

LIST OF FIGURES

Figure 1.1:	Circular flow of income model in illicit drug market	9
Figure 1.2:	Trends in drugs of abuse in Malaysia between 1998 and 2009	15
Figure 1.3:	Distribution of drug addicts in Malaysia between 1999 and 2003	16
Figure 1.4	Seized dangerous drugs according to the category of DDA 1952 in Malaysia between 1998 and 2007	18
Figure 2.1:	Frequency of drugs of abuse submitted for analysis in Malaysia in 2009	30
Figure 2.2:	General scheme of heroin production	31
Figure 2.3:	Opium poppy	33
Figure 2.4:	Flow chart of Thiboumery and Mohr Process	36
Figure 2.5:	Flow chart of Robertson and Gregory Process	37
Figure 2.6:	Flow chart of Barbier Purification	38
Figure 2.7:	Conversion of morphine to heroin base	41
Figure 2.8:	General routes of production of street heroin	47
Figure 3.1:	A general scheme of forensic science	53
Figure 3.2:	General steps for drug analysis	58
Figure 3.3:	General scheme of forensic analysis for evidential purposes	73
Figure 3.4:	General scheme of forensic analysis for intelligence purposes	73
Figure 3.5:	The mutual relationship between metaphysics and drug profiling in the forensic drug intelligence framework	100
Figure 3.6:	A continuum of forensic intelligence	106
Figure 3.7:	A basic concept of holarchy with the relating holons	114
Figure 4.1:	General photographic setup	125
Figure 4.2:	Elements in photography	126
Figure 4.3:	Appearance of different seal patterns	132

Figure 4.4:	Plastic packages showing their widths	133
Figure 5.1:	A map of Peninsular Malaysia showing four major geographical regions from which the illicit heroin samples were sampled	164
Figure 5.2:	Distribution of 311 cases from four geographical regions	166
Figure 5.3:	A comparison of three different original photographs of three samples taken at different times without photo editing	168
Figure 5.4:	Frequency of substance colors in 311 cases taken for profiling	172
Figure 5.5:	Distribution of substance texture in 311 cases taken for profiling	174
Figure 5.6:	A heroin sample unit in a cylindrical shape	175
Figure 5.7:	Frequency of wrapping styles in 311 cases taken for profiling	176
Figure 5.8:	An example of wrapping Type 3a	177
Figure 5.9:	Variation in the weight of substance shown by four cases	179
Figure 5.10:	Frequency of the weight of substance per package encountered in 311 cases	180
Figure 5.11:	Frequency of the weight of plastic packet encountered in 311 cases	182
Figure 5.12:	Frequency of width of plastic packet encountered in 311 cases	183
Figure 5.13:	Boxplots of thickness of commercial plastic packets and case plastic packets measured with two micrometers	186
Figure 5.14:	Frequency of thickness of plastic packet encountered in 311 cases	186
Figure 5.15:	A score plot representing four physical measurements obtained from 296 small packet cases analyzed by PCA in correlation mode, $%V_1 = 44.3\%$ and $%V_2 = 34.9\%$	187
Figure 5.16:	Five types of polymeric films encountered in 311 heroin cases	190
Figure 5.17:	Frequency of plastic encounters according to the geographical region in Malaysia	193
Figure 5.18:	Five spectra of Spot 1 obtained under different conditions	196
Figure 5.19:	Score plots of PCA (correlation mode) decomposed IR data obtained under different conditions	201

Figure 5.20:	Score plots of PCA (correlation mode) decomposed data, the spectral variations measured in Type 1 plastic packets in their respective widths	204
Figure 5.21:	Score plots representing IR data variation obtained from 197 Type 1 cases analyzed by PCA in correlation mode	206
Figure 5.22:	Chromatographic selectivity shown by two GC columns	211
Figure 5.23:	Chromatograms of a sample prepared in PTs and VFs	219
Figure 5.24:	A dendrogram expressed in similarity showing the relationships between ten samples analyzed under different conditions using Single linkage and Euclidean distance	222
Figure 5.25:	A score plot of PCA decomposed GC-FID data in correlation mode of ten samples analyzed under different conditions, %V ₁ = 55.6 % and %V ₂ = 26.4%	223
Figure 5.26:	Score plots of 43 data points obtained from Option 1 and decomposed by PCA	229
Figure 5.27:	Score plots of 43 data points obtained from Option 2 and decomposed by PCA	231
Figure 5.28:	Chromatograms of pre-cut and post-cut samples of B2	234
Figure 5.29:	Boxplots showing the % contents of eight major components encountered in 8 pre-cut samples, 32 post-cut (uncolored) and 32 post-cut (colored) samples	235
Figure 5.30:	A score plot representing 11 N _{selected} + S parameters of 216 data points decomposed by PCA in covariance mode into three dimensions, %V ₁ = 80.5%, %V ₂ = 16.8% and %V ₃ = 1.7%	243
Figure 5.31:	Dendograms expressed in distance showing the distances between clusters according to (a) Single linkage and Euclidean distance and (b) Ward linkage and Manhattan distance	248
Figure 5.32:	Dendograms expressed in distance showing the distance relationships between 90 random case samples using (a) Single linkage and Euclidean distance and (b) Ward linkage and Manhattan distance	250
Figure 5.33:	Reconstructed TIC of a mixture of standards at equal concentrations analyzed by GC-MS	253
Figure 5.34:	Reconstructed TIC of a case sample analyzed by GC-MS	256
Figure 5.35:	Three other major components tentatively identified by GC-MS	257

