FORENSIC PROFILING OF HEROIN SEIZED FROM NORTHERN REGION OF MALAYSIA

by

MOHD ZAWAWI BIN YUSOFF

Thesis submitted in fulfilment of the requirements

for the degree

Master of Science

May 2017

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest appreciations to the All Mighty Allah, for his blessings to me and the journey to conduct this research. A special gratitude I give to my wife, my children, parents and family members for their support and considerations during my hard times.

I would like to express my greatest gratitude to my supervisor, Dr. Ahmad Fahmi Lim Abdullah for the interesting and challenging research project, for providing critical advice and the knowledge he supplied over the duration of this project. Special thanks goes to my co-supervisor, Dr. Chang Kah Haw for being endless helpful in providing his valuable advice, suggestions, guidance and encouragement at all stages of my research.

A very big thank you to Dato' Haji Ismail bin Talib, Director-General of the Department of Chemistry Malaysia who permitted me to pursue my postgraduate study. Special thanks to Dr. Chan Kar Weng for initiating the idea and for his strong support at the time the research was conducted. The entire staffs in Department of Chemistry Kelantan branch is also not to be forgotten in their part of this thesis. It would not have been possible without them.

I would also like to specially acknowledge the Science Officer at the School of Health Sciences, Universiti Sains Malaysia for assisting me to conduct my research. Thanks to the Dean of the school who has unconditionally supported my application. Last but not the least, I would like to thank to all my friends and everyone who had directly and indirectly helped me throughout my study.

CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF ABBREVIATIONS, SYMBOLS AND ACRONYMS

≈	About
%	Percentage
°C	Degree Celsius
°C/min	Degree Celsius per minute
µL	Microliter
µm	Micrometer
AADK	Agensi AntiDadah Kebangsaan
ATR	Attenuated Total Reflectance
ATS	Amphetamine-Type Simulant
BEC	Background equivalent concentration
CV	Coefficient of variation
e.g.	*exempli grantia* – for example
et al.	*et alia* – and others
etc.	*et cetera* – and other things
eV	Electron volt
FTIR	Fourier Transform Infra-red
HCA	Hierarchy Cluster Analysis
HS	Headspace
GC	Gas chromatography
GC-FID	Gas Chromatography-Flame Ionisation Detector
GC-MS	Gas Chromatography-Mass Spectrometry
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
i.d.	Internal diameter
i.e.	*id est* – that is
IS	Internal standard
m/z	Mass-to-charge
MAM	6-monoacetylmorphine
MDMA	3,4-methylenedioxymethamphetamine
min	Minute
mg/mL	Milligram per milliliter
mL	Milliliter

mL/min	Milliliter per minute
mm	Millimeter
MS	Mass spectrometry
N + 4R	Normalisation + Fourth root
NIST	National Institute of Standard and Technology
PCA	Principal Component Analysis
QC	Quality control
R^2	Regression coefficient
SD	Standard deviation
UNODC	United Nations Office of Drugs and Crimes
UV	Unit variance

PEMPROFILAN FORENSIK BAGI HEROIN YANG DIRAMPAS DARI WILAYAH UTARA MALAYSIA

ABSTRAK

Kedudukan strategik yang menghubungkan segitiga emas atau Afghanistan telah menjadikan Malaysia sebagai hub transit untuk aktiviti penyeludupan dadah. Sumber heroin yang semakin bertambah, yang berasal dari kawasan-kawasan tersebut, telah diedarkan ke bahagian Asia yang lain serta negara-negara Oceania. Oleh itu, pemprofilan dadah forensik boleh memberikan maklumat yang berguna tentang jalan penyeludupan dan sumber dadah bagi tujuan perisikan. Kajian ini bertujuan mengaitkan hubungan yang mungkin antara sampel dadah yang dirampas dari pelbagai sumber untuk meramal rangkaian penyeludupan heroin di bahagian utara Malaysia. Seratus lima puluh lima sampel heroin rampasan telah diperiksa secara fizikal untuk mengenal pasti warna dan tekstur pada sampel tersebut. Ujian warna Marquis, Foerhde, Janovsky dan Simon telah digunakan untuk tujuan penyaringan. Seterusnya, kesemua sampel dadah yang dirampas telah dianalisis dengan tiga teknik analitikal iaitu Transformasi Fourier Infra Merah dengan Pantulan Penuh Pengecilan (ATR-FTIR), kromatografi gas-pengesan haba pengionan (GC-FID) dan Plasma Ganding Teraruh-Spektometri jisim (ICP-MS). Prosedur kemometrik telah dilakukan ke atas keputusan analitikal untuk pemprofilan kimia dan seterusnya mengkelompokkan sampel-sampel heroin rampasan ke dalam kumpulan yang dijangkakan. Dalam kajian ini, pemeriksaan fizikal telah menampakkan empat jenis warna yang berlainan dan tiga bentuk tekstur antara sampel-sampel yang dirampas. Tindak balas positif pada reagen Marquis and reagen Foerdhe telah menunjukkan berkemungkinan hadirnya bahan yang berkaitan dengan opiat, termasuklah heroin. Satu kaedah GC-FID yang dioptimum dan ditentusahkan telah digunakan untuk

menganalisis sampel. Keadah tersebut membolehkan analisis sampel heroin secara pantas dalam lebih kurang 12 minit per ujian, dan seterusnya membolehkan analisis yang mudah, tepat dan jitu bagi prosedur berkepadatan tinggi yang sering berlaku dalam makmal narkotik. Kehadiran heroin telah dikenal pasti dengan menggunakan kromatografi gas-spektometri jisim. Sebagai tambahan kepada analisis GC, ICP-MS telah membolehkan analisis kuantitatif bagi unsur-unsur surih dalam sampel-sampel rampasan. Unsur-unsur surih yang hadir dalam sampel heroin rampasan boleh disebabkan oleh pencemaran daripada kaedah pemprosesan alatan masakan, dan bahan kimia yang digunakan semasa proses adukan dan pembungkusan. Keputusan analisis FTIR telah dikenakan dengan Analisis Komponen Prinsipal yang mendedahkan pembentukan empat kelompok heroin yang berbeza, iaitu sampel berketulenan tinggi, sampel yang diadukkan dengan polisakarida dan kafein, serta sampel yang berketulenan rendah. Analisis Kelompok Hierarki ekoran analisis FTIR membenarkan pembezaan sampel-sampel dadah kepada sepuluh sub kelompok dengan kemungkinan proses penapisan atau corak adukan yang serupa ketika pengedaran dadah. Secara umum, sampel heroin yang dirampas dari bahagian tengah Malaysia memberikan profil yang nyata berbeza, yang memisahkan mereka daripada sampel yang didapati di kawasan utara. Kemometrik adalah kaedah penerokaan untuk pengekstrakan maklumat tentang punca sampel heroin rampasan serta rantaian pengagihan mereka. Maklumat perbandingan ini menawarkan maklumat perisikan forensik yang berguna untuk bantu dalam mengaitkan kewujudan kelompok jaringan penyeludupan yang berlainan.

