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Technoscience in Crime Detection and Control: A Review

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Abstract: Technoscientific artefacts are increasingly perverted in increasing wave of crimes across the globe. It is only technoscience that can contain this problem by developing the matching techniques for crime detection, prevention and control. Using available literature, this study reviews the role of technoscience in equipping the world with tools for crime detection and control, thereby improving safety of living environment, personal and property security, proof and identity and authenticity. It is recommended that a larger allocation of resources be made for research and development of technologies for crime detection, prevention and control.

Key words: Technoscience, crime detection, control

INTRODUCTION

According to the UNODC, 2010 (http://www.legalnotice.org/):

- The United Nations crime congresses are the oldest periodic United Nations conferences devoted to a specific subject area [and]...they continue to remain one of the pillars of the leadership role of the United Nations in criminal policy at the international level

The theme of The Twelfth United Nations Congress on Crime Prevention and Criminal Justice was Comprehensive strategies for global challenges: crime prevention and criminal justice systems and their development in a changing world. The Congress, which marked the 55th Anniversary of United Nations congresses on crime prevention and criminal justice, was held in Salvador, Brazil, 12-19 April 2010. It emphasized the need for a holistic approach to criminal justice system reform to strengthen the capacity of criminal justice systems in dealing with crime, particularly its sophisticated forms. It offered a unique opportunity to stimulate in-depth discussion and proposals for action. An important item on the agenda was Recent developments in the use of science and technology by offenders and by competent authorities in fighting crime, including the case of cybercrime. The workshop framework of the c ongress included, among others, practical approaches to preventing urban crime and links between drug trafficking and other forms of organized crime: international coordinated response.

In a similar development, the overriding objective of the first European Congress on Tackling Organised Crime in Partnership was to explore ways in which the potential harm from the activities of organised crime can be identified, measured and prevented. The groundbreaking Congress, held at the Royal Hospital, Kilmainham, Dublin, Ireland, 20-21 November 2003, debated and developed ways to tackle this global threat of organised crime, recognising that, if left unchecked, it would increasingly cause serious harm, particularly social and economic harm, to governments and business sectors, while also seriously damaging the quality of life of citizens, noting for example, that the global economic impact of counterfeiting on legitimate companies in 2000 amounted to an estimated_450 billion and there was every indication that this figure was growing. The Congress, therefore, addressed the challenge of how this common interest could be harnessed through establishing mechanisms and structures to facilitate a partnership approach to lessen the impact of organised crime on private and public stakeholders, drawing where appropriate, on the relevant experience of existing partnerships (AKJ Associates, 2004).

Societal pattern changes along with the development of science and technology. The techniques adopted by the criminal for commission of various crimes within the society also change with technoscientific development. This presents challenges for the law enforcing agencies to check the potentiality of changing techniques of crime commission. Fundamental scientific research enables the development of new technologies for crime prevention. Increased involvement of the science and technology community in crime reduction strategy is, therefore, desirable. Crime detection, prevention, reduction and control have remained burning issues because crime poses great threat to the society, especially as criminals adopt increasingly sophisticated technologies for crimes commission (Clarke, 2004).

According to Kriel (2010), the realities of the future will be an increase in crime, particularly in the areas of violent crimes, especially with the use of firearms; gang crimes, especially by international syndicates and fraud and corruption. Criminal activities, excluding fraud and corruption, are already costing South Africa, for example, at least R43 billion per year, that is, more than R1 000 per person! The trends, requirements and strategies of science and technology, which will contribute to creating safer communities and promote the security of countries and their people, in order to realise sustainable social and economic benefits for the country over the next 20 years, need identification, appreciation, support and growth.

Against the background of increasing wave of crime, studies are picking up in this area (Laycock, 2004; Eneh, 2008a, b, 2009, 2010; Eneh and Owo, 2008). Researchers have harped on the need to improve police performance and more balanced approach with shift of policy emphasis towards crime control. Both steps are rooted in technoscience. This calls for more scientific method for crime control. Technology and the physical sciences have great applications in ICT, forensic science and technical equipment to policing (Home Office, 2005).

There is the need for stronger links between researchers and crime prevention experts for more focused objectives of current technoscientific academic research in this area of needs. This review article is an attempt to bridge this gap. After this brief introduction, the rest of the study is structured as follows. Definition of terms highlights crime and the concept of technoscience. The theoretical and conceptual framework looks at the use of technoscientific artefacts for crime commission against the background of the beliefs of two prominent schools of thought: the social constructionists and the technological determinists. The section on the role of technoscience in crime detection and control reviews the various aspects science and technology have helped the court to establish crime and deal with criminals. The section of conclusion and recommendations takes the rear.

DEFINITIONS OF TERMS

According to Wikipedia the Free Encyclopedia, 2010(http://www.portlandonline.com/police/index.cfm?c=29825), crime is the breach of rules or laws for which some governing authority (via mechanisms such as legal systems) can ultimately prescribe a conviction. Individual human societies may each define crime and crimes differently. While every crime violates the law, not every violation of the law counts as a crime; for example: breaches of contract and of other civil law may rank as offences or as infractions. Crimes are generally considered offenses against the public or the state, distinguished from torts, which are offenses against private parties that can give rise to a civil cause of action.

