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REVIEW ARTICLE

Biological warfare, bioterrorism, biodefence and the biological and toxin weapons convention

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Biological warfare is the intentional use of micro-organisms, and toxins, generally of microbial, plant or animal origin to produce disease and death in humans, livestock and crops. The attraction of bioweapons in war, and for use in terroristic attacks is attributed to easy access to a wide range of disease-producing biological agents, to their low production costs, to their non-detection by routine security systems, and to their easy transportation from one place to another. In addition, novel and accessible technologies give rise to proliferation of such weapons that have implications for regional and global security. In counteraction of such threats, and in securing the culture and defence of peace, the need for leadership and example in devising preventive and protective strategies has been emphasised through international consultation and co-operation. Adherence to the Biological and Toxin Weapons Convention reinforced by confidence-building measures sustained by use of monitoring and verification protocols, is indeed, an important and necessary step in reducing and eliminating the threats of biological warfare and bioterrorism.

Biological warfare is the intentional use of micro-organisms, and toxins, generally, of microbial, plant or animal origin to produce disease and/or death in humans, livestock and crops. The attraction for bioweapons in war, and for use in terroristic attacks is attributed to their low production costs, The easy access to a wide range of disease-producing biological agents, their non-detection by routine security systems, and their easy transportation from one location to another are other attractive features (Atlas, 1998). Their properties of invisibility and virtual weightlessness render detection and verification procedures ineffectual and make non-proliferation of such weapons impossibility. Consequently, national security decision-makers defence professionals, and security personnel will increasingly be confronted by biological warfare as it unfolds in the battlefields of the future (Schneider and Grintner, 1995).

Current concerns regarding the use of bioweapons result from their production for use in the 1991 Gulf War; and from the increasing number of countries that are engaged in the proliferation of such weapons i.e. from about four in the mid-1970s to about 17 today (Cole, 1996, 1997). A similar development has been observed with the proliferation of chemical weapons i.e. from about 4 countries in the recent past to some 20 countries in the mid-1990s (Hoogendorn, 1997).

Other alarming issues are the contamination of the environment resulting from dump burial (Miller, 1999), the use of disease-producing micro-organisms in terroristic attacks on civilian populations; and non-compliance with the 1972 Biological and Toxins Weapons Convention (Table 1*)*. The diverse roles of micro-organisms interacting with humans as “pathogens and pals” has been described with *Leishmania* infections, and with the presence of *Bacteroides thetaiotaomicron* in the intestines of humans and mice (Strauss, 1999). Also the development of “battle strains” of anthrax, bubonic plague, smallpox, Ebola virus, and of a microbe-based “double agent” has been reported (Thompson, 1999).

Biological/Chemical warfare characteristics

Biological, chemical and nuclear weapons possess the common property of wreaking mass destruction. Though biological warfare is different from chemical warfare, there has always been the tendency to discuss one in terms of the other, or both together. This wide practice probably arises from the fact that the victims of such warfare are biological in origin unlike that in the Kosovo War in which destruction of civic infrastructure, and large-scale disruption of routine facilities were the primary goals, e.g. the loss of electricity supplies through the use of graphite bombs. Another consideration is that several biological agents e.g., toxic metabolites produced by either micro-organisms, animals or plants are also produced through chemical synthesis.

One of the main goals of biological warfare is the undermining and destruction of economic progress and stability. The emergence of bio-economic warfare as a weapon of mass destruction can be traced to the development and use of biological agents against economic targets such as crops, livestock and ecosystems. Furthermore, such warfare can always be carried out under the pretexts that such traumatic occurrences are the result of natural circumstances that lead to outbreaks of diseases and disasters of either endemic or epidemic proportions.

Biological and chemical warfare share several common features. A rather comprehensive study of the characteristics of chemical and biological weapons, the types of agents, their acquisition and delivery has been made (Purver, 1995). Formulae and recipes for experimenting and fabricating both types of weapons result from increasing academic proficiency in biology, chemistry, engineering and genetic manipulations. Both types of weapons, to date, have been used in bio- and chemoterroristic attacks against small groups of individuals. Again, defence measures, such as emergency responses to these types of terrorism, are unfamiliar and unknown. A general state of helplessness resulting from a total lack of preparedness and absence of decontaminating strategies further complicates the issue.

The widespread ability and interest of non-military personnel to engage in developing chemical and biologically based weapons is linked directly to easy access to academic excellence world-wide. Another factor is the tempting misuse of freely available electronic data and knowledge concerning the production of antibiotics and vaccines, and of conventional weapons with their varying details of sophistication.

Several other factors make biological agents more attractive for weaponization, and use by terrorists in comparison to chemical agents (Table 2). Production of biological weapons has a higher cost efficiency index since financial investments are not as massive as those required for the manufacture of chemical and nuclear weapons. Again, lower casualty numbers are encountered with bigger payloads of chemical and nuclear weapons in contrast to the much higher numbers of the dead that result from the use of invisible and microgram payloads of biological agents.

To a great extent, application or delivery systems for biological agents differ with those employed for chemical and nuclear weapons. With humans and animals, systems range from the use of live vectors such as insects, pests and rodents to aerosol sprays of dried spores and infective powders. In the case of plants, proliferation of plant disease is carried out through delivery systems that use propagative material such as contaminated seeds, plant and root tissue culture materials, organic carriers such as soil and compost dressing, and use of water from contaminated garden reservoirs.

In terms of lethality, the most lethal chemical warfare agents cannot compare with the killing power of the most lethal biological agents (Office of Technology Assessment, 1993). Amongst all lethal weapons of mass destruction —chemical, biological and nuclear, the ones most feared are bioweapons (Danzig and Berkowsky, 1997).

Biological agents listed for use in weaponization and war are many. Those commonly identified for prohibition by monitoring authorities are the causative agents of the bacterial diseases anthrax and brucellosis; the rickettsial disease *Q* fever; the viral disease Venezuela equine encephalitis (VEE), and several toxins such as enterotoxin and botulinum toxin.

As a rule, microbiologists have pioneered research in the development of a bioarmoury comprised of powerful antibiotics, antisera, toxoids and vaccines to neutralise and eliminate a wide range of diseases. However, despite the use of biological agents in military campaigns and wars (Christopher et al, 1997), it is only since the mid-1980s that the attention of the military intelligence has been attracted by the spectacular breakthroughs in the life sciences (Wright, 1985). Military interest, in harnessing genetic engineering and DNA recombinant technology for updating and devising effective lethal bioweapons is spurred on by the easy availability of funding, even in times of economic regression, for contractual research leading to the development of:

- vaccines against a wide variety of bacteria and viruses identified in core control and warning lists of biological agents used in biowarfare (Table 3)
- rapid detection, identification and neutralisation of biological and chemical warfare agents
- antidotes and antitoxins for use against venoms, microbial toxins, and aerosol sprays of toxic biological agents
- development of genetically-modified organisms
- development of bioweapons with either incapacitating or lethal characteristics
- development of poisons e.g. ricin, and contagious elements e.g. viruses, bacteria
- development of antianimal agents e.g. rabbit calcivirus disease (RCD) to curb overpopulation growth of rabbits in Australia and New Zealand
- development of antiplant contagious agents e.g. causative agents of rust, smut, etc.

Bioweapons

Bioweapons are characterised by a dual-use dilemma. On a lower scale, a bioweapons production facility is a virtual routine run-of the-mill microbiological laboratory. Research with a microbial discovery in pathology and epidemiology, resulting in the development of a vaccine to combat and control the outbreak of disease could be intentionally used with the aid of genetic engineering techniques to produce vaccine-resistant strains for terroristic or warfare purposes. The best known example,reported by UNSCOM (Table 3), is the masquerading of an anthrax-weapon production facility as a routine civil biotechnological laboratory at Al Hakam. In summary the dual-use dilemma is inherent in the inability to distinctively define between offence -and defence- oriented research and development work concerning infectious diseases and toxins. Whilst progress in immunology, medicine, and the conservation of human power resources are dependent on research on the very same agents of infectious diseases, bans and non-proliferation treaties are associated with the research and production of offensive bioweapons.

Genetic engineering and information are increasingly open to misuse in the development and improvement of infective agents as bioweapons. Such misuse could be envisaged in the development of antibiotic-resistant micro-organisms, and in the enhanced invasiveness and pathogenicity of commensals. Resistance to new and potent antibiotics constitutes a weak point in the bio-based arsenal designed to protect urban and rural populations against lethal bioweapons. An attack with bioweapons using antibiotic-resistant strains could initiate the occurrence and spread of communicable diseases, such as anthrax and plague, on either an endemic or epidemic scale.

The evolution of chemical and biological weapons is broadly categorised into four phases. World War I saw the introduction of the first phase, in which gaseous chemicals like chlorine and phosgene were used in Ypres. The second phase ushered in the era of the use of nerve agents e.g. *tabun*, a cholinesterase inhibitor, and the beginnings of the anthrax and the plague bombs in World War II. The Vietnam War in 1970 constituted the third phase which was characterised by the use of lethal chemical agents e.g. Agent Orange, a mix of herbicides stimulating hormonal function resulting in defoliation and crop destruction. This phase included also the use of the new group of *Novichok* and mid-spectrum agents that possess the characteristics of chemical and biological agents such as auxins, bioregulators, and physiologically active compounds. Concern has been expressed in regard to the handling and disposal of these mid-spectrum agents by "chemobio " experts rather than by biologists (Henderson, 1999).

The fourth phase coincides with the era of the biotechnological revolution and the use of genetic engineering. Gene-designed organisms can be used to produce a wide variety of potential bioweapons such as:

- organisms functioning as microscopic factories producing a toxin, venom or bioregulator
- organisms with enhanced aerosol and environmental stability
- organisms resistant to antibiotics, routine vaccines, and therapeutics
- organisms with altered immunologic profiles that do not match known identification and diagnostic indices
- organisms that escape detection by antibody-based sensor systems

Public attention and concerns, in recent times, have been focused on the dangers of nuclear, biological and chemical-based terrorist threats (Nye, Jr. and Woolsey, 1997). This concern is valid given the significant differences between the speed at which an attack results in illness and in which a medical intervention is made, the distribution of affected persons, the nature of the first response, detection of the release site of the weapon used, decontamination of the environment, and post-care of patients and victims. Pollution and alteration of natural environments occurs with the passage of time, as a consequence of reliance on conventional processes such as dumping of chemical munitions in the oceans; disposal of chemical and biological weapons through open-pit burning; and in-depth burial in soil in concrete containers or metallic coffins (Miller, 1999). Incineration, seemingly the preferred method in the destruction and disposal of chemical weapons, is in the near future likely to be replaced by micro-organisms. Laboratory-scale experimentation has shown that blistering agents, such as mustard mixtures e.g. *lewisite* and *adamsite*, and nerve agents e.g. *tabun*, *sarin* and *saman* are susceptible to the enzymatic action of *Pseudomonas diminuta, Alteromonas haloplanktis*, and *Alcaligenes xylosoxidans.* In disposing of the chemical weapon stockpile of diverse blister and nerve agents, research now focuses on several microbial processes that are environment-friendly and inexpensive in preference to costly conventional chemical processes in inactivating dangerous chemical agents, and degrading further their residues (Mulbry and Rainina, 1998).

Chemical weapons are intended to kill, seriously injure or incapacitate living systems. Choking agents such as phosgene cause death; blood agents such as cyanide-based compounds are more lethal than choking agents; and nerve agents such as *sarin* and *tabun* are still more lethal than blood agents.

The use of bioweapons is dependent upon several stages. These involve research, development and demonstration programmes, large-scale production of the invasive agent, devising and testing of efficiency of appropriate delivery systems, and maintenance of lethal and pathogenic properties during delivery, storage and stockpiling. Projectile weapons in the form of a minuscule pellet containing *ricin*, a plant-derived toxin are ingenuously delivered through the spike of an umbrella. Well known examples of the use of such a delivery system are the targeted deaths of foreign nationals that occurred in London and Paris in the autumn of 1978.

