Chemical and Biological Weapons: Use in Warfare, Impact on Society and Environment

Gert G. Harigel

1. Introduction

Since the end of World War II there has been a number of treaties dealing with the limitations, reductions, and elimination of so-called weapons of mass destruction and/or their transport systems (generally called delivery systems). Some of the treaties are bilateral, others multilateral, or in rare cases universal. In the present paper only the chemical and biological weapons will be discussed, with emphasis on the Convention to eliminate them (CBWC).

The term "**weapons of mass destruction"** (WMD), used to encompass nuclear (NW), biological (BW), and chemical weapons (CW), is misleading, politically dangerous, and cannot be justified on grounds of military efficiency. This has been pointed out earlier [1] and discussed more recently in considerable detail in ref. [2]. Whereas protection with various degrees of efficiency is possible against chemical and biological weapons, however inconvenient it might be for military forces on the battlefield and for civilians at home, it is not feasible at all against nuclear weapons. Chemical weapons have shown to be largely ineffective in warfare, biological weapons have never been deployed on any significant scale. Both types should be better designated as **weapons of terror** against civilians and **weapons of intimidation** for soldiers. Requirements on their transport system differ vastly from those for nuclear warheads. They are extremely unpopular. Stockpiling of biological weapons is not possible over a long time scale [3, 4]. Only nuclear weapons are completely indiscriminate by their explosive power, heat radiation and radioactivity, and only they should therefore be called a weapon of mass destruction.

However, if one wants to maintain the term **"Weapons of Mass Destruction (WMD)",** it is a defendable view to ***exclude*** *chemical and biological weapons, but* ***put together with nuclear weapons*** *all those that actually has killed millions of people* in civil wars since World War II. These are mainly ***assault rifles,*** *like AK47s****, handguns,*** *and* ***land mines****,* to a lesser extent *mortars, fragmentation bombs, and hand grenades*.

This paper gives in Chapter 2 an overview on the history of chemical warfare, addresses in Chapter 3 the inventory of chemical weapons, discusses in Chapter 4 the elimination of chemical weapons and possible problems resulting for the environment (CW), reviews in Chapter 5 some non-lethal chemical weapons and chemical weapons which may be on the borderline to conventional explosives, and describes in Chapter 6 some of the old and new biological weapons (BW). The present status and verification procedures for the Chemical and Biological Weapons Convention (CBWC) are addressed in Chapter 7. Chapter 8 evaluates and compares the use of biological and chemical weapons by terrorists and by military in combat. The difficulties to use these weapons efficiently are in general underestimated, but their impact is exaggerated. This combination causes unjustifiable fear of the public and leads policy makers to wrong conclusions, among them to designate them as WMDs and keep nuclear weapons as a deterrent.

2. Chemical Warfare, Its History [5]

The Greeks first used sulfur mixtures with pitch resin for producing suffocating fumes in 431 BC during the Trojan War. Attempts to control chemical weapons date back to a 1675 Franco-German accord signed in Strasbourg. Then came the Brussels Convention in 1874 to prohibit the use of poison or poisoned weapons. During the First Hague Peace Appeal in 1899, the Hague Convention elaborated on the Brussels accord by prohibiting the use of projectiles that would diffuse "asphyxiating or deleterious" gases. This Convention was reinforced during the second Hague conference in 1907, but prohibitions were largely ignored during World War I. At the battle of Ypres/Belgium, canisters of chlorine gas were exploded in April 1915 by Germany, which killed 5'000 French troops and injured 15'000. Fritz Haber, a Nobel price winner in 1919 for invention of ammonium fixation, had convinced the German Kaiser to use chlorine gas to end the war quickly. History taught us about a different outcome. During World War I an estimated 124'000 tons of chemicals were used in warfare by all parties. Mustard gas - "the king of battle gases" - was then used on both sides in 1917, killed 91'000 and injured 1.2 million, accounting for 80% of the chemical casualties (death or injury). Chemical weapons caused about 3 percent of the estimated 15 million casualties on the Western Front [3]. To put these numbers into perspective, the total loss of Allied lives was ≥ 5 million, of the Central Powers 3.4 million, and the total of all wounded soldiers 21 million. Despite of its intensive use, gas was a military failure in WW I. The inhuman aspect and suffering was soon recognized and the year 1922 saw the establishment of the Washington Treaty, signed by the United States, Japan, France, Italy and Britain. In 1925 the Geneva Protocol for the prohibition of the use in war of asphyxiating poisonous or other gases ***and*** bacteriological methods of warfare was signed, and it had been a cornerstone of chemical arms control since then. The Geneva Protocol did neither forbid the stockpiling or the research on chemical weapons.

Despite the conventions, banning chemical weapons, Italians used them during the war 1935-36 in Ethiopia, the Japanese in China during World War II (1938-42), and they were used also in Yemen (1966-67). Various new chemicals were developed for use in weapons. Sarin, Soman, and VX followed Tabun, the first nerve gas, discovered in 1936.

During the Vietnam War (1961-1973), the US was accused of using lachrymatory agents and heavy doses of herbicides (defoliants) in much the same manner as chemical weapons. Some international organizations consider Napalm, its trade name, to be a chemical weapon, others put it on equal level with flame throwers, and consequently not falling under any of the articles of the CWC.

Sadism Hussein used chemical weapons against Iraqi civilians as well as against Iran soldiers between 1980 and 1988, with only a very small portion of total Iranian battle casualties. It is estimated that approximately 45'000 people were exposed to mustard gas in that war.

The Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons And on Their Destruction (CWC) [6], signed as of May 1999 by 122 states-parties, entered into force in 1997 after deposit of 65 ratification documents. There are 46 non-ratifying signatories, and 22 non-states parties [7].

