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EXPERIENCES, CHALLENGES AND THE FUTURE DIRECTION OF FORENSIC DNA DATABANKING IN MALAYSIA

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Abstract: The Forensic DNA Databank of Malaysia (FDDM) was officially established in December 2015 following the enactment of the Malaysian DNA Identification and DNA Identification Regulation Acts in 2009 and 2012, respectively. In this review, we highlight, for the first time, our experiences during the development of FDDM that now contains nearly 75,000 entries (0.23 % of DNA profiles potentially available from the entire population of Malaysia). These consist of short tandem repeat (STR) DNA profiles obtained from crime scenes (4,396), suspects (22,828), convicted offenders (32,403), detainees (211), drug dependants (9,740), missing persons (164) and volunteers (4,828). The last category are mostly family members of crime victims or FDDM staff. The new database has shown an increasingly important role in helping law enforcement agencies in Malaysia since its establishment, despite several challenges like shortage of technical expertise and funding. New recommendations, such as the adoption of next-generation sequencing capable of typing multiple genetic loci in a single reaction set up, even from trace and degraded forensic samples, are discussed. This could help empower the role of FDDM for criminal investigations in Malaysia.

KEYWORDS: Forensic, DNA databank, crime scenes, genetic loci

Introduction

The human genome contains several highly variable regions known as genetic markers and they differ considerably between individuals and populations. One such marker, known as short tandem repeats (STR), is widely used for forensic DNA profiling. These are small repetitive elements (di-, tri- and tetra-nucleotide repeats) that are found abundantly in genomes.

STR patterns are highly unique (except identical twins) and have become a valuable analytical tool to identify suspects in criminal investigations. One outstanding example of the utilisation of STR analysis was in the murder of Maureen McKinnel in New Zealand. Here, DNA profiling had helped solve a 16-year-old case (Institute of Environmental Science & Research, New Zealand, 2005), where the victim was strangled in her home on Boxing Day 1987, and a week later, her body was found on the rocks below Arrow River Bridge near Arrow town in Otago.

An unknown male DNA was found under McKinnel's fingernails, but no single individual was identified. The case remained unsolved until it was reopened in 2003, when DNA profiles from the victim and the unknown male suspect were added to the New Zealand DNA database. In the following year, Jarrod Allan Mangels was arrested for disorderly conduct and agreed to give a voluntary blood sample for DNA profiling. This was subsequently compared with those stored in the DNA databank and, surprisingly, it matched the record for the sample recovered from McKinnel's fingernails. In 2004, he pleaded guilty to the murder in Invercargill High Court and was sentenced to life imprisonment with a minimum non-parole period of 10 years.

In light of the case above, there is no doubt that forensic DNA analysis and a DNA databank can help solve criminal cases, even if the crime took place years ago (known as 'cold cases'). In fact, forensic DNA technologies and DNA data banking have been widely applied by law enforcement agencies in many countries and have helped identify individuals in criminal investigations in the United Kingdom, United States, Germany, Austria, France and The Netherlands (Jobling & Gill, 2004; Smith *et al.,* 2012). In the following sections, we discuss the implementation of forensic DNA profiling in Malaysia, with past experiences and future of the national DNA databank.

Malaysian DNA Legislation: The DNA Identification Act 2009 and DNA Identification Regulations Act 2012

The establishment of the Malaysian DNA database began with a cabinet decision in 2001 to request help from foreign experts in solving homicide cases. The minister in the prime minister's department then had suggested for the establishment of a forensic DNA database unit under the Royal Malaysia Police (RMP) to facilitate these efforts.

In 2004, a series of discussions on a new DNA identification bill took place between officials of the Biology Division under the Royal Malaysia Police Forensic Laboratory (RMPFL) and legal officers from RMP, the legal advisory office of the Home Affairs Ministry, and the Law Revision and Law Reform Division of the Attorney-General's Chambers. A final draft of the DNA bill was submitted to the Attorney-General's Chambers via the Home Affairs Ministry's legal adviser on 27th September 2007.

The DNA Identification Act 2009 (Act 699) and the DNA Identification Regulations 2012 [P.U. (A) 274/2012] were enacted on 3rd September 2012. Their purpose is to establish the Forensic DNA Databank of Malaysia (FDDM).

