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CHEMICAL, BIOLOGICAL, RADIOLOGICAL, OR NUCLEAR (CBRN) DETECTION: A TECHNOLOGICAL OVERVIEW

DRAFT SPECIAL REPORT

LORD JOPLING (UNITED KINGDOM)
SPECIAL RAPPORTEUR*

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* Until this document has been approved by the Committee on the Civil Dimension of Security, it represents only the views of the Rapporteur.

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I. INTRODUCTION

1. In the past, various terrorist groups have employed CBRN agents. In Europe, left-wing extremists have threatened their use against civilian populations or military targets; right-wing extremists in North America have conspired to poison city water supplies and have succeeded in acquiring significant quantities of deadly agents; state sponsors of terrorism have reportedly developed CBRN weapons suitable for terrorist use; food products have been deliberately contaminated, in some cases causing human casualties and/or considerable economic losses; insurgent groups in various parts of the world have sometimes used CBRN agents against government forces; and individual assassinations have been carried out by such means.

2. Despite widespread publicity about the threat, however, there have been few actual attempts by terrorists to cause mass civilian casualties using CBRN agents. Exceptions have been the typhoid poisoning of 750 people (none fatally) by the Rajneesh sect in Oregon, USA in 1984; and the various attempts by the Aum Shinri Kyo in Japan using both chemical and biological agents, the most “successful” of which resulted in 7 dead and 270 injured in Matsumoto, and 12 dead and 5,500 injured in Tokyo. Far more common have been unsubstantiated threats, hoaxes or relatively low-level incidents causing few—if any—casualties.

3. There have also been a limited number of attacks on nuclear power facilities worldwide; numerous unsubstantiated threats to trigger a nuclear explosive device; and at least one reported case of the use of radiological materials—albeit in a very limited manner, where Chechen rebels planted a cesium capsule in a park in Moscow)—by terrorists.

4. However, as information and capabilities spread widely through such means as the Internet, it is becoming increasingly difficult for the authorities to distinguish between a mere hoax and the real thing. This raises a number of difficult questions about the appropriate responses to such threats, which not only have the potential to be extremely disruptive to normal, day-to-day activities, but also may afford terrorist individuals and groups a potent instrument against society, even in the absence of a real capability or willingness to carry out an actual attack.

5. Governments and publics alike are viewing with growing concern the potential threat posed by CBRN weapons in the hands of terrorists. The question is, how easy would it really be for an individual terrorist or terrorist group to manufacture or otherwise obtain such weapons? Perhaps even more importantly: How easy would it be for them to deliver such weapons, or disperse such agents, and to what effect? Clearly, the answers vary depending on the type of weapon or agent that one is talking about.

6. Governments at all levels have been prompted to re-consider how ready and able they are to prevent or mitigate the impact of those threats to societies. Many elements can contribute to the minimisation or liquidation of some of these threats. Risks assessment and analysis, fighting proliferation and dissemination of CB agents, and the dismantlement of terrorist networks are all essential elements contributing to preventing accidents and attacks. A prevention policy should include monitoring and warning arrangements as well as detection mechanisms of toxic agents. Detection devices should be able not only to identify raw material for potential bombs, but also give the alert as soon as toxic agents are released in the atmosphere, in order to take advantage of the time between exposure of the public and widespread casualties. Governmental authorities, particularly local authorities, are confronted by the need to acquire capabilities to intervene quickly should radioactive materials be dispersed in the atmosphere. Here again, a system for early, efficient, and quick detection also enhances the authorities’ capacity to respond not only to terrorist attacks, but also to major technological accidents.

7. Following a first report presented in 2003 by Ms Wohlleben (Germany) on “Civil Protection: a general overview” assessing general threats and policy approaches, the Rapporteur Lord Jopling

(UK) decided this year to focus on the available detection mechanism of CNBR potential threats. Additional information regarding latest available devices in this sphere and corresponding fees will be added at a later date to this report in order to give a more detailed and updated view of the existing detection mechanisms.

