SCENARIO

Le nuove tecnologie e le attività di polizia: security e problematiche forensi

Nuove tecnologie, capaci di rilevare la presenza di esplosivi, sono state sviluppate a seguito dell'evoluzione della minaccia di attacchi terroristici nei confronti di possibili bersagli, quali aeroporti e altri mezzi pubblici di trasporto. La security e le problematiche forensi necessitano una valutazione fin dal primo stadio della ricerca, affinché le attività di pubblica sicurezza e di polizia giudiziaria siano supportate in maniera efficace. La capacità analitica di ciascun rilevatore può essere misurata seguendo un approccio probabilistico, basato sui risultati (veri positivi, veri negativi, falsi positivi e falsi negativi) ottenuti in una serie di test su campioni noti. Nelle attività relative alla security, quali i punti di controllo e screening dei passeggeri negli aeroporti, è importantissimo evitare falsi negativi, che comporterebbero l'imbarco di un oggetto proibito. I falsi positivi possono essere accettati, anche se dilatano il tempo necessario per lo screening dei passeggeri e dei loro bagagli. In progetti mirati a individuare una 'fabbrica di bombe' criminale è fondamentale evitare falsi positivi in modo da risparmiare ai cittadini una inutile invasione della propria privacy. Se infine si considera il mondo forense tradizionale, quando si riportano dati chimici come prove in un processo, l'incertezza deve essere ridotta al minimo, in quanto la Corte deve essere messa in grado di stabilire la verità oltre ogni ragionevole dubbio.

New technologies and police activities: Security and forensic issues

The development of new technologies able to detect explosives has followed the evolution of the threat of terrorist attacks to possible targets, such as airports and other public transport. The security and forensic issues need to be evaluated in the early research stage to effectively support police activities. The analytical capability of any detector can be measured by following a probabilistic approach, based on the results (true positives, true negatives, false positives and false negatives) obtained in a set of tests on known samples. In security activities, such as at passenger screening checkpoints in airports, it is very important to avoid false negatives, resulting in a forbidden item being boarded. False positive results can be accepted, but they increase the time needed for screening passengers and their luggage. In projects aiming to spot a criminal "bomb factory" it is very important to avoid false positive results so as to spare citizens useless intrusion in their private lives. When considering the traditional forensic world, uncertainty must be minimised when reporting chemical information as evidence in the Court, since the Court needs to establish the truth beyond any reasonable doubt.

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Introduction

The use of new technologies for police activities is a very interesting subject to discuss how research and development of new technological tools can help guarantee people the right to security with increased efficacy. A major threat is the criminal use of explosives by terrorists. New tools, aimed at detecting illegal activities in their early stages or trace of the explosive used after an attack, need to be conceived on a fitness-to-purpose basis. Security and forensic issues need to be evaluated in the early stage of the research and development process so as to avoid that new tools do not properly fit with the police needs.

Explosives, whether compounds or mixtures, are substances, "which are in a metastable state and are capable, for this reason, of undergoing a rapid chemical reaction without the participation of external reactants such as atmospheric oxygen" [1].

Explosives can be divided into six groups from a chemical point of view: nitro-compounds (dinitrotoluene, trinitrotoluene), nitric esters (nitroglycerine, nitrocellulose, pentrite), nitramines (RDX, HMX), derivatives of chloric and perchloric acids, and a last group of various compounds capable of producing an explosion, such as fulminates or peroxides. The peroxide-based explosives such as triacetone triperoxide (TATP) and hexamethylene triperoxide diamine (HMTD), belonging to the last group of various compounds, have been recently involved in terrorist attacks [2-5].

There are still restrictions for passengers on carrying liquids, aerosols and gels (LAGs) aboard, introduced in 2006 following a foiled plot to detonate homemade liquid explosives aimed at blowing up several aircrafts during the flight from London-Heathrow Airport [6].

The role of chemistry in this type of forensic studies is very important [7] and a preliminary discussion about the relationship between chemistry and forensic science will help to understand how new technologies can support the police dealing with security and forensic issues.

Chemistry and forensic science

In the XIX century the publications about the use of chemistry to help solve forensic problems dealt mainly with toxic substances and poisons. Naquet wrote about «Legal Chemistry», which «is applied to that branch of the science which has for its office the solution of problems proposed in the interest of Justice» [8]. Following the historical evolution in this field, it is possible to recognise that some fundamental issues, such as the meaning of legal or forensic chemistry, were never discussed and clarified. In 1981, Maehly and Stromberg [9] wrote about chemical criminalistics and admitted that «the definition of this discipline is still under discussion and varies from country to country». In the present paper we are going to talk about chemistry and forensic science, considering how technology can support the police forces in their activities to guarantee the security of citizens and during the criminal investigations.