The entire function of FDDM is to legally store DNA profiles and any related information to be used for human identification in forensic investigations. It stores the data of analyses carried out by the Chemistry Department (KIMIA), police or any government agency designated by the home affairs minister. The data is also used to locate missing people and identify human remains. It is interesting to note that, before the enactment of the DNA Identification Act 2009, DNA profiles could only be accessed by KIMIA chemists from casework files. They had to get new samples from suspects and perform direct comparisons on a case-by-case basis. If there was no suspect, then the case would remain unsolved.

The RMP was first to take the initiative to set up a committee comprising police officers and KIMIA chemists. The DNA Databank Steering Committee was established in 2005 as a body responsible for developing a national DNA database in Malaysia. Most of the police representatives were officers from the RMP Forensic Laboratory and Legal Division, while those from KIMIA were forensic chemists. At the inception of this project, two subcommittees were initiated; a Legislative Subcommittee and Scientific and Technical Subcommittee. The Legislative Subcommittee facilitated legal research and reported on legal implications of the national DNA database, which helped in drafting the bill. These tasks were all led by the RMP Legal Division in Bukit Aman. The Scientific and Technical Subcommittee was formed to recommend systems to manage the new national DNA database.

In accordance with Section 7 of Act 699, access to the DNA databank is limited only to a gazetted officer, who is either the head of the DNA databank, the deputy head or officers designated by the home affairs minister. The authority and responsibilities of the databank head were also described in detail. They covered the management, control, and supervision of the Malaysia DNA databank. The law prescribed that any use of the databank should only be for the purpose of forensic comparison with DNA profiles related to an investigation.

The FDDM was officially established on 1st December 2015 under the jurisdiction of

RMP and KIMIA, and the personnel from both agencies were gazetted as DNA databank officers. Operational details of FDDM are discussed in the following sub-sections.

Type of DNA Samples: Intimate and Non-intimate Samples

According to Section 13 of Act 699, intimate samples are defined as blood, semen or any other tissue or fluid taken from a person's body. They include swabs and samples taken externally (including pubic hair), or internally from a body orifice other than the mouth.

In contrast, non-intimate samples are defined as any hair except pubic hair, samples that are taken from or under a nail, and saliva and buccal swabs that are taken from any part of a person's body other than those that would otherwise be classified as intimate.

The act prescribes that if a person is reasonably suspected of having committed a serious offense, or is a detainee or drug dependent, then an intimate and/or non-intimate sample may be taken for analysis with approval from an officer with the rank of deputy superintendent and above.

Written consent is only required from suspects when taking an intimate sample. No consent is required for obtaining a non-intimate sample. In addition, no action can be taken if a person refuses to give an intimate sample. Besides that, as referred to in Section 13(7) of Act 699, if a person refuses to provide a non-intimate sample or the sample cannot be obtained despite all reasonable effort, then the person may be taken before a magistrate to obtain a non-intimate sample if the court is satisfied that there is reasonable cause. Furthermore, an intimate or non-intimate sample may be taken for forensic DNA analysis from any person who is serving a term of imprisonment to store their DNA profile under specific indices (convicted offenders).

Types of DNA Profiles Stored in FDDM

FDDM contains DNA profiles and related information derived from both intimate and non-intimate samples. Section 3(3) of Act 699 describes seven types of indices. In brief, they are:

1. Crime scene: The crime scene index contains DNA profiles that are found on a person, any object or at any place where an offense was committed (including within or on the body of a victim, or carried by the victim at the time when the offense was committed).
2. Suspect: This index contains DNA profiles that are taken from a particular individual reasonably suspected of having committed an offense and includes suspects who have not yet been charged in any court.
3. Convicted offender: Contains DNA profiles of convicted individuals.
4. Detainee: The detainee index contains DNA profiles obtained when a sample has been taken from a detainee under the Dangerous Drugs (Special Preventive Measures) Act 1985 [Act 316 as on 1st January 2006]
5. Drug dependant: This index contains DNA profiles from known drug-dependent persons.
6. Missing person: The missing person index contains DNA profiles where a sample is taken from the body or parts of the body of an unidentified deceased individual or from an artifact belonging to a missing person (e.g. toothbrush), or from the next-of-kin of the missing person.
7. Voluntary: Voluntary index contains DNA profiles from samples that are taken from those who voluntarily give their DNA records to be stored in FDDM. They include reference DNA profiles from family members of victims and staff of the FDDM unit.