II. CHEMICAL AND BIOLOGICAL THREATS: DETECTIONS MECHANISMS

8. There have recently been reports of new or renewed interest by a number of traditional international terrorist groups in obtaining chemical and biological weapons. These groups include: the Palestinian Islamic Jihad, Hezbollah, the Algerian Armed Islamic Group (GIA), Egyptian Islamic Jihad, Hamas, Sikh and Chechen terrorists, the Kurdistan Workers' Party (PKK), the Khmer Rouge, and the Liberation Tigers of Tamil Eelam (LTTE). These reports are usually quite vague, and not all of them have been particularly credible, but the trend is worrisome. Senior US government officials have publicly asserted that the terrorist financier Osama bin Laden has been actively seeking chemical, biological, and nuclear weapons for use against Western targets. The recent apparent resurgence of the Aum Shinri Kyo in Japan is also troubling, given the technical knowledge possessed by some of its remaining followers and the possibility of yet-undiscovered stocks of CB agents or precursors

Chemical and Biological Detection Technologies:

9. The ideal chemical or biological sensor would fulfil a host of criteria. It would be: inexpensive; easy to use; rapidly deployable (hand-held); able to detect all dangerous pathogens; able to detect those pathogens in real time; able to detect them from diverse sample types; usable 'stand-off' detection; and, most importantly, always correct.

10. The dangers of false positives (detecting a non-existent threat) and false negatives (failing to detect a real threat) are obvious. To guide policy-makers and to reassure a concerned public, there must be faith in the equipment used. Designers must balance the need for sensitivity with the danger of false alarms, with all the consequences they entail.

11. Currently available technologies do not allow for the creation of a perfect sensor. There are a number of different technologies that have been developed for the detection of chemical and biological agents and new innovations are in progress. They all offer certain advantages and all suffer from flaws.

12. The US Counter proliferation Program Review Committee concluded that 'technical challenges remain in the areas of biological collection, detection and identification, quantification, sample processing, interferent (i.e., false positive and negative alarms) and ambient biological background rejection, and genetic probe development. Other challenging areas that still remain today are size, weight, and power reduction of detectors; power generation and consumption; development of integrated biological and chemical detection systems; and the fusion of sensor data with mapping, imagery, and other data for near-real-time display of events.

13. Despite this, the Centre for Technology and National Security Policy at the US National Defense University asserts that there is no theoretical reason that the above criteria cannot eventually be fulfilled. This report therefore offers a snapshot of current technologies and their ability to warn of a chemical or biological weapons attack on a civilian population.

A. BIODETECTION

14. It is worth distinguishing at this point between detect-to-warn and detect-to-treat systems. The former would detect a threat in time to prevent public exposure. Such real-time detection is currently unavailable in the field of biological detection and the more reliable the detection instrument is; the longer it takes to identify a defined threat. Detect-to-treat remains the more realistic goal at present. This would allow responders to take advantage of the time between exposure of the public and widespread casualties.

15. A WHO report concluded that ‘the development of sensitive and rapid methods of detecting and identifying biological agents in the environment will be difficult because of the large number of potential agents. Significant advances will have to be made in technology before such methods can be made widely accessible, and they may therefore not be available for some time.

16. One of the major concerns of the biological threat is the number of possible toxins that could be maliciously employed. Experts believe that up to 1,000 toxins could be made from natural or genetic sources but only 13 vaccines are currently available and only in limited quantities. This shortage of vaccines puts a greater emphasis on the need for some kind of effective warning system that can minimise exposure.

17. There are various inequalities in biowarfare between attack and defence, of which the lack of vaccines compared to known toxins is one example. It is far cheaper and less labour-intensive to create a bioweapon than to defend against it; biowarfare is a field that favours the terrorist. Detection initiatives intend to go some way in redressing this imbalance.

18. The US and Europe have both become gradually more concerned at the bioterror threat. Whilst September 11 was a watershed in security assessments, the anthrax attacks on the US postal system in September and October 2001 were an additional wakeup call, leaving 17 dead whilst the perpetrators were never caught. Ultimately, those who survived were the ones who were diagnosed early, underlining the utility of detect-to-treat systems.

19. In response, both sides of the Atlantic have explored means to warn of a biological attack. This effort has been greatest in the US, where the US BioWatch initiative has increased spending 18-fold since September 11, from $414 million in fiscal year 2001 to $7.6 billion in 2004.