FORENSIC PROFILING OF HEROIN SEIZED FROM NORTHERN REGION OF MALAYSIA

ABSTRACT

A strategic location connecting the Golden Triangle or Afghanistan has prompted Malaysia as a transit hub for trafficking activities of illicit drugs. An increasing source of illicit heroin, originating from these regions, has been transhipped to other parts of Asia and also Oceania countries. Therefore, forensic drug profiling could provide useful information on the trafficking routes and the origin of drugs for intelligence purpose. This study is aimed at establishing the possible relationship among the heroin samples seized from different sources for predicting the trafficking network of illicit heroin in northern region of Malaysia. One hundred and fifty-five seized heroin samples were examined physically to determine their colours and texture. Colour tests, namely Marquis, Foerhde, Janovsky dan Simon's were used for screening purposes. Subsequently, all seized drug samples were analysed using three analytical techniques, namely Attenuated Total Reflectance-Fourier Transform Infra-red spectroscopy (ATR-FTIR), Gas Chromatography-Flame Ionisation Detection (GC-FID) and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The analytical results were subjected to chemometric procedures for chemical profiling and subsequently cluster the seized heroin samples into possible groups. In this study, physical examination showed the appearance of four different colours and three varying textures among the seized samples. The positive reactions on Marquis and Foerdhe Reagents have shown the potential presence of opiate related substances, including heroin. An optimised and validated GC-FID method was used to analyse the samples. The method allowed rapid analysis of heroin samples within approximately 12 minutes per run, thus enabled simple, precise and accurate analysis in high

throughput procedure often encountered in Narcotic Laboratory. The presence of heroin was confirmed by using Gas Chromatography-Mass Spectrometry. Additional to GC analysis, ICP-MS has enabled the quantitation of trace elements in the seized samples. Trace elements present in seized heroin samples could be due to contamination from processing methods, cooking utensils and chemicals used during cutting and packaging process. Results of FTIR analysis were subjected to principal component analysis that revealed the formation of four different clusters of illicit heroin, namely samples of high purity, samples cut with polysaccharide and caffeine, as well as samples of very low purity. Hierarchy Cluster Analysis following the FTIR analysis allows the discrimination of drug samples into ten sub-clusters with the possibility of attributing similar refining process or cutting pattern during drug trafficking. In general, heroin samples seized from central regions of Malaysia gave significantly different profiles, separating them from those obtained in northern region. Chemometrics are good exploratory methods to extract information about the origin of seized heroin sample and their distribution chains. This comparative information offers beneficial forensic intelligence to help establish the existence of different clusters of trafficking network.

CHAPTER ONE

INTRODUCTION

1.1. Heroin

Heroin (also known as diamorphine or diacetylmorphine) is a semi synthetic compound from morphine which is present as natural product opium, the dried latex from *Papaver somniferum* (EMCDDA and Europol, 2016) as shown in Figure 1.1.

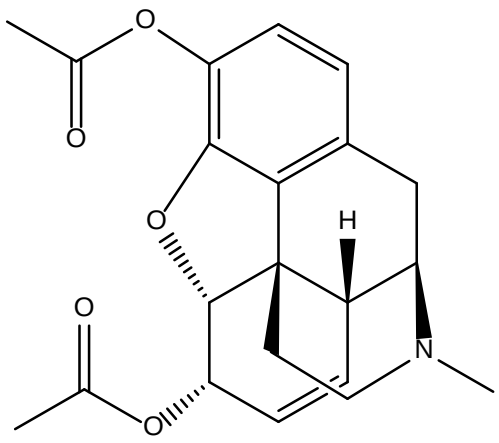


Figure 1.1: Chemical structure of heroin

Heroin is a morphological opiate alkaloid that is present as free base or salts (commonly as hydrochloride salt but sometimes in the form of tartrate or less commonly as citrates) (United Nations, 1998a; Cole, 2003; EMCDDA and Europol, 2016). The first synthesis of heroin was reported in 1874, and was commercially produced by Bayer Company that named it as heroin in 1898 (United Nations, 1998a; EMCDDA and Europol, 2016). In its original medical use, it is meant as a narcotic analgesic for the treatment of pain that comes in the form of liquid or tablets (EMCDDA and Europol, 2016). The illicit heroin is off-white powder which is often abused by smoking, snorting or injecting after being solubilised with a weak acid (EMCDDA and Europol, 2016) depending on its purity. The injectable heroin is often the highest grade

of illicit heroin graded as No 4, *i.e.* the purified hydrochloride salt. Grade No 3 heroin is the purified base form used for smoking, while heroin of grade No 2 and No 1 are unprocessed raw heroin in salt or base form (EMCDDA and Europol, 2016).

1.1.1 Source of Heroin

Heroin is produced from morphine which originated from opium (United Nations, 1998a). The cultivation of opium plants, especially the poppy species of *Papaver somniferum* are the source of heroin. Asia has two major opium production regions in the world as the source for heroin production, the Southeast Asia (mostly Myanmar and Laos People's Democratic Republic), and the Southwest Asia (mostly Afghanistan and Pakistan). Another region of opium production in the word is the Latin America (mainly Mexico, Colombia and Guatemala).

According to the survey conducted by UNODC (2014), in Southeast Asia alone, about 62,000 hectares of opium poppy cultivation were active in Laos PDR, Myanmar and Thailand in 2013. Myanmar continues to be the biggest country cultivating opium with an area of 55,500 hectares with potential opium production of 500-820 tonnes. On the other hand, Laos PDR has an area of about 5,700 hectares with potential opium production of 87-176 tonnes in the latest report by UNODC (UNODC, 2016b). Due to the hilly cultivating areas and lack of proper irrigation, the opium yield in the region is comparatively lower compared to those areas found in Southwest Asia such as Afghanistan, where opium poppy are planted on good soils and flat where better irrigation were received (UNODC, 2014). Generally, opiates from Southeast Asia were supplied to East and Southeast Asia, as well as to Oceania (UNODC, 2016c).