Crime is an act committed or omitted in violation of a law forbidding or commanding it and for which punishment is imposed upon conviction; an unlawful activity; a serious offense, especially one in violation of morality; an unjust, senseless, or disgraceful act or condition; (in Law) an act or omission prohibited and punished by law; an evil act; (informal) something to be regretted. It includes, but is not limited to, theft, embezzlement, disseisin (the process of wrongfully or unlawfully dispossessing a person of his rightful real property), embracery (the crime of attempting to influence or suborn a judge or jury by bribery, threats, etc.), extortion (obtaining of money by threat of violence), fugitation (fleeing from justice, as by a criminal), gangdom (organized crime), knavery (petty dishonesty or fraud), malfeasance (wrongdoing or improper or dishonest conduct, especially by a person who holds public office or a position of trust), malversation (fraudulent behavior, extortion, or corruption by a person who holds public office or a position of trust), mayhem (Law: an intentional crippling, disfigurement, or mutilation of another), miscreancy (criminal action or behavior; wrong-or evil-doing), misfeasance (a form of wrongdoing, especially the doing of something lawful in an unlawful way so that the rights of others are infringed) and misprision (improper conduct or neglectful behavior, especially by a person who holds public office), ropery (Archaic: roguish or criminal behavior or action, conduct deserving of hanging), skulduggery (underhanded, dishonest, or deceptive behavior or actions).

Others are barratry (vexatious inciting of lawsuits and quarrels), capital offense (a crime so serious that capital punishment is considered appropriate), cybercrime (crime committed using a computer and the internet to steal a person's identity or sell contraband or stalk victims or disrupt operations with malevolent programmes), felony (a serious crime, such as murder or arson), forgery (criminal falsification by making or altering an instrument with intent to defraud), fraud (intentional deception resulting in injury to another person), Had crime (Islam: serious crime committed by a Muslim and punishable by punishments established in the Koran; Had crimes include apostasy from Islam, murder, theft and adultery), highjack or hijack (seizure of a vehicle in transit either to rob it or divert it to an alternate destination), Tazir crime (Islam: minor crime committed by Muslims; crimes that are not mentioned in the Koran, so judges are free to punish the offender in any appropriate way; in some Islamic nations Tazir crimes are set by legislation).

Again, there are infraction or misdemeanour or violation or infringement (a crime less serious than a felony), regulatory/statutory offence (crime created by statutes and not by common law), thuggery (violent or brutal acts as of thugs), high treason or lese majesty or treason (a crime that undermines the offender's government), vice crime (a vice that is illegal), victimless crime (an act that is legally a crime, but that seems to have no victims), war crime (a crime committed in wartime; violation of rules of war), abduction or kidnaping or snatching (take away to an undisclosed location against the victim's will and usually in order to extract a ransom), shanghai/impress (take someone against his will for compulsory service, especially on board a ship; The men were shanghaied after being drugged), commandeer or pirate (to take arbitrarily or by force), skyjack (to subject an aircraft to air piracy, carjack (to take someone's car from him by force, usually with the intention of stealing it), blackmail (to obtain through threats), scalp (to sell illegally, as on the black market), bootleg (to sell illicit products, such as drugs or alcohol; They were bootlegging whiskey), push (to sell or promote the sale of illegal goods such as drugs, traffic (to deal illegally), rustle or lift (to take illegally, shoplift (to steal in a store), stick up or hold up (to rob at gunpoint or by means of some other threat) and mug (to rob at gunpoint or with the threat of violence. There is also crime as an evil act not necessarily punishable by law, such as crimes of the heart, evildoing or transgression (the act of transgressing; the violation of a law or a duty or moral principle) (http://www. thefreedictionary.com/crime).

There is a close and effective relationship between science and technology. Much of modern technology is intimately related to scientific knowledge and science itself has become increasingly linked to technology through its dependence on complex instrumentation to explore the natural world. More similarities than differences can be found between science and technology. Both terms imply a thinking process, both are concerned with causal relationships in the material world and both employ methodology that results in empirical demonstrations that can be verified by repetition. The symbiotic and synergistic relationship between modern science and modern technology has thrown up the term technoscience to describe the essentially merged, even hybrid, enterprise (Eneh, 2008a).

THEORETICAL AND CONCEPTUAL FRAMEWORK

The social constructionists believe that it is the social groups that define and give meaning to technological artifacts. For example, a motor car has come to acquire more meaning and value than the developer had in mind: it is not just a means of transport, it can be a status symbol, a reflection of self-image, a source of treasury revenue, a criminal's machine for ram-raiding, a competitor for rail travel provisions, the basis for a manufacturing service job and much more. On the other hand, believers in the technological determinism opine that, once launched, technology assumes a life of its own as an autonomous agent of change, driving history. Far from being society's servant, technology is society's master, increasingly shaping our destinies in ways which seem inevitable and irresistible. We are progressively being manoeuvred into ways of acting, both in the home and in employment, which are not of our own deliberate choosing, but which are dictated by the technologies in operation in the society at the time. The motor car was not invented to support out-of-town shopping and depopulation of the city centres; nor was the association of fast cars with crime (Eneh, 2008a).

Historical evidence lends some support to some intermediate positions between the poles of social constructivism and technological determinism. Large, complex technological systems seem capable of developing a momentum of their own and technologies can display latent inclinations that predispose people to develop certain lifestyles rather than others (Eneh, 2008a).

THE ROLE OF TECHNOSCIENCE IN CRIME DETECTION AND CONTROL

Coping with the challenge of increasing use of sophisticated technologies for crime commission necessitated the forensic science-criminalistic science for the scientific study or investigation of crime-which had to become an essential prerequisite part of crime investigative agencies. The operation of forensic science is nothing but the application of techniques and methods of basic science for various analysis of exhibits associated with crimes. According to Assam Police, 2010(http://assampolice.com/art2.htm) an ideal forensic science laboratory comprises eight important branches of science: Chemistry, Physics, Biology, Serology, Ballastics, Toxicology, Question Documents and Photography. The scientific examination of a forensic scientist adjoins a missing link or strengthens a weakness in the chain of investigation by furnishing impartial evidence, thereby helping the court to establish a crime and the appropriate punishment.