20. Basic information on major bioterrorism agents:

Disease	**Incubation period**	**Type of vaccine**	**Treatment**
Anthrax not contagious	Symptoms can occur within 7 days of infection.	Vaccine is protective against invasive disease however, it is primarily given to military personnel and high risk population.	Treatment protocols exist for cases of inhalational and cutaneous anthrax
Botulism: -Botulism is a muscle-paralyzing disease caused by a toxin made by a bacterium. A single gram of crystalline toxin, evenly dispersed and inhaled, would kill more	Ingestion of pre-formed toxin leads to illness few hours to days. With foodborne botulism, symptoms begin within 6 hours to 2 weeks	Vaccine availability has been developed by the US Department of Defense	If diagnosed early, foodborne and wound botulism can be treated with an antitoxin, which blocks the action of toxin circulating in the blood. This can

than 1 million people, although technical factors would make such dissemination difficult. -not contagious			prevent patients from worsening, but recovery still takes many weeks.
Plague: -Yersinia pestis used in an aerosol attack could cause cases of the pneumonic form of plague. Contagious: -The bacteria can spread to others who have close contact with them.	One to six days after becoming infected with the bacteria, people would develop pneumonic plague.	-Currently, no plague vaccine is available -Contamination can be avoided with a treatment to be taken within 7 days of their exposure. Treatment consists of taking antibiotics for at least 7 days.	To prevent a high risk of death, antibiotics should be given within 24 hours of the first symptoms. Several types of antibiotics are effective for curing the disease and for preventing it
Smallpox: Smallpox is a serious, contagious, and sometimes fatal infectious disease.	This incubation period averages about 12 to 14 days but can range from 7 to 17 days.	-Vaccine availability -If given to a person before exposure to smallpox, the vaccine can completely protect them. Vaccination within 3 days after exposure will prevent or greatly lessen the severity of smallpox in most people. Vaccination 4 to 7 days after exposure likely offers some protection from disease or may decrease the severity of disease.	There is no specific treatment for smallpox disease, and the only prevention is vaccination.
Hemorrhagic fever: -Illness is characterized by abrupt onset of fever, myalgia, and headache. Other signs and symptoms include nausea and vomiting, abdominal pain, diarrhea, chest pain, cough, and pharyngitis.	-Incubation period of usually 5--10 days -The viruses carried in rodent reservoirs are transmitted when humans have contact	-With the exception of yellow fever and Argentine hemorrhagic fever, for which vaccines have been developed, no vaccines exist that can protect against these diseases.	Patients receive supportive therapy, but generally speaking, there is no other treatment or established cure for VHFs. Ribavirin, an anti-viral drug, has been effective in treating some individuals with Lassa fever or HFRS.
Inhalational tularemia : Tularemia is one of the most infectious pathogenic bacteria known. It requires inoculation or inhalation of as few as 10 organisms to cause disease. Inhalation of *F. tularensis* causes an abrupt onset of an acute, non-specific febrile illness	-Illness beginning 1--14 days after exposure -Release in a densely populated area would be expected to result in an abrupt onset of large numbers of acute, non-specific febrile illness beginning 3–5 days later with pleuropneumonitis developing in a significant proportion of cases during the ensuing days and weeks.	In the United States, a live attenuated vaccine derived from a virulent *F. tularensis* biovar palaearctica (type B) has been used to protect laboratorians routinely working with the bacterium. Until recently, this vaccine was available as an investigational new drug. It is currently under review by the Food and Drug Administration.	-Available -In a contained casualty setting, where individual patient management is possible,

Means of Detection:

21. *Sensor technology* is the most obvious example of biodetection. The fundamental challenge is that biological agents have different properties and many sensors are pathogen-specific; each test must be tailored to recognise a specific pathogen. Also, a more deadly pathogen (an agent that causes disease) requires a more sensitive detection system because a smaller dose in the air will be fatal.

22. JASON, an independent scientific advisory group that provides consulting services to the U.S. government on matters of defence science and technology, identified three broad types of biosensors in its 2003 study on biodetection.

23. *Environmental Monitoring* refers to the continuous automatic monitoring of the environment in fixed locations. They collect air samples that are then filtered, concentrated and analysed. Environmental monitors are not equipped for definitive identification of pathogens and in the event of detecting an abnormal presence, further tests are needed. Although cheap, they are unable to detect a broad range of pathogens.

