CBRNE Forensics.*

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RESUME

CBRNE et Sciences médico-légales.

Les lieux d'attentat CBRNE possèdent certaines particularités, la plus importante d'entre elles étant le conflit existant entre le maintien de la vie et la préservation de l'intégrité de la scène et des indices. En général, la priorité est toujours donnée aux soins médicaux d'urgence. Dans la majorité des cas, les premiers intervenants sont du personnel non spécialisé (le lieu d'attentat est dans un endroit éloigné; les enquêteurs spécialisés ne sont pas facilement disponibles). Le non-respect des lois, règles et règlements existants peut aboutir à des situations où les indices ne pourront pas être utilisés au tribunal. D'autre part, en général les spécialistes des investigations sur site ne connaissent pas les procédures CBRN et l'équipement spécialisé (EPI). Il existe de plus divers risques en matière de santé et de sécurité pour les premiers intervenants sur le site comme des produits chimiques (présents sur la scène dans les cas de laboratoires clandestins par exemple, ou produits chimiques utilisés dans le cadre de l'investigation); matières biologiques (par exemple, le sang et les liquides organiques peuvent présenter un risque de VIH/sida et d'autres infections); explosifs non explosés (par exemple des pièges); armes à feu; facteurs environnementaux, tels que chaleur ou froid excessifs; structures non sûres (en particulier lors du prélèvement d'indices sur des scènes d'incendie et de bombardements); environnement exposé (par exemple délinquant encore présent sur la scène) et d'autres risques : objets contondants, risques radiologiques, nucléaires et électriques, gaz, etc. L'objectif principal du prélèvement d'indices est de donner des idées sur « comment les choses se sont passées » et ce processus contient certaines variables telles que la substance impliquée; la méthode de dégagement; le type de dispositif utilisé; le mécanisme de détonation; les matériaux de support; l'origine et la signature de production. Les indices seront utilisés au tribunal (national ou international) et des accusations seront déposées contre un groupe, une organisation ou une nation spécifique. A cet égard, les agresseurs présumés seront représentés par des conseillers et des experts compétents qui vont essayer de trouver des lacunes dans les indices et le processus. La méthodologie mise en place dans une scène de crime CBRNE suit les mêmes étapes que sur une scène de crime classique : (1) Préservation de la scène et des indices; (2) Détection, prélèvement et préservation des indices matériels (partie centrale du travail mené sur les lieux); et (3) sélection des moyens de transport et de stockage adaptés au type d'indices matériels pour assurer l'intégrité des indices transmis au laboratoire. En raison du potentiel de létalité de l'environnement

de travail, les robots représentent une bonne approche alternative toujours avec les limitations engendrées par la mécanisation des fonctionnalités humaines. Et le défi reste donc l'humanisation des fonctions robotiques aussi proches que possible de celles des enquêteurs humains. L'expérience montre que cette tâche est extrêmement difficile et complexe mais la simplification des méthodes mises en place dans une scène de crime en combinaison avec les technologies de pointe (c'est-à-dire des exosquelettes équipant les robots) rendra bientôt disponible des solutions utilisables et précises.

KEYWORDS: CBRNE, Forensics, Evidence, Crime scene, Investigation.
MOTS-CLÉS : *CBRNE, Criminalistique, Preuve, Scène de crime, Enquête.*

Every incident, be it a crime, accident, natural disaster, armed conflict, or other, leaves traces at the scene. The goal of the subsequent investigation is to correctly interpret the facts; reconstruct the events; and understand what happened. Due to the transient and fragile nature of those traces, their reliability and the preservation of their physical integrity depend to a very large extent on initial actions at the scene of the incident. Acting with care and professionalism is critical for the admissibility of evidence for court purposes as well as for human rights inquiries and humanitarian action.

DEFINITIONS

A **crime scene** (CS) is any physical scene, anywhere that may provide potential evidence to an investigator. It may include a person's body, any type of building, vehicles, places in the open air or objects found at those locations[1].

Crime scene investigation (CSI) is a process that aims at recording the scene as it is first encountered and recognizing and collecting all physical evidence potentially relevant to the solution of the case[2].