DNA Sample Retention and Removal of DNA Profiles from FDDM

The new DNA database has become a valuable information source and intelligence tool for law enforcement agencies. However, it is desirable that DNA profiles of innocent individuals be removed from all databases (Balding, 2002). In reference to Section 17 of Act 699, the head of the DNA databank shall safely and securely store

all intimate and non-intimate samples that were collected for forensic DNA analyses. However, any collected biological samples should be destroyed and DNA profiles stored in FDDM be removed under the following scenarios;

1. Investigations reveal that the person is someone who is not involved in the commission of any offense;
2. The charge against them in respect of any offense is withdrawn;
3. They are discharged by a court for an offense which he/she has been charged in trial;
4. On appeal, he/she is acquitted of an offense which they have been charged in an earlier at trial and found guilty; or,
5. On appeal, a person is not charged in any court for any offense within a period of a year from the date the samples were taken.

FDDM: Development and Current Progress

The first step in establishing the FDDM was to purchase a fully-automated MP I FTA card puncher, MP II robotic liquid handler (Perkin Elmer, Waltham, Massachusetts, USA) and an ABI 3100 genetic analyser (Applied Biosystems, Forster City, California, USA) to be located at RMPFL in Cheras, Selangor. The RMPFL adopted the DNA database system from the Institute of Environmental Science & Research, New Zealand (FEEDS).

In the early phase, 300 DNA profiles (sourced from crime scenes and reference samples from KIMIA and RMPFL) were stored in FDDM. The future began looking positive for FDDM when RMP applied for DNA laboratory accreditation from the Department of Standards Malaysia (MS ISO/IEC 17025:2005), and police officers were sent for specific DNA analyst training at various local and international institutions.

The European Network of Forensic Science Institutes (ENFSI) DNA Working Group (2017) recommended that a DNA laboratory should at least be ISO-17025 (or national equivalent) accredited and subjected to challenging proficiency tests. Ultimately on 4th September 2013, the RMPFL was awarded the MS ISO/IEC 17025: 2005 certification by the Department of Standards Malaysia and, to date, is manned by 15 fully-trained analysts. At the same time, RMP is collaborating with KIMIA to conduct proficiency tests in its DNA laboratory every year because this is necessary to maintain the accreditation of its DNA analysis services (ENFSI DNA Working Group, 2017).

DNA Sampling

Blood or buccal cells are the most common biological samples in DNA analysis (Brito *et al.,* 2011). The RMP relies exclusively on buccal swabs to collect samples from suspects, detainees, drugs dependents, volunteers and missing person's next-of-kin. Blood samples and other intimate samples can only be taken by government medical practitioners and they are sent to KIMIA for analysis under the DNA Identification Act 2009.

For the police, buccal cell samples are collected by a trained officer at a One-Stop Forensic Identification Centre (PIFOS) in any one of the 160 police district headquarters nationwide. Each PIFOS is equipped with buccal cell sample collection kits, which comprise the donor's information card, gloves, face mask, user instructions and a DNA collection device. Each buccal swab sampling kit is bar-coded and these are used as a unique identifier for each sample as they move through the various stages of collection before being sent for analysis at RMPFL, where the profile will be loaded into FDDM.

Analyses of DNA Samples

Up to the end of 2016, DNA profiling at RMPFL was performed using the AmpFlSTR® Identifiler® direct polymerase chain reaction (PCR) amplification kit (Applied Biosystems, 2009). This was a multiplex assay optimized to amplify 16-STR loci (D8S1179, D2S1338, D21S11, D19S433, D7S820, vWA, CSF1PO, TPOX, D3S1358, D18S51, TH01, Amelogenin, D13S317, D5S818, D16S539 and FGA) directly

from a buccal sample without resorting to DNA extraction. Target STR loci were amplified from a 1.2 mm punch of each sample template, in a reaction volume of 25 µl, using the GeneAmp® PCR System 9700 thermocycler (Applied Biosystems, 2009). Capillary electrophoresis was carried out using a 3500xL genetic analyzer and the GeneMapper™ ID-X ver. 3.2 software was used to analyze the data.