Small-pox virus has long been used as a lethal weapon in biological warfare. The decimation of the American Indian population in 1763 is attributed to the wide distribution by the invading powers of blankets of smallpox patients as gifts (Harris and Paxman, 1982). More recently, WHO after a 23-year campaign declared the eradication of smallpox world-wide in 1980. A landmark date of June 1999, had been set in 1996, for the destruction of the remaining stocks of smallpox virus that were being maintained in Atlanta, Georgia, USA, and Koltsovo, Siberia, Russia. Current issues, however, such as the emergence of immunosuppressed populations resulting from xenotransplantation and cancer chemotherapy, loss of biodiversity, and the re-emergence of old diseases have necessitated a re-evaluation of the decision to destroy "a key protective resource". Fundamental research and field tests continue to focus on determining the minimum infective dose of the biological agent required to decimate targeted populations, the time period involved to cause disease instantaneously or over a long period of time, and the exploitation of the entry mechanisms such as inhalation, ingestion, use of vectors, and the contamination of natural water supplies and food stocks.

The institution of food insecurity is a subtle form of economic and surrogate biological warfare. Conflicts over shared water resources in some regions of the world are commonplace. Human health, food security and the management of the environment are continuously being threatened, regionally and globally, by dwindling reserves of water (Serageldin, 1999). Within the framework of a real world perspective of biotechnology and food security for the 21st century, soil erosion, salinisation, overcultivation and waterlogging are other constituents (Vasil, 1998). Deliberately contaminated food containing herbicide, pesticide or heavy metal residues, and use of land for crops for production of luxurious ornamental plants and cut flowers, is another constituent of food insecurity. Again, new and emerging plant diseases affect food security and agricultural sustainability, which in turn aggravate malnutrition and render human beings more susceptible to re-emerging human diseases (DaSilva and Iaccarino, 1999). The deliberate release of harmful and pathogenic organisms, that kill cash crops and destroy the reserves of an enemy, constitutes an awesome weapon of biological warfare and bioterrorism (Rogers et al, 1999).

Anticrop warfare, involving biological agents and herbicides, results in debilitating famines, severe malnutrition, decimation of agriculture-based economies, and food insecurity. Several instances using late blight of potatoes, anthrax, yellow and black wheat rusts and insect infestations with the Colorado beetle, the rapeseed beetle, and the corn beetle in World Wars I and II have been documented. Defoliants in the Vietnam War have been widely used as agents of anticrop warfare. Cash crops that have been targeted in anticrop warfare are sweet potatoes, soybeans, sugar beets, cotton, wheat, and rice. The agents used to cause economic losses with the latter two foreign-exchange earnings were *Puccinia graminis tritici* and *Piricularia oryzae* respectively. Wheat smut, caused by the fungus *Tilettia caries* or *T. foetida* has been used as a biowarfare weapon (Whitby and Rogers, 1997). The use of such warfare focuses on the destruction of national economies benefiting from export eamings of wheat – an important cereal cash crop in the Gulf region. In addition, the personal health and safety of the harvesters is also endangered by the flammable trimethylamine gas produced by the pathogen. Species of the fungus *Fusarium* have been used as a source of the mycotoxin warfare in Southeast and Central Asia.

Foodborne pathogens are estimated to be responsible for some 6.5 to 33 million cases on human illnesses and up to 9000 deaths in the USA per annum (Buzby et al, 1996). The costs of human illnesses attributed to foodborne causes are between US$2.9 and 6.7 billion, and are attributed to six bacterial pathogens—*Salmonella typhosa, Campylobacter jejuni, Escherichia coli 0157H:H7, Listeria monocytogenes, Staphylococcus aureus* and *Clostridium perfringens* found in animal products. Consequently, there is the dangerous risk that such organisms could be used in biological warfare and bioterrorism given that *Salmonella, Campylobacter* and *Listeria* have been encountered in outbreaks of foodborne infections, and that cases of food poisoning have been caused by *Clostridium, Escherichia* and *Staphylococcus.* Bacterial and fungal diseases are significant factors in economic losses of vegetable and fruit exports. Viral diseases, transmitted by the white fly *Bemisia tabaci* are responsible for severe economic losses resulting from damage to melons, potatoes, tomatoes and aubergines. The pest, first encountered in the mid-1970s in the English-speaking Caribbean region has contributed to estimated losses of US$50 million p.a in the Dominican Republic. Economic losses resulting from infestation of over 125 plant species, inclusive of food crops, fruits, vegetables and ornamental plants have been severe in St. Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, Trinidad and Tobago, and the Windward Islands. In Grenada, crop losses in the mid-1990s were estimated at UD$50 million following an attack by *Maconnellicoccus hirsutus*, the *Hibsicus Mealy Bug*. Kadlec (1995) has explained how "the existence of natural occurring or endemic agricultural pests or diseases and outbreaks permits an adversary to use biological warfare with plausible denial" and has drawn attention to several imaginative possibilities.

The interaction of biological warfare, genetic engineering and biodiversity is of crucial significance to the industrialised and non-industrialised societies. Developing countries that possess a rich biodiversity of cash crops have a better chance of weathering anticrop warfare. On the other hand, the food security of the industrialised societies, especially in the Northern Hemisphere, is imperilled by their reliance on one or two

varieties of their major food crops. The use of genetic engineering, whilst enhancing crop yields and food security, could result in more effective anticrop weapons using gene-modified pathogens that are herbicide-resistant, and non-susceptible to antibiotics. Threats to human health exist with the biocontrol and bioremediation agent *Burkholderia cepacia* during agricultural and aquacultural use (Holmes et al, 1998). Attention has also been drawn to the new and potential threats arising from the uncontrolled release of genetically modified organisms (Av-Gay, 1999).
Another aspect of biological warfare involves the corruption of the youth of tomorrow –the bastion of a nation's human power with cocaine, heroin and marijuana derived from drug and narcotic plantations reared by conventional and/or genetically engineered agriculture. On the other hand, the eradication of such drugs plant crops through infection with plant pathogens could prove counterproductive in yielding more knowledge and skills to wipe out food crops, and animal-based agriculture.

Bioterrorism

Popular scenarios of bioterrorism, that may have some mythical origins and cinematic Hollywoodian links, include the use of psychotic substances to contaminate food; the use of toxins and poisons in political assassinations; raids with crude biological cloud bombs; use of dried viral preparations in spray powders; and low-flying cruise missiles adding destruction and havoc with genetically-engineered micro-organisms.

Public awareness of the growing threat of bioterrorism in the USA is gathering momentum (Henderson, 1999). Development of national preparedness and an emergency response focus in essence, on the co-ordination of on-site treatment of the incapacitated and wounded, on-spot decontamination of the affected environment, detection of the type and character of the biological agent, and its immediate isolation and neutralisation. The rise of bioterrorism as a priority item on the agendas of international concern and co-operation is now being reflected in the establishment of verification procedures to guard against contravention of the Biological and Toxin Weapons Convention, and in efforts in institutionalising a desirable and much needed state of preparedness. In the USA, there has been a boost in funding for such research and defensive measures (Marshall, 1999). International workshops and seminars focus on the peaceful use of biotechnology and the Convention on Biological Weapons (Table 3). In addition several other measures are in force to monitor the development and use of bioweapons (Pearson, 1998). Data generated by the Human Genome Project helps in the use of genomic information

- to develop novel antibiotics and vaccines,
- to enhance national and civil defence systems to contain and counteract the use of biological agents in the manufacture of bioweapons,
- to minimise and eliminate susceptibilities of different peoples, cultural and ethnic groups to hitherto unfamiliar or unknown diseases such genomic research could fuel the production of ethnic or peoples' specific weapons.

Curators and conservationists of biological diversity, public health officials, and biosecurity personnel, developing emergency preparedness provide convincing arguments to continue to maintain live viral stocks for the preparation of new vaccines in guarding against the re-emergence of small-pox as a result of either accidental release or planned use in bioterrorism. The microbiological community, and especially culture collections have an important role to play in educating the public to contain unexpected and sudden outbreaks of diseases through minimising the easy acquisition of microbial cultures for use in bioterrorist threats. To offset the illegitimate use of microbial cultures, obtained through either fraudulent or genuine means, the microbiological community naturally occupies a central role in answering the challenges posed in the production of bioweapons Biological agents may be obtained from culture collections providing microbial species for academic and research purposes; supply depots of commercial biologics; field samples and specimens; and application of genetic engineering protocols to enhance virulence (Atlas, 1998). An example is the acquisition by a laboratory technician, of the causative agent of bubonic plague through the routine mailing system. In addition to expanding and safeguarding the planet's microbial genetic heritage, certified microbiologists can contribute to the building up of the defences of peace through the development of educational and public health training programmes, and surveillance protocols in counteracting bioterrorism.

A recent survey of over 1400 research institutions, universities, medical colleges, and health science centres in the USA focused on research activities, production capabilities and containment facilities that may necessitate compliance declarations with the protocols of the Biological and Toxin Weapons Convention (Weller et al, 1999). However, in the absence of a systematised infrastructure, the administrative, educational, economic and legal costs are burdensome and considerable. Compliance declarations and regimes are of direct consequence with institutions that are engaged in routine and genetically–engineered research with specialised groups of microbial pathogens and toxins; that possess high-level containment facilities and laboratories; that are engaged in the design and engineering of high-production capacity bioreactors with fermentation volumes of 100-litres and above; and that do contract research for government and industry with biological agents that could serve as potential triggers of biological warfare and bioterrorism (Weller et al, 1999).

In brief, the very skills and technologies that are used by industry to screen, process and manufacture drugs and vaccines could be used to develop bioweapons. Given the increasing risks to pertaining to the threats of bioterrorism and bioweapons, and the dilemma of dual-use technologies, site-verification of existing facilities and data assemblage and monitoring activities seem to be necessary. Nevertheless, despite bio-industrial concerns based on potential risks pertaining to loss of confidential biotechnological data and proprietary genetic holdings, compliance with the Biological and Toxin Weapons Convention is a must. The role of industry in designing apt verification measures is a crucial element in the strengthening of the convention (Department of Foreign Affairs and Trade, 1999). Doing so, as a fundamental and primary step, provides recognition of the utility of the convention, and at the same time strengthens its importance and authority in the outright banning of the production, stockpiling and manufacture of undesirable bioweapons (Monath and Gordon, 1998). The practice of such investigations emphasises the growing need for the development of a verification protocol that deters and discourages violation of the Convention (Butler, 1997).

The necessity of producing and stockpiling the small-pox vaccine has been emphasised in testimony by the author of the Hot Zone and Cobra Event (Preston, 1998). These are entertainment scenarios about the outbreaks of the Ebola virus in the nearby surroundings of Washington, D.C., and a bioterroristic event in New York City respectively. The potential outbreak of an epidemic of the now eradicated small-pox, in a population that has not been vaccinated since the registration of the last known case in Somalia in 1977, is a human disaster waiting to happen and which can be contained and avoided well ahead in time.

Another aspect of bioterrorism is to disrupt agriculture, to decimate livestock, to contaminate the environment, and to seed food insecurity through intentional food poisoning and food infection. Concerns, recently, have been expressed about the possible outbreak of gastrointestinal anthrax in Badakhshan, Afghanistan (Scott and Shea, 1999), and in the border areas neighbouring Tajikistan, following first reports of symptoms which are also common to cholera, gastrointestinal anthrax, plague, tularaemia and listerosis.

Appropriate control measures in combating bio- and chemical terrorism, and the production of bioweapons would involve:

- Enactment of national laws that criminalize the production, stockpiling, transfer and use of chemo- and bioweapons
- Enactment of national laws that monitor the use of precursor chemicals that lend themselves to the development of chemical and bio-weapons
- Establishment of national and international databanks that monitor the traffic of precursor chemicals, their use in industry outreach programmes, and their licensed availability in national, regional and international markets
- Establishment and use of confirmatory protocols in the destruction and dispersal of outdated stockpiles, and chemical precursor components.

