CHEMICAL AND BIOLOGICAL WEAPONS: IMPACT OF NEW TECHNOLOGIES

Dissertation submitted to the Jawaharlal Nehru University in partial fulfilment of the requirements for the award of the degree of

MASTER OF PHILOSOPHY

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CERTIFICATE

Certified that dissertation entitled **"Chemical and Biological Weapons: Impact of New Technologies"** submitted by me in partial fulfilment of the requirements for the award of the degree **MASTER OF PHILOSOPHY** has not been previously submitted for any other degree of this or any other university and is my own work.

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To My Grand Parents and My Parents

Contents

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Chapter One:
Introduction

Anthrax attacks in the United States following September 11, 2001 terrorist attacks have renewed debates about threat of use of chemical and biological weapons (CBW). Although political events during the preceeding few decades like the Biological and Toxic Weapon Convention 1972, end of cold war and the signing of Chemical weapons Convention in 1993 has reduced the fear of use of CBW in warfare. But again, recent Afghanistan conflict during 2003 and Iraq crisis in 2004 have proved that pathogens and chemical agents continue to be used and are likely to be used in future asymmetric warfare of this kind.[1] Similarly the 9/11 having shifted the focus to international terrorism has also perhaps caused inclination amongst non -state actors towards the use of chemical and biological weapons (CBW). This of course is not completely new. In the recent past as well, non-state actors have used biological and chemical agents to terrorise people like Aum Shinrikyo Cult in Japan. This had been the last major case before Anthrax during 2002.

The history of use of CBW in warfare is indeed long. We can find the detailed record of their use in warfare as early as 1364 AD, when plague infested

[1] Lele, A V, "Biological Terrorism: Threat and Risk assessment", *Strategic Analysis,* 26(3), 2002, p. 341.

bodies were catapulted over city walls and this is speculated that it caused bubonic plague epidemic that spread across medieval Europe in Mid 1300s. During 18th century, British soldiers and later U.S. government deliberately infected North American Indian population by providing them with blankets which had been exposed to smallpox viruses.[2]

Equally old has been the history of building norms against CBW. The censure against CBW has always been far stronger in history. The CB Warfare was always described as barbarous and a morally unaccepted form of warfare, a dirty way to fight and a painful way to die. But for many years, especially by the militaries CBW were not considered as the weapon of battlefield. So obviously when the debate over the issue of Weapons of Mass Destruction started, CBW were again not even discussed. But since the cold war begun, some CBW were sometimes discussed in the same terms as strategic nuclear devices and again bracketed together as "weapons of mass destruction" or WMD.

CBW as WMD:

Those who compared CBW with nuclear weapons, were not ready to accept CBW as WMD but those who were predicting the future and changes in nature of war itself, emphasised on some new dimensions related to CBW potentially. So

[2] Geissler, Erherd, *Biological and chemical weapons today*, Oxford University press, oxford, 1986, p. 37.

started the debate on CBW as WMD. The WMD, at its face value involves "special" threats that can affect a large area, create a persistent danger for life lasting hours to days to years and share common defensive measures. There are definitions which considered CBW as weapons of mass destruction. Like, on 5 September 1947, the U.S. submitted a draft resolution, which defined WMD as "Weapons which included atomic explosives, radioactive material, lethal chemical and biological weapons and any weapons developed in the future which have characteristics comparable in destructive effect to those of the atomic bomb or other weapons mentioned above."[3] Then, American government defined WMD as "Any weapon or device that is intended or has capability to cause death or serious bodily injury to a significant number of people through the release, dissemination, or impact of toxic or poisonous chemicals or their precursors; a disease organism or radiation or radioactivity."[4]

So we can say that a weapon is considered as weapon of mass destruction when it has the capability of:-

a) mass level destruction

b) of tilting the balance in war equations, and

c) making a decisive impact on international system.

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[3] SIPRI, "The Problem of Chemical and Biological Warfare", SIPRI Yearbook, Vol.IV, 1970, p. 193.

[4] As cited in, Oppenheimer Andy, "Creating Panic", *World Today*, 59(2), 2003, p. 20.

At face value, the CBW doesn't fulfill all the three criteria. However, the proponents of CBW as WMD have always emphasised not on its past or present but on its future and potential and now, in the light of new technologies, their use by terrorists and changing nature of war they are increasingly being considered as weapon of mass destruction. Since the end of the Cold War, this perception has become more strong with reduced threat of nuclear holocaust and increasing threat of use of CBW by terrorist organisations. The very understanding of security has changed with time. In fact, cyber attacks against computers that threaten the interests of a large number of people may also join the WMD category. Because of the involvement of terrorist organisations in using these weapons and terrorism as the major threat for international system, we can say that CBW has the capability to tilt international system so despite of having sharp differences even with tactical nuclear weapons, CBW are finally coming close to qualify as weapons of mass destruction.[5]

Each weapon system has particular characteristics. So instead of comparing different weapon systems, we can analyse them separately whether they fulfill criteria of WMD or not. If we see those weapons from a realist perspective, we find that in this anarchic world where 'power' is the basic desire for which the actors of international system can go to any extent even cheating

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[5] Garden Tim, "Weapons of Mass Destruction", *World Today*, 57(10), 2001, p. 4.

other actor, these weapons are of great importance. It's true that today power is not confined to military power and legacy but even now, arms race and proliferation is becoming more intensive day by day. The international community may have parts that talk of world peace and security but weaponisation is a reality.

As far tactical nuclear weapons, they require a great deal of technology and funding. They can cause massive collateral damage and are lethal to the majority of the target within a short time. They are generally seen as weapons that can have decisive impact because they can affect at the national level of even bigger powers. Tactical nukes focus primarily on explosive blast as their force specially air bursts that can create tremendous heat and gamma radiation as secondary casualty causes. There are also radiological dispersal devices which are designed to spread radiological contamination. By comparison, the CBW have only two level effect, immediate casualty and secondary casualty because of contamination in case of biological weapons or gene mutations in case of chemical weapons. In both these cases it is easier to build immunity as also protection, compared with nuclear weapons.

Power, Security and CBW:

In some ways, the evolution of CBW have changed the connotations of concepts like 'power' and 'security' that each nation tries to have grip on. This

has, accordingly, impacted on their national response to CBW in the long run. This linkage between CBW and nuclear weapons has since come to be part of debates and CBW have since come to be known as poor man's nuclear weapons. This has since strengthened the belief on nations using CBW to retaliation against nuclear threats by nuclear weapon powers.

To recall, following the Geneva Protocol of 1925, the biological weapons convention of 1972 was the first disarmament agreement in which it banned not just the "use" but also the "production" of a whole class of bioweapon. This had been both the cause as well as the consequence of the fact that there was little military interest in CBW on regular basis. But, in the recent years, with development of new technologies especially those in genetic engineering, this norm building against biological and chemical weapons couldn't keep pace with developments in research and development. Apart from impacting on their potency and accuracy, new innovations have also made CBW easier to deliver to its targets. Recent development in Biotechnology has increased the effectiveness of the Delivery System of these Weapons.

The CBW can be deployed in three ways: by contaminating food or water supplies; by releasing infected vectors; and by creating an aerosol cloud to be inhaled by the victims. Biological agents are most likely delivered covertly and by aerosol. Other routes of entry are considered less important but are potentially

significant. This has changed the power of CBW altogether. In case of a battlefield attack, CBW are delivered in the form of artillery rounds, bombs, or missiles/ICBMs or by cloud generators either by slow moving aircraft or ground-based equipment. The Urban Delivery system of these weapons is equally important where the medium of dispersal could be almost anything; say a postal envelope as seen during the Afghanistan conflict or a flea bomb as seen in the subways of Tokyo.[6] The threat of use of these weapons is increasing with advancement in technology, increasing interest of their use among non-state actors and increasing number of countries to use these weapons as a deterrent and we can't just overlook it.

It has a general assumption that because of the scientific difficulties, non state actors can not assemble these weapons but the Aum Shinrikyo and the Al Qaeda have since put serious question marks on all those notions. In fact these terrorist organisations have already moved towards the various versions of these weapons. The problem is just not related to use of CBW by non state actors, but there is a possibility of transfer of these weapons by non-state actors to different states and vice versa. Groups such as Al Qaeda have international networks which add to this possibility.

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[6] Zilinkas, Raymond A., "Biological *Warfare 2002*", Lynne Rienner Publishers, London, P.120.

Unique Features of CBW:

Of course, CBW have their unique qualities. For example, unlike the conventional weapons, CBW can be directed against crops and livestock. Plant and animal pathogens may be used against agricultural targets, creating both potential economic loss and the possibility that a terrorist or criminal group might seek threat of such an attack for economic advantage. Advancement in genetic engineering technologies over the past decade has made biological warfare more lethal. The current database, which is being developed for commercial genetic engineering in the field of agriculture, animal husbandry and medicine, is potentially convertible to the development of a wide range of new pathogens that can attack plant, animal, and human population.[7]

The use of CBW in warfare can be particularly threatening for political economic and social interests. First of all, terrorism trends show a deadly cocktail of religious and political motives and has displayed their fascination towards CBW. In fact global problem of terrorism has changed the meaning, strategy and features of war itself. Because of the involvement of non-state actors, these weapons have acquired a great importance in battlefield. Infect today few terrorist organisations that are supported by state actors are in a position to acquire the required technology to convert biological agents into WMD. All these unique

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[7] Herby, Peter, "Biotechnology, Weapons and War: Grim Future", *World Today*, 59(5), May 2003, p.9.

features of CBW plus breakthrough in biotechnology make the CBW more likely candidate to qualify as WMD.

Another view on CBW being potentially WMD highlights how they could easily be developed and remain cheap in cost. Some dangerous pathogens and chemicals are being used for pharmaceutical purposes and so their dual use remains too difficult to detect and verify. However because they have a problem of corrosion and so of stockpiling, CBW were not considered as very reliable weapons. But there have emerged new technologies by which they can be stockpiled.

There remains still several unique limitations when it comes to using CBW in battlefields. Problem of weak delivery system, their easy corrosion, problem of maintenance, problem of identification of attacker, problem to identify their attack and problem of security of attacker itself are some of the problems which puts a question mark on military potency of these weapons but this is also a fact that despite of all these problems, they have acquired great military interest lately.

Then there is also problem of trust in verifying should they be unleashed by a rouge nation or terrorist group or even by accident. For example, there are categorical claims from China that it had neither manufactured nor possessed any

type of biological weapons. However, according to a 2001 report by the US Department of Defence, "China continues to maintain some elements of an offensive biological weapon program it is believed to have started in the 1950s. China is believed to possess an offensive biological warfare capability based on technology developed prior to its accession to the BWC in 1984".[8]

Regional Scenarios:

To see the impact of CBW on regional security strategies we can consider the case of North East Asia and Middle-East. In North East Asia, North Korea is believed poised to use CBW.[9] The vulnerability of domestic populations in South Korea and elsewhere in the region to such attack is more pronounced then military vulnerability. In today's scenario we have clearly seen that not only the nuclear weapons but chemical weapons have also posed a big challenge for world security by the side of North Korea.

The Middle East as well, CBW poses a different kind of challenge, one in which many of the parties to Arab-Israel and Persian Gulf conflicts appear capable of going for war with CBW. Especially, their past record like that of Iran-Iraq war of 1980's provide credibility to such prepositions. Before the U.S. attack on Iraq we have seen that Saddam Hussein opted to attack air and naval ports and

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[8] Eric Croddy, China's role in the Chemical and Biological Disarmament regimes, *the Nonproliferation Review*, Spring 2002, p.54.

[9] E. Johnson, Smart, *The niche threat: deterring the use of chemical and biological weapons*, national defence university press, Washington DC, 1997, p. 29.

other logistic nodes with chemical weapons.[10] The U.S. strategised of active military engagement through naval presence, peacekeeping and bilateral contacts to target its CBW armed adversary. The U.S. attack on Iraq is debatable but the important thing is the impact of biological and chemical weapons on security that have guided regional security in West Asia.[11]

In Europe as well, CBW are not entirely irrelevant today. The conflict in Bosnia had generated many reports, particularly of Chemical weapons use. On other hand, in the Latin American countries, national security policy is based on cooperation but we cannot neglect the possibility of use of CBW by non-state actor and terrorists, which would pose a question mark for regional security. In Sub-Saharan Africa, interstate wars have minimal possibility of the use of hemical and Biological weapons but still we can't ignore the "Minimal Possibility."[12]

If we analyse the actual effect of CBW in these regions these have, to the least, surely complicated the achievement of stable military balances. Besides, they have created new challenges for the conduct of military operations and this

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[10] Ibid.

[11] Mauroni, Albert J., "*America's Struggle with Chemical – Biological Warfare*", Praeger Publishers, Westport, p.199.

[12] Heden,Carl Goran (ed.); "*The problem of Chemical and Biological Warfare; A study of the Historical, Technical, Military, Legal and Political aspects of CBW and possible Disarmament Measures*", vol.vi, Almqvist and Wiksell International, Stockholm, Humanity Press New York, 1975, p. 120.

challenge perhaps lies above the conventional but below the nuclear level. These weapons make it more difficult to keep local conflicts local. Actually some believe that in many countries the problem of CBW as WMD is not well understood by the members of the armed forces, who could face these terrible weapons should they be unleashed by rouge nation or terrorist group or even by accident and so could create a major problem for international security.

Potential Verses Reality:

While most nations have rejected the use of such weapons, we must confront the possibility of having to deter and defend against CBW stockpiles. The possibility that such weapons can be used and to deter their use by other remains and possibilities. Particularly nations that cannot hope to challenge the United States seriously with the conventional force see CBW as means to challenge U.S. Iraq could be cited as a prominent example of this. Some scholars have identified these states with a new term "Niche Threat".[13]

The CBW capabilities of states of developing world may be stratergic in conflict against similarly sized competitions in their region if they can be used to achieve massively destructive effects or to tilt the political dynamic of conflict in favour of one side or another.

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[13] Stuart E. Johnson (ed.), *The Niche Threat: Deterring the use of Chemical and Biological eapons,* National defence University Press, Washington DC, 1997, p7.

The threat of their use may be then operate powerfully on the perceived choices of the targeted nation's leaders. Then, against states of the developed world, the threat of the use of CBW may not have very severe consequences, but new technologies make them smarter and more destructive which pose new challenges to deter and defend CBW.

While whole world community has condemned the use of CBW in war, the CBW getting attention and importance because of emergence of new technologies in several new fields especially those in genetic engineering. To understand these developments in new technologies and their impact on CBW, it's very important to see how the evolution of new technologies of CBW has impacted on their profile and use in earlier times.

CBW have sure been used in history and have become far more self sufficient, thereby challenging conventional detection and deterrence efforts, and underlying the norms building process against these weapons. With tremendous progress in science and new technology, there continues a genuine gap between legitimate research and commercial biotechnology and offensive warfare programs. It is this continues evolution of CBW technologies as weapons of war and the livelihood of future witnessing several new technologies transforming the profile of CBW as weapons of war that one sees likelihood of CBW coming closer to qualify as WMD.

Chapter Two:
History of CBW Warfare

Historically speaking, recognition of the potential impact of infectious diseases on armies had resulted in the first crude use of chemical and biological agents as weapons of warfare. These have been since contemplated to be used to contaminate wells, reservoirs, and other water sources of armies and civilian populations under attack since very early days and it's still a choice. CBW therefore are not something 'new'. Their actual use and actual impact in war though have been far more negligible compared to the space that CBW have occupied on destructive warfighting technologies. We can see their traces in history. Yet, at the same time, they are not like conventional weapons technologies that have been primarily responsible for the evolution of warfighting.

One of the earliest recorded attempts of using CBW as integral to war strategy was one against a population during the 14th century siege of kaffa (now Feodosia, Ukraine). The attacking Tatar force experienced an epidemic of plague. The Tatars attempted to convert their misfortunes into an opportunity by catapulting the cadavers of their deceased into the city to initiate a plague epidemic. An outbreak of plague was followed by the retreat of defending forces and the conquest of Kaffa. Ships carrying plague infected refugees sailed to

Constantinople, Geneva, Venice and other Mediterranean ports and are thought to have contributed to the second plague epidemic.[1]

Smallpox was used as a biological weapon against native Americans in the 18th century. During the French and Indian War (1754-1767), Sir Jeffery Amherst, commander of British forces in North America, suggested the deliberate use of smallpox to "reduce" native American tribes hostile to the British.[2] An outbreak of smallpox at Fort Pitt resulted in the generation of fomites and an opportunity to execute Amherst plan. On June 24, 1763, Captain Ecuyer, one of Amherst's subordinates gave blankets from the smallpox hospital to the Native Americans and recorded in his journal, "I hope it will have the desired effect".[3] Various other contacts between colonists and native Americans may have contributed to these epidemics.

These early attempts of using biological weapon also however illustrate the difficulty of differentiating naturally occurring epidemics from alleged or attempted biological attack and this problem has had continued relevance because naturally occurring endemic diseases have been alleged as biological attacks for propaganda purpose.

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[1] Derbes V.J., "De Mussis and the great plague of 1348: a forgotten episode of bacteriological war", *Journal of American medical Association,* Chicago, 196, 1966, p. 59.

[2] Sipe C.H., The *Indian Wars of Pennsylvania*, Telegraph Press, Harrisburg, 1929, p.21.

[3] Ibid., p.22.

Evolution of Modern Microbiology

The formulation of Koch's postulates and the development of modern microbiology during the 19th century increased the capability to isolate and produce stocks of specific pathogens. There are evidences which suggest that Germany developed an ambitious biological warfare program during World War I, featuring covert operations in neutral trading partners of the Allies to infect livestock and contaminate animal feed to be exported to Allied forces.[4] Bacillus anthracis and Burkholderia (Pseudomonas) Mallei, the etiologic agents of anthrax and glanders, were to be used to infect Romanian sheep for export to Russia. Cultures confiscated from the German Legation in Romania in 1916 were identified as B anthracis and B Mallei was allegedly used by German saboteurs operating in Mesopotamia to infect 4500 mules and in France to infect horses of the French cavalry.[5]

Japan conducted CBW research in occupied Manchuria from 1932 until the end of World War II under the direction Shiro Ishii (1932-1942) and Kitano Misaji (1942-1945). Unit 731, a biological warfare research facility located near the town of Pingfan, was the center of the Japanese biological weapons development program and contained 150 buildings, 5 satellite camps, and a staff

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[4] Tucker Jonathan B, "Biological Weapons threat", *Current History*, 96 (609), 1997, p. 72.

[5] Witcover J., *Sabotage at Black Tom: Imperial Germany's Secret war in America*, Algonquin Books of Chapel Hill, Chapel Hill NC, 1989, p. 33.

of more than three thousand scientists and technicians. Additional units were located at Mukden, Changchun, and Nanking. Prisoners were infected with pathogens including B anthracis, Neisseria meningitides, Shigella spp, Vibrio Cholerae and Yersinia pestis. At least ten thousand prisoners died as a result of experimental infection or execution following experimentation during the Japanese program between 1932 and 1945.[6] Participants in the Japanese program who had been captured by the Soviet Union during World War II admitted to 12 large scale field trials of biological weapons in testimony obtained during war crimes prosecution.[7] At least 11 Chinese cities were attacked with biological agents. Attacks featured contaminating water supplies and food with pure cultures of B anthracis, V cholerae, Shigella spp, Salmonella spp, and Y pestis. Cultures were also spread and sprayed from aircrafts.

Hitler reportedly issued orders prohibiting biological weapons development in Germany. However, with the support of high-ranking Nazi party officials, German scientists began biological weapons research, although their results were far behind those of other countries. Prisoners in Nazi concentration camps were forcibly infected with Rickettsia prowazekii, Reckettsia mooseri, hepatitis A virus and Plasmodia spp and treated with investigational vaccines and drugs. These inhumane experiments were done to study pathogenesis, to develop

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[6] Williams P, Wallace D, *Unit 731: Japan's Secret Biological warfare in World War II,* The Free Press: New York, 1989, p.144.

[7] Ibid., p. 147.

vaccines against rickettsiae and to develop sulfonamides rather than to develop biological weapons.[8]

The only known German tactical use of biological warfare was the pollution of a large reservoir in northwestern Bohemia with sewage in May 1945. Ironically, the combination of a vaccine and a serologic test was used as a biological defense against the Nazis. With this, physicians used foemalin-killed Proteus OX-19 as a vaccine to induce biological false-positive tests for typhus in an area of occupied Poland and residents were protected from deportation to concentration camps.

The Allies developed biological weapons for potential retaliatory use in response to German biological attack. Bomb experiments of weaponised spores of *B anthracis* were conducted on Gruinard Island near the cost of Scotland and resulted in heavy contamination. Viable anthrax spores persisted until the island was decontaminated with formaldehyde and seawater during 1986.[9]

The US Program

In the United States, an offensive biological programme was begun in 1942 under the direction of a civilian agency, the War Reserve Service. The programme included a research and development facility at Camp Detrick, testing

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[8] Stockholm International Peace Research Institute (SIPRI), *The Rise of CB Weapons: The Problem of Chemical and Biological Warfare*, Humanities Press, New York, 1971, p.103.