3. The Inventory of Chemical Weapons

Chemical weapons have been produced during the twentieth century by many countries and in large quantities. They are still kept in the military arsenals as weapons of in kind or flexible response. Old ammunition is partially discarded in an environmental irresponsible way.

3.1 Military value of chemical weapons

By their nature, chemical arms have a relatively limited range: they create regional rather than global security problems, and slow the tempo of operations. In this, they are militarily more akin to conventional arms than to nuclear or biological weapons.

The above arguments are further substantiated by a United Nations study [8] that compared the hypothetical results of an attack carried out by one strategic bomber using either nuclear, chemical or biological weapons. A one-megaton nuclear bomb, the study found, might kill 90 percent of unprotected people over an area of 300 square kilometers. A chemical weapon of 15 tons might kill 50 percent of the people in a 60 square kilometre area. But a 10-ton biological weapon could kill 25 percent of the people, and make 50 percent ill, over an area of 100'000 square kilometres. These efficiencies assume, however, that chemical and biological agents can be spread over a large surface and reach the ground level, whereas nuclear weapons can be exploded at any predetermined altitude and on ground level with the desired efficiency.

Even extended use of chemical weapons had no decisive impact on outcome of wars, had only local success, and made wars uncomfortable, to no purpose. For this and other reasons it is difficult to see why they are around in the first place. However, they had been produced in enormous quantities and mankind has to deal with their very costly elimination.

Should scientists be held responsible for their invention, production, use, and also for the elimination of chemical weapons? Certainly not entirely, since military and politicians demanded their production. However, we need the help of scientists for the difficult job of neutralising or eliminating them.

3.2 Classification of chemical weapons

Binary munitions contain two separated non-lethal chemicals that react to produce a lethal chemical when mixed during battlefield delivery. Unitary weapons, representing the by far largest quantity of the stockpile, contain a single lethal chemical in munitions. Other unitary agents are stored in bulk containers. The characteristics of chemical warfare agents and toxic armament wastes are described in detail in [9]. The reader is referred to this article, which summarises the chemical and physical characteristics of blister, blood, choking, nerve, riot control, and vomiting agents, as well as their effects on the human body.

3.3 Abandoned Weapons

The easiest - say cheapest - way to *eliminate* (?) chemical weapons in the aftermath of World War II appeared to dump them into ocean [10]. There had been a worry that, after their defeat in 1945, Germans could be tempted to use part of their arsenal, which totaled 296'103 tons. Therefore, the weapons were captured and dumped into the sea. There are more than 100 sea dumping of chemical weapons that took place from 1945 to 1970 in every ocean except the Arctic. 46'000 tons were dumped in the Baltic areas known as the Gotland Deep, Bornholm Deep, and the Little Belt. *The Continental Committee on Dumping* involved the US with 93'995 tons, France with 9'250 tons, Britain with 122'508 tons, and Russia with 70'500 tons.

The US dumped chemical weapons in the Scandinavian region, totaling between 30'000 and 40'000 tons, nine ships in the Skagerrak Strait and two more in the North Sea at depth of 650 to 1'180 meters.

The Russians alone have dumped 30'000 tons in an area, 2'000 square kilometres in size, near the Gotland and Bornholm Islands.

Between 1945 and 1949, the British dumped 34 shiploads carrying 127'000 tons of chemical (containing 40'000 tons mustard gas) and conventional weapons in the Norwegian Trench at 700 meters depth.

The chemical weapons at the bottom of the Baltic Sea (mean depth of the Baltic Sea is 51 meters) and the North Sea represent a serious danger for the aquatic life. The shells of the grenades corrode and will eventually start to leak. The corrosion of these weapons is already so advanced that identification of the former owners is virtually impossible. Consequently, nobody can be made nowadays responsible for the ultimate elimination.

During the 1950s, the US conducted an ambitious nerve gas program, manufacturing what would eventually total 400’000 M-55 rockets, each of which was capable of delivering a 5-kg payload of Sarin [10, 11]. Many of those rockets had manufacturing defaults, their propellant breaking down in a manner that could lead to auto ignition. For this reason in 1967 and 1968 51’180 nerve gas rockets were dropped 240 km off the coast of New York State in depths 1'950 to 2'190 meters, and off the coast of Florida.

The US is responsible for 60 sea dumping totalling about 100'000 tons (equal to 39 filled railroad box cars), of chemical weapons filled with toxic materials in the Gulf of Mexico, off the coast of New Jersey, California, Florida, and South Carolina, and near India, Italy, Norway, Denmark, Japan, and Australia.

Some of the above figures appear to be not entirely coherent and do not add up well to the total, demonstrating among other things that no careful bookkeeping had been done during this inadmissible actions.

The CWC does not cover sea-dumped chemical weapons; in fact it makes a clear exception for them (CWC, Article III, § 2). The CWC does not provide the legal basis to cover chemical weapons that were dumped before 1985. They remain an uncontrollable time bomb.

3.4 The existing arsenal

The arsenal of chemical weapons has to be subdivided into two categories:

(i) The "stockpile" of unitary chemical warfare (CW) agents and ammunitions, comprising the material inside weapons and chemicals in bulk storage, and

(ii) The "non-stockpile" material, including buried chemical material, binary chemical weapons, recovered chemical weapons, former facilities for chemical weapons production, and other miscellaneous chemical warfare material.

3.4.1 The stockpile of unitary chemical warfare agents and ammunition

The **D**efence **I**ntelligence **A**gency (DIA) in the US reports [12, 13]:

Middle East

Egypt: First country in the Middle East to obtain chemical weapons training, indoctrination, and material. It employed phosgene and mustard agent against Yemeni Royalist forces in the mid-1960s, and some reports claim that it also used an organophosphate nerve agent.

Israel: Developed its own offensive weapons program. The 1990 DIA study reports that Israel maintains a chemical warfare testing facility. Newspaper reports suggest the facility be in the Negev desert.