Incidents of bioterrorism in the last two decades, fortunately were rare. In the USA, the most publicised case is that of the deliberate contamination of salad bars in 1984, with *Salmonella typhimurium*, an intestinal pathogen. The bioterroristic act, carried out by members of the Rajnaashee cult in Oregon, was aimed at securing an electoral result by incapacitating voters lacking empathy with the cult's preferential candidate (Torok and Tauxe, 1997). This outbreak of salmonellosis, and that of shigellosis (Kolavic and Kimura, 1997) are documented examples of bio-threats to public health. Reporting of such cases is often rare since credence is generally attributed to the more common occurrence of food infection or food intoxication rather than to the criminal, and intentional, contamination of food supplies and catering facilities.

In another well publicised case, the Japanese *Aum Shinrikyo* sect released the nerve agent *sarin* in a Tokyo subway in 1995 following failure to obtain the Ebola virus for weaponisation in 1992 from (then) Zaire, and inability thereafter to release anthrax spores from a building, and botulinum toxin from a vehicle.

Bioterroristic risks are minimised through effective responses built around the development of preventive and control measures to contain, control, minimise, and eradicate outbreaks of travel-related vaccine preventable diseases. Tropical medical practitioners, public health personnel, immunologists, microbiologists, and quarantine authorities have an important role to play in safeguarding against potential bioterrorism in the future through timely detection of hepatitis *A* and *B*, yellow fever, Japanese encephalitis, rabies, typhoid, anthrax, plague and meningitis. To counter possible bioterrorist attacks using stolen or illegally acquired stocks of the dreaded small-pox virus, the WHO has postponed the agreed upon destruction date of June 1999 to December, 2002. It is likely at that time, that yet another postponement may occur.

Control, monitoring and reporting systems

Reporting of outbreaks of disease, often attributed to natural causes, should always be taken seriously since such outbreaks often result from non-compliance with the prohibitions embodied in international conventions in force. Potential nosocomial transmission of biological warfare agents occurs through blood or body fluids (e.g. haemorrhagic fever and hepatitis viruses); drainags and secretions (e.g. anthrax, plague, smallpox); and respiratory droplets (e.g. influenza plague, smallpox). The obligatory notification and reporting of outbreaks of diseases in humans, animals and plants helps to contain and neutralise the threats of biological warfare and bioterrorism. Such practice, in accordance with existing health codes and complementary reporting systems (Table 3), helps to develop a reservoir of preparedness capacity.

The development of a response strategy and technology in monitoring the control of weapons is at the core of a state of preparedness in the USA (New York Academy of Sciences, 1998). Current anti-bioterrorism measures involve the devising of unconventional effective countermeasures to combat misuse of pathogens encountered either naturally or in a genetically modified state. Such a strategic response involves:

- the use of bacterial RNA-based signatures and corresponding structural templates through which all pathogens can be potentially identified through appropriate trial and error testing, and verification;
- development of a data base of *virtual* pathogenic molecules responding to the bacterial signature templates;
- development, evaluation and use of effective antibacterial molecules that eliminate pathogens but do not harm humans nor animals (Ecker and Griffey, 1998).

Guidelines and recommendations have been formulated for use by public health administrators and policy-makers, medical and para-clinical practitioners, and technology designers and engineers in developing civilian preparedness for terrorist attack (Institute of Medicine, 1999). Areas covered deal with rapid detection of biological and chemical agents, pre-incident analysis of the targeted area, protective clothing, and use of vaccines and pharmaceuticals in treatment and decontamination of mass casualties.

The lack of basic hygienic procedures accompanying the use of domestic and public health facilities in the discharge, and disposal of human wastes has contributed to a large extent of the state of unpreparedness in responding to obnoxious biological weapons. Furthermore, the indiscriminate use of chemotherapeutics, and the overuse of antibiotics, has contributed to a complacent sense of invincibility in confronting once easily eradicated causative agents of disease. Henderson (1999) in summarising important distinctions between chemical and biological terrorism emphasised the need for an awareness and allocation of resources in devising appropriate responses to threats of bio- and chemoterrorism. Crucial elements of appropriate and timely responses are the renovation and modernisation of the public health infrastructure, the necessary networking of the para-clinical and specialised medical forces involving nurses, general health practitioners, epidemiologists, quarantine specialists and experts in communicable diseases. In brief, an appropriate optimal response constitutes a co-ordinated management of medical capability and restorative efforts backed up by supporting extension services.

Several examples of scientific societies, and of national, regional and global initiatives addressing the global threats of emerging infections and disease have been documented (DaSilva and Iaccarino, 1999). The African biotechnological community is aware of the need of safety considerations and risk assessment in the development and use of bioengineering micro-organisms (Van der Meer et al, 1993). Activities in Uganda, Kenya, Zimbabwe, Tanzania, South Africa, and the Southern African Development Community (Angola, Botswana and Zimbabwe) constitute a revelation of regional academic capacity and competence in addressing issues formulating guidelines, and programming initiatives concerning food security, recombinant DNA biosafety guidelines, and environmental biosafety protocols.

Destruction and deterioration of the environment is usually preceded by the emergence and spread of infectious diseases. In Southern Africa, beset by war-plagued conditions, migration of tribal populations and overnight development of nomadic villages, the loss of life and erosion of human resources results from the occurrence of AIDS, malaria, tuberculosis, meningitis and dysentery. Academic and affluent societies are often stricken by outbreaks of *hamburger disease*. The causative agent is a virulent commensal *Escherichia coli*.

AIDS in South Africa is likely to become a notifiable disease as a consequence of governmental concern in containing the widespread occurrence of the disease (Cherry, 1999). The Department of Industrial Health in Singapore, in fostering a favourable workplace environment, requires the reporting of an outbreak or occurrence of anthrax listed amongst 31 notifiable industrial diseases. The rare outbreak of encephalitis in Malaysia, more recently, reached alarming proportions of concern with severe economic and health implications for other Southeast Asian countries e.g. Laos and Vietnam, thus prompting the destruction of large numbers of the porcine population suspected of harbouring the virus.

The role of chemical protective clothing in the performance of military personnel in combat and surveillance situations has been reviewed (Krueger and Banderet, 1997). The performance and output of military and auxiliary personnel is severely affected following exposure to chemical weapons using nerve agents and disabling chemicals. Interference with a loss of physiological functions such as loss of muscle control, paralysis of body movements, loss of memory, dermal discoloration, prolonged deterioration of vision, speech intelligibility, and the like result in loss of psychological confidence, and professional competence.

The development of chemical protective clothing incorporating chemical and biochemical protectants, such as hypochlorites, phenolics, soap waxes, and antidotes, helps offset psychological stress and trauma, and combat anxiety. Anti-biowarfare and anti-bioterrorism research has led to the development of rub-on polymer creams and anti-germ warfare lotions that provide protection also against the influenza virus (Dobson, 1999a,b). Chemical protection in the form of rubberised hoods and tunics, gloves, boots, and gas masks helps guard against tear gas agents, nerve agents and chemical irritants delivered either by aerosols or liquid sprays. Recently, the incorporation of antibiotics in routine textiles as anti-odour and anti-infection agents has been reported (Barthélémy, 1999).

Weapons of mass destruction, be they nuclear, chemical or biological in nature, constitute a threat to national security, and to regional and international co-operation (New York Academy of Sciences, 1998). Civilian and military vulnerability to biological weapons can be overcome by resorting to the development of biosensors, fast-reacting bio-detection agents, advanced medical diagnostics, and effective vaccination and immunisation programmes.

Bio -detection has been spurred on through the development of biorobots (Treindl, 1999). Mechanised insects with computerised artificial systems mimic through microchips or biochips certain biological processes such as neural networks that gather and process neural impulses that influence behavioural sensitivities to stress and dangerous responses to substances of biological and chemical origin. These micro-gadgets can carry out in a single operation tasks such as DNA processing, screening of blood samples, scans for the presence and identifications of disease genes, and monitoring of genetic cell activity normally carried out by several laboratory technicians.

Furthermore, the ability to incorporate such dual-use cyberinsects and biorobots in the potential weaponnization of biological agents needs to be addressed and curbed. Biorobots of the household pest- the cockroach, *Blaberus discoidalis*, the desert ant- *Cataglyphis*, and the cricket- *Gryllus bimaculatus* are already the subject of *in situ* research. The cricket robot is being developed, in the USA, through academic research within the framework of the Defence Advanced Research Projects Agency (DARPA) robotics program. The main *raison d'être* of robobiology is the development of miniaturised models with biomechanised minds that could be used also in space biology exploration. Moreover, like humans and other living systems, their life span is not limited by the deleterious effects of toxic chemicals and wastes.

To help the medical community save lives during and in the immediate aftermath of bioterrorist attack, DARPA has sponsored projects that rapidly identify pathogens for treatment either with a combination of antimicrobial substances or nannobombing with potent biosurfactant emulsions (Alper, 1999).

The development of advanced biological and medical technologies aim at saving the 30 to 50 per cent of lives that are traditionally lost in frontline battlefield areas, and, reducing drastically the 90 per cent combat deaths that occur in close combat prior to medical intervention. Such technologies involve the development and use of surgical robot hands, trauma care technology, and remote teledecontamination of biologically polluted environments.

Tissue-based biosensors provide reliable alerts and assessments of human health risks in counteracting bioterrorism and biowarfare. Comprised of multicellular assemblies, and wide-ranging antibody templates, such sensors detect. and predict physiological consequences arising from biological agents that have not been fingerprinted nor identified at the molecular level. Alerts and assessments are made through the use of reporting molecules that express themselves through the phenomena of luminescence, fluorescence, etc. For example, the pigment bacteriorhodopsin obtained from the photosynthetic *Halobacterium salinarum* is used as a sensor for optical computing, artificial vision, and data storage. Defensive and deterrent technologies are being developed to afford maximum protection to civilian and military personnel; and to reduce to a minimum the fall-out damage resulting from bioweapons that use unconventional pathogen countermeasures, controlled biological systems and biomimetics in the defence against biowarfare and bioterrorism (Table 4 a-c).

DARPA's Unconventional Pathogen Countermeasures program focuses on the development of a powerful and effective deterrent force that limits, reduces and eliminates damage and spread out resulting from use of bioweapons. Such countermeasures focus on:

- Impeding and eliminating the invasive mechanisms of pathogens that facilitate their entry through inhalation, ingestion, and skin tissue
- Devising broad-spectrum medical protocols and treatments that are effective against a wide range of pathogenic organisms and their deleterious products
- Enhancement of external protection using polyvalent adhesion inhibitors in protective clothing, biomimetic pathogen neutralising materials, and personal environmental hygienic protection systems

A novel challenge for the biotechnological industry is the development of effective biological defence programmes based on novel fundamental research in biotechnology, genetics and information technology. Biosensor technology is the driving force in the development of biochips for the detection of pesticides, allergens, and micro-organisms;

- gaseous pollutants e.g. ammonia, methane, hydrogen-sulphide, etc
- heavy metals, phosphate and nitrates in potable water
- biological and chemical pollutants in the dairy, food and beverage industries

using the tenets of reliability, selectivity, range of detection, reproducibility of results, and, standard indices of taxonomy, contamination and pollution. Biodefense programs are now being developed around the unique sensorimotor properties of biological entities. Bees, beetles, and other insects are being recruited as sentinel species in collecting real-time information about the presence of toxins or similar threats.

Biosensors, using fibre optic or electrochemical devices, have been developed for detecting micro-organisms in clinical, food technology, and military applications (King et al, 1999; Mulchandani et al, 1999). An immunosensor is used for the detection of *Candida albicans* (Muramatsu et al, 1986). *Bacillus anthracis*, and bacteria in culture are detected by optical sensors (Swenson, 1992). In addition, several systems have been developed in the USA to detect biological weapons. Generic and polyvalent immunosensors have been devised to detect biological agents that cause metabolic damage and whose antigenic structure has been specifically genetically altered to avoid detection by antibody-based detection systems. Other biodetection systems functioning as early warning/alert systems involve the detection of biological particle densities by laser eyes and electronic noses with incorporated alarms Emphasis in such systems is less on the identity of the biological agent, and more on the early warning aspect which constitutes an effective arm in counteracting the threat of bioterrorism in daily and routine peace time environments (Schutz et al, 1999).