[9] Ibid. p.104.

sites in Mississippi, and a production facility in Terre Haute, Ind. Experiments were conducted using pathogens, including B anthracis and Brucella suis. However, the production facility lacked adequate engineering safety measures. For example, test of the fermentation and storage processing using nonpathogenic Bacillus subtilis var globigii as a Banthracis simulant disclosed contamination of the plant and environs. These findings precluded large scale production of biological weapons during World War II, although 5000 bombs filled with Banthracis spores were produced at a pilot plant at Camp Detrick.[10] After the war, production facility was leased and converted to commercial pharmaceutical production. Basic research and development activities were continued at Camp Detrick. Ishii, Misaji, and other Japanese scientists in American custody who had participated in the Unit 731 program were granted release from war crimes prosecution on the condition that they would disclose information got during their program.

The U.S. program expanded during the Korean War (1950-1953). A new production facility incorporating adequate biosafety measures was constructed at Pine Bluff, Arkansas. Technical advances allowed large scale fermentation, concentration, storage and weaponisation of microorganism; production was begun in 1954. In addition, a program to develop countermeasures, including

[10] Harris R, Paxman JA, *A Higher Form of Killing*, New York Press, NewYork, 1982, p. 34.

vaccines, antisera, and therapeutic agents to protect troops from possible biological attack, was begun in 1953.

Animal studies were performed at Fort Detrick, at remote desert sites, and on barges in the Pacific Ocean. Human experimentation using military and civilian volunteers was initiated in 1955. Biological munitions were detonated inside 1-million liter, hollow, metallic, spherical aerosolisation chamber at Camp Detrick. Volunteers inside chamber were exposed to Francisella tularensis and Coxiella burnetii. These and other challenge studies were done to determine vulnerability to aerosolised pathogens and efficacy of vaccines, prophylaxis, and therapies under development. Additional studies were done using simulants. Aspergillus fumigatus, B subtilis var globigii, and Serratina marcescens were selected for use as simultants; these organisms were thought to be nonpathogenic and were used to study production and storage techniques as well as aerosolisation methods, the behaviour of aerosols over large geographic areas, and the effects of solar irradiation and climatic conditions on the viability of aerosolized organisms. Cities were surreptitiously used as laboratories to test aerosolisation and dispersal methods when simultants were released during covert experiments in New York City, San Francisco, and other sites between 1949 and 1968.[11]

[11] Ibid., p.41.

Concern regarding potential public health hazards of simultant studies were raised after an outbreak of urinary tract infections caused by nosocomial S marcescens occurred at Stanford University Hospital between September 1950 and February 1951.[12] The outbreak followed covert experiments using S marcescens as a simultant in San Francisco. The outbreak involved 11 cases, resulting in 1 transient bacteremia and 1 death from endocarditis. All patients had undergone urinary tract catheterization, and 5 had undergone cystoscopy for urologic indications. Exposure to multiple antibiotics was cited as a contributing factor to the outbreak. No similar outbreaks were reported by other hospitals in the San Francisco area. This outbreak is thought to represent an early example of nosocomial epidemics caused by opportunists of low virulence, related to antibiotic use of new medical devices, and surgical procedures.

The Soviet Response:

The Soviet Union, China and North Korea accused the United States of using warfare against North Korea and China during the Korean War. These accusations were supported by a series of investigations conducted by International Scientific Commission, a group of scientists, and organisations not part of the Commission. Although these investigations were described as impartial, they were carefully controlled by the North Korean and Chinese

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[12] WHO Group of Consultants, *Health Aspects of Chemical and Biological Weapons*, World Health Organisation, Geneva, 1970, p. 3.

governments.[13] The United States admitted to having biological warfare capabilities, but denied using biological weapons. The United States requested impartial investigations. The International Committee of the Red Cross suggested the formation of a special commission to investigate, and the World Health Organisations offered to intervene.

Neither China nor North Korea responded to the International Committee of the Red Cross, and the World Health Organisation's offer was rebuffed as a disguised attempt to espionage. Consequently the United States and 15 other nations submitted a resolution to the United Nations (UN) requesting the formation of a neutral Commission to investigate the allegations; however, implementation of the resolution was prevented by the Soviet Union. The credibility of the United States was undermined by its failure to ratify the 1925 Geneva Protocol, by knowledge of its offensive biological warfare program, and suspected court collaboration with the Unit 731 scientists.[14] The accusations of US use of biological weapons attracted wide attention and resulted in the loss of international goodwill towards the United States. This episode demonstrated the propaganda value of biological warfare allegations.

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[13] Rolicka M., "New studies disputing allegations of bacteriological warfare during the Korean war", *Journal of American Medical Association,* Chicago, 43(3), 1995, p. 97.

CBW Use during 20th Century:

The history of CBW technologies traces itself largely back to a single man, Fritz Haber, who developed poison gases for Germany during the First World War. Haber was a world-famous chemist, who had developed a crucial process for extracting nitrates from the atmosphere. This process was used to manufacture fertilizer, and later to make explosives.

When the war broke out in August 1914, the Germans were confident they would win. With the front deadlocked, Haber focused his mind on what he could contribute to German victory. He believed that poison gas would penetrate the strongest trenches and fortifications, allowing the German army to score critical breakthroughs through Allied defences.[15]

The Germans conducted the first chlorine gas attack on 22 April 1915, against French and Algerian troops facing them at Ypres in Belgium. The Germans set up cylinders of chlorine gas and opened their valves. The results of the gas attack were devastating. The French and Algerian soldiers choked, their lungs burning, and slowly died. Those who could escape the cloud fled in panic. Allied casualties in the two days of gas attacks were estimated at 5,000 dead, with 10,000 more disabled, half of them permanently.[16]

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[14] Ibid. p. 98.

[15] Stockholm International Peace Research Institute (SIPRI), *The Rise of CB Weapons: The Problem of Chemical and Biological Warfare*, Humanities Press, New York, 1971, p.85.

[16] Ibid., p.86.

The attack was unbelievably effective. Irritant chemicals, essentially tear gases, had already been fired in artillery shells by both the French and the Germans. Even the German military was astonished by the results of Haber's chlorine gas. They were not prepared to exploit the breach they had made in Allied lines, and did not commit any serious force for a follow-up attack. This may have been partly because they didn't have the protective gear for large numbers of troops at the time.

The Germans launched a number of gas attacks during May 1915, with the last taking place on 24 May. The gas attacks then ceased. The prevailing winds over the lines had changed direction, and except for two small-scale attacks in October, the Germans did not return to gas attacks in earnest on the Western Front until December.[17]

The change in prevailing winds allowed the Germans to use their new poison gases on the Russians. On 31 May 1915, Haber supervised the first chlorine gas attack on the Eastern Front.[18] Gas proved extremely deadly against the Russians, though it was not very effective in winter cold, as it tended to freeze. The Russians ended up suffering more gas casualties than all the other

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[17] Witcover J., *Sabotage at Black Tom: Imperial Germany's Secret war in America*, Algonquin Books of Chapel Hill, Chapel Hill NC, 1989, p. 48.

[18] Ibid.

combatants combined, and their attempts to retaliate in kind would often prove ineffective.

1915-1916: Allied Response:

The Allies were unsurprisingly outraged at the German use of poison gas. The British Army assigned Major Charles Howard Foulkes of the Royal Engineers to implement a response. Foulkes quickly implemented schemes for CBW defence and offence.[19]

In June 1915, 2,500,000 "Hypo Helmets" were issued to Allied troops. These were primitive gas masks, made of flannel that was chemically impregnated to neutralise chlorine, with eyepieces made out of celluloid. They were better than nothing, but they could not resist an extended gas attack. Given enough gas, any filter would eventually become saturated and ineffective.[20]

On 25 September 1915, the British conducted their first gas attack at Loos, Belgium, using 5,500 cylinders of chlorine gas, in support of a major ground offensive. The gas attack was partly failed, with the gas blowing back into Allied lines, resulting in thousands of Allied casualties.

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[19] Harris R, Paxman J., *A Higher Form of Killing: The Secret Story of Gas and Germ Warfare*, Chatto and Windus, London, 1982, p. 130.

[20] Ibid., p. 131.

However, the effect of gas on the Germans was brutal and the Allies were able to quickly overrun the Germans' front-line trenches.

The British smashed themselves against the German rear defences and suffered high number of casualties. The Germans counterattacked and pushed back the penetrations within a week. On 9 December 1915, with the winds again in their favour, the Germans launched another gas attack on the Allied lines, this time against the British at Ypres in Belgium. The Germans used chlorine and a new gas, phosgene.

Phosgene was another industrial chemical by-product. Phosgene had a specific destructive interaction with lung tissue, and its lethal concentration was only an eighteenth that of chlorine. Its action was subtle and deadly. A soldier who inhaled a lethal dose of phosgene would feel some irritation at first, and then feel fine for a day or two. The British had realised the summer before that phosgene might be used as a poison gas and were prepared for it. They had developed the improved "P Helmet", with better rubber exhaust tube.

The British were quick to adopt phosgene themselves. In June 1916, during the battle of the Somme, they poured out a huge cloud of phosgene and chlorine gas along a 27 kilometer front. The cloud penetrated up to 19 kilometers behind German lines, killing everything unprotected. The British became particularly fond of phosgene.

Mustard Gas

The combatants continued to improve the technology for CBW. In early 1916, both the French and the Germans began firing gas shells out of conventional artillery, and the British began to use gas barrages on a large scale. Artillery shells could not achieve the gas concentrations provided by cylinders, but they could reach far back into enemy lines, reducing the risk of gas exposure to friendly forces.

While the Allies had at first lagged the Germans in developing new chemical weapons, they soon came up with innovations of their own. The first was the British "Livens Projector", invented by Captain F.H. Livens.[21] The Livens Projector was simply a metal pipe about a meter or so long that was buried in the soil at a 45 degree angle. Large numbers of the projectors were set up in banks. Each projector was loaded with a drum containing about 14 kilograms of gas, and the bank of projectors was fired by an electrical charge, sending the drums tumbling through air for a range of over about a mile. Exited with the success, British became very competent at setting up and using massed Livens Projectors, and developed a variety of projectiles for it. The Germans tried to copy it, but the

[21] Perry J. P., Robinson, *Chemical and Biological Warfare Developments*, Oxford University Press, Oxford, 1986, p. 36.

Livens Projector gave the British an edge on the Germans in gas warfare and the Germans never quite caught back up.[22]

The Germans had another trick of their own, however. On the evening of 12 July 1917, the Germans fired shells into British trenches at Ypres, but when they burst the shells released a brown oily fluid, not a gas. The stuff had a horrible smell, something like rancid garlic or mustard, but it otherwise didn't seem particularly offensive and caused only slight irritation to eyes and throat. The results were horrible, with all affected losing large patches of skin and many of the men blinded. Some died from the massive damage done to throat and lungs.

The formal name of mustard gas is dichloroethyl sulfide. Mustard was a blistering agent, or in formal medical terms a 'vesicant'. It had actually been evaluated by the British some time earlier and rejected as insufficiently lethal. In fact, although mustard gas didn't have the killing power of phosgene, it was still a very useful weapon.[23] The Germans had realised that improved allied gas masks and training had rendered chlorine and phosgene gas ineffective. So then they put their skills to work to develop a chemical weapon for which a gas mask could offer no protection.

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[22] Ibid., p.38.

[23] Heden,Carl Goran (ed.); *The problem of Chemical and Biological Warfare; A study of the Historical, Technical, Military, Legal and Political aspects of CBW and possible Disarmament Measures*, vol.vi, Almqvist and Wiksell International, Stockholm, Humanity Press New York, Sweden, 1975, p. 94.

The oily fluid of mustard gas could persist for a long time and continue to cause misery and pain to anyone who came in contact with it. But Mustard gas was a vile substance and manufacturing it was difficult and dangerous. The British Army did not obtain mustard gas until September 1918, and the Allies never seriously used mustard gas in combat. They made do with phosgene with a vengeance. In early 1918, the British responded to the German mustard gas attacks with dense clouds of phosgene to overwhelm gas masks, with the poison released from big cylinders on train cars rolled up behind the lines.

The Americans set up a "Gas Service" after they entered the war in 1917, which led to the "Chemical Warfare Service (CWS)" in 1918. The US Army was not all that enthusiastic about CBW.[24]

An armistice was declared in November 1918, and the shooting stopped. Gas was estimated to have killed thousands of men and injured a lot more. The number of men killed by gas was small compared to the number killed by other means, but gas had played a particularly unpleasant role in the conflict. Gas shells and other delivery systems had been refined, as had defensive technologies and procedures.[25] All the combatants had been preparing even nastier chemical weapons when the war ended.

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[24] Ibid., p.98.

[25] Haber, L.F, *The Poisonous Cloud Chemical Warfare in the First World War*, Oxford University Press, Oxford, 1986, p.68.

Development of New Agents

Four classes of agents had been developed during the war and were being refined in the postwar period:

Asphyxiants or choking agents, which attacked the lungs and could cause victims to drown in their own lung fluids. The classic agents were chlorine and phosgene, but other agents were used during the war.

Diphosgene was similar to phosgene in composition and action, but easier to handle. Chloropicrin, known as vomiting gas was much less effective than phosgene and had a nasty strong odour that gave away its presence, but it could penetrate gas mask filters more easily and was sometimes used in combination with other gases.

Blistering agents, consisting of several different forms of mustard gas. The original German chemical agent was sulfur mustard, but after the war nitrogen mustard agents were synthesised and manufactured as well. Nitrogen mustard was easier to manufacture and more persistent than sulfur mustard.

The Americans did make a significant contribution to CW in the form of a blistering agent named Lewisite, developed in 1918 by W. Lee Lewis. Lewisite was similar to mustard gas in its ability to cause damage to a victim's entire body, but much faster acting. Lewisite was an oily liquid that ranged from clear to dark coloured, depending on impurities. Pure product had little smell, but impure

product smelled something like geraniums. It was an arsenic based or arsenical compound that caused a burning sensation on the skin within about 15 seconds.

A family of other broad effect irritants were developed in the postwar period as well, known as nettle gases as they made a victim feel as if he had been dragged through stinging nettles. The best-known of the nettle gases was phosgene oxime. The name is somewhat misleading as it had no strong chemical relationship to phosgene, and of course had a much different action.

Blood agents, most specifically aqueous hydrogen cyanide (HCN), also known as prussic acid or hydrocyanic acid, which blocked the absorption of oxygen in the blood. Cyanides had been used in combat by the Allies to an extent, but though deadly in enclosed spaces, they tended to dissipate quickly in open air, and they had little useful effect in low concentrations.

A wide range of nonlethal, or less lethal, gases, including tear gases and vomiting agents. Many different tear gases were used during World War I, such as chloracetone and bromacetone, and after the war new tear gases were developed, including chloracetophenone (CN) and ortho-chlorobenzylidene malononitrile.

If gas warfare continued in secret, in public it was made illegal through a series of international treaties that culminated in the Geneva Protocol of 1925. in all 38 countries signed the protocol, renouncing the use of chemical weapons, though the treaty was not ratified by the U.S. and Japan. There were major

loopholes in the treaty. It had few or no verification or enforcement clauses; and the major powers continued to develop chemical weapons in secret. During the late 1920s, the Soviets began to develop their own gas warfare capability with cooperation from Weimar Germany, and in the same timeframe the Japanese obtained their own gas warfare capability.[26]

1934-1940: Development of Nerve Gas

Another German chemist, Gerhard Schrader developed a highly lethal organo-phosphate compound in December 1936, which he named 'Tabun'. Tabun was the first member of a fourth class of poison gases, known as "nerve gases", or more correctly "nerve agents", as they were dispersed as a fine aerosol of liquid droplets, not a gas. The Germans discovered a few years later that tabun worked by interfering with the transmission of nerve impulses across synapses. Victims lost bodily control until they were no longer able to breath, causing suffocation. Tabun was invisible, odorless, and could kill in extremely tiny quantities. A gas mask was little protection, as tabun would be absorbed through the skin.[27]

Tabun was far too dangerous to be safely used as a pesticide. Although Schrader had not been looking for a weapon, he realised the military potential of his discovery. He was a dutiful German and reported his discovery to the

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[26] Stockholm International Peace Research Institute, *Chemical Disarmament: Some Problems of Verification*, Stockholm, 1973, p.110.

[27] Perry J. P., Robinson, *Chemical and Biological Warfare Developments*, Oxford University Press, Oxford, 1986, p. 71.

authorities, as required under Nazi law of any discovery that might have military applications. Schrader was not enthusiastic about developing chemical agents like Haber, but he did it nonetheless. The Nazis set him up in a secret military research lab. In 1938, he discovered an even more lethal nerve agent similar to tabun, which he named "sarin".[28]

CW was coming back into style. A big conflict was coming, and chemical weapons were expected to be used, both on the battlefield and against civilian populations.

Notable among offencive improvements were respiratory agents more poisonous than chlorine, such as phosgene, and chemicals that damaged the skin and attacked the eyes, especially mustard gas. The defence kept on developing with the introduction of better gas masks, protective clothing, and battlefield tactics for minimising exposure. More than 100,000 tons of various chemical warfare agents were used in World War I; but gas was an unimportant weapon in overall military terms, largely because of the effectiveness of defenses against it. In World War II, chemical weapons were stockpiled by both sides, but they were not used and were not integrated into military planning. Records indicated various reasons for this:

[28] Ibid., p.73.

(1) military opinion that chemical weapons would be no more effective than conventional weapons and would complicate and delay operations,

(2) fear of retaliation, especially against civilian centers, and

(3) Aversion to gas warfare by political and military leaders, reflecting the proscriptions of the Geneva Protocol.

Use in Recent Times:

Chemical weapons were used in only a few of the more than 200 wars fought after World War I. In each case—as in Ethiopia (1935–36), China (1938–42), the Yemen (1966–67), and Iraq–Iran (1984–88)—chemicals were used against forces initially lacking gas masks. The weapons modern lethal chemical weapons employed the Organophosphorous nerve agents first produced but not used by Germany during World War II. Related to certain insecticides but much more toxic to man, they would cause intense sweating, filling of the bronchial passages with mucus, dimming of vision, uncontrollable vomiting and defecation, and finally paralysis and respiratory failure. Death would result from asphyxia, generally within a few minutes after respiratory exposure or within hours if exposure were through a liquid nerve agent on the skin. The U.S. stockpile of chemical warfare agents, loaded into munitions or stored in bulk, included the nerve agents sarin and VX, while the Soviet Union stocked the nerve agents sarin, VX, and soman. Of these three nerve agents (all liquids), sarin would evaporate the most rapidly and would pose mainly a respiratory hazard. VX, the least

volatile, would act primarily as a contact poison. Soman, with volatility intermediate between that of sarin and VX, would pose both respiratory and contact hazards.

In addition to nerve agents, both nations stocked mustard gas and the irritant CS, which was also used by police. The Soviets also stocked lewisite, a blister agent developed but not used by the United States during World War I. Mustard gas and lewisite would not be nearly so lethal as the nerve agents, causing casualties principally from incapacitating blisters and temporary blindness. Their full effects would take several hours to develop, although lewisite, in contrast to mustard gas, would cause immediate pain to the skin and eyes. Liquid chemical warfare agents, such as mustard gas, lewisite, and the nerve agents, could be loaded into artillery projectiles, bombs, or missile warheads, to be dispersed by an explosive charge as a vapour cloud or a liquid spray. Liquid agents might also be carried in tanks and sprayed from aircraft at low altitude. Greater persistence and more controlled dispersion might be obtained by the addition of thickeners. Solid agents, such as CS, might be dispersed explosively or aerosolised from pyrotechnic mixtures in various munitions.

An innovation put into quantity production by the United States in 1987 was the binary sarin artillery projectile, in which two relatively nontoxic precursors of sarin were held in separate canisters. Upon firing, the two chemicals

would mix and react to form sarin. One of the canisters might be stored and shipped separately, to be inserted into the projectile at the ammunition depot or the gun site. This built-in safety feature was intended to provide greater operational flexibility in the storage and transport of the weapon. The binary principle could be applied to other types of chemical warfare agent. The amount of a chemical warfare agent required to create a hazardous cloud over a target area would be highly dependent on air movements. The weight of sarin, for example, required to produce a lethal respiratory hazard to unprotected persons over most of an open mile-square area could be between 0.3 and 10 tons, depending on atmospheric conditions. As an illustration, the delivery of these amounts by 155-millimetre artillery would require the firing of approximately 100 to 3,000 projectiles. For causing casualties to unprotected troops, chemicals could be more effective than an equivalent weight of conventional high-explosive fragmentation weapons. For troops with good protection, however, the reverse would be true; soldiers with modern antichemical protection would be far less vulnerable to chemicals than to conventional weapons.

New Technologies:

No doubt the new technologies made CBW more usable in warfare but parallel to that, defence technologies have also been developed. The first and most important line of defense against chemical warfare agents (also needed for protection against radioactive fallout) was the individual protection provided by

masks and protective clothing, and the collective protection of combat vehicles and mobile or fixed shelters. Filters for masks and shelters contained specially treated activated charcoal to remove vapours, and paper membranes or other materials to remove particles. Such filters typically could reduce the concentration of chemical (and biological) warfare agents by a factor of at least 100,000.

Masks could be donned in less than 10 seconds and could be worn for long periods, even in sleep. Modern protective garments were made of fabric containing activated charcoal or other adsorptive forms of carbon. A complete suit typically weighed about two kilograms. The fabric could breathe and pass water-vapour perspiration. In warm weather, periods of heavy exertion in full protective gear would have to be limited in order to avoid heat stress, or else protection would have to be partly relaxed, as by partially opening the protective jacket. Under common European conditions, military units routinely exercised at or near full protection for several days continuously. Other items for chemical defense were detectors and alarms sensitive to nerve and blister agents, prophylactic and antidote drugs that would provide partial protection against nerve agents, and equipment for decontaminating people and equipment. The effectiveness of chemical weapons against prepared forces would depend more on the interference with fighting performance imposed by wearing protective equipment and taking other precautions than on direct casualties.