Syria: It began developing chemical weapons in the 1970s. It received chemical weapons from Egypt in the 1970s, and indigenous production began in the 1980s. It allegedly has two means of delivery: a 500-kilogram aerial bomb, and chemical warheads for Scud-B missiles. Two chemical munitions storage depots, at Khna Abu Shamat and Furqlus. Centre D'Etude et Recherche Scientifique, near Damascus, was the primary research facility. It is building a new chemical-weapons factory near the city of Aleppo.

Iran: Initiated a chemical and warfare program in response to Iraq's use of mustard gas against Iranian troops. At end of war military had been able to field mustard and phosgene. Had artillery shells and bombs filled with chemical agents. Was developing ballistic missiles. Has a chemical-agent warhead for their surface-to-surface missiles.

Iraq: Used chemical weapons repeatedly during the Iraq-Iran war. Later it attacked Kurdish villagers in northern Iraq with mustard and nerve gas. Since end of Gulf War UN destroyed more than 480'0000 liters of Iraq's chemical agents and 1.8 million liters of precursor chemicals.

Libya: Obtained its first chemical agents from Iran, using them against Chad in 1987. Opened its own production facility in Rabta in 1988. May have produced as much as 100 tons of blister and nerve agents before a fire broke out in 1990. Is building a second facility in an underground location at Tarhunah.

Saudi Arabia: May have limited chemical warfare capability in part because it acquired 50 CSS-2 ballistic missiles from China. These highly inaccurate missiles are thought to be suitable only for delivering chemical agents.

Asia

North Korea: Program since 1960s, probably largest in the region. Can produce "large quantities" of blister, blood, and nerve agents.

South Korea: Has the chemical infrastructure and technical capability to produce chemical agents, had a chemical weapons program.

India: Had CW stocks and weapons.

Pakistan: Has artillery projectiles and rockets that can be made chemical-capable.

China: China has a mature chemical warfare capability, including ballistic missiles.

Taiwan: Had an "aggressive high-priority program to develop both offensive and defensive capabilities", was developing chemical weapons capability, and in 1989, it may be operational.

Burma: Its program, under development in 1983, may or may not be active today. It has chemical weapons and artillery for delivering chemical agents.

Vietnam: In 1988 was in the process of deploying, or already had, chemical weapons. Also it captured large stocks of US riot control agents during and at the end of the Vietnam War.

Europe

Yugoslavia: The former Yugoslavia has a CW production capability. Produced and weaponized Sarin, sulphur mustard, BZ (a psychochemical incapacitant), and irritants CS and CN. The Bosnians produced crude chemical weapons during the 1992-1995 war.

Romania: Has research and production facilities and chemical weapons stockpiles and storage facilities. Has large chemical warfare program, and had developed a cheaper method for synthesizing Sarin.

Czechoslovakia: Pilot-plant chemical capabilities that probably included Sarin, Soman, and possibly VX.

France: Has stockpile of chemical weapons, including aerosol bombs.

Bulgaria: Has stockpile of chemical munitions of Soviet origin.

USA: Has the second largest arsenal of chemical weapons in the world, consisting of ~31'000 tons of chemicals, and 3.6 million grenades [14]. The chemical weapons contain about 12'000 tons of agents, and 19'000 tons are in bulk storage. Details on composition and location are given in Table 1.

Russia: An estimate of the Russian stockpile in 1993 puts it at ~40'000 agent tons, of which one-fourth is of pre-World War II vintage. A larger portion seems to be in bulk storage [15]. Out of the officially declared quantity 30'000 tons are phosphoric organic agents (Sarin, Soman, VX), the remaining 10'000 tons are composed of 7'000 tons Lewisite (in containers ?), 1'500 tons of mixture of mustard gas and Lewisite (GB, GD, VX), and 1'500 tons mustard gas. Slightly different numbers on the composition of the arsenal are given in ref. [16].

Locations of the US Unitary Chemical Stockpile

Site	Agent	Agent Tons	Percent of Stockpile
Anniston Army Depot (ADAD), Anniston, AL	GB, HD, HT, VX	2'253.63	7.4
Aberdeen Proving Ground (APG), Edgewood, MD	HD	1'624.87	5.3
Blue Grass Army Depot (BGAD), Richmont, KY	GB, HD, VX	523.41	1.7
Johnston Island (JI), Pacific Ocean	GB, HD, VX	1'134.17	3.7
Newport Chemical Activity (NECA), Newport, IN	VX	1'269.33	4.2
Pine Bluff Arsenal (PBA), Pine Bluff, AR	GB, HD, HT, VX	3'849.71	12.6
Pueblo Depot Activity (PUDA), Pueblo, CO	HD, HT	2'611.05	8.5
Tooele Army Depot (TEAD), Tooele, UT	H, HD, HT, GA, GB L, TGA, TGB, VX	13'616.00	44.5
Umatilla Depot Activity (UMDA), Herminston, OR	GB, HD, VX	3'717.38	12.2
Total		**30'599.55**	**100.0**

Non-persistent nerve gas agents: Tabun (GA) and Sarin (GB) and their thickened products (TGA and TGB)
Mustard agents (H, HD and HT)
Lewisite (L)
Persistent nerve agent (VX)

Agents of the US Unitary Chemical Stockpile

Agent	Site	Agent Tons	Percent of Stockpile	Total
GA	TEAD	1.41	0.005	**1.41**
GB	ANAD	436.51		
	BGAD	305.64		
	JI	617.48		
	PBA	483.69		
	TEAD	6'045.26		
	UMDA	1'041.01	29.1	**8'902.59**
H	TEAD	319.77	1.5	**319.77**
HD	ANAD	456.08		
	APG	1'624.87		
	BGAD	90.63		
	JI	164.86		
	PBA	94.20		
	PUDA	2'551.94		
	TEAD	5'694.64		
	UMDA	2'339.52	42.5	**13'016.74**
HT	ANAD	532.30		
	PBA	3'124.55		
	PUDA	59.11		
	TEAD	181.51	12.7	**3'897.47**
L	TEAD	12.96	0.004	**12.96**
TGA	TEAD	0.64	0.002	**0.64**
TGB	TEAD	3.48	0.01	**3.48**
VX	ANAD	828.74		
	BGAD	127.15		
	JI	351.83		
	NECA	1'269.33		