With a total of more than about 183,000 hectares of cultivation land in Afghanistan (UNODC, 2016a), opiate were supplied to the neighbouring countries and countries in Europe, the Near and Middle East, Africa and South Asia (UNODC, 2016c). The opium production in Southwest Asia, especially by Afghanistan dropped significantly (19%) in 2015 and opium harvest was reported to be at its lowest since the establishment of Taliban (UNODC, 2016a). In Latin America region, Mexico was estimated to have opium poppy cultivation of 28,100 hectares with a capacity of opium production of 300-400 tonnes. The main markets for Latin America opiates are the North America and some markets in the South America (UNODC, 2016c).

As indicated by UNODC, opium is produced in about 50 countries worldwide, with global cultivation areas of 281,000 hectares in 2015 (UNODC, 2016c). Though there was a drop of 38% in 2015 from previous year, it was estimated that 4,770 tonnes of opium was produced, where 3410 tonnes were processed to produced 327 tonnes of heroin and the remaining 1360 tonnes of opium were consumed (UNODC, 2016c).

1.1.2 Outline of heroin production and distribution

Morphine is the starting material extracted from opium using the lime method. Several sources have indicated that heroin was synthesised from morphine via acetylation reaction with the presence of acetic anhydride, heated to near boiling and then cooled (United Nations, 1998a; Cole, 2003; UNODC, 2005; EMCDDA and Europol, 2016). The final product, heroin is the isolated by treating the mixture with sodium carbonate when cooled. The heroin base is then collected by filtration (United Nations, 1998a).

Figure 1.2 illustrates an indicative schematic overview of six stages in the production and distribution process of heroin adapted from published source (EMCDDA and Europol, 2016). A detailed review on heroin production and synthesis pathway is subsequently included in Section 2.1. In brief, the cultivation of the poppy species of *Papaver somniferum* provides the opium latex source which is then dried to produce opium. Morphine is extracted using chemicals such as calcium hydroxide and ammonium chloride. The conversion of morphine into heroin is then done via the addition of acetic anhydride and sodium carbonate in a process called acetylation. Adulteration with other cutting agents such as caffeine and paracetamol may occur, prior to packaging and distribution (EMCDDA and Europol, 2016).

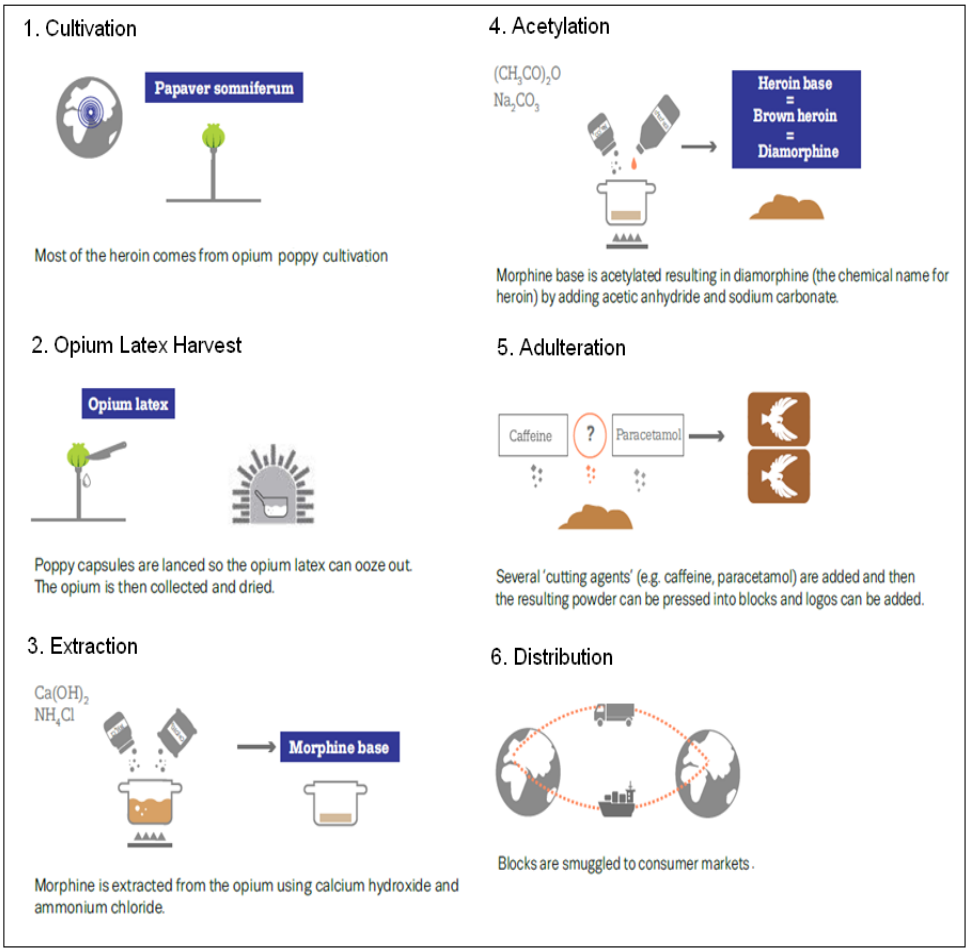


Figure 1.2: Schematic overview of heroin production and distribution (Adapted from: EMCDDA and Europol, 2016)

Figure 1.3 shows the quantities of heroin and morphine seizure by their trafficking route from 1998 to 2014 as reported from the responses to the annual report questionnaires by countries taking part in the survey, and reported in World Drug Report (2016). In 2014, the largest quantities of opiates were seized in South-West Asia, followed by Europe. The Balkan route (marked red in Figure 1.3) through Iran and Turkey via South-Eastern Europe to Western Central Europe is the most important trafficking route. The seizure data also shows an increase in the smuggling of opiates from the Golden Triangle to the markets in South-East Asia (UNODC, 2016c). The heroin from South-East Asia also accounts for about 70- 80% of the total heroin seized in Australia (UNODC, 2016c) indicating the complexity of distribution network.

