soviet bioweapons program, and he penned a 2012 essay about novel hi-tech weaponry, including “genetic psychophysical” weapons. Scientists are rightfully skeptical about the concept of genetic weaponry, but Putin has also discussed the concept publicly (Hoffman, 2021; Leitenberg et al., 2012; Petersen, 2022; Thomas, 2020). Like their predecessors, current Russian scientists might fool Putin, but few dare openly defy him.

While Cooperative Threat Reduction programs demolished some of the program’s infrastructure, such as Stepnogorsk, and helped

convert other facilities to commercial or other peaceful activities, concerns about a continuing program persist (Smithson, 2016). Alibek characterized the publication by Obolensk scientists of work to create an antibiotic- and vaccine-resistant anthrax as a misguided effort to try to normalize genetic engineering for military purposes (Pomerantsev et al., 1997; Stepanov et al., 1996; Preston, 1998). Before Alibek's departure, Soviet research with animal pox viruses, such as camelpox or monkeypox, was underway to further enhance the USSR's smallpox warfare agent. Alibek argues that other Russian scientific publications showed continued research on chimera agents and smallpox (Tucker, 1999). Popov echoed such concerns and noted that his former colleagues later published only a few "lousy, lousy papers," a sign the old rules were back. In other words, current work on novel pathogens would never see publication (Homeland Defense, with Popov, 2000; Leitenberg et al., 2012; Hoffman, 2009a).

Popov, the scientist who successfully developed a pathogen-inside-a-pathogen warfare agent, stated that U.S. intelligence officials did not debrief him until 8 years after he arrived in America. Even then, the debriefers pressed him about the possibility of proliferation from four former Soviet bioweapons facilities. They did not really ask about his past work (Wolfinger, with Popov, Nova Online, 2001). Similarly, Alibek recalled that his first intelligence debriefers were far more concerned about counting beans than the advanced warfare agents he was describing. One top scientific debriefer from the U.S. Army Medical Research Institute of Infectious Diseases dismissed Alibek's description of engineering pathogens against known medications and enhancing the virulence of pathogens as "sheer fantasy." Based on prevailing Western logic that dead is dead and Ebola was already very deadly, Alibek's U.S. scientific debriefers could not grasp why any military would seek such weapons. Only when a former U.S. biowarrior later joined the debriefings did U.S. officials begin to accept Alibek's significant revelations (Alibek and Handelman, 1999).

A 2020 US report repeated concerns that Russia has "maintained an offensive weapons program," had not documented the full elimination of its bioweapons program or its conversion to peaceful purposes, and since 1992 had annually claimed "nothing new to declare." The 2025 US assessment concluded that Russia was "extensively modernizing" inherited bioweapons infrastructure such as Russia's 48th Central Scientific Institute, Sergiev Posad-6, home to Soviet research on Rickettsia and viruses like smallpox, Ebola, and other hemorrhagic fevers (US State Department, 2025; Warrick and Ley, 2025).

4.2 The Iraqi program

Israeli and US intelligence agencies began warning of an Iraqi bioweapons program in the late 1980s, identifying Salman Pak as a biological research facility in 1989. Israel stipulated that Iraq's program focused on anthrax, typhoid, and cholera. Just prior to the 1991 Gulf War, the CIA reported that Iraq had "deployed a militarily significant number of bombs and artillery rockets filled with botulinum toxin and anthrax" and possibly biological tipped SCUDs (Central Intelligence Agency, 1991). Experts who saw the Western intelligence in the years before 1991 had serious misgivings about its accuracy and completeness, saying "the intelligence was very limited with regard to specific sites and locations involved in the program," that it was "a

fantasy in some way," and "based more on probabilities than evidence" (Smithson, 2011).

The decimation of Iraq's possible unconventional weapons capabilities was a high priority for Operation Desert Storm's bombing campaign. Analysts used visible signatures such as site security (e.g., multiple fences, guard towers, air defense batteries) and significant air handling and processing capability to identify possible bioweapons program targets. Thus, the targets bombed are a barometer for the accuracy of what was visible and known through other means about Iraq's bioweapons program.