	PBA	147.27		
	TEAD	1'356.33		
	UMDA	363.86	14.5	**4'444.51**
TOTAL			**100.0**	**30'599.55**

US Binary Chemical Stockpile

Site	Type Fill	Component Tons	Total
APG	QL	0.73	
	DF	0.57	1.30
PBA	QL	48.21	
	DF	126.51	174.72
TEAD	OPA	33.58	33.58
UMDA	OPA	470.59	470.59
TOTAL			**680.19**

Methylphosphonic difluoride (DF)
Isopropyl alcohol and isopropylamine (OPA)
Ethyl 2-diisoprpylaminoethyl methylphosphonite (QL)

Tables 1. US Unitary and Binary Chemical Stockpiles

The above tables give the location of the nine depots and the variety of chemical weapons stored, which is an indication for the complexity for their elimination or transport problems.

3.4.2 The non-stockpile material

Data on non-stockpile material are scarce. Some estimates are available for the US [11].

All the material recovered in the US thus far contains only hundreds of tons of agent and could, in theory, be placed in a single 8-metre-by-25-metre storage building [11]. A considerable amount of money will be required for the destruction of all former facilities for chemical weapons production constructed or used after January 1, 1946.

Abandoned chemical weapons do represent a safety risk. Between 1985 and 1995 Dutch fishermen reported more than 350 cases where chemical weapons, dumped into the Baltic Sea, were caught in fishing nets, some resulting in serious burns. In China during World War II the Japanese left 678'729 chemical weapons. Recent negotiations resulted in Japan's agreement to collect and destroy these weapons. The most persistent agents - sulfur mustards - can remain dangerous for decades.

Recovery of ammunitions from World War I still continues. Annual collections by France amount to about 30-50 tons along the old front line, by Belgium to 17 tons (c. 1'500 items) [17].

4. Elimination of Chemical Weapons

The CWC not only prohibits the use, production, acquisition and transfer of chemical weapons, but also requires the states-parties to destroy their existing weapons and production facilities. For the US the deadline is April 29, 2007. The CWC prohibits disposal by dumping into a body of water, land burial or open-pit burning, and requires that the chosen technology destroy the chemical agent in an irreversible manner that also protects the safety of humans and the environment.

4.1 Program and costs

The process of elimination is a slow, tedious one, with rising costs as time passes by. A bilateral US - USSR agreement in June 1990 to destroy at least 50 percent of their stockpiles by 1999 and to retain no more than 5'000 tons of agent by 2002 is long outdated [18]. Since 1985, the US Army's cost estimate for the *stockpile disposal* program has increased from estimates in 1985 of $1.7 billion to $15.7 billion as of today, and its projected completion date has slipped from 1994 to 2007 [15, 11]. The *non-stockpile disposal* program is currently projected to cost $15.1 billion - nearly the cost of the stockpile disposal program - and will take until 2033 to complete [11]. There the major cost factor arises from the difficulties of detection of scattered chemical weapons, due to insufficient book-keeping, the necessity to design and built new mobile disposal systems, and last not least overcoming the public opposition of destruction or transporting lethal CW in the vicinity of habitats. The provisions in the CWC will not apply to weapons buried on its territory before 1 January 1977.

4.2 The abandoned weapons

Chemical weapons are buried on land, dumped into the sea and simply lost at many places on our globe [17]. Finding, collecting and destroying them might be as difficult, dangerous and time consuming as those of land mines.

4.3 Status and problems with the destruction of the existing active arsenal

Since the weight of a typical chemical weapon is roughly ten times that of the agent it contains, and other nations may have as much as 10-15 percent of the combined Russian and US stockpile, the mass of the material to be destroyed comes to roughly 500'000 tons - nearly 100'000 truckloads of material. Munitions must be taken apart, separated from the chemical agents. The cost of disassembly can outrun the cost of agent destruction many fold - in some cases by 10-20 times. The US choose high-temperature incineration and chemical neutralization as its preferred destruction technique. Until the end of 1999 about 22 percent of its chemicals had been incinerated [7].

The destruction of the Russian arsenal faces both, financial and technical challenges [16]. Russia does not want to copy the well-proven American incineration technology. Its own neutralization-bituminization program has not been developed beyond the laboratory bench, and therefore had destroyed only a few thousand weapons [19]. The idea of incineration of their chemical weapon arsenal by nuclear explosion is studied in Russia's former weapons laboratories [20]. This procedure, even if it is feasible deep underground, is not compatible with the Comprehensive Test Ban Treaty (NPT) and will find also serious resistance from environmentalists.

4.4 A Comparison of chemical weapons agents with other waste problems

Our civilization produces a great variety of waste products, with differing degrees of danger for the environment and people. They range from household waste, electronic waste from the information age, to toxic waste from chemical factories, by-products of the mining industry, coal and oil firing, and last not least to those from military and civil use of nuclear energy. Among these waste products is a largely unknown environmental hazard due to the one-to-two-hundred tons of Mercury, that have been discharged into nature during the manufacturing of nuclear weapons in the US (Hanford/Washington). Its impact on the food chain can become catastrophic on a regional level [21]. Even the most widely used propellant of weapons, Trinitrotoluol or TNT, is a threat to the environment because of its persistency and its ability to enter easily into ground water.

