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Editorial

Technology is critically important for proliferation monitoring, detection and control of potentially harmful biological components. Policy makers and analysts are keenly looking at the 7th Review Conference of the BTWC as there have been major developments in the field of science and technology in the last five years. In view of this, this issue attempts to highlight the important developments in the field of biotech and chemical industries.

In this issue, Dr. B. M. Gandhi discusses few dual-use technologies and their importance. He argues that developments in areas of engineering, computing, chemistry, physics etc are greatly affecting the growth of biotechnology. Mr. Animesh Roul argues that the newer developments in the area of chemical industry have increased the threat from chemical weapons. In the opinion section, Dr. Y. Ashok Babu highlights the fact that with the recent terrorist incidents and increased threat from non-state players the idea of a possible attack by BW agents has gained strength.

This issue also features other regular sections like Country Profile, Kaleidoscope, Chemical and Biological News and Book Review.

As per our readers feedback, we wish to publish issues in the future that focus on a subject of particular concern.

Contributions and feedback are welcome and can be addressed to: editorcbw@gmail.com

Weapons of War: State Actors and Chemical Weapon through the Years

Mr. Animesh Roul

The author is Executive Director, Society of Study of Peace and Conflict

Summary

Throughout the history of warfare attempts have been made to use chemical agents as weapons of war. Most attempts were unsuccessful until the growth of the chemical industry during the latter-half of the 19th century. By the outbreak of World War I in 1914, the first military chemical agents were already in the arsenals of the major powers.

Like the other weapons of mass destruction, Chemical warfare agents (Chemical weapons-CW) have all the appalling elements which represent a serious danger to the living beings at large. Countries like the US, UK, China, Russia, Iraq and Libya were the pioneers in the field of chemical weapons research and production in the world. As a matter of fact, any country which possessed a well-developed chemical industry could produce chemical agents for warfare purposes. Presently, large numbers of industrialized countries have the potential to produce a variety of chemical agents.

Chemical warfare agents have been defined in a report authorized by the United Nations General Assembly as "chemical substances, whether gaseous, liquid, or solid, which might be employed because of their direct toxic effects on human, animals and plants."[1] These toxic chemical agents (CWs) may be used to accomplish a wide variety of military missions. Tagged as 'search weapons', the CW agents are able to penetrate shelters, buildings, trenches, bunkers and other types of military fortifications; they are also capable of inflicting casualties over large areas without damaging vital economic and military infrastructures. Chemical weapon agents are largely invisible and indiscriminate in their effects and offer a prospect of killing or incapacitating enemies and civilians. This category of insidious weapons generates more fear than any other conventional munitions; could very well terrorize civilian populations and demoralize any ill-equipped and exposed military units.

CWs in World Wars

Throughout the history of warfare attempts have been made to use chemical agents as weapons of war. Most attempts were unsuccessful until the growth of the chemical

industry during the latter-half of the 19th century. By the outbreak of World War I in 1914, the first military chemical agents were already in the arsenals of the major powers. The French were the first to use chemical agents in the form of tear gas grenades against the Germans, who defoliated with tear gas artillery shells. Their effect was minimal, mainly due to a complete lack of understanding of how to utilize such weapons. On April 22, 1915, the Germans launched a chlorine gas attack against British and French troops at Ypres resulting in 5000 deaths.[2] The second major development was the use by the Germans of mustard gas and phosgene at Verdun in 1917. The persistence of this agent and its effects were such that in a few months the number of British casualties reached 125, 000, one third of the total British gas casualties for the whole war.[3]

The only incidents involving the actual use of gases between the world wars were in 1936, when the Italians employed a type of mustard gas against the Abyssinians (Ethiopians), and several occasions in 1937 and 1945, when Japan attacked China. About 50,000 Ethiopian army fatalities were caused by chemical weapons during the Italian invasion. It is stated that the Italians used mainly vesicants and asphyxiants.[4]

The use of gas against Chinese civilians was extensive between 1941 and 1942. When Chinese peasants took refuge from the invaders in the caves and tunnels, the Japanese troops used chemical agents to drive them out. In May 1942, Japanese soldiers are said to have discharged gas into the tunnels, killing some 800 Chinese people.[5] After World War II, there have been numerous reports of the use of poison gas in warfare. The first was in Korea and China in the early 1950s. It was claimed that in May 1951, one B-29 aircraft attacked the city of Nampo (North Korea) with gas bombs. As a result, a thousand people were affected and nearly 50% died of suffocation.[6] Again in July, August and in January of the next year, US planes were said to have spread gas in Won San and Hwanghai. However, the casualties and damage done by these attacks were not known.

CWs in the Post World War Era

During the 1963-67 civil-wars in the Yemen between the Royalist regime and the Republican authorities, allegations were made that lethal gas was used by Egyptian forces. It was alleged that gas had killed people and animals by asphyxiation in Kitaf (North Yemen) in January 1967.[7]

Chemical agents were used on a large scale as defoliants to remove jungle growth and prevent their use as cover for guerrilla activities in Indo-China in 1960-70. After this, it was left to the Iran-Iraq conflict to spawn yet another round of large scale use of chemical weapons in war. The war showed definite evidence of the employment of nerve and mustard agents in the Persian Gulf War during 1980-88. It is necessary to discuss at length the massive use of chemical agents in these two above mentioned wars, not only because of large-scale employment of chemical agents but also because of its devastating effects on ecology and mankind. Also the curious case of Libya needs special mention here which secretly stockpiled CWs even after declaring and destroying some of them as per international obligations.

Beginning in 1961, the United States started the "experimental" use of herbicides in South Vietnam as a weapon to exterminate forests and crops The initial objective was to undermine the economic resources of the national liberation movement. In 1962, defoliants became a central weapon in overall chemical and biological warfare strategy of America throughout South-east Asia. Estimates suggest that between 1965

and 1970, more than 50,000 tons of herbicides were dropped on South Vietnam alone.[8] Although the operation began with the intention of merely destroying the economic base of the National Liberation Front (NLF), it was soon expanded into a critical aspect of the shift from ground to air power in South Vietnam. Besides destroying crops, defoliants were used to destroy the forest canopy that hid NLF Forces from detection by air.

The major anti-plant agents that were employed by the United States in Indo-China were 2,4-D, 2,4,5-T, cacodylic acid and picloram. The agents used have been described in two classes, herbicides and defoliants.[9] Most of the anti-plant chemicals were dispersed from C-123 transport aircraft equipped to deliver somewhat over 3600 litres. Some were dispensed from helicopters, and others by truck and boat-mounted spray rigs.Official American reports state that from 1961 only five million acres of land were sterilised. But Vietnamese statements contend that in the first two months of 1969 alone, some 37 of the 44 provinces of South Vietnam were sprayed, contaminating 285,000 people. At least 500 people died. In these raids more than 905,000 hectares of rice, orchards and other crops were destroyed. Between late 1961 and October 1969, it is estimated that 43 per-cent of the arable land and 44 per-cent of the total forest area of South Vietnam were sprayed at least once and in many cases two or three times with herbicides. Over 1,293,000 people were directly contaminated.[10] Due to this, agricultural productivity has been severely curtailed in many regions. The delta area of South Vietnam, once considered the rice bowl of South-east Asia, became an importer of rice from foreign countries.[11] Besides defoliants and herbicides, more than 7,000 tons of other poisonous gases were used between 1964 and 1969.

Both Iran and Iraq used poison chemicals a number of times during the course of war between 1980 and 1988. By 1983, Iraqi production of mustard gas was sufficient for Iraq to begin to deliver small amounts with artillery, fighters, and MI-8 helicopters. It is unclear exactly when Iraq developed bombs using chemical agents, but it seems to have used 250-kilogram bombs bought from Spain.[12] In comparison to Iraq, Iran seems to have begun a crash effort to acquire an internal production capability in 1983-1984. These efforts began to pay off in 1986-1987. Iran began to produce enough lethal agents to load its own weapons. Like Iraq, it could produce blood agents like hydrogen cyanide and phosgene gas.

It was alleged by Iranian governmental agencies that by the autumn of 1984 Iraq had used chemical weapons in more than 130 instances since the beginning of the Gulf War in 1980, killing or injuring at least 3500 people, including non-combatants.[13] On March 12, 1985, within a few hours of the opening of the long-expected Iranian offensive across the Hoveyzeh Marshes, the official Iranian news agency announced that Iraq intended to use chemical weapons. Over the next four weeks, according to Iranian reports, there were 32 further attacks in which 4600 Iranians were killed or injured by chemical weapons.[14]

Iraq continued to use chemical agents in its war with Iran. During the second week of February 1986, around 10 percent of a large Iranian force attacking Faw became casualty to chemical weapons; some 2000 people are said to have been burned with mustard gas on February 13 alone.[15] In mid April 1987, it was alleged that Iran used mustard, tabun and phosgene in artillery shells against Iraqi forces on the Southern Front causing 385 casualties.[16] This was denied by the Iranian government. Iraq made massive use of chemical weapons during its re capture of

Faw in early 1988 and in its assaults to recover its positions outside Basra. By April 1988, Iran claimed that the new round of attacks had raised the total number of casualties from chemical weapons since the start of the war to around 25,600, with some 260 dead.[17] During the final months before the cease-fire, Iraq used chemical weapons in its attacks on Iranian positions in Mehran, the Majnoon Islands, the Hawizeh Marshes and Deh Loran. The worst single use of gas against civilians occurred at the village of Halabjah on 16 March 1988 when mustard gas and nerve agents were used to kill up to 5,000.[18]

The other example is Libya which produced chemical weapons during the 1980s, and is suspected to have used CWs against Chadian troops in September 1987.[19] The notorious Rabta industrial complex (located southwest of Tripoli) produced mustard gas, sarin, and phosgene. The Gaddafi regime declared possession of at least 25 metric tonnes of mustard agent and 1,400 metric tonnes of precursor chemicals, which are used to make chemical weapons.[20] Even though the Rabta remained inactive and Libya destroyed some chemical weapon artillery shells under the supervision of the Organization for the Prohibition of Chemical Weapons (OPCW), it is now came to light that the just ousted Libyan regime has stockpiled CWs secretly, in an apparent breach of promises made in 2004 when Libya joined the OPCW.

Conclusion

The intentional use of chemical weapons in Vietnam has set a dangerous precedent. Though some have gone so far as to describe it as a valuable experiment in ecology, it must be considered as one of the most irresponsible and criminal acts of the century. This so-called experiment led to a major proliferation of chemical weapons, especially in the Third World countries, where chemical weapons are considered a "poor man's" nuclear weapon. Most of these countries argued for the production and stockpile of CWs only because of the idea of a chemical weapons stockpile as a deterrent. The production and use of chemical weapons for the Iran-Iraq war and the case of Libya's secret CW arsenal demonstrated the proliferation and capability of State actors to produce militarily significant arsenals of weapons of mass destruction.

However, this proliferation of chemical weapons was not confined to nations alone. The ability of terrorist groups and individuals to disseminate chemical weapons is an issue of considerable concern in recent times. The 1995 Japanese subway attack demonstrates this ability when the religious cult Aum Shinrikyo used lethal sarin nerve gas in a busy subway in Tokyo, killing and injuring many people.[21] This development aptly reflected the availability and danger of CWs in the hands of terrorist groups as well as rogue states.

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Biological agents: Uncontrolled entry of exotic pathogens a major dent for Indian economy and security

Dr. Y. Ashok Babu

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Summary

During and after World War II, various kinds of biological agents were weaponised. These included anthrax causing bacilli, vibrio cholera, and burkhalderia species against livestock, among others. All the countries that are signatory to the BWC have destroyed stockpiles of biological warfare agents. Small quantities of samples are still available with some of developed countries for the purpose of developing vaccines and detection technologies in case of future outbreaks.

The history of use of biological agents (BW) date backs to 595BC, where extracts of toxic plants hellebore was used to poison the water supply of town Delphi during first sacred war. Since then, use of biological agents evolved both in variety and delivery technology till Biological Weapons Convention came in force in 1973, which has reduced the threat of use of biological warfare agents. However, even before that, with the development of nuclear bomb, use of biological agents as weapons of choice become less attractive since biological agents lack the magnitude of destruction when compared to nuclear weapons and also due to the fact that medical technologies to contain the spread of most of the biological agents advanced due to breakthrough research. However, with the recent terrorist incidents and increased threat from non-state players, the threat of possible use of BW agents has re-emerged.

Based on the potential extent of destruction a biological agent can cause, they are classified in to two different groups; 1.Contagious pathogens such as bacteria, virus which can spread rapidly across the population causing mass destruction and 2.Biological toxins, which are non-contagious but are highly lethal such as botilinumtoxin, risin, saxitosin etc.

During and after the World War II, various kind biological agents were weaponised. It most included anthrax causing bacilli, vibrio cholera, and burkhalderia species against livestock, among others. All the countries that are signatory to the BWC have destroyed stockpiles of biological warfare agents. Small quantities of samples are still available with some of developed countries for the purpose of developing vaccines and detection technologies in case of future outbreaks. Though India does not have any biological warfare agents in its procession, it has signed and ratified the BWC in 1973.

The Present Scenario

The threat of the use of biological agents by non-state players reemerged after the controversial use of anthrax spores in the mails sent to US congressmen. Subsequently, the threat perception has become larger than the threat itself. This changed perception has tremendously increased the financial burden on developed and developing countries alike. The cost of development of defense against BW agents is enormous when compared to that of developing the weapon, especially in the developing and poor countries where the infrastructure is poor. Development of defence technologies in this area includes surveillance, detection (Diagnosis), prognosis and protection (medical protection). The complexity of detection and protection against biological agents varies between types of pathogen. For example, viral agents are most potent of the biological agents due to the complexity of development of protection techniques when compared to other pathogens and also due to their rate of spread to larger areas.