24. One such environmental monitor is the Autonomous Pathogen Detection System (APDS) developed at Lawrence Livermore National Laboratory (within the US Department of Energy). The APDS is stationed in one place for continuous monitoring and is designed to work much like a smoke detector, but for pathogens. The system automatically samples the air around the clock, without human assistance, and sounds an alarm if pathogens are detected. The current system is configured to test simultaneously for 11 agents and can be expanded to 100 agents. It identifies particles within one hour and double-tests each sample to decrease the likelihood of false positives and increase the reliability of identification. A built-in fan pulls in the air, which passes through a glass tube containing water. The water traps any particles in the air, and the resulting fluid is pumped to the next stage for sample preparation and testing, using a technique called the polymerase chain reaction (PCR). PCR is needed to amplify the sample to allow detection of trace amounts of the pathogen, which could nonetheless be deadly.

25. *Sample Collection* refers to the process of collecting a sample and then analysing it, either on the spot or back at a laboratory. This is the core process of the BioWatch programme. Filter paper is often used to collect the data. The results can be very specific in identifying particularly pathogens but this makes the system inherently less able to detect novel biological agents. Sample collection is also a labour-intensive a costly process.

26. Lawrence Livermore’s Biological Aerosol Sentry and Information System (BASIS) is a typical sample collection system. BASIS collects air samples at defined locations and at specified time intervals to help determine both the time and place of the release. Aerosol collection hardware continually collects, time-stamps, and stores samples. A mobile field laboratory then analyses DNA from the samples and can identify and characterise a threat organism. BASIS was deployed in Salt Lake City, Utah, for the 2002 Winter Olympic Games. BioWatch features elements of the BASIS technology but, instead of a mobile laboratory, uses laboratories that are part of the federal Laboratory Response Network operated by the Center for Disease Control and Prevention (CDC).

27. *Rapidly-Deployable Sensors* are mobile detectors, often hand-held, which have the obvious benefit of being deployable to the area of a suspected incident. However, they too are often pathogen-specific and therefore unable to recognise a broad range of agents, making them of diminished utility. The demands of reduced size and greater mobility obviously impact upon the effectiveness of the machines too.

28. An example of such a sensor is the Handheld Advanced Nucleic Acid Analyzer (HANAA), developed at Lawrence Livermore. About the size of a brick, the system was designed for

emergency response groups, such as fire fighters and police. Each handheld system can test four samples at once, either the same test on four different samples or four different tests on the same sample. HANAA can provide results in less than 30 minutes, compared with the hours to days that regular laboratory tests typically take, using the PCR technique, which amplifies agent-specific DNA fragments to a detectable level.

29. Beyond sensor-based detection systems, which remain an imperfect science as noted above, there are other means of improving a detect-to-treat biodetection architecture. The Centre for Technology and National Security Policy at the US National Defense University conducted a 'Wargame', simulating a biological attack scenario, and concluded that the most effective means of rapid detection was through a broad, layered biodetection network. In other words, current technological shortcomings mean that it not sufficient to rely on a single means of detection. The JASON study reached a similar conclusion. So, beyond sensor technologies, what would that architecture contain?

30. *Syndromic Surveillance* refers to the process of collecting and analysing statistical data on health trends, particularly symptoms reported by people seeking care in health care facilities. It may also involve sales of particular types of medicine because bioterrorist agents such as anthrax, plague, and smallpox initially present flu-like symptoms and an outbreak could thus be recognised by increased sales in flu-related medicines. By focusing on symptoms rather than confirmed diagnoses, syndromic surveillance aims to detect bioterror events earlier than would be possible with traditional disease surveillance systems. It is a system in development on both sides of the Atlantic in the US and Britain. A recent study by RAND's Center for Domestic and International Health Security assessed the utility of such surveillance. It recognised the inherent risk of false-positives and the chances of environmental distortions such as flu season and concluded that, being a relatively untested methodology, health departments should be cautious about investing in costly new syndromic surveillance systems.

31. Beyond syndromic data, a network of data surveillance could also be extended to the areas of *Pharmaceutical Sales Data* and *Medical Claims Data*. Although both face logistical and accuracy challenges, they could theoretically be included in this broad architecture of information.

32. *Sentinel Organisms*, meaning the use of animals and even plants for detection, offer another potential source of information. A dog, for example, has an olfactory (sense of smell) capacity that is four times larger than that of humans. In another example, the US Army recently used pigeons in the invasion of Iraq as its first line of detection of chemical and biological agents since they are more sensitive to certain agents than humans. The potential in this area is broad and studies are currently underway to find a means of incorporating such detection into the overall architecture. It ranges from simple monitoring of veterinary data patterns to advanced bioengineering of plant cells to indicate the presence of certain agents.