Forensic science (synonym with *forensics*) is the scientific method of gathering and examining information about the past which is then used in a court of law[3].

CBRNE is a well-known abbreviation describing chemical, biological, radiological and nuclear (CBRN) threats. Recently the letter «E» was added (CBRNE) to indicate that most of these agents are accompanied by detonation of explosives. When comes to terrorist actions, the acronym is more realistic as «CRE» since explosion greatly affects pathogens and nuclear weapons are considered beyond reach (for the time being). There is also the possibility of an improvised nuclear device (IND) while chemical and radiological agents can be released (emitted) from a device without explosion as well (CED/RED). CRE incidents represent abrupt emergencies lasting a few hours while bioterrorism or a pandemic is a progressively developing emergency that might last weeks, months or even more.

CONVENTIONAL VS. ASYMMETRIC DISASTERS

Following a natural disaster, a technological accident or a conventional bombing of any magnitude, people involved quickly surpass the initial shock, reorganize and try to help those in need aside with first responders at the incident's site.

In contrast, based on the victims' behavior during the Tokyo subway sarin incident (1995) it is expected them to behave as follows[4-10]:

- 20% of victims will remain in place (dead, severely wounded and/or contaminated with minimal or no expectation to survive) (triage category: black)
- 80% of victims able to walk, run or even crawl will flee the scene before the arrival of first responders (time needed for PPE donning, traffic jam, distance from assembly station to the incident site etc)
- Worried-well (in a ratio of 1: 5 [contaminated vs. psychogenic response) individuals are expected to rush into hospitals overwhelming their functionality to the point that might lead to health system's collapse.

An additional feature is that weapons of mass destruction have a strong mass disruption element aiming to cause chaos and havoc within the urban web. In that respect numbers of dead are not expected to be huge and explosives that might be used will not be in quantities enough to cause complete building collapse or similar. Underground detonation possesses specific problems as well – some of them might affect surface structures.

The operational picture is quite different when military munitions are used for the dispersal of CR agents against population[11] (e.g. Halabja massacre in 1988 and the recent use of chemical weapons in Syria – chlorine bombs included). Until now there is no report of RDD detonation worldwide (although there is evidence that this is possible[12] – e.g. Chechen rebel's cases with cesium devices [explosives/mine] at Ismailofsky Park [Moscow] and at a railway near Chechnya's capital Grozny).

CONVENTIONAL CRIME SCENE INVESTIGATION

In conventional crime scene investigation each and every piece of evidence represents a small piece of the big puzzle and helps in the reconstruction of the actual event. Working experience is the buffer that directs investigators and provides clues that are sometimes almost invisible to the inexperienced first responder.

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Individual studying cannot completely fill this gap but it surely helps and on the Internet there are many documents providing concrete knowledge[13-16].

CBRNE CRIME SCENE

CBRNE crime scenes possesses certain peculiarities the most important of which is the conflict between preserving life and maintain the integrity of the scene and the evidences within. Based on the Tokyo's experience this dilemma is practically cancelled and the CBRNE crime scene will have only corpse and related evidence (solid, liquid, gases). On the other hand apart from existing hazardous environment first responders are expected to face additional health and safety problems due to chemicals (either those present at the scene, for instance, in the case of clandestine laboratories, or chemicals used as part of the investigation); biological materials (e.g. blood and body fluids may present a risk of HIV/AIDS and other infections); unexploded explosives (e.g. booby traps or secondary explosive devices [IEDs] specifically targeting first responders); firearms; adverse environmental factors (e.g. excessive heat or cold); unsafe structures (especially when collecting evidence at fire and bombing scenes); insecure environment (e.g. offender still present at the scene) and other risks: sharp objects, radiological, nuclear and electrical risks, gases, etc.

All the above make the working forensic environment extremely dangerous for the life of first crews entering the scene. In general, if there is a conflict between preservation of evidence and the possibility of saving a human life, priority is always given to emergency medical care.

