SSPC Issue Brief

Peaceful application of Ricin: Need to reframe policies

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This paper is an effort to assess empirical evidence related to threat perception of one of the most dreaded biological weapon of mass destruction, Ricin. The evidence shows a realistic view to the notorious perception of Ricin, suggesting a need to reform the CWC policies!

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For long, the state response to any terrorist action in India and around the world has been such that the perpetrators of terror usually achieve their ill-intentioned objectives. The world believes in free flow of scientific knowledge and technological developments. But as a reaction to such terrorist actions, we tend to keep aside rational thinking and restrict this very flow of knowledge, thereby compromising the scientific discoveries for peaceful purposes. The need of the hour is a prudent diplomatic outlook to balance Science and Diplomacy while debating security concerns and convergence of Chemistry and Biology with "dual use" potential.

This paper is an effort to rationalize the gravity of the threat posed by one of the most dreaded biological weapon of mass destruction, Ricin!

Ricin as part of CWC

Chemical Weapons Convention (CWC)is the most important international disarmament pact, known for its contribution in reducing the probability of using chemical, biological, and toxin weapons; and for the enhancement of the protection against these weapons[1]

According to Article II of the CWC, 'Chemical weapons', defined in three parts, are identified first as all toxic chemicals and their precursors, except those intended for purposes allowed by the CWC. Such purposes include peaceful uses, protection against toxic chemicals, military purposes not related to the use of toxic chemicals as a method of warfare and law enforcement.

Ricin was listed in Schedule 1 of CWC due to its toxic nature, easy availability and no known peaceful use at that time.

For purposes of the CWC implementation, Schedule 1 of Chemicals contains Ricin and Saxitoxin as "placeholder" of protein and non-protein toxins.[1]

What is the new research?

Tremendous technological development has occurred in the last 20 years. New research findings spread over all these years compel us to review the earlier opinion that Ricin does not have any peaceful applications. Now with these scientific and technological advancements and their economic impact on varied industries, there is a need to reframe policies with regards to Ricin, which can be useful in the following ways:

- Early Phase-I clinical trial with pure Ricin and related protein Abrinfor cancer treatment has been conducted successfully. This trial is concluded with the highest tolerated dose recommendation along with drug administration schedule for next Phase II clinical trial.[2]Ricin is a valuable drug for cancer treatments waiting for further clinical explorations.
- Ricin,as intact whole toxin[3], its isoforms[3,4,5]and its derivatives in the form of separated chain-A[4]and chain-B are already commercially available[6] from various

1 Pitschmann V, Hon Z. Military Importance of Natural Toxins and Their Analogs. Molecules. 2016 Apr 28;21(5):556

2 Fodstad Ø, Kvalheim G, Godal A, Lotsberg J, Aamdal S, Høst H, et al. Phase I Study of the Plant Protein Ricin. Cancer Res. 1984 Feb 1;44(2):862–5.

3 Lectins: RicinusCommunis Agglutinin II (RCA II, RCA60, ricin), Unconjugated | Vector Labs [Internet]. [cited 2018 Mar 16]. Available from: https://vectorlabs.com/unconjugated-ricinus-communis-agglutinin-ii-rca-ii-rca-sub-60-sub-ricin.html

manufacturers (Vector labs, Sigma Aldrich) and are extensively used as research tools.

- Ricin is one of the most commonly employed plant toxins to generate immunotoxins.[7]Derivatives of Ricin are also useful as toxin conjugates with monoclonal antibodies for cancer therapeutics.[7,8]Gene-engineering techniques are widely used to make recombinant immunotoxin conjugates.[9] Recently, one immunotoxin conjugate containing Ricin deglycosylated A-chain has been approved by US FDA for treatment of T-cell lymphoma.
- New-found dermal therapeutic activity of Ricin derived from castor beans,on the hair follicles, has opened a whole new potential therapeutic dermal application of Ricin for the management of unwanted hair. Ricin and Abrin are known to be dermally inactive to cause any harm, as the amount of toxin getting absorbed through the skin is negligible. However, it has been established that these proteins induce hair follicle dystrophy, thereby inhibiting the growth of the hair follicles without affecting other skin structures.[10,11,12]
- This new-found dermal activity of Ricin has potential not just for cosmetic purpose of inhibiting unwanted hair follicles, but also for:
  - Treating skin cancers
  - Treating skin before grafting for oral reconstruction surgery for oral cancer patients
  - The major pollutants of leather industry are the chemicals used for de-hairing the hide. This new-found technology has the potential to reduce these pollutants substantially by pre-treating the cattle reared for premium leather before slaughter.
- There can be peaceful and economically beneficial use of toxic waste of castor oil industry consisting Ricin, for future peaceful use. Toxic waste of one industry can be