In the recent times, there have been outbreaks of infection with various exotic and mutant viral pathogens across the world which includes avian influenza, SARS, Swine flu, Dengue fever etc. The rapidity of spread and virulence of these pathogens is comparable to that of any classified biological agents. Unfortunately all these exotic infections have had easy entry into India and they have caused enormous loss in both human and financial terms. As mentioned earlier, the spread of this pathogen is faster than any other bacterial pathogen. Therefore, rapid development of diagnostic techniques and procurement of medicines is essential which in turn causes enormous financial burden. Contrary to belief, during the recent instances of outbreaks, even though temperate climates were more favorable for spread of pathogen, many countries such as Japan, USA, and EU members were successfully able to contain the spread of these pathogens due to the availability of modern infrastructure and effective surveillance. As mentioned earlier, surveillance is the first and strongest step to contain spread of pathogen. However, in many cases, surveillance and detection work together to contain spread of pathogens. Focusing on the above aspects tremendously reduces the risk of infection and also eases the associated financial burden. Disease or pathogen surveillance in the above scenario is a co-ordinate task involving people of various expertises ranging from intelligence and law enforcement agencies to scientist and doctors. As pathogenicity and ease of spread of diseases like SARS is comparable to BW agents, preparedness to combat against these exotic pathogens should be at the same level. Japan and other countries successfully prevented the entry and spread of exotic pathogen by many tier surveillance and monitoring systems right from the entry points such as Airports, Sea ports and other cross country entry points. They were successful because preventive measures of pathogen surveillance are cost effective when compared to enormous financial burden that the spread of pathogen bring about.

Conclusion

India's biotechnology and pharmaceutical industries are developing in positive ways. They are also interacting with other agencies to increase their effectiveness in research and development of appropriate medicines. However, since India is a developing and expanding market, efforts need to be made to put in place adequate checks and balances to ensure that their growth is not harmed because of vested interests. At another level, there is a necessity for effective disease surveillance right from the point of entry into the country to prevent spread of exotic and dangerous pathogens. These prophylactic

measures can effectively reduce the financial burden and loss of human life.

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An Overview of the Advances Made in Biotechnology and Related BTWC Concerns

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Summary

BTWC is apprehensive of development of dual-use technologies in the areas of genetic engineering, biotechnology and microbiology, for high growth of products and processes that are capable of being used for purposes inconsistent with its objectives and provisions. These include all microbial and other biological agents or toxins, naturally or artificially created or altered, irrespective of their origin or method of production.

This paper is a collation of information available from literature in public domain.

Introduction

The Biological and Toxin Weapons Convention (BTWC) entails prohibition of the development, production and stockpiling and acquisition of biological and toxin weapons. Efforts were made to negotiate a protocol to include detailed investigation and verification to ensure that participating countries fulfilled their obligations of non-acquisition or retention of microbial or other biological agents or toxins harmful to plants, animals and humans, in types and in quantities that would have no justification for prophylactic, protective and other peaceful purposes. However, the discussions were inconclusive.

BTWC is apprehensive of development of dual-use technologies in the areas of genetic engineering, biotechnology and microbiology, for high growth of products and processes that are capable of being used for purposes inconsistent with its objectives and provisions. These include all microbial and other biological agents or toxins, naturally or artificially created or altered, irrespective of their origin or method of production. Increased knowledge of uses of many pathogenic species of micro-organisms, extraction of toxins and other biological agents and the pace of development in civil biotechnology further accentuate the possibilities of production and hostile use of biological agents. Dual-use technologies, even though they may not in principle contravene BTWC, can be used to create agents for offensive purposes. Current efforts by nations focus intensively on technologies for creating new means of protection against biological threats.

Developments in areas like physics and chemistry and engineering, computational and material sciences greatly impact progress in biotechnology. Genetic

engineering, biotechnology, toxicology, molecular biology and other related sciences have also made it possible to create a new generation of biological weapons (BW). Scientific and technological developments which would lead to transformation in organisms to be used as BW could include (i) increase in the virulence and antibiotic resistance of pathogenic agents; (ii) enhancing non-transmissible agents for airborne transmission; and (iii) creating organisms or biological products capable of acting on humans and ecosystems (parasites, insect-pests, disease vectors, etc.). Technical developments of major concern to BTWC would include:

Bio-defence: BW are capable of inflicting casualties over a large area with military effectiveness. Factors impacting their effectiveness may include use of novel agents that are not well characterized and for which there may not be vaccines or treatment. Decontamination may be difficult if deployed sensors cannot detect the agents utilized. The process of scientific and technological changes in detection, identification, diagnosis and protection provides increased capabilities to counter or protect against BW.

Genetic modifications: Advances in genetics and genetic modification techniques are making new types of vaccines feasible. There is considerable research towards genetically modified live vaccines able to immunize simultaneously against multiple antigens. Advances in knowledge of the molecular basis of antigens have led to antibody reagents of improved specificity.

Mechanism of action of micro-organisms: Understanding the mechanism of action of micro-organisms gives direct access to the mechanism of action of potential BW agents. Using molecular biology, mechanisms of virulence and infection have been identified; the same techniques may also permit deliberate manipulation of these mechanisms. Transferring certain genetic traits into naturally infectious micro-organisms can potentially create organisms of greater virulence, antibiotic resistance and environmental stability. Changing the microbes genetically could alter their immunogenicity, thereby invalidating vaccines and sero-diagnostic techniques. Otherwise harmless micro-organisms could be altered to produce toxaemia or disease: the host would continue to recognize them as innocuous and therefore not defend against them.

Micro-biological developments: Human understanding of a number of factors of direct relevance to protein synthesis and assembly has increased enormously. Remarkable progress has been made in the application of this knowledge to the production and isolation of heterologous proteins from *E. coli* and other bacteria like *yersenia*. Different expression systems are being tried.

Human Genome Project (HGP): The immediate benefits of HGP will be the identification and localization of genes causing hereditary diseases and simplification of the development of pharmaceutical drugs for treatment of hereditary diseases. It will also greatly refine their prenatal diagnosis. Investigations also provide sufficient data on ethnic genetic differences between population groups. Such data would also provide target-suitable micro-organisms to attack known receptor sites for which differences exist at cell membrane level or even to target DNA sequences inside cells by viral vectors.

Toxins and Regulators: Genetic engineering has made possible large-scale extraction and production of potent toxins, which until now were available only in minute quantities and only upon isolation from immense amounts of natural biological materials. These toxins

can now be produced in kilogram quantities in a short time with minimum cost, which could be of military significance. Rapid progress has also occurred in the modification of naturally occurring bioregulators, in understanding the physiological effect of certain essential biological substances when they are present in abnormal concentrations or under abnormal conditions, and in understanding the possible pathogenic effects of proteins.

Of special interest to BTWC are applications of biotechnology in directed molecular evolution such as genetic modification, recombinant technologies, proteomics, bio-informatics, and synthetic and systems biology. Some of these technologies vis-à-vis potential applications of consequence to BTWC are discussed in the following paragraphs.

Recombinant DNA (R-DNA) Technologies

Recent advances in biotechnology have enabled rapid and relatively inexpensive identification, characterization, mapping, manipulation and synthesis of genes and short strands of genetic material. They have helped in advancing modification of DNA or RNA in plant or animal cells or in micro-organisms like bacteria, viruses or fungi, resulting in their acquiring new unique properties. These techniques have a very wide range of applications in healthcare, agriculture and animal husbandry. They are being developed as simple to use and cost-effective; and because of their efficiency and range of potential applications, a larger number of people has access to them for use in academic institutions and industry. At the same time, these technologies have opened avenues for dual use for nefarious purposes. rDNA techniques of relevance to BTWC include:

i. **Genetic engineering:** Genetic engineering technologies have helped in manipulation of both DNA viruses and RNA viruses by inserting specific genes or nucleotide sequences into a host genome. Through reverse genetic engineering, researchers can introduce viral RNA into bacterial cells, where it can then be manipulated much more easily. Clones have already been constructed for viruses like poliovirus, yellow fever virus, H1N1 influenza A, rabies, and others. It is also now possible to reverse-engineer dangerous viruses like corona viruses, H1N1 influenza A and H5N1.

ii. **DNA synthesis:** DNA synthesis is de novo generation of genetic sequences that specifically program cells for the expression of a given protein. Technology enhancements coupled with automation and mechanization have increased the speed, ease, and accuracy with which larger sequences can be generated chemically. Examples are syntheses of genomes of poliovirus and the 1918 influenza virus. This raises concerns that more complex dangerous organisms, such as the smallpox virus, may be synthesized de novo some day.

iii. **Genome sequencing:** HGP and advances in sequencing technology have helped generate genomics data for a number of pathogenic micro-organisms. These data have helped characterize their properties and their mode of action, including virulence factors, which form the basis for new therapies, vaccines and medicinal drugs. This wealth of information can also be misused to enhance the pathogenicity of micro-organisms through genetic modification or to convert harmless organisms into a pathogenic variant

that is difficult to detect, diagnose or treat.

iv. **Fusion protein:** This technology involves insertion of a toxin in a protein, enabling it to identify and kill specific cells. This is currently being researched with a view to target and kill cancer cells. But programming the toxin differently could make it possible to kill cells essential to life.

v. **Combinatorial chemistry:** Combinatorial chemistry involves technologies to generate huge libraries of synthetic compounds with diverse properties in order to screen them for activity against biological drug targets. It contributes to drug discovery and development and to the search for better superconductors and biosensors for the detection of medically important molecules and environmental toxins. But these libraries could also be quickly and easily searched by those with malign intent for compounds with the potential to interact with endogenous physiological pathways for use as biochemical weapons.

vi. **High-Throughput (HTP) Technologies:** HTP screening used for assessment of compounds with therapeutic potential implies technologies, such as automated sequencing, mass spectrometry proteomics, transcriptomics, proteomics and metabolomics approaches coupled with advanced computational approaches to capturing information about an organism on a global scale to analyse and build a predictive model. The use of micro-organisms or higher cells in tissue culture genetically engineered to monitor a specific biological activity has made it possible to screen several thousands of compounds for the desired drug properties. This in turn has generated a wealth of genetic information on basic DNA, protein, and functional informational resources available worldwide. Some of these compounds will inevitably have activities that are toxic or affect animals and humans in harmful ways. Access to this knowledge would allow rapid identification of potentially dangerous agents.

vii. **Directed Drug Design:** Rational drug design uses structural knowledge of the drug targets to design novel chemical compounds that bind to selected sites on the surface of target molecules or mimic the structure of the target molecule, thereby competing for a receptor molecule's binding site(s). This technique is more specific than combinatorial chemistry in that it allows the scientist to target a desired site and function, and design a drug with particular properties rather than screen through a large library of compounds looking for those properties.

viii. **Synthetic Biology:** The system incorporates use of technologies in DNA synthesis, bioinformatics, and reverse genetics in order to fabricate useful microbes and learn about the underlying principles of cellular function by reducing biological systems to their simplest components and by creating models of genetic circuits. Synthetic biology allows researchers to develop a registry of biological parts and essentially create tiny programmable computers from living organisms. Re-engineered bacterial proteins when tagged with TNT are able to detect chemical or biological agent signatures or clean up environmental pollutants. The technology would also allow

creating new or existing pathogens for malicious purposes.

viii. **DNA Shuffling**: DNA shuffling involves *in vitro* homologous recombination of genes by random fragmentation and polymerase chain reaction reassembly and amplification to evolve genes and novel proteins with novel or improved functions. It allows generation of novel proteins, viruses, bacteria and other organisms in a cost-effective manner and in a fraction of the time required with classical breeding. This technology has been extended to production of small-molecule pharmaceuticals, pharmaceutical proteins, gene therapy vehicles and transgenes, bacterial and viral vaccines and laboratory animals. On the obverse side, the technology is open for adoption to generate potentially lethal viruses and bacteria.

ix. **Artificial synthesis of viruses:** Small viruses are being synthesized, based on availability of genetic code. Thus, a complete, fully functioning polio virus was synthesized in 2002 by a group of American researchers. Constructing viruses that are difficult to obtain remains a possibility as long as the genetic code is known. For larger viruses, technologies like Polymerase Assembly Multiplexing using microchip arrays are being standardized. For still larger viruses like smallpox, technologies are being tried to introduce DNA changes into the genome of other family members of poxviruses, which may lead to a change in the host range of these viruses to include humans. These developments may be disturbing: the structure of viruses is extremely simple compared to bacteria, and immunity – either natural or conferred through vaccination – has over the years disappeared in the human population. New technologies may also be able to build more complex viruses is due course of time.

x. **RNA interference (RNA*i*):** RNA*i* technology has the potential to suppress cellular production of certain proteins in the physiological processes to halt undesirable processes or stimulate desirable ones of importance in therapeutic use. Efforts are being made to develop this tool to target disease-causing genes and proteins that are inaccessible to conventional drugs. Short, single-stranded nucleic acids (aptamers) and protein-DNA chimeras (tadpoles) have high binding affinity and are being explored in animal models for their potential to be used in the inhibition of blood clot formation and treatment of age-related ocular degenerative changes. The effectiveness of small interfering RNA (*si*RNA) as antiviral has been demonstrated *in vivo* for Ebola virus infection of primates. RNA*i* technology also has major implications in the functioning of the mammalian cells. Studies have demonstrated the role of siRNA in animals' regulation of gene expression by micro-RNA molecules (*mi*RNA), which interact with cellular RNAs to suppress certain proteins and silence the expression of target genes. siRNA are otherwise also sufficiently active to function as potent antiviral agents to modulate gene expression in adult animals.

