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Interpol Review of Drug Analysis 2019-2022

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1. Routine and improved analyses of abused substances

Improved methods of analysis, i.e., faster, more discriminatory, more sensitive, less costly, etc., are needed for all abused substances. Additionally, standard analytical data are required for previously unknown or rarely encountered substances and/or new "designer drugs."

Drug seizures and clandestine laboratory operations are continuously monitored to provide a comprehensive overview of new developments. Ongoing research in the forensic community, as well as in the general fields of analytical chemistry and toxicology, provide new and/or improved methods of analysis for abused substances. Reports providing standard analytical data for new drugs of abuse and/or improved analytical protocols for known drugs of abuse are generated for the forensic and enforcement communities.

1.A.A – Individual Compounds or Substances.

1.A.B – Individual Natural Products Containing Abused Substances.

1.A.C – Common Groups or Classes of Compounds or Substances.

1.A.D - Synthetic Cannabinoids and Cannabimimetics.

1.A.E – Mixed or Unrelated Individual (Named) Compounds or Substances.

1.1. *Individual compounds or substances (except individual synthetic cannabinoids and cannabimimetics, which are compiled under 1.D)*

1.1.1. *Alprazolam*

2020 Optimization and Validation of an High-Performance Liquid Chromatography-Ultraviolet/visible analysis (HPLC-UV/vis) method for the detection and simultaneous quantification of alprazolam with celecoxib and diclofenac sodium in pharmaceutical formulations and human serum [1]; Mid-Infrared Spectroscopy (MIR), Near-Infrared Spectroscopy (NIR), and Raman spectroscopy for quantitative analysis of alprazolam in a low-content powder blends [2]; **2021** electrochemical sensor for voltametric quantification of alprazolam [3]; a density functional theory (DFT) investigation of the detection of alprazolam by boron nitride nanocage using infra-red (IR), natural bond orbital (NBO), and frontier molecular orbital (FMO) computations [4]; use of FTIR with fentanyl and benzodiazepine immunoassay strips for the identification of counterfeit alprazolam tablets [5]; **2022** study of the molecular structure, spectroscopy, and photochemistry of alprazolam including multinuclear (H-1, C-13 and N-15) NMR and UV spectroscopies, and in crystalline phase (P-1 polymorph) through IR and Raman spectroscopies [6].

1.1.2. *Amphetamine (AMP)*

2020 Study of the enantiomeric profile of AMP in several batches of tablets seized from the illegal market [7]; sensor for detection of ultra-trace amounts of AMP [8]; extraction method for the determination of AMP drugs in water samples using liquid chromatography-mass spectrometry [9]; **2021** new colorimetric assay for AMP [10]; detection of AMP using a nanotube sensor based on DFT calculation [11]; electrochemical detection of AMP in seized samples based on the derivatization by 1,2-naphthoquinone-4-sulfonate NQS [12]; DFT study on detection of AMP by silicon carbide nanotubes [13]; **2022** nontarget screening of production waste samples from Leuckart amphetamine synthesis using liquid chromatography-high-resolution mass spectrometry (LC-HRMS) as a complementary method to gas chromatography mass spectrometry (GC-MS) impurity profiling [14]; a new hybrid nanomaterial for detection of AMP [15].

1.1.3. *1-Benzylpiperazine (BZP)*

2021 electrochemical method for BZP determination in beverage (vodka, whisky and white wine) and seized street samples using differential pulse voltammetry (DPV) and cyclic voltammetry (CV) [16].

1.1.4. *Brorphine*

2021 liquid chromatography tandem mass spectrometry (LC-MS/MS) and liquid chromatography mass spectrometry with a quadrupole time-of-flight (LC-QTOF-MS) for quantitative analysis of Brorphine [17].

1.1.5. *Carfentanil*

2020 review [18]; **2021** classification model for carfentanil based on the chemical impurity profile of carfentanil synthesized using three

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different methods and analyzed by GC-MS and UHPLC-HRMS [19]; systematic analysis of the sale of Carfentanil on the darknet [20]; strategic decision making and implementation of a LC-MS-MS quantitative test method for carfentanil [21]; review [22].

1.1.6. 1-(3-chlorophenyl)piperazine (mCPP)

2020 voltammetric method for determination of designer drug mCPP including an evaluation of possible interfering compounds that including adulterants commonly found in seized drugs - lidocaine, acetaminophen, acetylsalicylic acid, caffeine, benzocaine, procaine, phenacetine, cocaine and MDMA [23]; **2021** portable electrochemical method for the detection of mCPP in seized samples [24];

1.1.7. Clonazepam

2020 Liquid-liquid extraction (LLE) paired with surface-enhanced Raman spectroscopy (SERS) to detect clonazepam in beverages [25]; Fluorescence sensor using Carbon Dots (CDs) doped with nitrogen as sensing materials for fast and selective determination of Clonazepam [26]; **2021** electrochemical sensor for voltametric detection of clonazepam [27,28];

1.1.8. Cocaine

2019 DART-HRMS method to detect organic impurities in cocaine samples seized in China [29]; electrochemical sensor for direct detection of cocaine [30]; analysis of the role of TiO2 nanoparticles and UV irradiation in the enhancement of SERS spectra to improve levamisole and cocaine detection [31]; aptamer-based liquid crystal sensor for detection of cocaine [32]; **2020** High-throughput screening of cocaine, adulterants, and diluents in seized samples using capillary electrophoresis with capacitively coupled contactless conductivity for detection and simultaneous quantification of cocaine, levamisole, lidocaine, carbonate, borate, chloride, nitrate, nitrite and sulfate [33]; a method using carbon paste chemically modified with N, N′-ethylene-bis-(salicylideneiminato) manganese(II) to detect cocaine hydrochloride by linear sweep voltammetry (LSV) in aqueous medium [34]; synthesis of an optical sensor for use in the detection/quantification of lidocaine in seized cocaine hydrochloride samples [35]; development of a sensor based on molecularly imprinted polymer nanoparticles (nanoMIPs) and electrochemical impedance spectroscopy (EIS) for the detection of trace levels of cocaine [36]; chemosensor for detection of cocaine [37]; comparison study of the performance of three spectroscopic techniques [MIR, Raman and NIR] on a total of 364 seized powders - 276 cocaine powders (with concentrations ranging from 4 to 99 w%) and 88 powders without cocaine [38]; sensor for detection of cocaine [39–41]; sensor for detection of cocaine by-products [42]; novel application of 740–1070 nm small-wavelength-range NIR spectroscopy and machine learning algorithms for on-site detection of cocaine in illicit substances [43]; nanosensor for cocaine detection [44]; Surface-enhanced Raman Scattering (SERS) method for detection of cocaine on banknotes [45]; Ion Mobility Spectrometry (IMS) and LC-MS/MS for detection of cocaine on banknotes [46]; portable handheld Raman spectrometer for detection of cocaine [47]; colorimetric sensor for cocaine [48,49]; fluorescence sensor for cocaine [50]; **2021** plasma-printed paper-based SERS substrate for detection of Cocaine at concentrations from 1 to 5000 ng/mL [51]; comparison of seven commercial SERS substrates A-G for the analysis of cocaine [52]; a multiple detection paper-based analytical device that combines colorimetric and electrochemical measurements for determining the composition of seized cocaine samples in order to isolate adulterant content [53]; ICP-MS and Inductively coupled plasma - optical emission spectrometry (ICP-OES) analysis of inorganic profiles of seized Cocaine [54]; statistical analysis of the cutting agents found in 2118 cocaine samples that were seized in the Northern Region of Colombia from 2015 to 2017 [55]; electrochemical sensor for determination of cocaine in seized samples [56]; two new electrodes chemically modified with [Co((+/−)-t3MeOsalcn)] or [Cu((+/−)-t-3MeOsalcn)] and their use in free-base cocaine and cocaine hydrochloride identification [57]; voltammetric sensors for the oxidation of cocaine hydrochloride on the surface of carbon paste electrodes chemically modified with Schiff base complexes and their potential use for cocaine detection and quantification in seized samples [58]; examination of the challenges for detecting cocaine in smuggling samples where the samples were first screened with a cocaine color test and MIR analysis, followed by confirmation analyses with GC-MS and GC-FID to identify and quantify cocaine and cutting agents and additional characterization by scanning Electron Microscopy-Energy Dispersive X-ray spectroscopy (SEM-EDX) analyses [59]; feasibility study to examine the use of smartwatches for detection of cocaine use [60]; electrochemical profiling of cocaine samples [61]; purity study on cocaine seized in Denmark from 2006 to 2019 [62]; performance evaluation of a handheld Raman spectrometer for cocaine detection based on (i) its performance on 0–100 wt% binary cocaine mixtures, (ii) retrospective comparison of 3168 case samples from 2015 to 2020 analyzed by both GC-MS and Raman, (iii) assessment of spectral selectivity, and (iv) comparison of the instrument's on-screen results with combined partial least squares regression (PLS-R) and discriminant analysis (PLS-DA) models [63]; 3D-printed graphene-polylactic acid (G-PLA) electrodes to identify and quantify cocaine in seized drugs [64]; electrochemical detection method for cocaine analysis [65]; a photonic crystal fiber (PCF) with high relative sensitivity was designed and investigated for the detection of cocaine [66]; **2022** electrochemical sensor for detection of cocaine [67]; sensor for cocaine [68]; CV to investigate the interfacial behavior of cocaine cutting agents [69]; review [70]; development of a model for the comparison of seized cocaine based on retrospective analysis of data generated from UHPLC-TOF-MS drug screening [71]; development of an UHPLC-Orbitrap-HRMS analytical methodology for the determination of cocaine in banknote dust samples [72]; portable electrochemical detection coupled with a peak recognition algorithm for the on-site screening of cocaine and its main cutting agents in suspicious and confiscated samples [73]; review of research articles on chromatography and mass spectrometry techniques used for the detection of cocaine, published between 2015 and 2021 [74]; review of common impurities, adulterants, and cutting agents encountered in cocaine [75].

1.1.9. Codeine

2019 capillary electrophoresis method for the analysis of codeine phosphate, paracetamol, caffeine from pharmaceutical dosage forms [76]; flow injection analysis system coupled to multiple pulse amperometry (FIA-MPA) for detection of codeine and acetaminophen in pharmaceutical samples [77];

1.1.10. Deschloro-N-ethyl-ketamine (2-oxo-PCE)

2020 detection of a newly emerged drug, deschloro-N-ethyl-ketamine (2-oxo-PCE), an analog of ketamine, through forensic drug and toxicological examinations of exhibits from drug seizure cases and blood samples taken from drivers of driving under the influence of drug (DUID) cases [78].