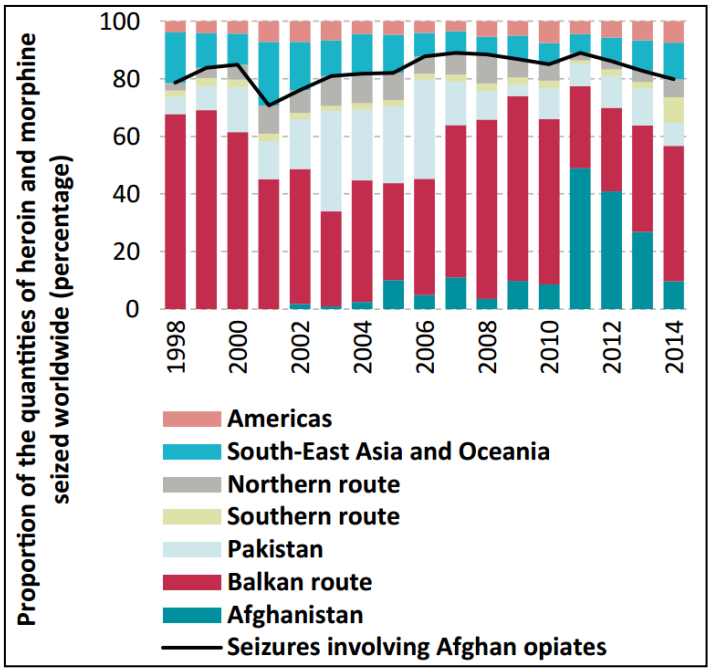


Figure 1.3: Quantities of worldwide seized opiates (heroin and morphine) by trafficking route (Source: UNODC, 2016c)

1.2 Heroin Abuse: The Degree of Problems

UNODC estimated that the numbers of opiate (*i.e.* opium, morphine and heroin) users remain unchanged from previous year at 17.4 million people aged between 15-64 (UNODC, 2016c) out of a total of 33 million opioid users, note that opioid refers to substances that bind to body's opioid receptors, broadly include opiate and other synthetic drugs which produce opiate-like effects, such as fentanyl and oxycodone (EMCDDA and Europol, 2016). In general, the abuse of heroin is responsible for drug-related health and social costs including criminal justice cost. Some countries have seen some signals of increase availability of heroin or purity (as seen in Italy recently) that may pose risk to the users and the potential for new users of heroin (EMCDDA and Europol, 2016).

1.2.1 Heroin Users in Malaysia

The National Anti-Drug Agency (also known as AADK) under the Home Ministry maintains the data of drugs of abuse and published their findings in the form of annual report and is available at http://www.adk.gov.my/. At the time of writing, the latest annual report available was the 2015 report. Table 1.1 shows the number of drug users officially recorded by AADK from year 2012 to 2015.

Table 1.1: Total of users based on types of drug used from 2010-2015

Year	Opiate*	Opium	Methamphetamine	Cannabis	ATS Pills	Psychotropic Pills	Others	Total
2012	8,472	9	4,761	1,427	286	66	80	15,101
2013	16,035	0	2,901	1,885	476	18	46	21,361
2014	14,496	0	4,117	1,919	1774	6	43	22,355
2015	16,616	0	8,133	1,389	1314	1	26	27,479

*includes morphine and heroin

Form the total users, the opiate users form the largest portion of the drugs users registered by AADK, ranging from 56 to 75% of the total drug user populations as shown in Figure 1.4.

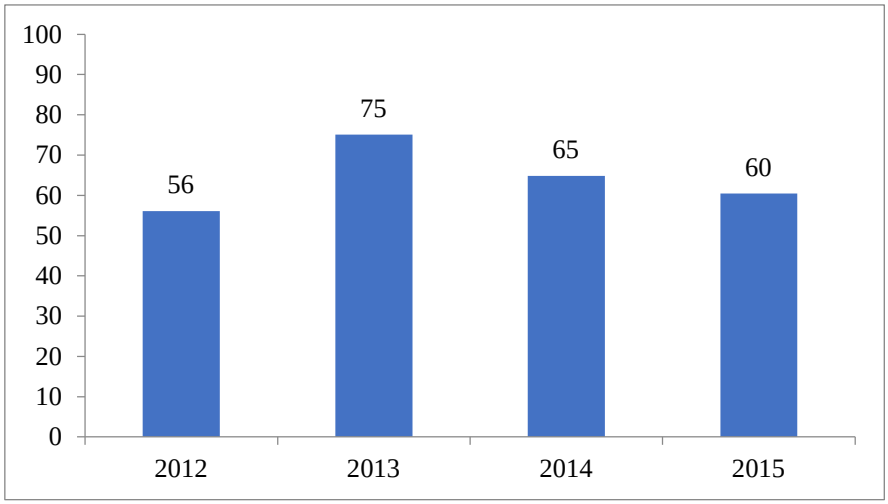


Figure 1.4: Percentage of drug users using opiates (heroin and morphine) from AADK report (Source: AADK, 2016)

From the total number of users nationwide as indicated in Table 1.1, opiate users in the state of Kelantan were about 1000-2000 people registered by AADK. It is important to note that the actual number of unregistered drug user in Figure 1.4 might be much higher than the official data indicated. Nonetheless, there was increasing trend in numbers from 2013 to 2015 that needs serious attention by the authorities as shown in Figure 1.5.

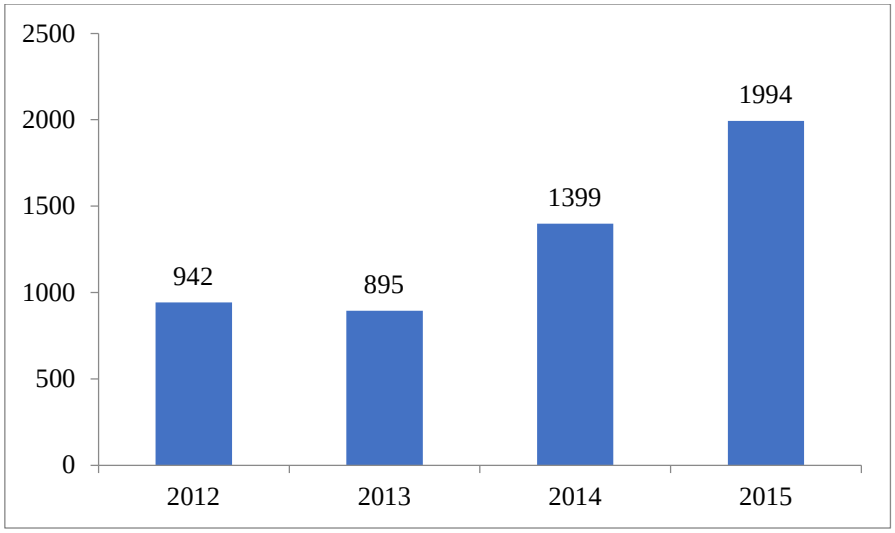


Figure 1.5: Number of drug users using opiates (heroin and morphine) in Kelantan from AADK report (Source: AADK, 2016)

1.2.2 Heroin Seizure

AADK also maintains data of drugs seized collected from several sources including Customs and Royal Malaysia Police. These drugs were categorised into six major classes, namely heroin, cannabis, raw opium, prepared opium, methamphetamine and pill forms of amphetamine-type stimulants and new psychoactive substances. Table 1.2 tabulates the amount and types of seized drugs from 2012-2015.