Such electronic noses result from a combination of neural informational networks with either chemical or biological sensor arrays and miniaturised spectral meters. Compact, automated and portable, electronic noses offer inexpensive on-the-spot real-time analysis of toxic fuel and gas mixtures, and identification of toxic wastes, household gas, air quality, and body odours (Wu, 1999).

The goal of such programmes is to prevent unpleasant technological surprises arising from misuse of biological agents, chemicals, ethical pharmaceuticals, and obnoxious gases. The preparedness involves the intelligence monitoring of the capabilities, intentions, and resource materials of potential opponents, and terrorists.

In testimony to the U.S. Senate Public Health and Safety Committee, it was emphasised that:

a) the strategy of developing and producing dual purpose diagnostics, therapeutics, and vaccines that protects public health and defends against biological weapons
b) the control and elimination of infectious diseases through improved surveillance, early warning, communication and training networks, and
c) the availability of front line preparedness and response in responding to bioterrotism and biological warfare (ASM, 1999) are integral constitutive elements of a preparedness domestic capacity against bioterrorism (Preston, 1998).

Concluding remarks

Biological warfare can be used with impunity under the camouflage of natural outbreaks of disease to decimate human populations, and to destroy livestock and crops of economic significance.

Attempts to regulate the conduction of warfare and the development of weaponry using harmful substances such as poisons and poisoned weapons are enshrined in conventions drawn up with respect to the laws and customs on land (Table 1). These early instruments of war –prevention measures, and eventual confidence-building and peace-building measures, have evolved from normal practices and characteristic usages established amongst, civilised peoples; from the basic laws of humanity; the tenets of long established and widely accepted faiths, and the dictates of public conscience.

In that context, the conventions outline steps and measures to safeguard buildings and historic monuments dedicated to art, religion and science, and to clinics and hospitals housing the sick and wounded, provided they are not engaged in combat. Use of such personnel in experiments designed to enhance the lethality of weaponry containing harmful substances such as poisons, disabling chemicals and ethical pharmaceuticals is implicitly and strictly prohibited. In the history of the interactions between science, culture and peace, the term Unit 731 is associated with the demeaning of science and humanity, their values and ethics. The activities carried out by Unit 731 in World War II were prohibited as far back as 1907 (Table 1).

In neutralising the effects of biological agents and rendering them ineffectual for use as bioweapons, bioindustries are now concentrating on the development of a wide range of biotherapeutics – antibiotics and vaccines (Stephanov et al, 1996; Perrier, 1999; Russell, 1999; Zoon, 1999) through development of biologically-based defence science and technology programmes. Current bioweapons defence research is now focusing on developing biosensors containing specific antibodies to detect respiratory pathogens likely to be dispersed through sprays and air cooling systems. Also contract research centres around the use of biotechnologies to remediate environmental areas contaminated with heavy metals, herbicides, pesticides, radioactive materials, and other toxic wastes.

The genetic screening of human diseases and drug discovery have been facilitated by research advances in the field of bioinformatics (Lehrach et al, 1997). The automated and computerised study of shared information in the genomic DNA of biological resources in tandem with digital processing and graphic computation techniques, offers a base for the development of devices for monitoring environmental degradation and development of biodefense programmes (Table 4 a-c). The aim of such research in developing sensors for the timely detection and neutralisation of biological weapons is reflected in “Sherlock Holmes’ dog that doesn’t bark”, i.e the silence of the sensor indicates the presence of a biological agent (Morse, 1998).

Development of national preparedness and emerging responses to biological agents, either in bioterroristic or combat situations, is dependent upon the rapidity of intervention by trained antiterroristic personnel comprised of microbiologists, doctors, hospital staff, psychologists, military or law-enforcing forces, and public health personnel. In this regard, the economic impact of a bioterroristic attack has recently been assessed (Kaufmann et al, 1997). Investing in public health surveillance helps enhance domestic preparedness in dealing with, bioterrorism, emerging diseases and foodborne infections.

The likelihood of genetically engineered micro-organisms contributing to the emergence of new infections cannot be ignored. Public reaction to the introduction of genetically engineered crops into Europe, at this time, is accompanied by controversy and fears for environmental safety. The uncertainty accompanying the potential outbreaks of new scourges is another complicating factor. Increasing public awareness and understanding of safety issues and the release of genetically engineered organisms into the environment helps to overcome unsubstantiated fears and misconceptions, and to secure confidence through a state of preparedness. On such strategies, a ready and effective response exists to combat potential catastrophes and outbreaks of emerging diseases. The science and value of environmental safety evaluations constitute a right step in this direction (Käppeli and Auberson, 1997).

New threats from weapons of mass destruction continue to emerge as a result of the availability of technology and capacity to produce, world-wide, such weapons for use in terrorism and organised crime (Department of Defence, 1996). Novel and accessible technologies give rise to proliferation of such weapons that have implications for regional and global security and stability. In counteraction of such threats, and in securing the defence of peace, the need for leadership and example in devising preventive and protective responses has been emphasised through the need for training of civilian and non-civilian personnel, and their engagement in international co-operation. These responses emphasise the need for the reduction and elimination of bioterrorism threats through consultation, monitoring and verification procedures; and deterrence, through the constant availability and maintenance of a conventional law and order force that is well-versed in counterproliferation controls and preparedness protocols (American Society for Microbiology, 1999).

Adherence to the Biological and Toxin Weapons Convention, reinforced by confidence-building measures (United Nations, 1997) is indeed, an important and necessary step in reducing and eliminating the threats of biological warfare and bioterrorism (Tucker, 1999).

References

Alper, J. (1999). From the bioweapons trenches, new tools for battling microbes, Science 284:1754-1755.

American Society for Microbiology (1999). Bioterrorism: frontline response, evaluating U.S. preparedness, March 30, (http://dev.asmusa.org/pasrc/bioterrorismdef.htm)

Atlas, R.M. (1998). Biological weapons pose challenge for microbiological community, ASM News 64: 383-388.

Av-Gay, Y. (1999). Uncontrolled release of harmful micro-organisms, Science 284:1621.

Barthélémy, P. (1999). Les textiles antibactériens et anti-odeurs passent avec succès l’épreuve du marché, *Le Monde*, Samedi, 16 Janvier.

Butler, D. (1997). Talks start on pooling bio-weapons ban, Nature 388:317.

Buzby, J. C., Roberts, T. Jordan Lin, C-T. and MacDonald, J.M. (1996). Bacterial foodborne disease: medical costs and productivity losses, Agricultural Economic Report Nº 741, publ. Economic Research Service, U.S. Department of Agriculture, Washington, D.C., pgs.80.

Cherry, M. (1999). South Africa reveals plans to make AIDS a notifiable disease, Nature 399:288.

Christopher, G.W., Cieslak, J.T., Davlin, J.A., and Eitzen

Jr., E.M. (1997). Biological warfare: a historical perspective (http://www.usamriid.army.mil/content/BiowarCourse/HX-3.html)

Cole, C.A. (1996). The spectre of biological weapons, Scientific American 275:60-65.

Cole, (1997). The eleventh plague – The politics of biological and chemical warfare ed. Cole, L.A., W.H. Freeman and Company, New York, pgs 289.

Danzig, R. and Berkowsky, P.B. (1997). Journal American Medical Association 278:431.

DaSilva, E.J. and Iaccarino, M. (1999). Emerging diseases: a global threat, Biotechnology Advances 17: 363-384

Department of Defence (1996). Proliferation: threat and response, April, US Government Printing Office, Washington, D.C., 20402-9328.

Department of Foreign Affairs and Trade (1999). Strengthening the biological weapons convention, Australian Biotechnology 9:112-114.

Dobson, R. (1999a). Germ warfare lotion can protect you against flu, Innovation —*The Sunday Times*, 18 July.

Dobson, R. (1999b). Race hots up to counter bio-terrorism weapons, Innovation —*The Sunday Times*, 15 August.

Ecker, D. and Griffey, R. (1998). Drugs to protect against engineered biological warfare (http://www.ibisrna.com/public/biowar/%2/003.html)

Harris, R. and Paxman, J. (1982). A higher form of killing, Noonday Press, New York, pg. 74.

Henderson, D.A. (1999). The looming threat of bioterrorism, Science 283:1279-1281.

Holmes, A., Govan, J. and Goldstein, R. (1998). Aquacultural use of *Burkholderia (Pseudomonas) cepacia*: A threat to human health, Emerging Infectious Diseases
4:221-227.

Hoogendorn, E. J. (1997). A chemical weapons atlas, Bulletin of the atomic scientists 53:35-39.

Institute of Medicine (1999). Chemical and biological terrorism: research and development to improve civilian medical response, U.S. National Academy Press, pgs 304.

Kadlec, R. P. (1995). Biological weapons for waging economic warfare. In: Battlefield of the future: 21st century warfare issues, eds. Schneider, B.R. and Grintner, L.E., Department of Defence, Air University, U.S. Department of Defence, pgs.287.

Kaufmann, A.F., Meltzer, M.I. and Schmid, G.P. (1997). The economic impact of a bioterrorist attack: are prevention and post attack intervention programs justifiable? Emerging Infectious Diseases 3:83-94.

Käppeli, O. and Auberson, L. (1997). The science and intricacy of environmental safety evaluations, Tibtech 15:342-349.

King, K.D. Anderson, G.P., Bullock, K.E., Regina, M.J., Saaski, E.W. and Ligler, F.S. (1999). Detecting staphylococcal enterotoxin B using an automated fibber optic biosensor, Biosensors and Bioelectronics 14:163-170.

Kolavic, S. and Kimura, A. (1997). An outbreak of *Shigella dysenteriae* type 2 among laboratory workers due to intestinal food contamination, Journal of the American Medical Association 278:396-398.

Krueger, G.P. and Banderet, L.E. (1997). Effects of chemical protective clothing on military performance: a review of the issues, Military Psychology 9:255-286.

Lehrach, H., Bancroft, D. and Maier, E. (1997). Robotics, computing and biology, Interdisciplinary Reviews 22:37-43.

Marshall, E. (1999). Bioterror defence initiative injects shots of cash, Science 283:1234-1235.

Miller, J. (1999). In Soviet Dump, Deadly germs live on, *International Herald Tribune*, Paris, 3 June.

Monath, T.P. and Gordon, L.K. (1998). Strengthening the biological weapons convention, Science 282:1423.

Morse, S. (1998). Defending against biological warfare: programs of defence advanced research projects agency (DARPA). In: Technology and Arms Control for Weapons of Mass Destruction, publ. New York Academy of Sciences, N.Y., USA, ed. Raymond, S.U., pgs 23-28.

Mulbry, W. and Rainina, E. (1988). Biodegradation of chemical warfare agents, ASM News 64:325-331.

Mulchandani, P., Mulchandani, A., Kaneva, I. and Chen, W. (1999). Biosensor for direct determination of organophosphate nerve agents 1. Potentiometric enzyme electrode, Biosensors and Bioelectronics 14:77-85.

Muramatsu, H. Kajiwara, K., Tamiya, E. and Karabe, I. (1986). Piezoelectric immunosensor for detection of *Candida albicans* microbes, Analytica Chimica Acta 168:257-261.

Nye, Jr., J.S. and Woolsey, R.J. (1997). Heed the nuclear, biological and chemical terrorist threat, *International Herald Tribune*, Paris, 5 June.

New York Academy of Sciences (1998). Technology and arms control for weapons of mass destruction, ed. Raymond, S.U., publ. New York Academy of Sciences, New York, USA, pg. 45.

Office of Technology Assessment (1993). Proliferation of weapons of mass destruction: assessing the risks, Washington, D.C., U.S. Government Printing Office, pg. 50.

Pearson, G.S. (1998). The threat of deliberate diseases in the 21st Century (http://www.brad.ac.uk/acad/sbtwc/other/disease.htm)

Perrier, J.J. (1999). Les nouveaux visages de la vaccination, Biofutur, Mai, pgs 14-18.

Preston, R. (1998). Statement before the Senate Judiciary Subcommittee on technology, terrorism and government information, and the select committee on intelligence on chemical and biological weapons threats to America: are we prepared? (http://www.senate.gov/~judiciary/preston.htm)

Purver, R. (1995). Chemical and biological terrorism: the threat according to the open literature, CSIS/SCRS (http://www.csis-scrs.gc.ca/eng/miscdocs/tabintre.html)

Rogers, P., Whitby, S. and Dando, M. (1999). Biological warfare against crops, Scientific American 280:70-75.