Two key sites emerged unscathed. Al Hakam was an isolated facility in the desert south of Baghdad with a layout that mimicked Al Muthanna's, surrounded by significant security. Al Hakam was not identified prior to the war as a dedicated bioweapons production and filling site. Al Daura, a civilian fermentation facility and the sole high-level biosafety containment manufacturing facility in Iraq, was known before the war but did not have a high security signature (Smithson, 2011).

The pre-war intelligence assessment was basically accurate for Salman Pak and Al Taji, which were bombed. The Coalition barraged Al Muthanna because it was a major chemical weapons facility, but intelligence did not identify its biological research, development, testing, and filling role. Erroneously, pre-war intelligence tagged Al Kindi and Al Latifayah as biowarfare agent production sites. The Infant Baby Milk Production Plant at Abu Ghraib was not involved in the program but was destroyed. Finally, Coalition bombs struck 19 storage bunkers but not the sites where Iraq deployed filled biological warheads and bombs (Smithson, 2011; UNMOVIC, 2005).

To help UNSCOM fulfill its mission after the 1991 Gulf War, the U.S. government provided UNSCOM with satellite imagery and U-2 photography (Krasno and Sutterlin, 2003). UNSCOM could schedule U-2 photography of Iraqi facilities and activities and also request historical U-2 images. Initially, U.S. intelligence analysts and photo interpreters objected when what UNSCOM's inspectors found did not conform with their analysis. Diplomatically, UNSCOM's chief, Rolf Ekeus, arranged joint sessions where UNSCOM inspectors could review imagery with the analysts. After inspectors with biological expertise and on-the-ground experience with Iraqis and at Iraqi facilities explained why their conclusions about images taken 13 miles above did not correlate with reality, the interpretations of imagery analysts improved (Ekeus, 2023; Smithson, 2011).

A 10 November 1998 British intelligence dossier asserted Iraq continued to make biological weapons, while a September 2002 Joint Intelligence Community dossier stated: "Iraq had sufficient expertise, equipment and material to produce biological warfare agents within weeks using its legitimate bio-technology facilities." Furthermore, Iraq had "military plans" and "command and control arrangements in place" to use "chemical and biological weapons," some of which were "deployable within 45 min of an order to use them." The dossier also stated Iraq had mobile biological labs and production capabilities (British Government Assessment, 2002). The 45-min-to-deploy claim rested on a single, uncorroborated source (Select Committee on Foreign Affairs, 2003).

With "high confidence," a 2002 US intelligence estimate stated Iraq's biological weapons program was "active," "larger," "redundant," "concealed," and "more advanced" than it was before the 1991 War. The estimate specified one mobile railway and six mobile tractor-trailer production units. Iraq "has" liquid and dried agents, possibly

including smallpox. In addition to mobile research and filling units, the assessment stated that Iraq had seven mobile units that could, within several days, produce five different toxin and bacterial agents in quantities equal to what Iraq manufactured before the 2001 Gulf War (Central Intelligence Agency, 2002). On February 5, 2003, U.S. Secretary of State Colin Powell made the case for war in a United Nations speech that emphasized the mobile bioweapons trailers (Weisman, 2003).

After the 2003 Gulf War, the Iraq Survey Group found no credible evidence to substantiate the assessment of a mobile bioweapons capability and confirmed that Iraq did not have an active biological weapons program (Duelfer Report III, 2004a; Duelfer, 2009). A U.S. presidential commission also issued a scathing review of the pre-war assessment, stating that the mobile bioweapons assertion was based on a sole Iraqi defector codenamed Curveball (Commission on US Intelligence Capabilities, 2005). Others harsh critiques of intelligence failures regarding Iraq's purportedly revived biological weapons program followed (Drogin, 2007; Jervis, 2010).

5 Discussion

These case studies elicit several observations. First, one man's trash is another's treasure. France, the United Kingdom, United States, and Canada had biological weapons programs, but concerns linger about bioweapons programs in Russia, North Korea, Iran, and China (Geissler and Courtland Moon, 1999; US State Department, 2025; Harris, 2020). Like the USSR and Iraq, these four states all have authoritarian governments (Freedom House, 2025).

As Table 1 summarizes, the USSR conducted a mammoth, highly bureaucratic and diverse bioweapons program, while a despot's whims and a comparatively small group of scientists and technicians executed Iraq's program. The Soviet and Iraqi programs centered on anti-personnel biological agents to sicken or kill humans, but both nations also developed and produced anti-agricultural agents to undercut their enemies' economies.