In plants, RNA*i* is commonly being used as antiviral defence mechanism. *si*RNA molecules, initially identified in plants, are able to promote the sequence-specific degradation of messenger RNAs and are therefore able to suppress gene expression.

Theoretically, the approach of using RNA*i* technology has wide implications for developing therapeutics for a number of diseases and as a research tool in functional genomics. The technology also allows long-term, efficient silencing of an allele that segregates with ethnicity. Silencing of genes that function in innate immunity could lead to conditions that mimic, at least superficially, natural disease. The whole approach of RNA*i* defines a significant change in the utility of genetic weapons technology. RNA*i* would have dual-use implications. New therapeutic options for treating cancer and other diseases could also lead to manipulating gene expression to do harm.

Human Genome Project (HGP)

HGP, completed in 2003, discovered all the estimated 20,000-25,000 human genes and makes them accessible for further biological study. It also determined the complete sequence of the three billion DNA subunits bases in the human genome. The technology and resources generated by the project and related genomics research have already created a major impact on research across the life sciences. The potential for commercial development of genomics research presents a wealth of opportunities, which are now being exploited.

Information generated by HGP has wide applications in biomedical research leading to improved diagnosis of diseases, drug design, pharmacogenomics, gene therapy, etc. Microbial genomics research has led to sequence of bacteria useful in energy production, environmental remediation, toxic waste reduction, and industrial processing. Other applications are in the areas of environment risk assessment for individuals from toxic materials, DNA forensic sciences including fingerprinting, pollutants, breeds, etc. Genomic studies are also directed towards study of evolution, migration and mutation with age. Understanding plant and animal genomes will help in studies of disease patterns in plants and animals, disease-resistant plants and animals, reduced management costs, and better, nutritious and pesticide-free foods.

However, HGP has also raised serious concerns. Elucidation of the structure of human DNA and the functioning and regulation of genes makes it possible to identify markers which determine the racial and ethnic differences between people and target the genetic makeup and ethnicity of specific groups of people. A study in the US on the Y-chromosome and mitochondrial DNA in populations from different regions has suggested that the data generated could be used for developing methods to selectively disturb cellular respiration and energy exchange, sexual reproduction and a number of other important functions connected with the Y-chromosome.

Data analysis of the human genome showed that hundreds and even thousands of sequences obtained could serve as targets for selective BW based on the difference in frequency of genetic markers between races and difference in the frequency of polymorphisms. A recent study in Taiwan has discovered that Severe Acute Respiratory Syndrome (SARS) can be associated with specific genetic profiles.

Genomics and Proteomics

Genomics

After completion of the human genome and rat sequences in HGP, there have been dramatic advances in the sequencing of mammalian genomes. Several hundred eukaryotic genome sequencing projects are underway. Technology developments,

including capillary sequencing machines and high-density overlapping oligonucleotide chips, allow rapid re-sequencing of genomes. Genome sequences are now available for hundreds of pathogens, especially bacterial and viral pathogens of public health importance. The technology is being used to study the extent of sequence variation that exists within a species. Genome sequencing of pathogens using HTP screening has helped in better understanding of antibiotic resistance and emerging and re-emerging bacterial and viral diseases.

The International HapMap Project, initiated in 2002, is a multi-country effort to identify and catalogue genetic similarities and differences in human beings and a major effort toward identifying genes affecting health, disease, and individual responses to drugs and environmental factors. Information generated under the project would be available in the public domain and could be exploited to target specific groups with harmful agents. Identifying populations most vulnerable to certain diseases also makes them vulnerable to isolation as potential targets.

Use of advanced sequencing technologies has also led to mapping of the molecular signatures of the bioregulatory systems of the body and how these regulatory pathways respond to disease-induced disturbances. The information, which is critical as target for therapeutic and preventive intervention or manipulation, can also be used for a novel biological attack. Significant advances have also been made in genomic medicine, where patient-tailored treatment of diseases is prescribed based on analysis of his/her genetic makeup.

Proteomics

The proteome is traditionally studied through a combination of gel electrophoresis and mass spectrometry. Use of HTP automated technologies and fractionation strategies coupled with mass spectrometry and gel separations has made it possible to detect low levels of proteins or sub-groups of proteins and analyse protein mixtures. Proteomics can differentiate isolates or strains and greatly enhances our knowledge of host-pathogen interactions, protein-protein interactions, host response to infection and pathogenesis. Proteomics also has applications in identification of candidates for diagnosis, therapy, detection systems and vaccines; this knowledge could be exploited for non-peaceful purposes.

In comparative proteomics, proteins from different growth conditions, strains or species can be labelled and differentiated using mass spectrometry to identify proteins having a role in virulence, interaction with the host or the environment, and antibiotic resistance. Identified proteins can be used as vaccine candidates or targets for therapeutics or diagnosis. In addition, identifying proteins expressed under a wide variety of conditions can lead to the identification of targets for detection systems.

The 'immunome': The study of immuno-dominant proteins which trigger immune response to infection and that of the interaction of antibodies and antigens can lead to an understanding of the humoral immune response and identification of antigenic determinants for inclusion in future vaccines. The introduction of protein arrays enables the rapid analysis of hundreds of proteins in parallel. These techniques are being used to detect and diagnose biomarkers as well as possible vaccine candidates.

Synthetic biology: In most cases, with the exception of RNA viruses, DNA acts as a blueprint producing all the essential elements required for a functional biological

system. Technological gains in chemical DNA synthesis have facilitated synthesis of DNA constructs, which has made de novo synthesis of some small viruses a reality. Efforts are being made to synthesize large viruses' constructs and chemical synthesis of bacterial genomes.

Protein expression and production technologies: Progress in rDNA technology has allowed cloning directly into expression vectors and high-fidelity easy transfer of genes between expression vectors. This has decreased the time and efforts required to clone a target gene and reduce the level of expertise required. Advances in vectors and plasmids to enhance the expression of soluble and problematic proteins have raised the potential to generate significant quantities of a protein to be produced from synthetic DNA. Expression systems are commercially available for production of proteins within bacteria, yeast, plants, filamentous fungi, insect and mammalian cells.

Synthetic biology has allowed construction of functional genetic circuits in cells and micro-organisms, merging engineering approaches with biology. Sets of standardized genetic building blocks are developed and suitably assembled to perform specific functions such as detection of toxic chemicals, explosives and biological agents, disease diagnosis and therapeutic intervention, production of pharmaceuticals, bioremediation of pollutants, energy generation, etc.

Chemical DNA synthesis facilitates efficient and cost-effective production of natural products with potential uses in therapeutics or for other beneficial purposes. The technology is of particular benefit especially when analysing proteins from dangerous organisms, in that the gene can be chemically synthesized, and then cloned into, expressed in and purified from a suitable host cell without the need to handle the original organism. This may preclude the need for containment facilities and procedures normally required for work on pathogens. But this technology has the potential for misuse, since exotic pathogens are exploited without having the necessary infrastructure.

The rapidly developing field of synthetic biology also has the potential to create risks for society, due to either unintentional consequences for health or the environment or deliberate misuse.

Advances in recombinant technology have led to increasing focus on the production of proteins from pathogenic hosts in micro-organisms which are more easily and safely handled on a large scale. High containment facilities, cost and skilled labour make it a distinct possibility in reality. An example is a recombinant protective antigen as the basis of a new-generation anthrax vaccine.

Gene Therapy

Gene therapy uses healthy genes to treat or prevent disease by inserting a normal gene into the genome to replace an abnormal, disease-causing gene. It typically uses a carrier molecule or vector, such as a harmless virus, to deliver the healthy gene to the target cell. This technology is also used to introduce new genetic material into the cells of individuals with the specific target receptors or to inhibit the expression of endogenous genes. The technique, though in an experimental state and yet being standardized, has major potential benefits for human and animal health in the treatment of genetic diseases and in the modulation of gene expression such as suppression of inappropriate immune reactions. The silencing of alleles associated with ethnicity now appears theoretically possible.

Studies however have also reported setbacks in the development of vectors for delivery of such therapy. Repeated application of high doses of adenovirus vectors is apprehended to lead to immuno-pathology; lentivirus/ retrovirus vectors may also be associated with cancer-causing effects. Safety considerations also have the potential for misuse, providing the opportunity to achieve long-term expression of a deleterious gene in a target population.

Development of affinity media for both laboratory- and manufacturing-scale purification of affinity-tagged protein results in high yields of a specific product. New systems are now available for laboratory-scale automated purification of several proteins simultaneously.

Continuing progress in processing equipment for the pharmaceutical and biotechnology industries has led to the emergence of portable bioreactors featuring disposable contact materials that eliminate cleaning, sterilization and validation and can easily be used for virus production, monoclonal antibody production, cell culture and production of human therapeutics. But these developments are potentially open for misuse. Successful protein expression and production strategies, including portable systems, can facilitate dual use: benefits to the pharmaceutical and biotechnology industries as well as potential BW production. Transgenic plants could be engineered to produce large quantities of bio-regulatory proteins or toxins, which could be extracted from plant cells or used directly as BW agents. Being natural bioreactors, they eliminate the need for much sophisticated equipment for producing them in large amounts.

Systems Biology

Systems biology or integrative biology involves the application of systems – and signal-oriented approaches – to understanding inter- and intracellular dynamic processes. Tools that could be used to manipulate complex biological systems include gene silencing, novel binding reagents like nucleic acid, peptide aptamers, engineered antibodies, immune modulators, etc. Advanced HTP tools are used to study the complex interactions involving networks of molecules, including DNA, RNA and proteins to analyse cellular regulatory networks and pathways and genomic and proteomic setup. These tools have a great impact in improving the predictive accuracy of models of biological systems, which allows physicians better management of preventive and therapeutic measures based on genotypic and phenotypic makeup of individuals. The same advances could also make it easier to identify ways to maliciously manipulate biological systems.

Micro-fluidics and micro-fabrication technologies have been used in manipulation of a wide variety of processes at miniaturized scales using automation. These technologies find application in DNA analysis, immunoassays, cell analysis and measurements of enzyme activity and have greatly enhanced the diagnostic ability of disease outbreaks. Such technologies are applicable in both naturally occurring and deliberately created conditions and open the road to identify ways to maliciously manipulate biological systems, thus introducing novel aspects of future bio-defence and bio-threat agents.

Host-pathogen Relationship

Microbial genome sequencing programmes have led to better understanding of the pathogenicity and virulence factors contained in the genetic makeup of micro-organisms. They have greatly improved the knowledge of how several micro-organisms effect pathogenesis through characterization of their discovered virulence factors. There is increasing awareness that many of these virulence factors act in concert with one another and with host factors.

There has also been an increase in the studies of the response of the host to infection in order to fully characterize the virulence of micro-organisms. Although DNA micro-arrays have been used to study the gene expression profiles of pathogens, there has recently been a substantial increase in transcriptional profiling of the host in response to infections with pathogens. Experiments that measure the host transcriptional response to a pathogenic strain, relative to an attenuated strain that lacks a key virulence determinant, provide knowledge on how these interactions develop into pathogenesis. This increase in knowledge in the host's role in pathogenesis and, consequently, an understanding of mechanisms of immune protection may potentially open an avenue for misuse through the development of molecules for weakening the immune response to specific pathogens.

Vaccines and Therapies

Market requirement of vaccines and biological agents has grown tremendously. In India, the requirement of therapeutics has registered an annual increase of between 15 and 20 per cent. Global research continues towards improvement and development of new vaccines and technologies. New micro-organisms, new molecules, carrier systems and delivery modes are being adopted using new principals to improve the efficacy of biological materials. Vaccines and diagnostics are available for almost all the known disease conditions. There is an equal interest among nations to develop or acquire vaccines and biological agents for defence purposes since these show possibilities of discovery of compounds with potential for misuse.

Significant advances in technologies, accompanied by sophistication in engineering processes, have helped in the diagnosis of and development of antiviral drugs, especially reverse transcriptase inhibitors, DNA polymerase inhibitors or protease inhibitors for treatment of a range of infectious and non-infectious disease like HIV, hepatitis B and C and malaria, influenza viruses H1N5, H1N1, etc. Vaccines and anti-viral drugs are also being developed of defence interest, including anthrax, poxvirus infections, etc. As we have seen earlier, recombinant and gene technologies have also been used to develop DNA vaccines and sub-unit vaccines and artificially produce small viruses and other oligo-nucleotides.

The use of phage/ribosomal display technologies, combinatorial chemistry, molecular modelling and HTP screens has helped in the discovery and design of potential therapeutic peptides. Specific peptides for a particular cell surface receptor bring about an intracellular effect on a target cell and/or a physiological change in the target organism. Some of these peptides are increasingly in use to target specific markers in oncologic conditions. Immuno-modulators such as cytokines and non-specific immune stimulators strengthen the immune defence system to protect against a range of pathogens. Commercial-scale synthesis of peptides can also provide significant quantities of desired pathogens produced in

recombinant micro-organisms or in transgenic plants or animals.

New antiviral drugs have been developed using reverse transcriptase inhibitors like VIREAD (tenofovir disoproxil fumarate) for treatment of HIV, and DNA polymerase inhibitors like HEPSERA (adefovir dipivoxil) to arrest replication of the virus responsible for chronic hepatitis B.