A ***crude estimate*** of the importance of the chemical weapon waste relative to other human waste production can be made taking data from the annual production of waste in kilogram per inhabitant in France:

	Kg/person/year
Household (kitchen garbage, diverse domestic scrap)	360
Agriculture (plastic, farming scrap)	7'300
Industrial waste (metal waste, iron, non-iron, powders, technology waste)	3'000
thereof classified as **toxic waste**	100
Hospital waste	15
Nuclear waste (packaged)	1.2
Total waste	10'776

Table 2
Annual waste production in kilogram per person in France [22]

And by assuming that waste production per person in France (population 58 million) and the United States (population 267 million) is comparable (probably an underestimation of the US figures), the total waste of these categories can be estimated for the US in tons per year:

	tons/year
Household	$100 \cdot 10^6$
Agriculture	$2 \cdot 10^9$
Industrial waste	$800 \cdot 10^6$
thereof toxic waste	**$30 \cdot 10^6$**
Nuclear waste	**$320 \cdot 10^0$**
Chemical weapons waste	**$500 \cdot 10^0$**
Total waste	$3 \cdot 10^9$

Table 3
Crude estimate of annual waste production in the US

It is assumed that the 30'000 tons of US chemical weapons material were accumulated over ~60 years, i.e. on the average 500 tons produced per year. The above ***order of magnitude estimate*** shows, that nuclear and chemical weapons wastes are in the same ball part, but are hundred thousand times smaller than the other toxic/dangerous waste. Due to the complexity of the toxic items, a qualitative comparison of present and future dangers for mankind and environment by taking **only** the quantitative aspects into consideration can and should not be made since it may lead to wrong conclusions.

5. Non-lethal chemical weapons

All weapons are made out of chemical elements, be it the metal shell of a grenade, sometimes made of depleted uranium, the explosive agent to propel it or the material filled into its encasing. The dangers of highly toxic, volatile rocket fuel on the delivery systems of nuclear warheads in Russia may be very high [23]. For this simple reason alone it is difficult to come up with an all-encompassing definition for chemical weapons.

Are chemicals still material of weapons if they are used in very low concentrations? The latter point may be illustrated by the double use of Zyklon B (or Cyclon B in English), that is used as fumigant for the purpose of pest and vermin control. It had been applied in *low concentration* in a beneficial way in the Nazi concentration camp of Dachau, while utilized in *high concentration* in the gas chambers of Auschwitz, it lead to one of the most criminal acts committed in the twentieth century [24].

Dozens of technologies are being studied or developed under the elastic rubric of "non-lethal weapons" [25]. They include infrasound, supercaustics, irritants like tear gas, and all those that could be aimed at non-human targets - such as combustion inhibitors, chemicals that can immobilize machinery or destroy airplane tires. The text of the CWC does not give always an unambiguous answer or definition what is a chemical weapon agent. It could be asked if the following agents fall into the category of chemical weapons, some of them old as war [9], like (i) ***Military Smoke Agents,*** (ii) ***Incendiaries*** producing fires and burns of skin? Where do the recently used or newly developed ones belong, like (iii) ***Depleted Uranium Ammunitions***, (iv) ***Sticky Foam, Super Lubricants*** ("slickums and stickums"), or (v) ***Pulsed Chemical Laser Beams*****?**

The preamble to the *Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May Be Deemed To Be Excessively Injurious or To Have Indiscriminate Effects* (CCW), and less formally referred to as the **"Inhuman Weapons Convention"**, expressed the wish for amendments. Among those was the elimination of laser weapons, which are now banned by the *Protocol IV, which* was adopted by the Conference of the States Parties to the Convention and entered into force on 30 July 1998 [26, 27].

Other weapons are being negotiated, like submunitions in the form of bomblets assembled in clusters and delivered by aircraft or by artillery, rockets or guided missiles, be equipped with devices making them harmless if they fail to explode. One canister may contain 50 bomblets, or 600, or even as many as 4'700, depending on the model, and may cover a ground area from 100 to 250 meters in diameter. The bomblets, when fitted with delayed action fuses, are effective area-denial weapons. Usually about 30% fail to explode and remain as mines, like many in Kosovo after the 1999 war.

Depleted Uranium (DU), which draw a lot of public attention in the recent decade, is a by-product of enriching natural uranium - increasing the proportion of the U235 atom which is the only form of uranium that can sustain a nuclear reaction and is used in nuclear reactors or nuclear weapons. The remaining depleted uranium has practically no commercial value. The Department of Energy in the US (DoE) has a 560'000-metric-ton stockpile, with very limited civilian use as a coloring matter in pottery or as a steel-alloying constituent [28]. Depleted uranium is chemically toxic like other heavy metals such as lead, but it is primarily an alpha particle emitter with radioactive half-life of 4.5 billion years.

In the 1950's the US became interested in using depleted uranium metal in weapons because it is extremely dense, pyrophoric, cheap, and available in high quantities. Kinetic energy penetrators do not explode; they fragment and burn through armour due to the pyrophoric nature of uranium metal and the extreme flash temperatures generated on impact. They contaminate areas with extremely fine radioactive and toxic dust. This in turn can cause kidney damage, cancers in the lung and bone, non-malignant respiratory decease, skin disorders, neurocognitive disorders, chromosomal damage, and birth defects [29]. Depleted uranium weapons are proliferating and are likely to become commonly used in land warfare. The United States, the United Kingdom, France, Russia, Greece, Turkey, Israel, Saudi Arabia, Kuwait, Bahrain, Egypt, Thailand, Taiwan and Pakistan are possessing or manufacture depleted uranium weapons. Many NATO countries may follow suite. These weapons were used in large quantities first in the 1991 Gulf War [29, 30], and then again during the Kosovo War in 1999 [31]. The question can be asked if DU is mainly a chemical, or a radiological weapon? An immediate answer is not to be expected before classified material becomes available, and the medical reason for the Golf-War Syndrome is identified, which shows up in thousands of American soldiers. It appears that effect of the radioactive by inhalation of small doses will have only a small impact on risk to die of cancer, whereas the heavy metal effect seems to dominate [32]. Be it as it might be, depleted uranium is dangerous, but is pales in comparison with the other direct and indirect effects of war.