In the majority of cases first responders are non-forensic personnel (crime scene is in a remote location; skilled crime scene investigators are not easily/readily available). Failure to comply with existing laws, rules and regulations can result in a situation where the evidence cannot be used in court.

CBRNE CRIME SCENE INVESTIGATION

Initial scene evaluation and good planning are essential in order to provide answers to certain question such as: What is believed to have taken place? What is the magnitude of the problem? Is any specialized expertise/medical assistance required? Are there any particular dangers at the scene? What other assistance might be required? Is the scene an indoor/outdoor scene? Is it a remote location? What local resources will be available? Who else needs to be informed? What equipment is required? What are the weather conditions? Apart from these, other important aspects of the planning phase deal with the nature of the incident, context of the case, planning the expertise and equipment likely to be required and proper protection of crime scene until the CSI personnel and equipment arrive.

The main purpose of collecting evidence is provide insights on «how things happened» and this process

Figure 1-3: Chemical Warfare Agent forensics in a clandestine lab (Joint US-GR drill; Athens 2006).

includes certain variables such as agent released; mode of release; type of device used; detonation mechanism used; carrier means; origin and production signature etc. Evidences will end up in a court (national or international) and accusations will be addressed against a specific group, organization or nation. In that respect the alleged offenders will be represented by competent counselors and experts that will try to find gaps in proofs and procedures.

Methodology used in CBRNE crime scene follows the same three steps as with conventional crime scene:

1. **Preservation of the scene and its evidence** (delineation of the area to be protected; area cordoning; controlled human access; strict anti-contamination measures; management of adverse weather conditions; victim's privacy and human rights' issues). Documentation aims at producing a permanent, objective record of the scene, of the physical evidence and of any changes that take place. Documentation is the starting point for the chain-of-custody.

2. **Recognition, recovery and preservation of physical evidence** is the central part of the work at the scene aiming at locating and identifying a maximum of potentially relevant evidence and the selection of appropriate recovery methods and adequate packaging to preserve integrity of evidence collected. The most relevant and important evidence may not be obvious or directly visible to the naked eye. It is reasonable to expect that in almost all cases physical evidence is missed and not recovered.

3. **Selection of transportation means and storage** is the final phase of the 3-step procedure. Investigators should ensure that issues such as priority of submission, transportation conditions and safety, related documentation and long term storage should be adequately addressed.

WHO IS GOING TO COLLECT THE CBRNE EVIDENCE?

Investigating criminal acts involving CBRN materials presents a number of unique challenges. The most important one: «Who is going to collect the CBRNE evidence?» CBRN people do not know forensics while CSI people are usually not familiar with CBRN procedures. On top of this reality, a competent defense counsel will question the evidence and everything to do with the evidence by asking questions related to collection site, procedures, methodologies employed (with emphasis on sterility) and many more. In addition evidence will be challenged in public forums (e.g. August 2013 Sarin attacks in Ghouta, Syria) – mainly on the Internet.

The problem extends from crime scene back to the laboratory and morgue for many reasons such as[17]:

- Traditional forensic labs may be ill-prepared to deal with dangerous CBRN materials;
- CBRN labs may not have the ability to process and exploit conventional crime scene evidence (corps, personal items, shrapnel contaminated with CBRN material);
- Post-mortem examination is also an important capability gap;
- Time and speed causes several other conflicts due to the nature of the agents' released (gasses dissipate, vapors disperse, liquids evaporate, short-lived isotopes decay, and microbes die); time also interacts with health and safety of forensic technicians;
- It is hard to operate forensically while people are shooting at you;
- Rescue efforts may compromise a crime scene;
- Decontamination of living and dead victims can destroy or degrade critical evidence.

Figure 4: Biological Warfare Agent forensic investigation in a clandestine lab - on the left there is an improvised incubator (Joint US-GR drill; Athens 2006).

The SLAM consortia, led by the European CBRNE Center at Umeå University, is already working on the development of common and/or comparable methods, procedures and protocols for analysis and identification of CBRN substances allowing a significant comparison of results from different laboratories and operators within Europe following a CBRN incident[18]. Addressing the need for operational and strategic support, the vast and complex area of CBRN analysis has been structured into three discrete applications: (1) the immediate incident response; (2) the post incident monitoring; and (3) the forensic use.