B. CHEMICAL DETECTION

33. Chemical weapons detection has traditionally been within the military domain and current detection capabilities have largely arisen from that sector. Chemical agents are less difficult to detect than biological agents. The ability to detect the presence of even single molecules already exists, but only in sophisticated laboratory environments. Current detection systems still fall short of the ideal needs for civilian detection purposes, as outlined above. They are either not sensitive enough, not mobile, or require a trained user. There are a host of technologies that are used to detect chemical agents. The following are some of the more widely used examples and none offer a perfect solution.

34. *Colorimetric Indicators* are at the most basic end of the chemical detection scale. They are available to first responders and are cheap, fast and simple to use. They contain an acid–base

indicator that changes colour when exposed to specific agents in liquid form, causing the paper to change colour. These indicators are highly prone to false positives from various everyday substances, even smoke. They are essentially an early warning system that must be confirmed by further laboratory testing. The same colorimetric principle is also used in detection tubes, which pump vapour or gas through the tube. They are agent-specific, requiring a different tube for every agent.

35. The US military uses M8 and M9 detection paper. M8 paper is blotted on liquids that arouse suspicion. It identifies agents by changing colour within 30 seconds of exposure: dark green for vesicants, yellow for nerve agents, and red for blister agents. M9 paper has adhesive backing that allows it to be attached to clothing and equipment. M9 paper detects the same agents as M8 paper but does not change colour to enable identification. M9 paper tends to react faster than M8 paper and can be attached to vehicles that are entering areas filled with vapour to determine contamination.

36. *Ion Mobility Spectrometry* is another means of point (hand-held) detection. It uses an electric field to recognise differences in the velocity of ions and has been miniaturised to the point that it is used in mobile detection without diminished resolution. This process is used in many current detection systems, mainly because it is fairly resistant to contamination and false-positives.

37. The US Army's Improved Chemical Agent Monitor (ICAM) uses IMS technology and it is now also available to civilian first responders. The ICAM detects vapours of chemical agents by sensing molecular ions of specific mobilities (time of flight) and uses timing and microprocessor techniques to reject interferences. The monitor detects and discriminates between vapours of nerve and mustard agents. The ICAM is, however, vulnerable to errors in enclosed spaces or heavy smoke. It can also require recalibrating if saturated.

38. *Surface Acoustical Wave Detection* is a popular choice for first responders due to the relatively low cost. It can also detect multiple agents simultaneously. These SAW devices use piezoelectric quartz crystals coated in polymers, which absorb certain chemicals. The limit of this absorption process in turn limits the sensor's sensitivity. Other molecules being inadvertently absorbed can also undermine the process.

39. The MiniCAD mk II is a portable detector that is lightweight, battery operated, and available commercially. It is based on SAW technology, which is deemed to produce fewer false positives than ion mobility spectrometry. Nonetheless, the Expert Assistance (Equipment Test) Program for the U.S. Army Soldier and Biological Chemical Command Program Director for Domestic Preparedness undertook an assessment of the device and concluded that 'the problematic behaviour observed throughout the evaluation limits the usefulness of the SAW MiniCAD as a viable warning device'.

40. *Mass Spectroscopy*, usually used in conjunction with *Gas Chromatography* (GC-MS), represents the most reliable and sensitive means of detection and is regarded as the industry standard method for identifying chemical agents. It involves breaking apart a molecule before accelerating the charged fragments and bending their paths in a magnetic field. Although highly sensitive and able to tackle mixed samples, the technology is not currently small enough to be incorporated into mobile systems. It is also expensive and requires sample preparation before testing, which needs trained personnel. It is thus not used in detection systems available to civilian first responders. The accuracy of the technology is reflected by the fact that it is the only approved technique for CWC (Chemical Weapons Convention) inspection on-site analysis.

41. *Infrared Radiation* is employed in various chemical agent detectors. Chemical agents each have a unique infrared fingerprint based on their vibrational wavelength. Passing infrared light through gases or vapours results in specific wavelengths of light being absorbed. Infrared

Spectroscopy measures the quantity of light that is absorbed at given wavelengths in order to identify the agent. Distinguishing these different wavelengths is straightforward in a laboratory but remains difficult to transfer to mobile detectors.