Delivery of sufficient quantities to the appropriate target cells or tissues across the blood/brain barrier is a significant challenge to the development of therapeutic peptides. Vaccine delivery systems using new aerosol generating devices and improved adjuvant, live vectors and micro-encapsulation technologies are being developed commercially for effective delivery of therapeutics. Therapeutic use of targeted monoclonal or polyclonal antibodies has proved useful to prevent and treat virus-induced diseases.

Penetration enhancers with ability to penetrate the skin or mucous membranes to improve the absorption of medicinal drugs also lower the threshold at which micro-organisms or toxins become harmful. The potential benefits of advances in technology for delivery of drugs and vaccines also raise the potential for misuse, such as making new routes for the delivery of BW, especially immune modulators and immune stimulators to attack the immune system. Such methods could also result in the intentional or unexpected discovery of compounds with potential for misuse.

Bio-regulators

Bio-regulators or Physiologically Active Materials (PMNs) are naturally occurring substances present in very low concentrations in the body. They conduct biological activity that regulates and coordinates a number of physiological processes, including cardiovascular function, respiratory system, nervous system and immunity. Bio-regulators include hormones, signal molecules, enzymes and inflammatory mediators. Knowledge in this field has made it possible therapeutically to intervene in order to boost desirable processes or slow down harmful ones. Advances in the areas of life science research on bio-regulation of physiological functions has led to characterization of bio-regulators and the search for promising compounds for pharmaceuticals. There has been a tremendous increase in the identification of peptides, both toxins and bio-regulators that control biological processes. An excess of certain regulators is found to lead to sleep disturbance and behavioural changes. Administering other regulators will lead to autoimmune reactions or, because they can affect blood pressure or cellular ion homeostasis, to heart rhythm disturbances, organ failure, paralysis, coma and death.

PMNs are aimed specifically at the cells to ensure the first line of antiviral and anti-tumorogenic protection. Studies have also been directed at explaining interactions in different receptor systems and determining new targets connected with the disturbance of physiological concentrations of endogenous PMNs.

The possibility to manipulate toxins or bio-regulators or to produce them in pure form in large quantities opens up new perspectives that have to be considered with implications for BTWC. Bio-regulators are considered to pose a serious threat of being used for illicit purposes due to the increased understanding of inter- and intra-cellular processes and control of central biological processes of mammalian systems, including human.

Production Biotechnology

Industrial application of biotechnology for large-scale production of micro-organisms and cell products has increased tremendously. The new techniques simplify the large-scale production of all kinds of bio-engineered products and organisms in more modest sized plants at rapid speed and cost-effectiveness. This has been beneficial from the point of view of public health, food and agriculture, but it has also increased the potential of misuse for developing and large-scale production of potential agents to be used as BW.

Genetic modification of micro-organisms or plants has helped overproduction of proteins and made the fusion of proteins economical, efficient and quicker. Heterologous expression systems and associated production technologies using yeasts, bacteria and fungi are engineered to produce recombinant proteins and therapeutic compounds in bulk scale for legitimate commercial purposes. Optimization of these technologies is equally applicable in large-scale expression and production of proteins and toxins suitable to be used as BW, such as botulinum. Technologies have been optimized for production of live attenuated vaccine for several bacterial and viral pathogens having key virulence factors removed, either through serial passage or through targeted genetic manipulation. The production technology required to produce a live attenuated anthrax vaccine is identical to that required to produce live virulent anthrax agent in bulk.

Toxin Production

Worldwide consumption of toxins for medical therapy and scientific research has reached a level of hundreds of grams and kilograms per year, and the projected future growth of toxin therapies will require tens to hundreds of kilograms of material annually. It is extremely difficult to distinguish between production of medical or militarily useful quantities.

The major impact of genetic engineering relevant to BTWC is the possibility of large-scale production of toxins. Improvements in biotechnology have led to the production of potent toxins, which until now were available only in minute quantities and only upon isolation from immense amounts of natural biological materials. These toxins can now be produced in kilogram quantities within a short time with minimum cost, which could be of military significance.

Use of rDNA techniques permits the transfer of genetic material between widely divergent species. The increase in knowledge of many of the pathogenic species of micro-organisms, and knowledge of toxins and other biological agents and the continuing pace of developments in civil biotechnology areas, has increased the possibilities for production and hostile use of biological agents affecting the normal environment around the human being.

Improvements in technologies have helped production in significant quantities of recombinant animal toxins that are difficult to isolate from a natural source. The technologies as well as the quantities produced have obvious implications as BW agents. Also, information gained in studies on the utility of toxin sub-units in targeting therapeutic agents to specific cells has the potential to be exploited for targeting harmful agents.

Much interest these days has been generated in identification and purification of toxins from marine resources having therapeutic potential. Though isolated in small quantities, they have already been shown to

have potential of exploitation for generating significant amounts of bioactive substances of both therapeutic and harmful effects. Recently a bioactive peptide, a synthetic conotoxin compound produced by cone snails, has been licensed for use in the treatment of severe chronic pain.

Botulinum toxin is a therapeutic for a number of disease conditions. The catalytically active and toxic A-subunit portion of these toxins conjugated with antibodies raised against specific antigens found on the surface of tumour cells is used for site-directed anti-cancer therapy. B-subunit toxins are being exploited to study intracellular delivery mechanisms like delivery of therapeutic agents to neural cells for the treatment of neural dysfunctions. It is also well known that botulinum toxin is a potential bio-agent for military use.

The potential benefits of advances in technology and delivery of drugs and vaccines also raise the possibilities of misuse, to improve delivery systems for BW agents, especially immuno-modulators and immuno-stimulators for attack of the immune system.

Computational Biology and Bioinformatics

Bioinformatics is the application of large-scale data analysis techniques to the life sciences, encompassing such areas as biology and medicine, computer science, statistics, mathematics and physics. Bioinformatics has become an essential component of modern biology in academic, government and industry research sectors since a lot of biological data are being generated using techniques of genome sequencing, proteomics and HTP data collection. To interpret and utilize these data, bioinformatics has continued to develop in parallel, supported by advances in computer technology and the accessibility of data and tools via the internet and on computers. Bioinformatics is working with HTP technologies to make it easier to create novel structures and substances from biomaterials and is creating new scientific and commercial opportunities.

Complete genomes of an increasing number of organisms have been sequenced and characterized. Genebank public repository containing records of organisms' genetic content doubles in size every month. Together with computational biology, bioinformatics has made it possible to predict properties and complete metabolic pathways from sequence information generated from the genetic material isolated from different environments. Bioinformatics is also being used in the analysis and modelling of pathogens, understanding of their pathogenicity and virulence, and in the study of host-pathogen relationship vis-à-vis antibiotics. Bioinformatics is also being used successfully to produce predictions for vaccine candidates, virulence factors, drug targets and novel therapeutics. Using the genetic information, compounds have been prepared in the laboratory which mimic the natural organisms. The technical developments in chemistry have made it possible to isolate and characterize compounds from very complex environments even when present in very low amounts. These advances could also be misused in the development of pathogen strains with increased virulence or drug resistance, or with improved stability to assist survival within the environment. The complementarities and synergy of technologies used in biotechnology, nanotechnology and information technology are converging in ways that will enable life processes to be manipulated, with far-

reaching implications and great potential for nefarious and disastrous outcomes.

Nanotechnology

Nanotechnologies are defined to include designing, characterization, production and application of structures, devices and systems by controlling the shape and size of materials at nanometre scale. Advances in the ability to produce and characterize materials at nano-scale have resulted in materials with novel and useful properties having great potential to bring benefits to many areas of research and application. This technology combines biotechnology, synthetic biology and information technology to design molecular structures capable of performing a wide range of functions.

Application of nanotechnologies in materials and technologies, electronics and micro-systems and clean technologies has already benefited day-to-day requirements. In the life sciences and medicines, nanotechnology has wide applications in bio-nano materials, bio-sensors, biomarkers and nano-particles, cancer diagnostics, imaging and treatment, drug delivery and therapeutics, including gene therapy and nano-medicine. A prime example of the use of nano-particle science is for creation of novel and highly efficient delivery systems for difficult-to-deliver biologically active compounds.

Nano-biotechnology has particular promise in disease diagnosis, including nano-particles capable of targeting specific diseased cells, containing both therapeutic agents and a sensor that regulates their release into the cell. Nanotechnology thus has direct application to drug discovery to study drug-receptor interactions at the single molecule level. Other applications include production of materials and devices such as scaffolds for cell and tissue engineering, and sensors that can be used for monitoring aspects of human health. Micro-sensors or implants made of biological material are smaller and more effective than current implants. Current applications also focus on using custom nano-scale materials for *in vivo* applications such as molecular imaging and detection, reporters for therapy efficacy determination, multifunctional therapeutics, disease prevention and control. As a growth industry nanotechnology commercially is expected to eventually put the pharmaceutical market in the shade. Production, delivery, and packaging technologies that allow biological systems to be manipulated in a defined, deliberate manner are evolving very quickly to serve the pharmaceutical, agricultural and healthcare fields. Some of these technologies have not been traditionally viewed as having relevance to future biological threats.

The rapid expansion of nanotechnology, however, has also raised new challenges in the safety, regulatory and ethical domains that will require wider consideration. Interactions between nano-particles and living cells and material provide for the synthesis of novel substances, which possess greater toxicity and irreversibility of action than any identified previously. This ability of nano-particles to easily pass through human biological barriers when combined with qualitatively new toxicological properties, and its irreversible consequences, could lead to the creation of a new class of physiologically active materials that could become the basis for developing a new type of lethal BW. For emerging technologies in this field with potential for development of novel or enhanced biological agents with improved delivery methods, it is difficult to predict the outcome of many research areas and thus the impact on potential BW applications.

That nanotechnology has the potential to deliver toxic agents maliciously is evidenced by the fact that the European Commission

has published a Nanotechnology Action Plan and the OECD (Organization for Economic Cooperation and Development) is working to promote international cooperation in the health and environmental safety-related aspects of manufactured nano-materials. Various national, regional and international stakeholders are also interacting with each other in the same direction.

Polymers

Polymers are substances with a high molecular mass composed of a large number of repeating units (monomers). Biological macromolecules or natural polymers include carbohydrates, starch, cellulose and glycogen and chitin. Advances in technology have helped in commercial development of synthetic polymers from petroleum products like polyethylene and nylon. Synthetic polymers made out of glycolic and lactic acids and other biodegradable materials have shown properties of stimulus responsiveness to the environment and can be used for a variety of purposes related to biotechnology and biomedicine. Known as smart polymers, they can detect even slight changes in their environment. Smart polymers have been in increasing use in the areas of diagnostics, biosensors, pollutant detection, food contaminants, etc. Smart polymers are known to be among the best drug delivery systems, as smart polymer matrices release drugs by a chemical or physiological structure-altering reaction, often a hydrolysis reaction resulting in cleavage of bonds and release of drug as the matrix breaks down into biodegradable components.

Some recent smart polymer applications include use of molecular imprinted polymers in combination with peptides in diagnosis of mycotoxins, use of nucleic acid biosensors using polymer transducers for rapid detection and identification of biological pathogens, and use of micro-fluidic chips in combination with monolithic porous polymers for extracting biological and chemical toxins from air, soil and water samples.

Drug Delivery

A number of new matrices have been identified as carriers for prolonged and sustained delivery of drugs and pharmaceuticals. At the same time, routes of administration of drugs and vaccines ensure maliciously target delivery to infested areas. Advances made in areas like drug design, synthetic biology, systems biology, aerosol technology, nanotechnology, micro-encapsulation, etc. have advanced the knowledge for targeted delivery of drugs but have also provided insights to systems required for nefarious use: these need to be assessed.

Nano-emulsion technologies: Significant progress has been made recently in the use of large porous particles (LPP) for delivery of drugs through adsorption in the lungs. LPP are considerably larger than the size regarded as optimal for inhalation and deep deposition. But due to their low density, LPPs are inhaled and the drugs are delivered efficiently. The LPPs' large surface area, in the size range of 25 to several hundred nano-metres, can be used to carry a large number of small particles. The concept is frequently used to coat LPPs with nano-particles carrying drugs for optimized aerosol delivery. On the obverse side, these techniques could potentially be used to develop highly efficient aerosol delivery systems for micro-organisms (viruses and possibly also small bacteria), toxins or chemical compounds for BW purposes.

Micro-encapsulation

Micro-encapsulation entails prolonging the shelf life of micro-organisms or proteins in the body or the environment by coating or enclosing them in a biopolymer capsule. Minuscule solid particles, liquid droplets or gas bubbles are enveloped in protective coating comprising of any of a number of compounds like organic polymer, hydrocolloid, sugar, wax, fat, metal or inorganic oxide. The coating protects against their evaporation, oxidation and contamination, thus ensuring that they are released over a longer period of time. The technique has application in controlled and delayed drug delivery, including micro-encapsulated proteins and peptides and engineered and live cells for therapeutic purposes. Considerable knowledge to achieve these aims efficiently has been generated. Micro-encapsulation of drugs has been exploited to carry micro-organisms to selectively target viruses or bacteria as vectors for delivery of genes and proteins and as viral delivery vectors to insert genes into chromosomal DNA. At the same time, the knowledge generated helps in the harmful spread of micro-encapsulated peptides, proteins including toxins and bioregulators, and micro-organisms while avoiding environmental exposure to ultraviolet light and other oxidative stresses.