The extent of such interference, and hence the military value of chemicals in comparison with other weapons, was difficult to assess. Estimates based on controlled field exercises, of the reduction in performance in military units under chemical attack ranged from near zero to more than 30 percent, depending on the mission and the conditions of the exercise.

The development, production, and stockpiling of weapons based on them were outlawed by the 1972 Biological Weapons Convention, to which more than 100 states were party, including all five permanent members of the United Nations Security Council. The treaty also covered weapons based on naturally occurring poisons, known as toxins, however produced. As with chemical weapons, actual employment of biological weapons was outlawed by the 1925 Geneva Protocol. At the time of their destruction in accordance with presidential directives of 1969 and 1970, the biological weapons of the United States (the only country for which authenticated information was available) included dry powder or liquid-slurry formulations of the microbes that cause tularemia, Q fever, Venezuelan equine encephalitis, rice blast, and stem rust of wheat. They also included a number of toxins, such as paralytic shellfish poison. A variety of dispensers, both large and small, were also on hand. Biological weapons designed to dispense airborne clouds of pathogenic microbes could in theory kill or incapacitate unprotected populations over very large areas. Such weapons were never used.

Implication of CBW for security strategies:

An important fact of the U.S. stratergy after the cold war has been the projection of its power into zones of conflict but the proliferation of CBW have complicated this. Before discussing this, its important to see the types of power projection that US has been wielding in recent years. There have been three types of power projection broadly. These includes –

1. To 'show the flag' and demonstrate presence.
2. To honour alliance relations with regional patterns and
3. To intervene whether collectively in support of a U.N Security Council resolution or unilaterally in defence of regional interests.

The proliferation of CBW with other advanced military capabilities has made the projection of power more difficult and costly, and the proliferation of WMD in particular has increased the likelihood that the costs of projection in human terms also be large. In fact this use of CBW made it possible for the advanced powers to intervene militarily in developing countries without serious military cost. Nevertheless, despite with tremendous progress in science and new technology, there continues a genuine gap between legitimate research and commercial biotechnology and offensive warfare programs. The main focus of the next chapter will be on analysing the impact of new technologies on CBW.

Chapter Three:
Technologies of CBW

The great achievements of technologies over recent years have produced advances in agriculture and industrial processes and have revolutionised the practice of medicine. The very technologies that fuel these benefits to society, however, pose a potential risk of being misused as well. For example, there always remains a possibility that these technologies could also be used to create more modern and more lethal CBW. Biotechnology represents this historic dual use dilemma in which the same technologies can be used to create a medicine and misused to make a CBW.

Chemical weapons known as Nerve Agents were discovered accidentally by German Scientist Gerhard Schrader in 1936. Schrader was working on developing a chemical to fight insects (insecticides), on his success he sprayed a dilute solution of what is now known as the Tabun Nerve Agent on a group of insects. After some time, he developed side effects related to vision and breathing that lasted three weeks. Although Chemical Agents such as chlorine and phosgene gas were first used during the First World War in trench warfare their lethality did not compare to that of nerve agents.[1] Nerve Agents work by unbalancing the

[1] Steinbrunner J.D., Harris E.D., "Controlling dangerous pathogens", *Issues in Science and Technology*, Texas, Spring 2003, p. 47.

Nervous system and thus paralysing the subject's muscles and arresting the respiratory system causing death.

New Technologies:

Technological evolution of Biological Weapons are more difficult to trace in history. Biological Agents work by several ways, either by directly infecting the human body with disease or unbalancing the body's system as with toxins.

Then there are questions of their lethality which also remain dependent of their production, delivery and of course on technologies of immunisation against CBW. Chemical Weapons have the property of killing instantly with a lethal dose possible as 10 milligrams, that's one hundredth the weight of a gram. The lethal dose of chemical weapon would usually cause a paralysis of muscles and the stopping of breathing. However, biological weapons do not kill instantly, a very small amount of bacteria can infect and kill hundred percent of people exposed in three to seven days such as anthrax.[2] Certain biological weapons can have the added effect of being contagious unlike chemical weapons, further multiplying their lethality factor. Biological Weapons can be further modified by genetic engineering, it is certainly possible that a biological weapon targeting an ethnic group is being or has been developed by the military. There are some documented incidents of the use of such military weaponry against a civilian population, such

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[2] Stockholm International Peace Research Institute (SIPRI), *The Rise of CB Weapons: The Problem of Chemical and Biological Warfare,* Humanities Press, New York, 1971, p.33.

examples being the Tokyo subway attack and an incident were a U.S. Ship leaked mustard gas in an Italian harbor killing upto 1000 people during the Second World War.

Despite being known as poor man's nuclear weapons, CBW do involve difficult technologies and processes. Military grade CBW's are usually in the form of a very fine powder for the purpose of easy dispersal over the target zone. An equivalent improvisation by an individual is nearly impossible as a lot of equipment and expertise is needed to achieve the powdered form. It is very easy and cheap to achieve a sludged consistency. For example take samples of anthrax from an infected farm animal and use a biological culture medium such as blood "agar" to allow the anthrax bacteria to multiply resulting in a large supply of anthrax sludge. This sludge cannot be dispersed effectively over a large area so this technique is quite useless.[3] Also, CBW are much more expensive to improvise and no substantive quantity and quality can be manufactured by a college level Chemistry graduate. The procedure would require chemicals and equipment available in Chemical supply companies. An example is the Tokyo Subway attacks where an unconcentrated form of Sarin Nerve Agent was used to cause havoc more for its hype and panic rather than being a deadly military

[3] Bobison, J.P.P., *"Chemical and Biological warfare Developments: 1985"*, Oxford University Press, SIPRI CBW Studies No.6, Oxford, 1986, p.32.

weapon. The procedures and research to improvise CBW's are readily available to the public.[4]

Deployment Techniques:

The second most important aspect of CBW is how delivery to the target is handled. To contrast effective and ineffective techniques the Tokyo Subway incident can be used again as an example. In this case a bottle of a crude form of sarin was opened and left to evaporate naturally with severe effects on the commuters. An effective technique would involve the wide dispersal of Sarin at an altitude above a city center. A small aeroplane can be used to achieve this with horrific results to the population below. A spray nozzle or 'drop box' could be used for any CBW assuming they are of the correct consistency as they reach their target bodies. Another way is to attach a low temperature explosive device to a container of CBW and set it to explode a certain altitude above a crowded area using an electronic altemeter detonator. In such a dispersion scenario the Boiling Point of the CW is important as it defines the way the chemical disperses and reacts to high temperatures. As an example if volatile Sarin is exploded above the target on a very hot day a lot of it would evaporate needlessly, further to that the area would only be contaminated for a short time as the sarin would all evaporate eventually.[5]

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[4] Ibid., p.33.

[5] Tucker Jonathan B., Sands Ammy, "An Unlikely Threat", *Bulletin of Atomic Scientists*, 435, 1999, p.46.

A very complicated problem exists with deployment of CBW. For example the substances used are so toxic that physical contact can cause death to the person handling the weapons. Conventional techniques have artillery shells filled with CBW. This is usually overcome by filling the shells with the substance seconds before the shell is inserted and launched by artillery, therefore avoiding the hazardous transportation of CW or BW shells by conventional soldiers.[6] In the case of CW a special alternative exists to this in the form of Binary Weapons. Instead of storing a CW two reactants are stored separately and mixed en route to the target by the rotating artillery shell after just being dispatched by the cannon.[7]

Ways to protect against:

Chemical weapons can gain entry to the body through contact, inhalation or ingestion. Similarly Biological Weapons designed for effective dispersion. To protect against such weaponry the body will have to be totally isolated from the substance and a filter established for breathing. This is what an NBC (Nuclear Biological Chemical) suit does.[8] These suits can be reused repeatedly or come in the disposable form. In addition there is always the chance of exposure even with a suit so protective medication is required; For CW an injection of Atropine along with an inhibitor related to the nervous system is required such as Contrathion, in

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[6] Ibid., p.47.

[7] Ibid., p.49.

[8] Collins J.M., "Nuclear, Biological and Chemical Weapons Proliferation: Potential Military Countermeasures", *Bulletin of Atomic Scientists*, 442, 1997, p.2.

combination these two chemicals work against the loss of balance in the nervous system caused by the CW.[9] BW's are more complicated as a vaccine is required to protect against the effect of the BW disease or the use of a powerful antibiotic to help fight the infection such as DoxyCycline. Coupled together the NBC suits, medication and early warning devices help protect against the threat of CBW.

Let's look at some prominent example of CBW:

> Sarin, chemical name Isopropyl Methyl Phosphonoflouridate can be synthesized in a good chemical laboratory, it is a thin oily liquid clear to amber in color and odourless. The fatal inhalation dosage is 10 milligrams. Death can occur to the target in 1 to 10 minutes with indications of dim vision, runny nose, and tightness in the chest, nausea, diarrhea, coma and respiratory failure. Sarin used to be the standard nerve agent used by the United States. It was invented by Gerhard Schrader during World War II. The main trouble with using Sarin is that it is very volatile so tends to evaporate from the target area before its full effect can take place.[10]

VX Gas is another a powerful Chemical weapon which can be listed amongst the most lethal categories to define it.

> VX, chemical name S-(2-DiisopropylAminoEthyl)-0-EthylMethylphonothiolate can be synthesized in a good chemical laboratory, it is a heavy oily liquid like motor oil clear in color and odourless. The fatal inhalation dosage is 10 milligrams,

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[9] Ibid., p.4.

[10] Steinbrunner J.D., Harris E.D., "Controlling dangerous pathogens", *Issues in Science and Technology*, Texas, 576, Spring 2003, p. 47.

> Death occurs to the target in 10 minutes with indications of dim vision, runny nose, tightness of chest, sweating, muscular twitching, nausea, vomiting, weakness and coma. VX was discovered out of insecticide research done in Britain. VX has a high vapor pressure in contrast with Sarin therefore it is very persistent on the target as it does not evaporate easily. This factor gives VX a very lethal skin contact dosage of 2 milligrams as compared to Sarin's 10 milligrams.[11]

Anthrax is one of the most challenging and known Biological Weapon. Anthrax (Bacillus Anthracis) was discovered in the mid 19th century. It is thought to be behind the death of many people in medieval Europe and ancient Egypt.

> The Japanese first looked into the use of anthrax as a military weapon in 1930. It is considered as the perfect biological weapon because of the fact that it is extremely persistent. It will contaminate the area of a natural target for years before it can be cleaned up. Once exposed it is fatal to 100% of all exposures and will lead to death in 3 to 7 days. Although it is not contagious several different types exist; Anthrax can be lethal when inhaled but other types exist that are activated on contact with the skin. Anthrax has received a lot of coverage in the news recently due to the Anthrax Letters which were posted to the U.S. after the September 11 incident.[12]

Botulin Toxin is a different kind of Biological weapon. Botulin is an exception to the rule of Biological Weapons.

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[11] Ibid., p.49.

[12] Steinbrunner J.D., Harris E.D., "Controlling dangerous pathogens", *Issues in Science and Technology*, Texas, 576, Spring 2003, pp. 54.

The Bacteria Clostridia Botulinum produces the Botulin Toxin as a by product. The fatal dose of the Botulin Toxin is 1 microgram, that's one millionth of a gram in weight. Theoretically speaking, 1 gram of this toxin is enough to kill 1 million people making it the second best poison in the world. A lot of coverage of this weapon has been attributed to food poisoning; therefore it is not expected to be used as a weapon. Small quantities of Botulin Toxin can be created rather easily with basic Biological principles.[13]

Emerging New Technologies:

More complex genetic interventions, such as multiple gene transfers and novel agents are becoming possible today. Harmless bacteria may be equipped the capability to cause illness and death, and even inter-species hybrids involving large gene sequences are a real possibility.

A group of British researchers had pleded guilty in 2001 to charges that they improperly handled a genetically engineered hybrid of the viruses causing hepatitis C and dengue fever. British authorities characterised the virus as "more lethal than HIV".[14] 'Dengatitis' was deliberately created by researchers who wanted to use fewer laboratory animals in a search for a vaccine for Hepatitis C. Under unsafe laboratory conditions, the researchers created and nearly accidentally released a new hybrid human disease whose effects, fortunately, remain unknown; but which may have displayed different symptoms than its

[13] Ibid., p.56.

[14] Sankar P, Cho M.K., "Toward a new vocabulary of human genetic variation", *Science*, Washington DC, 43, 2002, p.298.

parents and thus been difficult to diagnose, and have required a new, unknown treatment regime.[15]

Synthesis of biowarfare agents by new technologies:

Today access to highly virulent agents and strains is increasingly regulated and restricted. Smallpox viruses, eradicated outside the laboratory more than 20 years ago, are today most likely present in only two high security laboratories in the US and Russia. But it is only a question of time before the artificial synthesis of agents or agent combinations becomes possible.

Artificial poliovirus:

Poliovirus was recently synthesised by a US research team at the State University of New York in Stony Brook. The researchers built poliovirus "from scratch" through chemical synthesis. Starting with the gene sequence of the agent, which is available online, the researchers synthesised virus sequences in the lab and ordered other tailor-made DNA sequences from a commercial source. They then combined them to form the full polio genome. In a last step, the DNA-sequence was brought to life by adding a chemical cocktail that initiated the production of a living, pathogenic virus. The experiment was funded by the US Defense Advanced Research Projects Agency (DARPA).[16]

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[15] Ibid., p.300.

[16] Cello J, Paul AV, Wimmer E , "Chemical synthesis of poliovirus cDNA: generation of infectious virus in the absence of natural template", *Science* , Washington DC,44,2002, p.256.

In principle, this method may be used with other viruses that have a similarly short genetic sequence (genome). This is true for at least five viruses that are considered to be potential biowarfare agents, including Ebola, Marburg and Venezuelan Equine Encephalitis. Ebola and Marburg are very rare viruses that may be difficult to acquire for potential bio weaponeers.[17] Using the method that has now been published for polio, Ebola might be synthesised in a laboratory. At present the method is mastered by only a few highly trained experts, although this is unlikely to remain so for long.

Recreating the Spanish flu:

Annual outbreaks of Influenza kill many people, particularly the elderly; but a case of the flu is generally not perceived as a very big threat. But flu viruses can be devastating. In 1918 and 1919, the so-called 'Spanish flu' killed an estimated 20-40 million people worldwide and, since then, the highly changeable flu virus has resurfaced in a variety of particularly virulent forms.[18]

The strain of influenza virus that caused the 1918 global epidemic was exceptionally aggressive. It showed a high capacity to cause severe disease and a potential to kill fit young adults rather than the elderly. This high mortality rate, especially amongst the younger, lowered the average life expectancy in the USA

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[17] Ibid., p.258.

[18] Madjid M, Lillibridge S, Mirhaji P, Casscells, "W Influenza as a bioweapon", *Journal of Royal Social Medicine*, 87, 2003, p.345.

by almost ten years.[19] Creation of this particularly dangerous influenza strain, as it is currently pursued by a US research team, may thus pose a serious biowarfare threat.

New types of weapons:

Many other new weapons may become possible in the decades to come. The deciphering of the human genome, synthetic genes and organisms, new approaches to gene therapy and drug delivery, and the sheer volume of genetic engineering experiments with potentially pathogenic microorganisms will increase the availability of much more sophisticated biological agents with a potential for hostile use, not only in classical warfare scenarios, but also for peacekeeping, military operations other than war, low intensity conflict, and covert operations. To illustrate the possibilities, examples of future weapons based on current technologies follow:

a) Food Weapons

So called "edible vaccines" and "biopharming" (i.e. the production of vaccines or other bioactive substances in edible crops) can be put to hostile use. In the past decade, genetically engineered plants have been investigated as a means to produce and deliver vaccines. There are already a variety of research reports demonstrating that engineered plants can elicit an immune response in humans and clinical trials on humans are currently underway to test vaccines produced in

[19] Ibid., p. 344.

edible crops.[20] These vaccines may be isolated from the plant for further processing or directly delivered to the patients by consumption of the engineered plant. Vaccines are only one type of bioactive substances being produced in edible crops. Several US companies are using genetically engineered crops to produce industrial enzymes, growth hormones, and other potent pharmaceutical compounds. These techniques pose a serious risk to human health and the environment, especially when the highly active pharmaceuticals are introduced into edible crops.[21]

The possibility of misuse of these crops or for hostile purposes is serious. In long term conflicts, it may be tempting to weaponise engineered crops, spiking them with, for example, disease-inducing e.g. cancer or debilitating compounds e.g. affecting human or animal fertility or built-in deficiencies that could lead to crop failure. Such weaponised germplasm may thereafter be introduced in the target country's seed supply and consequently its food supply through covert actions or simply by means of seed sales or humanitarian aid. This may not be possible with crops that are exported by the target country, as, given today's global market, the spiked food could end up in the aggressor's food supply. But for most countries it will be possible to identify food or feed crops in the target country that are not exported.

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[20] .http://www.prodigene.com/pr/pro-nih/2003aug12.

[21] .http://www.foe.org/camps/comm/safefood/biopharm/BIOPHARM_REPORT.pdf

There are routes to possibly achieve similar effects without sophisticated knowledge to engineer a specific crop with a specific compound. Theft of a few corn kernels from one of the many trials with edible plants producing bioactive substances may be enough. Pharmaceuticals such as blood clotters or blood thinners may not be a weapon of choice, but introduction into the food supply would not be technically difficult. Profusion of such artificial traits would likely produce panic and could be very difficult and expensive to eradicate. A potent growth hormone, which has been field trialed in the U.S., or a drug called trichosanthin, which has also been tested. Trichosanthin, considered to be a potential anti-cancer agent, has the same mode of action as the biowarfare agent ricin and is a strong abortion-inducing compound. In the U.S., trichosanthin production in tobacco plants was induced by a genetically engineered plant virus. That same virus also easily infects crops such as tomatoes and peppers.[22]

Edible weapons pose a serious problem for BW non-proliferation efforts. No biological arms control effort could stop a person from stealing a handful of kernels, growing more, and introducing them into a country's food supply. The technology and especially its products are inherently difficult to control –there were a variety of cases in past years, where specific genetically engineered crop varieties showed up in unexpected places. In one case, a corn variety that was not permitted for human consumption by U.S. regulatory agencies showed up in a

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[22] Wheelis M, Dando M , "On the brink: biodefence, biotechnology and the future of weapons control", *Chemical & Biological Weapons Convention Bulletin* 2002, p.146.

broad variety of human food supplies – despite it being approved for animal feed only.[23]

Considering how easy and effective the hostile abuse of these genetically engineered crops is once they are developed, a complete ban on the production of hazardous compounds in edible crops appears to be justified but it will be technologically more challenging for a future biowarfare program to develop its own food weapon if the technology is not further developed. With each experiment and each field trial, more knowledge on how to turn food crops into dangerous weapons will be accumulated, simultaneously creating pathways to weapons.

A complete ban on this particular technology will not cause severe scientific or industrial setbacks. All bioactive compounds that are currently produced in edible crops may as well be produced through other means that are less prone to hostile use. Some small biotech companies that specialise in biopharming may face problems, but others that focus on different technologies well benefit from such a move.

b) Insect Fighters

The idea to use insects to deliver biological warfare agents is not new. Insects were systematically explored as a mechanism to spread a variety of diseases like plague in the World War II Japanese BW program and the postwar

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[23] .http://www.washingtonpost.com/ac2/wp-dyn/A23092-2001Mar18

US program. In many cases, such insect vector BW was dismissed as too complicated and unreliable. But genetic engineering may open a new way to use insects as weapons. In the same way as genetically engineered plants may be misused as 'food weapons', insects may be engineered to produce toxic compounds and deliver them through their natural feeding habit – e.g. in the saliva of mosquitoes.[24] Again, these compounds may exert a broad range of possible effect, from non life threatening illness to sterility to widespread fatal illness in a target population.

Techniques to use insects to deliver vaccines have already been developed and patented. The idea to develop what one company calls 'flying syringes' is based on the concept where every individual must be inoculated by trained medical personnel. Genetically engineered mosquitoes or other biting insects could instead deliver minute quantities of vaccine through the saliva every time they bite. The relevant techniques are still in their infancy. In comparison to genetic engineering of crops, for example, insects lag behind; but within several years, development of insect combatants may become a real possibility.[25]

It is, however, questionable, whether genetically engineered insects may really become a weapon of choice. It will be nearly impossible to control these insects and limit their activity to the target country. Even if insects are chosen that are thought to be restricted to certain climate conditions, natural evolution and

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[24] Wheelis M, Dando M, " Back to bioweapons?", *Bulletin of the Atomic Scientist* ,2002, p.59.
[25] Ibid., p.61.

global climate change may rapidly overcome this restriction. State sponsored biowarfare programs tend to be very concerned about restricting unintended distribution of the biowarfare agent most typical bacterial biowarfare agents are not contagious and will thus hardly engage in the flying syringe concept.

c) Ethnic specific biological weapons

Current wisdom holds that population specific biological weapons are practically and theoretically impossible. Practically, many consider it impossibly difficult to use genetic variability to kill or otherwise affect populations. Others, including geneticists, argue that no suitable ethnic specific genes exist in the first place. Both notions are wrong. New technologies are indeed available to translate specific genetic sequences into markers or triggers for biological activity. And a recent analysis of human genome data in public databases revealed that hundreds, possibly thousands, of target sequences for ethnic specific weapons do exist. It appears that ethnic specific biological weapons may indeed become possible in the near future.[26] Weapons targeting specific population may be used in an all out war, in the battlefield or against civilian population, or they may be used in covert operations in conflict situations and with long-term effects, in order to destabilise, harm economically or weaken an enemy society.