The forensic science is a very diverse and unpredictable field of study that generally involves very hazardous and onerous duties and responsibilities pertaining to various natures of crimes, such as murder and rape. It deals with risky material exhibits, such as blood, saliva, firearms, ammunitions, explosives and explosive substances, liquor, hashish, opium, adulterated petrol, kerosene, diesel, etc. and other chemical vehicles involved in accidents, various types of paints, weapons used in burglary and arson, different types of poison and poisonous substances, hair, skeletal remains and other plant or animal remnants. The forensic scientist also examines forged signatures and documents along with the photographic analysis of all material exhibits. The forensic scientist connects the material exhibits with the committed crime and the relevant acts and laws of the land. The forensic scientists work with limited quantity and amount of materials generally left behind or carried away by criminals, various impressions and marks of tools used in commission of crime, forced engine or chassis marks or restoration of an erased number upon metallic dates, paints and glass articles and stamp impressions of authorities to establish the facts for the determination of clues of commission of crimes and the criminals (http://assampolice.com/art2.htm).

The forensic chemist determines purity of chemical material exhibits, such as petrol, diesel, kerosene, liquor, opium, ganja and explosive. Using various methods of analysis, he establishes facts, based upon which the investigating officers can make out the clues to the crime. The forensic biologist examines biological exhibits, from micro organism to higher plant or animal. From the skeletal remains, the forensic biologist determines the sex, origin, stature and age of the deceased. Using superimposition method, he identifies the skull and helps the investigating authority to come to a conclusion regarding the crime. In a suspected death case, the forensic biologist ascertains the cause of death and analyzes various poisonous plant materials in cases where plant poison is administered in the commission of crimes (http://assampolice.com/art2.htm).

The forensic serologist establishes the facts of various crimes. In the case of a murder, where knife and other weapons are involved, he ascertains the staining of the weapon with human blood. He establishes the facts of disputed paternity cases by testing the blood group in question. He collects DNA sample from individuals and compares them directly with the DNA sample from the crime scene. Form his findings, the investigating officer can get a definite clue in a particular case to identify the culprit of the crime (Wallace, 2006).

The forensic ballasticist is the only expert to ascertain the use of a particular firearm in committing the crime. He examines the types of fire arms, ammunitions and explosive substances used in commission of the crime and establishes the firing ranges, distance, direction and angle of firing. From his findings, the investigating officer can come to a reasonable conclusion in regarding the particular crime. The forensic toxicologist determines the clues to the crime that involves poison. He analysis the viscera and other relevant materials to establish the quality and quantity of poison used for accidental, suicidal or intentional cases. From his report, the investigating officer can obtain vital clues for detecting the criminals involved and the courts can have positive evidence for coming to a conclusion in a particular case (http://assampolice.com/art2.htm).

A document expert examines the various types of documents directly or indirectly involved in a forgery case involving handwriting. From the report of the handwriting expert, the investigating agency can detect the culprit of a particular case. The handwriting examiner also gives opinions to help the court on typed papers, time of writing and the age of the ink used for writing the documents in question. Using photographic evidence, the forensic photography expert establishes the connecting link of various clues of a crime. Where the facts of erasure are involved, the photographer establishes the facts of erasement with a degree of precision and thereby, help the courts to come to a definitive opinion with regard to the case.

According to the Royal Society of Chemistry (RSC, 2005), chemical sensors and detectors are of particular relevance in relation to crime reduction. Sensors require effective recognition systems and efficient transduction mechanisms. New recognition systems that deliver the desired affinity and hence specificity for the target analyte, include systems based on enzymes, whole organisms and cell and tissue based systems. The key challenges in the development of cell-based sensors are integration of viable cells and tissues with synthetic materials, identification of strategies to improve genotypic and phenotypic stability and longevity of cells and the preservation or enhancement of physiological input/output responses.

The fundamental understanding of olfactory systems of live animals and insects could enable production of biosensors with equivalent sensitivity that are readily field deployable. The development of plug-and-play fully integrated systems to replace more limited sensors for repeated measurements of the same sample analyte or for detection of several analytes is highly desirable. Miniaturisation plays a key role in this area. The need for remote identification of low level concentrations of specific chemical and biological agents requires new spectroscopic methods and advances in instrumentation. Effective interrogation of databases requires further developments in data mining, inductive reasoning, cluster analysis, neural networks and evolutionary computing. Microfluidics offers potential advances with respect to miniaturisation of spectroscopic instrumentation, or for exploitation in fully integrated sensing devices (RSC, 2005).

Physical, chemical and biological sensor technology could play a major role in reducing crime. Key areas of applicability may involve the proof and protection of identity and authenticity, personal and property security, trade mark and brand preservation, document, passport, visa and banknote fraud, smart tagging and chemical encryption, food safety and adulteration, tracking people, property and events, including the identification of buried or burnt cadavers, detecting substance abuse at work, in clubs or at the roadside, including alcohol, sedatives, hypnotics, anxiolytics, opioids, inhalants, stimulants, hallucinogens, psychodelics, anaesthetics and steroids, tamper-evident smart packaging, aids for forensic science and crime detection, arson, fire and firearms investigations and anti-terrorism with conventional or chemical and biological weapons. Key analytes include food adulterants, toxic chemicals, volatiles, illicit drugs, explosives, chemical and biological agents and body fluid components. At scenes of crime, key analytes are body fluids (aged samples in particular), DNA and fingerprints; also chemical and biological warfare agents, explosives and illicit drugs (RSC, 2005).