Aerosol Technology

Pharmaceutical and biopharmaceutical industry is constantly looking for new technologies for administration of therapeutic compounds to treat patients using different vehicular routes. Aerosol technology is among the widely accepted delivery vehicles to deliver biologically active organisms or compounds, including therapeutic molecules, to target structures. New advances in the field of aerosolization include micro-encapsulation. Different delivery vehicles for micro-encapsulation and sustained release of particles have also been used, based on the particle size of the aerosolized substance and its ability to be delivered directly into the bloodstream. Aerosolization provides efficient and regulated delivery of therapeutics directly to the target. Potential delivery platforms also include the use of bacterial plasmids or viral vectors for cloning the genes encoding bio-regulators, transgenic insects for production and inoculation, nano-scale delivery systems, and liposome or biodegradable micro-spheres for controlled release. Examples are propellant metered-dose inhalers, dry-powder inhalers, and nebulizers that are frequently used to deliver drugs directly to the lungs and circulatory system in asthma patients. Drug particles used in these technologies provide the enormous adsorptive surface of the lungs to enhance their effectiveness. Aerosol-based ano-emulsion technology is also being used to deliver insulin directly through nasal absorption. Nevertheless, all these technologies also raise concerns about the delivery of bio-regulators and other toxic substances through use of aerosol technology.

Diagnostic Technologies

Advances in diagnostic technologies involve equipment and materials that help detect with more precision, accuracy and speed minute quantities of pathogens or genetic makeup having the highest specificity and sensitivity for any disease conditions, including viral and bacterial infections. Rapid and specific detection of minute quantities of DNA has been achieved using reverse transcriptase polymerase chain reaction (RT-PCR), a variant of polymerase chain

reaction used in generation of many copies of a DNA sequence. A number of gene probe systems for array have been developed along with strategies to overcome problems of non-specific hybridization, including a wide range of fluorescent detection molecules. Easy-to-use hand-held devices have been developed commercially for rapid diagnosis and environmental sampling.

Antibody-based technologies have been developed and are commercially available for diagnosis of almost all disease conditions, including viral, bacterial and parasitic infections. Diagnostics have been developed using antibodies/antigens labelled with enzymes, isotopes and fluorescence to achieve detection by colour assays, fluorescence or luminescence. Antibody-based biosensors are also being used for disease detection and environmental monitoring.

Advances in antibody-based production technologies use matured hybridoma cell lines. Monoclonal antibodies – murine-derived, chimeric and humanized – have been developed. Advances in phage display technologies allow production of single-chain antibody systems that are more robust and capable of operating in harsher environments and over greater temperature ranges than conventional antibodies. Other technologies, including oligosaccharide and array-based chips for carbohydrate detection, nano-particles including gold nano-particles being used as matrix in detection technologies for biological agents and the presence of toxins, optical biosensors for real-time detection and identification of airborne antigen, bioluminescence techniques for generic detection and Dip-stick technologies based on lateral flow devices offer different methods of detection and identification. New technologies of micro-fluidics and micro-fabrication entail a wide variety of processes and manipulations carried out at miniaturized scales, usually through automation. Micro-fluidic or "lab-on-a-chip" technology is potentially useful in point-of-care diagnostics, including DNA analysis, immunoassays, cell analysis and enzyme activity measurements. Sophisticated, miniaturized diagnostic systems have immense ability to identify and respond to disease outbreaks, whether naturally occurring or deliberately caused.

Animal Healthcare

Initiatives have been taken worldwide, through multi-pronged approaches, for improvement of animal health through programmes in the areas of diagnosis of exotic diseases like West Nile Fever (WN), salmonellosis, PPR, blue-tongue virus, bovine tuberculosis, etc. and vaccine development for foot-and-mouth disease (FMD), infectious bovine rhinotracheites (IBR), rabies, anthrax, new castle disease, etc. Major initiatives have also been taken in areas of genomic analysis, molecular characterization including sequencing, genetic mapping, expressed sequence tags, comparative sequence analysis, etc.

Outbreaks of infectious diseases in animals have regularly been connected with terrorist activities or offensive BW programmes. Examples include: bird influenza in 2004 and 2005, the 2003 epidemic of atypical pneumonia, and the 2001 outbreak of FMD. Recent epidemics of SARS, Avian Influenza, Swine flu, and FMD outbreak in the UK have necessitated countries to develop their own veterinary surveillance strategy and policies and operational guidelines for control and management of outbreaks of exotic animal diseases, including standardization of laboratory technologies for detection of zoonotic diseases of public health importance. The veterinary surveillance

strategy also records patterns of emerging diseases and alterations in endemic diseases.

The knowledge gained in development of vaccines and other intervention strategies for safeguard of animal health and the magnitude and effects of global animal and zoonotic disease outbreaks has raised public awareness further, as also the potential for use of such agents for hostile purposes. Genetic alteration or modified vaccines would make such outbreaks more difficult to manage. Safeguard of animal and public health and surveillance and management of exotic diseases would need to be based on differentiation of natural, accidental or deliberate release of biological agents into the environment.

Plant Pests and Diseases

Agri-biotechnology has been growing steadily despite controversies related to "transgenics". The spectrum of biotechnology applications in agriculture includes generation of improved crops; microbes; use of molecular markers to tag genes of interest; accelerating of breeding through marker-assisted selection; fingerprinting of cultivars; DNA-based diagnostics for pests/pathogens of crops; and assessment and monitoring of biodiversity. The majority of commercially available genetically modified (GM) crops have agronomic advantages like herbicide tolerance or insect resistance. Strategic research areas include expression profile; functional validation; signal transduction; transgenic; and genetic enhancement. But the use of modern technologies to improve the quality and quantity of farm products as well as food products raises possibilities also for modifications leading to agro-terrorist activities. Farms and food supply remain among the most exposed targets, and impossible to guard adequately.

Climate changes and human population growth are expected to induce increased pest and disease problems, particularly due to invasive organisms. The best efforts at plant protection are also not able to constrain development of alien pests and diseases. Research in biological pest control has resulted in increased interest in the development of more refined dispersal models for biological aerosols. At the same time, the knowledge gained on persistence and ecological effects when releasing genetically modified organisms would also be of value while considering the effects of releasing BW agents in the environment. By using genetic engineering it may also be possible to programme the survival of a released bacterial population. Microbial pathogens could also be genetically engineered to maximize infectivity and pathogenicity. Likewise, they could be modified to increase or decrease their environmental stability and persistency, thereby cancelling out vaccines and sero-diagnostic techniques.

Research in biological pest control has resulted in increased interest in the development of more refined dispersal models for biological aerosols. The knowledge gained on persistence and ecological effects when releasing genetically modified organisms would also be of value while considering the effects of releasing BW agents in the environment. With genetic engineering it may also be possible to programme the survival of a released bacterial population. Knowledge gained in the area of bio-pesticides could in principle be misused by an aggressor intending to attack crops. Some aspects of the dissemination technology would also be relevant to the deliberate release of organisms or toxins harmful to humans or animals.

Genetic Modification in Plants

Field releases of GM crops and transgenic plants have grown enormously since the first field trial was held in 1986. The principal GM crops being used are soybean, maize and cotton. These crops mostly contain a single transgene that modifies the plant for herbicide tolerance or insect resistance. A number of other GM plants are being tested for traits that influence virus resistance, crop quality, male sterility and disease resistance.

There is considerable interest and a lot of research has been going on in the development of crops with enhanced foods and pharma crops. In enhanced foods, GM crops containing omega-3 fatty acid are being developed as an alternative to fish source in the diet, and vitamin A enriched GM rice (golden rice) is being investigated in field trials. In pharma crops, GM crops containing pharma-active molecule, termed as edible vaccines, are being investigated as bioreactors for producing sufficient materials to initiate clinical trials. An example is development of an authentic insulin molecule in safflower.

Advances in expression technologies have led to use of some of the plant viruses like cowpea mosaic virus, tobacco mosaic virus, potato virus X, and tobacco rattle virus as vectors for the expression of foreign proteins in plants. These vectors have been applied in several areas of plant sciences, including the expression of vaccines and high-value pharmaceuticals. Modified viruses are being utilized for plant genomic studies via virus-induced gene silencing, leading to their use in medical and other fields. But the potential availability of these vectors for applications as bioreactors for developing useful bio-products for human beings may also lead to their potential use to develop toxic compounds.

Like other applications of GM technologies, developments in the field of GM crops have the potential for misuse. For example, anti-crop agents can be designed with improved properties. The deliberate or accidental introduction of GM seeds or crops within a country that has not approved such products could have serious economic consequences due to the efforts required in detection and clean-up operations. Also, microbial pathogens could be genetically engineered to maximize infectivity and pathogenicity. Likewise, they could be modified to increase or decrease their environmental stability and persistency. These developments have potential to be applied for beneficial peaceful purposes, but also may be applied maliciously.

Bio-pharming

Plants and animals are used to produce bioactive molecules intended for industrial products and pharmaceuticals. Bio-pharming enables production of vaccines and antibodies that otherwise are too expensive or inefficient to produce using conventional production methods. The same technologies, however, are helping the scientists to explore plants as a cost-effective way to produce agents capable of bio-warfare or as antibodies for use against potential bio-warfare agents. Genetic modification of plants renders them more lethal than non-transgenic crops. Large quantities of bio-regulatory or other toxic proteins having potential to be used as biological agents can be produced in a short time, eliminating the risk of discovery.

Biological Pest Control

Significant progress has been made in the study of microbial agents for the purpose of biological control of pests and diseases of plants. Advances in molecular biology

research have the potential to revolutionize the efficacy of bio-control agents. This has caused a paradigm shift in the use of chemical crop protection technologies. Efforts are also being made to explore vast sources of largely untapped naturally occurring organisms with the potential to provide new toxins suitable for pest control and their formulation. The availability of novel synthetic chemicals with a more benign environmental and health profile remains a factor for consideration.

Most important research and development has focused on *Bacillus thuringiensis (Bt),* towards the worldwide growth of transgenic Bt crops. Further efforts are aimed at finding new genes and toxins from Bt strains with more effective pesticide toxins, to increase the range of targets that can be controlled using either conventional bio-pesticides or transgenic methods. In this effort complete genome has been sequenced of the entomo-pathogenic bacterium, *Photorhabdus luminescens,* as a source of new genes for insect control. An unusual soil-dwelling bacterium (*Pseudomonas entomophila*), which is unique in that it is resistant to the immune defences of insects, promises to deliver new bio-pesticides. A novel strain of a new species of bacteria, *Bacillus nematocida*, has been discovered with activity against nematodes. Some endotoxins produced by Bt display antibacterial effects on some other micro-organisms.

Molecular technologies have also been utilized to enhance the insecticidal toxicity of Bt toxins by combining the attributes of the Bt toxin with other micro-organisms, including baculovirus-based systems and other bacteria. Delivery of toxins via other microbial expression systems is a possible alternative to the production of transgenic plants. But these developments also have the potential for misuse in a BW programme: expertise in the transfer of Bacillus genes among closely related species could be utilized for malign purposes, as could manufacturing expertise and facilities and field delivery systems.

Research in biological pest control has also increased the hunt for development of refined aerosol models for effective dispersal of biological agents. Using genetic engineering technologies also makes it possible to programme the survival of a released bacterial population and the effect in the environment. The knowledge of persistence and ecological effects would also be of value while releasing the genetically modified organisms. At the same time, knowledge gained in the areas of dissemination technology of bio-pesticides could be misused by an aggressor to release organisms or toxin harmful to crops, animals and to some extent in humans.

Bio-prospecting

Advances have been made in new technologies – bio-prospecting – to explore the immense biological and chemical diversity in nature that has been difficult to access by natural methods. New tools are being used for actively screening for novel compounds produced by living organisms in different environments to evaluate their potential for use in medicine, agriculture and industry.

The microbial community represents the largest source of genetic diversity on the planet. A large number of new compounds of biological origin and mostly produced by the microbial community have been identified from different environmental sources. Studies of the compounds also reveal the large overlapping fractions of microbial genomes that could be used to disclose entire genomes of previously unknown micro-organisms even if present in very low

amounts. There is a strong demand to develop techniques for expression of the genetic information in various heterologous hosts to produce and characterize the new compounds of interest using DNA sequencing technologies. Bio-prospecting could also identify microbes that might serve as pathogens and provide an early warning for potential disease-causing agents. For drug development, agriculture and industry the information generated by bio-prospecting would be very significant in the near future.

New tools such as satellite mapping using high-resolution landscape datasets of pests and diseases, including insects and their behaviour, would greatly benefit eradicating invasive alien pests and diseases. The exploitation of new mobile computing, GPS, digital photography, telephone technologies, etc. provides precision and accuracy to information, which enables rapid transmission of key data for computation for better management of pest outbreaks. Conversely, bio-prospecting could be used as databank regarding the biological activity of dangerous pathogens and novel agents having severe effects and toxicity for humans, with the intent of introducing them into an immunologically naïve population. It could also impact on available measures of protection. The information on the novel compounds would also provide scope for modifications or synthesis by chemical means.

Bio-remediation

Bio-remediation technologies are being used worldwide to clear the environment of the harmful effects of the pollutants and convert them into useful products. Czech scientists, for example, have used bio-remediation technologies to detoxify mustard gas (yperite), using enzymatic catalysis with haloalkane dehalogenases. Haloalkane dehalogenases also provides useful applications in the production of alcohols to treat Alzheimer's disease or in biosensors to detect chemicals in the environment.