Russell, P. K. (1999). Vaccines in civilian defence against bioterrorism, Emerging Infectious Diseases 5:498-504.

Schutz, S., Weiszbecker, B., Koch, U.T. and Humonel, H.E. (1999), Detection of volatiles released by diseased potato tubers using a biosensor of intact insect antennae, Biosensors and Bioelectronics 14:221-228.

Scott, S.J. and Shea, J. (1999). Anthrax feared in Afghanistan outbreak, The American Reporter, 5, February 26.

Schneider, B. R. and Grintner, L. E. (1995). Eds. Battlefield of the Future: 21st Century warfare issues, Air University, U.S. Department of Defence, pgs.287.

Serageldin, I. (1999). Biotechnology and water security in the 21st Century, (http://www.mssrf.orgsg/d99-biotech-water.html)

Stephanov, A.V., Marinin, L.I., Pomerantsev, A.P. and Staritsin, N.A. (1996). Development of novel vaccines against anthrax in man, Journal of Bacteriology 44:155-160.

Strauss, E. (1999). Microbes features as pathogens and pals at gathering, Science 284:1916-1917.

Swenson, F.J. (1992). Development and evaluation of optical sensor for the detection of bacteria, Sensors and Actuators B 11:315-321.

Thompson, D. (1999). The germ warrior, Time, July 26, pg 73.

Torok, T. and Tauxe, T. (1997). A large community outbreak of salmonellosis caused by intentional contamination of restaurant salad bars, Journal of the American Medical Association 278:389-395.

Treindl, R. (1999). Les biorobots: des insects à puces, Biofutur, Mai pgs.34-37.

Tucker, J.B. (1999). Historical trends related to bioterrorism: an empirical analysis, Emerging Infectious Diseases 5:498-504.

United Nations (1997). Annex VI. Confidence-building Measures F., Document No. CDA/BWC/1997/CBM, 30 May, pg. 688.

Van der Meer, P. J., Schenkelaars, P., Visser, B. and Zwanugobani, E. (1993). eds. Proceedings- African Regional Conference for International Cooperation on Safety in Biotechnology, 11- 14 October, Harare, Zimbabwe, pgs. 190.

Vasil, I.K. (1998). Biotechnology and food security for the 21st century: A real-world perspective, Nature Biotechnology 16:399-400.

Weller, R.E. Lyu, C.W., Wolters, C. and Atlas, R.M. (1999). Universities and the biological and toxin weapons convention, ASM News 65:403-409.

Whitby, S. and Rogers, P. (1997). Anticrop biological warfare – implication of the Iraqi and U.S. programs, Defence Analysis 13:303-318.

Wright, S. (1985). The military and the new biology. Bulletin of the Atomic Scientists 41:10-16.

Wu,T. Z. (1999). A piezoelectronic biosensor as an olfactory receptor odour detection electronic nose, Biosensors and Bioelectronics 14:9-18.

Zoon, K. C. (1999). Vaccines, Pharmaceuticals Products, and Bioterrorism: Challenges for the U.S. Food and Drug Administration, Emerging Infectious Diseases 5:534-536.

Table 1. Chronological Summary of Conventions, Protocols and Resolutions curbing biological warfare

Year	Convention	Remarks
1899 Hague, Netherlands*	The Laws and Customs of War on Land (II)	• Entering into force in 1900, the Convention in defining the rules, laws and customs of war, based on deliberation of the Brussels Peace Conference of 1874, prohibited the use of poison and poisoned weapons as well as the use of arms, projectiles and/or material calculated to cause unnecessary suffering
1907 Hague, Netherlands**	The Laws and Customs of War on Land (IV)	• Entering into force in 1910, the Convention covers issues, and customs in more detail, relating to belligerents, prisoners of war, the sick and wounded, means of injuring the enemy, and bombardments, etc.
1925 Geneva, Switzerland	Prohibition of the Use in War of Asphyxiating, Poisonous or other Gases, and of Bacteriological Methods of Warfare	• In force since 1928, the protocol prohibits the use in war of asphyxiating, poisonous or other gases, and of all analogous liquids, materials or devices, and, the use of bacteriological methods of warfare
1972 Geneva, Switzerland	Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction	• Entering into force in 1975, the Convention - prohibits the development, production, stockpiling, acquisition and retention of microbial or other biological agents or toxins that have no justification for prophylactic, protective or other peaceful purposes - their use as weapons, or in military equipment, missiles and other means of delivery for hostile use or in armed conflict - furthers development and application of scientific discoveries in the field of bacteriology (biology) for the prevention of disease, or for other peaceful purposes
1974 Paris, France	Prevention of Marine Pollution from Land-Based Sources	• Amended by a protocol in march, 1986, the Convention covers - prevention of pollution of the sea inclusive of marine estuaries, by humankind either by direct or indirect means, through introduction of substances of energy resulting in deleterious effects as hazards to human health, living marine resources, marine ecosystems, and damage to amenities, or interference with other legitimate uses of the sea
1976 Geneva, U.N.	Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques	• Adopted by the Resolution 31/72 of the U.N. General Assembly on 10 December, 1976, and open for signature in Geneva, 18 May, 1877, the Convention focuses on any technique that changes "through deliberate manipulation of natural processes -- the dynamics, the composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space"
1981 Abidjan, Cote d'Ivoire	Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	• The Convention which entered into force in 1984 covers - the marine environment, coastal zones, and related inland waters within the jurisdiction of the States of the West and Central African Region - the introduction, directly or indirectly, of substances or energy into the marine environment, coastal zones, and related inland waters resulting in deleterious effects that harm living resources, endanger human health, obstruct marine activities (inclusive of fishing) and alters the quality and use of seawater and reduction of amenities. - promotes scientific and technological co-operation to monitor and assess direct and/or indirect pollution, and to engage in networking exchange of scientific data and technical information.
1983 Bonn, Germany	Co-operation in Dealing with Pollution of the North Sea by Oil and Other Harmful	• Agreement, by the governments of Belgium, Denmark, France, Germany, the Netherlands, Norway, Sweden, the U.K., and the European Economic Community, based on an agreement reached in Bonn, 1969,

	Substances	covers - prevention of pollution of the sea by oil and other hazardous substances - development of mutual assistance and co-operation in combating marine pollution and destruction of marine bioresources
1989 Basle, Switzerland	Control of Transboundary Movements of Hazardous Wastes and Their Disposal	• Known as the Basel Convention, it entered into force in 1992, and covers a variety of hazardous wastes resulting from wastes such as clinical wastes, household wastes, radioactive wastes, and toxic wastes resulting from the production of biologicals, medicines, the chemical industry, etc.***
1991 Bamako, Mali	Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes with Africa	• Known as the Bamako Convention, and yet to enter into force, the Convention focuses on the - need to promote the development of clean production methods, including clean technologies, for the sound management of hazardous wastes produced in Africa, in particular, to avoid, minimise, and eliminate the generation of such wastes - protection, through strict control, the human health of the African population against the adverse effects which may result from the generation and movement of hazardous wastes within the African Continent.
1992 Bucharest, Romania	Protection of the Black Sea against Pollution	• The Convention takes into account the - special hydrological and ecological characteristics of the Black Sea, and the susceptibility of its flora and fauna to pollutants and noxious wastes of biological and chemical origin resulting from disposal systems, and dumping by aircraft and seaborne craft - need to develop co-operative scientific monitoring systems to minimize and eliminate pollution of the Black Sea
1993 Geneva, Switzerland	Prohibition of the Production, Stockpiling, and Use of Chemical Weapons and on Their Destruction	• Entering into force in 1997, the Convention prohibits the development, production, stockpiling, acquisition or retention of chemical weapons, their transfer, directly or indirectly to anyone, as well as their use in any military preparations or in missile delivery systems or weapons

* Year of the First International Peace Conference based on invitations from Czar Nicholas II of Russia and Queen Wilhelmina of the Netherlands

** Year of the Second International Peace Conference. The Third Conference scheduled for 1915 never took place due to outbreak of the First World War.

*** The reader is referred to Annexes I – V appended to the Treaty and which covers the range, categories and characteristics of hazardous wastes and conditions concerning their transboundary movement and disposal.

Table 2. Biological and Chemical Warfare Characteristics

Biological	Chemical
• Natural odourless occurrence	• Obtained synthetically with characteristic odour
• Invisible particles normally dispersed through aerosol spray	• Normally volatile in nature and dispersed either through mists or aerosol sprays
• Entry through inhalation or ingestion	• Entry through inhalation or dermal absorption
• Pre-exposure treatment confers or enhances immunity through use of toxoids, vaccines, antibacterial protective clothing, biosensors and smoke-detectors	• Pre-exposure treatment relies on use of gas-masks, antichemical protective clothing and use of chemosensors for toxic substances
• Post-exposure treatment relies on antibiotics or in combination with vaccines	• Post-exposure treatment relies on use of antidotes and neutralizing agents
• Effects of biological agents and toxins are diverse resulting in incapacitation or death occurring after contraction of disease resulting from infection by a specific biological agent e.g. anthrax caused by *Bacillus anthracis* and plague caused by *Yersinia pestis*	• Effects of chemical agents are either instantaneous or delayed for a few hours, with the onset of symptoms such as allergy, respiratory discomfort, intense irritation of mucous membranes, malfunctioning of physiological processes, resulting in dose-dependent death or incapacitation
• Can be weaponized into artillery rounds, cluster bombs, and missile warheads	• Long history of use as poison bombs, in artillery rounds, and in missile warheads
• Production methods are simple and cheap relying on non-sophisticated technology and easily obtainable knowledge in biology, genetics engineering, medicine and agriculture	• Simple and complex production methods needing appropriate corresponding equipment and technology for simple and sophisticated chemical synthesis, purification and development of lethal doses
• Not easily detected in export control and searches by routine detection systems, e.g. X-rays	• Detection facilitated through odour escape, and packaging in inert metallic containers showing up on X-ray screens

Table 3. Control, Preventive and Monitoring Activities

Agency	**Activity - Description**
AG	***Australia Group*** • Chaired by Australia, the "Australia Group" was formed in 1984 as a result of CW use in the Iran-Iraq War. Its monitoring actions dealing with the exports of dual-use chemicals and biological equipment complement measures in support of the 1925 Geneva protocol, the 1972 Biological and Toxins Weapons Convention and the 1993 Chemical Weapons Convention. There are presently 30 members of the Group, including: Argentina, Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, South Korea, Spain, Sweden, Switzerland, United Kingdom, United States of America, and the European Community Commission (Observer). • *Export Controls on Materials Used in the Manufacture of Chemical and Biological Weapons** - *Control List of Dual-Use Chemicals: Commercial and Military Application* e.g. 1) Thioglycol for plastics and CW mustard gas 2) Arsenic trichloride for ceramics and CW Lewisite - *Control List of Dual-Use Chemicals Manufacturing Facilities and Equipment, and Related Technology* and e.g. 1) Reaction Vessels, storage tankers 2) Valves, Toxic Gas Monitoring Systems and Detectors - *Control List of Dual-Use Biological Equipment for Export Control* e.g. 1) Fermentors (100L capacity and above) 2) Centrifugal Separators - *Control Core List of Biological Agents*** comprised of 1) Viruses (20), rickettsiae (4), bacteria (13) 2) GMOs containing nucleic acid sequences associated with pathogenicity or coding for toxins*** in the core list of microorganisms - *Warning List***** comprised of 1) Viruses (8), bacteria** (4), GMOs and toxins*** - *List of Animal Pathogens for Export Control*** comprised of 1) Viruses (15), and Mycoplasma mycoides, GMOs and Fungi (6) - *List of Biological Agents for Inclusion in Awareness Raising Guidelines* 1) Bacteria (2), Fungi (2), Virus (1), and GMOs.
APIC	***Association for Professionals in Infection Control and Epidemiology*** • Multidisciplinary and international in concept and operation, APIC focuses on advancing, world-wide, healthcare epidemiology and preventing illness and spread of infection • In partnership with the Centres for Disease Control and Prevention (CDC) has devised a *APIC/CDC Bioterrorism Readiness Plan: A Template for Healthcare Facilities*. The plan focuses on responses to

bioterrorism built around the use of anthrax, botulism toxin, plague and smallpox, post-exposure community management, precise prophylactic decontamination measures specific for the type of each biological threats in use, and development of appropriate healthcare control and bio-defense measures to counteract and neutralize future bio-based terroristic attacks that could lead to the onset of epidemics. Diagnostic laboratory facilities and implementation of surveillance and control measures, on a conventional war scale are limited. In fact, preliminary planning in devising effective measures have revealed that stockpiles of vaccines antibiotics as effective bio-defense shields to restrict mass casualties, and contain potential epidemics are either inadequate or non-existent e.g. as witnessed in the tragedies in former Zaire, Rwanda and Kosovo.