Many of these situations require sensor devices packaged into hand-held or portable systems, with bench-top back-up systems for legal verification of the presence or use or abuse of analytes, where appropriate. Sensor devices must be capable of application in the field to monitor food, water, soil and air samples. Important considerations for sensor deployment concern the balance between generic and specific detection, rapid response, low-cost disposability versus re-usability, simplicity of use by lay personnel, robustness, mass producibility and long shelf life. As a general rule, irrespective of the physical, chemical or biological nature of the sensing technology, one of the key characteristics required of the sensor is a rapid response with a qualitative or quantitative signal output. However, the complexity of signal transduction events in biological sensors generally militates against rapid (min-h) quantitative responses, whereas chemical sensors may display similar characteristics with response times in the s-min range and physical sensors approach real time measurements (ns-s) (RSC, 2005).

Sensor devices for on-site measurements require improved sample collection, handling and pre-concentration or purification in order to reduce false alarm rates and give credibility to the measurements of the target analytes. There is, therefore, ample scope for miniaturisation with on-chip sample handling, fluidics, detection and signal processing to fabricate devices and instruments with enhanced portability, speed of response (reflecting the reduced diffusion distances) and reliability. Under such circumstances, the logistics burden associated with such monitors could be greatly reduced to virtually eliminate wet consumables and to lower power consumption to a level compatible with hand-held instrumentation. Using a micro-engineering approach may also lead to the holy grail of sensor research, a universal detector for physical, chemical and biological analytes, where multiple technologies are combined and integrated on a single chip. The ability to collect, process and read samples on-site allows more samples to be taken and measured at source and therefore, a more complete picture of the concentration profiles and topical and geographical distribution of the target analyte to be realised in both space and time domains. Such data, collected on-site and correlated with GPS coordinates, would allow mapping and subsequent modelling of the whole scene of crime with a holistic systems approach (RSC, 2005).

Current sensor technologies will require extensive moderation to be applicable to field analysis. Conventional bench-top hyphenated and spectroscopic techniques, such as Tandem MS-MS, Isotope Ratio MS, GC-MS, ESI-, MALDI-, AP-MALDI-, IR-MALDI- and MALDITOF-MS, UV-VIS, Raman spectroscopy, Raman-FTIR, Raman-(E)SEM, terahertz imaging and HPLCRaman-MALDI-MS, are well suited to sophisticated laboratory analysis, but will require substantial development and miniaturisation to be used reliably in the field. Such techniques have the advantage of being more generic for multiple classes of analyte than mono-selective sensor technologies, but they currently suffer from large logistics burdens and require skilled operation and interpretation of results. Sensor technologies appropriate for analytes of interest to crime, security and forensic applications require development for each specific analyte, concentration and sample matrix and are unlikely to be available off-the-shelf. Sensors require development of both the recognition system and the transducer mechanism to be effective. An important issue is that novel recognition systems based on binding systems [antibody fragments (scFv), aptamers, peptides, molecularly-imprinted polymers], enzymes, cell and tissue based systems and whole organisms will be required to achieve the desired affinity and specificity for the target analyte (RSC, 2005).

Cell-and tissue-based sensors offer unique potential for selective detection, including the ability to detect and/or classify novel analytes, to relate sensor data to human physiology, pathology and toxicity, to integrate numerous input stimuli into non-linear cellular responses, adaptive dynamic range and to leverage emergent techniques in cell biology. However, despite these advantages, the key challenges for cell-based sensors are the integration of viable cells and tissues with synthetic materials, the identification of strategies appropriate to improve genotypic and phenotypic stability and longevity of cells and the preservation or enhancement of physiological input/output responses. Cell sourcing, particularly of uniform or synchronous cultures, stem cells from both adult and embryonic sources, immortalized cell lines and knock-out cells as control populations all require consideration (RSC, 2005).

Furthermore, a number of engineering considerations relate to how to localise and confine cells in micro-patterned arrangements, how to monitor indirect measures of cell behavior, metabolism or releasates and how to incorporate and monitor fluorescent or luminescent technologies into genomes. Other considerations include improved storage, automation, modularity and portability, application of data mining, informatics and knowledge engineering, maintenance of aseptic environment and development of strains that can exist anaerobically. Nevertheless, despite these challenges, cell-based systems clearly show potential for further development (RSC, 2005).

Live animals, plants or insects may also provide the basis for low logistics burden mobile detectors. The use of bees, beetles and marine organisms has already been suggested and preliminary work demonstrates remarkable degrees of sensitivity and selectivity for the target analytes. However, the use of insects currently has limitations when used in field deployment due to difficulties with location/detection of the organisms. Miniaturised tracking devices could overcome these limitations. A greater understanding of how insect sensors work could enable production of biosensors with equivalent sensitivity and more readily field deployable (RSC, 2005).

The novel recognition systems must be fully integrated with the transducing mechanism and device geometry. Such transducer systems may incorporate direct measurements or particle probes (nanostructured silicon smart dust, upconverting phosphors, Q dots, gold nanospheres and magnetic beads) linked to colorimetric changes monitored with piezoelectric, optical (photonic crystals, reflectivity, evanescent wave, holography, fibre optic bundles, ARROW devices, the resonant mirror, SERS, SERRS, waveguides and gratings), acoustic [Quartz Crystal Microbalance (QCM) operating at 10 MHz, REVS, cantilever sensors, Love wave, SAW, Lamb wave and Magnetic Acoustic Resonator Sensor (MARS) operating at frequencies up to 1 GHz] and micro-fabricated sensors (MEMS, micro-fluidic devices, LOAC systems) (RSC, 2005).