Non-lethal Biological Weapons (Nlbw)

Non-lethal weapons are intended to incapacitate personnel or materiel without visible injury or damage. NLBW involve potential military use of agents causing slow-onset infections and to create novel anti-animal or anti-plant BW that have consequences leading to economic losses.

Studies for creating NLBW are reported in the field of allergology, specifically the production of genetically engineered allergens. Recombinant allergens would include elements from the pollen of plants and epidermal and microbial allergens. Creation of highly productive recombinant strains will make it possible to produce large volumes of allergens in short periods of time. Another area for NLBW is reportedly based on the development of biological agents capable of pathologically acting directly on the genomes of people and animals without an infectious process. Pathology symptoms of such agents would have a lifelong nature, resemble hereditary diseases and be inherited from generation to generation, decreasing the viability of that hereditary line.

The social and economic consequences of outbreaks of animal and plant diseases are significant. The bubonic plague epidemic of 1994 in India, the outbreak of FMD in 2001 in Great Britain, epidemics of bird influenza H7N3 in Canada in 2004 and H7 virus in 2005 in North Korea, the 2003 epidemic of atypical pneumonia in Hong Kong, have been examples of huge economic loss. These epidemics also caused destruction of animals

and birds leading to reduction in tourism and a significant loss of exports. These financial implications become the source of motivation to create agents for use for prohibited purposes. This also increases significantly the danger of novel anti-animal and anti-plant BW being developed. Virtually all of the developments connected to agents of infectious disease can be realized not only for human pathogens, but also for animal and plant pathogens.

The Road To Weaponization

Some of the advanced technologies, tools and designs that lead to weaponization are:

- Rendering a vaccine ineffective;
- Conferring resistance to therapeutically useful antibiotics or antiviral agents in pathogenic organisms to produce an untreatable pathogen that is resistant to common antibiotics;
- Enhancing the virulence of a pathogen or rendering a non-pathogen virulent, to inflict increased human damage;
- Increasing the transmissibility of a pathogen so that it is more easily transmitted through a population;
- Altering the host range of a pathogen so that people would lose immunity to the disease;
- Enabling the evasion of diagnosis and/or detection by established methods so that in case of biological attack, there is delay in diagnosis and subsequent treatment;
- Undertaking genetic sequencing of pathogens to reconstruct a pathogen or develop a novel pathogen for deployment against a target population with no natural immunity;
- Synthesizing pathogenic micro-organisms to facilitate reconstruction of extinct or construction of novel pathogens;
- Enabling weaponization of a biological agent or toxin in making biological attacks more likely; and
- Experimentation with the smallpox virus so that it could be used in a biological attack.

Conclusion

Advances in biotechnology have brought in major changes in biology and life science areas through new techniques of genetic engineering and sequencing technologies, including rDNA technology that permits the transfer of genetic material between widely divergent species and changes in the character of micro-organisms. The increase in knowledge of many pathogenic species of micro-organisms, toxins and other biological agents and the continuing pace of developments in civilian-related biotechnology areas have further increased the possibilities for production and hostile use of biological agents, making BW an attractive option for governments seeking to acquire weapons of mass destruction. A BW programme can be hidden amidst dual-purpose industries.

Technologies like biotechnology, nanotechnology and information technology are converging in ways that will enable life processes to be manipulated with far-reaching implications and great potential for nefarious and disastrous outcomes. The tools discussed above interactively create unanticipated opportunities for these technologies to be used for the benefit of humanity and agriculture, while opening equal opportunities for their malicious use.

Interestingly, preparation of effective protective material against BW requires significant purification procedures and infrastructure for state-of-the-art produced vaccines, therapeutics, therapies, and prophylactic products; but the potential misuse of these technologies for the creation of effective BW does not require infrastructure of similar sophistication.

The implications of the advances in biological science and technology relevant to BTWC are being considered in relation to national implementation of Articles III, IV, VII and X. Monitoring and assessment of the scientific developments in biological sciences is considered important for the States Parties in their preparedness to counter outbreaks of disease, whether natural, accidental or deliberate, and in ensuring that national bio-security and bio-safety arrangements are up to date and effective enough to strengthen BTWC.

Chemical Weapons in Sri Lanka

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Summary

While the Sri Lankan Government and security forces have confirmed the possession of chemical weapons by the LTTE, it is very difficult to verify the actual use of such weapons. However, there are occasional media reports available of LTTE's chemical attack.

During the Eelam Wars in Sri Lanka, there was considerable concern about the use of chemical weapons. Allegedly, both the LTTE and Sri Lankan army had possessed such weapons. However, no strong evidence of the use of chemical weapons during the war has been found yet.

Possession and Use of Chemical Weapons by the LTTE

According to Prof. Peter Chalk, a leading expert on Tamil Tiger's strategies, LTTE is the first known terrorist group to use chemical weapons.[1] The then Sri Lankan Prime Minister Ratnasiri Wickramanayaka said in 2007 that his Government had evidence that the LTTE had plans to use chemical weapons against the Sri Lankan security forces.[2] Sri Lankan Foreign Secretary Palitha Kohona also confirmed that the government had found evidence that the LTTE were seeking to buy thermobaric weapons and launchers. In addition, during the Eelam wars, Sri Lankan security forces detected that the tigers were transporting large quantities of acid. The Sri Lankan Military had also reported capture of a large stock of gas masks and chemical resistant costumes from an LTTE camp at Udayarkattukulam in the Mullaithivu district in the north.[3]

While the Sri Lankan Government and security forces have confirmed the possession of chemical weapons by the LTTE, it is very difficult to verify the actual use of such weapons. However, there are occasional media reports available of LTTE's chemical attack. It was reported that LTTE used locally manufactured chemicals to attack Sri Lankan Army's Kiran camp at Trincomalee in 1990.[4] however, the Sri Lankan Government in power during that period did not take the issue seriously and also did not make any effort to inform the

international community. Allegedly, the LTTE again used thermobaric rockets in a 2005 attack that killed thirteen sailors, leaving bodies burned beyond recognition.

The chemical weapons possessed by the LTTE were locally manufactured as well as acquired from foreign countries. Reportedly, LTTE had a toxicological laboratory housed in two floor underground in the jungles of Vanni. The underground laboratory was protected by three storied building above-ground. "Pro-LTTE Sri Lankan chemical experts and engineers who worked in Western countries are said to be the brains behind the building of the lab as well as the toxicological products".[5]

It was also suspected that a West European country closely aligned with the LTTE might have provided the chemical weapons to the LTTE via another East European country under a bi-lateral agreement with that country with special secret instructions for onward shipment to Vanni. It is interesting that according to a media report of November 2005, the foreign power which provided the chemical weapons to the LTTE had obtained an assurance from the Tigers that they would not use these weapons against the Sri Lankan Armed Forces.[6] They were basically meant for destroying the cadres of the breakaway rebel group led by Colonel Karuna in Eastern Sri Lanka.[7]

Minimum loss to its cadres was the main objective of the LTTE to use the chemical weapons. After the LTTE was thrown out of Jaffna in 1995, it was planning to launch a major assault on Jaffna. Anticipating a heavy loss of manpower, LTTE adopted a new strategy of immobilising the Sri Lankan forces through chemical weapons before a counter-offensive could be launched. But there are examples when this technique backfired as according to Prof. Peter Chalk, the LTTE used a chemical weapon to attach an army camp in one of its early offensive, but it backfired because the winds brought most of it back and deposited the chemical on the LTTE side.[8]

Possession and Use of Chemical Weapons by the Sri Lankan Army

There are serious apprehensions that thermobaric bomb - a bomb that uses a fuel-air explosive capable of creating overpressures equal to an atomic bomb – was used by the Sri Lankan Army during the Eelam War 4.[9] Sri Lankan army reportedly had acquired the Russian RPO-A rockets in 2001 via a British company, Gladstone Industrial Holdings.

A petition, which was sent to Mr. Ban Ki Moon, UN Secretary General; Respected Ms Navi Pillay, UN High Commissioner for Human Rights; Dr. Manmohan Singh, Prime Minister of India and Heads of Government of South Asian Countries, sought independent verification of the use of such weapons. The petition said,

> "it is very important that the truth about the actual use of these 'weapons of mass destruction' including thermobaric bombs be independently verified and its source of supply identified. If indeed these horrific weapons have been used, the international community should immediately initiate prosecution of the highest functionaries of the Sri Lankan state and the Government of the country that supplied these bombs for commission of war crimes and crimes against humanity."[10]

UN Expert Panel Report on Accountability in Sri Lanka had also presented the allegation of Sri Lankan Army using cluster bomb munitions or white phosphorous or other chemical substances against civilians during the war. Since the panel was not able

to reach to any conclusion regarding their credibility, it recommended further investigation into this allegation.[11] The Sri Lankan Government refused to conduct any such investigation and on the contrary, it regularly tries to silent anybody who wants to initiate any independent investigation into this matter. According to the wife of Prageeth Ekneligoda, the political columnist and cartoonist who has been missing since 24 January, 2010, the main reason for his disappearance is an investigation he carried out on the alleged use of chemical weapons by the Sri Lanka forces in 2008.[12]

It is very difficult to validate the media reports on either LTTE or the Sri Lankan Armed forces. As a party to the chemical Weapons Convention[13], Sri Lankan Government has officially denied having such weapons. It is noteworthy that in a chemical warfare, user also needs to adopt precautionary measures. Precautionary measures adopted by the Sri Lankan Army when they came to know about the possession of such weapons by the LTTE were as follows;

- Alerted regional and international intelligence agencies and media
- Used more camouflage for constructing bunkers etc. to avoid detection
- Frontline troops (especially attacking troops) were equipped with Oxygen gas masks.
- Advance dressing stations (ADS), front most medical installation were provided medical drugs etc. for burning injuries etc.

LTTE's reactions to the Possession of Chemical Weapons by the Sri Lankan Army were;

- Warned the Chandrika Kumaratunga government of disastrous consequences if it inducted the recently acquired weapons with chemical warheads into the north-eastern theatre of war.[14]
- Called upon the concerned nations of the international community, particularly the United States, Britain, European Union and India to condemn Sri Lanka for the acquisition of weapons with chemical warheads and to impress upon the Sinhala Government the detrimental effects of their use in the Tamil homeland.

Conclusion

It can be argued that despite the possibility of occasional use of chemical weapons, Sri Lanka is not assuming a high threat from chemical weapons. The weapons reportedly used during the Eelam wars were very primary. According to Sri Lankan Army, most of the chemical weapons found from the LTTE have already been destroyed. The remaining ones are in Army's armouries for which army maintain several strict regulations and procedures to keep account of them so that they don't fall in the wrong hands.

Endnotes:

1 "Tamil Tigers ready to attack Sri Lankan forces with toxic weapons", *Asian Tribune,* July 12, 2006, accessed on 9 November 2011, available at http://www.asiantribune.com/index.php?q=node/1034

2 "LTTE Ready to Use Chemical Weapons: PM", *The Times of India,* September 6, 2007, accessed on 6 November 2011, available at http://articles.timesofindia.indiatimes.com/2007-09-06/rest-of-world/27954292_1_ltte-chemical-weapons-sri-lanka-s-tamil-tigers

3 B. Muralidhar Reddy, "Sri Lankan Army finds chemical warfare equipment", *The Hindu,* March 13, 2009, accessed on 2 November 2011, available at http://www.hindu.com/2009/03/13/stories/2009031354791300.htm

[4] "Air Force More Than Matches New Tiger Weapon", The Nation, September 29, 2008 Accessed on 10 November 2011, available at http://www.lankanewspapers.com/news/2008/9/32965_space.html

[5] Tamil Tigers ready to attack Sri Lankan forces with toxic weapons", *Asian Tribune,* July 12, 2006, accessed on 6 November 2011, available at http://www.asiantribune.com/index.php?q=node/1034

[6] "Acquisition of Nerve gas and other Lethal Chemical Weapons by the LTTE", *The Asian Tribune,* November 21, 2005, accessed on 6 November 2011, available at http://www.asiantribune.com/acquisition-nerve-gas-and-other-lethal-chemical-weapons

[7] Ibid.

[8] "Tamil Tigers Ready to Attack Sri Lankan Forces with Toxic Weapons", *The Asian Tribune,* July 12, 2006, accessed on 6 November 2011, available at http://www.asiantribune.com/index.php?q=node/1034.

[9] Hambling, David, "Thermobaric Slaughter in Sri Lanka?", May 1, 2009, accessed on 6 November 2011, available at http://www.wired.com/dangerroom/2009/05/thermobaric-slaughter-in-sri-lanka/.

[10] "Appeal on Sri Lanka by concerned South Asia citizens", 10 April 2009, accessed on 6 November 2011, available at http://transcurrents.com/tc/2009/04/_appeal_on_sri_lanka_by_concer.html

[11] "Report of the Secretary General's Panel of Experts on Accountability in Sri Lanka", March 31, 2011, accessed on 6 November 2011, available at http://www.un.org/News/dh/infocus/Sri_Lanka/POE_Report_Full.pdf

[12] "Prageeth missing due to 'chemical weapon probe", January 28, 2011, accessed on 6 November 2011, available at http://www.bbc.co.uk/sinhala/news/story/2011/01/110128_prageeth_galle.shtml

[13] Sri Lanka signed and ratified the Chemical Weapons Convention on the January 14, 1993 and August 19, 1994 respectively. The Ministry of Industry and Commerce is the national Authority responsible for the implementation of the Chemical Weapons Convention in Sri Lanka which also functions as the lead agency in case of chemical emergencies in the country.