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4 Lectin from <I>Ricinuscommunis</I> (castor bean) Agglutinin RCA₁₂₀ L7886 [Internet].Sigma-Aldrich. [cited 2018 Mar 26]. Available from: https://www.sigmaaldrich.com/catalog/product/sigma/l7886

5 Lectins: RicinusCommunis Agglutinin I (RCA I, RCA120), Biotinylated | Vector Labs [Internet]. [cited 2018 Mar 26]. Available from: https://vectorlabs.com/biotinylated-ricinus-communis-agglutinin-i-rca-i-rca120.html

6 Ricin A chain from Ricinuscommunis (castor bean) | Sigma-Aldrich [Internet]. [cited 2018 Mar 26]. Available from: https://www.sigmaaldrich.com/catalog/substance/ricinachainfromricinuscommuniscastorbean123459663828711?lang=en&region=IN

7 Polito L, Djemil A, Bortolotti M. Plant Toxin-Based Immunotoxins for Cancer Therapy: A Short Overview. Biomedicines. 2016 Jun 1;4(2):12.

8 Rust A, Partridge LJ, Davletov B, Hautbergue GM. The Use of Plant-Derived Ribosome Inactivating Proteins in Immunotoxin Development: Past, Present and Future Generations. Toxins. 2017 Oct 27;9(11):344.

9 Wayne AS, FitzGerald DJ, Kreitman RJ, Pastan I. Immunotoxins for leukemia.Blood. 2014 Apr 17;123(16):2470–7.

10 Kondhalkar MB, Dr KA, Dr MW, Paygude S, Dr PP. Ugly Duckling or a Swan: Exploring therapeutic potential of Ricin for inhibiting unwanted hair growth. Matters. 2017 Feb 16;3(2):e201702000001.

11 Kondhalkar M.B., Parab P.B. 7th World Congress for Hair Research Abstracts. J Invest Dermatol. 2013 May;133(5):1391–439.

12 Kondhalkar M., Dudhbhate A., Apte K., Banerjee R., Parab P. Clinical Study to Evaluate Safety and Efficacy of a Topical Hair Minimizing Lotion in Healthy Human Volunteers [Internet]. [cited 2017 May 23]. Available from: http://www.avensonline.org/wp-content/uploads/JCTP-02-0007.pdf

put to good use by substantially reducing toxic pollution and creating valuable therapeutic applications and economic impact for another industry.

- Castor bean extracts are widely used for agricultural applications such as for control of nematode infestations.[13]

Economic impact

As India is the largest producer and exporter of castor oil and derivatives, the economic impact of such reforms have huge potential economic benefits for India with specific focus on Ricin research.

Cosmetic industry

According to Euromonitor, the global hair removal market is poised at USD 18 billion and is a very fast growing industry. A non-invasive Ricin based treatment for management of unwanted hair will prove to be a game changer for this industry.

Leather industry

The conventional de-hairing method involves the use of high proportions of lime and sulfide, which contributes to 80– 90% of the total pollution load in the leather industry and generates noxious gases as well as solid wastes, e.g. hydrogen sulfide and lime.[14] Pretreatment of cattle with Ricin formulations may prove to a catalyst in reducing the pollution caused by this industry.

Cancer therapeutics

Pharmaceutical industry is always on the lookout for new therapeutic candidates for chemotherapy applications.

Once Ricin is commercialized for peaceful applications, economic impact on all these industries will be tremendous. Hence, the need to reframe the policies for Ricin is crucial.

History of amendments to CWC

To date, no State Party to the Chemical Weapons Convention (Convention) has proposed an amendment pursuant to Article XV of the Convention.[15] Proposals to change the Annexes of the Convention have, however, been made on two occasions and adopted pursuant to the procedures set forth in paragraphs 4 and 5:

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13 Adomako J, Kwoseh CK. Effect of Castor Bean (Ricinuscommunis L.) Aqueous Extracts on the Performance of Root-Knot Nematodes (Meloideogyne spp.) on Tomato (Solanumlycopersicum L.). J SciTechnol Ghana. 2013 Jan 1;33(1):1–11.