1.1.11. Diazepam

2019 a layered double hydroxide/poly(tyrosine) film for electrochemical determination of diazepam [79]; 2021 an electrode for voltammetric determination of diazepam in pharmaceutical formulations [80].

1.1.12. 3,4-Dichloro-N-[2-(dimethylamino)cyclohexyl]-N-methylbenzamide (U-47700)

2020 review the medicinal chemistry, preclinical pharmacology, clandestine availability, methods for detection, and forensic toxicology of U-47700 and its analogues [81]; review [82];

1.1.13. N,N-Dimethyltryptamine (DMT)

2020 voltammetric determination of DMT in water [83].

1.1.14. N,N-diethyl-2-{[(4-ethoxyphenyl)methyl]-1H-benzimidazol-1-yl}-ethan-1-amine (dihydrochloride)

2021 spectroscopic characteristics and crystal structure of this etazene-a benzimidazole opioid identified in seized material [84].

1.1.15. N-(2,6-dimethyl-phenyl)-1-phenethylpiperidine-2-carboxamide (NDMPPPC)

2021 identification of NDMPPPC in a seized powder using single-crystal X-ray diffraction analysis [85].

1.1.16. Eutylone

2022 electrochemical detection of synthetic cathinone eutylone in seized samples [86].

1.1.17. Fentanyl

2019; cyclic square wave voltammetry with screen-printed carbon electrodes for analysis of fentanyl [87]; electrochemical method for field detection of fentanyl [88]; separation and detection of fentanyl from complex mixtures using gradient elution moving boundary electrophoresis [89]; **2020** assessing the limit of detection of Fourier Transform Infrared.

(FTIR) spectroscopy and immunoassay strips for fentanyl [90]; use of Eosin Y as a potential new color test for use in detecting fentanyl [91]; FTIR spectroscopy and immunoassay strips for checking content of fentanyl in drugs [90]; SERS method for detecting fentanyl and two of its chemical precursors, despropionylfentanyl (4ANPP) and N-phenethyl-4-piperidinone (NPP) [92]; electrochemical method for the detection of fentanyl in aqueous solutions [93]; sensor for fentanyl detection in presence of interferents in pharmaceutical preparations, serum and urine [94]; Square-wave adsorptive stripping voltammetry (SWAdSV) with a carbon electrode for detection, identification, and semi-quantitation of fentanyl in seized drug samples [95]; electrochemical sensor for voltammetric determination of fentanyl [96]; preparation of disposable single-walled carbon nanotube network electrodes for the detection of fentanyl [97]; **2021** glassy carbon electrode for electrochemical determination of fentanyl [98]; evaluation of the performance of two immunoassay techniques versus LC-MS/MS for the detection of fentanyl [99]; portable Raman spectrometer for detection and quantification of fentanyl both powder binary mixtures and more complex ternary mixtures [100]; colorimetric method for detection of fentanyl using a Rose Bengal probe [101]; study of false positives obtained when using fentanyl test strips on street sample preparations that included illicit stimulants, cutting agents and/or pharmaceuticals [102]; handheld, spatially offset Raman spectroscopy (SORS) system used to obtain SERS spectra of fentanyl under simulated field conditions [103]; SPME-GC-MS to collect and establish the vapor signature of pure pharmaceutical-grade fentanyl and diluted pharmaceutical-grade fentanyl [104]; portable SERS approach for rapid, on-site identification and quantification of trace fentanyl laced in recreational drugs [105]; multivariate analysis aided SERS (MVA-SERS) multiplex quantitative detection of trace fentanyl in illicit drug mixtures using a handheld Raman spectrometer [106]; surface-enhanced shifted excitation Raman difference spectroscopy (SE-SERDS) for trace detection of fentanyl in beverages [107]; **2022** a surfactant-involved colorimetric assay for detection of fentanyl [108]; electrochemical sensors for fentanyl detection [109]; SERS platform for portable detection and identification of trace fentanyl [110].

1.1.18. Flunitrazepam

2019 hybrid electrocatalyst modified SPCE was developed for the determination of flunitrazepam [111]; Lab-on-a-screen-printed electrochemical cell for drop-volume voltammetric screening and detection of flunitrazepam to a wide range of untreated and undiluted spiked samples (Pepsi cola (R), Vodka, Whisky, Tequila, Gin, and Rum) [112]; **2020** electrochemical sensor for on-site detection of flunitrazepam in spirits [113]; electrochemical sensor for trace analysis of flunitrazepam in aqueous solutions [114]; **2021** carbon paste electrode for electrochemical determination of flunitrazepam [115]; electrochemical sensor for detection of Rohypnol/flunitrazepam in drinks [116]; miniaturized sensing device for the determination of flunitrazepam in carbonated soft drinks, energy drink, and malt beverage [117]

1.1.19. Gamma-Hydroxybutyric Acid (GHB) (also gamma-Butyrolactone (GBL), 1,4-Butanediol (BD))

2019 complementary approach for accurate determination of carbon isotopic compositions in gamma-hydroxybutyric acid using gas chromatography/combustion-isotope ratio mass spectrometry [118]; **2020** ultra-high-performance liquid chromatography-tandem mass spectrometry (UHPLC-MS/MS) method for the simultaneous quantification of GHB, GBL, and 1,4-BD in four popular beverages, including carbonated drinks, tea, apple cider vinegar, and coffee [119]; H-1-NMR results of seven kinds of beverages spiked GBL indicated that were spiked with GBL where the GBL was transformed into GHB in six popular beverages under certain conditions which could happen during transportation and storage [120]; detection method based on DLLME and GC-MS/MS for GHB in beverages [121]; two new oxazole derivatives for detection of gamma-hydroxybutyric acid (GHB) in soft drinks and alcoholic beverages, by color and fluorescence changes [122]; review [123]; GC-MS analysis of GHB in energy drinks [124]; **2021** a total vaporization solid-phase microextraction (TV-SPME) method with GC-MS for the detection of GHB and GBL in alcoholic beverages [125]; review [126]; LLE-FTIR based method to GBL in adulterated beverages [127]; forensic routine cases were measured to consider the potential of additional GC-MS analysis for GHB related acids (3,4-dihydroxy butyric acid, 2,4-dihydroxy butyric acid and glycolic acid) [128]; colorimetric chemosensor for the real-time in situ detection of GHB in soft drinks and alcoholic beverages [129]; heteroditopic chemosensors for detecting GHB in soft drinks, alcoholic beverages and synthetic urine [130]; a colorimetric detection kit was developed to enable rapid GHB detection in beverages [131]; **2022** development of a fluorescence probe based on a cyanostilbene scaffold for the detection of GHB [132]; method for in situ colorimetric GHB detection using various self-protection products coated with 2-(3-bromo-4-hydroxystyryl)-3-ethylbenzothiazol-3ium iodide (BHEI) as a chemical receptor embedded in hydrogels [133].

1.1.20. Heroin

2019 DART-HRMS followed by multivariate statistical analysis to infer the sources of heroin samples seized in China [134]; electrochemical strategies to detect heroin in street samples without the use of electrode modifications [135]; **2020** HPLC-MS/MS method for detection and quantification of the main alkaloids in heroin [136]; **2021** development of an HPLC-MS/MS method for the quantification of the main alkaloids in heroin [137]; ATR FT-IR method for classification and determination of the concentration range of illicit heroin in seized samples [138].

1.1.21. Isotonitazene

2020 identification and full chemical characterization of isotonitazene (N,N-diethyl-2-[5-nitro-2-({4-[(propan-2-yl)oxy]phenyl}methyl)-1H-benzimidazol-1-yl]ethan-1-amine), a potent NPS opioid and the first member of the benzimidazole class of compounds to be available on online markets [139]; LC-MS/MS method for quantitative analysis of isotonitazene and LC-QTOC-MS for metabolite discovery [140]; **2021** review [141]; identification of 40 fatal overdoses involving isotonitazene from January 1, 2020 to July 31, 2020 [142]; **2022** detection of isotonitazene following a local surge in opioid overdoses [143].

1.1.22. Ketamine

2019 rapid colorimetric sensing system using competitive ELISA test on a microfluidic paper-based analytical device for the detection of ketamine [144]; **2020** Square wave voltammetry method for on-site determination of ketamine in street samples and seizures [145]; dual-mode colorimetric and fluorometric nanoprob for detection of ketamine drinks [146]; trimodal (potentiometric, fluorimetric and colorimetric) paper microfluidic chip device for onsite determination of ketamine hydrochloride as a date rape drug in beverages [147]; **2021** antibody conjugated boronic acid modified silver chip with MALDI-TOF MS for rapid analysis of ketamine [148]; cloud-enabled smartphone based fluorescence sensor for quantitative detection of ketamine [149]; enantioselective monitoring of the biodegradation of ketamine and norketamine in wastewater by LC [150]; CE-TOF-MS method for detection of ketamine in blood and beverages [151]; **2022** review of the history of ketamine [152]; bibliometric analysis about the S-enantiomer of racemic ketamine (esketamine) research published between 2000 and 2020 [153]; indicator displacement assay for ketamine detection [154].

1.1.23. Lysergic Acid Diethylamide (LSD) and analogues

2020 Identification and analysis of LSD derivatives (4-Acetyl-N,N-diethyl-7-methyl-4,6,6a,7,8,9-hexahydroindolo[4,3-fg] quinoline-9-carboxamide (ALD-52), N,N,7-triethyl-4,6,6a,7,8,9-hexahydroindolo [4,3-fg]quinoline-9-carboxamide (ETH-LAD), 7-Allyl-N,N-diethyl-4,6,6a,7,8,9-hexahydroindolo[4,3-fg]quinoline-9-carboxamide (AL-LAD), N,N-diethyl-7- methyl-4-propionyl-4,6,6a,7,8,9-hexahydroindolo [4,3-fg]quinoline-9-carboxamide (1P-LSD)) in illegal paper sheet products by GC-MS, LC-MS, LC-Q-TOF-MS and NMR [155]; **2021** screening method of Lysergic Acid Diethylamide (LSD) in blotter papers using square wave voltammetry with a Boron-Doped Diamond Electrode (BDDE) [156]; cluster of cases involving laboratory-confirmed LSD in a powder that was sold as cocaine [157]; **2022** analysis of blotters found to contain the N-methyl-N-isopropyl isomer of LSD (MIPLA), and techniques to differentiate it from LSD and the N-methyl-N-propyl isomer (LAMPA) [158].