Table 1.2: Total of users based on types of drug used from 2012-2015

	Heroin (Kg)	**Cannabis (Kg)**	**Raw Opium (Kg)**	**Prepared Opium (Kg)**	**Methamphetamine (Kg)**	**ATS Pills & Others Pills****
2012	410.20	751.08	9.51	2.87	608.67	7,186,558.00
2013	763.12	898.80	0.01	0.30	1,658.51	1,981,101.00
2014	455.82	578.19	0.02	0.11	761.71	2434794
2015	742.57	1,745.20	0.05	0.09	1,141.40	3019521

Beside methamphetamine and cannabis, heroin seizure was in the range of about 410- to 760 kg per year as also indicated in Figure 1.6. If the success rate of smuggling is estimated to be 50%, it is estimated that 800 to 1,500 kg of heroin are circulating in the country, which is a threatening signal to national security and social well-beings.

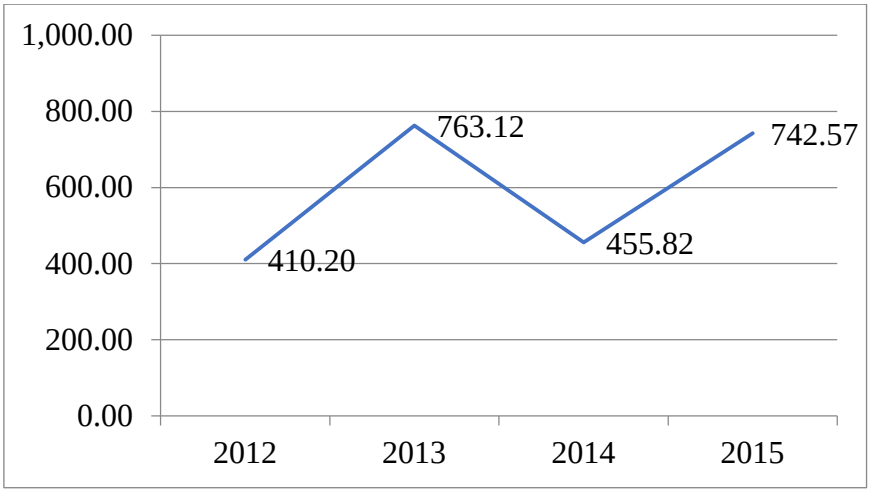


Figure 1.6: Trends in the amount of heroin seizure in kg from 2012-2015 (Source: AADK, 2016)

The data of AADK on the amount of heroin seizure might not have directly reflected the degree of problems as a result of heroin abuse. A better data would be the number of heroin case samples subject to forensic laboratory for analysis. Table 1.3 tabulates the number of heroin case samples submitted for forensic determination in Narcotics Section of Chemistry Department of Malaysia in Kelantan. On average, there were only about 200 cases per month in 2014, but this number has increased by 50% to about 300 cases in 2015. A sharp increase was observed in 2016 where an average of 400 cases per month was received, doubled in amount compared to 2014 (Department of Chemistry Malaysia, 2016).

The increasing trend of number of cases received for analysis may indicate either there was a linear increase in the cases involving heroin or due to a more stringent enforcement. Nonetheless, this increasing trend reflects the degree of heroin related problems in the state of Kelantan.

Table 1.3: Number of heroin case samples submitted for analysis in Chemistry Department of Malaysia (Kelantan Branch).

Month	**Year**		
	2014	**2015**	**2016**
Jan	177	272	374
Feb	233	231	407
Mac	271	297	356
April	266	291	374
May	208	296	445
June	246	398	451
July	240	284	346
August	194	329	483
Sept	244	338	463
Oct	236	327	665
Nov	211	353	428
Dec	245	326	232
Total	2771	3742	5024

1.2.3 Control and Legislation of Heroin

There are three international drug control treaties issued by the United Nations, namely the Single Convention on Narcotic Drugs (1961), the Convention on Psychotropic Substances (1971), and the United Nations Convention against Illicit Traffic in Narcotic Drugs and Psychotropic Substances (1988).

The Single Convention on Narcotic Drug (1961) aims to combat drug abuse via international action. The treaty listed two forms of intervention and control, namely (i) to limit the possession, use, trade in, distribution, import, export, manufacture, and production of drugs exclusively to medical and scientific purposes, and (ii) to combat drug trafficking through international cooperation to deter drug traffickers. Under this convention, heroin and morphine are classified as Schedule I drug (United Nations, 2016b).

The Convention on Psychotropic Substances in 1971 establishes global control over psychotropic substances in responding to the diversification and expansion of the spectrum of drugs of abuse. Controls over a number of synthetic drugs according to their abuse potential on the one hand and their therapeutic value on the other were established. Examples of added drugs in Schedule I are Lysergic acid (LSD), 3,4-methylenedioxy-methamphetamine (MDMA) and cathinone (United Nations, 2016a)

The Convention against Illicit Traffic in Narcotic Drugs and Psychotropic Substances in 1988 reinforces the obligation of countries to apply criminal sanctions against illicit production, possession and trafficking of drugs including provisions against money laundering and the diversion of precursor chemicals (such as acetic anhydride used for heroin production). It also facilitates international cooperation such as extradition of drug traffickers, controlled deliveries and transfer of proceedings (United Nations, 1998b).

In the United States, heroin is an illegal and highly addictive drug. The Controlled Substances Act of 1970 classifies heroin as a Schedule I drug. The possession, sale and trafficking of heroin bring stiff penalties in the United States. Upon conviction, the typical sentencing is long jail time and large fines but may be slightly vary between different states.

In the United Kingdom, heroin is a Class A drug that will lead to seven years in prison and an unlimited fine or both for possession upon conviction, while a sentence of life in prison and unlimited fine or both upon conviction of supply and production of the drug (UK Government, 2016)

In Malaysia, the Dangerous Drugs Acts (1957) regulates the importation, exportation, manufacture, sale, as well as the use of opium and certain other dangerous drugs and substances. Heroin and morphine are Schedule I drugs and possession to supply for such drug leads to heavy sentence. For instance, under section 39B, a possession of 15 g or more heroin and morphine will receive the mandatory death sentence (ACT 234, 1952).