Cantilever sensors, developed originally by IBM (Zurich), can now be fabricated in arrays of up to 4000, can be modified chemically by ink-jet printing and can detect sub-pmol amounts of analyte in solution. The sensitivity of the MARS sensor is very high by virtue of its higher operating frequency and the ability to monitor at multiple harmonics within the MHz-GHz range. Such systems may find application for the detection of explosives, viruses and pathogenic organisms. Coupled with these transducer technologies, other requirements include more sensitive CMOS chips, LED light sources and photo-detector arrays and advances in data analysis, informatics and knowledge management. Suitable combinations of sample collection and handling and recognition systems, transducers and micro-fabricated devices should allow the construction of integrated devices containing the capacity to assay multiple analytes simultaneously or sequentially in a rapid manner on-site from crude samples. Such fully integrated systems could be made plug-and-play to allow replacement of the sensor for repeated measurements of the same analyte or for the detection of a range of different analytes. Furthermore, a holistic systems approach is desirable which fits sample status and geographical distribution with a suitable model (RSC, 2005).

Current relevant research includes applying immunodiagnostics to the development of dipstick or test strip technology. This area is considered to be particularly relevant to anti-counterfeiting in the pharmaceutical industry. Spectroscopic methods are being employed to provide fingerprints of complex biological and chemical mixtures. This holistic analytical approach uses FT-IR, Raman and SERS data in conjunction with neural networks and evolutionary computing. This approach could be used to identify a wide range of materials from chemical and biological agents to food adulterants. Spatial separation/resolution with novel films can overcome the problem of degraded DNA or mixed DNA profiles recovered at the scene of a crime. This research impacts on the problems of human identification-which are significant in both high volume and low volume-high profile crime and is also relevant to mass disasters and the investigation of war crimes, for example. Proper identification of the offender and victims is fundamental to the investigation of crime of all kinds. The use of holographic multi-cells enables the simultaneous detection of sets of species of interest. This technique delivers specificity and speed at low cost. Detection systems can be tailor-made and detection can be carried out remotely. This research appears to be quite mature and seeking wider application (RSC, 2005).

Attaching chromophores to certain types of evidence facilitates SERRS detection. SERRS delivers extremely low levels of detection; however, the downside is analytical complexity and so the challenge lies in simplifying the technique. Microfluidics covers a broad area of research currently applied to a wide range of analytical challenges as it offers great potential. Microfluidics has particular importance in crime reduction and detection in that it presents the major advantages of portability and speed, together with sample integrity and remote operation. It also offers the potential to provide both temporal and spatial resolution. Parallel processing either on the same chip or moving fluids from one layer to another adds a powerful dimension and, although processes are diffusion limited, this can be turned into an advantage and facilitate complex chemistry (RSC, 2005).

A number of detection/analysis methods can be incorporated, such as conductivity (inferential) and Raman (SERRS) (specific). Parallel processing using sensor or detector arrays is also relevant. Current systems can provide 106 assays per cm^2. The use of arrays precludes the need for absolute selectivity, which is not required at the molecular level. A particular example of this area of research is the development of arrays of partially selective detectors using molecularly imprinted polymers incorporating SAW detection. MEMS-particularly quadropole MS-has wide relevance. There has been some degree of success with the fabrication of the MS. Ionisation will be a challenge, as will be achieving the low pressures required. However, the pressure problem might be overcome by manufacturing sealed units for single use. Initial results using MEMS MS indicate poor resolution at high mass range but improvements are being developed. Light Isotope Ratio Mass Spectrometry (IRMS) is already having an impact on crime detection and prevention in the field of foodstuffs, drugs and explosives. In addition, ICP MS is used to profile the trace elements in homogeneous evidence types, such as glass and precious metals. Several research teams are developing IRMS for a number of evidence types, including drugs and packing materials. The World Health Organisation estimates that 10% of all world trade in branded pharmaceutical goods is counterfeit, leading to huge financial loss for the pharmaceutical industry. More important, however, is the implied serious public health risk. Counterfeit products are often indistinguishable from the genuine article: what makes them so dangerous is the complete absence of quality control by the manufacturer. Fake drugs may harm and even kill. Their use can also lead to false indications that certain pathogens are becoming resistant to genuine treatments that actually are effective (RSC, 2005).

The examination of scenes of crime is part of the process of crime detection rather than prevention. However, crime prevention is aided by detection in that it may lead to identifying and removing perpetrators and provides useful intelligence. Not surprisingly turn around time and the related issue of bringing the analytical tool to the crime scene are probably the most important drivers. Analysis at the crime scene raises the issue of incorporating a level of expertise that is fit for purpose; the minimum level is referred to as quick and dirty. Furthermore, non-expert use raises the important issue of validation. Early evidence or intelligence may be of great benefit in giving the right direction to an investigation from the beginning. The parallel processing of mixed evidence types could also increase speed but recovery and management of such evidence may prove to be challenging (RSC, 2005).

A more general requirement is maximising evidence recovery; the more information gleaned from a crime scene the better i.e., the complete characterisation of the scene should be an aim. Maximising the value of evidence is another key driver. Examples include detecting and identifying drugs of abuse in body fluids, both in the laboratory and at the crime scene. Temporal resolution (i.e., when was evidence deposited?) is also highly desirable. Contamination control is always a topic of concern and is related to the lower limits of detection available as analytical science progresses. Such lower limits of detection are not always a driver in forensic science unless they increase the value of evidence or provide evidence that would otherwise not be available to the justice system, e.g., LCN DNA. The justifiable emphasis on DNA research and development in LCN and SNPs may be responsible for under-resourcing of R and D in other fields of crime detection and prevention. Non-DNA R and D might profitably be directed to the profiling of materials in order to determine authenticity and provenance (RSC, 2005).