1.1.24. Mephedrone (4-Methylmethcathinone)

2020 capillary electrophoresis method for the chiral separation of mephedrone and its metabolites [159]; **2022** electrochemical sensor capable of detecting mephedrone [160].

1.1.25. Metaphedrone (3-methylmethcathinone)

2019 review [161].

1.1.26. Methamphetamine (MA)

2019 Analysis of aerosolized methylamphetamine from e-cigarettes using SPME-DART-HRMS and SPME-GC-MS [162]; fluorescent nanosensor for detection of methylamphetamine [163]; supercritical fluid chromatography-tandem mass spectrometry method could be a powerful analytical tool for methylamphetamine impurity profiling [164]; **2020** a novel fluorescent nanosensor based on graphene quantum dots embedded within molecularly imprinted polymer was developed for detection and determination of methylamphetamine [165]; chemosensor for detection of MA [166]; determination of the stereoisomeric distribution of R-(−)- and S-(+)-MA using HPLC-MS and GC-MS [167]; use of IRMS alongside conventional chemical profiling techniques to investigate whether methylamphetamine samples of differing P2P origins can be distinguished through drug profiling [168]; smartphone-based device for rapid on-site MA detection [169]; fluorescent drug detection device based on LED induction (FD-LED) for MA [170]; NIR-PLS quantitative modelfor seven adulterants with MA purity ranging from 10% to 100%, [171]; fluorescent nanosensor for detection of MA [172]; **2021** fluorescence resonance energy transfer-thermal lens spectrometry (FRET-TLS) for the determination of MA [173]; H-1 NMR method for discrimination of the enantiomers of MA from ephedrine and pseudoephedrine using chiral solvents [174]; review of the optical and electrochemical sensors used to date for MA detection in seized and biological samples [175]; development of an IMS method to detect MA using pyridine as a dopant in the presence of nicotine [176]; development and validation of a modified LC-ESI-MS/MS method for the simultaneous determination of MA and its isomer N-isopropylbenzylamine (N-IBA) in forensic samples [177]; SERS method for detection of MA [178,179]; investigation of the reaction mechanisms of three different synthesis methods (Nagai, Hypo, and Moscow) for MA [180]; establishment of likelihood ration models to evaluate the cause of MA contamination resulting from either use or clandestine manufacturing [181]; **2022** study of forensic markers of 1-phenyl-2-propanone synthetic pathways for identification of precoursors to methamphetamine [182]; impurity profiling of MA synthesized from alpha-phenylacetoacetonitrile (APAAN) including the identification of five new impurities and two previously identified impurities [183]; investigation of the use of stable isotope ratio mass spectrometry (IRMS) to determine the precursor and precursor origin of MA drug samples [184]; development of an electrochemical detection technique to determine the residual methamphetamine contamination on household surfaces [185]; benchtop NMR spectroscopy for quantification of illicit drugs (methamphetamine) in binary and ternary mixtures with impurities and cutting agents (N-isopropylbenzylamine, phenethylamine and dimethylsulfone) [186]; study of the changes in the methylamphetamine chemical profile for samples received as part of the National Measurement Institute's Methylamphetamine Profiling Program during January 2011 to December 2020 [187]; potential modulation combined with electrochemiluminescence for the determination of MA [188]; electrochemiluminescent immunosensors for detection of MA [189]; review of the drug profiling trends identified by the Drug Enforcement Administration (DEA) Methamphetamine Profiling Program (MPP) [190]; stereoselective profiling of methamphetamine at a wastewater treatment plant [191]; portable optical fiber immunosensor for MA [192].

1.1.27. Methcathinone

2022 sensor for rapid detection and purification of methcathinone [193].

1.1.28. 5-Methoxy-N,N-dimethyltryptamine (5-MeO-DMT)

2022 review or research with 5-MeO-DMT including pharmacology, chemistry and metabolism of 5-MeO-DMT, epidemiological studies, and reported adverse and beneficial effects [194]; synthesis and characterization of 5-MeO-DMT using HPLC [195].

1.1.29. 3,4-Methylenedioxymethamphetamine (MDMA)

2019 LC-MS/MS determination of content and dissolution profiles of MDMA tablets [196]; characterization of seized ecstasy tablets using GC-MS and UV spectroscopy, and a method using IR spectroscopy to first differentiate ecstasy from other party drugs and further quantify MDMA in the tablets. The study included a comparison between NIR and Mid-IR spectroscopy in combination with partial least squares-discriminant analysis (PLS-DA) and-regression (PLS) [197]; **2020** application of 3D printed tools for ESI-MS analysis of MDMA/MDEA in homemade pills [198]; electrochemical method for MDMA detection in seized samples [199]; **2021** electrochemical sensor detect MDMA by Linear Sweep Voltammetry in aqueous medium [200]; investigation of the 3D structure of MDMA in solution by vibrational circular dichroism and electronic circular dichroism supplemented by conventional IR and ultraviolet absorption spectroscopies [201,202]; MDMA-related mortality trends across Australia, Finland, Portugal and Turkey [203]; **2022** method validation for the quantification of MDMA in tablets based on the United Nations Office on Drugs and Crime (UNODC) guideline for quantitative NMR (qNMR) [204]; SERS sensing of MDMA and the corresponding precursors including safrole and piperonal [205]; quantitative analysis of 302 substances suspected by police to contain MDMA and seized at New South Wales music festivals between October 2019 and March 2020 [206]; development of a method for the detection of MDMA in latent fingerprints using surface plasmon resonance and lateral flow technology [207].

1.1.30. Methylenedioxypyrovalerone (MDPV)

2020 electrochemical detection of MDPV [208]; 2021 sensor for the direct analysis of MDPV [209].

1.1.31. Metonitazene

2021 LC-QTOF-MS/MS screening for metonitazene followed confirmation by LC-MS/MS [210];

1.1.32. Midazolam

2021 electrochemical paper-based analytical device (ePAD) using square wave voltammetry measurements of midazolam maleate in beverages [211];

1.1.33. Morphine

2019 novel and sensitive sensor for morphine based on electrochemically synthesized poly(p-aminobenzenesulfonicacid)/reduced grapheneoxide (poly(p-ABSA)/RGO) composite modified glassy carbon electrode [212]; nine step method to synthesize morphine from o-vanillin [213]; immunochromatographic lateral flow strip with gold nanoparticles labeling was developed for monitoring of morphine [214]; electrochemical sensor for detection of morphine [215]; **2020** Review of electrochemical detection methods of differeent moodified electrodes for deteection of morphine [216]; synthesis and use of poly(cetyltrimethylammoniumbromide)/graphene oxide (poly(CTAB)/GO) composite as novel sensor for morphine detection [217]; sensor for determination of morphine and diclofenac via differential pulse voltammetric, cyclic voltammetric, and chronoamperometry [218]; fluorescence immunoassay method for detection of morphine [219]; **2021** surface ionization mass spectrometry method for the direct detection and analysis of morphine [220]; a quantitative lateral flow immunoassay instrument that uses magnetic resistance sensors for quantitative measurement of morphine [221]; comparison of two different sensing platforms (electrochemical impedance spectroscopy and a quartz crystal microbalance) for the detection of morphine [222]; evaluation of the use of plant extracts and herbal products as a SPME sorbet for use with RP-HPLC and LC-MS/MS for detection of Morphine and Codeine [223]; electrochemical sensor for DPV determination of morphine [224]; utilization of a gas-phase chloride attachment with IMS for selective detection of morphine in a morphine/codeine mixture [225]; N, Cl-doped deep eutectic solvents-based carbon dots as a selective fluorescent probe for determination of morphine in food [226]; electrochemical sensor for detection of morphine in drug samples [227]; **2022** electrochemical sensor for simultaneous detection of Diclofenac and Morphine [228]; sensor for detection of morphine [229,230]; methodology to isolate morphine from opium and heroin (deacetylated to morphine) for isotopic analysis and regional analysis of submissions from Mexico, South America, Southwest Asia, and Southeast Asia [231]; electrochemical sensors for detection of morphine in unprocessed coffee and milk [232].

1.1.34. Oxycodone

2021 Development of a molecularly imprinted polymer based on the magnetic graphene oxide and carbon dots nanoparticles for ultrasonic assisted dispersive solid-phase microextraction of oxycodone [233]; electrochemical sensor for detection of oxycodone [234].

1.1.35. Para-fluoro-4-methylaminorex (4′F-4-MAR)

2019 4′F-4-MAR has been characterized by high resolution mass spectrometry and nuclear magnetic resonance [235];

1.1.36. Phencyclidine (PCP)

2020 method to differentiate and identify phencyclidine (PCP) and four of its analogues-tenocyclidine (TCP), rolicyclidine (PCPy), 3-methoxy phencyclidine (3-MeO PCP), and 4-methoxy phencyclidine (4-MeO PCP) using microcrystalline tests followed by Raman microspectroscopy, and chemometrics [236]; **2021** characterization of 3-MeO-PCP and 3-MMC in seized powders by liquid chromatography-high-resolution accurate-mass Orbitrap mass spectrometry (LC-HRAM-Orbitrap-MS), and solid deposition gas chromatography-FTIR spectroscopy (sd-GC-FTIR) [237];

1.2. Phenobarbital

2019 Electrochemical characterization and voltammetric determination of benzoyl derivatives of phenobarbital using glassy carbon electrode [238]; sensor for detection of phenobarbital [239]; **2020** SERS method for detecting low concentrations of phenobarbital using a commercially available portable Raman module [240]; **2022** electrochemical sensor for determination of phenobarbital [241]; fluorescence nanoprobe for the detection of phenobarbital [242]; sensor for determination of phenobarbital in pharmaceutical, blood and urine samples [243].

1.3. Phenyl-2-propanone (P2P, Phenylacetone)

2021 synthesis and investigation of impurities found in clandestine laboratories from synthesis of Phenyl-2-propanone (P2P) analogues from substituted benzaldehydes [244]; investigation of the formation of P2P degradation products during long-term storage and the factors that affected P2P degradation [245]; **2022** analysis of phenylacetone precursors (ethyl 3-oxo-2-phenylbutyrate, methyl 3-oxo-4-phenylbutyrate, and ethyl 3-oxo-4-phenylbutyrate) by GC-MS and their conversion to P2P to identify and elucidate the synthesis method of P2P [246].