In 2017, RMP began using a 24-STR loci typing kit called the GlobalFiler® PCR amplification kit, which was also supplied by Applied Biosystems. This new kit covered the same 16-STR loci in the AmpFlSTR® Identifiler® kit, as well as eight additional loci (D22S1045, Y-INDEL, SE33, D10S1248, D1S1656, DYS391, D12S391 and D2S441).

The smaller DNA profiles produced by older kits will be upgraded (if possible) after a match has been discovered in the national DNA database. This is to decrease the possibility of an adventitious match and for them to be comparable with DNA profiles stored in other countries (ENFSI DNA Working Group, 2017). Despite the kit upgrade, both old and new STR typing kits used by RMPFL have included a far larger number of STR loci compared with 12 used by other law enforcement agencies, such as Interpol and ENFSI (INTERPOL, 2009; International Forensic Strategic Alliance, 2014).

Uploading DNA Profiles to FDDM

There are two sources of DNA profiles for the databank. The police upload their reference profiles from buccal swabs taken at PIFOS centres while KIMIA uploads its profiles from crime scene samples, intimate samples, samples from unidentified remains and those from artifacts of missing persons.

Numbers of DNA Profiles Stored in FDDM

To date, RMPFL has analyzed 74,570 buccal swabs since its accreditation in 2013. A total of 63,266 samples were analyzed using the AmpFlSTR® Identifiler® kit while the recent 11,304 samples were processed using the GlobalFiler® kit (Table 1).

The population of Malaysia was around 32,356,876 in 2017, thus FDDM currently stores around 0.23 % of the total DNA profiles potentially available from the whole population. Convicted individuals form the largest fraction in FDDM, followed by suspects and drug-dependent persons.

Table 1: Types of DNA profile stored in FDDM.

DNA Database Indices	AmpFISTR® Direct PCR Amplification Kit (16 loci)	GlobalFiler® PCR Amplification Kit (24 loci)
Crime scene*	396	0
Suspect	22,792	36
Detainees	183	28
Drug Dependent	6,506	3,234
Convicted	24,600	7,803
Volunteers	4,786	42
Missing person	3	161
Total	**63,266**	**11,304**

*crime scene and dead body profiles.
Source: Data were obtained from DNA Databank Division (D13), Criminal Investigation Department, Royal Malaysia Police.

Number of Hits in FDDM

Between 2016 and early year 2018, only 21 matches were recorded from the DNA profiles stored in FDDM. The comparison sources of these matches are given in Table 2. This number of hits was only 0.03 % of the total of DNA profiles deposited in FDDM, and was considered

quite low compared with the numbers reported in the United Kingdom National DNA Databank (UKNDNAD) and New Zealand DNA Databank — around 13 % to 33 % (Harbison, *et al.,* 2001; Martin, 2004).

This might due to a low number of DNA profiles in FDDM (74,570 vs. 2.4 million in UKNDNAD). In addition, FDDM was only launched at the end of 2015 while other national DNA databases had been operating for more than 15 years (Schneider & Martin, 2001; Harbison *et al.,* 2001; Martin, 2004; Voegeli *et al.,* 2006). In our opinion, FDDM has great potential to be an effective crime prevention and investigation tool in Malaysia and a larger number of hits will appear as more DNA profiles are uploaded into the system.

Table 2: Numbers of hit matches from FDDM.

No.	Type of offense	Hit indices
1	Rape	Drug Dependent vs. crime scene
2	Rape	Suspect vs. crime scene
3	Rape	Suspect vs. crime scene
4	Rape	Convicted vs. crime scene
5	Rape	Convicted vs. crime scene
6	Rape	Convicted vs. crime scene
7	Rape	Convicted vs. crime scene
8	Rape	Crime scene vs. crime scene
9	Housebreaking & Rape	Convicted vs. crime scene
10	Housebreaking	Drug Dependent vs. crime scene
11	Housebreaking	Suspect vs. crime scene
12	Housebreaking	Crime scene vs. crime scene
13	Possession of an unlawful firearm	Suspect vs. crime scene
14	Gang-robbery	Suspect vs. crime scene
15	Gang-robbery	Suspect vs. crime scene
16	Gang-robbery	Suspect vs. crime scene
17	Gang-robbery	Convicted vs. crime scene
18	Murder	Suspect vs. crime scene
19	Murder	Suspect vs. crime scene
20	Murder	Suspect vs. crime scene
21	Murder	Crime scene vs. crime scene

Source: Data were obtained from DNA Databank Division (D13), Criminal Investigation Department, Royal Malaysia Police.