Although, this requires considerable resources, databases need to be populated with chemical data to enable scene-of-crime interrogation and the identification of unknowns. Human identification is a major problem that is frequently encountered in high volume crimes, high profile-low volume crimes and crimes involving a large number of fatalities or when the location of a violent crime and the location of the victim differ. The further exploitation of current techniques, such as IMS, mini-MS and Raman, perhaps in terms of scope, is also of value. The potential of nanoscience, in particular nanoparticles, may be exploited to provide quick and dirty methods and holographic detection could be developed to address particular needs. In more general terms, data mining employing inductive reasoning, cluster analysis, neural networks and evolutionary computing have the potential to provide significant advances. These techniques are particularly relevant: database applications represent an important development in crime prevention and detection and the processing of both raw and generated data will be key to gaining benefit. The need to capture the skills of the expert is a related area that calls for further development. Consideration should be given to populate the NDNADB with SNPs rather than SGM+data. The SNPs probably has greater potential for development as a scene of crime tool. However, there are significant political and resource implications in relation to these issues (RSC, 2005).

Counterfeit products, especially drugs, represent a major problem for the pharmaceutical industry. Their detection can be relatively straightforward, e.g., misspelled labelling or poor quality packaging, though in many cases, detection can be more difficult. Holograms are the most popular overt tagging system for authentication and have the advantage of consumer confidence in the technology. Counterfeit preparations may contain no active ingredient or, worse, the wrong active ingredient, with potentially disastrous consequences for the user. In the past, the existence of counterfeits was largely ignored both by the pharmaceutical industry and by drug regulatory authorities. But, this has changed in recent years. New technologies for detecting counterfeit products are constantly being investigated, including methods for identifying the active component and also for detecting commonalities of origin. The use of analytical techniques is crucially important for curbing counterfeiting. Electrospray ionisation mass spectrometry (ESI-MS), combined with accurate mass measurement on a (quadrupole) orthogonal acceleration time-offlight mass spectrometer (oa-Q-TOF) and the technique of combined liquid chromatography/MS, can be effective for identification of unknown compounds in counterfeit products. Near-infrared spectroscopy (NIR) is a new tool that also allows detection of pharmaceutical counterfeits. The spectra contain physical and chemical information which can be unique to the site of manufacture and an important operational advantage is that sample measurement is non-destructive and rapid (less than a minute) (RSC, 2005).

There is ready scope for the development of analytical tools to be employed at the crime scene, bearing in mind non-expert use and the need for validation. Microfluidics is probably the prime candidate since the area offers particularly promising advances in the medium to long term. The low fabrication costs, versatility in terms of separation and detection methods, enhancement of analytical performance, low power requirements and low reagent consumption are among the advantages offered. Pre-concentration, or more colloquially clean-up, whereby specificity is increased by some process or other, is a common problem in analytical science and resources are required to study increased specificity. The general drivers for analytical tools are smaller, faster, smarter, more specific and of course, cheaper or more cost effective (RSC, 2005).

In general terms, if an analytical tool is taken to comprise a front end, a separation system, a detection system and a processing system and its use requires sample collection, sample preparation, sample presentation, analytical processing, data processing and producing results that have meaning in the real world, then the area having greatest overall potential is microfluidics, which offers miniaturisation, crime scene deployment, rapid turnaround, arrays for parallel processing and integration with other systems e.g., detection and data handling. Much of the current relevant research that is not already aimed at microfabrication may be adapted to that end. Another key area for development is the profiling of evidence types by a variety of criteria, such as spectroscopic, composition, synthetic route, stable isotope ratio and trace element. The ability to populate databases and interrogate those databases for profiles that match materials found at a crime scene will be an important advance. To this end, data mining, inductive reasoning, cluster analysis, neural networks and evolutionary computing should also be developed to maximise the evidential value of the data generated (RSC, 2005).

Novel materials are continually being developed in research laboratories. Occasionally, such materials are designed to meet the demands of industrial partners who provide the financial support. Examples of crime drivers for materials research would include stronger, safer, lighter, smaller and smarter materials that are cheaper than currently available products. Areas that have direct relevance to fighting crime, where novel materials could be applied, include protective equipment for law enforcement agencies, explosive safe materials for construction of rubbish bins or glass replacements (for anti-terrorist applications), bar-code tagging of fabrics to counter fraud and counterfeit, photo-bleachable materials to render photocopying ineffective and thermochromic materials that change from colourless/light to dark coloured on heating. These are all current research activities (RSC, 2005).

The aggressive sea creature, mantis shrimp, which lives mostly in the warmer waters of Australasia, is the only form on earth known to have hyperspectral vision, which enables it to recognize different types of coral, prey and predators, all of which may appear the same colour. Unlike the human eye, which is limited to visible light, hyperspectral imaging can detect and measure ultraviolet and infrared. Using similar techniques to and hyperspectral imaging power of, the mantis shrimp, scientists have developed a way of using hyperspectral imaging to collect and process information from across the electromagnetic spectrum. Certain objects leave unique fingerprints across the electromagnetic spectrum, known as spectral signatures, which aid the identification of the materials that make up a scanned object. Hyperspectral imaging is used across a variety of industries, ranging from crime fighting, medicine and food manufacturing to agricultural, defence and even astronomy. It is being used to identify improvised and unexploded explosive devices. Farmers use it on unmanned aerial drones to identify crop problems. It is also used to test the quality and consistency of cakes. Experts have built a range of equipment which use the same techniques as mantis shrimp to identify fake from reality, thereby combating counterfeit drugs, find fake spirits, fight fraud, solve murders, check teeth and test the quality of cake (Gilden Photonics, 2010).