Once the major dilemma – who is going to actually do the work – is resolved, the basic fundamentals of crime scene evidence collection can be applied to CBRN crime scenes.

CBRNE FORENSICS' PROCEDURES

Among the many procedures applied there are some that are of greatest importance such as: (1) tying a sample to a specific place and time (list of detailed evidence recording); (2) integrity of the container (special collection bags (depending on the constitution of the sample); unique seal and trucking number (barcode?) for each bag; list of evidence collected); (3) chain of custody – detailed written description of the «route» of the sample from the scene all the way to the lab. There should be NO gaps or periods of time where nobody had custody of the material. Radio frequency identification (RFID) technology might offer an attractive solution for a more effective and error-free chain of custody[19]; (4) use of «blanks» – is both a technical and procedural safeguard to help prove the integrity of forensic processes. There are several kinds of blanks and various nomenclatures for them. You are going to use glass sample jars to keep solid and liquid samples collected in the field. You have procured a number of sterile jars. Some of these jars, picked at random from the lot of jars that you bought, need to be left in the laboratory. These that you leave in the laboratory can be tested after the operation to ensure that they are

actual truly sterile. In addition, some of the jars should be taken out to the field but not used; (5) sterility – detailed verification of procedures employed proved by videos/photos and usage of blanks left in the lab will provide solid proof for ènon contaminated evidence; (6) cross-contamination (i.e. it is fine to wear gloves for picking up one shell fragment, but if you do not change gloves, any other shell fragment or anything else you handle after it may have contamination transferred to it. The same thing happens with tools – a shovel can spread contamination as easily as dirty gloves); (7) consistency - wherever and whenever possible, attempt to collect samples of relatively standard size. This will make it easier to do one-to-one like-for-like comparisons. If you are swabbing a floor, for example, use a template to make sure that each time you are swabbing a similar amount of the floor surface. Use a new template each time – even a plain piece of paper with a 10 cm x 10 cm hole in it can be used as a template; (8) investigators' equipment is also evidence - your boots and gloves are likely to contain samples of investigative interest. They become part of the evidence. A positive test on your protective clothing indicates that somewhere along your journey that day, you were exposed to the material in question. Same applies for robotic structures deployed; (9) background readings – very useful procedure especially for natural occurring diseases such as anthrax (spores). Collect enough samples from areas where there was no obvious indication of having been involved in the suspected attack in order to prove that spores were not in place before the attack; (10) weather effects – in conventional crimes a tent over the crime scene might be a good solution to prevent loss of evidence. In a chemically contaminated environment the type of agent might pose some additional problems: some degrade faster than others; some will contaminate the tent while some toxic industrial chemicals may interact with tent material reducing its efficiency[20].

OBSTACLES DURING CBRNE INVESTIGATIONS IN CONFLICT AREAS

If CBRNE forensics is a complicated procedure in urban environment during an isolated terrorist asymmetric incident one can imagine how extraordinary difficult would be conducting the same procedures in a conflict area.

Obstacles to CBRN investigations in conflict areas are related to: (1) transitory nature of CBRN evidence (Chemical Warfare Agents (CWAs) evaporate or degrade in the environment or drift away with the wind or hydrolyzed; Biological Warfare Agents (BWAs) are generally not visible to the naked eye and degrade quickly; traces of biomarkers in blood and urine do not last forever after an incident); (2) passage of time erodes any crime scene, large or small (things that were in the crime scene can be taken away, deliberately or inadvertently; new things can be introduced into the crime scene that was not there during the incident); (3) size of the crime scene (scene may be large, particularly when we are referring to agents and munitions that have widespread effects [CB attack]; area of suspected use might be populated with many people coming and going while a full investigation could require very big numbers of investigators [logistics' burden]); (4) threats to the safety of the investigators (investigators may lack the ability to operate freely and unencumbered; security teams may be sympathetic to one side or another in the conflict; an unsafe environment adds to stress on the investigators and stress might lead to errors); (5) conventional warfare will damage or destroy evidence (fire, explosions, and other battlefield effects will destroy munitions' debris, degrade or disperse materials, or have other deleterious effects on potential evidence; witnesses die or flee); (6) proper procedures are hard to follow or cannot apply in an active war zone (e.g. fingerprinting using powders or chemical development techniques might contaminated the scene further or change the properties of the agents released[20]).