[14] LTTE came out with the following Press Release on 16 August 2001: "We are perturbed over reports that the Sri Lanka government has purchased new infantry weapon system with chemical warheads. This Russian made rocket propelled 'thermobaric' weapon is internationally banned for its lethal toxic effects on combatants and civilians. The acquisition of this banned weapon by Sri Lanka marks a new and dangerous escalation of the armed conflict in the island.", Thermobaric Warfare and Humanitarian Concerns, D. B. S. Jayaraj, 19 August 2001, Accessed on 6 November 2011, available at http://www.sangam.org/ANALYSIS_ARCHIVES/Jeyaraj_8_20_01.htm

Kaleidoscope: Geneva Protocol and Its Importance in the context of Bio-Weapons

As argued in this issue, the incidents of the actual use of chemical and biological weapons peaked during the World War I. While the German forces used these weapons on the maximum number of occasions, British forces bore its maximum brunt with more than 125,000 casualties. Since Europe was the theatre of the Great War, it was here that the consequences of the use of biological weapons were seen for the first time in the modern war history. As a consequence of this, urgent action was felt necessary in order to ban the use of bio-weapons in a large scale war.

The Geneva Protocol or the *Protocol for the Prohibition of the Use of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare* was signed on June 17, 1925 and it entered into force on February 8 1928. By 2010, 137 had ratified and acceded to the Protocol. It is significant to note that the Geneva Protocol did not ban the research and development, stockpiling, trade and exchange and testing of bio-weapons on one hand as its focus was only 'the prohibition of use'. On the other hand, important users of bio-weapons did not sign it till late. For example, the United States and Japan did not sign it until 1970.

Geneva Protocol is an extension of the provisions of Hague Conference of 1899 as it widens the definition of bio-weapons. It was critical because the advances in bio-chemical research in the period between Hague Conference and Geneva Convention had expanded the scale of bio-weapons to a large attack level, thereby increasing its lethality in terms of scale and civilians had also become the potential target due to the nature of war and lack of detection techniques. Therefore, Geneva Protocol helped bring the large scale use of bio-weapons under the category of war crimes, thereby reducing its attractiveness as weapons of choice.

In this sense, Geneva Protocol can also be said to be the predecessor to the Non-Proliferation Treaty (NPT (1968) and the Biological Weapons Convention (BWC) (1972) Chemical Weapons Convention (CWC) (1993).

Chemical and Biological News

ARMS CONTROL

Captured Chemical Weapons in Libya Were Declared to the OPCW by Former Government

September 28, 2011

Libyan sources have informed the OPCW that they are taking all necessary measures to control stockpiles of chemical weapons that were captured last week. These are the same stocks that were declared to the Organisation by the former regime of Muammar Qaddafi in compliance with the Chemical Weapons Convention (CWC). The OPCW has not been advised by the Libyan sources of the discovery of any previously undeclared stockpiles.

"It is important for the OPCW that these stockpiles are secured and misuse is prevented, and ensuring this remains a national responsibility under the provisions of the Chemical Weapons Convention," said OPCW Director-General Ahmet Üzümcü. "From this perspective we welcome the fact that Libyan authorities are taking necessary measures to secure the bunkers."

Before the outbreak of the crisis the Qaddafi regime had destroyed 55% of its declared amounts of sulfur mustard (mustard gas) and 40% of its precursor chemicals for making weapons, as well as its entire stockpile of more than 3,500 aerial bombs designed for use with chemical weapons. These activities were halted in February 2011 when the destruction facility malfunctioned, at which point the OPCW withdrew its team of inspectors until repairs could be made.

The remaining chemical weapons are stored at a military facility about 700 kilometers southeast of Tripoli. The stockpiles now consist of about 9 metric tonnes of sulphur mustard agent and over 800 metric tonnes of precursor chemicals. The new government in Tripoli, which has been recognised by the United Nations, inherits Libya's obligations as a State Party to the CWC to destroy the remaining stockpiles in their entirety under international verification by OPCW inspectors.

The OPCW is closely monitoring developments in Libya and will be prepared to return its inspectors to the country as soon as circumstances permit. Once destruction activities are able to resume it should be possible to destroy the remaining sulfur mustard agent, which poses the biggest concern, within a month.

Source: http://www.opcw.org/news/article/captured-chemical-weapons-in-libya-were-declared-to-the-opcw-by-former-government/

US: Libyan Uranium, Chemical Weapons Secure

August 25, 2011

The U.S. State Department said Thursday it believes that Libyan stockpiles of mustard agent and uranium are secure, despite continuing turmoil there. U.S. officials are less sure about the status of shoulder-fired anti-aircraft weapons that were in Libyan leader Moammar Gadhafi's military arsenal.

The Gadhafi government, in a bid to escape terrorism-related sanctions and political isolation, renounced weapons of mass destruction in 2003 and later gave up key components of a nascent nuclear weapons program.

But Libya's continued to possess large quantities of mustard agent — a potential component of chemical weapons. And a stockpile of low-enriched uranium, or yellowcake, has been a matter of

international concern as the country descended into conflict.

Nonetheless, State Department spokeswoman Victoria Nuland told reporters on Thursday that the United States is confident, based on assurances from Libya's Transitional National Council, or TNC, and observations by U.S. intelligence, that Libya's stockpiles of uranium and mustard agent are secure.

She said the yellowcake uranium is under guard at a nuclear research site near Tripoli.

"It is at the Tajoura nuclear research facility. It is safeguarded there. We are able, through our national technical means, to assert that we believe it is secure. And in any case, Libya doesn't have the means right now to turn yellowcake into anything dangerous,' Nuland said.

Nuland said that in the process that led to the normalization of relations between the United States and Libya in 2006, the Gadhafi government surrendered nuclear weapons equipment it had obtained from Pakistan's A.Q. Khan network two years earlier. She said it gave up its last highly-enriched uranium in 2009.

The State Department spokeswoman said Libya still possesses a large quantity of mustard agent that could potentially be used to fill artillery shells and missile warheads. But she said that, too, is secure at a guarded ammunition complex.

"It is inside massive steel containers within heavy bunkers. These bunkers were sealed by the Organization for the Prohibition of Chemical Weapons, the OPCW. Our judgment is that they remain secure. And again, these are not weapon-ready chemicals. They can't be converted on a dime [i.e., quickly] and they're in these massive drums inside a heavy bunker. And we are able to monitor the security with national technical means," Nuland said.

"National technical means" commonly refers to spy satellites and other U.S. intelligence assets.

Nuland said the main proliferation concern from Libya involves portable shoulder-fired anti-aircraft missiles, or MANPADS — short for Man Portable Air Defense System. The Gadhafi government is thought to have stockpiled perhaps thousands of the weapons, which could be used to shoot down commercial airliners.

Since the Libyan conflict began, U.S. personnel have been working with countries bordering Libya, and more recently with the TNC, to try to detect MANPAD smuggling attempts.

Nuland decried what she called "fear-mongering" reporting on the subject, but also said that there is no reliable information on the extent of the Libyan MANPAD problem, if there is one.

MANPADS have rarely been linked to terrorist attacks. One attack was an unsuccessful attempt by an al-Qaida-affiliated group to shoot down an Israeli airliner at the Kenyan port city of Mombassa in 2002.

Source: http://www.globalsecurity.org/wmd/library/news/libya/2011/libya-110825-voa08.htm?_m=3n%2e002a%2e285%2eur0a0005sv%2e990

DISARMAMENT

Iran's Nuclear, Chemical and Biological Capabilities: A Net Assessment

VCDNP hosted a panel discussion on 27 May 2011.

On May 27th, 2011 several experts gathered in Vienna to discuss Iran's nuclear capabilities in light of a recently released International Institute of Strategic Studies (IISS) dossier detailing Iran's nuclear, chemical, and biological capabilities. Panel experts included Mark Fitzpatrick, Director of the Disarmament and Non-proliferation Programme at IISS, Ambassador Ali Asghar Soltanieh, Resident Representative of the Islamic Republic of Iran to the IAEA, and Ambassador Rüdiger Lüdeking, Resident Representative of the Federal Republic of Germany. The event was co-organized by the Vienna Center for Disarmament and Non-Proliferation (VCDNP), the International Institute for Strategic Studies and the Diplomatic Academy of Vienna. Elena Sokova, Executive Director of the VCDNP, served as moderator.

The event began with a presentation by Mark Fitzpatrick in which he highlighted the findings of his recently released dossier, "Iran's Nuclear, Chemical and Biological Capabilities: A Net Assessment." Both Ambassador Soltanieh and Ambassador Lüdeking followed with comments of their own. The discussion was particularly timely considering the May 24, 2011 report by Yukiya Amano, Director General of the International Atomic Energy Agency, in which he claims the IAEA possesses evidence that Tehran has conducted work on a highly sophisticated nuclear triggering technology that experts say could be used for only one purpose: setting off a nuclear weapon. The presentation and the comments generated an engaging discussion among the panelists and numerous questions from the audience.

Source: http://vcdnp.org/110527_iran_capabilities_panel_discussion.htm

Minister of Foreign Affairs of Iraq Visits the OPCW to Discuss Implementation of the Chemical Weapons Convention

September 08, 2011

The visit by H.E. Mr Hoshyar Zebari on 7 September 2011 was the first made to the OPCW headquarters by an Iraqi Foreign Minister since the country joined the Chemical Weapons Convention (CWC) in early 2009.

Mr Zebari met with OPCW Director-General Ahmet Üzümcü and discussed a variety of issues related to the Convention, including preparatory measures for the destruction of Iraq's remnant chemical weapons stockpiles and production facilities. Mr Zebari was also briefed on the OPCW's work with Iraq in the areas of chemical demilitarization and CWC implementation support.

Source: http://www.opcw.org/news/article/minister-of-foreign-affairs-of-iraq-visits-the-opcw-to-discuss-implementation-of-the-chemical-weapon/

NATIONAL AND INTERNATIONAL DEVELOPMENTS

Burundi ratifies the Biological Weapons Convention

London confirmed Burundi's ratification on 18 October 2011. This brings the membership of the BWC to 165 States Parties.

Source: http://www.unog.ch/80256EE600585943/(httpPages)/87CF9BFD24A8D05FC1257574004B285B?OpenDocument

Biological weapons expert Tucker, 56, was known for fluency in politics

T. Rees Shapiro, August 4, 2011

Jonathan B. Tucker, 56, one of the country's foremost experts on biological and chemical weapons and an influential nonproliferation advocate, was found dead July 31 at his home in the District.

A spokeswoman in the District's Office of the Chief Medical Examiner said determination of the cause of death was pending further investigation.

Last year, Dr. Tucker stepped down after nearly 15 years as a research fellow in Washington at what is now the Monterey Institute's James Martin Center for Nonproliferation Studies. At his death, he was awaiting a security clearance for a new job at the Department of Homeland Security.

A former editor at the journal Scientific American, he wrote authoritative histories on chemical warfare and the eradication of smallpox. In the early 1990s, he worked on arms control and nonproliferation matters at the State Department and the congressional Office of Technology Assessment.

By many accounts, Dr. Tucker possessed a scientist's probing mind and a policy wonk's fluency on national security issues. These traits earned him a trusted reputation on Capitol Hill and made him a key source to journalists seeking a credible opinion on biological and chemical weapons.

"Jonathan was a rare breed in that he knew the science of the issue, which was really complicated, and also knew the policy side," said Paul Carroll, program director at the Ploughshares Fund, a nonproliferation group. "He was one of really a handful of people that could talk to both of these audiences, to both chemists and diplomats."

In 1995, Dr. Tucker served as a United Nations weapons inspector in Iraq and helped comb laboratories there for lethal germs, noxious gases and other toxic substances. He used his firsthand knowledge of Iraqi leader Saddam Hussein's chemical weapons program to advise the U.S. government before the invasion of Iraq in early 2003.

Dr. Tucker provided expert testimony to Congress on how he thought Hussein could potentially use his alleged arsenal against the American assault. He said U.N. representatives routinely discovered and destroyed hidden caches of Iraqi biological and chemical weapons after the 1991 Persian Gulf War.

Based on his research, Dr. Tucker told The Washington Post in 2003 that Hussein "may very well use whatever he has" in a "last-ditch defense situation."

Dr. Tucker added that the artillery systems Hussein used in the Iran-Iraq war of the 1980s had since become obsolete and would not effectively distribute germ weapons.

Hussein "could contaminate areas," Dr. Tucker said, but any possible usage of the weapons would "only slow the oncoming forces down" because U.S. troops had protective suits.

Ultimately, the precautions were unnecessary. Saddam had dismantled his weapons program years earlier.

Jonathan Brin Tucker was born in Boston on Aug. 2, 1954. He was a 1972 graduate of the private Phillips Academy in Andover, Mass.

He graduated from Yale University three years later with a degree in biology. He

received a master's degree from the University of Pennsylvania before earning a doctorate in nonproliferation studies from the Massachusetts Institute of Technology.

His marriage to Karen Fifer ended in divorce. Survivors include his mother, Deborah Tucker of Cambridge, Mass.; and a sister.

Dr. Tucker's experience as a weapons inspector helped him to be named in 1995 to the Presidential Advisory Committee on Gulf War Veterans' Illnesses.

The group was organized to investigate claims that troops who fought in the Persian Gulf War suffered from ailments possibly linked to chemical weapons.

Although he received high performance reviews, Dr. Tucker was dismissed from the team before the report was completed. In interviews afterward, Dr. Tucker said he was removed because he refused to limit his research to data provided solely by the government.

Dr. Tucker continued to investigate independently, conducting interviews with combat veterans and scouring declassified intelligence documents.