Chemical weapons may be masked as pesticides, fertilizers, dyes, herbicides, or defoliants. Between 1962 and 1971 more than 72 million liter herbicides were distributed over South Viet Nam [33], thereof more than 44 million liter were the defoliant *agent orange*, containing about 170 kg dioxin. American scientists developed a means of thickening gasoline with the aluminum soap of naphtenic and palmitic acids into a sticky syrup that carries further from projectors and burns more slowly but at a higher temperature. This mixture, known as **Napalm,** can also be used in aircraft or missile-delivered warheads against military or civilian targets. A small, high explosive charge scatters the flaming liquid, which sticks to what it hits until burned out. Is Napalm still only a herbicide even when used in too large a quantity, and then *accidentally* affecting humans?

White phosphorous is used as a shell and grenade filler in combination with a small high-explosive charge. It is both an incendiary and the best-known producer of vivid white smoke. Small bits of it burn even more intensely than Napalm when they strike personnel.

Herbicides are not covered by the Convention but they are banned under the **Prohibition of Military or any other Hostile Use of Environmental Modification Techniques** (ENMOD), adopted by the UN General Assembly on the 10th of December 1976 and entered into force the 5th of October 1978 [34].

In order to curb the production of chemical weapons, require their identification, e.g. by trace elements in ammunition!

6. Old and New Biological Weapons

The use of biological agents as weapon has always had an even more adverse world opinion than chemical warfare. A SIPRI Monograph describes among other topics the changing view of biological and toxin warfare agents, the new generation of biological weapons, the changing status of toxin weapons, a new generation of vaccines against biological and toxin weapons, and the implications of the BWC [35].

Claims that biological agents have been used as weapons of war can be found in both the written records and the artwork of many early civilizations [35]. As early as 300 BC the Greeks polluted the wells and drinking water supplies of their enemies with the corpses of animals. Later the Romans and Persians used the same tactics. In 1155 at a battle in Tortona, Italy, Barbarossa broadened the scope of biological warfare, using the bodies of dead soldiers as well as animals to pollute wells. In 1863 during the US Civil War, General Johnson used the bodies of sheep and pigs to pollute drinking water at Vicksburg. The use of catapults as weapons was well established by the medieval period, and projecting over the walls dead bodies of those dead of disease was an effective strategy for besieging armies. In 1763 the history of biological warfare took a significant turn from the crude use of diseased corpses to the introduction of specific decease, smallpox ("Black Death"), as a weapon in the North American Indian Wars. This technique continued with cholera or typhus infected corpses. In 1915, during World War I, Germany was accused of using cholera in Italy and plague in St. Petersburg. There is evidence Germany used glanders and anthrax to infect horses (1914) and cattle, respectively, in Bucharest in 1916, and employed similar tactics to infect 4'500 mules in Mesopotamia the next year.

The period 1940 - 1969 can be considered the golden age of biological warfare research and development. Especially the 1940s were the most comprehensive period of biological warfare research and development.

6.1 Definitions [35]

Biological warfare (BW) agents, or biological weapons, are *'living organisms, whatever their nature, or infectious material derived from them, which are intended to cause disease or death in man, animal, and plants, and which depend for their effects on their ability to multiply in the person, the animal, or plant attacked'*. BW agents, however, might be used not only in wars, but also by terrorists. One should therefore refer to living organisms *'used for hostile purposes'*.

6.2 Toxic warfare agents and other chemical warfare agents

Toxins are poisonous substances usually produced by living organisms. Toxin warfare (TW) agents, or toxic weapons, are toxins used for hostile purposes.

TW agents unequivocally are types of chemical warfare (CW) agent. CW agents, or chemical weapons, are chemical substances whether gaseous, liquid, or solid, which are used for hostile purposes to cause disease or death in humans, animals or plants and which depend on their direct toxicity for their primary effect.

TW agents, like all other CW agents, are inanimate and are incapable of multiplying. They are CW agents irrespective of whether they are produced by a living organism or by chemical synthesis or even whether they are responsible for the qualification of that organism as a BW agent.

Nevertheless, TW agents are often mistakenly considered to be biological weapons, and definitions of biological warfare (BW) occasionally include TW agents.

New chemical weapons agents, who are 5 to 10 times more dangerous than VX, the most dangerous toxic gas known today.

The successful control of biological weapons is a daunting task [37]. Ensuring safety from biological and toxin weapons is a more complex issue than controlling chemical or nuclear weapons. This is due to the character of the relevant technologies. More than those, biotechnology is of dual-use, i.e. the same technology can be used for civilian and permitted military defensive purposes as well as for prohibited offensive or terrorist purposes.

6.3Biological Warfare against Crops

Intentionally unleashing organisms that kill an enemy's food crops is a potentially devastating weapon of warfare and terrorism [38]. All major food crops come in a number of varieties, each usually suited to specific climate and soil conditions. These varieties have varying sensitivities to particular diseases. Crop pathogens, in turn, come in different strains or races and can be targeted efficiently against those crop brands. This way it might be possible to attack the enemy's food stock, but preventing damage to the own. However, such a strategy may not work for neighboring countries, where agricultural conditions are similar to the aggressor. The spread of those organisms holds the risk of worldwide epidemic, and the use of these weapons may very well be counter productive. Any such warfare would be directed primarily against the civilian population. Due to the delays involved it would not affect immediately the outcome of a war.

Nevertheless, many countries developed during the twentieth century anticrop substances.