Legal Aspects Associated with Sharing DNA Profiles Stored in FDDM

Malaysia has been an active member of Interpol since September 1961. The Interpol National Central Bureau (NCB) of Malaysia is directly under the command of the inspector-general of police. Member countries can submit DNA profiles to Interpol's automated database known as "DNA Gateway", which contains more than 155,000 DNA profiles contributed by more than 70 countries (Interpol, 2017).

The DNA Gateway regularly detects links between DNA profiles submitted by member countries and their database. Analysts can access the database via the global police communications system and this process can be extended beyond the member country's National Central Bureaus to include their forensic centres

and laboratories. Based on Act 699, the head of FDDM may share DNA profiles from unknown crime samples with foreign law enforcement agencies or Interpol. In order to protect the privacy rights of all data stored in FDDM, both personal DNA profiles and related information will remain strictly under FDDM custody. However, they may still be compared with crime scene DNA profiles submitted to DNA Gateway.

Ethics and Issues Related to Forensic DNA and DNA Databank in Malaysia

The concept of DNA profiling is an essential element in forensic science and involves many contemporary scientific, ethical, legal and human rights issues (Gamero *et al.,* 2006; Van Camp & Dierickx, 2008; Kaye, 2009; Taylor & Colman, 2010; Voultsos *et al.,* 2011). Thus, the establishment of the DNA database has been controversial and will continue to generate public debate. Some people think that DNA profiles from individuals should not be kept in any sort of DNA database to protect their privacy and liberty. Many countries have enacted laws and have strict policies relating to forensic DNA and DNA profiling.

In the Malaysian context, the DNA bill was first read in Parliament on 18th August 2008. It caused much controversy regarding its provisions, timing, speed and purpose. Some members of parliament argued that the proposed bill had political motives and these were vigorously debated (Munir & Yong, 2008). The lawmakers said the Data Protection Act should have been passed and implemented before the DNA bill. Their reasoning was that there were grave concerns pertaining to the provisions of the DNA bill, especially those related to data protection. The collection of the personal data that were processed and stored in the DNA databank must be organized in accordance with data protection principles. Other strongly debated issues included the collection and profiling of intimate and non-intimate samples. These had since been fully covered by the DNA Identification Act 2009 and DNA Identification Regulation Act 2012.

Challenges and Future Direction of Forensic DNA Profiling and DNA Databank in Malaysia

DNA technology has developed considerably and lots of new discoveries have been made that benefit humankind. This is especially true in forensic science. Progress in DNA technology has driven the application of DNA analyses in criminal investigations and the development of the DNA databank in Malaysia. The following sub-sections discuss the future challenges and make recommendations for the improved development of DNA profiling and DNA databank management in Malaysia.

Technical Expertise

The major challenge in DNA profiling comes from human factors at every stage of the crime investigation. These include improper handling of biological specimens and misinterpretation of analytical data. Mishandling of biological evidence may result in contamination and DNA sample deterioration. In extreme cases, the integrity of the evidence may even be questioned due to labeling issues. Thus, police officers, especially those from crime scene units, should receive proper training (by RMP or KIMIA) on biological sample collection and preservation.

The accuracy and validity of forensic DNA profiling also depend on the exercise of care at all stages of analysis in the laboratory. The analytical work should not only follow the relevant standard operating procedures, but must be performed by highly-trained and qualified personnel. The same goes for interpretation of results, which in many cases, rely on professional judgment and expertise. Thus, analysts should maintain their proficiency and competency via validation exercises and in-service professional training.

New Genetic Markers for Human Identification

Statistics on violent crime in Malaysia within the last10 years (2008-2017) provided by the Intelligence, Operations and Record Division

(D4) of the Royal Malaysia Police's Criminal Investigation Department (CID) are shown in Figure 1. These reports are collected annually from all states in Malaysia. The RMP classification scheme lists six types of violent crime relevant to DNA profiling; burglary, gang robbery, robbery, snatch theft, rape and murder.