42. The M21 Remote Sensing Chemical Agent Alarm (RSCAAL) uses IR spectroscopy for stand-off detection. In other words it can analyse a cloud from a distance (up to 5km), rather than in close contact with it. It continuously monitors the background spectrum and provides comparative analysis if a cloud obscures this background. The major drawbacks with the M21 unit are cost, size, the needs for trained users and its propensity to be obscured by adverse weather conditions.

43. As well as these oft-used detection techniques, a host of others exist which all have various shortcomings in field or mobile usage. Examples include *Flame Photometry*, which burns a sample in a hydrogen flame and identifies it from the resulting emission, or *Photoionisation*, which uses ultraviolet light to ionise vapours or gases and then monitors the change in electrical current.

III. RADIOLOGICAL AND NUCLEAR THREATS: MECHANISMS FOR DETECTION

44. Terrorist groups armed with radiological weapons are one of the gravest risks our societies face. Unlike nuclear weapons, radiological dispersal devices (RDD), or “dirty bombs”, are not extremely hard to acquire, transport or build. RDD are relatively easy to assemble, carry and deliver. Unlike nuclear weapons, a radiological device does not trigger a nuclear reaction. Through a conventional explosive, it spreads radioactive material contaminating personnel, equipment, facilities, and terrain. While such weapons would bring about far less damage than a nuclear detonation, RDDs have an enormous intimidation power. Radiation emitting materials can be delivered using a variety of means: human agents, the destruction of a nuclear plant or facility containing nuclear material, shipment or remote controlled devices whose explosion disseminates the radiological agent, or placement in facilities or water supplies. Aircraft, missiles and rockets can also be used as a means of delivery to target military or civilian objectives or to contaminate livestock, fish, and food crops.

45. There are only a few radioactive sources that can be used effectively in an RDD. The greatest security risk is posed by Cobalt-60, Cesium-137, Iridium-192, Strontium-90, Americium-241, Californium-252, and Plutonium-238. The most typical areas where radiological materials are used are hospital radiation therapy (Iodine-125, Cobalt-60, Cesium-137), radiopharmaceuticals (Iodine-131, Iodine-123, Technetium-99, Thalium-201, Xenon-133), nuclear power plants fuel rods (Uranium-235), universities and laboratories. Other common radiological materials are Iridium-192 and Plutonium-239.

46. In the event of a release of radiological material, three types of radiation-induced injury can occur: external irradiation, contamination with radioactive materials, and incorporation of radioactive material into body cells, tissues, or organs. More specifically, there are four types of radiation that are emitted:

47. *Alpha Radiation* is able to travel only a short distance in the air and cannot penetrate the skin. Materials emitting alpha radiation can harm humans only if inhaled, swallowed or absorbed through open wounds. An ionization chamber such as the CD V-715 cannot detect alpha radiations in the absence of concomitant beta and/or gamma radiation. In addition, instruments are unable to detect alpha radiation through water, blood, dust, or paper, as alpha radiation is not penetrating. As a consequence, clothing and turnout gear can keep alpha emitters off the skin. Various instruments are available to detect alpha radiation emitting materials, but special training is essential for making accurate measurement. One example is the palm handheld precision Geiger-mueller meter that detects and measures alpha, beta, gamma and x-ray forms of radiation.

The unit is built around a halogen-quenched detector tube. Such instruments are designed for emergency response, domestic preparedness, hazardous material safety, law enforcement, and compliance verification applications. This type of instrument is critically important to early responders whose task is to determine if a particular area is a nuclear or radiological “hotzone”. Initial responders are thereby enabled to make informed decisions and establish perimeters, and to prepare the ground for the deployment of second tier personnel and more technical equipment for in-depth analysis.

48, *Beta Radiation* occurs when high-energy electrons are emitted from the nucleus of an atom during radioactive decay. The skin or a very thin sheet of metal can stop beta electrons. Beta radiation can travel in air and is moderately penetrating. Skin injury can occur if beta-emitting materials remain on the skin for a prolonged period of time. It can reach to the germinal layer of the human skin, where new skin cells are produced. If deposited internally, beta contaminants may be harmful. A survey instrument (such as a Geiger counter CD V-700) can detect beta radiation. Some beta radiations (like carbon-14, tritium, and sulfer-35), however, have poor penetrating power and can be difficult or impossible to detect. An ionization chamber such as the CD V-715 cannot detect beta radiation. Clothing and turnout gears provide some protection to the skin.