Status of Different Countries Stockpiles:

[26] Brenner CH, "Difficulties in the estimation of ethnic affiliation1", *Bulletin of the Atomic Scientists* ,2002, p.28.

The fall 2001 anthrax attacks in the United States and the discovery that the al Qaeda terrorist network has pursued the development and acquisition of weapons of mass destruction have recently focused attention on chemical and biological weapons proliferation. At least 13 countries are currently pursuing biological weapons and at least 17 states have chemical weapons programs, according to Secretary of Defense Donald Rumsfeld. (***See Annexure I***).

The countries are possessing or developing chemical or biological weapons and, where possible, stockpiling CBW and working on potential delivery systems. Most of the states have ballistic missile capabilities. However, ballistic missiles are only included as a potential chemical or biological weapons delivery system if U.S. intelligence reports have explicitly indicated that they could be used in such a capacity. But we can not deny the possibility of such condition as in earlier wars, we can see the use of different CBW delivery systems (***See Annexure II***).

The chart also details whether each state has signed, ratified, or acceded to relevant international treaties: the 1972 Biological Weapons Convention (BWC), which bans offensive biological weapons development and possession; the 1993 Chemical Weapons Convention (CWC), which outlaws chemical weapons development, possession, and use; and the 1925 Geneva Protocol, which forbids the use of chemical and biological weapons in war.

Despite of all efforts to forbid the use of CBW, countries are still working on new techniques of preparing, stockpiling and delivering CBW. For example, U.S. has recently got the patent for 'Bullet Trap Rifle Granade Cargo Projectile', specialy designed to deliver CB agents.

However, Rifle muzzle launched projectiles have been in existence for years but this new invention is directed to a payload delivering projectile which is capable of being launched from the end of a rifle muzzle in a safe and effective manner. This method of launching projectiles provides advantages in terms of range and accuracy over hand-thrown counterparts.Such kind of new innovations and application of new technologies to make more sophisticated and smarter CBW increases the possibility of their military use.

This new Rifle Granade Cargo Projectile comprises of:

launch tube defining an interior cavity, and having an opening at one end with an inner diameter sized to fit over the end of a muzzle of a rifle; a bullet trap fixedly located in the launch tube cavity opposite from the launch tube opening, the bullet trap adapted for safely capturing a bullet fired from the muzzle and a payload assembly mounted on the launch tube opposite from the opening end, the payload assembly further configured for safely releasing a payload associated therewith in a controlled manner during delivery in absence of shrapnel formation or fragmentation.[27] (***See picture***)

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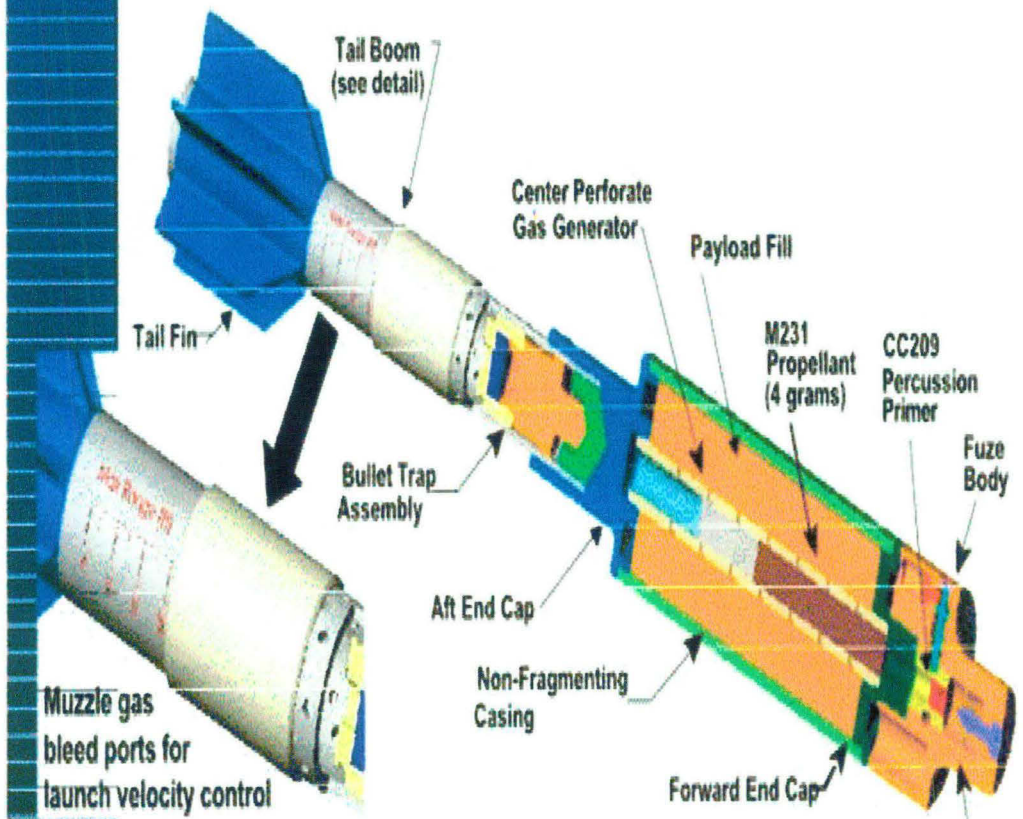
[27] .http://www.sunshine-project.org/pub/press rel/2003may8.

ENGINEERING TECHNOLOGY INCORPORATED

Application of Propellant Dissemination Technology for Non-Lethal Aerosols

BULLET TRAP RIFLE GRENADE CARGO PROJECTILE



Physical Specifications:

Overall Length:	13.5 inches
Outside Diameter:	2.0 inches
Total Mass:	1.50 pounds
Fill Mass:	230 grams
Maximum Range:	517 feet

ETI Part Number: 8277072
Bullet Trap Rifle Grenade Smoke Projectile

ETI BTRG Smoke Projectile for IR Screening

ETI-VG-8277-06-21

Multiple Responses:

New technologies of CBW has posed a new challenge for the diplomatic, technical, military, medical, and intelligence communities, but the political arena may hold the biggest stick to deter biological warfare aggression. The BWC and CWC are the international vehicle to prevent biological proliferation. But unfortunately, it does not provide for complete verification. This is especially challenging given that the dual-use technology that produces biological and chemical agents.

The technical community has the greatest and most urgent challenge to develop effective detectors, both on the battlefield and in biological agent detectors similar to metal detectors. This effort should be a top priority. There should also be technological exploration, in concert with the intelligence community, for means to detect clandestine biological production facilities. Both human intelligence and the national technical means must be greatly improved.

The military challenge is to train and equip to respond to a detected biological threats. To respond on the battlefield, militaries must develop effective, comfortable, and long-wearing protective clothing to replace the existing ensemble. The military must also be capable of responding to a more strategic biological warfare threat—the production facilities and stored munitions. Planners must work with the technology community to develop a capability to bomb a CBW target and destroy the viability of the agents before they can be brought to

bear on friendly forces and without causing unacceptable levels of collateral damage. For obvious political reasons, such precision-guided munitions should, also, be kept non-nuclear.

The medical community should continue to work on biological warfare vaccinations and chemical attack's treatment that are broad-based, safe, and in sufficient quantities to inoculate those people most susceptible to CBW attacks. Doctors should also strive to improve the post-attack treatment in terms of rapid diagnosis, effective medical treatment, and a responsive surge capability to administer to large numbers of CBW exposed patients.

The intelligence community must be strengthened and sensitised in its efforts to gather data on the CBW threat. More resources should be directed toward identifying CBW threats by human and national technical means. And in the end, all these players should be able to also coordinate their analysis and build joint responses to make defence against emerging new CBW technologies as also to build up and deploy requisite defensive (and immunity) technologies. Some work at this direction indeed has already been initiated. This is especially important now in order to deter terrorism in the interim until human intelligence and national technical means can provide more definitive solutions to detect and defend CBW threat potentially.

Chapter Four:
Defence against CBW

With the advancement in technologies of production, stockpiling and delivery of CBW, technologies have also emerged as a defence against CBW. The defence against CBW doesn't include technologies only but also comprises increasing public awareness, developing community health and implementing a better norms building against CBW. For purpose of this study defence against CBW is broadly catagorised into

- Detection and verification regimes.
- Defence by evolving norms and to strengthen non proliferation or disarmament ; and
- Defence against their indirect or long term impact or immunology.

To begin with, the main aim of CBW detectors and sensors is to alert to an imminent danger. As also strengthen verification regimes that seek to prevent any such eventualities. The type of sensing systems currently in use or under near-term consideration for detecting CBW have come to be focused in view of new threats of terrorism. Current defence and detector technologies, for CBW, are a must if one has to respond rather than only detect. Alerting civilians, troops to the immediate danger of agent attack is often the only goal of a normal detector. More sophisticated or additional instrumentation further refines the nature and concentration of the danger. Depending on the type of agent, the same technology is sometimes appropriate for after-incident investigation, which is critical for law

enforcement. Many of the technologies discussed are appropriate for first-responders, there are various diagnostic tools to determine medical or veterinary treatment after exposure or infection. Much of the defence against CBW also depends on detection being effective and timely.

Biological Weapons Detectors

To first deal with detectors in CBW, they have to deal with a whole variety. Biological agents come in many forms - from delicate RNA-based filoviruses to robust spores of the Bacillus anthracis bacterium to toxins which can be called both as biological and chemical agents. These differences creates problem in preparing a single detector for all biological agents.

The "gold standard" for identification of microbiological species remains culturing - literally growing a colony of microbes on a nutrient containing surface (Petri dish) and observing it with the eye or through a microscope. Culturing is inexpensive and highly sensitive but slow. Roughly a minimum of a million (10^6) bacteria are necessary to form a visible colony.[1] Detection of single cells is possible but only after long incubation times, usually days. Typical evaluation times are twelve to twenty-four hours for many bacteria but can exceed a week for exotic, slow-growing or more difficult to culture agents.

[1] Simpson B., *Weapons Technology: A Survey of Current Developments in Weapons Systems*, Brassey's Publications, London, 1986, p. 52.

Remote or Standoff Detection

The initial criteria for monitoring and surveillance of potential biological agent at a distance is the observation of aerosolised masses (clouds). Spotting and evaluating the contents of a cloud is referred to as "standoff" detection. At a rudimentary level, these detector types aim to alert to the presence of an (approaching) cloud. Depending on the situation the recipient of that alert may be military, civil authorities, public health personnel or an individual. From that basic awareness, a more refined assessment of the contents, such as water droplets, inert inorganic material, dead biotic particulates or non-pathogenic microbes is pursued.[2] Ideally a standoff detector will also be able to provide some information as to the nature of an aerosolised agent.

Cloud Recognition

One technique which is familiar from weather reporting is the use of Doppler radio detecting and ranging (radar). Using reflected radio waves, the shape, size, directionality and speed of a cloud can be monitored.[3] The elapsed time before the radio waves return to a receiver and the change in the radio waves' energy upon return to a receiver provide information about a cloud. For example, shape can offer clues to differentiate natural-occurring cumulus clouds from

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[2] Iqbal S.S., Mayo M.W., Bruno JG, Bronk BV, Batt CA, and Chambers JP, "A review of molecular recognition technologies for detection of biological threats," *Biosensors & Bioelectronics*, 15, 2000, p. 549.

[3] Ember L, "From weather radars to chem.-bio detectors," *Chemical & Engineering News*, 80, 2002, p. 23.

cigar-shaped ones (difficult to determine visually at night), which are indicative of aerosol release from a single source such as a plane or a moving vehicle.

Another tool for cloud detection and recognition, LIDAR, is based on the same physical principles as radar, except instead of bouncing longer wavelength radio waves off a target, higher energy light waves are used. An acronym for "Light Detection And Ranging," LIDAR is occasionally attributed to "Laser Identification and Ranging" by those who want to emphasise the recognition feature. Using lasers that generate light waves in the infrared, the ultraviolet and the visible portion of the electromagnetic spectrum, the multiple energy wavelengths of LIDAR furnish more detailed information,[4] including three-dimensional imaging.[4] Limitations on detection distance and resolution are due to the collection and processing portions of the detector. The more specific the level of data desired, the closer the instruments must be located to the cloud.

Under controlled conditions, detection of aerosolised clouds at long distances has been achieved.[5] The temperature of a cloud can also be calculated using LIDAR data. Commercial applications for LIDAR include weather and upper atmosphere monitoring, elevation monitoring for planes and police monitoring of speeding automobiles. Water vapor and smog are potential interfering compounds for infrared-based LIDAR systems. The drawbacks are primarily financial and the current limited distance capability. LIDAR instruments

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[4] Weibring P, Ember L, and Svanber S, "Versatile mobile lidar system for environmental monitoring," *Applied Optics*, 42, 2003, p. 3594.

[5] Lee KJ, Youngsikpark, Bunkin A, Nunes R, Pershin S, and Voliak K, "Helicopter-based lidar system for monitoring the upper ocean and terrain surface," *Applied Optics*, 41, 2002, p. 401.

are not cheap - costing about $4,000 for a simple LIDAR used for speed monitoring.[6]

The U.S. Army's Long Range Biological Standoff Detection System (LR-BSDS) uses LIDAR-based technology to detect aerosol clouds from long distances. The Short Range Biological Standoff Detection System (SR-BSDS) combines infrared LIDAR with ultraviolet light reflectance (UV). The latter provides enhanced discrimination capabilities. Biological agents can be distinguished from non-biological material based on the excitation of the intracellular fluorescent compounds.[7] The most commonly targeted compounds are the amino acid tryptophan, the coenzyme nicotinamide adenine dinucleotide (NADH), the cellular energy storage molecule adenosine triphosphate (ATP) and the vitamin riboflavin. Identification of these compounds verifies that the sample is biological in origin. Possible false positives include pollen, molds, organic excreta and certain agricultural fertilizers based on decaying organic matter, e.g., "night soil."

Recent laboratory work using laser-induced breakdown spectroscopy (LIBS) has demonstrated the ability to remotely detect aerosolised and surface-adhered (on soil, rock, etc.) bacteria. The LIBS-based systems not only detect the

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[6] Lognoli D, Lamenti G, Tirelli D, Tiano P, Tomaselli L, and Pantani L, "Detection and characterization of biodeteriogens on stone cultural heritage by fluorescence lidar," *Applied Optics*, 41, 2002, p.1783.

[7] Ibid., p.1787.

presence of an agent but also differentiate among bacterial species and among potential biological interferents (pollen, molds) with one instrument.[8]

Aerosol Particle Sizers (APS)

Weaponised biological agents have characteristic physical dimensions. In order to be effective, agents must be small enough to not drop out of the cloud. Respirable particles have diameters between 0.5 and 20 μm (10^{-6} m). These are the particles which have the physiological potential to embed in the narrow passages (alveoli) or upper portions of the lung. Particles larger than 100 μm fall from the cloud; particles smaller than 0.5 μm are easily respired and do not remain in the lungs. Aerosol particle sizers (APS) take advantage of those size characteristics for detecting BW agents. A strongly uniform particle distribution in the size range associated with an inhalable risk or a substantial increase in numbers relative to a typical background may be indicative of the release of a biological agent.[9] At the heart of APS instruments, nonetheless, is simply an attempt to detect higher than normal concentrations of airborne particles.

In APS systems, particles are drawn through an orifice into a steady high-speed air flow. The velocity of the carrier air remains constant throughout. The introduced particles accelerate at rates proportional to their size. Particles impact a collector or pass through a laser light beam to characterise the size.[10] While most

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[8] Ibid.

[9] Morel S, Leone N, Adam P, and Amourous J, "Detection of bacteria by time-resolved laser-induced breakdown spectroscopy," *Applied Optics*, 42, 2003, pp. 6191.

[10] Liu Byh, Yoo S-H, and Chase S, "Lower detection limit of aerosol particle counters," *Journal of the Institute of Environmental Sciences*, 38, 1995, p. 37.

particle sizers are fairly large and heavy systems, hand-held analysers are commercially available.

Flow cytometry is a sophisticated particle counting technique in which particles are accelerated in a moving stream. Laser light scattering provides information with respect to the size, number and, when combined with fluorescent dye molecules, the chemistry of a sample. The ready combination of flow cytometry with UV or fluorescence methods provides more information about the nature of the material.[11]

Once the presence of aerosolised particles has been established, the next level of awareness which is important for the detection of a potential BW threat is to seek specificity with regard to the agent, i.e., what exactly is it? These are sometimes referred as discriminatory techniques. Detectors for agent identification primarily use two general ideas: **(1)** looking for a pathogen-specific tag or **(2)** taking the sample apart.

Immunoassays

Immunoassay-based detectors copies the human body's natural immune system. The immune system produces highly specific proteins, called antibodies in response to antigens from foreign bacterium, toxins or other microbiological organisms. Antigens are molecules on the surface of the foreign microbes.

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[11] Ibid, p. 38.

Antibodies form strong and specific interactions with antigens. This specific response is the foundation of immunological detectors.

Disposable hand-held assay (HHA) test kits, such as enzyme-linked immunosorbent assays (ELISAs), or tickets for detecting biological warfare agents have been available since the early 1990s. Using laboratory-produced antibodies, HHA tickets recognise the antigen in a sample to which that antibody would be produced if human infection occurred. This technique is pathogen-specific.Immunoassys need some sort of optical signal generator - something that will glow when the detecting antibodies encounter a hit. Typically, this is done with a fluorescent or chemiluminescent dye molecule that is chemically bonded to the detecting antibodies. The detection limit with fluorescence-based tags is on the order of 10^3 cells per ml and slightly lower for chemiluminescence.[12]

The use of colloidal gold particles to generate a red indicator color without the need for a fluorescent light source has been used by the U.S. military and commercialised for the general public, although the detection limit is less sensitive than for other methods.

Some immunochromatographic tickets have exceedingly high reported false positive rates. False positives are responses to something which the detector is not supposed to respond.

[12] Iqbal SS, Mayo MW, Bruno JG, Bronk BV, Batt CA, and Chambers JP, "A review of molecular recognition technologies for detection of biological threats," *Biosensors & Bioelectronics*, 15, 2000, p. 549.

Genetic Detection

In genetic-based detectors, DNA or RNA isolated from a sample is exposed to nucleic acid sequences, or oligonucleotides, which correspond to a suspected biological agent. These sequences are commonly referred to as "probes," as one can imagine a sequence "probing" a sample, finding its genetic match. Similar to antibodies in immunoassay tests, these specific pieces of genetic material are typically tagged with an optical signaling molecule in order to indicate a positive result.

It is critical that probe sequences - the region of DNA or RNA targeted - be chosen well. If overly specific, a genuinely pathogenic strain may be missed yielding a false negative. Concurrently, if the chosen sequence is widely shared among a species or genus, it has the potential to respond to vaccine strains or to nearest-neighbor species, leading to false positives for innocuous non-pathogenic microbiologicals. A wise approach is to use oligonucleotides that target the virulence encoding DNA portion. In this way, genetically engineered species may also be identified.[13] Simple genetic-based ticket detectors are pathogen-specific, like the immunoassay counterparts.

Genetic-based detection is typically combined with an amplification technique, such as polymerase chain reaction (PCR) in order to generate larger quantities of genetic material in a shorter time frame than if the material were

[13] Slezak T, Kuczmarski T, Ott L, and Torres C, "Comparative genomic tools applied to bioterrorism defence," *Briefs in Bioinformatics*, 4, 2003, pp. 149.

cultured.[14] Although many traditional instruments require a minimum of two to four hours, significant breakthroughs in thermocycling and microfluidics have led to reported analysis times of less than ten minutes. The amplified DNA can subsequently be compared to a library of unique oligonucleotides in order to identify the pathogen.

PCR and other DNA amplification techniques, while extremely powerful, are not without drawbacks. They are labor intensive, require consumable reagents, are restricted to liquid samples, offer marginal portability (typically exceeding 50 lbs), are demanding on power resources and are expensive.[15] Different sample preparations are required for hardy anthrax spores than for a comparatively delicate filovirus. Currently, there is also a minimum of thirty minutes for protocol optimisation.

Portable and handheld devices that combine PCR with genetic-based detection are result of new technology. They have significant advantages in terms of specificity and detection limits over immunoassays, bur they also suffer from limitations. Drawbacks that affect this type of system are the critical need for proper preparation, including thermal cycling for amplification, auxiliary reagents, high costs and highly trained operators of the devices. Nucleic acid

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[14] Belgrader P, Benett W, Hadley D, Long G, Mariella R, Milanovich F, Nasarabadi S, Nelson W, Richards J, and Stratton P, "Rapid pathogen detection using a microchip PCR array instrument," *Clinical Chemistry*, 44, 1998, pp. 2194.

[15] Jones M, Alland D, Marras M, El-Hajj H, Taylor MT, and McMillan W, "Rapid and sensitive detection of mycobacterium DNA using Cepheid SmartCycler and Tube Lysis system," *Clinical Chemistry*, 47, 2001, p. 1917.

probes also have finite life spans and generally require controlled storage conditions (e.g., freezers).