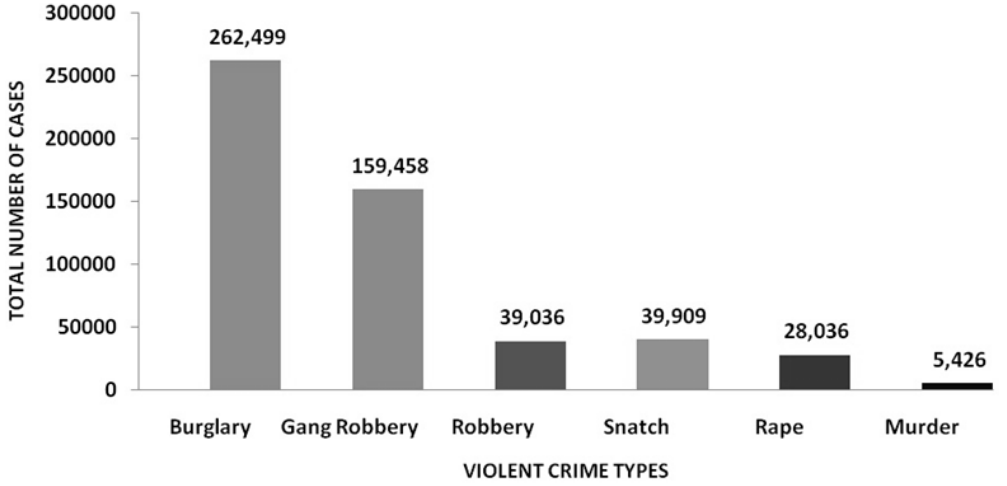

Figure 1: Violent crime cases recorded in 10 years (2008 to 2017).
Source: Data from Criminal Investigation Department, Royal Malaysia Police, Bukit Aman.

Burglary is the most common violent crime. It constitutes 49 % of the total violent crimes recorded Malaysia for 10 years (2008-2017). During their investigations, investigating officers collect contact trace evidence, especially DNA evidence. Furthermore, the perpetrators of such crimes are mostly recidivists. Repeat offenders can be traced within a short period of time if their DNA profile is stored in the national DNA database. If there is no hit, then the unknown DNA profile will be kept in the database for future crime scene vs. crime scene/ suspect matching. In this context, several crimes committed by an individual/gang can be easily tracked.

A total of 28,036 rape cases were reported. Biological evidence from rape cases tend to be a mixture of the victim and suspect DNA profiles. It is important to note that the FDDM does include unknown mixture profiles. Therefore, including additional autosomal loci will not likely solve the problem of identifying perpetrators using the DNA database where the samples are mixed (Ge *et al.,* 2014). In fact, a new marker from the Y chromosome (Y-STR) should be added in the current DNA profiling procedure, especially for sexual assault cases. The paternally inherited Y-STR marker is an extremely powerful way to exclude the majority of potential male donors. This is particularly so when there is only one male contributor in a sample taken from sexual assaults cases (Ge *et al.,* 2011; Myers *et al.,* 2011; Ge & Budowle, 2012).

Special attention should be given to investigations involving missing persons and disaster victims. There are several approaches suggested by the disaster victim identification (DVI) Interpol protocol. These include (but are not limited to) fingerprints, dental records, medical records, distinguishing body marks (including tattoos), personal belongings and DNA profiling. However, identification will always be difficult when it involves old and/or severely damaged biological specimens (e.g. burnt or decomposed remains). In Malaysia, DVI via dental morphology is often difficult because some Malaysians over 10 years of age either do not, or only rarely, go for dental check-up. Thus, DNA profiling methods, particularly mitochondrial DNA (mtDNA),

is often the last resort for finding missing persons and DVI. Molecular signals from this maternally-inherited DNA marker are relatively resistant to degradation because it exists in larger copies than nuclear DNA. Therefore, it would be a potentially useful approach if RMP/KIMIA could establish a mtDNA genotyping methodology in their laboratory and include mtDNA profiles as part of FDDM.