1.4. α-Pyrrolidinopentiophenone (Flakka, alpha-PVP)

2019 Identification and estimation of the relative contents of organic and inorganic impurities in the bulk powder of 15 batches of alpha-PVP by GC-MS and ICP-MS [247]; **2020** review [248];

1.4.1. Quinolin-8-yl-3-[(4,4-difluoropiperidin-1-yl) sulfonyl]-4-methylbenzoate (2F-QMPSB)

2021 detection of 2F-QMPSB and acid precursor 4-methyl-3-(4,4-difluoro-1-piperidinylsulfonyl) benzoic acid (2F-MPSBA) in seized material and characterization using characterized GC-MS, H-1, C-13, F-19 and N-15 NMR and HR-MS/MS combined with chromatographic separation [249].

1.4.2. Testosterone

2020 DES-ABLLME-HPLC method for determination of testosterone and methyltestosterone [250];

1.4.3. Tramadol

2019 LC-MS/MS method for simultaneous determination of tramadol hydrochloride in the presence of some suspected mislabeled drugs such as alprazolam, diazepam, chlorpheniramine maleate, diphenylhydramine and paracetamol [251]; electrochemical method to quantify tramadol hydrochloride in pure solutions and pharmaceuticals, employing the flow injection analysis (FIA) technique [252]; voltammetric platform using a glassy carbon electrode for determination of tramadol [253]; a tetrahedral amorphous carbon (ta-C) electrode coated with a thin dip-coated recast Nafion membrane for selective electrochemical determination of tramadol and O-desmethyltramadol [254]; sensor for detection of tramadol [255]; electroanalytical quantification of Tramadol [256]; **2020** synthesis and utilizing graphene (Gr)/Co3O4 nanocomposite for the development of a novel electrochemical sensor to detect tramadol by linear sweep voltammetry, differential pulse voltammetry, CV, and chronoamperometry [257]; development of two chromatographic methods (HPLC and HPTLC) for the simultaneous analysis of chlorzoxazone, diclofenac sodium and tramadol hydrochloride in presence of three of their related substances and potential impurities [258]; an amplified tramadol electrochemical sensor was fabricated based on surface modification of pencil graphite electrode by CuO nanoparticles and polypyrrole [259]; Rapid synthesis of BaFe12O19 nanoparticles for the electrochemical detection of tramadol in the presence of acetaminophen [260]; sensing platform based on Pt doped NiO/MWCNTs nanocomposite for enhanced electrochemical determination of epinephrine and tramadol simultaneously [261]; sensor for the simultaneous voltammetric detection of Acetaminophen and Tramadol [262]; sensor for qualitative and quantitative determination of tramadol using cyclic and square wave voltammetry techniques [263]; novel voltammetric method for the quantification of tramadol in pharmaceutical forms and urine samples [264]; electrochemical sensor for tramadol and acetaminophen [265]; graphite electrode for electrochemical determination of tramadol [266]; HPLC-UV method for identifying contaminants in Russian-made tramadol hydrochloride [267]; sensor for determination of tramadol in pharmaceutical samples [268]; electroanalytical sensor for tramadol with a detection limit of 50.0 nM in drug samples [269]; simultaneous quantification of acetaminophen and tramadol hydrochloride using a modification-free boron-doped diamond (BDD) electrode [256]; kinetic spectrophotometric method for tramadol trace level detection [270]; **2021** spectrophotometric method for detection of trace levels of tramadol [270]; electrochemical sensor for determination of tramadol [271]; electrode for simultaneous voltammetric determination of tramadol and paracetamol [272]; fluorescent aptasensor assay for determination of tramadol [273]; electrochemical sensor for Tramadol, Codeine and Caffeine [274]; RP-HPLC-PDA method for determination of paracetamol, caffeine and tramadol in pharmaceutical formulations [275]; electrochemical sensor for determination of tramadol in pharmaceutical samples, spiked beverages, saliva and urine [276]; electrochemical sensor for simultaneous determination of dopamine and tramadol [277]; **2022** HPLC method with fluorimetric detection for analysis of Tramadol in binary mixtures with Ibuprofen (mixture 1) and Chlorzoxazone (mixture 2) in tablets and plasma [278]; electrochemical sensor for tramadol [279, 280].

1.4.4. Xylazine

2021 first detection of the psychoactive veterinary compound xylazine in Toronto [281]; xylazine detection and involvement in drug overdose deaths [282]; LC-MS/MS method to identify xylazine withing fentanyl screen-positive urine with possible application to seized samples [283]; detection of Xylazine in 42 deaths in Connecticut from March to August 2019 [284]; electrochemical sensor to determine xylazine in spiked beverages by adsorptive stripping voltammetry (AdSV) [285].

1.5. Individual Natural Products Containing Abused Substances (except natural products laced with synthetic cannabinoids and/or cannabimimetics)

1.5.1. Overviews and/or Reviews

2019 GC-MS analysis of fifty samples of medicinal herbs collected from herb shops located in different parts of Iran [286]; overview of over 400 performance and image enhancing drugs confiscated in Italy in the period 2017–2019 [287]; evaluation of DNA extracted from the forensically relevant "legal high" plant species: Ipomoea purpurea, Artemisia absinthium, Mitragyna speciosa, Datura stramonium, and Papaver somniferum [288]; **2020** review of the types of drugs that may be illegally added in health food according to their pharmacological activities, advances in detection technologies for illegal drugs and future development prospects [289]; **2021** review of the significance of medicinal plants in forensic investigations to detect criminal offenses [290]; review of toxicological aspects and analytical methods for twelve plant specimens (Areca catechu, Argyreia nervosa, Ayahuasca, Catha edulis, Datura stramonium, Lophophora williamsii, Mandragora officinarum, Mitragyna speciosa, Piper methysticum Forst, Psilocybe, Salvia divinorum and Tabernanthe iboga) [291].

1.5.2. Ayahuasca

2019 mutagenicity of ayahuasca beverage and their constituents using the Salmonella/microsome assay [292]; extraction method based on solid-phase extraction to determine the major alkaloid components, DMT. harmine, harmaline, harmalol, and tetrahydroharmine, in ayahuasca using ultra-performance liquid chromatography-tandem mass spectrometry [293]; analytical method for the quantification of the main active ayahuasca compounds [294]; **2020** development and validation of a DART-HRMS method for the quantification of DMT in ayahuasca [295]; development of an UHPLC-MS/MS method for the determination of ayahuasca alkaloids and its application in seized ayahuasca products [296]; phytochemical characterization using UHPLC-Q/TOF-MS to determine the content of flavonoids, total phenolic compounds, the phenolic profile and 48 secondary metabolites [297]; stability study of the main ayahuasca alkaloids (dimethyltryptamine, DMT; harmine, HRM; tetrahydroharmine, THH; harmaline, HRL) followed by analysis using LC-ESI-MS/MS [298]; **2021** qualitative (optical and electron microscopy) and quantitative (qPCR) analysis of Peganum harmala seeds in hallucinogenic preparations, such as the psychedelic drink ayahuasca [299]; systematic review of websites offering ayahuasca experiences for sale on the internet [300]; determining the elemental composition of ready-to-consume ayahuasca samples produced in Brazil using microwave radiation-assisted acid decomposition and elemental analysis by ICP-MS and ICP-OES [301]; UHPLC-MS/MS analysis of the chemical composition of traditional and analog Ayahuasca [302]; **2022** review [303]; review of latest methods used to analyze the composition of the beverage and biological matrices [304].

1.5.3. Coca (Erythroxylum)

2020 new variety of Erythroxylum from Peru [305]; **2021** MALDI(+) FT-ICR-IMS for analysis of the distribution of alkaloids on the surface of coca leaves [306]; cytotoxicity evaluation studies performed with extracts or pure substances obtained from Erythroxylum species [307]; Qualitative phytochemical analysis followed by HPTLC analysis of the leaves of Erythroxylum moonii Hochr [308].

1.5.4. Ephedra (all species)

2019 study of the Chloroplast genomes of the three Ephedra species encoded 118 genes, including 73 protein-coding genes, 37 tRNA genes and 8 ribosomal RNA genes [309]; field surveys of Ephedra plants in the Zarayshan Mountains of Tajikistanto to determine total ephedrine and pseudoephedrine content [310]; characterization of the complete chloroplast genome of Ephedra sinica Stapf (Ephedraceae) [311]; chloroplast genome of Ephedra sinica (Ephedraceae) [312]; LC-MS/MS method for the determination of ephedrine in various food supplements [313]; capillary electrochromatography separation of ephedrine and pseudoephedrine isomers [314]; **2020** review of characterization methods to isolate compounds of Ephedra species characterized by MS-based techniques LC-MS, LC-ESI-MS, HPLC-PDA-ESI/MS, LC-DA-D-ESI/MSn, LC/Orbitrap MS, etc. [315]; characterization of difference fractions of ephedra extracts and ephedrine alkaloids [316]; **2021** LC/MS quantitative analysis of ephedrine and pseudoephedrine in Ephedrae herba [317]; phytochemical fingerprint profile of the bioactive compounds from Ephedra fragilis including optimization of extraction and chemical characterization using RP-HPLC [318]; HPTLC supplemented with injection port derivatization GC-MS for analysis of ephedra herbal extracts [319]; DART-TOF-MS applied to whole plant bio-imaging of Ephedrae Herba for localization of major Ephedra Alkaloids [320]; identification of plant materials containing ephedrine alkaloids using DNA barcoding and TaqMan real-time PCR assay [321]; **2022** comparison of volatile oils and primary metabolites of raw and honey-processed ephedrae herba by GC-MS and chemometrics [322]; qualitative profiling of Ephedra alata monjauzeana using RP-HPLC-ESI-QTOF-MS [323]; relationship between ephedrine alkaloid profile in Ephedra gerardiana and soil characteristics [324];

characterization of the phyto-chemical profile of Ephedra alata subsp. alenda seeds extract using HPLC-ESI-QTOF-MS [325]; HPLC method for the simultaneous determination of five alkaloids (norephedrine, norpseudoephedrine, ephedrine, pseudoephedrine, and methylephedrine) in Ephedrae Herba [326]; collection of 224 ITS2 sequences representing 59 taxa within Ephedra and a 23-base pairs genus-level nucleotide signature (GTCCGGTCCGCCTCGGCGGTGCG) was developed for the identification of the whole genus signature and for the identification of Ephedra-containing products [327].