Political and military leaders initiate requests for biological weapons, but scientists have tremendous influence on the germ weapons at their disposal. Frankly, non-scientists lack the knowledge and skillsets to conceive of, produce, and weaponize basic biological weapons, much less the multifaceted biowarfare agents that Soviet scientists created. Iraqi scientists also had significant sway over Baghdad's biological arsenal, which, illogically, included aflatoxin. Scientists in authoritarian states can be duped by promises of interesting, important work, bribed with high salaries and other rewards, and coerced into a bioweapons program, but they have scant ability to refuse participation. Attempts to leave a bioweapons program risks retribution for the scientists and their families, including jail and death.

Both case studies highlight the importance of not assuming that other countries will adhere to the widely held ethical boundaries enshrined in the BWC. Notably, Moscow negotiated and signed the 1972 BWC while operating a bioweapons program to cheat on the accord. The Iraqi case study also shows that cutting-edge equipment and technology, operational efficiency, and military logic may not be present in a covert bioweapons program.

Like all organizations, intelligence agencies are susceptible to limited thinking and to groupthink (Janis, 1972). Both case studies

TABLE 1 Comparison of Soviet and Iraqi bioweapons programs.

Program characteristics	USSR	Iraq
Number of scientists, engineers, technicians	≈65,000	≈500
Motivations	Compete with (now defunct) Canadian, US, and British bioweapons programs, asymmetrical warfare advantage	Deter regional enemies Iran and Israel, bolster Saddam's ego, use against Israel, Saudi Arabia, US-led Coalition forces
Level of science, technology	Advanced, cutting-edge	Rudimentary to moderate
Organizational structure	Multi-layered supervision of military, academic, and "industrial" bioweapons facilities	Short command structure for research, production, testing, and weaponization sites
Biosafety	Advanced but accidents still occurred	Rudimentary to moderate
Delivery systems	Advanced missile, aircraft delivery of dry, environmentally-hardened agents	Wet agents in SCUD missiles, bombs, rockets, aircraft sprayers
Military doctrine	Multiple options against military and civilian targets	Saddam-centric
Visibility	Western intelligence agencies missed and discounted valid program indicators	Western intelligence missed program indicators
Means of program confirmation	Defectors, Trilateral inspections, Cooperative Threat Reduction programs	UNSCOM inspections

demonstrate these pitfalls through a lengthy delay in identifying an accident at a bioweapons facility as the cause of the Sverdlovsk anthrax outbreak and failing to label Vozrozhdeniye Island and Al Hakam military facilities.

Iraq's significant use of chemical weapons against Iran and its own civilians indicated a possible covert Iraqi bioweapons program (Ali, 2001; Hiltermann, 2007; Burke and Floweree, 1991; Human Rights Watch, 1994). Soviet and Iraqi leaders, caught red-handed, robustly denied their bioweapons programs and spared no effort to camouflage and mothball their programs so they could be revived when opportunity arose. Not only has Putin publicly stated an interest in pursuing next generation genetic psychophysical weapons, Russia also retains Soviet-era bioweapons seed cultures, has never allowed outside access to core Ministry of Defense biological facilities, and is spending billions modernizing biological facilities.

Meanwhile, the Covid-19 pandemic underscored global vulnerabilities to infectious disease, which may prompt unscrupulous leaders to reconsider pursuing bioweapons. And, although UNSCOM

inspections compelled Iraq to admit producing and weaponizing germ weapons, the international community has failed to add inspections to the BWC.

Pearl Harbor and the 9/11 attacks demonstrate that intelligence failures to warn can change global history. The multitude of biological facilities worldwide makes finding bioweapons programs a needle-in-the-haystack exercise, but improvements in overhead imagery resolution and signals and measurement capabilities, use of artificial intelligence to assist imagery analysis, and metadata analysis of other data should assist this uphill climb.

Intelligence agencies should still regularly consult outside experts with relevant first-hand knowledge. Alibek and Popov noted their debriefers failed to: (1) ask the right questions; (2) understand technical details about novel biowarfare agents; and (3) appreciate the strategic significance of the USSR's bioweapons capability. Hence, intelligence agencies must quickly gather the appropriate technical expertise and re-engage with former Soviet and Iraqi bioweaponers. Former Trilateral and UNSCOM inspectors can also explain the difference between what things look like on site and from remotely collected data.