49. *Gamma Radiation* is high-energy photons emitted from the nucleus of atoms. They easily penetrate into body tissue and many materials, and they are potentially lethal. Thick layers of dense materials, such as lead, can protect from gamma ray exposure. Gamma radiation has the ability to travel many metres in the air and to penetrate the human tissue. It quickly permeates most materials. Gamma rays represent the major external hazard, while gamma rays emitting radioactive materials are both an external and internal hazard for the human body. Clothing and turnout gear provide little shielding from penetrating radiation. Gamma rays can be detected with survey instruments, including civil defense instruments. A standard Geiger counter (such as the CD V-700) can measure low levels of radiation, while an ionization chamber is able to measure high levels of gamma rays. Most of the time, gamma radiation is emitted together with alpha and beta radiation. Gamma radiation will not be detected by any instrument designed to measure exclusively alpha radiation (such as an alpha scintillation counter). The most appropriate instruments to measure accumulated exposure to gamma radiation are pocket chamber (pencils) dosimeters, film badges, thermo luminescent, and other types of dosimeters.

50. *X-Rays* are an invisible and highly penetrating electromagnetic radiation of much shorter wavelength (higher frequency) than visible light. As with gamma rays, only thick layers of dense materials can defend from x-rays.

51. The threat arising from terrorists trying to smuggle illicit radioactive materials or a nuclear fission weapon has forced governments to embark on programmes to detect radiological materials at major points of entry (ports, airports, borders). Detection mechanisms of such substances are still being improved and much attention needs to be concentrated on localisation and the proliferation of material. The number of orphaned sources (lost, abandoned or stolen radiological sources) has diminished in the past several years, but remains an issue. The physical protection of radiological sources, at medical facilities, food irradiation enterprises, and disposal sites, continues to raise concerns in some parts of the world. Some countries are facing difficulties disposing of these sources: most of the nations' disposal sites will reach full capacity in the next half decade. Without increased disposal capacity, the likelihood that sources will not be properly guarded increases.

A. TRAFFICKING OF NUCLEAR SUBSTANCES

52. The events of September 11, 2001 have intensified concern that terrorist groups will attempt to steal weapons-useable nuclear material in order to build a nuclear weapon. Although stocks of these materials—plutonium and highly-enriched uranium (HEU)—exist in many countries around the world, the largest inventory in the world is held in the Newly Independent States of the former Soviet Union (NIS). Owing to economic and political turmoil, this material is vulnerable to theft. Since 1991, there have been numerous reports of the theft of such nuclear material from facilities in the NIS, and a close examination of open source evidence reveals 14 confirmed cases of theft or attempted theft of weapons-useable material from NIS facilities between 1991 and 2001.

53. Multiple instances of profit-motivated nuclear hoaxes have been reported in the media in the past two decades, in which sellers offer weapons-usable or weapons-grade nuclear material and instead deliver some other bogus radioactive, or in some cases, non-radioactive substance. Such scams increased when economic conditions in the former Soviet Union and Eastern Europe declined in the late 1980s and early 1990s. The region's economic decline coupled with weakened security and enforcement mechanisms and a growing interest on the part of both state and non-state actors to illegally obtain nuclear materials all created favorable conditions for nuclear trafficking scams.

B. DETECTION AT POINT OF ENTRY

54. Terrorists intending to smuggle radiological materials into target countries aim at exploiting weaknesses of the control mechanisms at ports, terminals, border crossing and airports. Both the UK and the US have embarked on ambitious programmes to install hundreds of detectors at major points of entry.

55. As 90% of all traded goods travels by sea on approximately 72 million sea containers, ports detection mechanisms are of paramount importance. In this respect, national authorities must try to guarantee security without harming commerce. As 100% inspection is not practical for high-volume ports, automatic identification of the container or truck would reduce the impact of inspections on cargos. There is also the overall imperative to make detection equipment affordable.

56. The main challenge to overcome is to deploy automated equipment able to alert inspectors in the presence of a large volume of cargo. Effective detection mechanisms should be able to identify radioactive isotopes and the full range of radiation types (alpha, beta, gamma, x-rays). Detectors should identify materials used in a nuclear weapon or RDD, natural sources of radiation, and isotopes commonly used in medicine and industry.