Technology and security

On December 10th, 1948 the General Assembly of the United Nations adopted and proclaimed the Universal Declaration of Human Rights, where it is stated that «Everyone has the right to life, liberty and security of person» [10]. Prevention of crimes is a priority for all police forces all over the world. When dealing with threats to people and properties, the subjects in charge of security can decide to take an action such as to open correspondence or to stop the people getting on a plane, if the presence of an explosive charge is suspected.

Police forces and other subjects in charge of security are often helped by technological tools, developed to detect explosives, firearms and other dangerous items. In airports the design concept of passenger screening checkpoints is based on a multi-level approach with arch metal detectors and conventional *x*-ray equipment, followed by advanced metal, explosive and hazardous substance detectors, and state-of-the-art *x*-ray equipment. A complete manual physical search can be finally carried out whenever needed.

The most common systems for field screening of explosive traces to be used (see Figure 1) are ion mobility spectrometers (IMS) and chemiluminescence detectors [11, 12]. Ion Mobility Spectrometry (IMS) is a high sensitive analytical technique able to detect a wide range of chemical compounds (both organic and inorganic) at trace levels in gas phase or particulate.

FIGURE 1 Portable explosive detector used in criminal investigations in Italy. Courtesy of. G.G. Vadalà

Most of the IMS applications are in the military, security and forensic fields (chemical warfare agents, explosives and illicit drugs), mainly because analyses can be very fast and IMS instruments can be rugged enough to be field-portable and easy to use to enable non-scientific personnel to operate it under strictly controlled conditions. Another analytical system used for detection of explosives is EGIS®, originally based on high-speed gas chromatography, combined with a highly selective and sensitive chemiluminescence detector, able to screen carry-on baggage, checked baggage, vehicles. A key issue when detecting explosives is the vapour pressure of explosives [13].

Currently, trained dogs can be considered the best choice to detect explosives in the vapour phase since there are able to give positive results at lower concentrations compared to technology-based sensors [14]. However, the development of new technologies and devices is increasingly necessary, especially because dogs can only work for a short period of time before being fatigued.

The analytical capability of a detector can be measured following a probabilistic approach, based on the results (true positives, true negatives, false positives and false negatives) obtained in a set of tests on known samples. For example it is easy to recognise that metal detectors have a high rate of "false alarms", meaning that most of the alarms do not correspond to firearms or other dangerous metal items. These results can be used to calculate the false alarm rate and the probabilistic sensitivity and specificity of the technique. The probabilistic sensitivity is the probability to have a positive result, given the presence of the searched substance. The probabilistic specificity is the probability to have a negative result, given the absence of the searched substance. Whenever an alarm is given by a detector, the following decision/action depends mainly on the legal framework, the parameters determining the analytical capability of the detector and the time limit for the decision/action. In an airport, an example of false negative result is a terrorist boarding on a plane with an explosive charge. Passenger screening checkpoints need to avoid false negative results, but it is also necessary to consider that the time required for screening passengers and their luggage has to be limited. All the people giving false positive results suffer additional time spent for a complete manual physical search. Any technology for security needs to give evidence of clinical, social, and ethical acceptability, too [15]. A good example of study of the effects on health of security technologies is in the document of the EU Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) about scanners for passenger screening based on x-ray technology [16].

There is another aspect of the relationship between technology and security to be discussed. «Police officers who respond to a potential dangerous event must do so within the limitations of their training, support network and equipment. Personal safety is a primary concern» [17]. When specialists arrive on the scene of a (possible) crime, spot tests or chemical detectors can play a critical role if explosive substances are present. The best implemented strategy is based on chemical information (e.g., adopting self-protection measures, setting up an incident command centre, throwing a cordon...). In these situations not only probabilistic sensitivity and specificity, but also the limited time that can be waited before taking any decision must be considered. A detector with very good detecting capability can be useless if the analysis time is too long. The spot tests can be very useful for bulk detection. An example are the field tests for TNT based on the formation of coloured Meisenheimer and Janowsky anions in alkaline acetone or methanol. For more sensitive approaches there are procedures based on fluorescence emission or on optical chemosensing, yet the use of biosensors generally results in procedures having the best selectivity [18-21].

Spectroscopic approaches such as micro-Raman spectroscopy are capable of very sensitive detection, enabling to detect the amount of explosive obtained from a single fingerprint [22], or permit Standoff Detection, allowing a particularly safe approach to the chemical analysis of explosives [23], also permitting the analysis of explosives enclosed in containers [24].