1.3 Problem Statement

Increasing trends on heroin seizures have been reported in Malaysia. Continual supply of heroin would eventually lead to economical loss and deteriorating of general social well-beings. The number of samples submitted for forensic laboratory analysis has also increased annually, indicating the degree of heroin problem. However, little is known about their source of origin and supply chain network that serves as forensic information for law enforcement agencies such as Royal Malaysian Customs Department and Royal Malaysia Police to track down to the source of supply. Currently, routine laboratory analyses are limited to the scope of establishing the identity of the sample and their quantity. Further analytical characterisation is seldom conducted, and therefore a need for the laboratory analyst to explore further information is important.

1.4 Aims and Objectives

The evaluation of physical features or the chemical profiles of heroin samples in a systematic way could be utilised for investigative intelligence. Thus, this study aims to characterise the heroin case samples collected over a period of two years from 2012 to 2014. A number of 145 samples seized from northern region of Malaysia were taken into consideration in the study and compared with ten heroin samples from central region. In order to achieve the aims, three objectives were set as follows:

i. To evaluate physico-chemical characteristics of heroin samples through physical examination and colour tests.
ii. To evaluate the chemical characteristics through instrumental analyses, including ATR-FTIR, GC-FID and ICP-MS.
iii. To perform a comparative analysis of heroin samples using chemometric methods, including PCA and HCA.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews the manufacturing of heroin and the properties of heroin which include both physical and chemical aspects. In addition, the various analytical methods of heroin examination and the profiling of heroin samples are also critically discussed.

2.1 Manufacturing of heroin

The manufacturing of heroin has been briefly outlined in Figure 1.2 in Chapter One via the acetylation process using morphine and acetic anhydride as the starting materials (United Nations, 1998a; Cole, 2003; UNODC, 2005; EMCDDA and Europol, 2016). Zerell *et al.* (2005) had documented a clandestine heroin manufacturing process in Afghanistan. The process started from the extraction of morphine from raw opium by stirring raw opium in hot water until a homogeneous suspension was formed. This was followed by the addition of calcium oxide (anhydrous lime) with addition of more hot water before leaving it to stand overnight. The oily layer was formed as morphine solution. This layer of morphine solution was separated from the water-insoluble opium components. Once separated, ammonium chloride was added to the morphine solution and stirred to precipitate out the morphine base. The precipitation was then wrapped in the filtering cloths and stamped out before leaving it to dry (Zerell *et al.*, 2005).

Alternatively, the conversion of morphine to heroin started with the addition of acetic anhydride (in small excess) to the morphine base. The mixture was allowed to stand for about an hour before being heated for another 30 minutes. The product, the brown heroin base, was

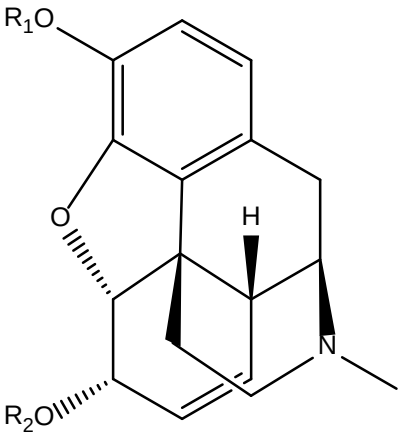
then poured into hot water, stirred and filtered. Sodium carbonate solution was added to precipitate out the brown heroin base. The brown heroin base was then dissolved in diluted hydrochloride acid followed by the addition of activated carbon, in which the activated carbon was subsequently filtered out using filter paper to produce clear heroin solution. The heroin was then precipitated using diluted ammonium solution and filtered through cloth to produce white heroin. Finally, the white heroin base was converted to heroin hydrochloride using hydrochloride acid and a small amount of acetone, filtered and dried (Zerell *et al.*, 2005).

In actual clandestine manufacturing, the authors found that the use of chemical was kept as minimal as possible, due to the restricted availability of some chemicals as well as high cost of transporting chemicals (Zerell *et al.*, 2005). The understanding of such clandestine process is very important for forensic scientist during forensic investigation on drug origin, chemical traces and characteristics of drugs for subsequent profiling work.

It is worth noting that other than the acetic anhydride reaction, a “home bake” method was also reported in New Zealand using pharmaceutical products containing codeine as starting material to prepare morphine and heroin (Bedford *et al.*, 1987). Due to unavailability of morphine in New Zealand, the clandestine chemist used pharmaceutical products containing high proportion of codeine. In this home bake method, codeine was extracted using chloroform and dried as crystalline solid. Codeine was then reacted with pyridine hydrochloride to produce morphine before being converted to heroin using acetic anhydride with a reported conversion rate of about 60% (Bedford *et al.*, 1987). In brief, forensic scientist shall be aware of possible synthesis pathways that could be used, especially when performing a profiling study.

2.2 Physical and Chemical properties of heroin

Heroin is one of the members of morphine group of drugs as indicated in Figure 2.1. Other names commonly used to refer to heroin include diamorphine, acetomorphine and diacetylmorphine. The chemical formula of heroin base is $C_{21}H_{23}NO_5$ with a molecular weight of 369.4 and a melting point of 173°C. The melting point for heroin hydrochloride monohydrate is 243-244°C (United Nations, 1998a).



morphine	$R_1{=}R_2{=}H$
heroin	$R_1{=}R_2{=}OCCH_3$
3-acetylmorphine	$R_1{=}OCCH_3$; $R_2{=}H$
6-acetylmorphine	$R_1{=}H$; $R_2{=}OCCH_3$

Figure 2.1: Structural formula of some morphine group of drugs (Gibson, 1977)

In terms of solubility, heroin base is soluble in carbon tetrachloride whereas all salts of heroin are completely insoluble. Among the heroin salts, heroin hydrochloride is soluble in chloroform and dichloromethane. Heroin tartrate and heroin citrate are insoluble in these solvents (United Nations, 1998a).

2.3 Cutting agents and impurities

Heroin samples are often mixed with other substances generally known as the cutting agents (*i.e.* adulterants and diluents) for various purposes including to increase its profits to the seller (Broseus *et al.*, 2016) or to improve its presentation to the buyers (Schneider and Meys,

2011). The impurities in this thesis refers to the materials found with heroin such as codeine or added to it during processing such as barium from the contaminated lime ($Ca(OH)_2$) used during extraction of heroin (Bell, 2006). The following sections further describes the cutting agents and impurities encountered in heroin.