DNA microarrays or "chips" are being investigated for biological agent detection application. Allowing for parallel exposure of the potential pathogen to hundreds of specific substrate-immobilised oligonucleotides, these detection systems have significant potential.[16]

While immunoassays are limited by typically being single agent specific, the biggest challenge for nucleic acid-based detectors is susceptibility to interferents. The way a sample is obtained and how it is handled can significantly affect the results. In addition to biological agents from the surrounding environment, concentration of a sample can greatly enhance the ability to identify agents that are dilutely dispersed which even being dilute very harmful for human-being.

Biowatch

In July 2003, the Department of Homeland Security working with the Environmental Protection Agency and the Centers for Disease Control revealed a thirty-one city program to monitor for BW agents in the air. "Biowatch," the system employs approximately five hundred air filters that are collected every twelve hours, and the filter contents are analysed for BW agents using genetic-

[16] Cheng J, Frotina P, Surrey S, Kricka LJ, and Wilding P, "Microchip-based devices for molecular diagnosis of genetic diseases," *Molecular Diagnostics*, 1, 1996, p. 198.

based detection equipment.[17] This could be called an attempt, on some level, to create a horizontal sensor web in which a single detector technology is distributed spatially across the country.

Chemical Weapons Detectors

Present chemical techniques readily allow for the detection of single molecules. The experimental instruments and conditions for such detection are limited to sophisticated research laboratories. Detectors for chemical warfare agents and chemical terrorist weapons must function in demanding, real-world where price, ability and time are important factors. Many CW agent detectors rely on adaptation of classical techniques from analytical chemistry to meet these demands.

As is the case for detecting biological agents, the most challenging aspect for chemical agent identification is often extracting the particular agent from the other chemicals in the environment. We can see some of the important detection technology present for the detection of Chemical Weapons.

Infrared Spectroscopy

Characteristic vibration wavelengths of most CW agents occur in the infrared (IR) region of the electromagnetic spectrum. When IR light passes through a gas or vapor cloud, certain wavelengths of light are absorbed based on

[17] Grate JW, Martin SJ, and White RM, "Acoustic wave microsensors," *Analytical Chemistry*, 650, 1993, p. 940A.

the chemical structure of the compounds in that cloud. Routine IR instruments measure the amount of light absorbed at a specific wavelength to look for a characteristic chemical group, such as the phosphorus-oxygen bond of nerve agents. More sophisticated instruments scan regions of the IR spectrum to generate a "fingerprint" pattern for individual chemicals. The corresponding distinguishing wavelengths are easily determined in a laboratory setting. With that data, huge libraries for comparison can be easily stored in portable instruments. Currently available IR spectrometers offer a limited level of standoff detection. The U.S. military's M21 Remote Sensing Chemical Agent Alarm (RSCAAL) employs infrared spectroscopy for standoff detection. Major limitations of IR-based sensors are cost, complexity and size of instrumentation.[18]

Raman Spectroscopy

A technique similar to infrared spectroscopy, Raman spectroscopy also relies on known wavelengths of light at which organic molecules vibrate. Raman spectroscopy has also been used for non-destructive evaluation of CW agents in glass ampoules and bottles.[19] Raman is not applicable for identification of agents in munitions, as the technique requires a glass window through which light can pass.

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[18] Basche T, Moerner WE, Orrit M, and Wilding P,(ed.) *Single-Molecule Optical Detection, Imaging and Spectroscopy:* John Wiley & Sons, New York, 1996, p.256.

[19] Christensen S, MacIver, B, Procell L, Sorrick D, Carrabba, M, and Bello J, "Nonintrusive analysis of chemical agent identification sets using a portable fiber optic raman spectrometer," *Applied Spectroscopy*, 53, 1999, p. 850.

Electrochemical

In electrochemical or chemiresistor detectors, an electrical current changes in response to an interaction with a CW agent. The most common basis for an electrochemical gas sensor is a conducting wire or filament that is coated with a reactive material that oxidizes rapidly when it encounters a CW agent. The oxidation of the surface material exposes the conducting wire to air and the electrical resistance increases substantially. The change in current or increase in temperature is the signal for CW exposure. Other electrochemical detectors employ chemically selective membranes allowing only certain chemical types to pass - those which are required to complete a circuit. Again the change in current is the signal for CW presence. A newer type of chemiresistor instrument involves a quartz or silicon substrate which is coated with a conducting polymer. The degree of current change is dependent on the chemistry of the absorbing agent. The polymers provide limited specificity such that classes of CW agents can be differentiated. The response time for electrochemical sensors is generally very fast (less than a minute, often seconds.)

Electrochemical sensors are specific to single agents or, more commonly, to classes of analytes. Arrays of different sensors can be used to provide coverage for multiple types of agents.

Ion Mobility Spectrometry

Ion mobility spectrometry (IMS) or plasma chromatography relies on small differences in the velocity of ions along a cylindrical tube, a "drift tube",

across which a constant electric field is applied.[20] Drift tubes have been miniaturised to the size of a credit card while retaining resolution. IMS instruments are quantitatively capable of detecting and identifying vapor-phase chemical agents and degradation products. The response time is proportional to agent concentration; at "medium" to "high" ambient concentrations, response time is generally less than sixty seconds. Prominent examples of detectors using ionic mobility spectrometry include the U.S. military's Chemical Agent Monitor (CAM and ICAM) and Automatic Chemical Agent Alarm (ACADA). Airports frequently use IMS instruments for detecting explosives.[21]

Flame Photometry

In flame photometric detection (FPD), a sample is ignited in a (very small) hydrogen flame. A characteristic emission spectrum is produced that serves as a fingerprint for the atoms in the compounds analysed. In this way, a quantitative reading of the amount of a certain element, such as phosphorous or sulfur, in a sample can be detected. Optical filters can be selected for specificity of a target agent. A light detecting element (typically a photodiode) recognises patterns that correspond to CW agents. An FPD detector can also be combined with a GC to improve complex mixture separation. Shortcomings include high cost and limited

[20] Driskell WJ, Shih M, Needham LL, and Barr DB, "Quantitation of organophosphorus nerve agent metabolites using isotope dilution gas chromatography-tandem mass spectrometry," *Journal of Analytical Toxicology*, 26, 2002, p. 10.

[21] Black RM, Clarke RJ, Read RW, and Reid MTJ, "Application of gas-chromatography-mass spectrometry and gas chromatography-tandem mass spectrometry to the analysis of chemical warfare agent, found to contain residues of the nerve agent sarin, suphur mustard and their degradation products," *Journal of Chromatography A*, 662, 1994, p. 321.

resolution compared to GC-MS. The French AP2C monitor and the Israeli CHASE detector use FPD technology.

Photo ionisation

Photo ionisation detector (PID) systems use ultraviolet (UV) light to ionize (remove the most loosely held electrons) from a vapor or gas. A detector measures the amount of ions based on a change in electrical current. PID systems are highly quantitative when compared to a calibrated known sample and provide excellent sensitivity in such situations.[22] While popular, PID systems have very limited specificity and are highly subject to false positives in unknown or mixed environments. They are also costly and complex. Nonetheless, for applications such as leak testing, PIDs are appropriate.

Surface Acoustical Wave Sensors

Like the BW detector counterpart, SAW devices are based on piezoelectric materials that produce an electrical current when subjected to pressure or mechanical stress. Instead of antibodies or complimentary nucleic acid sequences, detectors for CW agents use individual piezoelectric quartz crystals (typically six or eight) or interdigitated electrodes coated with thin layers of different absorbent polymers.[23] A chemical will selectively absorb into the

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[22] Lenz DE, Brimfield AA, and Cook LA, "Development of immunoassays for detection of chemical warfare agents," *Immunochemical Technology for Environmental Applications,* Aga DS and Thurman EM, eds. (Washington, DC: American Chemical Society, 1997), pp. 77-86.

[23] Varfolomeyev S, Kurichkin I, Eremenko A, and Efremenko E, "Chemical and biological safety. Biosensors and nanotechnological methods for the detection and monitoring of chemical agents," *Pure and Applied Chemistry*, 74, 2002, p. 2316.

polymer based on chemical properties of each agent; generally each polymer-coated crystal will have an affinity for a different general class of organic vapors. The individual responses provide an array-based detection system. The innate sensitivity and response of SAW-based devices are limited by the polymer's absorption ability. Most SAW detectors incorporate an analytical preconcentrator in order to overcome these limitations; the commercially available SAW-based instrument incorporates a GC prior to exposure to the SAW detector. The SAW device alone is very small - the size of a penny. The U.S. military's Joint Chemical Agent Detector (JCAD) employs SAW-based technology. The JCAD is a handheld, lightweight CW detector. Reportedly, it is enabled to detect new forms of nerve agents.[24]

The absorbent polymers used in SAW devices are susceptible to damage from certain highly reactive vapors. Hydrofluoric acid (HF) is one such vapor. HF is also a degradation product from the hydrolysis (chemical break down due to water or ambient humidity exposure) of sarin, soman and cyclosarin. The polymers used are often susceptible to interference from absorption of water and, therefore, the sensors must be calibrated (and re-calibrated) to account for ambient relative humidity.

[24] Parker WE, Buckley WM, Kreek SA, Caffrey AJ, Mauger GJ, Lavietes AD, and Dougan AD, "A portable system for nuclear, chemical agent and explosives identification," *American Institute of Physics Conference Proceedings*, 576(1), 2001, p. 1073.

Enzyme-Based

Enzyme or immunoassays approaches have been utilised for military and commercial CW detectors. Some enzyme-based CW detection systems exploit the intent of organophosphate nerve agents to bind to acetylcholinesterase - an enzyme - as a detection technique. Enzyme-linked immunoassays (ELISAs) have been developed, much like the BW agent counterpart, with specificity for G-type nerve agents.[25] Other systems, exploit the natural enzyme that catalytically hydrolyses (breaks down in the presence of water) organophosphates. Organophosphorous hydrolase (OPH) can be incorporated into hand-held assays or tickets.[26] A pH sensitive probe reacts to change in acidity due to the hydrolysis of G-type nerve agents. The response can be as simple as a colorimetric pH indicator changing from red to blue or a potentiometric electrode.

As new technologies emerge, there remains a need to pursue significant and powerful testing. There is little doubt of the value in developing new and better instrumentation, much of which may arise from fundamental research. In the era of new devices and new experimental techniques, there is a need of extensive research procedures. Among the foremost reasons are to limit false negatives and false positives at real-world sites. Excessive false positives can lead to response fatigue and ignoring a real incident; a false negative that fails to detect

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[25] Lenz DE, Brimfield AA, and Cook LA, "Development of immunoassays for detection of chemical warfare agents," *Immunochemical Technology for Environmental Applications,* Aga DS and Thurman EM, eds. (Washington, DC: American Chemical Society, 1997), p. 6.

[26] Varfolomeyev S, Kurichkin I, Eremenko A, and Efremenko E, "Chemical and biological safety. Biosensors and nanotechnological methods for the detection and monitoring of chemical agents," *Pure and Applied Chemistry*, 74, 2002, p. 2316.

a CBW agent release could cause a disaster of the highest order - the loss of human life.[27]

There currently exist a wide variety of techniques that provide excellent detection capabilities for CBW agents. Each, however, has drawbacks and limitations. The prospect of a single detector amenable to all CW and BW agents is laudable, although unrealistic with current technology. Layered detectors and sensors that function together in a web-like manner to monitor progressively more refined levels - from cloud and particle detection to differentiation between biological and nonbiological components to concentration information - are a near-term approach to unified and comprehensive CBW detection.[28] There is also a considerable political challenge in the design and implementation of such a sensor system.

Norms Building against CBW

The development, production, and stockpiling of chemical and biological weapons were outlawed by the 1972 Biological Weapons Convention, to which more than 100 states were party, including all five permanent members of the United Nations Security Council. The treaty also covered weapons based on naturally occurring poisons, known as toxins, however produced. As with chemical weapons, actual employment of biological weapons was outlawed by

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[27] Emanuel PA, Chue C, Kerr L, and Cullin D, "Validating the performance of biological detection equipment: the role of the federal government," *Biosecurity and Bioterrorism*, 1, 2003, p. 137.

[28] Ibid., p. 138.

the 1925 Geneva Protocol. At the time of their destruction in accordance with presidential directives of 1969 and 1970, the biological weapons of the United States (the only country for which authenticated information was available) included dry-powder or liquid-slurry formulations of the microbes that cause tularemia, Q fever, Venezuelan equine encephalitis, rice blast, and stem rust of wheat.[29] They also included a number of toxins, such as paralytic shellfish poison. A variety of dispensers, both large and small, were also on hand. Biological weapons designed to dispense airborne clouds of pathogenic microbes could in theory kill or incapacitate unprotected populations over very large areas.[30] Such weapons were never used. Limiting the development of chemical weapons is more difficult, since it is harder to uncover their production.

The "Chemical Weapons Convention (CWC)" came into effect in 1997 and, on paper, is extremely strict. The CWC took the Geneva Protocol one step further, banning the manufacture and storage of chemical weapons as well. It even bans the use of nonlethal agents, specially for combat operations. The CWC also places restrictions on trade in certain chemicals that can be used as the Basic ingredients for synthesizing CW agents, and allows intrusive inspections on short notice, implemented by workers of the "Organisation for the Prohibition of Chemical Weapons (OPCW).[31]

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[29] Stock Thomas, Haug Maria, and Ralder p., "Chemical and Biological Weapon developments and arms control", Sipri,1996, p.661.

[30] Ibid., p.663.

[31] Zanders Jean, Pascal,Eckstein Susanna and H.John, "Chemical and Biological WeaponDevelopments and Arms Control",Sipri,1997, p.449.

The CWC has had some significant successes. As of 1998, 168 countries had signed up and 110 had ratified the agreement. India and South Korea joined and admitted to having CW stockpiles, which now must be destroyed under OPCW supervision. France and China claim to now have destroyed their chemical weapons and are waiting for verification by OPCW inspectors.[32]

However, the BTWC is weak, as it lacks much in the way of enforcement measures, and it has been widely violated in practice. There has been a push towards adding such measures, in the form of "challenge" inspections of suspect sites where an inspection team can arrive without prior notice at any time, with no right of refusal.[33]

A major problem with BTWC is it's ambiguity on the legality of such agents. If they were not used in a war, and were used with the consent of the country in which the bioagents were dispersed, that would be perfectly legal under the BTWC. However, as with the use of "nonlethal" chemical agents in Vietnam, critics are quick to point out that a limited use of bioagents could set a dangerous precedent for the future.[34]

One argument against chemical weapons is that they are inferior to conventional steel and explosives. Any reasonably trained and equipped military force can endure a gas attack with few casualties, though chemical defensive

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[32] Ibid., p.451.

[33] Ibid., p,452.

[34] SIPRI Yearbook, "*The Problem of Chemical and Biological Warfare*", Humanities Press, New York,1999, p.103.

measures are a great nuisance, particularly for an army on the move. Furthermore, gas weapons tend to require more care in handling than other weapons, and in the confusion of battle gas can backfire against an attacker due to changes in wind direction and other confounding events.

The difficulty and danger of storing, handling, and using chemical agents makes them troublesome even as a terror weapon, as the failure of the Aum Shinrikyo subway attack demonstrated. Traditional explosive bombs are much more convenient and remain very effective weapons for terrorists. The most significant drawback of chemical weapons is environmental. Their manufacture tends to be a nasty process, and once produced and stockpiled, they require substantial security and maintenance that is hard to assure over a period of decades. Disposal of decrepit chemical weapons is a dangerous and extremely expensive task.

Public and Community Health

The biomedical role of public health in the rapid identification of a biological or chemical attack and its medical management is also very important. to strengthen preparedness and response plans with regard to the social and mental health consequences of biological and chemical attacks is a potential defence against CBW.

Attacks involving biological or chemical weapons may induce significant mental and social effects in a number of ways - even when the agents induce low

levels of mortality and physical morbidity. First biological and chemical attacks are associated with the experience of intense social and psychological distress, especially fear. Second, physical exposure to biological and chemical agents may induce organic mental disorders. Third, exposure to any severe stressor, whether natural or human-made, is a risk factor for a range of long-term social and mental problems (including anxiety and mood disorders as well as non-pathological trauma and grief reactions). Fourth, fear of biological and chemical attacks may be associated with epidemics of medically unexplained illness.[35]

Mental health considerations must be integrated adequately into public health assessment, preparation and response plans. In certain countries, resistance may exist to having mental health professionals involved in a public health response during an acute crisis. Part of preparing for a public health response is affirming beforehand the essential role of mental health experts throughout the emergency. Principles and strategies described here are primarily for application in resource-poor countries, where the vast majority of the world's population lives.

WHO has proposed eight principles for public mental health activities in emergencies. These principles are also valid for situations involving biological or chemical weapons and are as follows:

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[35] World Health Organisation, Health Aspects of Chemical and Biological Weapon: Report of a WHO Group of Consultants, Geneva, 2002.

1. Preparation before the emergency.

In co-operation with citizens, national and local preparation plans should be made and should involve: (a) vulnerability analysis (to identify: potential scenarios, weaknesses in the public mental health system during crisis, needs and capability, and resources needed to respond ,(b) a co-ordination plan with specification of focal persons responsible within

each relevant agency in each relevant administrative region, (c) detailed contingency plans to prepare for an adequate social and mental health response, (d) realistic training of relevant personnel in indicated social and mental health interventions, (e) prepared and protested risk communication plans (WHO, in press b) and (f) a contact list of relevant national and international public mental health experts who may give appropriate advice.

2. Assessment.

Interventions in both the acute and post-emergency phase should be preceded by careful planning and rapid assessment of the local context (e.g., setting, culture, history and nature of problems, local perceptions of distress and illness, ways of coping, community resources, etc). Of note, population based assessments of the prevalence of mental disorders is difficult, resource-intensive and typically unhelpful in developing disaster response plans. To plan for interventions in the post-emergency phase, it is recommended to mainly assess (a) available mental health and social services and resources (including assessment of the number, functions and location of those human resources who can deliver

relevant interventions) (input indicators) and (b) daily functioning of individuals and communities (outcome indicator). When assessment uncovers a broad range of needs that will unlikely be met, assessment reports should specify urgency of needs, local resources and potential external resources.

3. Collaboration and co-ordination.

Government authorities need to be supported by an appropriate, knowledgeable public mental health adviser, who will ensure that mental health aspects of the incident are given appropriate consideration and that mental health organisations collaborate with each other and with the general health and social services sector. Interventions should involve consultation and collaboration with governmental and nongovernmental organisations (NGOs) in the area. A multitude of agencies operating independently without co-ordination leads to waste of valuable resources. The performance of political leadership is critical to maintaining effective relationships between organisations.

4. Integration into primary health care.

Led by the health sector, mental health interventions should be carried out within general primary health care (PHC) and could in addition be organised in other pre-existing structures in the community, such as schools, community centers, youth and senior centers, and places of worship. Care by families and active use of resources within the community should be maximised. Clinical on-the-job training and thorough supervision and support of PHCworkers by mental

health specialists are essential components for successful integration of mental health care into PHC.

5. Access to services for all.

Setting up separate, vertical mental health services for special populations is discouraged. As far as possible, access to mental health services should be for the whole community and not be restricted to subpopulations identified on the basis of exposure to biological or chemical agents. Services delivered within a single integrated system can – when necessary - be tailored to address the needs of different subpopulations (such as support groups specifically for bereaved families in the event of deaths, or providing outreach services and awareness programmes to vulnerable communities or minority groups that are reluctant or not able to attend clinic services).

6. Training and supervision.

Training and supervision activities should be by mental health specialists—or under their guidance—for a substantial amount of time to ensure lasting effects of training and responsible care. However, during the acute emergency phase, non-professional caregivers may be rapidly trained to provide psychological first aid, a relatively, uncomplicated intervention. However, during the post-emergency phase, short one-week or two-week skills training without thorough follow-up supervision is likely too short to adequately train basic mental health treatment skills.

7. Long-term perspective.

In the aftermath of a population's exposure to severe stressors, it is preferable to focus on medium- and long-term development of community based and primary mental health care services and social interventions. Unfortunately, impetus and funding for mental health programmes are highest during or immediate after acute emergencies, but mental health effects end to last much longer than the duration of the acute crisis.

8. Monitoring indicators.

Activities should be monitored and evaluated through indicators that need to be determined if possible before starting the activity. Indicators should focus on inputs (available resources, including pre-existing services), processes (aspects of programme implementation and utilisation), and outcomes (e.g., functioning of beneficiaries).[36]

It is actually impossible to eliminate completely the risk of CBW ending up in the hands of those who desire to use them for malign purposes. So society must learn to understand and counter the risks. The focus must turn on building a strong and better public health system to diminish the use of CBW. With this, a global surveillance is needed to detect and respond in an efficient manner against CBW.

[36] World Health Organisation, Health Aspects of Chemical and Biological Weapon: Report of a WHO Group of Consultants, Geneva, 2003.

Events since September 11 have made clear the threat posed by terrorist use of non-conventional weapons, including chemical and biological agents. While conventional weapons such as explosive devices pose a more immediate threat in many areas overseas, use of chemical or biological agents cannot be excluded and must be considered a growing threat.