To overcome the current and future challenges in missing person identification, crime scene sample testing (particularly mixture analysis) and DVI, the forensic DNA service and DNA databank should include a comprehensive set of genetic markers (e.g. mtDNA and Y-STR) coupled with the additional autosomal STR systems now used. It is believed that the inclusion of these new markers will allow for a better analysis of mixture samples and support clarification of kinship in missing person identification (Ge *et al.,* 2014). The latest molecular technology using next-generation sequencing (NGS) platforms are able to type multiple genetic loci from a number of samples in a single reaction set-up. In addition, NGS only requires a tiny amount of DNA template in a sample. Thus, it is highly suitable for trace and degraded forensic samples collected from human remains and crime scenes. Overall, there is an obvious need for the inclusion of multiple genetic markers in forensic DNA analysis, and NGS seems to offer the best way forward (Jager *et al.,* 2017).

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DNA technology has developed considerably and lots of new discoveries have been made that benefit humankind. This is especially true in forensic science. Progress in DNA technology has driven the application of DNA analyses in criminal investigations and the development of the DNA databank in Malaysia. The following sub-sections discuss the future challenges and make recommendations for the improved development of DNA profiling and DNA databank management in Malaysia.

Technical Expertise

The major challenge in DNA profiling comes from human factors at every stage of the crime investigation. These include improper handling of biological specimens and misinterpretation of analytical data. Mishandling of biological evidence may result in contamination and DNA sample deterioration. In extreme cases, the integrity of the evidence may even be questioned due to labeling issues. Thus, police officers, especially those from crime scene units, should receive proper training (by RMP or KIMIA) on biological sample collection and preservation.

The accuracy and validity of forensic DNA profiling also depend on the exercise of care at all stages of analysis in the laboratory. The analytical work should not only follow the relevant standard operating procedures, but must be performed by highly-trained and qualified personnel. The same goes for interpretation of results, which in many cases, rely on professional judgment and expertise. Thus, analysts should maintain their proficiency and competency via validation exercises and in-service professional training.

New Genetic Markers for Human Identification

Statistics on violent crime in Malaysia within the last 10 years (2008-2017) provided by the Intelligence, Operations and Record Division (D4) of the Royal Malaysia Police's Criminal Investigation Department (CID) are shown in Figure 1. These reports are collected annually from all states in Malaysia. The RMP classification scheme lists six types of violent crime relevant to DNA profiling; burglary, gang robbery, robbery, snatch theft, rape and murder.

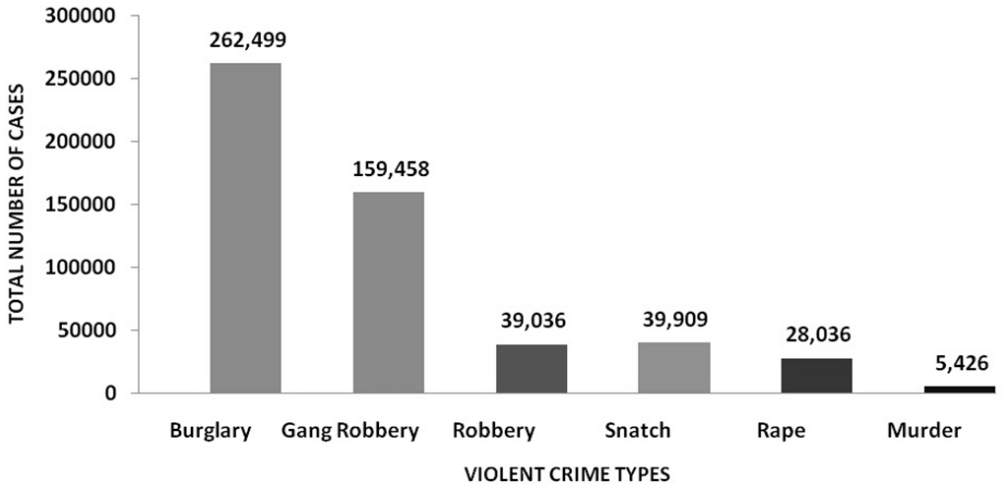

Figure 1: Violent crime cases recorded in 10 years (2008 to 2017).
Source: Data from Criminal Investigation Department, Royal Malaysia Police, Bukit Aman.