1.5.5. Khat (Catha edulis)

2020 Ethanolic extracts of young and mature leaves of three khat cultivars were subjected to GC-MS for hierarchical cluster analysis revealinig the existence of two major clusters where the extracts of young leaves were found to contain the maximum content of cathinone; however, methoxyamphetamine was found in only one extract of young leaves [328]; **2021** LC-MS/MS analysis of the concentration of cathinone and cathine from a seizure of fresh Khat leaves compared with two seizures of dried material [329]; systematic literature review of 514 scientific publications published from 1997 to 2020 to analyze research trends [330]; **2022** Khat use screening test [331].

1.5.6. Kratom (Mitragynine speciosa)

2019 validated DART-HRMS method for the quantification of mitragynine in Kratom plant materials [332]; UPLC-MS/MS) method for the quantification of ten key alkaloids in Kratom (corynantheidine, corynoxine, corynoxine B, 7-hydroxymitragynine, isocorynantheidine, mitragynine, mitraphylline, paynantheine, speciociliatine, and speciogynine) [333]; **2020** investigation of the stability of Mitragynine, 7-hydroxymitragynine, speciociliatine, speciogynine and paynantheine [334]; ICP-MS method to measure the concentrations of 13 elements in 19 kratom samples obtained from an online distributor selling kratom for the purpose of using the elements to discriminate among purported country of origin, “suborigin,” and strain [335]; use of H-1 and/or C-13 NMR to characterize 19 alkaloids including the indole alkaloid mitragynine (1) and its diastereoisomers speciociliatine (2), speciogynine (3), and mitraciliatine (4); the indole alkaloid paynantheine (5) and its diastereoisomers isopaynantheine (6) and epiallo-isopaynantheine (7); the N(4)-oxides mitragynine-N(4)-oxide (8), speciociliatine-N(4)-oxide (9), isopaynantheine-N(4)-oxide (10), and epiallo-isopaynantheine-N(4)-oxide (11); the 9-hydroxylated oxindole alkaloids speciofoline (12), isorotundifoleine (13), and isospeciofoleine (14); and the 9-unsubstituted oxindoles corynoxine A (15), corynoxine B (16), 3-epirhynchophylline (17), 3-epicorynoxine B (18), and corynoxeine (19) [336]; review [337]; SERS method for detecting mitragynine in kratom [338]; PCR-RFLP method for identifying the origins of illegally distributed kratom products [339]; evaluation of mitragynine and toxic metal levels in kratom products [340]; examination of the online marketplace for kratom [341]; characterization of kratom leaf samples [342]; **2021** genomic study of Mitragyna speciosa [343]; 1D and 2D NMR and HRMS data analysis of ten indole and oxindole alkaloids isolated from the leaves of Malaysian Mitragyna speciosa [344]; review of chemical content of kratom and analytical methodologies [345]; extraction method of main indole alkaloids (mitragynine, paynantheine, and speciogynine) from the fresh leaves of Mitragyna speciosa [346]; DNA barcoding combined with high-resolution melting (Bar-HRM) analysis to differentiate *M. speciosa* from allied Mitragyna and to assess the capability of Bar-HRM assays to identify *M. speciosa* in suspected kratom samples [347]; evaluation of four field portable devices (DART-TD-MS, hand-held MS, portable IMS, and portable FT-IR) as field-deployable screening techniques for the detection of mitragynine in food and drug products [348]; **2022** development of a UHPLC-HRMS method for the analysis of 8 indole alkaloids (7-hydroxymitragynine, ajmalicine, paynantheine, mitragynine, speciogynine, isopaynantheine, speciociliatine, and mitraciliatine) and 6 oxindole alkaloids (isomitraphylline, isospeciofoleine, speciofoline, corynoxine A, corynoxeine, and rhynchophylline) in US-grown kratom plants and commercial products [349]; polymerase chain reaction coupled with lateral flow immunochromatographic assay (PCR-LFA) for the detection of *M. speciosa* in forensic specimens [350].

1.5.7. Marijuana and Hemp (Cannabis sativa) and associated Phytocannabinoids

2019 Three chromatographic analytical methods (UHPLC-MS/MS and GC-MS-FID) were evaluated regarding selectivity, sensitivity, analytical accuracy, and precision for the quantification of major phytocannabinoids [351]; new analytical method based on RP-HPLC with ESI-MS/MS detection for the determination of cannabidiol (CBD) and related cannabinoids in honey [352]; thin film transistor for determination of the CBD/Delta(9)-tetrahydrocannabinol (Delta(9)-THC or THC) ratio from rapid plant extracts [353]; DI, MALDI MS, and IMS techniques to detect and determine the distribution of cannabinoid compounds on the surface of fresh and aged Cannabis leaves [354]; analysis of cannabinoids in seized marijuana by densitometric high-performance TLC [355]; UHPLC-DAD for the qualification and quantification of the cannabinoids cannabidiolic acid (CBDA), CBD, Cannabinol (CBN), THC, cannabichromene (CBC) and Delta-tetrahydrocannabinolic acid (THCA), in medicinal cannabis biomass and resin obtained by SFE [356]; tetrahydrocannabinol detection using semiconductor-enriched single-walled carbon nanotube chemiresistors [357]; fast detection of 10 Cannabinoids by RP-HPLC-UV method in Cannabis sativa L. [358]; review of published literature on the use of various GC-based analytical methods for the analysis of naturally occurring cannabinoids published during the past decade [359]; review on the recent advances in HPLC, UHPLC and UPLC analyses of naturally occurring cannabinoids (2010–2019) [360]; LC-DAD method for quantification of 12 major cannabinoids in Cannabis dried plant materials, concentrates, and oils [361]; **2020** validation of a fast GC-FID method for simultaneous determination of 29 terpenes and cannabidiol in hemp [362]; review of the scientific literature about the extraction of products of industrial interest from Cannabis sativa L [363]; GC-FID method to determine CBD and cannabigerol (CBG) in hemp extract [364]; a review of the chemical characteristics, therapeutic uses, and legal aspects of the Cannabinoids of Cannabis sativa [365]; phytochemical investigation of the lipids extracted from seeds of Cannabis sativa by GC-MS showed 43 cannabinoids, of which 16 are new [366]; development and validation of a new LC-MS/MS method for the quantification of fifteen cannabinoids for multiple matrices. (Method performance fulfills the SANTE/11813/2017 requirements for products compliance testing with various national legislations on cannabinoids levels in food products). [367]; review of potential pitfalls of methods for qualitative and quantitative determination of the main phytocannabinoids: Delta(9)-THC, CBD, CBG, CBC [368]; isocratic HPLC method for analyzing cannabinoids in hemp (Cannabis sativa and Cannabis indica) plant material and its extracts [369]; analysis of extracts from 7 cultivars of Cannabis sativa L. using GC-TOF/MS and LC-QTOF-MS/MS in high resolution mode to identify one hundred sixty-nine compounds [370]; microwave-assisted extraction method for obtaining polyphenols and cannabinoids from C. sativa L. Cannabis herb [371]; study to assess the utility of the multi-element quantification of the composition of different cannabis plant parts and soil samples using ICP-OES to determine geographic origin [372]; cannabinoid profiles of 15 hemp varieties were analyzed using HLPC [373]; novel, automated dispersive pipette extraction (DPX) method to enable fast, hands-free selective isolation of THC and its precursors for downstream GC-MS analysis [374]; analysis of the polyphenolic fraction contained in polar extracts of four different commercial cultivars (Kompoti, Tiborszallasi, Antal, and Carmagnola Cs) of hemp inflorescences through spectrophotometric (TPC, DPPH tests) and spectrometry measurement (UHPLC-Q-Orbitrap HRMS) [375]; analysis of five major Cannabinoids of industrial hemp (Cannabis sativa L.) [376]; GC x GC-TOFMS method for non-targeted chemical analysis to identify new chemical exposures in marijuana blunt smoke [377];

evaluation of ten different TLC mobile phase systems to determine the most effective mobile phase for the analysis of cannabinoids in Cannabis sativa L. products using HPTLC [378]; LLE-HPLC-DAD method to isolate CBD and CBDA [379]; overview of extraction methods for cannabinoids [380]; review of published GC methods for the analysis of cannabinoids [359]; review of advances in HPLC, UHPLC and UPLC methods for the analysis of cannabinoids [360]; selective pressurized hot water extraction method for extracting cannabinoids from cannabis seeds [381]; NIR Hyperspectral Imaging (HSI-NIR) coupled with machine learning for detection and classification of Cannabis sativa L. [382]; analytical platform for the detection of cannabinoids [383]; raman-based method for differentiation of the spectroscopic signatures of CBG, cannabigerolic acid (CBGA), THCA, CBD, and CBDA [384]; hand-held Raman spectrometry method for determining if plant material is hemp or cannabis and content of THCA [385]; evaluation of data preprocessing to reduce false positives during the comparison of GC-MS chemical profiles of seized cannabis samples [386]; review of quality control for cannabis production for recreational, pharmaceutical and medicinal uses [387]; GC method for simultaneous determination of major terpenes and cannabinoids in plant samples and their extracts - DL ranged from 120 to 260 ng/mL for terpenes and from 660 to 860 ng/mL for cannabinoids [388]; **2021** review of the origin, history, cultivation and data on the morphological, genetic, and phytochemical characteristics of local cultivated varieties of Cannabis in Morocco [389]; quantification of 11 cannabinoids using LC-DAD in a non-representative sampling of 147 products labeled as containing hemp or cannabidiol and ICP-MS analysis for identification of toxic elements [390]; review of cannabis policy in the United States [391]; applications of HPLC-UV for potency testing, enantio-discrimination of chiral cannabinoids by SFC and purification of cannabinoids through preparative chromatography [392]; electronic nose (e-nose) based on commercially available gas sensors as a portable solution for detection for marijuana in supsected seized marijuana, pseudo-narcotic marijuana, and cigarettes [393]; use of organic electrochemical transistors for the detection of Delta(9)-THC down to 0.1 nM [394]; review of analytical methodologies for detecting both cannabinoids and terpenes in complex cannabis matrices [395]; a sample preparation method for homogenization of hemp followed by analysis using HPLC [396]; review of the methods and protocols for the extraction of naturally occurring cannabinoids [397]; study of the effect of the endocannabinoid system and the endocannabinoidome on the pharmacology of cannabinoids, including Delta(9)-THC and CBD [398]; development and validation of a qualitative LC-MS/MS method to screen and confirm the presence of nine phytocannabinoids (THC, 11-hydroxy-THC, 11-nor-9-carboxy-THC, cannabidiol, 7-carboxy cannabidiol, cannabinol, cannabigerol, Delta 9-tetrahydrocannabivarin (THCV), and 11-nor9-carboxy-THCV) [399]; use of GC-FID and GC-MS herbal fingerprints for intra (within)- and inter (between)-location variability evaluation with a focus on finding an acceptable threshold to link seized samples [400]; non-targeted LC-MS/MS method for the analysis of seized cannabis [401]; **2022** characterization of solvent extracts derived from marijuana and hemp using optical and spectroscopic techniques [402]; review of the advances in electrochemical sensor technologies for the detection of THC in synthetic samples, plants and oral fluid [403]; investigation of the effects of short-term environmental stresses on the onset of cannabinoid production in young immature flowers by analysis and quantification of the phytocannabinoids including CBGA, CBG, CBDA, CBD, THCA, THC, and CBN using HPLC [404]; a chromatographic paper-based electrochemical device to determine Delta (theta)-tetrahydrocannabinol and cannabidiol in cannabis oil [405]; Raman microscopy and chemometrics for the classification of different marijuana varieties [406]; review [407]; evaluation of an LC-PDA method for the determination of 11 cannabinoids in 4 hemp plant reference samples from the University of Kentucky Proficiency Testing Program (UK-PT) for cannabinoids, and 15 commercially available hemp oils [408].