Brainstorming sessions should also be held with those who visit biological facilities worldwide (e.g., safety experts, equipment installers), life sciences and biotechnology pioneers, pharmaceutical research and production experts, and attendees of pertinent international conferences. Thoughtful question lists can produce useful insights and strategies from these experts to help unmask covert bioweapons programs (Smithson, 2001; Smithson, 2004). Finally, a few disruptors—the maverick thinkers who envision how to reinvent processes and organizations to serve a need more successfully—should be mixed with these experts occasionally to ensure that all lines of inquiry are pursued.

Lastly, national leaders can relieve the pressure on intelligence agencies by re-engaging on the prevention end of the equation. In 1984, the Australia Group began to create and implement biological export control lists to hinder covert bioweapons programs. Cooperative Threat Reduction Programs debuted in 1991 to thwart proliferation of the USSR's nuclear capabilities, later expanding to address biological and chemical nonproliferation and safety and security at nuclear, biological, and chemical facilities (Harahan, 2014; Cooperative Threat Reduction Programs, 2025; Smithson, 1999). No major new tool to address state-level bioweapons activity has been created in decades, but Washington has proposed developing an AI system to monitor BWC compliance (Field, 2025). Should such a system prove useful, upgrading the BWC by adding inspections to provide concrete evidence and dismantle bioweapons programs, like UNSCOM did in Iraq, will still be necessary.

References

- Ali, J. (2001). Chemical weapons and the Iran-Iraq war: a case study of noncompliance. *Nonproliferation Rev.* 8, 43–58. doi: 10.1080/10736700108436837
- Alibek, K., and Handelman, S. (1999). Biohazard: The chilling true story of the largest covert biological weapons program in the world-told from the inside by the man who ran it. New York, NY: Random House.
- Al-Marashi, I. (2002). Iraq's security and intelligence networks: a guide and analysis. *Middle East Rev. Int. Affairs* 6, 1–13.
- Al-Marashi, I. (2003). The clan, tribal and family network of Saddam's intelligence apparatus. *Int. J. Intell. Counter Intelligence* 16, 202–211. doi: 10.1080/08850600390198724
- Battle, J., and Burr, W. (Eds.) (2021). Israeli attack on Iraq's Osirak 1981: Setback or impetus for nuclear weapons: Briefing book 767. Washington, DC: National Security Archive.
- Bozheyeva, G., Kunakbayev, Y., and Yeleukenov, D. (1999). Former Soviet biological weapons facilities in Kazakhstan: past, present, and future, Occ. Paper 1. Monterey, CA: Center for Nonproliferation Studies.
- Brenner, S. (2012). The revolution in life sciences. *Science* 338, 1427–1428. doi: 10.1126/science.1232919
- British Government Assessment (2002). Iraq's weapons of mass destruction: The assessment of the British government. London: The Stationery Office Limited.
- Burke, G. M., and Floweree, C. C. (1991). International handbook on chemical weapons proliferation. Westport, CT: Greenwood Press.
- Central Intelligence Agency (1969). Soviet chemical and biological warfare capabilities. National Intelligence Estimate, Doc. 11-11-69. Washington, DC: Central Intelligence Agency.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AS: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. The Royal United Services Institute provided funding for the preparation of this article.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author declares that no Gen AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