ASA

Applied Science and Analysis, Inc.

- Established in 1983, this US-based international organization,

1) specializes in nuclear, biological and chemical defense worldwide, and provides expertise in:

- chemical and/or biological warfare defense
- environmental management and protection
- public health preparedness and risk assessment
- monitoring of nature, behaviour, mobility and fate of undesirable biological and chemical agents

2) Disseminates knowledge and information on topics such as:

- Biological Warfare and Vaccines, and the Use of Toxic Chemicals as warfare agents
- Detection and decontamination protocols for chemical and biological agents and toxins
- Chemical and biological medicinal treatment and emergency responses to agrochemical and industrial accidents and disasters.

ATSDR

Agency for Toxic Substances and Disease Registry

- The Agency with support of the US Department of Health and Human Services provides technical assistance on:

- Methodologies and protocols in mitigating and preventing exposure to hazardous substances into the environment
- developing responses to counter chemical-based terrorism using chemicals as skin-irritant, and choking agents
- decontamination and neutralization of oil-improvised incendiaries detrimental to agriculture and the environment
- hazards and risks posed by the transportation of toxic chemical residues, and infectious clinical and domestic wastes.

Bradford-SIPRI project

The joint University of Bradford-Stockholm International Peace Research Institute (SIPRI) Chemical and Biological Warfare Project

- Project aims through pooling of their Internet resources in providing a better dissemination of information on the 1993 Chemical Weapons Convention, the 1972 Biological and Toxin Weapons Convention, and allied chemical and biological warfare issues. On-line resources involve use of the Bradford and SIPRI databases concerning bioweapons and chemical weapons proliferation, containment and disarmament. Engaged in:

- Reporting of outbreaks of Diseases as part of Confidence-Building Measures in accordance with the WHO International Health Regulations (IHR – see also under *FAS*) and the Pan American Sanitary Code administered by the Pan American Health Organization (PAHO). The notifiable diseases are:

  a) acute epidemic poliomyelitis
  b) cholera
  c) epidemic cerebrospinal meningitis
  d) epidemic lethargic encephalitis
  e) influenza or epidemic la grippe
  f) plague

g) smallpox
h) typhoid and paratyphoid fevers
i) typhus
j) yellow fever

- Reporting of outbreaks of Annual Diseases to the Office International des Epizooties (OIE) in accordance with the International Annual Health Code (IAH), and the International Aquatic Annual Health Code (IAAH). Notifiable diseases are:

    a) 16 different terrestrial animal and bird diseases under the *Animal Code*:

    ~ African horse sickness
    ~ African swine fever
    ~ Contageous bovine pleuropneumonia
    ~ Foot and mouth disease
    ~ Highly contageous avian influenza
    ~ Hog cholera (classical swine fever)
    ~ Lumpy skin disease
    ~ Newcastle disease
    ~ Peste des petits ruminants
    ~ Rift Valley fever
    ~ Rinderpest
    ~ Sheep pox and goat pox
    ~ Swine vesicular disease
    ~ Vesicular stomatitis, and

    b) 10 aquatic animal diseases under the *Aquatic Animal Code*:

    ~ Bonamiosis
    ~ Epizootic haematopoietic necrosis
    ~ Haplosporidiosis
    ~ Infectious haematopoietic necrosis
    ~ Marteiliosis
    ~ Mikrocystosis
    ~ Oncorhynchus masou virus disease (*synonym*: salmonid herpesvirus type 2 disease)
    ~ Perkinsosis
    ~ Spring viraemia of carp, and
    ~ Viral haemorrhagic septicaemia (*synonym*: egtved disease)

- Surveillance of plant disease outbreaks in accordance with the non-mandatary International Plant Protection Convention.

CBACI

Chemical and Biological Arms Control Institute

- Activities focus on projects and programmes dealing with:

    - nonproliferation and the elimination of biological and chemical weapons
    - international co-operation in controlling Chemical and Biological Terrorism
    - containing the development of biological weapons arising from the misuse of technology resulting from
    - globalization of a co-ordinated policy of unilateral technology denial
    - developing a multilateral technology management strategic system that blends in confidence-building measures the concerns for technology protection with the benefits of technology sharing
    - responding to the challenge of conserving health as a defense rampant in the maintenance of global security by focusing on global trends:

        a) emerging and re-emerging diseases, overburdened and outdated health infrastructures, and new epidemics
        b) increasing resort to biological aspects for use in biological warfare and bioterrorism
        c) impact of disease on population dynamics, regional and international markets, and by

consequence on economic and political stability.

CBIAC *Chemical and Biological Defense Information Analysis Centre*

- Serving as a focal point for the US Department of Defense Chemical and Biological Defense Information Services, CBIAC provides, on a limited basis, publicly accessible information, through its web-site and the *CBIAC Newsletter* technical information and updates on:

  - The Progress and Prospects in an overview of the Biological Weapons Convention
  - Next Generation Technologies to counter proliferation e.g.:

    a) Miniaturized portable mass spectro meter for field detection of chemical and biological substances

  - The Biological Integrated Detection System (BIDS) Bunker which provides for training in detecting, through air sampling and identification protocols, the presence of biological agents in war condition

  - Developing, testing and evaluating

    a) Prepared readiness, and
    b) emergency response to threats of biological warfare, and bioterrorism

  - Developing, testing, evaluating and maintaining:

    a) high-quality easily accessible equipment and accessories for use in prepared readiness and emergency response operations
    b) developing computer-based instruction manuals and exportable training kits for use on-site field operations.

CBMTS *Chemical and Biological Medical Treatment Symposium-Industry*

- Series of specialized symposia organised by Applied Science and Analysis, USA, since 1994 with focus on medical treatment for poisoning from chemical and biological agents, agrochemicals, pesticides, and industrials chemicals. CBMTS meetings deal with:

  - the scientific and technical emerging responses required from the chemical, biological, pharmaceutical and petrochemical industries in times of war, terrorist acts, sabotage and accidents
  - epidemological surveillance an emergency management methodologies when encountering biological warfare and bioterrorism
  - eco-terrorism
  - incoming threats of bioweapons and possible medical responses in countries in transition
  - assessment of health impacts of war, bioterrorism, accidents, and outbreak of infectious diseases.

CNS *Centre for Nonproliferation Studies*

- CNS, the world's largest non-governmental organization combating the spread of weapons of mass destruction, is based in the Monterey Institute of International Studies, California, USA, with offices in Washington D.C., and Almaty, Kazakhstan

  It is engaged in a variety of subjects such as:

  - Strengthening the Biological Weapons Convention: Lessons from the UNSCOM experience*International Organizations and Nonproliferation project (IONP) Initiated in 1992, IONP emphasizes:

    a) the training of the next generation of policy experts in the field of nonproliferation and its varied aspects concerning ecological and chemical warfare
    b) the development of practical options for the updating and reinforcement of review and monitoring processes,

c) reinforcement of the capacity of international nonproliferation organizations in curbing and eliminating the proliferation of weapons of mass
d) destruction, and inclusive of biological and chemical ones
e) their valuable mediating role in promoting substantive and sustainable dialogue between governmental parties, and non-governmental sectors on the benefits of nonproliferation of mass destruction weapons and arms control

Projects such as:

- Chemical and Biological Weapons Nonproliferation Project (CBWNP) founded in 1996, monitors, in collaboration with the Center for Global Research of the Lawrence Livermore National Laboratory, the proliferation of chemical and biological weapons (CBW), developing strategies and confidence-building measures to create disincentives for production and distribution of such weapons. The project has focused through workshops on:

a) Sampling and analysis
b) Inspection procedures, and
c) Investigations of suspicious outbreaks of disease,

and specialized reports such as:

a) The Threat of Deliberate Disease in the 21st Century
b) Industry's Role, Concerns and Interests in the Negotiation of a BWC Compliance Protocol
c) Man Versus Microbe: The Negotiations to strengthen the Biological Weapons Convention.

ECE

Economic Commission for Europe

- Safety guidelines in biotechnology, issued in 1995 within the framework of ECE activities that originate from the 1986 Vienna Meeting of Representatives of the Participating States of the Conference on Security and Co-operation (CSCE) in Europe, focus on the exchange of information on laws and regulations relating to the safety aspects of genetic engineering. Contributions are from 30 countries in Europe and North America.

EFB

European Federation of Biotechnology

- In co-operation with Austrian governmental authorities and through its Working Party on *Safety in Biotechnology*
  - Organized international discussion forum, (May, 1998, Vienna) on *A strengthened Biological and Toxin Weapons Convention – Potential Implications for Biotechnology* with focus on:

a) Overview of Biological and Toxin Weapons
b) Historical and Political Perspectives of the Biological and Toxin Weapons Convention
c) Lessons arising from the experience of the UNSCOM for Biological Arms Control
d) The verification regime of the Chemical Weapons Convention and its implications for biotechnology
e) Regulatory controls for Human and Animal Pharmaceutical Products
f) Developments in Biosafety Regulations and Controls amongst several other relevant themes

EU

European Union

- Designed in the mid-1980s, the EU regulatory framework covers:

  - contained use of genetically-modified organisms (GMOs)
  - deliberate release of GMOs
  - protection of workers to risks and biological agents during work
  - product legislation (medicinal, and plant protection products, novel foods, feed additives, seeds, etc.)

- intellectual property protection
- The *Eurosurveillance* bulletin communicable diseases deals with surveillance networks supported by the European Union, and co-ordinated by the European Centre for the Epidemiological Surveillance of SIDA, St Maurice, France, and the Communicable Disease Surveillance Centre, London, U.K.

- Disseminates printed and electronic data emphasizing the different national approaches to prevention of communicable diseases, results of outbreak investigations, and measures to minimize further outbreaks and occurrences.

- Reports on the European Union's efforts to:

  (a) increase the exchange of information in public healthcare and epidemiology
  (b) promote the development of national networks for surveillance of communicable diseases in Europe

EXTONET

Extension Toxicology Network

- A co-operative effort of the Universities of California-Davis, Oregon State, Michigan State, Cornell and Idaho, Exotonet issues toxicology information briefs and information profiles concerning bioaccumulation; carcigenicity; cutaneous toxicity; toxicological dose-response relationships; entry and fate of chemicals in humans and the environment and risk assessment.

FAO

Food and Agricultural Organization

- Administers Code of Conduct on the Distribution and Use of Pesticides
- Drafts Code of Conduct for plant biotechnology as it affects the conservation and utilization of genetic resources

- ***Emerging Prevention System for Transboundary Animal and Plant Pests and Diseases***, (***EMPRES***)

  - Established in 1993, as a FAO Priority Programme, EMPRES is designed to prevent, control, and eliminate animal and plant diseases that:

    (a) easily spread across national borders and boundaries
    (b) jeopardize food security and endanger national economies and international trade in livestock and animal products
    (c) necessitate use of early warning systems to control emerging or evolving diseases

  - Regional Monitoring System for plant and animal pests on a priority basis Priorities in monitoring are: contagious bovine pleuropneumonia, foot and mouth disease (FMD), Newcastle disease, rinderpest, and rift valley fever. No plant diseases are encountered as priorities.

- ***Global Information and Early Warning System on Food and Agriculture*** (***GIEWS***)

  - Provides assessment of threats to the current food situation, worldwide; highlights major food emergencies, threats to food security by plant pests, and livestock diseases.