14 Shivam Gupta, Rocky Gupta, RonakTamra. CHALLENGES FACED BY LEATHER INDUSTRY IN KANPUR [Internet]. [cited 2018 Mar 16]. Available from: http://home.iitk.ac.in/~sgupta/tannery_report.pdf

15 Different amendment procedures are in place for the provisions of the CWC and the Annexes to the CWC (with exceptions). Amendments to the CWC are regulated according to a *formal* procedure enshrined in paragraphs 2 and 3 of Article XV whereas changes to the Annexes are governed by the *simplified* procedure in paragraph 5 of Article XV. The simplified procedure does not apply for Sections A and C of the Confidentiality Annex, Part X of the Verification Annex, and those definitions in Part I of the Verification Annex which follow the procedure relating to amendments of the CWC (Article XV(4)).

- Canada: In 1998, Canada proposed a change to Part VI of the Verification Annex of the Convention with regard to transfers of Saxitoxin.[16] The proposal was intended to make possible short-notice shipments of diagnostic test kits that contain Saxitoxin as a reference standard.[17] Canada's proposal resulted in the addition of paragraph 5bis to Section B, Part VI of the Verification Annex of the CWC effective 31 October 1999.[18]

- Libya: In 2004, the Socialist People's Libyan Arab Jamahiriya proposed a technical change to Part V of the Verification Annex to the Convention regarding the conversion of chemical weapons production facilities for purposes not prohibited under the Convention.[19] In particular, the proposal sought to address the conversion of CWPFs for states acceding to the Convention after the initial six-year period of the Conventions' entry into force.[20] The proposal resulted in the addition of paragraph 72bis to Part V of the Verification Annex.[21]

Bioterrorism

The word "Bioterrorism" often evokes strong reactions from petrified audiences imagining doomsday scenarios. However, itmust be notedthat most non-state and state-funded bio-weapon (BW) programs running for many years, involving best scientific knowledge, experts, equipment and infrastructure, did not yield successful BW. This led to abandonment of all these BW programs. Mere easy acquisition of biological agents does not result in a successful BW, in spite of all other available resources. Contrary to popular belief, there are great barriers to successful BW developments[22]:

Challenges in BW development

- Biological material (microbes or toxins) sensitive to many parameters such as environmental conditions, expertise in handling
- Unpredictability of agents throughout all developmental stages (research, development, small and large scale production, testing and weaponization)
- Need for "Functional overlap" between scientific teams developing and scaling up production of agents and weaponization experts developing modes of dispersal of BW-
- Seamless passage of expertise from one stage to next

16 EC-XIII/DG.7, dated 7 December 1998. See also EC-MII/1, dated 15 January 1999.

17 Walter Krutzsch, Eric Myjer& Ralf Trapp, *The Chemical Weapons Convention: A Commentary* (Oxford University Press, 2014) 578

18 See Depository Notification, C.N.916.1999.TREATIES-7, dated 8 October 1999; Depository Notification, C.N.157.2000.TREATIES-1, dated 13 March 2000.

19 EC-38/DG.2, dated 16 July 2004. The proposal was cosponsored by: Algeria, Cameroon, Eritrea, Italy, Kenya, Morocco, South Africa, Sudan, Tunisia, United Kingdom of Great Britain and Northern Ireland, United States of America, and Yemen. See also EC-38/DG.9, dated 7 September 2004.

20 Paragraph 72 of Part V of the Verification Annex read: 'conversion of a chemical weapons production facility shall be completed not later than six years after entry into force of this convention'.

21 Depository Notification, C.N.610.2005.TREATIES-4, dated 29 July 2005.

22 Ouagrham-Gormley SB. Barriers to Bioweapons: The Challenges of Expertise and Organization for Weapons Development. Ithaca, NY: Cornell University Press; 2014. 240 p. (Cornell Studies in Security Affairs).