Technoscience has equipped the world with tools for crime detection and control, thereby improving safety of living environment, personal and property security, proof and identity and authenticity. Some of the technologies developed for combating crimes include handwritten documents, handwriting analysis, security screening, speaker recognition, crime scenario modelling, video analysis and control, detecting unusual activities on video, video evidence recovery, video wireless LANs, biological agent detection, chemical agent detection, face recognition, security critical systems analysis, illegal materials trafficking, security marking materials, age-at-death analysis, data encrypting, people and property tracking, PCR development, latent fingerprint chemistry, fingerprint imaging, textile security marking, millimeter wave imaging, internet criminal detection, bomb blast protection, witness identification, luggage examination systems, fast protein profiling and enhance resolution imaging (http://www.epsrc.ac.uk).

Concealed weapons can be detected by using MM-wave imaging. To this end, algorithms are developed for automatic detection of threats (weapons, explosives) using MM-wave imagery, mechanism to ensure privacy of users is developed, MM-wave image formation is modeled, sensor for automatic screening is improved and operational and legal guidelines for system development is provided. Using novel lightweight materials bomb blast protection has been developed for use in street furniture. Also, the mechanical behavior of the materials at various rates of loading has been characterized for optimum design. The prototype of the bomb-proof container/liner has been fabricated and tested. It has short processing time. Materials are based on stack arrangements of metal and fibre reinforced composite layers. Thermoplastic-based FMLs have superior impact resistance and fracture toughness (Petillot, 2010).

Technoscience is helping to counter bioterrorism in three major areas of prevention, response and recovery. Creation of a perfect system to safeguard against terrorist use of a biological agent is impossible, but conscientious preparation reduces anxiety and greatly mitigates the consequences of bioterrorism attacks. Part of that preparation includes modeling techniques, bioforensics, methods for defining threats, specific and broad-spectrum antibiotic and novel antiviral agents and means for rapid vaccine fielding. Once an attack has occurred, a better prepared and reinforced health and agriculture response system will be needed, as will be a reliable and consistent communications plan. For those exposed, protocols for treatment and decontamination must be available. And for animal and plant exposures, an effective disposal and decontamination plan must be in place. For communicable diseases in particular, given the potential for initial exponential growth in the number of cases from a single diseased individual, it is crucial that a variety of methodologies, both prophylactic and reactive, be developed for limiting spread. These include vaccination, treatment, quarantine, movement restrictions, isolation and, in the case of nonhuman populations, culling. Because the potential for spread is determined by the number of secondary infections per primary infection, success in management can be achieved by a combination of reducing the infectious period and reducing transmission (National Academy of Science, 2010).

Studies must be done to develop decision rules and procedures for quarantine. These studies must be conducted with the goal of ultimately involving active participation of communities well before any event occurs. This will help reduce panic and irrational behavior in the case of an actual or suspected bioterrorism event. Quarantined communities must know where they will get medical care, antibiotics and vaccines, clean water, food and mortuary service if the need arises. A systems-level approach to dealing with bioterrorism threats, especially those involving communicable diseases, is needed. This approach must consider the integration of multiple modes of management, risk analysis in the face of inherent uncertainties concerning what agents will be introduced and potential interactions among multiple biological agents (National Academy of Science, 2010).

Investigations are conducted into the pathogenesis of bioterrorist infectious agents. Knowledge on the mechanisms of pathogenesis of all bioterrorist agents and of host responses to them is reviewed and action plan initiated to conduct laboratory research using the latest molecular biology tools. This research enhances understanding of the points at which these threats are most susceptible to useful intervention and will help identify new targets for developing diagnostics, drugs and vaccines. Microbial forensics and analysis of trace evidence reduces the major vulnerabilities of the overall lack of knowledge about how to respond to a given attack, together with the lack of intelligence information to help identify the organisms or chemical agents used in an attack (National Academy of Science, 2010).

All known pathogenic species are uniquely marked and identified by use of a combination of DNA sequence information (occurring naturally) and/or deliberately introduced additional DNA sequences (stegnographic tags). This enables assigning a unique code to every strain and variant, which would help in forensics, attribution and defense. Such tags might even be encrypted. The diversity of existing biological weapons and the ever-increasing number of possibilities through use of genetic recombination preclude simple therapeutic countermeasures to bioterrorism. Technoscience is into developing antimicrobials and antivirals (National Academy of Science, 2010).

New directions in materials research include developments in nanotechnology, which offers not only small dimensional size, but also the unique inherent properties of nanomaterials. Examples of such technology with application in crime research include photo-luminescent quantum dots with tuneable spectra to enable encoding of items using multiple dots, silicon-based nanoparticles with various coatings for different applications (e.g., fingerprint detection) and metal nanoparticles with selective recognition sites (used to detect drugs, bioagents and others, i.e., by a change in colour). Further objectives could include photoluminescent quantum dots in car paint finishes or glazing to enable easier identification of stolen cars or those involved in accidents and anti-mugging sprays that are chemically serial numbered to facilitate identification of attackers (RSC, 2005).