57. The weight of radiological devices can range from 36 to 180 kg. Their high absorption of the fissile material and emission of gamma rays and neutrons would make them detectable.

58. Radiological detection can be active and passive. The verification of explosives and nuclear materials corresponds to active detection, while passive detection utilises radiation portal monitors (RPMs) to detect gamma rays and neutrons emitted by nuclear weapons and radioactive materials. A problem is posed by high-density shielding that might prevent passive detection. In this case, gamma or X-ray radiographic imaging would reinforce RPMs in shielding detection, particularly of Uranium-235. In containers where gamma ray imaging cannot penetrate, inspection instruments will use high-energy X-rays for secondary detection. To complement RPMs, hand-held isotope identification together with other intrusive inspection techniques can be utilised for more effective detection. More reliable and faster than manual inspection are non-intrusive detection methods that allow also for the inspection of a larger number of containers. In addition, detecting

containers at ports of origin, as demanded by the US's Container Security Initiative (CSI), would reduce the delays at the ports of destination.

59. One of the most advanced detection mechanisms is a neutron generator sensor. Other sensors can detect long-range alpha-radiation. Some compact detectors are provided with a high-purity germanium crystal to find a radiation source. The identification of the radioactive isotope is made by the interaction of photon, gamma rays and X-rays with the germanium crystal that processes the resulting charge. A mechanism similar to that used in mobile phone antennae cools the germanium crystal.

60. Various gamma and neutron detectors are available commercially. Their use ranges from crane monitors to cargo monitors and portable search systems for personnel. To reduce the delay of false alarms, provoked for instance by radiation resulting from medical treatment, new gamma spectroscopy detectors are able to identify and distinguish specific radioisotopes.

61. Other types of radiological detectors include: ultrasonic thickness gauges (able to detect hollowed-out spaces within cargo containers); infrared systems able to identify hot and cold spots; portable explosives detectors, able to identify plasma's signatures of nitroglycerin, ammonium nitrate and other explosives; for personnel with limited technical expertise, user-friendly software is available to guarantee reliable detection and measurement.

62. To reduce delays and costs, cargo containers should be inspected only once, preferably at ports of departure, and then sealed by electronic systems to ensure that they would not be opened en route to their destination. Apart from monitoring ports and other points of entry for the illegal importation of radiation emitting materials, it is also vitally important to monitor the entry of illegal asylum seekers or migrants, some of whom could be potential terrorists.

63. When the Science and Technology Committee visited the SAIC complex in San Diego, California in 2004, members saw a demonstration of the SAIC's Vehicle and Cargo Inspection Systems (VACIS -$399,000.00 to $724,000.00 and from $1,197,000.00 to $1,197,000.00 for railways and Mercedes systems) that combines gamma ray imaging with radiation scanning and Optical Character Recognition (OCR) technology to provide a comprehensive solution to enhance security and productivity at terminal gates, quays, railways and other checkpoint locations. As the container passes through an arch, it is able to detect either the presence of human beings or the existence of suspicious impenetrable structures in which human being have been concealed. Such devices are already in existence in the US and the UK.

IV. CONCLUSIONS

64. This paper intends to list the various types of devices, which are already in existence, or in the course of development, to identify CBRN agents at the earliest possible moment. In the event of attempts to import these agents, or in the event of an actual release of CBRN agents, the most urgent step is to identify them so that appropriate measures can be taken to protect the civilian population.

65. In an ideal world, one might wish for a complete range of devices to be held ready for use in heavily populated areas. This would be massively expensive as the approximate costing in this paper demonstrated. But in the event of an actual CBRN attack, it is almost certain that current capabilities would be deficient, leading to strong criticisms of both national and local government by politicians, media and public opinion. So the more that can be done to prepare an early warning system, before a serious terrorist attack, the less will be the opportunities for criticism afterwards.

66. It would clearly be foolish for us publicly to seek to identify what measures have already been taken, thus, by implication, drawing attention to the gaps. Therefore, the purpose of this

paper is to highlight what could be done in advance to protect the civilian population. This will hopefully encourage politicians to enquire what preparation have already been made in their own countries and thereafter to urge their governments at national and local levels to do as much as is financially feasible to fill the gaps. Our civilian population are entitled to expect no less of us.

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