Factors affecting weaponization

- Endogenous factors- Organization structure and management policies affect seamless transfer of expertise within a program, system integrators ensure synchronization of all activities within the BW program
- Exogenous factors affecting the program- Political priority or interference, economic support, infrastructure, foreign expert support and change of location

Summary of Bioweapon programs[22]

Non-state/ state-funded BW program	*BW program duration and resources*
Soviet program	60 years, about $20B ▪ About 15,000 directly involved in BW ▪ Developed bombs, spray tanks ▪ Works on genetically engineered agents did not go beyond research phase; ▪ Works on BW---specific ballistic or cruise missiles did not go beyond research phase ▪Problems with ensuring survivability of agent due to speed and heat created during re-entry
American program	27 years, about $700m ▪ 4500 people involved at the height of the program ▪ Developed bombs and spray tanks; ▪ No BW---specific ballistic or cruise missiles
Iraq	20 years, >$80m ▪ About 100 people involved, with only about 25 with knowledge applicable to BW ▪ Produced large quantities of liquid agents, but unable to produce dry agent ▪ Ineffective weapons: delivery upon impact would have destroyed most of the liquid agent
AumShinrikyo, Japanese cult movement (Aleph, formerly AumShinrikyo is a Japanese doomsday cult founded by Shoko Asahara in 1984. It carried out the deadly Tokyo subway sarin attack in 1995 and was found to have been responsible for another smaller sarin attack the previous year.)	6 years about $10m ▪Failed at every stage of development, production and weaponization ▪Very few have successfully developed working BW

In spite of availability of resources very few could successfully develop BWs and Ricin could not be weaponized successfully.[22]

Botulinum toxin

Botulinum toxin is a torch bearer for de-glamorizing potential bio-crime agents into successful therapeutic agents with huge economic impact. Botulinum toxin and Ricin have many similarities:

- Botulinum toxin, one of the most likely biological battlefield threats,[23] is not listed in CWC. This has facilitated successful commercialization of Botulinum toxin (popularly known as Botox) for peaceful therapeutic applications.
- Botulinum toxin and Ricin as WMD have long history of toxicity, manufacturing, stockpiling, vaccines and weaponization.Assassinations of ReinhardHeydrich, head of the Gestapo and Security Service, with a hand grenade filled with Botulinumtoxin during World War II[23]and Georgi Markov case have similarities. But it was never conclusively proven that Botulinum toxin and Ricin respectively were used in these high profile assassinations.
- Both the BW agents have multiple restrictions due to easy availability of Ricin, Botulinum toxin and counterfeit Botulinum neurotoxins (BONTs).[24]

However, when empirical data of historical cases is analyzed further, there is distinct difference between both the agents.

LCT_{50}S FOR SELECTED TOXINS IN MICE AND RHESUS MONKEYS		
Toxin	**Mouse Lct_{50} ($mg.min/m^3$)**	**Rhesus Monkey Lct_{50} ($mg.min/m^3$)**
Botulinum A	0.0225	0.0225
Ricin	3-7	114
Saxitoxin	3	_
T-2 Toxin	200	_
Staphylococcus Enterotoxin B	NA	80- 100

Graph-I: Soured from MEDICAL ASPECTS OF CHEMICAL AND BIOLOGICAL WARFARE Zajtchuk Russ, Bellamy Ronald F p.608[23]

- Botulinum toxin is substantially more toxic than Ricin as indicated in Graph 1
- Historically, Ricin has been used as an agent for bio-crimes, whereas Botulinum toxin has been used as a bio-terror agent e.g. AumShinrikyo (1990-01), (April 1990-March 1995) [25]

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23 Zajtchuk Russ, Bellamy Ronald F. MEDICAL ASPECTS OF CHEMICAL AND BIOLOGICAL WARFARE [Internet]. Available from: http://www.bvsde.paho.org/tutorial1/fulltex/armas/textos/chebio/chebio.pdf

24 Kenneth D. Coleman, Raymond A. Zilinskas. Botulinum Toxin- The Security Threat from Producers of Counterfeit Botulinum Toxin [Internet]. Available from: https://www.hsdl.org/?view&did=715918

25 W. Seth Carus. Bioterrorism and Bio crimes: the illicit use of biological agents since 1900 pg 48-49 [Internet]. Center for Counterproliferation Research, National Defense University; 1998 [cited 2017 Oct 11]. Available from: https://fas.org/irp/threat/cbw/carus.pdf

- State BW programs- Canada 1946- 1958 (Botulinum toxin), Egypt (Botulinum toxin-unconfirmed), Syria (Ricin and Botulinum toxin).

Botulinum toxin (controlled agent) is not listed in any of the CWC schedules facilitating its commercial exploitation for various therapeutic applications.

Ricin- Facts vs Myths:
History

Despite all the publicity surrounding bioterrorism, very little effort, that too with very theoretical focus,has beendevoted to this unfortunately misunderstood subject. There is a stark contrast between opinions of many policy makers and analysts preempting apocalyptic scenarios of bioterrorism threats and those of other set of analysts who suggest that there is no necessity for any concern for lack of any empirical history. Review articles by CarusW. Seth[25, 26]presents a more realistic scenario with detailed analysis of bioterrorism cases since 1900 to 2001.