- Central Intelligence Agency (1991). Prewar status of Iraq's weapons of mass destruction, Doc. ID 934037. Washington, DC: Central Intelligence Agency.
- Central Intelligence Agency (1997). *Iraq's biological warfare program: Well-positioned for the future*, doc. OTI IR 97-012X. Washington, DC: Central Intelligence Agency.
- Central Intelligence Agency (2002). Iraq's continuing weapons of mass destruction programs, doc. NIE 2002-16HC. Washington, DC: Central Intelligence Agency.
- Cohen, A. (1998). Israel and the bomb. New York: Columbia Univ. Press.
- Cohen, A. (2001). Israel and chemical/biological weapons: history, deterrence, and arms control. *Nonproliferation Rev.* 8, 27–53. doi: 10.1080/10736700108436862
- Commission on US Intelligence Capabilities (2005). Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction. Report to the president. Washington, DC: Government Printing Office.
- Coughlin, C. (2002). Saddam: King of terror. New York: Ecco.
- Crossette, B. (1995). Iraq admits it produced germ arsenal. *New York Times*.
- Davis, C. J. (1999). Nuclear blindness: an overview of the biological weapons programs of the former Soviet Union and Iraq. *Emerg. Infect. Dis.* 5, 509–512. doi: 10.3201/eid0504.990408
- Defense Intelligence Agency (1980). USSR: Biological warfare. Intelligence Appraisal. Washington, DC: Defense Intelligence Agency.
- Defense Intelligence Agency (1986). Soviet biological warfare threat. Doc. DST-1619F-057-86. Washington, DC: Defense Intelligence Agency.
- Domaradski, I. V., and Orendt, W. (2003). Biowarrior: Inside the Soviet biological warfare machine. Amherst, NY: Prometheus.
- Drogin, B. (2007). Curveball: Spies, lies, and the con man who caused a war. New York: Random House.
- Duelfer, C. (2009). Hide and Seek: The search for truth in Iraq. New York: Public Affairs.
- Duelfer Report I (2004c). *Comprehensive Report of the Special Advisor to the DCI on Iraq's WMD. Regime Strategic Intent*, vol. I. Washington, DC: US Government Printing Office.
- Duelfer Report II (2004b). *Comprehensive Report of the Special Advisor to the DCI on Iraq's WMD. Iraq's chemical warfare program*, vol. II. Washington, DC: US Government Printing Office.
- Duelfer Report III (2004a). *Comprehensive Report of the Special Advisor to the DCI on Iraq's WMD. Biological Warfare*, vol. III. Washington, DC: US Government Printing Office.
- Duranty, W. (1938). SOVIET threatens to use gas in war. *New York Times*.
- Eisenstadt, M. (1990). The sword of the Arabs: Iraq's strategic weapons. Washington Institute Policy Papers, No. 21. Washington, DC: Washington Institute for Near East Policy.
- Ekeus, R. (2023). Iraq disarmed: The story behind the story of the fall of Saddam. Boulder, CO: Lynne Rienner Publishers.
- Federation, R. (1992). Declaration of past activities in offensive/defensive biological research and development programs. Section F, UN doc. DDA/4-92/BWIII/add.2. Geneva: United Nations.
- Field, M. (2025). Trump dissed world leaders at the UN while asking for their help on a bioweapons prevention plan. *Bull. At. Sci.*
- Freedom House (2025). Freedom in the world, countries and territories. Washington, DC: Freedom House.
- Gastil, R. D. (1986). Freedom in the world political rights and civil liberties 1985–1986. Westport, CT: Greenwood Press.
- Geissler, E., and Courtland Moon, J. (1999). Biological and toxin weapons: Research, development and use from the middle ages to 1945. Stockholm: Stockholm International Peace Research Institute.
- Gordon, M. D. (2012). How Lysenkoism became pseudoscience: Dobzhansky to Velikovsky. *J. Hist. Biol.* 45, 443–468. doi: 10.1007/s10739-011-9287-3
- Harahan, P. (2014). With courage and persistence. Washington, DC: US Department of Defense.
- Harris, S. H. (1994). Factories of death. London: Routledge.
- Harris, E. (2020). North Korea and biological weapons: Assessing the evidence. Washington, DC: Henry L. Stimson Center.
- Hashim, A. (2003). Saddam Husayn and civil-military relations in Iraq: the quest for legitimacy and power. *Middle East J.* 57, 9–41.
- Heller, M., and Nekrich, A. M. (1985). Utopia in power: The history of the Soviet Union from 1977 to the present. New York: Summit Books.
- Hiltermann, J. R. (2007). A poisonous affair: America, Iraq, and the gassing of Halabja. Cambridge: Cambridge Univ. Press.
- Hoffman, D. E. (2009a). The dead hand. New York: Doubleday.
- Hoffman, D. E. (2009b). The other Berlin wall: how the Soviet bioweapons program was revealed. *Bull. At. Sci.*