Figure 5.36:	Boxplots showing the % analytes of eight target components in 311 illicit heroin case samples including zero values (absence)	260
Figure 5.37:	A score plot representing $N_{\text{selected}} + S$ parameters obtained from 309 cases analyzed by PCA in covariance mode, $\%V_1 = 41.2\%$, $\%V_2 = 37.2\%$ and $\%V_3 = 12.1\%$	263
Figure 5.38:	A dendrogram expressed in similarity showing the relationships between 309 case samples using Ward linkage and Manhattan distance	263
Figure 5.39:	Construction of a tetrahedron. P, Q, R and S are the plane areas to be used for computation	266
Figure 5.40:	Possible tetrahedral patterns constructed from different assignments of parameters to the arms	267
Figure 5.41:	Complexities imparted by four types of polyhedrons	267
Figure 5.42:	(a) and (b) show the ideal formation of triangles on the same plane for computation. (c) and (d) show false negatives arising from balance-off between two perpendicularly formed triangles on the same plane	271
Figure 5.43:	Tetrahedrons of 9 heroin samples	272
Figure 5.44:	A score plot showing the relationships between 9 case samples decomposed by PCA, $\%V_1 = 94.70\%$, $\%V_2 = 5.20\%$	274
Figure 5.45:	Chromatographic performance shown by four different GC columns using a single extract of Sample B	278
Figure 5.46:	Partially reconstructed chromatograms of a heroin extract of Sample B with the selected ramping rate	280
Figure 5.47:	Peak heights of n-alkanes analyzed in four different columns	281
Figure 5.48:	A chromatogram showing the positions of 12 target impurity peaks and the IS in a validation sample	282
Figure 5.49:	Names and structures of 12 impurity compounds	283
Figure 5.50:	A chromatogram showing the positions of seven n-alkanes and the IS in a control sample	285
Figure 5.51:	Chromatograms of heroin extracts in (a) n-hexane, (b) ethyl acetate, (c) chloroform and (d) toluene	290
Figure 5.52:	Comparison of blank extracts obtained with a plastic tube and a glass centrifuge tube.	293

Figure 5.53:	A score plot representing 12 N + S pretreated impurity peaks of 55 data points decomposed by PCA in covariance mode into three dimensions, %V ₁ = 71.2%, %V ₂ = 16.7% and %V ₃ = 6.3%	307
Figure 5.54:	Positions of 12 impurity peaks on an enlarged chromatogram for a 650 mg case sample (1.18 % heroin base)	310
Figure 5.55:	A score plot representing 12 N + S pretreated impurity peaks of 25 data point decomposed by PCA in covariance mode into three dimensions, %V ₁ = 48.0%, %V ₂ = 23.3% and %V ₃ = 12.0%	311
Figure 5.56:	A dendogram expressed in distance showing the distance relationships between 80 simulated samples using Ward-Squared Euclidean or Ward-Squared Pearson.	316
Figure 5.57:	Boxplots showing the concentrations of 12 target impurity peaks in 252 illicit heroin case samples including zero values (absence)	319
Figure 5.58:	A score plot representing N + S pretreated impurity data obtained from 252 cases analyzed by PCA in covariance mode, %V ₁ = 33.0 %, %V ₂ = 13.1% and %V ₃ = 9.7%	321
Figure 5.59:	A dendogram expressed in similarity showing the relationships between 252 case samples using Ward-Squared Euclidian or Ward-Squared Pearson	321
Figure 5.60:	Boxplots showing the concentrations of 12 target impurity peaks in 46 illicit heroin case samples including zero values (absence)	322
Figure 5.61:	A dendogram expressed in similarity showing the relationships between 46 case samples using Ward-Squared Euclidian or Ward-Squared Pearson.	324
Figure 5.62:	A dendogram expressed in similarity showing the relationships between 298 case samples using Ward-Squared Euclidian or Ward-Squared Pearson	325
Figure 5.63:	An unusual profile shown by Case 66	326
Figure 5.64:	RSD of a high purity sample (dotted line) and low purity sample (black line) analyzed at six different weights	335
Figure 5.65:	A dendogram expressed in similarity showing that the related samples prepared by direct dissolution with or without filtration are clustered in their respective groups using McQuitty linkage and Euclidean distance on standardized variables	338

Figure 5.66:	A score plot representing 16 N + 4R pretreated elemental data of 48 data points decomposed by PCA in covariance mode into three dimensions, %V ₁ = 71.4%, %V ₂ = 12.2% and %V ₃ = 10.8%	343
Figure 5.67:	Dendograms expressed in distance showing the distance relationships between 48 random case samples using (a) Single linkage and Manhattan distance and (b) Ward linkage and Squared Euclidean distance.	345
Figure 5.68:	A score plot representing N + 4R pretreated elemental data obtained from 309 cases analyzed by PCA in covariance mode, %V ₁ = 44.5%, %V ₂ = 19.2% and %V ₃ = 13.6%	357
Figure 5.69:	A dendogram expressed in similarity showing the relationships between 309 case samples using Ward linkage and Squared Euclidean distance	357
Figure 5.70:	A datasheet for a case sample in the database	360
Figure 5.71:	Summary of 18 matched profiles generated from the database	361
Figure A1:	Linearity curves for eight target major components	379
Figure A2:	Example of three times signal-to-noise calculation	380
Figure A3:	Mass spectra for 8 target major components	382
Figure A4:	Mass spectra for 12 target manufacturing impurities	385