This review comprises of detailed analysis of total 269 bio-terror cases researched involving allegations of varying degrees of interest, use, threatened use or possession of biological agents by the perpetrators.

- Out of 54 alleged bio-terrorist cases, only 27 can be substantiated.
- In addition, alleged 20 cases of covert state involvements of which only 11 had substantial evidence.
- Only 33 of the non-state cases reported actual acquisition of biological agents and out of these only 4 cases involving theft, the perpetrators had legitimate access to research labs.
- Out of 180 non-state cases, in 27 cases the perpetrators considered a toxin as an agent of choice, of which Ricin was considered in only 14 cases.
- In every reported case, the perpetrators manufactured Ricin by extracting it from castor beans. Only 3 cases were reported when the perpetrators actually extracted Ricin from castor beans.
- Out of 21 confirmed bioterror or bio-crime cases reported with use or attempted use, 20 cases reported casualties, including seven deaths. Of these, only two cases (Rajneeshees and Dr. Suzuki cases) accounted for almost 93 percent of all the confirmed victims of biological weapons use. None of those involved open use of Ricin!
- No case of confirmed death/s involving the use of Ricin as a bio-weapon has been reported. Confirmed reported cases resulting in death were seven self-inflicted Ricin administration by intra-venous (I.V.) route.[27]

These exhaustive analyses of cases by Carus W. Seth involving Ricin[25, 26] throw empirical data in line with more recent survey by George Smith that discounts the significance of threat perception of Ricin,[28] which is supplemented by a Congressional Research Service Report.[29]

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26 W. Seth Carus. The History of Biological Weapons Use: What We Know and What We Don't. Health Secur. 2015 Jul 29;13(4):219–55.

27 Schep LJ, Temple WA, Butt GA, Beasley MD. Ricin as a weapon of mass terror — Separating fact from fiction. Environ Int. 2009 Nov;35(8):1267–71.

28 Smith G. The American way of bioterror - an A-Z of ricin crackpots [Internet]. [cited 2018 Apr 9]. Available from: https://www.theregister.co.uk/2008/04/22/ricin_losers_roundup/

Toxicity

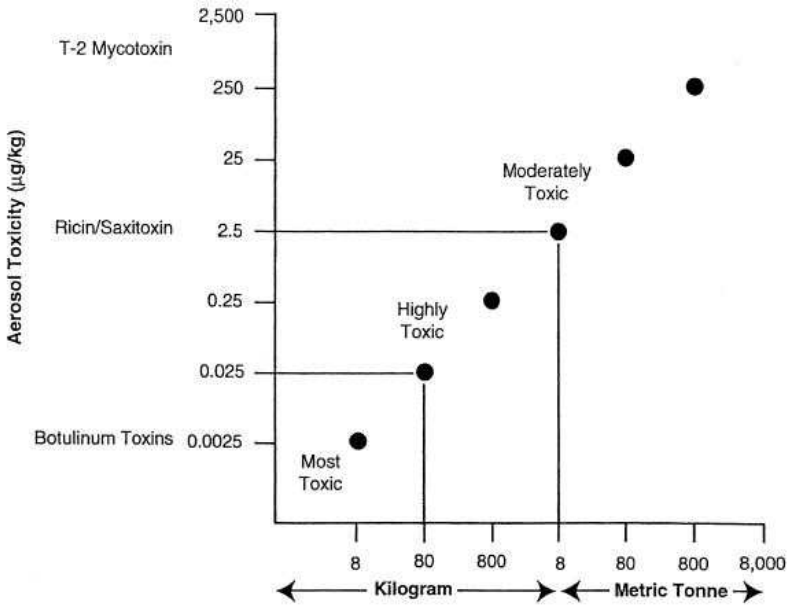
Ricin is a large, moderately toxic, protein toxin produced from the bean of the castor plant, Ricinuscommunis. It can be produced easily in relatively large quantities. Ricin was developed as a biological weapon by the United States and its allies during World War II.[23]

Although the use of Ricin was investigatedas a potential military weapon, it has been historically predominantly utilized in small quantities against specific individuals as bio-crime agent.