- ***Special Programme for Food Security*** (***SPFS***)

  - Designed to combat food insecurity as a weapon in destabilizing the economies of law-income food deficit countries.

FAS

Federation of American Scientists

- Originally founded in 1945 as the Federation of Atomic Scientists by members of the Manhattan Project who produced the first atomic bomb, the FAS focuses on the use of science, technology and policy for global security through:

- Conduction, since 1989 of a Biological and Toxins Weapons (BTW) verification programme which focuses on:

  a) development of confidence-building political and technical measures for purposes of verification
  b) arrangement of all signatures to article, in spirit and action, by the terms of the BTW Convention
  c) development of a legally building protocol that prevents further proliferation of biotechnological applications for use by military in war
  d) development of network of early warning sites for monitoring emergency infectious diseases in co- operation with WHO
  e) emphasizes the important contribution of WHO's *Revised International* Health regulations (IHR) to the compliance and verification regime, also referred to as VEREX, of the Biological Weapons Convention (BWC).

- ***Program for Monitoring Emerging Diseases*** (***PROMED***) involving worldwide e-mail consultations, is reflected in consultative conference between experts in human, animal and plant health. Since 1994, over 15,000 experts in some 150 countries participate in PROMED conferencing by e-mail on a daily basis the identity of the following users:

  - World Health Organization (WHO)
  - UN Agencies engaged in humanitarian and relief work
  - Laboratory Centres for Disease Control and Prevention (CDC) Atlanta, USA
  - Public Health Laboratory Service, UK
  - Pasteur Institutes in France (inclusive of that in Tahiti) and Vietnam
  - National Institute of Health, Japan amongst several other prestigious bodies

Henry L. Stimson Centre

The Henry Stimson Centre

- Named after Henry L. Stimson, a distinguished individual in defense and foreign policy in service to 3 American Presidents - Taft, Hoover, and F.D. Roosvelt, the Centre a non-profit independent public institute which:

  - is engaged in meeting challenges to global and regional security and stability posed by economic, environmental and demographic influences
  - in developing problem-solving initiatives that help minimize tensions arising from insecurity fuelled by the development and proliferation of chemical and biological weapons, and
  - in inducting research analysis, education and disseminating knowledge through the following projects on:
    a) Chemical and Biological Weapons Nonproliferation
    b) New Tools Peacekeeping
    c) Training for Peacekeeping
    d) The United Nations and Peacekeeping.
  - Report 24: *Biological Weapons Proliferation: Reasons for Concern, Courses of Action,* January 1998 of relevance with following chapter content:

    a) *The Threat of Deliberate Disease in the 21st Century* (Pearson, G)*
    b) *Industry's Role, Concerns, and Interests in the Negotiation of* a *BWC Compliance Protocol* (Woollett, G.)
    c) *Doubts about Confidence: The Potential Limits of Confidence-Building Measures for Biological Weapons Convention (*Chevrier, M.)
    d) *Verification Provisions of the Chemical Weapons Convention and Their Relevance to the Biological weapons Convention* (Tucker, J.)
    e) *Man Versus Microbe: The Negotiations to Strengthen the Biological Weapons Convention* (Smithson, A.E.)

HSP

Harvard Sussex Programme (HSP) on Chemical and Biological Warfare Armament and Arms Limitation

- A joint activity since 1991, of Harvard University (USA) and the University of Sussex (U.K.), HSP:

  - conducts and sponsors scholarly research dealing with CBW
  - publishes the quarterly journal – *The CBW Conventions Bulletin* (earlier known as *Chemical Weapons Convention Bulletin*)
  - convenes, since 1993, the *Pugwash Study Group on Implementation of* the Chemical and Biological Weapons Convention
  - collaborates with OPCW (*see below*) in the provision of training activities

  - possesses well-developed resource database concerning:

    a) Chemical and biological warfare (CBW)
    b) disabling chemicals
    c) the Australian Group, Pugwash conferences
    d) destruction of chemical weapons
    e) CBW in the Middle East, Africa
    f) Control of dual-use biotechnologies in manufaction of CBW weapons.
  - proposes *Draft Convention To Prohibit Biological and Chemical Weapons under International Criminal Law (1998)*
  - proposes *Draft Convention on The Prevention and Punishment of the Crime of Developing, Producing, Acquiring, Stockpiling, Retaining, Transferring or Using Biological or Chemical Weapons (1998)*

ICAO

- ***International Civil Aviation Organization***

  - Convention on International Civil Aviation covers:
    (a) disinsectization of aircraft and airport health and sanitary facilities

    (b) provision of safe food and water on aircraft and at airports with proper facilities for disposal of refuse, wastes, wastewater
    (c) healthcare certificates preventing air navigation of cholera, epidemic typhus, plague and yellow fever

  - Collaborates with WHO, since aircargo trade and travel is source of new and emerging diseases in potential airborne and seaborne bioterrorism

ICGEB

International Centre for Genetic Engineering and Biotechnology

- International Conference on the Peaceful Use of Biotechnology and the Convention on Biological Weapons (BWC), July 1998, organised by the ICGEB and the Landau Network – Centro Volta. Article 2 of the ICGEB, *inter alia*, provides for action "to promote international co-operation in developing and applying peaceful uses of genetic engineering and biotechnology, in particular for developing countries"

  - ICGEB provides a biosafety resource which is a scientific bibliographic database on *Biosafety and Risk Assessment in Biotechnology*. Topics of concerns focus on the environmental release of genetically-modified organisms (GMOs) and the risks for animal and human health (e.g. allergies and toxicity); for the environment (e.g. unpredictable gene expression); and, for agriculture e.g. alteration of nutritional values, and loss of biodiversity.

IFMBE

International Federation for Medical and Biological Engineering

- Established in 1959 by a group of medical engineers, physicists, doctors meeting in UNESCO, Paris, France, IFMBE, has also promoted activities in medical physics, and cellular and chemical engineering in improving the quality of life and protecting the environment. Emphasis is also given to development of healthcare technology as a component of the emergency response to environmental disasters.

IMO

International Maritime Organization

- Issuance of IMO guidelines for preventing the introduction of unwanted aquatic organisms and pathogens from ship's ballast water and sediment discharges
- Joint IMO/WHO research on ballast water as a medium in the spread of bacterial and viral epidemic-disease organisms
- Species protocols and type of packaging for authorised transmission of biological perishable materials

IRRO

International Resources on the Release of Organisms into the Environment

- Initiated by UNEP through the framework of the Microbial Strain Data Network, (MSDN) in 1990, IRRO is designated to function as:
  - A resource that feeds, and provides technical inputs of support for activities in biotechnology, biodiversity, bioremediation, etc.
  - An electric network facilitating access to microbial data resources maintained in different regions of the world
  - A forum for the dissemination and exchange of information on the kinds of relevant organisms and their characteristics

Johns Hopkins Center (CBS)

Johns Hopkins Center for Civilian Biodefense Studies

- The Centre focuses on development of national and international medical practices and policies coupled to the updating of public infrastructures in protecting the civilian population against bioterrorism.

MC

Mendoza Commitment

- Argentina, Brazil and Chile in Chile in 1991, the 3 states have agreed to:
  - keep their territories free from biological and chemical weapons
  - not develop, produce, obtain, stockpile, transfer or use biological or chemical weapons
  - to engage in the monitoring of biological or chemical agents that have the potential for use in biological or chemical weaponization

OPCW

Organization for the Prohibition of Chemical Weapons

- Established in 1998 to achieve the objectives of the Chemical Weapons Convention; to ensure the implementation of its provisions, to provide a forum for verification of compliance with the Convention's protocols and to engender consultation and co-operation amongst the States party to the Convention e.g. training course in May, 1999 on *Medical Defense against Chemical Weapons,* Tehran, Iran. Attention is also focused on the promotion of free trade in chemicals, and on international co-operation and exchange of scientific and technical information in the field of chemical purposes for peaceful purposes.

PHR

Physicians for Human Rights

- Since 1986, PHR, an organization of health professionals, scientists and private citizens has mobilized its medical and forensic resources to:
  - investigate and prevent violations of humanitarian law
  - improve health and sanitary environments and facilities in detention centres and prisons
  - provide medical care during times of war involving the use of all types of arms and weapons
  - investigate violations of international conventions in force prohibiting the misuse of harmful substances and agents that erode human physical and psychological health
  - investigate, research and document the use of mustard gas in the Anfal

campaign tear gas in Southeast Asia, and poisonous agents elsewhere in regional conflicts.

P*h*RMA

Pharmaceutical Research and Manufacturers of America

- Committed to the discovery, development and market production of breakthrough medicines to conserve human and improve the quality of life, PhRMA has promoted scientific and regulatory activities that focus on:

  - Highlighting the dangers of proliferation of biological and chemical warfare agents
  - Handling and Disposal of Hazardous Materials and Toxic Wastes
  - Surveillance of Emerging Infectious Diseases
  - The Threats of Bioterrorism.

PIR

Centre for Policy Studies in Russia

- Established in 1994, PIR focuses on international security , aims control, and civil-military issues. Research studies focus, amongst other subjects, on:

  - Nuclear, Biological and Chemical Terrorism
  - Educational programme on Arms Control as Non-proliferation
  - Sensitive Exports and Exports Control Measures
  - Destruction of Chemical Weapons in Russia
  - Analysis of implementation of the Chemical Weapons and Biological weapons Conventions.

Pugwash

Pugwash

- The village of Pugwash, Nova Scotia, Canada is associated in the all Pugwash activities since 1957 when it hosted the first conference of 22 eminent scientists from Australia, Austria, Canada, China, France, Japan, Poland, the U.K., the USA, and Russia (then USSR), to focus attention on the threat to civilization arising from the advent of thermonuclear weapons

- Plays an important role in providing an international forum in bringing together policy analysts and advisers for in-depth discussions on: chemical and biological weapons; crisis management in the Developing countries; promotion of sustainable development, and conservation of the environment against the threats of nuclear armoury and bioterrorist attacks

- Pugwash Conferences awarded Einstein Gold Medal by UNESCO in 1989 in recognition of their contribution to culturing, promoting and helping sustain peace worldwide through efforts aimed at reducing the deployment of weaponry of mass destruction and then eventual elimination

- Workshop,in 1988, on Public Health Systems in Developing Countries, in Habana, Cuba, focuses on the erosion of human resources as a result of the interactive equation between poverty and prevalence of infectious diseases; and on threat of emerging diseases e.g. anthrax and small pox that have been contained or eliminated, but which could result from reintroduction as a consequence of the use of the corresponding microbial agents in bacterial weapons.

RADISCON

The Regional Animal Disease Surveillance and Control Network (***RADISCON***)

- Designated for North Africa and the Middle East and the Middle East and the Arab Peninsula is a joint FAO/IFAD activity concerning 29 countries as follows:
  - Maghreb/Sahel Sub-region: Algeria, Chad, Libya, Mali, Mauritania, Morocco Niger and Tunisia
  - Middle East Sub-region: Egypt, Palestinian Authority, Israel, Jordan, Iran, Iraq, Lebanon, Syria and Turkey
  - Arab Gulf Sub-region: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates
  - Horn of Africa/Others Sub-region: Ethiopia, Sudan. Somalia, Djibouti, Eritrea and Yemen

- The network, since June 1996, reinforces methodologies in veterinary investigation laboratory diagnostic and information services, through regional co-operation, and assistance to the Animal Disease surveillance Systems of the network member countries. As a result of such activities, preparedness efforts and emergency responses to potential bio-based disasters are continuously updated.

- The value of FAO's different surveillance systems is exemplified in the swift action undertaken, to contain the outbreak of the debilitating FMD virus amongst beef cattle in Algeria, Morocco and Tunisia, through the RADISCON information network, the FAO/OIE World FMD Reference Laboratory, Pirbright, U.K., the EMPRES network (see above), and the Rome based European Commission for the Control of FMD.