In 1999, the Department of Defence, U.S. (DOD) announced its intention to commence the Family and Force Protection Initiative (FFPI) in order to provide enhanced protection against chemical and biological agents to the dependents of U.S. military service members and to civilian Department of Defence employees and their families. This program was first implemented for U.S. Forces Korea and the range of recipients has since been expanded. In December 2002 the Department of Defence,U.S. announced plans to begin smallpox immunization of certain DOD personnel.[37]

U.S. has had a chemical and biological countermeasures program since 1998, when it began to deploy chemical antidotes and antibiotics to selected posts abroad. The U.S. military has developed a field apparatus that can test an air sample for the presence of specific biological agents. Called a Biological Integrated Detection System (BIDS), it can confirm the presence of a handful of

[37] US Department of State, Fact Sheet: Building Defence against Chemical and Biological Weapons, Washington DC, 2003.

microorganisms, including anthrax and plague bacteria. However, there are scores of possible biological agents that cannot be easily detected.[38]

Several efforts are being made to develop a generic detector of dangerous organisms, using techniques like laser technology and mass spectrometry. Despite such efforts, the ability to rapidly identify all possible warfare agents in the field remains elusive.

UK is developing improved systems for warning and reporting, which will automatically take hazard data from sensors, predict duration and movement and alert units to an impending chemical or biological hazard. Improvements are also being made to individual protection equipment. A number of systems intended to destroy ballistic missiles are being developed, notably in the U.S. Such systems may play a part in helping to counter the risks posed by CBW and their means of delivery.

Basically in the intensified security environment of the post-11 September world, much attention has been placed on preparing for what was previously thought not to be so important. Threat of CBW attack has resulted in plans to develop and procure vaccines against biological weapon and stockpilation of medicines to guard against potential attack.

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[38] Ibid.

New techniques are being used to prepare a better defence system against CBW but the developing countries still need to improve their health system and public awareness. Apart from using new techniques to build a powerful defence system against CBW, strengthening norms against CBW is required.

Chapter Five:
Conclusions

'War', a curse but an unavoidable truth has gone through different paths of changes and developments. Technology breakthroughs have transferred the character of battlefield of the Twenty-first century. Today all over the world, military planes speak loudly and hopefully of Revolutionary Military Affairs (RMA), the Military Technical Revolution (MTR) and Information age warfare where they predict future of war full of more sophisticated and lethal weapons. In fact the features of war have not remained same. Today war is not confined in inter-state war only. It could be within a state i.e. a civil war or could be global, against terrorism and so importance of these unconventional weapons increases.

An ever-increasing number of countries and terrorist groups will gain the technical capability to acquire and use CBW. But use of these weapons by hostile states or terrorist groups is not inevitable. Even when locked in conventional wars, nations that have considered using these weapons have generally been deterred by the risk that their opponents would retaliate in kind or escalate the conflict elsewhere.

The use of biological weapons has been rarer than the use of chemical weapons. In the 14th century, plague-infected cadavers were catapulted into an enemy camp in the Russian Crimea. In colonial America, the British delivered blankets from their smallpox infirmary to Native Americans, hoping to infect them with the disease. In the 20th century, the only extensive military biological attacks were by Japan against China in the late 1930s and 1940s. The Japanese dropped plague and other bacteria from airplanes over several towns, causing outbreaks of disease. Until 2001, the only known terrorist use of a biological weapon in the United States occurred in 1984. Members of the Rajneesh cult in Oregon placed salmonella bacteria in the salad bars of several restaurants. At least 750 people became ill, although none died.(Refer to History of CBW)

Chemical and biological agents are most effective when dispersed into the air. These agents may be fitted into bombs or artillery shells that are designed to explode in the air and spread their contents over an enemy. In the 1980s the United States began to deploy binary chemical weapons. Before then chemical shells and bombs housed a single blistering or nerve agent. As they aged, these weapons could leak their poisons. A binary weapon is safer because it contains two relatively harmless chemicals. Only after firing do the chemicals combine to form a potent mix.

In some warfare or terrorist scenarios, an explosive release is not necessary. Members of Aum Shinrikyo attacked the Tokyo subway by packing

sarin in plastic containers. To release the nerve agent, they pierced the containers with sharp umbrella tips. The leaking liquid and vapour affected thousands of passengers.

Microorganisms are generally more fragile than chemicals, and some might not survive an explosion. But several, like anthrax spores, can remain potent after an explosive release. In any case, United States Army tests have shown that biological agents can be broadly dispersed in a variety of non explosive ways. In the 1950s and 1960s the Army released bacteria and chemical particles in hundreds of tests in populated areas throughout the country. Agents were sprayed at San Francisco from a boat offshore, dispensed from slow-moving cars in Minneapolis and St. Louis, and released from light bulbs dropped in the New York subway. The bacteria and chemicals in the tests were not as dangerous as actual warfare agents, although they posed some risks to the exposed populations. They demonstrated that an enemy or terrorist could expose millions of people to disease-causing organisms by a variety of simple techniques.(Refer to History of CBW).

After cold war, deterrence framework has totally changed. The concept of security and power has also changed. Today, threat to security could come in any form. Increasing threat of terrorism proves it. The removal of the superpower rivalry that provided a constraining framework is now coupled with the growing availability of the requisite technology to any nation with a moderate amount of

hard currency and a persistent determination to acquire such weaponry. As the conventional arms become more expensive, CBW become an attractive alternate.

Regional powers, rogue regimes and subnational groups all recognise the strategic leverage which they can gain from the acquisition of CBW. These weapons can give their possessor a distinctive range of military and political options for deterrence and intimidation, especially when combined with high-speed delivery vehicles, some with long ranges, including ballistic missiles which can reach their targets in minutes and cruise missiles and aircraft which can reach them in hours. Governments and subnational groups with even relatively small quantities of WMD and relatively limited numbers of delivery systems may be able to exert a high degree of strategic leverage against other governments by threatening to attack their vulnerable civilian populations, as Saddam Hussein threatened to attack the populations of Israel and Saudi Arabia.

Military significance is also a function of circumstance. The CBW capabilities of the states of the developing world may be strategic in conflict against similarly sized competitions in their regions if they can be used to achieve massively destructive effects or to tilt the political dynamic of conflict in favour of one side or another. Not all of the CBW capabilities of the alleged proliferates are likely to meet this criteria, although this will also be a function of the defence capabilities of the attacked states. The military forces of such states, if capable of fighting in a chemically contaminated environment in a sound protective posture

in form of effective personal protective gear, detectors, and decontamination gear could find a CBW attack not much destructive, but if the attack is massed or sustained for long period, it could bring immense destruction.

CBW has also occurred as a major challenge to regional security stratergies. In Northeast Asia, North Korea is alleged to produce and stockpile CBW. The Middle East poses another challenge, one in which many of the parties to the Arab- Israeli and the Persian Gulf conflicts appear of waging war with unconventional weapons. In Latin American region, CBW are in a way irrelevant to the security dynamic because of the core foundation is cooperative and comprehensive security but the tradition of opposition to US imperialism may produce non state actors willing to use CBW. Then in Europe, CBW are not entirely irrelevant today. The conflict in Bosnia has generated many reports, particularly of chemical weapon use. Ethnic cleansing of a particular ethnic community has now become possible with the development of ethnic weapon. The alleged use of food and anti crop weapons during Vietnam and Korean conflicts shows that use of CBW is not a fancy. (Refer to Introduction).

The effect of CBW proliferation also complicates the achievement of stable military balances and creates new challenges for the conduct of military operations above the conventional but below the nuclear level. Proliferation also heightens the risk of war in number of ways. It nourishes the ambitions of regional powers, increases regional frictions and thus the number of military

crisis, heightens the risk of unauthorised or accidental use of unconventional weapons, increases the destructiveness of war when it occurs, and improves the ability of regional actors to threaten military conflict outside the region.

While civilised nations have repudiated the use of such weapons, we must confront the possibility of having to deter and defend against chemical and biological weapons. The possibility that such weapons can be used and we can employ to deter their use. In recent years, the growing availability of dual-use technologies, materials, information, and expertise associated with the production and delivery of CBW has exacerbated the CBW proliferation problem. Indeed, the relative ease of acquiring these weapons has increased their attractiveness to proliferant states that cannot afford to acquire advanced conventional or nuclear weapons or lack the necessary technical capabilities. Moreover, history has shown that both state suppliers and unscrupulous companies are willing to sell sensitive technologies and materials to customers willing to pay.

Today, any state with a petrochemical or fertilizer industry can make CB warfare agents. Any state with medical research facilities or any fermentation based industry can prepare CBW. As the process of global industrialisation and economic integration developing more and more, more and more technologies will be in the hands of larger number of states. Increasing role of regional powers, non state actors and multi national corporations in world politics increases the

possibility of not only transfer of new technologies, but also the possibility of duel use of these technologies.

Given the dual-use dilemma and the rapid diffusion of legitimate chemical, pharmaceutical, and biotechnology industries around the globe, strengthened CBW export controls, but they do not offer a long-term solution to the proliferation problem.

The brave new world of genetic engineering is populated by some remarkable and disturbing creations today. The crassly utilitarian norms that are guiding innovations have so far produced animals to be used as factories for producing drugs; cows stuffed with bovine growth hormone; plants constructed to grow in soil drenched with herbicides that would normally kill them, as well as every other green thing in sight; bacteria that chew up materials used in weapons systems; and cross-eyed, arthritic pigs that yield more meat. What's most disturbing is that the genetic reconstruction of life is advancing on a global scale with almost no informed public discussion or effective oversight, and in the case of certain military uses, without even public knowledge.

Genetic Engineering can clearly contribute to make classical biowarfare agents more effective, it can ease access to them, enable the construction of novel CBW agents and opens the avenue for a broad array of new types of weapons. Completely new types of weapons are also becoming possible, including the use of food crops as tools for biological warfare. Even ethnically specific weapons,

hitherto thought to be impossible, have become a real possibility. It is of crucial importance for scientists and policymakers around the world to address the increasing threat and redouble efforts to strengthen the ban on CBW and to control critical technologies.

While in most cases the hostile utilisation of new technology has not occurred, so far, but it is obvious that once such technologies are more broadly exploited particularly in commerce, they may become easily acquired and used with malign intentions.

Molecular biology and genetic engineering are touching new horizons of developments. More technical possibilities will arise in the years to come that can be abused for hostile purposes. More likely and more alarming are the new types of weapons for newly-prevalent types of conflicts and warfare scenarios, for example, low intensity warfare and covert operations, for economic warfare or for sabotage.

Some aspects of biotechnology have raised deep ethical questions, but most developments in the field are serving to advance the quality of human life. But like all scientific advances there is a risk that these new technological capabilities will be used for destructive purposes. In particular, developments in biotechnology are making it possible to design advanced CBW agents that could prove even more devastating to humanity than their naturally occurring cousins.

For example, it might soon be possible for scientists to design and produce special pathogens of enhanced lethality, heightened resistance to medical treatment, predictable or controllable effects, or even the ability to infect people selectively, according to specific genetic characteristics. To prevent the hostile exploitation of biology and chemistry now and in the future, a bundle of measures must be taken.

Agreements to restrict or eliminate the production and use of biological and chemical weapons date back to the Geneva Convention of 1925. The Biological Weapons Convention was the first international agreement to ban an entire category of weapons. It was established three years after a unilateral decision in 1969 by the US to eliminate its own biological arsenal. Most major powers, including the former Union of Soviet Socialist Republics (USSR) and the United States, had become parties to the biological treaty when it went into force in 1975. Later, more countries joined in the agreement and the world appeared about to be rid of germ weapons. However, countries were still on the way to work on CBW technologies. In 1979 international medical experts learned of a mysterious outbreak of respiratory anthrax in the Soviet city of Sverdlovsk, the site of numerous secret military facilities. More than 60 civilians and an unknown number of military personnel died. After the breakup of the Soviet Union in 1991, the Russian government revealed that the Sverdlovsk anthrax outbreak had resulted from an accident at an illegal biological weapons facility.

In the 1991 Persian Gulf War, the United States and other coalition leaders worried that Iraqi president Saddam Hussein might unleash chemical and biological arms against them. Although he did not, the experience again prompted efforts to strengthen international agreements against these weapons. One result was the 1993 Chemical Weapons Convention, which contains an intrusive inspection system. Parties to the treaty have to allow outside monitors to visit suspected sites. By June 2001, 174 nations had signed the chemical treaty. To go into effect, the national legislatures of most countries must ratify, or approve, the treaty. As of June 2001, 143 of the signing countries had ratified or acceded to the treaty and had become binding parties to the agreement. The United States signed the treaty in 1993, and the U.S. Congress ratified it in 1997.

In 1993 representatives from 160 nations approved the Chemical Weapons Convention. This agreement banned production, use, sale, and storage of all chemical weapons. It also mandated destruction of existing stocks of weapons by the year 2005. The United States ratified this convention in 1997, despite concerns about the proliferation of chemical weapons among nations such as Libya, Syria, Iraq, and North Korea that were not signatories to the agreement.

First and foremost, the Chemical and Biological Weapons Convention needs to be strengthened through multilaterally agreed, legally binding verification measures. Then comes the measure of increasing public awareness of

these weapons as very few common men are aware of the use and horrible effect of CBW. Research restrictions are also necessary in certain situations, for example, in cases where a military abuse appears to be imminent, where no effective multilateral arms control or non-proliferation efforts are presently feasible, and where other technical avenues to reach the same scientific goal are potentially available. These criteria apply specifically to the production of bioactive compounds like pharmaceuticals, vaccines in edible crops and chemicals used in medicines and pesticides. With this, full transparency in all aspects of biomedical research and developments in biochemistry should be guaranteed.

An effective implementation of all these measures would greatly contribute to diminishing the threat of CBW, and support the global efforts in disarmament. A cooperative approach would be imperative to detect any chemical-biological proliferation relevant activities. This could best be undertaken in an institutional setting.

Some aspects of biotechnology have raised deep ethical questions, but most developments in the field are serving to advance the quality of human life. But like all scientific advances there is a risk that these new technological capabilities will be used for destructive purposes. In particular, developments in biotechnology are making it possible to design advanced biological warfare agents that could prove even more devastating to humanity than their naturally

occurring cousins. For example, it might soon be possible for microbiologists to design and produce special pathogens of enhanced lethality, heightened resistance to medical treatment, predictable or controllable effects, or even the ability to infect people selectively, according to specific genetic characteristics.

This newly emerging science and increasing impact of new technologies, if it is ever applied to weapons research, has the potential to revolutionise humankind's ability to destroy life, just as it is currently revolutionizing ways to save and enhance life. This is a scientific revolution every bit as profound as the dawning of the nuclear age, and one which is likely to command at least as much attention in the first half of the 21st century.

Annexure I

COUNTRY	BIOLOGICAL WEAPONS CAPABILITIES	CHEMICAL WEAPONS CAPABILITIES	TREATY STATUS
China	Possibly maintains some elements of the offensive biological weapons program it had before joining the BWC. Existing infrastructure would allow it to develop, produce, and weaponize agents. Potential delivery systems include cruise missiles, fighters, bombers, helicopters, artillery, rockets, mortars, and sprayers.	Has an advanced chemical weapons program, including a variety of agents. Researching more advanced agents. Delivery systems include artillery, rockets, mortars, landmines, aerial bombs, sprayers, and short- and medium-range ballistic missiles.	Geneva Protocol: Acceded 8/24/29. BWC: Acceded 11/15/84. CWC: Signed 1/13/93, ratified 4/25/97.
Cuba	Has at least a limited biological weapons research and development effort.	None.	Geneva Protocol: Acceded 6/24/66. BWC: Signed 4/12/72, ratified 4/21/76. CWC: Signed 1/13/93, ratified 4/29/97.
Egypt	Developed biological weapons agents by 1972,	Probably maintains a chemical weapons	Geneva Protocol:

	and there is no evidence suggesting it eliminated this capability.	stockpile.	Signed 6/17/25, ratified 12/6/28. BWC: Signed 4/10/72. CWC: Has not signed.
India	Has a biodefense research program. Existing infrastructure suitable for researching and developing pathogens. Potential delivery systems include short-range, anti-ship cruise missiles; short-range, air-launched tactical missiles; fighter aircraft; artillery; and rockets.	Declared in June 1997 that it possessed a chemical weapons stockpile. Has begun to destroy its chemical weapons stockpile under the CWC. Its industry will retain the ability to produce agent precursors—chemicals that can be used in chemical weapons production. Same potential delivery systems as for biological weapons.	Geneva Protocol Signed 6/17/25, ratified 4/9/30. BWC: Signed 1/15/73, ratified 7/15/74. CWC: Signed 1/14/93, ratified 9/3/96.
Iran	Has probably produced and weaponised biological agents. Production and weaponisation capability likely limited. Potential delivery vehicles include short-range cruise missiles; short-range, air-launched tactical missiles; fighter aircraft; artillery shells; and rockets.	Has a stockpile of chemical weapons. Previously known to have produced and stockpiled blister, blood, and choking agents and probably nerve agents. Seeking aid from Chinese and Russian entities to develop a more advanced, self-sufficient infrastructure. Delivery vehicles include artillery shells, mortars, rockets, and aerial bombs. Used chemical weapons	Geneva Protocol: Acceded 11/5/29. BWC: Signed 4/10/72, ratified 8/22/73. CWC: Signed 1/13/93, ratified 11/3/97.

		during the Iran-Iraq War.	
Iraq	Possesses "an active and capable" biological weapons program, according to CIA Director George Tenet. Declared in 1995 that it had produced approximately 30,000 liters of bulk biological agents or filled munitions, including anthrax, botulinum toxins, and aflatoxins. Also admitted it had filled missile warheads and aerial bombs with agent and had deployed biological munitions during the Persian Gulf War. The United Nations believes Iraq had produced three to four times more agent or munitions than it declared. Iraq is also thought to have conducted research on other agents and toxins. Questions remain about the scope of Iraq's program and what parts of the program Iraq has destroyed or currently retains. The United States strongly suspects Iraq has reconstituted its program since UN inspectors left Iraq in 1998 and is concerned that Baghdad is producing agents. Could be improving its agent research and development	Had extensive program before the Persian Gulf War under which it produced and stockpiled mustard, tabun, sarin, and VX. Delivered chemical agents against Iranian forces during the Iran-Iraq War using aerial bombs, artillery, rocket launchers, tactical rockets, and helicopter-mounted sprayers. Also used chemical weapons against its own Kurdish population in 1988. Program was largely dismantled by United Nations weapons inspectors in the 1990s, but Iraq retains some chemical weapons and has begun reconstituting its chemical infrastructure since inspectors left the country in 1998. Could resume agent production within a few weeks or months but would need foreign assistance to completely restore its production capabilities to pre-Persian Gulf War levels. Same potential delivery systems as for biological weapons.	Geneva Protocol: Acceded 9/8/31. BWC: Signed 5/11/72, ratified 6/19/91. CWC: Has not signed.

	capabilities. Means of delivery may include short-range, anti-ship cruise missiles; short-range ballistic missiles; short-range, air-launched tactical missiles; fighter aircraft; helicopters; artillery; rockets; and unmanned aerial vehicles.		
Israel	Possibly has a biological weapons research effort.	Probably has a chemical weapons program.	Geneva Protocol: Acceded 2/20/69. BWC: Has not signed. CWC: Signed 1/13/93.
Libya	Has a research and development program and may be able to produce small amounts of agent. Likely in need of foreign assistance to advance program further. Potential delivery vehicles include short-range, anti-ship cruise missiles; air-launched tactical missiles; fighter aircraft; bombers; artillery; helicopters; and rockets.	Produced mustard and nerve agent before 1990. Still has some elements of its chemical weapons program and is working to re-establish its chemical weapons capabilities, which had been limited by UN sanctions from 1992 to 1999. Is pursuing an indigenous production capability but is highly dependant on foreign suppliers. Attempted to use chemical weapons against Chadian troops in 1987. Same potential delivery systems as for biological weapons.	Geneva Protocol: Acceded 12/29/71. BWC: Acceded 1/19/82. CWC: Has not signed.
North Korea	Has developed and produced weaponised	Believed to possess sizable stockpile of chemical	Geneva Protocol:

	biological agents. May have biological weapons available for use. Potential means of delivery include short-range, anti-ship cruise missiles; bombers; rockets; mortars; sprayers; artillery; helicopters; and fighters.	weapons, including nerve, blister, choking, and blood agents. Delivery vehicles include ballistic missiles, artillery, and aircraft.	Acceded 1/4/89. BWC: Acceded 3/13/87. CWC: Has not signed.
Pakistan	Has ability to support limited biological weapons research and development effort. Potential delivery vehicles include short-range, anti-ship cruise missiles; short-range, air-launched tactical missiles; fighter aircraft; artillery; and rockets.	Has imported chemicals that it could use to make chemical weapons agent. Delivery vehicles could include missiles, artillery, and aerial bombs.	Geneva Protocol: Signed 4/15/60. BWC: Signed 4/10/72, ratified 9/25/74. CWC: Signed 1/13/93, ratified 10/28/97.
Russia	Despite having ratified the BWC in 1975, the Soviet Union maintained a large biological weapons effort. Russia publicly acknowledged this program in 1992 and said it had been halted. Agents weaponised included tularemia, typhus, Q fever, smallpox, plague, anthrax, Venezuelan equine encephalitis, glanders, brucellosis, and Marburg. Researched numerous other agents and toxins that can attack humans, plants, and	Possesses the world's largest chemical weapons stockpile: 40,000 metric tons of chemical agent, including VX, sarin, soman, mustard, lewisite, mustard-lewisite mixtures, and phosgene. The United States believes that Russia has not declared some of its chemical agents and weapons and notified Moscow in April 2002 that it could not certify that Russia was complying with the CWC.	Geneva Protocol: Acceded 4/5/28. BWC: Signed 4/10/72, ratified 3/26/75. CWC: Signed 1/13/93, ratified 11/5/97.

	livestock. Currently has a defensive research program. Some elements of the Soviet program may remain intact and could support agent and delivery vehicle production. The United States has received unconfirmed reports of continued offensive activities. Washington has serious concerns about the status of the weapons program inherited from the Soviet Union and remaining weapons capabilities. In April 2002, the Bush administration notified Moscow that it could not certify that Russia was complying with the BWC. Potential delivery vehicles include fighter aircraft, artillery, rockets, helicopters, short-range ballistic missiles, and cruise missiles. The former Soviet program planned to deliver certain agents, such as smallpox, anthrax, and plague, by ICBM.	Has started destroying its chemical weapons under the CWC but is not expected to complete destruction until at least 2012. Reports indicate that Moscow has worked on a new generation of chemical agents called "novichoks," which are allegedly designed to circumvent the CWC and evade Western methods to detect and protect against chemical weapons. Potential delivery vehicles include artillery, bombs, spray tanks, and short-range ballistic missiles.	
South Korea	None.	Possesses a chemical weapons stockpile and is destroying it under the CWC.	Geneva Protocol: Acceded 1/4/89. BWC: Signed 4/10/72,

			ratified 6/25/87. CWC: Signed 1/14/93, ratified 4/28/97.
Sudan	May be interested in developing a biological weapons program.	Is developing the ability to produce chemical weapons, possibly including VX. Has received Iraqi assistance.	Geneva Protocol: Acceded 12/17/80. BWC: Has not signed. CWC: Acceded 5/24/99.
Syria	Has a biological weapons program in the research and development stage and may be capable of producing a small amount of agent. No major weaponisation effort is likely underway. Cannot manufacture significant numbers of weapons without major foreign assistance. Potential delivery vehicles include fighter aircraft; helicopters; artillery; short-range, anti-ship cruise missiles; short-range, air-launched tactical missiles; and rockets.	Possesses sarin, which it can deliver by aircraft or ballistic missile, and is working to develop VX. Key elements of its program rely on foreign sources.	Geneva Protocol: Acceded 12/17/68. BWC: Signed 4/14/72. CWC: Has not signed.
Taiwan	Has upgraded its biotechnology capabilities, but it is unclear whether it is conducting illicit activities.	May have some chemical weapons.	Geneva Protocol: Has not acceded.