1.5.8. *Marijuana (Genetic and/or Proteomic Analyses)*

2019 identification of four functional SNPs that are likely to induce decreased THCAS activity in the fiber-type cannabis plants [409]; **2020** review of genomics of cannabis [410]; analysis of plastomes for genetic identification and characterization of drug and nondrug-types of Cannabis [411]; evaluation of the effectiveness and efficiency of two STR multiplex systems to individualize and differentiate seized Cannabis sativa samples by geographic region [412]; two highly polymorphic regions of the chloroplast genome of C. sativa, tps16 and clpP, to be used for determination of crop type and biogeographical origin [413]; determination of the genetic composition of ten drug seizures of Cannabis using PCR combined with a high resolution melting (HRM) strategy and a barcoding marker (ITS) [414]; high-throughput PACE (PCR Allele Competitive Extension) assays for C. sativa plant sex and cannabinoid chemotype [415]; Simple Sequence Repeats (SSRs) for determination of technical Cannabis cultivars and genetic variability [416]; characterization of cannabinoid content and investigation of CBDAS genotypes of >300 feral C. sativa plants [417]; **2021** investigation of the ancestry of a new cultivar and cannabinoid synthase genes in relation to cannabinoid inheritance [418]; genetic engineering methods in cannabis [419]; assessment of the genetic and phenotypic consistency in available high-CBD hemp varieties of seed or clones from 22 different named accessions meant for commercial production [420]; review of the history of Cannabis and the molecular pathways that underpin the production of key secondary metabolites that may confer medical efficacy [421]; investigation of the genetic identity of Cannabis supplied by National Institute on Drug Abuse (NIDA) relative to common categories within the species including wild Hemp (feral; 6) and cultivated Hemp (3), CBD drug type (3), and high THC drug type subdivided into Sativa (11), Hybrid (14), and Indica (10) [422]; study of how genetics effect cannabinoid content [423]; genetic study investigating phytochemistry, reproductive traits, growth architecture, and leaf morphology from 297 hybrid individuals from a cross between two diverse lineages [424]; genomic analysis of multiple Cannabis varieties from diverse lineages including two produced by NIDA [425]; identification and loci mapping of 69 loci associated with agronomic (34) and biochemical (35) trait variation [426]; DNA testing using a simple kit on suspected cannabis samples with exceptionally shaped leaves [427]; **2022** study of 73 Cannabis sativa whole-genome shotgun libraries to reveal eight different mtDNA haplotypes [428]; optimization and evaluation of a previously reported single nucleotide polymorphism (SNP) assay for determining C. sativa crop type to distinguish between marijuana and hemp [429]; development of a MiSeq FGx (R) assay targeting seven "hotspot" regions in the Cannabis sativa chloroplast genome that are highly polymorphic and informative in attempts to determine biogeographical origin and distinguishing between marijuana and hemp [430].

1.5.9. *Marijuana – Miscellaneous topics*

2021 marijuana cultivation security requirements, laws and regulations [431]; study to estimate the association between recreational cannabis laws and street prices, potency, quality and law enforcement seizures of illegal cannabis, methamphetamine, cocaine, heroin, oxycodone, hydrocodone, morphine, amphetamine and alprazolam [432]; review that provides background on the history and botany of Cannabis as well as a summary of Cannabis tissue culture [433]; study to measure the aromatic properties of cannabis flowers and concentrated extracts using comprehensive two-dimensional GC-TOF, FID, and sulfur chemiluminescence [434]; 2022.

1.5.10. *Marijuana ("Synthetic Marijuana")*

See "Synthetic Cannabinoids and Cannabimimetics" (Subsection 1.D).

1.5.11. *Mushrooms (including Psilocybe mushrooms)*

2019 review [435]; morphological, chemical, and genetic analysis of mycelia of psychedelic fungi collected from a clandestine laboratory using scanning electron microscopy (SEM), mass spectrometry, HRM analysis, and internal transcribed spacer (ITS) sequencing [436]; **2020** use of TLC, FTIR and GC-MS to differentiate Psilocin (4-hydroxy-N, N-dimethyltryptamine, 4-HO-DMT) and bufotenine (5-hydroxy-N, N-dimethyltryptamine, 5-HO-DMT) and benzene ring regioisomers, 6-hydroxy-N,N-dimethyltryptamine (6-HO-DMT) and 7-hydroxy-N, N-dimethyltryptamine (7-HO-DMT) [437]; immunochemical detection method for monitoring psilocybin and psilocin in dried powder of hallucinogenic mushroom (Psilocybe cubensis) [438]; **2021** chemoenzymatic synthesis of 5-methylpsilocin, a novel analogue of psilocybin with potential psychedelic activity [439]; stability study of psilocybin and its four analogues (psilocin, baeocystin, norbaeocystin, and aeruginascin) in psilocybe cubensis mushrooms [440]; medicinal properties and bioactive compounds from 79 species of wild mushrooms native to North America [441]; DNA-based identification of hallucinogenic mushrooms [442]; forensic detection method for hallucinogenic mushrooms via High-Resolution Melting (HRM) analysis [443]; **2022** phytochemicals and antioxidant activity of seven wild mushrooms [444].

1.5.12. Opium/Opium Poppy/Poppy Seeds/Papaver Somniferum (see also Papaver below, and Opioids in Subsection 1.C)

2019 method for determining the traceability of poppy cultivating areas using QuickBird-2 satellite imaging with ERDAS Imagine and eCognition Developer software for image processing and classification [445]; characterization of poppy seeds using lab-on-a-chip capillary electrophoresis [446]; UHPLC-MS/MS method to determine the content of porphyroxine and five primary alkaloids (morphine, codeine, thebaine, noscapine, and papaverine) in opium [447]; determination of morphine content of different preparations of poppy seed tea by HPLC [448]; HPLC-PDA method for profiling opioid alkaloids in papaver [449]; purification and product characterization of lipoxygenase from opium poppy cultures (Papaver somniferum L.) [450]; sensor for opium alkaloids [451]; stable isotope labeled internal standards for reducing matrix effect in determination of five opium alkaloids by liquid chromatography-quadrupole linear ion trap mass spectrometry (LC-QqQ (LIT)-MS/MS) [452]; **2020** FIA method to rapidly monitor the morphine content of poppy seeds [453]; **2021** elliptic Fourier transforms, with other morphometric descriptors to describe and identify Papaver setigerum, Papaver Somniferum and other Papaver taxa in order to track opium poppy domestication [454]; review of the chemistry and synthesis of five major opium alkaloids [455]; LC coupled with linear trap quadrupole and high-resolution Orbitrap multistage mass spectrometry to characterize 44 benzylisoquinoline alkaloids, including 22 BIAs in opium poppy latex and roots extracts using collision-induced dissociation (CID), higher-energy collisional dissociation (HCD), and pulsed Q collision-induced dissociation (PQD) MS2 fragmentation [456]; review of the physiochemical, medicinal and nutraceutical properties of poppy seeds [457]; dispersive SPE-HPLC method for determination of five opium alkaloids [458]; investigation the proportions of morphine, thebaine, noscapine, codeine, oripavine and papaverine alkaloids in nine poppy varieties and 36 lines [459]; **2022** Papaver Somniferum in Kamini [460]; machine learning to predict missing link enzymes of benzylisoquinoline alkaloid biosynthesis in Papaver Somniferum [461].

1.5.13. Papaver (Genetic and/or proteomic analyses)

2020 procedures for DNA extraction from Opium Poppy (Papaver somniferum L.) and Poppy Seed-containing products [462]; comparative cp genome analyses to study the evolutionary pattern in Papaveracea [463]; MALDI-MS method for detection of opiates in Papaver somniferum [464]; new EST-SSR markers for individual genotyping Opium Poppy Cultivars (Papaver somniferum L.) [465]; development of a quantitative real-time PCR (qPCR) method for the quantification of opium poppy DNA, evaluation of three commercial DNA extraction kits for their ability to isolate DNA from poppy seeds, and evaluation of nineteen opium poppy short tandem repeat (STR) markers for their use in a forensic identification panel [466]; **2021** characterization of a novel variable number tandem repeat markers of forensically important poppy species based on the genetic analysis of 164 samples collected in South Korea [467]; genomic analysis of P. somniferum [468]; genomic characterization of California poppy using the draft genome sequence [469] genomic profiling of WRKY genes involved in Benzylisoquinoline Alkaloid biosynthesis in California poppy [470]; **2022** molecular identification and phylogenetic analysis of Papaver based on ITS2 barcoding to detect and identify P. somniferum as well as common adulterants of the same genus [471]; genotyping-by-sequencing to investigate the genetic diversity and population structure in a collection of poppy germplasm consisting of 91 accessions originating in 30 countries of Europe, North Africa, America, and Asia [472]; IsoSeq on opium poppy to improve the gene annotation [473]; eleven simple sequence repeats (SSR) markers and two single nucleotide polymorphism (SNP) markers were mined to distinguish opium poppy from other six Papaver species [474].