CBRNE EVIDENCE SAMPLING

The samples to be collected are solid (including powders and soil); liquid; aerosol/vapor/gas; surface (i.e. swabbing a surface to pick up traces) and dermal (i.e. residue on skin). These samples can be retrieved from a variety of sources (shoes; gloves; trapped air; small animals; water; background samples; fragments & debris; vegetation; corners & crevices; head space of bag; dermal swabs; medical materials used or soul around munitions and porous material).

It is of great importance to find the means of dispersal (swabs and samples should be taken prior to collection): intact or nearly intact devices are ideal, but need to be handled with utmost care (fragments are better than nothing); devices that cannot be retrieved should be photographed, geo-located precisely, and measured; orientation of the device or fragments should be noted closely (use compass); any device in the ground should be accompanied by samples of the soil, as well as a measurement as to how deep the munition was impacted into the soil; unknown fragments that look like they could be part of a device or munition are of interest as well. It is of equal importance to be familiar with various types of means of dispersal in order to be able to identify them such as: rocket; missile warhead; bomblet/sub-munitions; artillery shell; mortar shell; spray tank; aerial bomb; gas cylinders; grenades; land mine; any abandoned or wrecked tanker trucks.

If there are corps or wounded/contaminated victims in the crime scene it would be highly supportive to collect medical evidence as well (blood; hair [scalp, beards, armpits; genitalia]; urine; vomit; tears; saliva and nasal secretions; any clothing that would have been contaminated and swabs of affected areas of skin). Put into paper any signs and symptoms recorded by medical providers (pulse rates; temperatures; blood pressures; oximetry readings; medications/antidotes provided and response of victims] or observed by bystanders. Apart from the clothing collected in sealed bags look also for existing cameras or videos that might have captured/recorded the incident as it was progressed.

If CSI team arrives late it is wise to obtain the bodies of deceased victims of the incident for analysis by competent forensic pathologists but do not exhume graves without proper competence. Here lays another problem: pathologists are also not very much familiar with PPE and procedures and CBRN-proof mobile mortuaries are both expensive and rare.

Finally, meteorological data from the time of the incident (s) should be retrieved though it is rather unlikely that this data will be of the quality needed for any but the most basic assumptions. Data from close to the alleged incident (s) is most useful and more easily available.

CBRNE CSI ROBOTICS

The biggest concern during a CBRNE incident is the safety of first responders entering the «Warm Zone». In that respect remotely controlled platforms could be a good alternative or complementary strategy providing valuable insights both at operational and forensics levels. So far, robots have been deployed for emergency response tasks including: urban search and rescue (USAR); wilderness search and rescue (WiSAR); and natural disasters. Robots can also provide a huge advantage in CBRN reconnaissance (route and area) and decontamination (human; combat systems; terrain) operations[21].

An aerial real-time operational picture would give a detailed high resolution analysis of the crime scene and would be very helpful in providing pathways of safe approach – especially if there are debris and ruins around. Ground unmanned vehicles (GUVs) would reach ground zero and collect evidence in a way that would be valid for court. Of course this specialized equipment has many limitations derived from the mechanization of human functionalities. And here lays the challenge: to humanize robotic functions as close as possible to those of human investigators. Experience has shown that this is extremely difficult and highly complex but the simplification of methodologies used in a crime scene will provide solutions both applicable and accurate. The usage of exoskeletons controlling robotic arms' function will add the required dexterity especially needed for tissue/biological fluids' sampling.