			Has pledged to adhere to the BWC and CWC.
United States	Unilaterally gave up its biological weapons program in 1969. Currently conducting research as part of its biodefense program that some say may violate the BWC.	Possesses about 31,000 tons of chemical weapons agent. Is currently destroying its stockpiles of mustard, sarin, VX, and blister agent under the CWC.	Geneva Protocol: Signed 6/17/25, ratified 4/10/75. BWC: Signed 4/10/72, ratified 3/26/75. CWC: Signed 1/13/93, ratified 4/25/97.
Federal Republic of Yugoslavia	None.	Possesses weaponised CS; suspected of having unweaponised mustard and sarin and, possibly, weaponised BZ.	Geneva Protocol: Signed 6/17/25, ratified 4/12/29. BWC: Signed 4/10/72, ratified 10/25/73. CWC: Acceded 4/20/00.

Sources: Defense Department, State Department, Central Intelligence Agency, Arms Control and Disarmament Agency, and the U.S. Army.

Annexure II

Delivery Systems Used for CBW

Type and designation of weapon	Agent	Payload (kg)	Mechanism
Ground and naval weapons			
Weapons for the individual soldier			
Grenade, frangible, M1	AC	0.3	Impact
Grenade, riot, M6A1	CN-DM	0.11	Burning
Grenade, riot, M7A1	CN	0.17	Burning
Grenade, riot, M7A3	CS	0.12	Burning
Grenade, riot, M25A2	CS1	0.05	Bursting
Grenade, pocket, XM58	CS	0.02	Burning
Grenade, rubber, XM47	CS	..	..
Cartridge, 40 mm, E21	BZ	..	..
Cartridge, 40 mm, XM674 (*Handy Andy*)	CS	0.05	Burning
Cartridge, 40 mm, XM675	CS	..	..
Cartridge, 40 mm, XM651E3	CS	0.03	Burning
Cartridge, 40 mm, soft-nosed, XM627	CS	..	..
Disperser, dry agent, portable, M3	CS1, *or*	4	Disperser
	CN1	9	
Disperser, liquid agent, hand-held, XM23	CS solution	..	Spray
Disperser, liquid agent, hand-held, XM30	CS solution	1.5 litre	Spray
Disperser, liquid agent, hand-held, XM32	CS solution	0.05 litre	Spray
Disperser, dry agent, back-pack, XM33	CS1	..	Disperser
Spray-gun, liquid agent, Mk1 Mod 0	CN solution	200 ml	Spray
Special munition, M1	TZ	..	Flechette
Special munition, E2	N, etc.	..	Bursting
Disseminator, dry agent, E41R2	N, UL2, etc.	0.01	Disperser
Pots, generators, cylinders, dispersers			
Generator, F7-A	HD	3	Burning
Generator, 50-lb, M16	BZ	..	Burning
Generator, portable, E22	UL1	2.6	Spray
Generator, portable, E32R1	N, UL2, etc.	1.0	Disperser
Generator, E44R2	BW agent	..	..
Special munition, M5	N, PG, etc.	..	Disperser
Smoke-pot	CS	..	Burning
Smoke-pot, floating, M7	GB	..	..
Cylinder, portable, M1A2	CG	14	Spray
Disperser, dry agent, skid-mounted, M2	CS1	5 per hopper	Disperser
Disperser, portable, M106 (*Mity Mite*)	CS1, *or*	3.2 per hopper	Disperser
	Herbicide	3 gallons	
Land mines			
Mine, land, 1-gallon	HD	4.5	Bursting
Mine, land, 2-gallon, M23	VX	5	Bursting
Artillery, mortar and related projectiles			
Cartridge, 4.2 inch mortar, M2	CG, *or*	2.8	Bursting
	HT	2.6	
Cartridge, 4.2 inch mortar, M2A1	HD	2.7	Bursting
Cartridge, 4.2 inch mortar, XM630	CS	0.9	Burning
Cartridge, 105 mm, M60	HD	1.4	Bursting
Cartridge, 105 mm howitzer, M360	GB	0.7	Bursting
Cartridge, 105 mm, XM629	CS	0.7	Burning
Projectile, 155 mm howitzer, M110	HD	4.4	Burning
Projectile, 155 mm howitzer, M121	GB, *or*	3	Bursting
	VX	3	
Projectile, 155 mm howitzer, XM631	CS	2.2	Burning
Projectile, 155 mm, XM693 (*Cry Pie*)	CS	..	..
Projectile, 155 mm gun, M104	HD	4.4	Bursting

Type and designation of weapon	Agent	Payload (kg)	Mechanism
Projectile, 155 mm gun, M122	GB, *or*	3	Bursting
	VX	3	
Projectile, 155 mm, binary chemical, XM687	GB2	..	Bursting
Projectile, 8 inch howitzer, M426	GB, *or*	7.2	Bursting
	VX	6.4	
Shell, gas, 175 mm, T223	GB, *or*	6.7	Bursting
	VX	6.0	
Shell, 5"/38, naval, Mk53	GB, *or*	1.4	Bursting
	VX	1.4	
Shell, 5"/54, naval, Mk54	GB, *or*	1.9	Bursting
	VX	1.9	
Shell, 6"/47, naval	GB	..	Bursting
Rocket, 66 mm, XM96	CS2	..	..
Rocket, 3.5 inch, shaped-charge, follow-through, M28A2	GB	..	Bursting
Rocket, 4.5 inch, T164	GB	1.5	Bursting
Rocket, 115 mm, M55 (*Bolt*)	GB, *or*	5	Bursting
	VX	4.5	
Warhead, 5 inch rocket, naval, Mk40	GB	2.2	Bursting
Multiple rocket launchers & ground-launched clusters			
Launcher, 115 mm rocket, 45-tube, M91	GB, *or*	225	(M55 rockets)
	VX	205	
Launcher, 5 inch rocket, 48-tube, naval	GB	105	(Mk40 warheads)
Launcher, 35 mm cartridge, 16-tube, E8	CS	1.2	(E23 cartridges)
Warheads for missiles and large rockets			
Warhead, 318 mm rocket, M206 (for *Little John*)	GB	31	(52 M139 bomblets)
Warhead, 762 mm rocket, M79 (for *Honest John*)	GB	177	..
Warhead, 762 mm rocket, M190 (for *Honest John*)	GB, *or*	217	(368 M139 bomblets)
	VX	210	
Warhead, guided missile, M213 (for *Sergeant*)	GB	..	(M139 bomblets)
Warhead, guided missile, M212 (for *Sergeant*)	GB, *or*	195	(330 M139 bomblets)
	VX	190	
Warhead, guided missile, M210 (for *Sergeant*)	BW agent	..	(M143 bomblets)
Warhead, guided missile, E23 (for *Sergeant*)	UL1	150	(740 E134 bomblets)
Warhead, guided missile, E27 (for *Lance*)	GB	..	..
Aircraft weapons			
Spray and disperser systems			
Spray system for drone, USD-2	UL1	24 gallons	Spray
Disperser, dry agent, helicopter, M4	CS1, *or*	23 per hopper	Disperser
	CN1	49 per hopper	
Disperser, dry agent, helicopter, M5	CS1, *or*	18 per hopper	Disperser
	CN1	40 per hopper	
Spray system, dry agent, helicopter, HIDAD	..	125 gallons	Disperser
Spray system, liquid agent, helicopter, HIDAL	Herbicide	200 gallons	Spray
Spray system, liquid agent, helicopter, AGAVENCO	Herbicide	200 gallons	Spray
Spray system, liquid agent, fixed-wing aircraft, FIDAL	Herbicide	275 gallons	Spray
Spray tank, liquid agent, A/B 23Y-1	Herbicide	..	Spray
Spray system, liquid agent, A/A 45Y-1	Herbicide	1 000 gallons	Spray
Spray system, liquid agent, A/A 45Y-2	Herbicide	..	Spray

Entered inventory	Remarks
1942	Became obsolete in 1944
Post-WWII	Can be rifle-fired; contains about 70 gm DM
Post-WWII	Can have a CS filling; can be rifle-fired
Early 1960s	Can be rifle-fired; $ 2.94 each in 1972 procurement
Early 1960s	A "baseball" grenade; can have CN1 or DM1 fillings; $ 3.42 each in 1972 procurement
1969	Half the size of the M7A3 grenade. ENSURE 211[b]
1972	..
..	Development curtailed in 1965
1967	Hand-fired, or fired from M79 grenade-launcher or M8 pyrotechnic pistol
1968	ENSURE 36.2
1968	Fired from M79 grenade-launcher. ENSURE 87.3; $ 4.35 each in 1972 procurement
..	Under development in 1972
Post-WWII	Modified M2A1 flamethrower
..	Under development in 1969
1971	Military version of *Mace*
1971	Military version of *Mace*
1972	..
Pre-WWII	Primarily used for shipboard CW training
..	Rifle fired; suited to other toxins, such as botulinal toxin
..	7.62 mm rifle shell with dry agent fill; 'M2XR' tested in 1969
..	Limited procurement in 1964; small rectangular can using carbon dioxide propellant
..	Under development in 1945 as a mustard-aerosol pot
Early 1960s	Component of M44 cluster, but can be used as a pot
..	User-tested in 1958; can also have OU1 or NU fills
..	Limited procurement in 1964; 8-second compressed-nitrogen payload discharge
..	Under development in 1965, a biological 'depositor'
..	Anti-convoy ground-dusting device under development early 1960s
..	ENSURE 216. For air- or ground-delivery; to generate CS aerosols for at least 15 minutes
..	Under development in 1960
1936	Became obsolete in 1946
Post-WWII	Modified crop-duster
1965	Modified petrol-engined air-compressor
Pre-WWII	Can be filled in the field
Early 1960s	Pop-up adapter-projector available
1941	645 000 M2 rounds gas-filled during WWII, about 84 per cent with mustard gas, 8 per cent with phosgene and 8 per cent with CN solutions
Post-WWII	4.5 km range
1968	4 BE canisters; 62 000 issued in South Viet-Nam during 1969–70; ENSURE 87.4
1940s	..
Mid-1950s	..
1968	3 BE canisters; 13 000 issued in South Viet-Nam during 1969–70; ENSURE 87.1; $ 70 each in 1972 procurement
1940s	..
Mid-1950s	..
..	5 BE canisters; under development in 1970. ENSURE 87.2
..	Under development in 1970
1940s	..

Entered inventory	Remarks
Mid-1950s	..
..	In prototype in 1970
Early 1960s	..
..	Under development in 1962; intended for M107 Gun (SP)
1950s	..
1950s	..
..	Under development in 1957
..	Under development in 1970 as a 4-round clip for portable launcher
..	Being developed as an antitank munition in 1965
..	Under development in 1954
1960	For M91 launcher; cost US Army about $ 120 each in early 1960s
Early 1960s	4.2 km range. For Mk 105 launcher. Can take an HD payload
1960	For M55 rockets
Early 1960s	..
1967	4 cartridges per tube; 30 000 issued in South Viet-Nam during 1968-1970; ENSURE requirement no. 36.1
Mid-1960s	Originally the E20 warhead. *Little John* (16 km range) is no longer in service
Early 1960s	95 per cent functioning efficiency, 62 per cent agent-dissemination efficiency. Replaced by M190 warhead. Gives 113 hectare effective area coverage
Early 1960s	Originally the E19R2 warhead: 95 per cent functioning efficiency, 86 per cent agent dissemination efficiency. *Honest John* has 38 km range
..	Originally the E9 warhead; under development in 1964
..	*Sergeant* has 139 km range
Mid-1960s	139 km range. Originally the E23 warhead (?). Under development in 1967
..	Under development in 1967
..	Development began in 1962 and was curtailed in 1970
..	The USD-2 was a reconnaissance drone with 120 mile range
Post WWII	Helicopter-rotor down-draught spreads agent; can be used from a jeep
1950s	Helicopter-rotor down-draught spreads agent; can be used from a jeep
1965	US Navy insecticide duster adaptable to CBW agents
1960s	US Navy insecticide sprayer; used with UH-1 helicopters. One of the first herbicide spray systems to be used in the Viet-Nam War
1967	Insecticide spray system adapted for UH-1 herbicide spray operations in Viet-Nam
1960s	US Navy insecticide sprayer; used with A1-E or A1-H aircraft
..	For A-1E aircraft; under development in 1965
1962	For C-123 or C-130 cargo aircraft; internal tanks, external spray-booms
..	Large pressurized internal tank for C-123 aircraft under development in 1964

Type and designation of weapon	Agent	Payload (kg)	Mechanism
Spray system, A/A 45-1	..	..	..
Spray tank, liquid agent, A/B 45-1	BW agent	..	Spray
Spray tank, liquid agent, A/B 45Y-1	BW agent	..	Spray
Spray tank, dry agent, A/B 45Y-2	BW agent	..	Disperser
Spray tank, liquid agent, A/B 45Y-3	Herbicide	..	Spray
Spray tank, dry agent, A/B 45Y-4	BW agent	..	Disperser
Spray tank, dry agent, A/B 45 4-4	BW agent	..	Disperser
Spray tank, A/B 45 4-1	..	..	..
Spray tank, liquid agent, E29R1	VX, etc.	..	Spray
Spray tank, dry agent, E41	N, UL2, etc.	65 gallons	Disperser
Spray tank, liquid agent, E44	Herbicide	..	Spray
Spray tank, liquid agent, M10	HD, etc.	30 gallons	Spray
Spray tank, liquid agent, Mk12 Mod 0	HD, etc.	40 gallons	Spray
Spray tank, liquid agent, M33	HD, etc.	70 gallons	Spray
Spray tank, liquid agent, M40	HD, etc.	200 gallons	Spray
Spray tank, liquid agent, TMU-28B	VX	..	Spray
Spray tank, dry agent, TMU-38/A	Incap.	..	Disperser
Spray tank, liquid agent, TMU-66/A	Herbicide	50 gallons	Spray
Spray tank, liquid agent, PAU-7/A	Herbicide	..	Spray
Spray tank, liquid agent, PAU-7/B	Herbicide	..	Spray
Spray tank, dry agent, Aero X2A	TX, etc.	65 gallons	Disperser
Spray tank, liquid agent, Aero 14B	GB, VX, NU, UL1, etc.	80 gallons	Spray
Free-fall bombs			
Bomb, 100-lb, M47A2	HD	31	Bursting
Bomb, 115-lb, M70A1	HD	27	Bursting
Bomb, 125-lb, M113	HD	..	..
Bomb, 500-lb, M78	CG, *or*	93	Bursting
	CK	80	
Bomb, 500-lb, Mk94	GB	50	Bursting
Bomb, 750-lb, MC-1	GB	100	Bursting
Bomb, 750-lb, BLU-52/B	CS2	123	Impact
Bomb, 1000-lb, M79	CG, *or*	190	Bursting
	CK, *or*	160	
	AC	88	
Bomb, 4 000-lb, M56	CG	1060	Bursting
Bomb, Mk116 Mod 0 (*Weteye*)	GB	..	Bursting
Bomb, *Bigeye*	..	..	..
Bomb, entomological	..	..	..
Cluster weapons[d]			
Canister cluster, 50-lb, E158R2	CS	5	(264 XM16 canisters)
Canister-cluster, 50-lb, XM15	CS	5	(264 XM16 canisters)
Canister-cluster, 130-lb, E159	CS	10	(2 E158R2 clusters)
Canister cluster, 130-lb, XM165	CS	10	(2 XM15 clusters)
Generator cluster, 175-lb, M44	BZ	..	(3 M16 generators)
Bomb cluster, 100-lb, M12	HD	26	(14 M69 bombs)
Bomb cluster, 500-lb, M19	HD	71	(38 M69 bombs)
Bomb cluster, 500-lb, M31	HD	..	(38 M74 bombs)
Bomb cluster, 750-lb, M43 (or CBU-5/B)	BZ	39	(57 M138 bombs)
Bomb cluster, 750-lb, E108R2	BW agent	..	..
Bomb cluster, 750-lb	BW agent	..	..

Type and designation of weapon	Agent	Payload (kg)	Mechanism
Bomb cluster, 1000-lb, M34A1	GB	90	(76 M125A1 bombs)
Bomb cluster, E133	BW agent	..	(E61R4 bombs)
Bomb cluster, M33	AB	..	(M114 bombs)
Bomb cluster, *Misteye II*	GB, *or* VX	..	..
Canister dispenser system, XM27	CS	8	(72 XM54 grenades)
Canister dispenser system, CBU-19/A	CS	..	(BLU39/B23 canisters)
Canister dispenser system, CBU-30/A	CS	25	(1280 XM16 canisters)
Bomblet dispenser system, CBU-15/A	GB	69	(BLU19/B23 bomblets)
Bomblet dispenser system, CBU-16/A	BZ	31	(BLU20/B23 bomblets)
Bomblet dispenser system, *Padeye I*	BZ	..	..
Bagged-agent dispenser system, XM28	CS2	326	(2 090 paper bags)
Bomblet dispenser system, XMC-1	UL1	180, *or* 950	(1944 E120 bomblets) (4608 E134 bomblets)
Dispenser system, BW submunitions	..	..	..
Air-to-ground rockets			
Rocket, LSFFAR, 2.75 inch, XM80	CS	..	..
Rocket, LSFFAR, 2.75 inch, submunition warhead, XM99	CS	..	..
Submunitions used in certain air and ground weapons			
Canister, XM16 (previously E49)	CS	0.02	Burning
Cartridge, 35 mm, E23	CS	0.02	Burning
Grenade, XM54	CS	0.12	Burning
Canister, BLU-39/B23	CS	..	Burning
Bomb, 6-lb, M69	HD	1.87	Tail-ejection
Bomb, 10-lb, M74	HD	..	Tail-ejection
Bomb, 10-lb, E29R1	HD	1.1	Burning
Bomb, 10-lb, M125A1	GB	1.18	Bursting
Bomb, 10-lb, M138	BZ	0.68	Burning
Bomb, E61R4	BW agent	..	..
Bomb, M114	AB	..	Bursting
Bomblet, E112	GB	..	..
Bomblet, spherical, E118	GB	..	Bursting
Bomblet, spherical, 4.5 inch, E130R2	GB	..	Bursting
Bomblet, spherical, 4.5 inch, E133	GB	..	Bursting
Bomblet, spherical, E139	GB, GD, etc.	..	..
Bomblet, spherical, M139	GB	0.6	Bursting
Bomblet, BLU-19/B23	GB	>0.6	Bursting
Bomblet, BLU-20/B23	BZ	..	Burning
Bomblet, BLU-21/B45	UL2	..	..
Bomblet, BLU-22/B45	UL1	..	..
Bomblet, US Navy	G-agent	1.4	..
Bomblet, US Navy	V-agent	0.45	..
Bomblet, spherical M143	BW agent	..	Bursting
Bomblet, 4.5 inch, spherical, E120	UL1, etc.	0.1	Spraying
Bomblet, 3.4 inch, spherical, E134	UL1, etc.	0.2	Bursting

Notes:

[a] This list includes many experimental weapons—most, if not all, of the BW devices, for example—that failed to reach the standardization or qualification stages of the development process; others that are listed are still undergoing development.