- Hoffman, D. E. (2021). Genetic weapons, you say? *Foreign Policy*.
- Hough, J. F., and Fainsod, M. (1979). How the Soviet Union is governed. Cambridge, MA: Harvard Univ. Press.
- Human Rights Watch (1994). *Iraq's crime of genocide: the Anfal campaign against the Kurds*.
- Janis, I. L. (1972). Victims of groupthink: A psychological study of foreign policy decisions and fiascos. Boston, MA: Houghton Mifflin.
- Jervis, R. (2010). Why intelligence fails: Lessons from the Iranian revolution and the Iraq war. Ithaca, NY: Cornell Univ. Press.
- Karsh, E., and Rautsi, I. (1991). Saddam Hussein: A political biography. New York: MacMillan Press.
- Kean, S. (2017). The Soviet era's deadliest scientist is regaining popularity in Russia. *The Atlantic*.
- Kelly, D. C. (2002a). Former trilateral and UNSCOM chief inspector. Interview by Amy Smithson.
- Kelly, D. C. (2002b). "The trilateral agreement: lessons for biological weapons verification" in VERTIC yearbook. eds. T. Findlay and O. Meier (London: Verification Research, Training and Information Center).
- Kneen, P. (1984). Soviet scientists and the state: An examination of the social and political aspects of science in the USSR. Albany, NY: SUNY Press.
- Krasno, J. E., and Sutterlin, J. S. (2003). The United Nations and Iraq: Defanging the viper. Westport, CT: Praeger.
- Leitenberg, M., and Zilinskas, R. A., with Kuhn, J. H. (2012). The Soviet biological weapons program. Cambridge, MA: Harvard University Press.
- Lexow, W. E., and Hoptman, J. (1965). "The enigma of Soviet BW" in Studies in Intelligence, vol. 9 (Washington, DC: Central Intelligence Agency).
- Lynch, C., and Warrick, J. (2001). Anthrax type that killed may have reached Iraq. *Washington Post*.
- Makayi, K. (1998). Republic of fear: The politics of modern Iraq. Oakland, CA: Univ. of California Press.
- Meselson, M., Guillemin, J., Hugh-Jones, M., Langmuir, A., Popova, I., Shelokov, A., et al. (1994). The Sverdlovsk anthrax outbreak of 1979. *Science* 266, 1202–1208. doi: 10.1126/science.7973702
- Millet, P. D., and Whitby, S. M. (2000). "State agro-BW programs" in Agro-terrorism: What is the threat? eds. J. Pate and G. Cameron (Monterey, CA: Center for Nonproliferation Studies).
- Moodie, M. (2001). The Soviet Union, Russia, and the biological and toxin weapons convention. *Nonproliferation Rev.* 8, 59–69. doi: 10.1080/10736700108436838
- New York Times (1973). "Oil takeover pact announced by Iraq."
- New York Times (2003). "Q & A: What is the Fedayeen Saddam?"
- Nixon, R. M. (1969). Statement on chemical and biological defense policies and programs. Office of the Historian. Washington, DC: The White House.
- Nova Online (2001). Interviews with biowarriors: Serguei Popov. Interview by Kirk Wolfinger. Public Broadcasting System.
- Parsons, C. (2007). PROFILE: Barzan, Saddam's banker and torturer in chief. *Reuters*.
- Petersen, R. (2022). Fear and loathing in Moscow: the Russian biological weapons program in 2022. *Bull. At. Sci.*
- Pomerantsev, A. P., Staritsin, N. A., Mockov YuV, and Marinin, L. I. (1997). Expression of cereolysin AB genes in *Bacillus anthracis* vaccine strain ensures protection against experimental hemolytic anthrax infection. *Vaccine* 15, 1846–1850. doi: 10.1016/S0264-410X(97)00132-1
- Popov, S. (2000). Interview-Serguei Popov. *J. Homeland Defense*.
- Preston, R. (1998). The bioweaponers. *The New Yorker*, 52–65.
- Reporters Without Borders (2024). Journalism under political pressure. *World Press Freedom Index*.
- Reuters (1983). Attempts to assassinate president Saddam Hussein. CIA FOIA electronic Reading room. Washington, DC: Central Intelligence Agency.
- Riasanovsky, N. V. (1977). A history of Russia. Oxford, UK: Oxford University Press.
- Rimmington, A. (1996). From military to industrial complex? The conversion of biological weapons facilities of the Russian Federation. *Contemp. Secur. Policy* 17, 80–112. doi: 10.1080/13523269608404128
- Salbi, Z., and Becklund, L. (2006). Between Two Worlds: Escape from Tyranny: Growing Up in the Shadow of Saddam. Garden City Park, NY: Avery.
- Scovel, J. (1991). Pistol, bodyguards got Saddam his law degree. *Tulsa World*.
- Select Committee on Foreign Affairs (2003). The 45 minutes claim. Ninth report, sess. 2002–2003. London: House of Commons.
- Smithson, A. E. (1998/1999/2003/2004). Site visits to 16 former Soviet/Russian biological weapons facilities.