Major issues of concern have to do with how fast the robots can be deployed; power autonomy of GUVs; task execution speed; disturbances caused that might affect the integrity of the crime scene (caterpillars; wheels; arthropods); transmission of data (Wi-Fi or cable) and possible effects on secondary activation of remote detonation mechanisms; payloads able to transport (CBRN sensors; flood lights; one or two [synergic] arms [exoskeleton controlled?[22]]; samples' storage procedures; frequency a task must be executed and decontamination (platform/sensors' sensitive electronics; samples). Of equal concern are certain legal and ethical issues that will govern the human-machine interaction and need to be carefully addressed and solved.

CONCLUSIONS

In the vast majority, CBRNE training of first responders is limited to operational *modus operandi* inside the «Warm Zone» and CBRNE forensics are rarely included in related drills. Recent events in Syria revealed the importance of CBRNE forensics and the problems accompanying any effort to prove that weapons of mass destruction were released (although it is time to retire this term that is both generic and not close to reality[23]). On the other hand, CSI personnel is not familiar with operations in CBRNE environment and the limitations personal protective equipment has on their dexterity and time spend at the criminal scene. On top of these is the required «preservation of crime scene»! But «*it is an inconvenient truth that the only people who don't destroy the crime scene at a CBRN event are the deceased!*»[20] Perhaps it is time to spot on this gap and put these two communities into contact for future joint operations. Our current experience is limited and new norms and regulations need to be established and tested. The National Forensic Science and Technology Center (NFSTC) in Largo, Florida, and the Netherlands Forensic Institute (NFI) in The Hague are in the process of putting these standards together, but there is still a lot of work to be done[24]. GIFT-CBRN (FP-7 EU research project) is towards the right direction providing a forensic toolbox according to ISO17025 for investigating CBRN incidents[25].

Despite the limited experience, robotic CBRNE forensics is the future alternative although robots are far (?) from replacing humans in this specific task.

ABSTRACT

CBRNE crime scenes possesses certain peculiarities the most important of which is the conflict between preserving life and maintain the integrity of the scene and the evidences within. In general, priority is always given to emergency medical care. In the majority of cases first responders are non-forensic personnel (crime scene is in a remote location; skilled crime scene investigators are not easily available). Failure to comply with existing laws, rules and regulations can result in a situation where the evidence cannot be used in court. On the other hand, CSI experts are usually not familiar with CBRN procedures and specialized equipment (PPE). In addition there are certain health and safety considerations for first responders at crime scene such as chemicals (either those present at the scene, for instance, in the case of clandestine laboratories, or chemicals used as part of the investigation); biological materials (e.g. blood and body fluids may present a risk of HIV/AIDS and other infections); unexploded explosives (e.g. booby traps); firearms; environmental factors (e.g. excessive heat or cold); unsafe structures (especially when collecting evidence at fire and bombing scenes); insecure environment (e.g. offender still present at the scene) and other risks: sharp objects, radiological, nuclear and electrical risks, gases, etc. The main purpose of collecting evidence is to provide insights on «how things happened» and this process includes certain

variables such as agent released; mode of release; type of device used; detonation mechanism used; carrier means; origin and production signature etc. Evidences will end up in a court (national or international) and accusations will be addressed against a specific group, organization or nation. In that respect the alleged offenders will be represented by competent counselors and experts that will try to find gaps in proofs and procedures. Methodology used in CBRNE crime scene follows the same three steps as with conventional crime scene: (1) preservation of the scene and its evidence; (2) recognition, recovery and preservation of physical evidence (the central part of the work at the scene); and (3) selection of the means of transportation and storage that are appropriate for the type of physical evidence to ensure the integrity of evidence submitted to the laboratory. Due to the lethality potential of the working environment, robots represent a good alternative approach of the scene always with the limitations derived from mechanization of human functionalities. And here lays the challenge: to humanize robotic functions as close as possible to those of human investigators. Experience has shown that this is extremely difficult and highly complex but the simplification of methodologies used in a crime scene in combination with cutting-edge technologies (i.e. exoskeletons controlling UGVs' arms) will soon provide both applicable and accurate solutions.

Potential Conflict of Interest: None.

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