For any incident involving dangerous materials, including explosives, it is important to avoid false negatives, resulting in possible unsafe behaviours in the presence of dangerous materials.

Research projects looking for new technologies able to detect and locate the illicit production of explosives in an urban environment have been carried out in the latest years and some of them are ongoing. FOI in 2012 exhibited the LOTUS project bomb-sniffer sensor, "the Raman system for the remote detection of traces of explosives, which is used under the EMPHASIS and HYPERION projects, as well as a biodetector based on honey bees for the detection of explosives, used under the PREVAIL project" [25].

In projects involving chemical sensors there are several possible operational advantages, e.g.:

1) real-time determination of the concentrations of specific sample constituents;
2) little to no power consumption;
3) operation without consumables and frequent maintenance;
4) unobtrusive sensing;
5) deployment in multiple locations forming distributed sensor networks" [26].

The most important requirements are always the sensitivity and the selectivity. When the aim of the network is to spot a criminal "bomb factory", it is very important to avoid false positive results so as to spare citizens useless intrusion in their private lives.

A project of this type is BONAS (BOmb factory detection by Networks of Advanced Sensors), aiming to design, develop and test a novel wireless sensor network for increasing citizen protection and homeland security against terrorist attacks, especially against the threat posed by Improvised Explosive Devices (IEDs) [27]. The sensor network will focus on the detection of traces of precursors used to produce IEDs. In this type of network approach, a key role is played by data fusion, considering that there are relatively few practical examples of data fusion in explosives detection and not many case studies [28].

Technology and forensic issues

The development of new methods for the analysis of explosives is of increasing importance not only for security issues but also for establishing criminal evidence [29]. There are two main types of forensic problems in casework: bulk analysis and trace analysis of residues. General comprehensive schemes for the analysis of post-explosion residues where first described in the 1970s. They can include the team approach for processing bomb-scene, visual examination of debris, sample preparation and analysis [30]. Analysis of traces on suspects or on their belongings are carried out with the same analytical techniques used for post-explosion residues but with different sampling approaches. Field tests on the crime scene «significantly enhance the productivity of the investigative/forensic science interface» [31]. The work of experts after the bombings occurred in Bali on 12th October, 2002 is a good example of the importance of having timely, albeit tentative analytical information at the crime scene [32]. The organic explosive trinitrotoluene (TNT) was detected using IMS at the scenes and confirmation was achieved by both gaschromatography (GC) with a chemiluminescence detector called Thermal Energy Analyser (TEA) and GC with Negative Chemical Ionisation Mass Spectrometry (NCI-MS).

Another example of how the detectors developed for airport security can be useful during criminal investigation is the use of EGIS® to make screening analyses during the investigation following the five bombings with explosive cars or vans, organised by Mafia, occurred in Italy in 1993 (three in Rome, one in Florence, and one in Milan). During the following years explosive detectors such as IMS or EGIS® were successfully used in the places were some explosive charges were prepared or hidden before the attacks. Results were later confirmed with other analyses [33] and reported to the Court. The term «confirmation» has gained widespread acceptance in analytical toxicology after appearing in the Mandatory Guidelines for Workplace Drug Testing in 1988. A confirmatory method provides full or complementary information, enabling to identify and, if needed, quantify the substance at the level of interest. Then, knowing which and how many analysis are required for identifying an explosive's trace is the main aspect in analytical chemistry, when applied to criminal investigations. If we want to give an unambiguous identification of a substance, necessary to report the chemical information as evidence in the Court, we must maximise the selectivity of the analytical procedure used. Using the probabilistic language it is possible to say that it is necessary to maximise the probability of the final analytical result supposing the presence of the compound of interest, and to minimise the probability of the analytical result given an alternative explanation. In some laboratories samples were analysed by gas chromatography and TEA three times, using three different columns. For others the minimum requirements for a positive identification is a separation technique combined with two detectors, based on different principles, or alternatively two separation techniques with one specific detection method [34]. The European Commission Decision of 12th August, 2002, implementing the Council Directive 96/23/EC concerning the performance of analytical methods and the interpretation of results, has become a reference document for any method in analytical chemistry having a forensic use [35]. According to this document, hyphenated techniques based on chromatography and mass spectrometry are the preferred methods to make confirmatory analysis, while methods based on chromatographic analysis without the use of spectrometric detection are not considered as suitable on their own for use as confirmatory methods. The European Council allows the use of a combination of independent techniques to confirm the identity of a substance. In this case a minimum number of identification points (IP) associated with each technique needs to be obtained. The Commission Decision includes performance criteria both regarding chromatographic separation and concerning the mass spectrometric analysis. The maximum number of identification points required in the Commission Decision is 4, corresponding to 4 ions in the Selected Ion Monitoring (SIM) or 2 fragments from the same precursor ion in tandem mass spectrometry. However, in order to qualify for the identification points required, a minimum of at least one ion ratio shall be measured and all relevant measured ion ratios shall meet some criteria.