It is widely believed by the experts that Ricin has many limitations to be used as a weapon of mass destruction.[25-27,30]

WMD as aerosol:

To cause any grievous injury,Ricin needs to be inhaled, injected or ingested by the victim. According to an estimate,a total of eight metric tons of Ricin would be required to cover 100 square km to kill half of the population (LD50). This is not just logistically impractical, but significant technological barriers for weaponizationmay also preclude such a use even for a well-funded non-state actor. Most experts believe that it would be difficult to use Ricin as a WMD, but its potential to be developed as a weapon of terror should not be discounted.[29] Thus these challenges exclude operational-tactical use of Ricin under the conditions of modern mobile combats that outweigh its easy availability and ease of preparation.[1,27]



Graph-II: soured from Franz DR, Jaax NK. Ricin Toxin. In: Zajtchuk R, Bellamy RF, editors. In: Textbook of military medicine: medical aspects of chemical and biological warfare [Internet]. Washington, DC: TMM Publications; 1997p.606[30]

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29 Shea DA, Gottron F. Ricin: Technical Background and Potential Role in Terrorism [Internet]. LIBRARY OF CONGRESS WASHINGTON DC CONGRESSIONAL RESEARCH SERVICE, LIBRARY OF CONGRESS WASHINGTON DC CONGRESSIONAL RESEARCH SERVICE; 2004 Feb [cited 2018 Feb 8]. Report No.: CRS-RS21383. Available from: http://www.dtic.mil/docs/citations/ADA444989

30 Franz DR, Jaax NK.Ricin Toxin. In: Zajtchuk R, Bellamy RF, editors. In: Textbook of military medicine: medical aspects of chemical and biological warfare [Internet]. Washington, DC: TMM Publications; 1997. p. 605– 634. Available from: http://ww.phsource.us/PH/CBRNE/MABCW/Medical%20Aspects%20of%20Chemical%20and%20Biological%20Warfare.pdf#page=621

Toxicity (in mouse LD 50) plotted against the quantity of toxin required to provide a theoretically effective open air aerosol exposure under ideal meteorological conditions to an area of 100 $km^{2.}$

Civic water contamination

Fortunately, civic water supply systems are far less vulnerable to Ricin. They are designed to eliminate impurities, particles, pathogenic microbes.

According to the US Department of Defense biological warfare analyst, to effectively contaminate the New York City water supply a "trainloads" of Botulinum toxin would be required. As Ricin is considerably less toxic than Botulinum toxin, the required quantities of Ricin for effective dissemination as WMD would be humungous.[23,31]

Easy availability

When all the above empirical data is considered, the "easily available" Ricin to be effectively deployed as a WMD has to be in purest stable form, of particular particle size, available in "sufficiently large quantities" and is "weaponized".

When one puts all the facts and statistics related to threat potential, historical use, and scientific developments for peaceful use along with its environmental and commercial impact in one big picture, a pertinent question comes out -- Does Ricin truly belong to the Schedule 1 of CWC?

Suggestions

Ricin should be removed from Schedule 1 and just like Botulinum toxin, with all declaration requirements, its commercial potential should be allowed to be exploited. The listing has so far only attracted negative attention to Ricin for bio-crime purposes, thereby putting tremendous pressure on civic administrations.

As summarized by Sonia Ben Ouagrham-Gormley[22],true barriers to bio-weapon development are not in restrictions for acquisition of biological materials, but the sustained development of the program resulting in weaponization. No single policy can curtail the BW proliferation threat, but considering the fragile nature of biomaterials, lessons learnt from the failures of non-state / state-funded BW programs should form the guiding principles to create higher barriers for future BW developments.

Once Ricin is removed from CWC Schedule 1, certain checks and balances may be enforced to create further barriers for use as a bio-weapon.

Suggested steps to be taken are:

- International controls, under CWC, over manufacturing units and periodic inspections

31 Jansen HJ, Breeveld FJ, Stijnis C, Grobusch MP. Biological warfare, bioterrorism, and biocrime.ClinMicrobiol Infect. 2014 Jun 1;20(6):488–96.

- Inspection and controls on entities that possess, use, or transfer select agents such as Ricin manufacturing labs, castor oil industry waste disposal, compliance for select agents on the lines of Botulinum toxin
- Lessons need to be learnt from challenge of counterfeit Botulinum toxin (BONTs)

- Providing guidance to regulated entities through the development of guidance documents, conducting workshops and webinars
- Investigation of any incidents in which non-compliance may have occurred

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