Iraq manufactured from the 70s onward wheat smut fungus, targeting wheat plants in Iran. France's biological weapon program by the end of the 1930s included work on two potato killers. During the Second World War the British concentrated on various herbicides. Germany investigated during the same period diseases like late blight of potatoes and leaf-infecting yellow and black wheat rusts, as well as insect pests, such as the Colorado beetle. Japan's World War II biological weapons program is not too well known, but it contains pathogens and chemical herbicides. The American efforts were substantial. They centered on products attacking crops of soybeans, sugar beets, sweet potatoes and cotton, intended to destroy wheat in the western Soviet Union, and rice in Asia, mainly China. Between 1951 and 1969 the U.S. stockpiled more than 30'000 kilograms of the fungus that causes stem rust of wheat, a quantity probably enough to infect every wheat plant on the planet. The U.S., using the “feather bomb” and free-floating balloons developed ingenious distribution and transport systems.

7. The Challenges for Implementation of the Chemical and Biological Weapons Convention.

Like most scientific and industrial developments there is the possibility to apply them for the good or for the bad. The responsibility of the scientists, as well as the politicians and military, is challenged. The production of the basic material for military or civilian application is closely intertwined. This makes any inspection and accusation of intended military use extraordinary difficult. In addition manufacturers fear for their patents and are worried about industrial espionage.

Production of biological warfare agents can be done in any hospital or small basement rooms, for chemicals it requires larger plants.

The 121 States Parties and 48 signatory states of the Chemical Weapons Convention have an implementation body, the *Organisation for the Prohibition of Chemical Weapons* (OPCW), which is operational since two years from The Hague [7]. It performed already more than 500 inspections. The OPCW has about 500 staff members, consisting of 200 inspectors and 300 administrative staff. Out of these 300 administrators most are verification experts and inspection planers. Among the most important old issues are: guidelines for low concentrations, the usability of old and abandoned chemical weapons. As mentioned above the Chemical Weapons Convention (CWC) does not cover sea-dumped chemical weapons.

There has not yet been progress in the establishment of an analogue organization for Biological and Toxin Weapons Convention (BWC) [17]. It might be placed in The Hague or in Geneva. Work on the protocol to strengthen the Biological Weapons Convention, as well as the verification protocol is still in its initial state. Of the 141 States Parties to the BWC only around 60 send delegations to the Ad Hoc Group (AHG). Not all of the AHG accept the concept of random visits. The establishment of an international organization to oversee the implementation of the BWC protocol is estimated to consist out of a staff of 233 people and an annual cost of approximately $30 million. There might be eventually about 70 inspectors carrying out approximately 100 visits per year. One of the disputed topics is related to new forms of biological weapons, caused by the biotechnology revolution [36]. The delivery system or the efficiency of these new agents has not changed, but their capability to manipulate human life processes themselves. Biological weapons should now be seen as a global threat to the human species, but not as an efficient weapon in warfare.

Inspections of biological agents will hit more resistance by the pharmaceutical and biotechnical industry than the one in the chemical industry.

The **B**iological **W**eapons **C**onvention (BWC) prohibits bacteria such as salmonella being used against soldiers. It would permit bacteria, that eat petroleum or rubber for the destruction of equipment for peaceful purposes, but prohibits their use for hostile application.

The dangerous leftovers from the chemical weapons race, like the ones from nuclear weapons construction, not to forget the land mines, will be still with us for a long time. Ethics, politics and international security should be closely interlaced to remove these inhuman weapons from Earth. There is an excellent opportunity for fruitful collaboration between defense conversion sector and the environmental community.

The CBWC has certainly the beneficial effect in reducing the arsenal of old weapons, but will not give a guarantee that new, clandestine developments in various countries will go on unnoticed.

8. WMD: Warfare, Terrorism, Comparative Perspective

The concept of weapons of mass destruction (WMD) should be revisited, as pointed out in the Introduction of this article.

8.1 Weapons in Warfare

The efficiency of weapons in warfare is closely related to the ***time parameter***:

- Number of enemy casualties in a given period,
- Number of weapons employed to obtain the desired result,
- Delivery time of weapons,

- Possibility for stockpiling over extended periods,
- Infrastructure affected by its use,
- Avoidance of negative impact upon own troops and civil population,
- End a war quickly,
- No efficient defense against weapons on short or long term.

Evidently, nuclear weapons are *“superior”* to any other weapons on all these points.

Is a specific weapon category useful in conflicts between countries and/or in civil war? Can it serve as a deterrent? Does its use have long term effects on the crop area?

Finding an answer to these questions can be facilitated by evaluation of previous wars.

In World War I an average of **one ton** of agent was necessary **to kill just one soldier**. Chemical weapons caused 5 percent of the casualties. The use of chemical weapons did not end the war quickly as had been predicted. During the war between Iraq and Iran through March 1997 27’000 Iranians were exposed to chemical grenades, only 265 died. During the entire war between these two countries chemical weapons killed 5’000, out of the total 600’000 from all causes, i.e. less than 1 percent.

The efficiency of chemical and biological weapons depends heavily on its dispersion, the upon the weather condition, determining the exposure and lethality for the combatants. A presumptive agent must not only be highly toxic, but also *‘suitably highly toxic’*, so that it is not too difficult to handle by the user. It must be possible to store the substance in containers for long periods without degradation and without corroding the packaging material. Such an agent must be relatively resistant to atmospheric water and oxygen so that it does not lose its effect when dispersed. It must also withstand the shearing forces created by the explosion and heat when it is dispersed. Transport of these agents by long-range missiles and efficient distribution will face enormous difficulties, causing their decomposition, mainly due to the heat development of the warhead at re-entry into the atmosphere.