Selectivity is the most important feature in validating an analytical procedure for forensic purposes, producing results to be reported as evidence in the Court, because of the need to establish the truth beyond any reasonable doubt. To explain the difference between a detection method and a confirmation method, it is possible to compare a fast and cheap method based on GC-MS to detect TATP [36] with a more expensive and time-consuming one based on HPLC-MS-MS [37]. The former is useful for security issues or to select forensic samples, but only the latter allows enough selectivity to avoid false positive and to report to the Court the chemical identification of TATP (the samples resulting positive after the GC method must be confirmed by the HPLC method).

Conclusions

When describing the contribution of analytical chemistry to security activities and to criminal investigation we find a common central idea: analytical chemistry supplies chemical information with the aim of helping decisions to be taken respecting a juridical framework. In the area of crime prevention, the probabilistic sensitivity and specificity of the techniques used can be limited because of the need to take decisions in a short time, as it happens during the control of people and luggage in airports, or in the activity to spot a criminal bomb factory. The acceptable degree of uncertainty is higher, when dealing with security problems, compared to criminal investigation, due to the limited time. When reporting chemical information as evidence in the Court uncertainty must be minimised, since the Court needs to establish the truth beyond any reasonable doubt.

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references & notes

[1] R. Meyer, J. Köhler, A. Homburg, 2007, Explosives, Sixth Edition, Wiley-VCH & Co. KGaA, Weinheim.

[2] T. Urbansky, 1964, in Chemistry and technology of explosives, Vol. I-III, Pergamon Press, Member of Maxwell Macmillan Pergamon Publishing Corporation, Oxford, New York, Beijing, Frankfurt, Sao Paulo, Sydney, Tokyo, Toronto.

[3] R. Schulte-Ladbeck, P. Kolla, U. Karst, 2006, "Recent methods for the determination of peroxide-based explosives", in Anal. Bioanal. Chem., 386, 559-565.

[4] R.M. Burks, D.S. Hage, 2009, "Current trends in the detection of peroxide-based explosives", in Anal. Bioanal. Chem., 395, 301–313.

[5] M.S. Meaney, V.L. McGuffin, 2008, "Luminescence-based methods for sensing and detection of explosives", in Anal. Bioanal. Chem., 391, 2557-2576.

[6] International Civil Aviation Organization (ICAO), Working Paper: High-Level Conference on Aviation Security (HLCAS), Montréal, 12 to 14 September 2012 (last access 18th June 2014). http://www.icao.int/Meetings/avsecconf/Documents/WP 14/LIQUIDS, AEROSOLS AND GELS.en.pdf

[7] J. Yinon, 1999, Forensic and environmental detection of explosives, John Wiley & Sons, Chichester.

[8] A. Naquet, 1884, Legal Chemistry. A guide to the detection of poisons, examination of tea, stains, etc., as applied to chemical jurisprudence, Second edition, revised with additions. D. Van Nostrand Company, New York.

[9] A. Maehly, L. Strömberg, 1981, Chemical Criminalistics, Springer-Verlag.

[10] General Assembly of the United Nations, 1948, Universal Declaration of Human Rights, Article 3, http://www.un.org/en/documents/udhr/index.shtml#a3 (last access 28th June 2014).

[11] P. Kolla, 1996, "The application of analytical methods to the detection of hidden explosives and explosives devices", in Angew. Chem. Int. Ed. Engl., 36, 800-811.

[12] D.H. Fine, G.J. Wendel, 1994, "Sampling of explosives by means of the EGIS vapor/particle detector", in Proceedings of SPIE-The International Society for Optical Engineering, 2092, Substance Detection Systems, 131-136.

[13] H. Östmark, S. Wallin, H.G. Ang, 2012, "Vapor Pressure of Explosives: A Critical Review", in Propellants Explos. Pyrotech., 37, 12 – 23.

[14] M. Marshall, J. Oxley, 2009, "Detection of explosives by dogs," in Aspects of Explosives Detection, 1st ed., M. Marshall and J. Oxley, Eds., 27–38, Elsevier, Amsterdam, Netherlands.

[15] E. Linos, E. Linos, G. Colditz, 2007, "Screening programme evaluation applied to airport security", in BMJ, 335, 1290-1292.

[16] EU Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), 2012, Health effects of security scanners for passenger screening (based on X-ray technology).