2.3.1 Adulterants

In forensic drug analysis, adulterants are active ingredients and typically (however not always) have effects "*that are grossly similar to the target drug's effect*" (Bell, 2006). As pointed out by Cole (2003), the reasons for adulterant addition are to either hide the lack of the desired drug, dilute it or add in other effect to the drug mixture (Cole, 2003). For instance, griseofulvin (Andreasen *et al.*, 2009) gave the bitter taste of the drug (Broseus *et al.*, 2016). It is important to point out that the term adulterants are defined differently in forensic toxicology, which is commonly referred to substance added to a biological sample (such as urine) to mask or suppressed the detection of another substances (Bell, 2006).

Several heroin comparative analyses have indicated that caffeine, procaine, meconin and methaqualone were common adulterants (O'Neil *et al.*, 1984; Barnfield *et al.*, 1988; Chiarotti *et al.*, 1991). In a survey conducted by Levy *et al.* (1996) from heroin seizures using FTIR, about 60% of the 2977 cases of heroin powders contain paracetamol (Levy *et al.*, 1996). Together with caffeine and paracetamol, theophylline was detected from heroin samples sourced from several regions in China (Zhang *et al.*, 2004).

Andreasen *et al.* (2009) investigated the composition of heroin seized in Aarhus, Denmark, and the study found that the common adulterants in heroin samples were caffeine and paracetamol, with a frequency of 99% and 97% respectively from a population of 132

samples obtained in 2002-2003. Other adulterants found were griseofulvin and diazepam (Andreasen *et al.*, 2009). When compared to the adulterants found in heroin samples obtained in 1992-1993 (n=146), the frequencies of observing caffeine (78%) and paracetamol (62%) were relatively lower when compared to samples of 2002-2003 while griseofulvin was completely not detectable (Andreasen *et al.*, 2009). Other adulterants encountered in 1992-1993, samples including phenobarbital, piracetam, methaqualone, procaine and barbital, were not detectable in the samples obtained in 2002-2003 (Andreasen *et al.*, 2009). This findings suggested the changes of adulterant choice over time. This was also supported by the findings of Kaa (1994) who have observed the change of adulterant using caffeine, procaine, phenobarbital, mehaqualone and paracetamol over a period of 12 years in Denmark (Kaa, 1994). A most recent reviewed by Broseus *et al.* (2016) indicated that caffeine and paracetamols are almost exclusively detected in heroin exhibits (Broseus *et al.*, 2016). Table 2.1 tabulates possible heroin adulterants sourced from UNODC (2005).

Table 2.1: Heroin adulterants (Source: UNODC, 2005)

Acetylsalicylic acid	Diphenhydramine	*N*-Phenyl-2-Naphthalene
Allobarbital	Gluthetimide	*N*-Phenyl-2-Naphthylamine
Aminophenazon	Griseofulvin	Procaine
Antipyrine	Lidocaine (lignocaine)	Quinine
Ascorbic acid	Methaqualone	Salicylamide
Barbital	Methylphenobarbitone	Salicylic acid
Benzocaine	Nicotinamide	Strychnine
Bisphenol-A	Paracetamol (acetaminophen) (+ acetyl-paracetamol)	Theophylline
Caffeine	Phenacetin	Thiamine
Chloroquine	Phenazon	Xylazine
Cocaine	Phenobarbitone (phenobarbital)	
Diazepam	Phenolphthalein	

2.3.2 Diluents

Several sources have indicated that sugars (*e.g.* glucose, lactose and mannitol) were common diluents (Chiarotti *et al.*, 1991; Kaa, 1994; Dams *et al.*, 2001; Hajdar and Ruzdic, 2003; UNODC, 2005). In an impurity study conducted by Kaa (1994), sugars (especially glucose and lactose) were detected in 67% of the samples (n=233). Mannitol hexaacetate was found in brown heroin seizures by El-Haj (2004), that made the authors to have postulated that mannitol was added before the acetylating step during heroin production (El-Haj *et al.*, 2004), thus could provide certain level of forensic intelligence on heroin production source.

The study by Andreasen *et al.* (2009) on heroin seized in Aarhus, Denmark and found that the diluents in heroin samples were mannitol and sucrose, with a very low frequency of 2% respectively from a population of 132 samples obtained in 2002-2003. When compared to the diluents found in heroin samples obtained in 1992-1993 (n=146), the frequencies of observing glucose was quite high (38%) (note: glucose was not seen in heroin samples of 2002-2003) while the presence of lactose, mannitol and sucrose from samples of 1992-1993 were relatively low, with the frequencies of 18%, 8% and 5%, respectively. Again, the study indicated the changes of diluents can change over time.

It is interesting to mention that the choice of diluents for different drugs also varies as indicated by Andreasen *et al.* (2009) where lactose and sucrose were common diluents in amphetamine samples seized in 2002-2003 (n=140), with a frequency of 65% and 39%, respectively, as opposed to the diluents found in cocaine samples seized in 2002-2003 (n=147) with the frequencies of 38% and 31% of the samples containing inositol and sucrose, respectively (Andreasen *et al.*, 2009). It is also important to note that several sources have

indicated that more than one sugar may be used (Kaa, 1994; Andreasen *et al.*, 2009). Table 2.2 tabulates possible heroin diluents sourced from UNODC (2005).

Table 2.2: Heroin diluents (Source: UNODC, 2005)

Calcium carbonate	Iditol hexa-acetate	Sodium chloride
Calcium chloride	Lactose/saccharose	Starch (usually corn)
Citric acid	Mannitol/mannit/sorbit	Sucrose
Fructose	Phthalic acid	Sucrose octa-acetate
Glucose	Potassium chloride	Tartaric acid
Glycine	Sodium carbonate	

2.3.3 Impurities

Heroin, being a product originally from opium, carries a certain amount of impurities from its opium source, manufacturing process and the chemicals used. Compounds co-extracted such as acetylcodeine and 6-acetylmorphine could remain above 0.5% relative to heroin in some high purity heroin samples (United Nations, 1998a). Codeine, morphine, noscapine and papaverine originally from opium were reported to be the frequent impurity in unpure heroin samples (United Nations, 1998a). 6-acetylmorphine is often associated with the hydrolysis of heroin. The process of hydrolysis was accelerated especially at pH of >9.22 (Zhang *et al.*, 2010). Table 2.3 lists the alkalodial impurities in heroin and their possible sources (UNODC, 2005).