However, a lack of cost-effectiveness of such developments may prevent their widespread use in counter-crime initiatives. On the other hand, the textile industry, having suffered a decline through competition from cheap imports, is experiencing a revival with the introduction of technology into the fibres to provide means of identification in the fight against counterfeit crime. Peculiar shapes and sizes of metal threads; machine-readable dyed-in codes; magnetic coding and patterns in the fibres are some concepts being developed or used (RSC, 2005).

Whilst vandalism is not classed as serious crime, it significantly affects the behavior and well-being of individuals and the general public. A cost-effective, functional replacement for glass which is not so dense as to affect the performance of cars, tube-trains and house structure and can also replace bottles and drinks glasses would be near the top of a wish list for countering damage and injury. Other transparent materials exist but they do not meet all the requirements. Additionally, could smart self-healing glass or coated glass be made at reasonable cost for particularly vulnerable locations There is also scope for development of materials for remedial clean-up. There are materials that can be used to facilitate post-graffiti cleaning of pre-impregnated stone and brick, but they are not widely applied, possibly on grounds of high cost and low effectiveness. Also, the range of chemical cleaners is restricted to those that can be used safely by operators in the street. The possibility of transferring other methods of cleaning from the chemistry laboratory is worth investigating. In a similar vein, the cost of removing chewing gum from streets and public places is enormous and could be eliminated by designing biodegradable gum. In addition to experimental developments, there is a fundamental need for modeling studies and verification of surface properties of novel materials, in particular simulation modelling of formulations, to facilitate processing and structural engineering (RSC, 2005).

There is enthusiasm among the academic community to explore new areas of materials research of direct relevance to crime reduction. However, research needs to be more focused and with clearer direction. Moreover, the importance of early dialogue between the academic community and agencies that fight crime is essential. To facilitate such dialogue the needs of police and other law enforcement officers should be articulated as a detailed operational requirement, perhaps *via* a website or focused workshops, to inspire materials scientists to focus on the crime agenda. A particular example of the needs of the police service relates to the chemical reagents and dyes used to detect fingerprints and other traces. As the chemical industry reacts to environmental, safety or commercial pressure, key components of these formulations become obsolete and reformulation is necessary. The need for effective delivery of active components to surfaces is paramount and innovation in this key area of crime detection is essential. Materials chemists are able to provide numerous novel composites, fibres and particles, etc., which are stronger or lighter/ smaller or provide a smart surface. The challenge is to develop these materials into products suitable for the law enforcement agencies in order to help with the crime detection, prevention and control agenda (RSC, 2005).

Security organs and researches function best as networks. Already, there are cognate networks for video-based biometrics, identification science, surveillance technology and crime science. These and other networks deserve support, in order to attract and harness the skills of natural scientists and engineers to engage in research that will produce and improve innovative technical approaches to prevent, detect and control crime in partnership with users. There is the need to develop and coordinate bioterrorism forensics capabilities and to establish this new multidisciplinary, multilayered field. While it might take 1-3 years to develop a new biological weapon, the average development time of a new drug or vaccine is 8-10 years. Thus with respect to development of counter-measures for biological weapons, a great need exists for broad-spectrum antibiotics and antivirals (RSC, 2005).

CONCLUSIONS

By equipping the world with tools for crime detection, prevention and control, technoscience is improving safety of living environment, personal and property security, proof and identity and authenticity. Some of the technologies developed for combating crimes include handwritten documents, handwriting analysis, security screening, speaker recognition, crime scenario modelling, video analysis and control, detecting unusual activities on video, video evidence recovery, video wireless LANs, biological agent detection, chemical agent detection, face recognition, security critical systems analysis, illegal materials trafficking, security marking materials, age-at-death analysis, data encrypting, people and property tracking, PCR development, latent fingerprint chemistry, fingerprint imaging, textile security marking, millimeter wave imaging, internet criminal detection, bomb blast protection, witness identification, luggage examination systems, fast protein profiling, enhanced resolution imaging, MM-wave imaging and algorithms for automatic detection of threats (detection of concealed weapons) and countering bioterrorism in three major areas of prevention, response and recovery.

It is recommended that a larger allocation of resources, particularly financial, be made to the research and development of the technologies that will make a significant contribution to fighting crime and improving the workings of justice in the future. At present nearly all the development and introduction of new technologies is done by the private security industry, which itself needs better coordination, management and recognition as an industry. This industry can and should, play a larger role in crime prevention and criminal justice, particularly in the technology field.

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LIST OF ACRONYMS

ESI-MS	=	Electrospray Ionisation Mass Spectrometry
FTIR	=	Fourier transform infrared spectroscopy
GC-MS	=	Gas chromotagry-mass spectrometry
HLPC	=	High Performance Liquid Chromatography
ICP MS	=	Inductively coupled plasma mass spec
IMS	=	Ion mobility spectrometry
LCN	=	Low copy number DNA-perversely 34 PCR cycles rather han 28
LOAC	=	Laboratory-on-a-chip
MALDI	=	Matrix Assisted Laser Desorption Ionisation
MARS	=	Wave and magnetic acoustic resonator sensor
MEMS	=	Microelectromechanical system
MS	=	Mass spectrometer/y
NDNADB	=	National DNA database
*NIR	=	Near-infrared spectroscopy
PCR	=	Polymerase chain reaction
*QCM	=	Quartz crystal microbalance
REVS	=	Rupture Event Spectroscopy
SAW	=	Surface acoustic wave scFv single chain fragment variable
*SEM	=	Scanning electron microscopy
SERS	=	Surface enhanced Raman spectroscopy
SERRS	=	Surface enhanced resonance Raman spectroscopy
SNP	=	(pronounced ‘snips’) single nucleotide polymorphism(s)

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