1.6. Common groups or classes of compounds or substances (except synthetic Cannabinoids and Cannabimimetics)

1.6.1. Amphetamine-Type Stimulants (ATSs) and Related Phenethylamines (PEAs)

2019 GC/MS method for fenethylline profiling of seized samples**;** LC-QTOF-MS method for the simultaneous analysis of 111 amine-based compounds belonging to ergogenics, anorectics and other active components including phenethylamines (amphetamines, ephedrines), sibutramine or yohimbine [475]; excitation-emission matrix fluorescence combined with parallel factor analysis for quantitative analysis of the ATSs illegal drugs [476]; **2020** investigation of the efficiency and effectiveness of a gas-to-liquid (GTL) extraction system for the extraction of amphetamine-type substances and their precursors from the vapor phase [477]; LC-MS/MS method for detection of the presence of synthetic amines in dietary supplements [478]; enantioselective HPLC-MS/MS method for the quantification of (R)-AMP, (S)-AMP, (R)-MA, (S)-MA, (1R,2R)-pseudoephedrine, (1S,2S)-pseudoephedrine, (1R,2S)-ephedrine, (1S,2R)-ephedrine, (1R,2S)-norephedrine, (1S, 2R)-norephedrine, (R)-cathinone, (S)-cathinone, and (1S,2S)-norpseudoephedrine (cathine) [479]; **2021** review of MA and AMP detection and roadside testing [480]; determination of the variations in delta C-13 and delta N-15 values of nitrogen sources used in the clandestine production of ATSs using isotope ratio mass spectrometry [481]; electrochemiluminescence strategy for the screening of MA and AMP [482]; review of laboratory-based and portable methods for detection of ATSs [483]; review of the prevalence of ATSs in Iran [484]; SALDI-MS method for the analysis of ATSs, including MA, MDMA, MDEA, and 4-fluoromethamphetamine (4-FMA) [485]; ATS drug classification using a one-dimensional convolutional neural network model [486]; **2022** colorimetric assay for detection of ATSs in aqueous solution, spiked drinks, and 'ecstasy' tablets [487]; development and validation of a GC-MS method for identification and quantification of AMP, MA, MDA and MDMA [488]; development of drug screening kits for the detection of ATSs in drinks [489]; analysis of feature selection method for 3D molecular structure of ATS drugs [490]; study of the pharmacological properties of MDA analogues and two related amphetamine-based compounds (N,alpha-DEPEA and DPIA) detected in street drug samples or in sport supplements [491]; chiral analysis of AMP (n = 143), MDMA (n = 94), and MA (n = 528) in samples seized in southern Germany in 2019 and 2020 using different chromatographic methods [492]; comparison of different chiral selectors for the enantiomeric determination of amphetamine-type substances by SPE-CE-MS/MS [493]; ultrahigh performance LC-MS/MS (UPLC-MS/MS) method coupled with magnetic SPE (MSPE) for determination of ultra-trace ATSs [494]; desk review of Vietnamese national drug policy documents regarding ATSs and in-depth key informant interviews were conducted from 2019 to 2021 [495].

1.6.2. Barbiturates

2019 separation of enantiomers of some chiral weak acids (including barbiturates) was studied in HPLC with chiral HPLC columns [496]; **2021** a DFT study to predict the acidity of barbiturates and their metabolites in the gas and aqueous phases [497]; study on the physical properties of low melting mixtures and their use as catalysts in the synthesis of barbiturates [498]; chemoselective synthesis of 5,4 ′-imidazolinyl spirobarbiturates via NBS-promoted cyclization of unsaturated barbiturates and amidines [499].

1.6.3. Benzodiazepines (BZDs)

2019 electrochemical sensor for the determination of clonazepam [500]; electrochemical sensor for the determination of five benzodiazepines (clonazepam, diazepam, alprazolam, chiordiazepoxide, oxazepam) with poly dopamine-poly folic acid (P(DA-FA)) nanocomposite modified glassy carbon electrode (P(DA-FA)-GCE) [501]; HPLC method for the simultaneous determination of three benzodiazepines [502]; Air-assisted liquid-liquid microextraction (AALLME) as an extraction method for three benzodiazepines (chlordiazepoxide, alprazolam, and lorazepam) followed by HPLC-UV for separation and determination [503]; simultaneous detection of a ternary mixture of the benzodiazepines diazepam, lorazepam, and flunitrazepam using an array of voltammetric sensors [504]; review of electrochemical-based approaches for the determination of the benzodiazepine class of drugs [505]; synthesis of flubromazepam positional isomers for forensic analysis [506]; analytical properties (LC-QTOF-MS, GC-MS and NMR) of the designer benzodiazepine 8-chloro-6-(2-fluorophenyl)-1-methyl-4H- [1,2,4] triazolo[4,3-a] [1,4]benzodiazepine (flualprazolam) seized in an anesthesia robbery case [507]; review provides a summary of sample preparation techniques (solid-phase extraction and Liquid-liquid phase extraction) and the methods for the detection and quantification of BZDs molecules [508]; liquid-chromatography high-resolution mass spectrometry method for the detection of 15 non-FDA approved BZDs [509]; **2020** spectrophotometric-reverse flow injection analysis (rFIA) method for the determination of Nitrazepam in pure and pharmaceutical preparations [510]; RP-HPLC method for the simultaneous determination of Clonazepam and metronidazole in pharmaceutical tablets [511]; microsolid-phase extraction for the preconcentration of Nitrazepam and Oxazepam before HPLC-DAD analysis [512]; FTIR and Raman spectroscopy method supported by Differential Scanning Calorimetry (DSC) for the screening and detection of benzodiazepine [513]; TD-DART-MS for the rapid and sensitive detection of a suite of 19 benzodiazepines [514]; sensor for detecting nitro-containing BZDs in beverages at DFSA crime scenes [515]; batch and cloud point extraction kinetic spectrophotometric method for determination of Nitrazepam and Clonazepam in pharmaceutical preparations [516]; MALDI-TOF-MS methodology for the quick and qualitative detection of benzodiazepines [517]; supercritical fluid chromatography coupled with tandem mass spectrometry method for the analysis of 140 chiral and non-chiral chemicals of emerging concern in environmental samples including benzodiazepines [518]; pipette-tip micro-solid phase extraction (PT-mu SPE) with corona discharge ionization-IMS (CD-IMS) for on-site fast detection of benzodiazepines in dietary supplements [519]; electrochemical sensor for measuring lorazepam in various matrices [520]; **2021** study of the characteristics of all recorded cases of novel benzodiazepines including toxicology and autopsy findings in Australia [521]; use of benzodiazepine derivatives in Spain between 2015 and 2020 [522]; LC-MS/MS method for identification and quantification of 16 novel and nonroutine benzodiazepines and suvorexant including bromazepam, clobazam, clonazolam, clotiazepam, diclazepam, estazolam, etizolam, flualprazolam, flubromazepam, flubromazolam, loprazolam, lormetazepam, phenazepam, prazepam, suvorexant, tetrazepam and triazolam [523]; handheld SERS-Raman method for determination of eight benzodiazepines (alprazolam, clonazepam, diazepam, estazolam, midazolam, temazepam, lorazepam and triazolam) in suspected counterfeit pharmaceuticals [524]; review of the type of NPS benzodiazepines in samples from a community drug checking program and comparison of the accuracy of point-of-care drug checking technologies when compared to confirmatory methods in this sample [525]; LC-MS/MS method for the detection and quantification of etizolam and its metabolite alpha-hydroxyetizolam, flubromazolam, clonazolam, diclazepam, delorazepam, bromazepam, flubromazepam, phenazepam, flualprazolam, flunitrazolam, and nitrazolam [526]; review of the distinct characteristics of designer benzodiazepine analogues in relation to their original prescription benzodiazepine compounds [527]; development and validation of an analytical method for the determination of two model-analytes of benzodiazepines (alprazolam and flunitrazepam) by HPLC-DAD [528]; review [529]; group-targeting SERS screening of total benzodiazepines [530]; **2022** fabrication of two selective and sensitive membrane electrodes used for evaluation of the electrochemical response of benzodiazepine drugs [531]; detection of 2-amino-3-(2-chlorobenzoyl)-5-ethylthiophene and 2-methylamino-5-chlorobenzophenone in seized yellow etizolam tablets marked “5617" [532]; SERS using a portable Raman spectrometer for the detection of etizolam in opioid drug mixtures (n = 100) obtained from the Vancouver Island Drug Checking Project [533].

1.6.4. Cathinones

2019 all regioisomers of CDC (i.e., 2-CDC, 3-CDC and 4-CDC) and CEC (i.e., 2-CEC, 3-CEC and 4-CEC) were acquired and analyzed using gas chromatography-electron ionization-mass spectrometry (GC-EI-MS), LC-DAD, FTIR and GC–CI–MS [534]review of the forensic and clinical aspects of bupropion (structurally related to cathinones) [535]; rapid tentative identification of synthetic cathinones in seized products using LC-MS/MS [536]; review [537]; chiral capillary electrophoresis method for the enantioseparation of 61 cathinone and pyrovalerone derivatives [538]; Four compounds (cathinone derivatives N-ethyl-2-amino-1-pheny lhexan-1-one hydrochloride, N-methyl-2-amino-1-(4-methylphenyl)-3-methoxypropan-1-one hydrochloride, N-ethyl-2-amino-1-(3,4-methylenedioxyphenyl)pentan-1-one hydrochloride and N-butyl-2-amino-1-(4-chlorophenyl)propan-1-one hydrochloride) found during seizure by drug enforcement agencies were identified and characterized by NMR, IR and Raman spectroscopies and X-ray crystallography [539]; differentiation of o-, m-, and p-fluoro-alpha-pyrrolidinopropiophenones by benzyltrimethylammonium hydroxide (Triton B)-mediated one-pot reaction [540]; review [541]; spectroscopic characterization of four synthetic Cathinones: 1-(4-Chlorophenyl)-2-(Dimethylamino)Propan-1-One (N-Met hyl-Clephedrone, 4-CDC), 1-(1,3-Benzodioxol-5-yl)-2-(Tert-Butylamino) Propan-1-One (tBuONE, Tertylone, MDPT), 1-(4-Fluorophenyl)-2-(Pyrr olidin-1-yl)Hexan-1-One (4F-PHP) and 2-(Ethylamino)-1-(3-Methylph enyl)Propan-1-One (3-Methyl-Ethylcathinone, 3-MEC) using single-crystal X-ray analysis, NMR, UHPLC-QQQ-MS/MS and GC-MS [542]; probe for quantitation and screening of 4-chloromethcathinone and cathinone analogues at crime scenes [543]; **2020** UV absorption properties of synthetic cathinones [544]; Study combines isotope-labeling, multi-stage mass spectrometry (MSn) and accurate mass measurements with high-resolution mass spectrometry (HRMS) to enhance the current understanding of the fragmentation pathways of alpha-pyrrolidinophenone synthetic cathinones and their application to the identification of emerging synthetic cathinone derivatives [545]; quantitative determination of chiral cathinone in fresh samples of Catha edulis [546]; review [547]; NMR methodology for chiral discrimination for several cathinones [548]; DFT calculations for prediction of Raman and infra-red spectra and activities of newly synthesized cathinones [549]; review [550]; structural analysis of new psychoactive substances methylone and pentylone [551]; the determination and separation of R- and S-enantiomers of methylone and ethylone by LC-MS/MS analysis [552]; analysis of synthetic cathinones in seized drugs using a portable low microflow LC with dual capillary columns and dual wavelength UV detection [553]; **2021** micellar electrokinetic chromatography (MEKC) mode of CE hyphenated to laser-induced fluorescence (LIF) detection method for analysis of synthetic cathinones [554]; analysis of synthetic cathinones in twelve seized products by Attenuated Total Reflectance