[17] ICPO Interpol, 2007, Bioterrorism Incident Pre-Planning & Response Guide.

[18] M.E. Germain, M.J. Knapp, 2009, "Optical explosives detection: from color changes to fluorescence turn-on", in Chemical Society Reviews, 38, 2543–2555.

[19] Y. Salinas, R. Martínez-Máñez, M.D. Marcos, F. Sancenón, A.M. Costero, M. Parra, S. Gil, 2012, "Optical chemosensors and reagents to detect explosives", in Chemical Society Reviews, 41, 1261–1296.

[20] Yáñez-Sedeño, et al., 2014, "Biosensors in forensic analysis. A review", in Anal. Chim. Acta, http://dx.doi.org/ 10.1016/j.aca.2014.03.011

[21] S. Girotti, S, Eremin, A. Montoya, M.J. Moreno, P. Caputo, M. D'Elia, L. Ripani, F.S. Romolo, E. Maiolini, 2010, "Development of a chemiluminescent ELISA and a colloidal gold-based LFIA for TNT detection", in Anal. Bioanal. Chem., 396, 687-695.

[22] S. Almaviva, S. Botti, A. Palucci, A. Puiu, F. Schnürer, W. Schweikert, F.S. Romolo, 2014, "Application of micro-Raman spectroscopy for fight against terrorism and smuggling", in Optical Engineering 53(4), 044113.

[23] S. Wallin, A. Pettersson, H. Östmark, A. Hobro, 2009, "Laser-based standoff detection of explosives: a critical review", in Anal. Bioanal. Chem., 395, 259–274 DOI: 10.1007/s00216-009-2844-3

[24] A. Pettersson, I. Johansson, S. Wallin, M. Nordberg, H. Östmark, 2009, "Near Real-Time Standoff Detection of Explosives in a Realistic Outdoor Environment at 55 m Distance", in Propellants Explos. Pyrotech., 34, 297 – 306 297 Full Paper.

[25] http://www.foi.se/en/Top-menu/Pressroom/News/2012/FOI-showcases-five-EU-projects-at-trade-fair-in-Germany/ (last access 28th June 2014).

[26] R.A. Potyrailo, N. Nagraj, C. Surman, H.Boudries, H. Lai, J.M. Slocik, N. Kelley-Loughnane, R.R. Naik, 2012, "Wireless sensors and sensor networks for homeland security applications", in Trends Analytical Chemistry, 40, 133-145.

[27] BONAS web site http://bonas.tekever.com (last access 28th June 2014).

[28] M.C. Kemp, 2013, "A review of sensor data fusion for explosives and weapons detection", in Proc. SPIE 8710, Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Sensing XIV, 87100X (May 29, 2013); DOI: 10.1117/12.2015530

[29] J.S. Caygill, F. Davis, S.P.J. Higson, 2012, "Current trends in explosives detection techniques", in Talanta, 88, 14–29.

[30] A.D. Beveridge, 1992, "Development in the detection and identification of explosives residues", in Forensic Science Review, 4 (1), pp. 17-49

[31] J. Almog, 2006, "Forensic Science Does Not Start in the Lab: The Concept of Diagnostic Field Tests", in J. Forensic Sci., 51(6), 1228-1234.

[32] D. Royds, S. Lewis, A.M. Taylor, 2005, "A case study in forensic chemistry: The Bali bombings", in Talanta, 67, 262–268.

[33] D. Perret, S. Marchese, A. Gentili, R. Curini, A. Terracciano, E. Bafile, F.S. Romolo, 2008, "LC–MS–MS Determination of Stabilizers and Explosives Residues in Hand-Swabs", in Chromatographia, 68 (7-8), 517-524.

[34] S.A. Phillips, R. Hiley, 1999, "Proceedings of the workshop on explosives trace analysis methods", DERA, UK, April 1999, In Science & Justice, 39(4), 261-268.

[35] European Communities. Commission Decision of 12th August 2002 implementing Council Directive 96/23/EC concerning the performance of analytical methods and the interpretation of results. Official Journal of the European Communities 2002; L 221: 8-36.

[36] F.S. Romolo, L. Cassioli, S. Grossi, G. Cinelli, M.V. Russo, 2013, "Surface-sampling and analysis of TATP by gas chromatography/mass spectrometry", in Forensic Sci. Int., 224, 96–100.

[37] M.E. Sigman, C.D. Clark, T. Caiano, R. Mullen, 2008, "Analysis of triacetone triperoxide (TATP) and TATP synthetic intermediates by electrospray ionization mass spectrometry", inRapid Commun. Mass Sp., 22, 84-90.