RG

RIO Group

- Established in 1986, and with the membership of Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Panama, Paraguay, Peru, Uruguay and Venezuela, the RIO Group:

    - Established in 1986, and with the membership of Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Panama, Paraguay, Peru, Uruguay and Venezuela, the RIO Group:
    - promotes the establishment of a weapons-of-mass-destruction-free zone in Latin America and the Caribbean
    - monitors the acquisition of dual-use technology and its transfers
    - prohibits the introduction of chemical and biological weapons (of mass destruction) that threaten regional security and co-operation as a result of an initiative – *the Cartagena Declaration* launched by Peru in 1991, and adopted by Bolivia, Colombia, Ecuador and Venezuela

SIPRI

Stockholm International Peace Research Institute (SIPRI)

- The main areas of SIPRI's research are:

    - Implementation of the 1993 Chemical Weapons Convention
    - Developments concerning disarmament of biological weapons
    - CBW terrorism
    - CBW demilitarization and regional concerns regarding armament and disarmament issues

- SIPRI conducts many research and academic activities. Amongst these is the Chemical and Biological Warfare (CBW) project which began 30 years ago in 1966, focuses on all developments regarding chemical and biological weapons. These include establishing of efficient and verifiable disarmament and use by terrorist and criminal groups. Other activities are:
    - Development of an Internet-based educational module on weapons proliferation
    - Acceleration of biological weapons disarmament
    - Monitoring of technology transfer concerning knowledge, equipment and materials within the remit of the Biological and Toxins Weapons (BTWC) and the Chemical Weapons Conventions (CWC)
    - Biological and Chemical Weapons Disarmament in the Commonwealth of Independent States
    - Conduction of SIPRI Chemical and Biological Warfare studies amongst which are:

        a) The International Organization for Chemical Disarmament (IOCD), No. 8, 1987
        b) Verification of Dual-Use of Chemicals under the Chemical Weapons Convention: The Case of Thiodigylcol, No. 13, 1991
        c) Control of Dual-Threat Agents: The Vaccines for Peace Programme, No. 15, 1994.

UNESCO

United Nations Educational Scientific and Cultural Organization

- International Forum on *Possible Consequences of the misuse of Biological Sciences*, December, 1997, Como, Italy in collaboration with ICGEB, and Landau Network – Centro Volta

- Supports programme on *Toxic waste management with special emphasis on biosystems* at International Chemical Studies (ICCS), Ljubljana, Slovenia, 1998
- International School for Molecular Biology and Microbiology established at Hebrew University of Jerusalem with motto *Science for Peace*, and in which framework programme activities are carried out with UNESCO support (1994/1996)

- Through its Field Office in Venice, UNESCO supports and endorses G*enoa Declaration on Science and Society* issued in 1995 by representatives of national and international scientific academies emphasizing the role of science in constructive dialogue between different cultures, and as powerful antidote to intolerance, and to ideological and racial barriers

UNEP

- ***United Nations Environment Programme***

  - Issues London Guidelines for the Exchange of Information and Chemicals in International Trade

UNIDIR

United Nations Institute for Disarmament Research

- Established in 1980 as an autonomous institute

  - to carry out independent research on disarmament and allied issues concerning international security
  - to provide relevant data on problems pertaining to international security, the arms race and disarmament in all areas, with special emphasis in the nuclear field, for purposes of facilitating greater security for all states, and economic and social development of all peoples
  - to promote informed participation by all states in disarmament efforts e.g. *"exchange of information on all outbreaks of infectious diseases and similar occurrences caused by toxins that seem to deviate from the normal pattern as regards type, development, place, or time of occurrence. If possible, the information provided would include, as soon as it is available, data on the type of disease, appropriate area affected, and number of cases."*

  - to improve international cooperation in the field of peaceful bacteriological activities through a conference of participants in projects and publications dealing with

    a) *Biological Warfare and Disarmament: Problems, Perspectives, Possible Solutions*
    b) *The Transfer of Sensitive Technologies and the Future of Control Regimes* with a focus on:
    ~ *Identifying Tomorrow's Key Technologies in Weapon Systems*, and in *Weapons Components*
    ~ *The Transfer of Dual-Use Technologies: The Missing Link Between Security and Development*
    ~ *Cooperative Technology Transfer Controls: Forging New Approaches to Solve Old Problems*

UNIDO

- ***United Nations Industrial Development Organizations***

  - Pioneers in 1987, the institution of ICGEB as UNIDO project
  - Gives support, in 1991, to establishment of the UNIDO/WHO/FAO/UNEP Informal Working Group on Biosafety
  - Issues, in 1992, *Voluntary Code of Conduct for the Release of Organisms into the Environment*
  - Creates in 1995, *Biosafety Information Network* and *Advisory Service (BINAS)* and releases *BINAS News* in collaboration with ICGEB

UNSCOM

United Nations Special Commission (UNSCOM)

- The Commission with a membership of 21 Member States: Australia, Belgium, Canada, China, Czech Republic, Finland, France, Germany, Indonesia, Italy, Japan, Netherlands, Nigeria, Norway, Poland, Russia, Sweden, UK, USA, and Venezuela, targets the elimination and destruction of suspected stockpiles of anthrax spores, botulinum toxin and aflatoxin that were employed for weaponization in aerial bombs and SCUD missile warheads prior to the onset of the Gulf War.

VERIFIN — ***Finnish Institute for Verification of the Chemical Weapons Convention***

- Initiated in 1973 as a chemical Weapons project, and as independent institute of the University of Helsinki, VERIFIN:

  - functions as the Finnish Authority for the Chemical Weapons Convention
  - helps in the development of analytic methods for the disarmament of chemical weapons
  - promotes postgraduate research and teaching concerning the disarmament and elimination of chemical weapons
  - co-operation with OPCW and the UN in the monitoring of compliance with the Chemical Weapons, and Biological Weapons Convention.

WASSENAAR — ***WASENNAAR Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies***

- The *Wassenaar Arrangement* of 33 countries and whose secretariat is based in Vienna, Austria came into force in 1995 as the successor to the *Co-ordinating Committee for Multilateral Exports (COCOM)* which was established in 1950, and is comprised of the original 17 COCOM members: Australia, Belgium, Canada, Denmark, France, Germany, Greece, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Spain, Turkey, UK and USA, and since 1995, with the addition of Argentina, Austria, Bulgaria, the Czech Republic, Finland, Hungary, Ireland, New Zealand, Poland, Romania, the Russian Federation, the Slovak Republic, South Korea, Sweden, Switzerland, and Ukraine with the following goals:

  - Transparency in the transfer of dual-use goods and technologies
  - Minimization of destabilizing stockpiles of such goods
  - Reinforcement of existing control regimes and conventions for weapons of mass destruction, and elimination of threats to international and regional peace and security resulting from unmonitored transfer of sensitive dual-use goods and technologies
  - Prohibition of militarization of sensitive dual-use goods and technologies

WHO — ***World Health Organization***

- In 1997, issues guidelines for the Safe Transport of Infectious Substances and Diagnostic Specimens

- In 1998, establishes Expert Group to review and revise 1970 document: *Health Aspects of Chemical and Biological Weapons.*

- In 1999, issues systematic, worldwide Action Plan and timetable to prevent reintroduction of wild polioviruses from the laboratory into the community

* Measures endorsed by G-7 Declaration on Conventional Arms Transfers.
***Source**: Communique from the London Economic Summit 1991, 16 July 1991*
** Except where the agent is in the form of a vaccine
*** Excluding immunotoxins
**** This group of biological agents, recognised as ubiquitous are still worthy of special caution since they have been part of BW programmes in the past
***** Duncan, A. and Johnson, K. G. 1997. *The Nonproliferation Review*, Vol. 4: pgs 49 - 54
****** Name in parenthesis indicates the author of Chapter

Table (4a). Example of devices for use in developing biodefence programmes

Bacillus Microchip	• Detects *Bacillus anthracis*, and identifies it from amongst other generic members such as *B. thuringiensis*, *B. subtilis* and. *B. cereus*
BIDS	• Biological Integrated Detection System detects through a laser-based sensor large areas under biological attack. Also functions as a warning system. BIDS is also capable of speeding up treatment of biowarfare casualties by narrowing down the range of identities of specific biological agents used as bioweapons. Variations of the system allow for the detection of between to 4 and 8 biological warfare agents in lees than an hour. The system is transportable for use by vehicle and laboratory-designed aircraft
CRP	• Critical Reagent Program designed to provide a ready available resources of antibodies, antigens, and gene probes for use in field detection and neutralization of biological warfare agents
IBAD	• Interim Biological Detector designed as a manual hand-held assay for use on ships with links to aural and visual alarms, IBAD provides advance warning of the presence of biological warfare agents through immunochromatographic analysis
IOTA	• Voltametric instrument comprised of miniaturized electrodes for optional use with antibodies, enzymes, organic dyes, and molecules for detection of heavy metals in body fluids, microorganisms, pesticide contaminants in foods and potable water, etc accompanied by graphic computation
JBPDS	• Joint Biological Point Detection System is designed for use in protecting ports, naval ships, airfields, and as a portable warning system in conjunction with meteorological data. Automatic detection and identification of up to 10 biological warfare agents in less than 30hrs.is feasible. Enhanced versions of the systems focus on providing rapid facilities for the identification of 25 biological warfare agents thus speeding up choice of treatment of casualties
LRBSDS	• Long Range Biological Standoff Detection System possesses a detection range of 50 kms, and through a laser eye distinguishes between artificial and natural aerosol clouds. The system has also been designed for complementary use with BIDS
LIBRA	• Comprised of quartz crystal resonators coated with optional layers of antibodies, enzymes, etc for use in identification of microorganisms, pesticides, and other dangerous organic molecules and chemical gases with computer prints
MAGIChip	• Micro-array of gel-immobilized compounds that identify simultaneously numerous biological agents through reliance on microbe-specific gene sequences, and microbe-specific sequences of ribosomal ribonucleic acids (*r*RNAs)
PAB	• Biosensor system with potentiometric alternating biosensing silicon chip which Interacts with a biological element such as cells, enzymes, etc with measured pH rates or redox potential variation. Used in determining metabolic variations in bacterial cells in response to presence of pollutants, drugs, hormones, pesticides, etc., with graphic computation
Portal Shield	• Used in the Southeast Asian region for the protection of harbours and airfields, this biodefence system facilitates biological detection and identification, decontamination of biosensor equipment and reduction of casualties

Table 4 (b). Examples of biodefence programmes conducted by university, industry and governmental agencies

Category	Characteristics	Research by laboratories			Remarks
		Government	Industry	University	
Antibacterials	• Development of common signatures of infected eucaryotic cells; use of cell-division proteins as broad-spectrum antibacterial targets; development of drugs against bioengineered biological warfare bacteria; use of gene-based broad-spectrum antimicrobial agents; and identification of novel targets that enhance pathogen vulnerability and neutralization	1	3	3	Research conducted in Sweden and the USA
Animal Systems	• Use of insect vectors as early warning systems e.g. detection of chemical signals by parasitic wasps, exploitation of arthropod interaction with biomolecular stimuli, and engineered bee-colonies for detection of harmful of biowarfare agents	1	1	3	
Antitoxins	• Determination of structural biology of Toxins, development of vaccines and potent toxoids, and rapid genetic identification of Gram-positive pathogens	1	1	3	Research conducted in Israel and the USA
Antivirals	• Development of protein-based protective agents; invasive intracellular antibiotics, identification of common target in RNA viruses; disruption of cell transport with non-peptide antiviral agents; and rapid drug responses to biological warfare and bioterrorism without loss in potency and effectiveness during stockpiled storage		2	4	

Table 4 (c) . Biodefence programmes – R & D areas

Type	**Features**
Casualty Care	• Programme depends on novel diagnostic non-invasive technologies coupled to rapid medical and surgical intervention in far forward battlefield areas thus reducing traumatic shock and speeding up containment of biowarfare agents through use of hand-held devices fitted up with ultrasonic imaging and remote telesurgical protocols
Tissue-based Biodefence	• Uses functional biosensors providing assessments of dangers and risks to civilian and military personnel through detection of biowarfare agents in low concentrations through industrial-research projects such as: - vascularized tissue sensors for detection of generic toxins and pathogens - rapid sensitive detection system for biological agents of mass destruction