Under ideal conditions 1 ton of Sarin dropped from an airplane could produce 3’000 to 8’000 deaths, however, under breezy conditions only 300 to 800. To obtain a sensible effect requires that airplanes fly at very low altitude (less than about 100 meters), and consequently the zone of lethality that could be covered remains small. Furthermore, agent particles larger than 10 micrometers do not reach the non-ciliated alveolar region in the lungs, and those, with a size of about 1-micrometer are exhaled. The optimal size is somewhere between 10 to 5 micrometers, which can not be obtained easily. Sunlight kills or denatures most biological agents. Anthrax efficiency may drop by a factor of thousand when the agent is used during a sunny day. Therefore, the agents have to be sprayed during nighttime.

8.2 Weapons for Terrorists

There is a largely unjustified fear of the public concerning terrorist attacks with chemical or biological agents, their impact on daily life, their frequency, and number of people possibly affected.

Between 1960 and 1980 there have been 40’000 international terror incidents (according to CIA), but only 22 out of them were performed with chemical or biological agents, showing a tiny ratio of 1/2’000. From 1900 till today there occurred 71 terrorist acts worldwide involving the use of biological or chemical agents, resulting in 123 fatalities, among those only one was American, hit by a cyanide-laced bullet. These acts produced 3’774 nonfatal injuries (784 Americans, 751 out of them by salmonella food poisoning by an Oregan-based religious sect). During the first nine decades of the 20^{th} century there have been 70 biological attacks (18 by terrorists), causing 9 deaths [39].

The Aum-Shinrikyo sect in Japan had about $1 billion at its disposal for development of chemical and biological weapons.

- Aum had appropriate equipment (even more than it was necessary).
- Aum had used commercial front companies to buy the equipment.
- Aum may have spent about $10 million in their effort to produce biological agents.
- Several of the individuals had post-graduate degrees.
- Aum had gathered a research library.
- Aum had sufficient time – four years – for their attempts.
- Aum had attempted to purchase expertise in Russia and obtain or purchase disease strains in Japan.

However, Aum failed to produce either of ***two biological agents,*** Clostridium botulinum, to obtain Botulinum toxin, and anthrax, and also did not manage to “disperse” them. Despite its efforts, spending $10 million on the development of biological agents. Aum sprayed botulinum toxin over Tokyo several times in 1990, and conducted similar activities with anthrax spores in 1993, but without any known effects. Actually, the cult had used a relatively harmless anthrax vaccine strain and the aerosolizer had no sufficient efficiency.

There are two well-publicized Aum attacks with ***chemical agents*** (Matsumoto, 3 kg of pure Sarin, 1994; Tokyo subway, 6-7 kg 30% pure Sarin, 1995), made under ideal conditions. Nevertheless, the Matsumoto assault killed only seven non-targeted innocents, and in Tokyo only twelve people died from direct contact with the liquid [40].

A more detailed description of risk assessment by terrorism with chemical and biological weapons can be found in [41]. This article provides results from computer simulation for dispersion of chemical and biological agents under various atmospheric conditions and their impact parameters on human health.

8.3 Comparative Perspective

Analysts have defined ***Mass Casualty*** as anything between 100 and 1'000 individuals arriving at hospitals. The numbers in the previous section are related to deaths, and a factor of up to about ten has to be applied to encompass individuals suffering non-lethal injuries. Evidently, similar factors have to be used for victims of conventional weapons in war.

In the discussion of biological agent terrorism as a potential mass casualty event it is quite revealing to look at the annual mortality in several public health sectors in the USA:

• Food-borne disease incidence:	76 million cases per year
	315'000 hospitalizations per year
	5'000 deaths per year
• Medical error mortality:	between 44'000 and 98'000 deaths per year
• Hospital contracted infections:	20'000 deaths per year
• The 1993 cryptosporidium outbreak in Milwaukee (water pollution) sickened	400'000 people
• Air pollution in the US results in	50'000 deaths per year
• Firearms result in	35'000 death per year.

Compared with these data, the impact of biological and chemical agents' terrorism in the past is absolutely negligible and will remain probably (hopefully!) small.

The arguments presented in this article – specifically in this last chapter - are not intended to slow down efforts for the elimination of chemical and biological weapons. The CBWC should remain an important treaty and should be fully implemented as quickly as possible. In particular, the arsenal of unused weapons, being in storage or *"disposed"* in the oceans or elsewhere, presents a considerable danger on short and long term for humans and the environment. Anybody killed by these weapons is one too much. However, we have to put these weapons and the ratified conventions in the right quantitative perspective.

In the view of the author most of the conventional weapons, in particular small arms, are weapons of ***Mass Killing***: According to a Red Cross inquiry [42] *Assault Rifles, like AK47s, Handguns, and Land Mines*, caused 64%, 10% and 10% of civilian casualties, respectively. The remaining 16% are almost equally shared between *Hand Grenades, Artillery (including fragmentation and incinerating bombs), Mortars, and Major Weapons*. During the 20th century these weapons had been used to kill 34 million soldiers in combat, 80 million civilians, plus soldiers who died from wounds, accidents or disease. The world was "*fortunate*" that only two nuclear bombs have been dropped in warfare until now. They killed ***"only"*** ~200'000 people. Nevertheless, the nuclear arsenal has to be on the top of the WMD-category, since it has the potential to erase humans from our planet in almost no time.

Maintaining nuclear weapons by the Nuclear Weapon States (NWSs) to deter production and stockpiling of chemical and biological weapons, mainly in *countries of concern*, can only be interpreted as an unjustifiable, unreasonable pretext to keep nuclear weapons indefinitely in stock. Is it politically wise to change the unfortunate, misleading definition of weapons of mass destruction (**WMD ≡ NW + CW + BW**), repeated again and again in the media, and deeply engraved into the mind of people? Will a new definition distract from the importance of the two, universally ratified treaties? Might it be counterproductive to do so in a time, where scientists are under increasing scrutiny and attack?

The author felt that informing the educated public and policy makers on a re-definition of ***WMD*** warrants the change and outweighs possible negative repercussions.

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