Table 2.3: Major and minor alkaloidal impurities in heroin samples and their typical sources (Source: UNODC, 2005)

Major and minor impurities	Typical sources
Acetylcodeine	Opium, codeine + acetic anhydride (Ac_2O)
3-O-acetylmorphine	Opium, morphine + Ac_2O
6-O-acetylmorphine	Heroin + hydrolysis
Codeine	Opium
Morphine	Opium
Noscapine	Opium
Papaverine	Opium

Note that major impurities are defined as compounds present >1% by weight (w/w), minor components usually present at a concentration of <1% w/w, while the trace components are usually <0.1% w/w which are typically undetectable using routine methods without an extraction step (UNODC, 2005). Some of the trace alkalodial impurities are listed in Table 2.4.

Table 2.4: Selected trace alkaloidal impurities in heroin samples and their typical sources (Source: UNODC, 2005)

Trace impurities	Typical sources
(1R,9S)-1-Acetoxy-*N*-acetyl- 1,9-dihydro-anhydronornarceine	Noscapine + Ac_2O
4-Acetoxy-3,6-dimethoxy-5- [2-(*N*-methyl-acetamido)]ethylphenanthrene	Thebaine + Ac_2O
4-Acetoxy-3,6-dimethoxy-8- [2-(*N*-methyl-acetamido)]ethylphenanthrene	Thebaine + Ac_2O
N-Acetylnormorphine	Morphine + Oxidation (O_2)+ Ac_2O + hydrolysis
N-Acetylnornarcotine	Noscapine + O_2 + Ac_2O
6-O-,*N*-Diacetylnormorphine	Morphine + O_2 + Ac_2O + hydrolysis
Papaveraldine	Papaverine + O_2
Thebaol	Thebaine + Ac_2O + hydrolysis
Triacetylnormorphine	Morphine + O_2 + Ac_2O

The presence of impurities, together with adulterants and diluents in a heroin sample, give a fingerprint of the exhibit, thus enable “chemical fingerprinting” or profiling of drugs samples to establish the possible source of origin, manufacturing process or linkages between samples related to distribution. This is further discussed in Section 2.5.

2.4 Forensic Examination of heroin

2.4.1 Presumptive Test

Presumptive test is used to screen the drugs. A combination of colour tests has been used by forensic laboratories. The tests used for opiates are the Marquis reagent, Mecke Reagent, Froehde Reagent (SWDRUG, 2015) and Mandelin reagent (Cole, 2003). Marquis reagent is prepared carefully by adding 10 mL of 40% formaldehyde (v:v formaldehyde:water) to 100 mL of concentrated sulfuric acid (Velapoldi and Wicks, 1974). Heroin will react to give a blue to violet product on colourless background (Kovar and Laudszun, 1989; Cole, 2003). Mecke reagent is prepared by dissolving 1.0 g of selenious acid in 100 mL concentrated sulfuric acid (Velapoldi and Wicks, 1974). Heroin will react to give a green or blue product (Johns *et al.*, 1979). Froehde reagent is prepared by dissolving molybdic acid in hot concentration sulfuric acid (Velapoldi and Wicks, 1974) and gives purple colour solution upon reaction with heroin (Johns *et al.*, 1979). Lastly, Mandelin reagent consists of ammonium vanadate and concentrated sulfuric acid (Velapoldi and Wicks, 1974). Upon reaction with heroin, an olive (green) coloured solution will appear (Johns *et al.*, 1979).

There are also colour tests for other drugs, commonly used in the Department of Chemsitry Malaysia. Simon’s reagent is common for secondary amine drugs testing, which are prepared by dissolving 1.0 g sodium nitroprusside in 50 mL of water and 2 mL of acetaldehyde. With methamphetamine and MDMA, a dark blue complex will be formed. For Janovsky test, the

presence of ketamine will be detected with the formation of purple precipitate (SWGDRUG, 2015b).

The results of colour tests could be greatly affected by the impurities and dye materials used in heroin samples. Interference from other drugs could occur and therefore interpretation of the results should be done with care. Although a positive control and a negative control tested side by side could serve as good laboratory practice in such case, it is unknown if the application of these colour tests would be easy and straight forward on heroin case samples of varying purities with the presence of colourants commonly encountered in Malaysia.

2.4.2 FTIR

Infrared spectrophotometry has been one of the common analytical techniques in narcotic drug laboratory. This is especially the case with the advent of portable FTIR. The earliest work on quantitative determination of heroin using FTIR was reported by Ravreby (1987). In Ravrevy's study, heroin hydrochloride was analysed and quantified using a carbonyl absorption peak as the analytical peak. The absorbance versus concentration of heroin in KBR disc was measured. The author concluded that mixed samples of heroin free base and hydrochloride could be better quantified by area integration of the two carbonyl peaks at the region in the range of 1720 to 1770 cm^{-1} (Ravreby, 1987).

A survey of heroin seized samples in Israel was conducted by Levy *et al.* (1996) using FTIR technique to scan a total of 3817 samples. Based on the features of the spectra, the authors concluded that it was possible to classify the samples into a large number of groups, and this information could be useful for gross comparison of heroin samples. The authors opined that closely related spectra could indicate the possibility of a common source, but cautioned the

readers that "*the comparison data alone are not sufficient to prove a connection between seizures*" (Levy *et al.*, 1996).

Welbo and Tebbett (1993) used Micro-FTIR for quick analysis of street heroin samples, in conjunction with microcrystal tests. The advantage of FTIR was attributed by its ability for rapid structural confirmation, and in some cases, without the need for extraction (Welbo and Tebbett, 1993). The authors concluded that if the common encountered diluents such as polysaccharides of less than 20% had little or no interference of FTIR analysis (Welbo and Tebbett, 1993).

The spectral features from FTIR could be used for sample differentiation and profiling. Using the fingerprint region of FTIR spectrum of cocaine samples, Marcelo *et al.* (2015) was able to group the samples into cocaine base and cocaine salt, as well as based on adulterants present in the samples. Principal Component Analysis (PCA) and Hierarchic Cluster Analysis (HCA) were used for subsequent sample clustering (Marcelo *et al.*, 2015). In brief, no study on heroin profiling using FTIR has been reported, and therefore, the profiling of heroin sample by ATR-FTIR shall be further explored in Malaysia.

2.4.3 Gas Chromatographic methods

The use of gas chromatograph (GC) since several decades ago has brought huge advancement in separation science, especially on organic compounds including drugs of abuse. With the advent of newer technology, GC coupled with flame ionization detector (FID) and mass spectrometer (MS) become the tool of choice in narcotics laboratories. Several recommended GC methods have long been established for heroin analysis by the United Nations for routine heroin analysis (United Nations, 1998a) as well as for heroin profiling (UNODC, 2005).