In testimony before a House government oversight subcommittee in 1997, Dr. Tucker said he found evidence that suggested Iraq deployed chemical weapons against coalition forces. His report contradicted the findings of the Defense Department and the CIA, which contended that no such armaments were used.

In 2008, the Research Advisory Committee on Gulf War Veterans' Illnesses found that many of the symptoms veterans exhibited after the Gulf War may have been linked to chemical weapons. The panel concluded that Congress should allocate at least $60 million in funds to research Gulf War veterans' health issues.

"He was right," said Jonathan Winer, a former deputy assistant secretary of state for international law enforcement. "Public policy changed."

Dr. Tucker's books included "Scourge: The Once and Future Threat of Smallpox" (2001), which traced the virus over 6,000 years, and "War of Nerves: Chemical Warfare from World War I to Al-Qaeda" (2006).

In a New York Times review, author and germ warfare expert Ed Regis called "Scourge" a "concise, suspenseful and scientifically accurate narrative."

Dr. Tucker's last book is scheduled for publication early next year. A collaborative effort by 16 international experts, the book focuses on emerging technology and its benefits — and potentially dangerous uses — in the fields of chemistry and biology.

Source: http://www.washingtonpost.com/local/obituaries/biological-weapons-expert-tucker-56-was-known-for-fluency-in-politics/2011/08/02/gIQAiIV2sI_print.html

Book Review

Iran's Nuclear, Chemical and Biological Capabilities - A net assessment (An IISS Strategic Dossier) 2011

Dr. M. Mahtab Alam Rizvi

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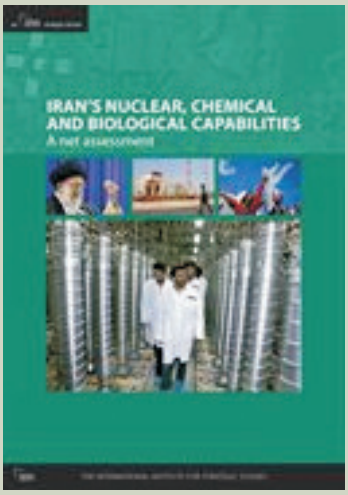
Summary

As a signatory to various treaties like the Non-Proliferation Treaty (NPT), the Geneva Protocol, the Chemical Weapons Convention (CWC) and the Biological & Toxin Weapons Convention (BTWC), the official Iranian state policy is against the possession and development of these weapons.



An Overview: Iran's Nuclear, Chemical and Biological Weapons Programme*

As a signatory to various treaties like the Non-Proliferation Treaty (NPT), the Geneva Protocol, the Chemical Weapons Convention (CWC) and the Biological & Toxin Weapons Convention (BTWC), the official Iranian state policy is against the possession and development of these weapons. However, due to reports contrary to the state's declared policy, various European governments and the United States (US) tend to view the Iranian weapons programmes very seriously. Towards this end, they have also used various means like sanctions and trade embargos to dissuade Iran from continuing with the weaponisation in any form as far as weapons of mass destruction are concerned. In the following sections, Iran's nuclear, chemical and biological weapons strategy is looked into in detail.

Nuclear Weapons programme

Iran's desire to develop a full-fledged nuclear fuel cycle is not new. During its cordial relations with the West especially during the Shah regime, Iran started looking for opportunities to develop nuclear technology and accumulate valuable scientific expertise in the subject, which was later inherited by founder of the Islamic Republic Imam Khomeini from the Shah. Before that, in March 1974, the Shah made a historic statement in which he indicated a desire to develop nuclear power plants capable of producing 23,000 MW within the next 20 years.[1] The same year, Iran signed contracts with the French company Framatome to build two pressurized water reactors capable of producing 950 MW of electricity. After the Islamic Revolution of 1979, Khomeini had

strong reservations about the nuclear projects on the grounds that they would make Iran dependent on foreign technology. However, very soon Iranian leaders realised the importance of nuclear power capacity and requested French and Germany companies to restart constructing nuclear power plants. However, owing to the US pressure, they declined to build any nuclear plants. Subsequently, Iran turned its attention to other potential suppliers such as Pakistan, Argentina, Spain, China and the Russia.[2] Finally, in 2010 Iran completed its first and also long delayed Bushehr nuclear power plant with the help of Russia.

Iran's nuclear programme has continued to raise doubts among western countries. In February 2003, while Iran began to acknowledge past secret activities, the International Atomic Energy Agency (IAEA) stressed its inability to verify the correctness and completeness of the Iran's declarations on the history and scope of its enrichment and fuel reprocessing activities, and the reliability of the peaceful nature of its nuclear programme.[3] In October 2003, then Iranian President Mohammad Khatami (reformist) and EU-3 (Britain, France and Germany) signed an agreement to halt nuclear enrichment programme for the time being. Though, hardliner President Mahmoud Ahmadinejad resumed the nuclear programme in 2005. Iran's refusal to give early notice of new nuclear facilities, the revelation in 2009 of a new secret enrichment plant at Fordow (near Qom) and commencement in 2010 of enrichment to nearly 20 per-cent[4] further heightened international concerns especially the West.

Ahmadinejad's stand on nuclear programme has escalated tensions between Iran and the West and led to the economic sanctions by United Nations Security Council (UNSC), the European Union (EU) and the US. These sanctions have paralysed the Iranian economy and have also succeeded in generating a debate among the Iranian elite over the country's nuclear policy. Because of Ahmadinejad's determined agenda to pursue a confrontationist policy, conservatives have been divided into two groups – moderate conservatives and neo-conservatives. Moderate conservatives are headed by Ali Larijani and Mohammad Baqer Qalibaf (the Mayor of Tehran). They have been critical of Ahmadinejad's offensive approach and the resulting deterioration in Iran's ties with the international community and the West in particular. Similar criticism has also been directed at Ahmadinejad by a coalition of centrists and reformists headed by former President Mohammad Khatami, Akbar Hashemi Rafsanjani and ex-Speaker of Majlis, Mehdi Karroubi.

It must be noted here that there is unanimity among the country's political elite that Iran should continue to pursue its nuclear programme for peaceful purposes. Their opinions are divided over the approach to be taken in dealing with the international community with reference to the enrichment programs. At the same time, it must be also noted here that then IAEA Director Mohammed El Baradei continues to appreciate the progress being made regarding Iran's nuclear activities and considers Iran's cooperation with IAEA teams in a positive light.

Iran's Chemical Weapons

In May 1998, for the first time Iran revealed the existence of a past chemical weapon (CW) programme, admitting that it was developed during the latter stages of Iran-Iraq War as a deterrent against a possible use of chemical agents by Iraq. However, Iran also claimed that it had terminated the programme after the 1988 cease-fire.[5] Iran expresses that the founder of the Islamic Republic Ayatollah Khomeini specifically prohibited the use of

CW on religious ground. Moreover, at the 1989 Paris Conference convened to reaffirm the Geneva Protocol (when Iran first joined the protocol), Iranian foreign minister Ali Akbar Velayati stated that Iran had 'never resorted to CW use, even in retaliation'.[6] Iran has also openly claimed a non-use policy, maintaining that CW are unethical and contrary to Muslim beliefs because they harm the environment. It has actively lobbied on behalf of the Organisation for the Prohibition of Chemical Weapons (OPCW), which verifies adherence to the CWC. The CWC imposes a number of basic obligations on states that are party to the convention. For example, under article I, the parties agree not to develop, produce, use, otherwise acquire, stockpile, or retain chemical weapons, or to transfer them to anyone, directly or indirectly.

On the other hand, according to the 2005 Non-compliance Report, the US considers that Iran has not revealed the full extent of its CW programme. The assertion is that Iran had manufactured and stockpiled first-generation CW agents-blister, blood, and choking chemical agents- and had weaponised some of these into artillery shells, mortars, rockets, and aerial bombs. The US also accuses Iran for violation of its CWC obligations because it is acting to hold and modernise key elements of its weapons infrastructure to include an offensive chemical weapons research and development (R&D) capability and spread mobilisation facilities.[7]

Despite claims and speculation about its capabilities and intentions, Iran has sometimes been said to be a CWC member in good standing. OPCW inspections in Iran have not left any unanswered questions and, like every other CWC member, it has not been found to be in violation of the convention. In 2007, the OPCW found that Iran was one of only 18 states to meet the submission deadline for the annual declarations regarding protected activities and anticipated production of chemical agents at Schedule I chemical facilities – only one facility is allowed with severely restricted activities.[8]

While no direct evidence exists to verify whether Iran is currently operating a CW programme, Western governments agree that Iran is seeking to acquire dual-use expertise, equipment and materials from a variety of foreign sources that would help it to develop an independent capability to produce advanced CW, such as nerve agents. Nonetheless, public information on specific Iranian procurement efforts provides some details on the type of dual-use items that Iranian companies have sought to acquire, which, in the judgement of some foreign governments, provide insights into Iran's past or present CW efforts. However, most of this information is from American sources.[9]

Biological Weapons Programme

Iran began an offensive biological weapons (BW) programme in the early 1980s during the Iran-Iraq War. Throughout the 1990s, the US government continually charged that Iran had a BW programme. During the war, Iran accused that Iraq had used BW. In response, then Iran's Majlis speaker Rafsanjani declared that Iran should develop BW in order to defend itself. Additionally, US officials speculated that Iran's interest in developing BW must have been further inspired by Iraq's admission in 1995 that it had a large and secret BW programme dating back to the mid-1980s and that it had prepared biological warheads (anthrax, botulinum toxin and aflatoxin) for al-Hussein missiles before the 1990 Gulf War.[10]

The full extent of its BW capability remains uncertain. The November 2004 "721 Report" of the Director of Central Intelligence gave this assessment;

> "Even though Iran is part of the BWC, Tehran probably maintained an offensive BW programme. Iran continued to seek dual-use biotechnical materials, equipment, and expertise that could be used in Tehran's BW programme. Iran probably has the capability to produce at least small quantities of BW agents".[11]

The 2005 Non-compliance Report reiterated the concern over the nature of Iran's BW-related activities, stating, "Iran is technically capable of producing at least rudimentary biological warheads for a variety of delivery systems, including missiles". Director of National Intelligence (DNI) or Office of the Director of National Intelligence (ODNI) John Negroponte said in February 2006 testimony that the threat from biological agents or even chemical ones "would have psychological and possibly political effects far greater than their actual magnitude".[12] The ODNI's most recent proliferation report to Congress in December 2009 adopted an even more cautious stance on the existence of an Iranian BW programme, saying that 'Iran has the capability to produce some biological warfare agents for offensive purposes, if it made the decision to do so'. The 2010 State Department arms-control compliance report said, 'available information also indicates Iran has remained engaged in dual-use activities that include procuring dual-use biological equipment and materials, conducting research involving BW-related pathogens and genetic engineering, and developing mechanisms that could be used to deliver biological agents.' The report concluded that 'Iran may not have ended activities prohibited by the BWC, although available information does not conclusively indicate that Iran is currently conducting activities prohibited by the Convention.'[13] Iran is believe to be building large, state-of the-art research and pharmaceutical production facilities that could hide pilot to industrial-scale production capabilities for a potential BW programme and could mask procurement of biological weapons-related process equipment.[14] It has been accused by both British and American intelligence that Iran employs several former Soviet biological engineers to work on Iran's BW arsenal.[15]

Conclusion

The 2005 Non-compliance Report judges from available information that Iran's offensive programme appears to be maturing, with a rapidly evolving capacity for the delivery of nuclear, chemical, and biological weapons in a variety of ways. Claims maid by the West that Iran has carried out activities in violation of its CWC and BWC obligations cannot be verified from the available public information and may have been exaggerated. However, in the nuclear field, Iran's violation of NPT safeguards obligations and obstruction of IAEA investigations into allegations of nuclear-weapons related work are well documented. At the same time, Iran continues to claim that its nuclear programme is entirely peaceful purposes.

Endnotes:

* This review is based on IISS Strategic Dossier, February 2011.

1 Mustafa Kibaroglu, "Iran's Nuclear Ambitions from a Historical Perspective and the Attitude of the West", *Middle Eastern Studies*, 43 (2) March 2007; pp. 223-225.

2 Ibid; p. 235.

3 Yonah Alexander and Milton Hoenig, "The New Iranian Leadership: Ahmadinejad, Terrorism,

Nuclear Ambition, and the Middle East", Praeger Security International, Wesport, 2008, p. 111.

[4] "Iran's Nuclear, Chemical and Biological Capabilities: A Net Assessment", The International Institute for Strategic Studies (IISS), London, February 2011, p. 47.

[5] Yonaha Alexander, no. 3, p.183.

[6] IISS, no. 4, p. 97.

[7] Yonah Alexandar, no. 3, p. 186.

[8] IISS, no. 4, p. 101.

[9] Ibid., p. 107

[10] Ibid., p. 109.

[11] Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Masss Destruction and Advanced Conventional Munitions, 1 July through 31 December 2003, Director of Central Intelligence, November 2004.

[12] John D. Negroponte, "Annual Threat Assessment of the Director of National Intelligence", Testimony before the Senate Select Committee on Intelligence, February 2, 2006, p. 10.

[13] IISS, no. 4, p. 112.

[14] U. S. Department of State, Adherence and Compliance with Arms Control, Non-proliferation, and Disarmament Agreements, August 2005, p. 20.

[15] Jonathan B. Tucker, "Bioweapons from Russia: Stemming the flow", Issues in Science and Technology. www.issues.org/15.3/p_tucker.htm

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