- Smithson, A. E. (1999). *Toxic archipelago: Preventing proliferation from the former Soviet chemical and biological weapons complexes*. Washington, DC: Stimson Center.
- Smithson, A. E. (Ed.) (2001). *House of cards: The pivotal importance of a technically sound BWC monitoring protocol*. Washington, DC: Stimson Center.
- Smithson, A. E. (Ed.) (2004). *Resuscitating the bioweapons ban: U.S. industry experts' plans for treaty monitoring*. Washington, DC: Center for Strategic and International Studies.
- Smithson, A. E. (2011). *Germ gambits: The bioweapons threat, Iraq and beyond*. Redwood City, CA: Stanford Univ. Press.
- Smithson, A. E. (2013). *Ugly truths: Saddam Hussein and Other insiders on Iraq's covert bioweapons*. Occ. Paper 17. Monterey, CA: Center for Nonproliferation Studies.
- Smithson, A. E. (2016). Why cooperative threat reduction still matters. *Bull. At. Sci.* 72, 322–331. doi: 10.1080/00963402.2016.1216673
- Stepanov, A. V., Marinin, L. I., Pomerantsev, A. P., and Staritsin, N. A. (1996). Development of novel vaccines against anthrax in man. *J. Biotechnol.* 44, 155–160. doi: 10.1016/0168-1656(95)00092-5
- Stork, J. (1975). *Middle East oil and the energy crisis*. New York: Monthly Review Press.
- Thomas, T. (2020). *Russian nonlethal weapons*. McLean, VA: Mitre Center for Technology and National Security.
- Tspis, K., Hafemeister, D. W., and Janeway, P. (1986). *Arms control verification: The technologies that make it possible*. Washington, DC: Pergamon-Brassey.
- Tucker, J. B. (1999). Biological weapons in the former Soviet Union: an interview with Dr. Kenneth Alibek. *Nonproliferation Rev.* 6, 1–10. doi: 10.1080/10736709908436760
- Tucker, J. B., and Zilinskas, R. B. (Eds.) (2002). *The 1971 smallpox epidemic in Aralsk, Kazakhstan, and the Soviet biological warfare program*. Monterey, CA: Center for Nonproliferation Studies.
- United Nations Monitoring, Verification, and Inspection Commission. (2006). *Summary of the Compendium of Iraq's Proscribed Weapons Programmes in the Chemical, Biological, and Missile Areas*, Doc. S/2006/420. New York: United Nations Security Council.
- UNMOVIC (2005). *Appendix: biological weapons programme of Iraq. Twenty-second quarterly report on the activities of the United Nations monitoring, verification and inspection Commission in Accordance with paragraph 12 of security council resolution 1284 (1999)*, doc. S/2005/545. New York: United Nations Security Council.
- US State Department (2020). *Adherence to and compliance with arms control, nonproliferation, and disarmament agreements and commitments*. Washington, DC: US State Department.
- US State Department (2025). *Adherence to and compliance with arms control, nonproliferation, and disarmament agreements and commitments*. Washington, DC: US State Department.
- Vince, O. (2016). *Architecture after excess: the palaces of Saddam's Baghdad. Failed Architecture*.
- Vladimirov, L. (1972). Gavlit: how the Soviet censor works. *Index on Censorship* 1, 31–43. doi: 10.1177/030642207200103-404
- Warrick, J., and Ley, J. (2025). *Russia has expanded site of past bioweapons research, satellite images show. Washington Post*.
- Weisman, S. R. (2003). *Threats and responses: Security council; Powell, in UN speech, presents case to show Iraq has not disarmed. New York Times*.
- Williams, D. (1996). *Swift Iraqi retribution shocking to Jordanians. Washington Post*.
- Yeltsin, B. (1992) *Decree of the president of the Russian Federation on providing fulfillment of international obligations in the field of biological weapons*. Decree no. 390. Moscow.