[b] ENSURE is an acronym for Expedite Non-Standard Urgent Equipment. It denotes an administrative procedure developed during the Viet-Nam War for accelerating the fulfilment of urgent requests from field-commanders for new items of equipment. ENSURE development projects circumvented the normal R,D,T,E cycle.

Entered inventory	Remarks
..	Internal tank, external booms
..	Under development in 1967; expendable; suited to F4-C aircraft
..	A 1962 USAF requirement under development in 1965. An expendable munition about 85 cm in diameter and 400 cm long, for high-speed tactical aircraft
..	Under development in 1969; tested with rice-blast spores
..	Under development in 1966; designated TMU-28/B with nerve-gas fill
..	Under development in 1966; tested with PG toxin agent
..	Mid-1960s design; for F100, F105 and F4-C aircraft
..	Suited to CNU-103/E shipping container, as is the A/B 45Y-1 tank
..	Used for high-altitude release trials in 1962
..	75–140 kg payload; under development in 1965 for F100, F105, F-4C and A-4D aircraft
..	Under development in 1964 for *Mohawk*, etc., aircraft
1940	Expendable; 92 000 produced for mustard gas during WWII; 4 per A20-A plane
..	US Navy smoke-tank for A-4B, etc., aircraft; weighs about 500 kg filled. Has been used with CS in Viet-Nam
1942	Nonexpendable; contours of 2 000-lb bomb; 2 per B-25 bomb-bay; 21 000 made in WWII
1942	Contours of 4 000-lb bomb; for wing-racks of B17 and B24
1966	For F111-A, etc., aircraft; in-board station of F105
..	Under development in 1965 for F-105, etc., aircraft
1969	For low-or-high-speed aircraft; a modular design, whereby up to 4 tanks can be mounted on a single wing station
..	Under development in 1970 for F-4, etc., aircraft
..	A modified version of the TMU-28/B
..	About 5 m long; suited to F-3D, F-7U, F-2H2 and A-4D aircraft
1960s	US Marine Corps spray tank for A-4D, AD-5, AD-6, AD-7 and FJ-4B aircraft; about 5 m long
Early 1940s	Heavily used in WWII with incendiary fill; obsolete for mustard soon after war
Mid-1940s	About 1.3 m long and 20 cm in diameter; 0.06 hectare instantaneous area coverage[c]
Late 1940s	Became obsolete in mid-1950s
1942	About 1.5 m long and 50 cm in diameter; 33 000 were filled with CK during WWII
1950s	US Navy and Marine Corps weapon. 0.6 hectare instantaneous area coverage
1950s	Modified 750-lb demolition bomb; 16 per F105-D/E/F aircraft; 1.3 hectare instantaneous area coverage. Previously, E110
1968	Converted BLU-1 napalm tank; 1 700 issued in South Viet-Nam 1968–1970
1943	63 000 gas-filled during WWII; 90 per cent of them with CK; AC filling obsolete by 1961; about 175 cm long and 50 cm in diameter
..	Experimental WWII weapon
1966	Replacement for Mk 94; said to be a 500-lb guided bomb
..	Under development in 1966; apparently a binary VX weapon
..	Presumably for vector-delivered BW agents
1967	Eight modules, each of 33 canisters; hand-dropped from aircraft up to 350 knots; ENSURE 30
1969	Modification of E158R2; $ 403 each in 1972 procurement
1967	For light aircraft fitted with bomb-shackles
1969	Modification of E159
Early 1960s	For wing-racks of light aircraft, such as L19, L20 or Mohawk
WWII	Obsolete for mustard-filling soon after WWII
WWII	Obsolete for mustard-filling soon after WWII
WWII	Obsolete for mustard-filling soon after WWII
Early 1960s	For subsonic delivery
..	Under development in 1954
..	Under development in 1965; *Sadeye* cluster of Flettner rotors

Entered inventory	Remarks
1954	For subsonic delivery; now obsolete; cost about $ 1200 each in mid-1950s; 3 hectares instantaneous coverage
..	Under development in 1958
..	Under development in 1957
..	Under development in 1966
1968	XM18 (SUU-14/A) 6 tube horizontal-ejection dispenser; for use up to 300 knots from UH-1 helicopters or light aircraft
1968	2400 issued in South Viet-Nam during 1968–1970
1968	SUU-13/A 40 tube downward-ejection dispenser; for high- or low-speed delivery
1968	SUU-13/A dispenser; for high- or low speed delivery
1968	SUU-13/A dispenser; suited to high-speed, low-altitude delivery
..	Under development in 1966; for high-speed delivery
..	19 tube downward-ejection device for sling-loading; under UH-1 helicopter. ENSURE 215, under development in 1970
..	24-tube downward-ejection system; one dispenser per B47 bomber or two per B-52
..	Under development in 1965; *Gladeye*-dispensed Flettner rotors
..	Under development in 1970
..	Under development in 1970
1967	Size of a flash-light cell; for E158, XM15, E159, XM165 and CBU-30/A
1967	For E8 launcher; skitters on ground, as does XM15 canister
1968	M7A3 grenade with modified fuse; for aircraft dispensers, such as XM27
1968	For CBU-19/A; skitters on ground
WWII	Obsolete soon after WWII, except with incendiary filling; for M12 and M19 clusters
WWII	Obsolete soon after WWII, except with incendiary filling; for M31 cluster
..	Experimental WWII weapon, intended for a 64-bomb cluster
1954	Now obsolete; for M34 cluster
Early 1960s	For M43 cluster (CBU-5/B)
..	For E133 clusters; under development in 1958
..	For M33 clusters; under development in 1957
..	Used in a 1957 *Corporal* warhead field test
..	Under development in 1958
..	Tested in *Little John*, *Honest John*, *Corporal* and *Sergeant* warheads by 1962
..	Under development in 1958
..	Tested with GA, GB and GD fillings during 1968–1969
Early 1960s	For *Honest John*, *Little John* and *Sergeant* warheads; previously, E130R2 (?)
1968	Larger than M139 bomblet; for CBU-15/A dispenser system
1968	Similar contours to BLU-19/B23; for CBU-16/A dispenser system
..	Under development in 1966
..	For SUU-13/A dispensers; under development in 1966
..	Tested in 1969
..	Tested in 1969
Mid-1960s	For *Sergeant* warhead; same size as E139 and M139 bomblets
..	Plastic, with pyrotechnic pressure source. Under development in 1960; primarily for XMC-1 dispenser
..	Plastic, for wet biological fills. Under development in 1962; primarily for *Sergeant* warhead

[c] By "instantaneous area coverage" is meant the area over which the payload of the weapon has spread 30 seconds after detonation.

[d] Other aircraft CW and BW cluster weapons are the CBU-2A/A and CBU-7/A munitions, which were under development in 1966. They may be carried by B-57 aircraft.

Source: Sipri Yearbook 1996.

Bibliography

Primary Sources:

Chemical and Bacteriological (biological) Weapons and the Effects of their Possible Use: Report, UN, New York, 1974, pp.100.

Conference of the Committee on disarmament, *A Report to the United States General Assembly and the United States Disarmament Commission*, CCD/ 520, 3 Sept. 1976, Geneva.

Parachini, John, *Combating terrorism: Assessing the threat of Biological Terrorism*, Rand, Testimony Series Oct.2001.

United Nations General Assembly, *A Resolution adopted on questions of Chemical and Bacteriological(biological) weapons,* A/Res/2662 (XXV), Washington DC, 7 December 1970.

United Nations General Assembly, A Resolution on Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (biological) and Toxin Weapons and their Destruction, A/2826 (XXIV), Washington DC,16 December 1971.

US Arms Control and Disarmament Agency, *Arms Control and Disarmament Agreements: texts and histories of negotiations,* US government Printing Office, Washington DC, 1996.

US Congress, Office of Technology assessment, *Proliferation of weapons of mass destruction: Assessing the risks,* 07-A-Isc559, Government Printing Office, Washington DC, Aug.1993.

World Health Organisation, *Health Aspects of Chemical and Biological Weapon, Science and Global Security,* Geneva, 2001.

World Health Organisation, *Health Aspects of Chemical and Biological Weapon: Report of a WHO Group of Consultants,* Geneva, 1991.

World Health Organisation, *Health Aspects of Chemical and Biological Weapon: Report of a WHO Group of Consultants*, Geneva, 2000.

World Health Organisation, *Health Aspects of Chemical and Biological Weapon: Report of a WHO Group of Consultants*, Geneva, 2002.

Secondary Sources:

Books

Bajpai, Kanti P., *Roots of Terrorism*, Penguin Books, New Delhi, 2003, pp. 181.

Biddle, WF, *Weapons Technology and Arms Control*, Praeger Publishers, New York, 1972, pp. 355.

Berry, James W, Chemical Villains: *A Biology of Pollution*, CV Mobsy, Saint Louis, 1974, pp. 189.

Bobison,J.P.P., *Chemical and Biological warfare Developments:1985*, Oxford University Press, SIPRI CBW Studies No.6, Oxford, 1986, pp.112.

Brassey, Rusi, *Weapons Technology: A Survey of Current Developments in Weapons Systems*, Brassey's Publications, London, 1986, pp. 102.

Bronk, J. Ramsey, *Chemical Biology: An Introduction to Biochemistry*, The Macmillan Company, New York, 1973, pp. 667.

Brown, Frederic J., *Chemical Warfare: A Study in Restraints*, Princeton University Press, Princeton, 1968, pp.355.

Chari P.R., Rajain Arpit (ed.); *Working towards a verification protocol for biological weapons*, Institute of Peace and Conflict Studies, New Delhi, 2002, pp. 85.

Dash, Debi Prasad, *Weapons of Mass Destruction: A Study in Restraints on Chemical Weapon System*, JNU, New Delhi, 1982, pp. 186.

E. Johnson, Smart, *The niche threat: deterring the use of chemical and biological weapons*, national defence university press Washington DC, 1997,pp. 123.

Freedman, Lawrence, *Arms Control: Management or Reform?* , Routledge and Kegan Paul, London, 1986, pp. 102.

Freedman, Lawrence , *Perspectives on Terrorism*, Hindustan Publication, New Delhi, 1985, pp. 245.

Geissler, Erherd, *Biological and chemical weapons today*, Oxford University press, oxford, 1986, pp. 207.

Haber, L.F, *The Poisonous Cloud Chemical Warfare in the First World War*, Oxford University Press, Oxford, 1986, pp.145.

Harris R, Paxman J., *A Higher Form of Killing: The Secret Story of Gas and Germ Warfare*, Chatto and Windus, London, 1982, pp. 234.

Hamza, Khidhir, *Saddam's Bomb maker: The Terrifying inside story of the Iraqi Nuclear and biological weapons Agenda*, 2000, pp.352.

Heden,Carl Goran (ed.); *The problem of Chemical and Biological Warfare; A study of the Historical, Technical, Military, Legal and Political aspects of CBW and possible Disarmament Measures*, vol.vi, Almqvist and Wiksell International, Stockholm, Humanity Press New York, Sweden, 1975, pp. 300.

Jane's NBC Defence, Thirteenth Edition, 2000-01.

John Caldwell, William B Jakoby, *Biological Basis of Detoxication*, Academic Press, New York, 1983, pp. 429.

Johnson, Stuart E (ed.), *The Niche Threat : Deterring the use of Chemical and Biological Weapons*, National Defence University Press, Washington DC, 1997, pp.125.

Trapp Ralf, *Chemical and Biological Weapon Free Zones?*, Oxford University Press for SIPRI, Oxford, 1987, pp. 211.

Livingstone, N.C. and Doughlas Jr., *CBW: The Poor Man's Atomic Bomb*, Mass Institute for Foreign Policy Analysis, Cambridge, 1984, pp.190.

Moore,C Bradley (ed.), *Chemical and Biochemical applications of Laswers* (ed.), New York, 1974 , XI, pp. 398.

Ngyen, Khac Vien, *Chemical Warfare*, Vietnam Press, Vietnam, 1970, pp. 187.

Perry J. P., Robinson, *Chemical and Biological Warfare Developments*, Oxford University Press, Oxford, 1986, pp. 110.

Stockholm International Peace Research Institute, *Chemical Disarmament: Some Problems of Verification*, Stockholm, 1973, pp.210.

Stringer, Col. H.L., *Deterring Chemical Warfare: U.S. Policy Option for the 1990's*, Mass Institute for Foreign Policy Analysis, Cambridge, 1986, pp.312.

Zilinskas, Raymond A; *Biological Warfare*, Lynne Rienner Publishers London, 2001,pp. 120.

Articles

Balmer, Brian, "Drift of Biological Weapons Policy in the UK 1945-1965", *Journal of Strategic Studies*, 20 (4), (Dec.97), pp. 115-45.

Bartley R.L. and Kucewiz W. P., " Yellow Rain and the Future of Arms agreement", *Foreign Affairs*, 61(4), (Spring 83), pp. 124-130.

Belgrader P, Benett W, Hadley D, Long G, Mariella R, Milanovich F, Nasarabadi S, Nelson W, Richards J, and Stratton P, "Rapid pathogen detection using a microchip PCR array instrument," *Clinical Chemistry*, 44, (June1998), pp. 2191-2194.

Cohn, Samuel K, Black Death: End of a Paradigms, *American Historical Review*, 107(3), 2002(June): pp.39-46.

Chittaranjan, Kalpana, "Biological Weapons and Biological Weapons Convention", *Strategic Analysis*, 21(6), (Sep. 1997), pp. 877-86.

Chyba, Christopher F, "Biological Terrorism and Public Health", *Survival*, 43(1), (Spring 2001), pp. 93-106.

Christensen S, MacIver, B, Procell L, Sorrick D, Carrabba, M, and Bello J, "Nonintrusive analysis of chemical agent identification sets using a portable fiber optic raman spectrometer," *Applied Spectroscopy*, 53, (Aug1999), pp. 850-855.

Derbes, VJ, " De Mussis and the Great Plague of 1348: A Forgotten Episode of Bacteriological War", *JAMA: 196*,1966,p. 59-62.

Driskell WJ, Shih M, Needham LL, and Barr DB, "Quantitation of Organophosphorous nerve agent metabolites using isotope dilution gas chromatography-tandem mass spectrometry," *Journal of Analytical Toxicology*, 26, (Jan 2002), pp. 6-10.

Doughlas Jr., J.D., " Chemical Weapons: An Imbalance of Terror", *Strategic Review*, 10(3), (Spring 82), pp.34-39.

Eric Croddy, "China's role in the Chemical and Biological Disarmament Regimes", *the Nonproliferation Review*, spring 2002.

Ember L, "From weather radars to chem.-bio detectors," *Chemical & Engineering News*, 80,(march 2002), pp. 23-42.

Floweree, C.C., "Chemical Weapons: A Case Study in Verification", *Arms Control Today*, 13(4), (Apr 83), pp. 24-28.

Gacinovic, Radoslav D, "Terrorism- Threat to the 21st Century", *Review of International Affairs*, 50-51(1087-8), (Dec-Jan 2000), pp. 18-23.

Goldblat, Jozef, " Third Review of the Biological Weapon Convention: issues and proposals " vol. VI, *research paper/ UN Institute for Disarmament Research,* No.9 New York: U.N.1991,pp.79-97.

Garden Tim, " Weapons of Mass Destruction", *World Today* , 57(10), (Oct. 2001), pp. 4-6.

Grate JW, Martin SJ, and White RM, "Acoustic wave microsensors," *Analytical Chemistry*, 650, (Summer1993), p 940A-945.

Hasham, Mariyam, " Terrorism: New Century, New War", *World Today*, 57(10), (Oct. 2001), pp. 12-13.

Herby, Peter, " Biotechnology, Weapons and War: Grim Future", *World Today*, 59(5), (May 2003), pp. 9-11.

Iqbal SS, Mayo MW, Bruno JG, Bronk BV, Batt CA, and Chambers JP, "A review of molecular recognition technologies for detection of biological threats," *Biosensors & Bioelectronics*, (15),(spring 2000), pp. 549-578.

Jayan, P.A., "Chemical Weapons Convention First Review Conference: A Critical Evaluation", *India Quarterly*, 59(1-2), (Jan.- June 2003), pp. 235-60.

Joshi, Monalisha, "Bioterrorism Threat and India's Experience", *Mainstream*, 40 (39), (Sep.2002), pp. 15-17.

Joshi, Monalisha, "The Question of Ethics", *Mainstream*, 40 (51), (Dec. 2002),pp. 13-14.

Jones M, Alland D, Marras M, El-Hajj H, Taylor MT, and McMillan W, "Rapid and sensitive detection of mycobacterium DNA using Cepheid SmartCycler and Tube Lysis system," *Clinical Chemistry*, 47, (Spring 2001), pp.1917-21.

Kaplan, M.M., "Another View", *The Bulletin of The Atomic Scientist*,(Vol. 39), (Nov. 83), pp. 56-61.

Kartha, Tara, " Terrorism: A New Face of War?", *World Focus*, 21 (9), (Sep.2000), pp. 11-14.

Katsva, Maria, " Weapons of Mass Destruction Brain Drain From Russia: Problems and Perspective", *Strategic Digest*, 30(9), (Sept.2000), pp. 1263-77.

King, J.H., " The Comprehensive Chemical Weapons Ban", *Arms Control Today*, 16(6), (Sep. 86), pp. 22-26.

King Jonathan and Stabinsky, "Biotechnology Under Globalisation: The Corporate Expropriation of Plant, Animal and Microbial Species", *Race and Class*, 40(2-3), (Oct 98- Mar.99), pp.73-89.

Lele, A V, "Biological Terrorism: Threat and Risk assessment", *Strategic Analysis*,26(3), (July- Sept.2002), pp. 341-55.

Lele, Ajay, "Biological Weapons and the United States", *Strategic Digest*, 31(1), (Nov. 2001), pp. 1488-96.

Lee KJ, Youngsikpark, Bunkin A, Nunes R, Pershin S, and Voliak K, "Helicopter-based lidar system for monitoring the upper ocean and terrain surface," *Applied Optics*, 41, (Apr 2002), pp. 401-406.

Liu Byh, Yoo S-H, and Chase S, "Lower detection limit of aerosol particle counters," *Journal of the Institute of Environmental Sciences*, 38, (Sept 1995), pp. 31-37.

Lognoli D, Lamenti G, Tirelli D, Tiano P, Tomaselli L, and Pantani L, "Detection and characterization of biodeteriogens on stone cultural heritage by fluorescence lidar," *Applied Optics*, 41, (Jan 2002), pp. 1780-1787.

Lockie, Stewart, "Chemical Risk and the Self- calculating Farmer: Diffuse Chemical use in Australian Broad acre Farming Systems", *Current Sociology*, 45(3),(July 97), pp.81-97.

Martin, Susan B, Role of Biological Weapons in International politics: The Real Military Revolution , *Journal of Strategic Studies*, 25(1), (March 2002),pp. 63-69.

Morel S, Leone N, Adam P, and Amourous J, "Detection of bacteria by time-resolved laser-induced breakdown spectroscopy," *Applied Optics*, 42, 2003, pp. 6184 -6191.

Moodie, Michael, "Bioterrorism: Risk and Response", *World Today*, 57 (11), (Nov.2001), pp. 4-6.

Nayan, Rajiv, " Chemical Weapons Convention: Challenges Ahead", *Strategic Analysis*, 21(12), (March 98), pp. 1817-30.

Nayan, Rajiv, "Trends in the Missile Technology Control Regime", *Strategic Analysis*, 22(6), (Sep. 98), pp. 867-81.

Nayan, Rajiv, " Chemical Weapons Convention and India", *Strategic Analysis*, 20(4), (July 97), pp. 639-42.

O' Neil, Andrew, "Terrorist use of Use of Weapons of Mass Destruction: How Serious is the Threat ?", *Australian Journal of International Affairs*, 57(1), (Apr. 2003), pp. 99-112.

Oppenheimer, Andy, "Weapons of Mass Destruction: Creating Panic", *World Today*, 59 (2), (Feb. 2002), pp. 19-20.

Quester, George H, "Mismatched Deterrents Preventing the Use of Nuclear, Biological and Chemical Weapons", *International Studies Perspectives*, 1 (2), (August 2000), pp. 165-76.

Radhu, Michael, " Terrorism after the Cold War: Trends and Challenges", *Orbis*, 46(2), (Spring 2002), pp. 275- 87.

Robinson, J.P.P., "Disarmament and Other Options for Western Policy- Making on Chemical Warfare", *International Affairs*, 63(1) (Winter 86-87), pp. 45-52.

Selden, Mark, "Terrorism Before and After 9/11", *Economic and Political Weekly*, 37(27), (Sept. 2002), pp. 3795-96.

Steinbruner , John D, " Biological Weapons: A Plague Upon all Houses", *Foreign Policy*, (109) (Winter 97-98), pp. 85-112.

Terill, Jr. W.A., " Chemical Weapons in the Gulf War", *Strategic Review*, 14(2), (Spring 86).

Tower, John, " The Politics of Chemical Deterrence", *Washington Quarterly*, 5(1), (Spring 82), pp.56-59.

Thraenert, Oliver, " Biological Weapons and Problems of Nonproliferation", *Aussen Politik*, 48(2), (1997), pp. 148-57.

Tucker, Jonathan B , "Chemical and Biological Terrorism: How a Real Threat ?", *Current History*, 99(636), (April 2000), pp. 165-76.

Tucker, Jonathan B , "Biological Weapons Threat", *Current History*, 96 (609), (Apr.97), 167-72.

Vachon, G.K., " Chemical Weapons and the Third World", *Survival*, 26(2), (Mar.84), pp.29-33.