Burglary is the most common violent crime. It constitutes 49 % of the total violent crimes recorded Malaysia for 10 years (2008-2017). During their investigations, investigating officers collect contact trace evidence, especially DNA evidence. Furthermore, the perpetrators of such crimes are mostly recidivists. Repeat offenders can be traced within a short period of time if their DNA profile is stored in the national DNA database. If there is no hit, then the unknown DNA profile will be kept in the database for future crime scene vs. crime scene/ suspect matching. In this context, several crimes committed by an individual/gang can be easily tracked.

A total of 28,036 rape cases were reported. Biological evidence from rape cases tend to be a mixture of the victim and suspect DNA profiles. It is important to note that the FDDM does include unknown mixture profiles. Therefore, including additional autosomal loci will not likely solve the problem of identifying perpetrators using the DNA database where the samples are mixed (Ge *et al.,* 2014). In fact, a new marker from the Y chromosome (Y-STR) should be added in the current DNA profiling procedure, especially for sexual assault cases. The paternally inherited Y-STR marker is an extremely powerful way to exclude the majority of potential male donors. This is particularly so when there is only one male contributor in a sample taken from sexual assaults cases (Ge *et al.,* 2011; Myers *et al.,* 2011; Ge & Budowle, 2012).

Special attention should be given to investigations involving missing persons and disaster victims. There are several approaches suggested by Interpol in disaster victim identification (DVI). They include (but are not limited to) fingerprints, dental records, medical records, distinguishing body marks (including tattoos), personal belongings and DNA profiling. However, identification will always be difficult when it involves old and/or severely damaged biological specimens (e.g. burnt or decomposed remains). In Malaysia, DVI via dental morphology is often difficult because some Malaysians over 10 years of age either do not, or only rarely, go for dental check-ups. Thus, DNA profiling methods, particularly mitochondrial DNA (mtDNA), is often the last resort for finding missing persons and DVI. Molecular signals from this maternally-inherited DNA marker are relatively resistant to degradation because it exists in larger copies than nuclear DNA. Therefore, it would be a potentially useful approach if RMP/KIMIA could establish a mtDNA genotyping methodology in their laboratory and include mtDNA profiles as part of FDDM.

To overcome the current and future challenges in missing person identification, crime scene sample testing (particularly mixture analysis) and DVI, the forensic DNA service and DNA databank should include a comprehensive set of genetic markers (e.g. mtDNA and Y-STR) coupled with the additional autosomal STR systems now used. It is believed that the inclusion of these new markers will allow for a better analysis of mixture samples and support clarification of kinship in missing person identification (Ge *et al.,* 2014). The latest molecular technology using next-generation sequencing (NGS) platforms are able to type multiple genetic loci from a number of samples in a single reaction set-up. In addition, NGS only requires a tiny amount of DNA template in a sample. Thus, it is highly suitable for trace and degraded forensic samples collected from human remains and crime scenes. Overall, there is an obvious need for the inclusion of multiple genetic markers in forensic DNA analysis, and NGS seems to offer the best way forward (Jager *et al.,* 2017).

Funding and Data Security

Overall, DNA profilling is well established and up to date in Malaysia. However, to maintain this area of expertise requires funding to support capacity building, infrastructure development and adoption of the latest technology. Funds may come directly from the government or from the private sector. They should be used to support analytical work in the laboratory, staff recruitment and maintain competency among personnel via attendance of professional meetings and training. Thus, funding from the government for agencies and institutions providing forensic services, such as RMP and KIMIA DNA laboratories, have to be monitored and channeled appropriately to avoid creating a delay (e.g. due to backlogs etc.) in our justice system.

Besides economic and technical issues, another challenge for DNA databases is maintaining data security. Access to the FDDM system must be restricted only to officers designated by the home affairs minister and these officers should receive specific training on security risks to the information stored in FDDM. Appropriate precautions should be taken to make sure any information cannot be easily be changed and/or otherwise manipulated in order to maintain the integrity of the system.

Conclusion

Our review highlights several of the major features of FDDM in comparison with those overseas and explains how forensic DNA analysis and the FDDM have helped law enforcement agencies in Malaysia to identify individuals in criminal investigations. However, we feel that several issues, challenges and recommendations described should be given attention by the forensic community and law enforcement agencies in Malaysia. These include new markers for identification, funding and data security. We believe that, if properly resolved, it will contribute substantially towards the successful application of new forensic DNA technologies and secure the integrity of DNA data banking in the country.

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