Fourier Transform Infrared (ATR-FTIR), GC-MS, and NMR [555]; a multivariant canonical discriminant analysis (CDA) approach for the differentiation of synthetic cathinone isomers using GC-EI-MS [556]; comparison of the mass spectra of 4-FMC, 4-MeO-alpha-PVP, 4-F-alpha-PVP, PV8, and alpha-pyrrolidinohexanophenone between LC-ESI-LIT-MS and GC-EI-MS [557]; electrochmical pofiling of synthetic cathinones in 26 confiscated samples from seizures and illegal webshops with validation using LC-MS characterization [558]; development of a targeted GC-MS method for synthetic cathinones [559]; a spectroscopic structural study of synthetic cathinones (clephedrone, flephedrone, and brephedrone) and their major human metabolites, desmethyl derivatives [560]; SPE Sequential Injection Analysis (SIA) method combined with NMR for determination of synthetic cathinones in seized drug samples [561]; H-1 quantitative NMR (H-1 qNMR) method for quantification of cathinone analogues using maleic acid as the internal standard [562]; **2022** investigation and resolution of interferences in the detection of 4-methyl-alpha-pyrrolidinopropiophenone (4-MePPP) by LC-QTOF-MS [563]; overview of enantioselectivity studies and enantioseparation analysis of synthetic cathinones [564]; preparation and evaluation of molecularly imprinted polymers as selective SPE sorbents for the determination of cathinones in river water [565]; characterization of three cathinone derivatives (1-[1-(4-methylphenyl)-1-oxohexan-2-yl]pyrrolidin-1-ium chloride (1, C17H26NO + center dot Cl-, the hydrochloride of 4-MPHP), 1-(4-methyl-1-oxo-1-phenylpentan-2-yl)pyrrolidin-1-ium chloride (2; C16H24–NO + center dot Cl-, the hydrochloride of alpha-PiHP) and methyl[1-(4-methylphenyl)-1-oxopentan-2-yl]azanium chloride (3; C13H20NO + center dot Cl-, the hydrochloride of 4-MPD)) by X-ray crystallography [566]; potentiometric sensor array to distinguish and detect cathinone derivatives [567]; bibliometric review of global research trends in psychoactive cathinones as illegal addictive substances from 1994 to 2018 [568].

1.6.5. *"Ecstasy Tablets" (that is, Tablets or Powders specified in their Titles or Abstracts as Ecstasy – these may in fact contain MDMA, a mixture of MDMA with one or more other Drugs, or only one or more non-MDMA Drugs)*

2019 analysis of clandestinely produced seized ecstasy tablets [569]; H-1 quantitative NMR and UHPLC-MS analysis of seized MDMA/NPS mixtures and tablets [570]; **2020** reversed-phase LC-DAD method for quantitative analysis of MDMA in ecstasy tablets [571]; vibrational spectra of three species (free base, cationic, and hydrochloride) of both S (+) and R(−) enantiomeric forms of ecstasy [572]; quantification of MDMA in tablets using benchtop H-1 NMR spectroscopy via either linear regression ('manual' method) or partial least squares regression ('automated' method) approaches without the need for an internal standard, and compared against contemporaneously obtained GC-MS data [573]; two datasets of ecstasy pills seized in the northeast of Switzerland between 2010 and 2011, the first of which contains 621 forensic-grade images of pills and the second consists of 486 MIR spectra [574]; **2021** electrochemical screening strategy for MDMA in ecstasy street samples [575]; **2022** two-step electrochemical sensor is introduced for the detection of MDMA and 2C–B in Ecstasy tablets [576].

1.6.6. *Ephedrines*

2019 Enantiomeric resolution of ephedrine racemic mixture using molecularly imprinted carboxylic acid functionalized resin [577]; multiphase extraction method for separation of ephedrine from pinellia ternate [578]; LCMS method for the enantiomeric separation of typical illicit drugs such as ephedrines (ie, 1S,2R(+)-ephedrine and 1R,2S (−)-ephedrine) and pseudoephedrine (ie, R,R(−)-pseudoephedrine and S,S(+)-pseudoephedrine) [579]; three compounds obtained from ephedrine (Ephedrone (methcathinone) hydrochloride and its fundamental derivatives N-acetylephedrine and N-acetylephedrone) were identified and characterized by GC-MS, NMRS, IR, Raman spectroscopy, and X-ray crystallography [580]; study of Raman spectroscopic differences between Ephedrine and pseudoephedrine using micro-Raman spectroscopy and UV resonance Raman spectroscopy [581]; **2021** electrochemical sensor for voltammetric (CV, DVP and square wave voltammetry) analysis of ephedrine in pharmaceutical dosage [582]; an ephedrine sensing method using an electrified liquid-liquid interface supported with an array of apertures micro-punched in the self-adhesive polyimide tape [583]; Birch reaction method was employed to synthesize amphetamine from ephedrine and detect the most known TLC byproduct of clandestine manufacture of amphetamines [584]; H-1 NMR method for quantification of ephedrine alkaloids (methylephedrine, ephedrine, norephedrine, norpseudoephedrine, pseudoephedrine, and methylpseudoephedrine) and ephedra herbal preparations [585]; electrochemical sensor for determination of ephedrine hydrochloride [586]; HPLC-IT/TOF-MS method for identification of impurities in chloroephedrine samples and preparation of a chloroephedrine standard [587]; method for chiral separation of ephedrine and its stereoisomers by supercritical fluid chromatography tandem mass spectrometry (SFC-MS/MS) [588]; isotope profiling of delta N-15, delta C-13, and delta H-2 isotope clusters of ephedrine/pseudoephedrine to characterize the origin of the precursor in seized methamphetamine samples [589]; calixarene based portable sensor for the direct assay of ephedrine in non-prescribed herbal supplements used as adjunctive therapy for weight loss [590]; analysis of the ephedrine in Pinellia tuber marketed products by LC-TOF/MS [591]; novel stationary phase coatings by zeolite SiO2NPs coupled with beta-cyclodextrin (beta-CD) or beta-CD/L-phenylalanine were developed for chiral open-tubular capillary electrochromatography and applied to the chiral separation of ephedrine and pseudoephedrine [592]; method for the rapid detection of ephedrine and pseudoephedrine chiral enantiomers using erythrosin B for the resonance Rayleigh scattering probe [593,594]; **2022** UV–Vis spectrophotometric method to estimate ephedrine hydrochloride in pharmaceutical drugs [595]; synthesis of eight new organotin derivatives containing ephedrine-substituted dithiocarbamate ligands [596]; high-resolution H-1 MAS NMR to distinguish between 1R, 2S-ephedrine [597]; UPLC-Q-TOF-MS and HS-SPME-GC-MS for the analysis and identification of ephedrine in Jizhi Syrup [598]; elucidate the effects of aldehydes in ethyl acetate on the analysis of ephedrines by GC/MS [599]; UPLC-MS/MS method for detection of ephedrine substances [600]; UHPLC/MS/MS method to detect five ephedrine analogues and two pairs of diastereoisomers [601].

1.6.7. *Ergot Alkaloids (EAs)*

2019 analysis of EAs in wheat and rye products in Italy [602]; LC-FLD method for the analysis of EAs in Rye Products using Lysergic Acid Diethylamide as an Internal Standard [603]; 2D LC-MS/MS method for the simultaneous determination of 350 pesticides, 16 mycotoxins, the six most important EAs (e.g. ergotamine/ergotaminine) and two modified mycotoxins (deoxynivalenol-3-glucoside and zearalenone-sulfate) [604]; **2020** a rapid NIRS method to detect and quantify alkaloids [605]; determination of the covariation of ergot severity and the content of 12 EAs using HPLC and ELISA [606]; NMR study for the complete assignment of the H-1, C-13, and N-15 NMR signals of two alkaloids [607]; LC-MS/MS method for determination of EAs and tropane alkaloids (TAs) [608]; **2021** review [609]; UHPLC-MS/MS analysis of EAs [610]; analytical workflow including mass spectral library, generic sample preparation, chromatographic separation, and analysis by HRMS was developed and applied to 156 compounds including 90 plant toxins (pyrrolizidine alkaloids (Pas), TAs, glycoalkaloids, isoquinoline alkaloids and aristolochic acids), 54 mycotoxins (including EAs and Alternaria toxins) and 12 phytoestrogens (including isoflavones, lignans and coumestan) [611]; UHPLC-MS/MS method for determination of major EAs (ergometrine, ergosine, ergotamine, ergocornine, ergokryptine, ergocristine) and their epimers (ergometrinine, ergosinine, ergotaminine, ergocorninine, ergokryptinine, and ergocristinine) [612]; review of analytical methods for EAs [613]; serotonin receptor activity profiles for nine commercialized EAs and corresponding risks of causing hallucinations [614]; UHPLC-MS/MS method for the quantification of six EAs (Ergocornine, ergocristine, ergometrine, ergosine, ergotamine, alpha-ergocryptine) and their corresponding epimers [615]; LC-MS/MS method for monitoring 12 EAs [616]; simultaneous determination of 11 EAs by UHPLC-MS/MS [617]; development and validation of an LC-MS/MS method to determine fifteen toxic alkaloids (EAs, PAs and TAs) [618]; UHPLC-MS/MS method to detect ten EAs [619]; UHPLC-q-Orbitrap MS method to monitor both mycotoxins, e.g., ochratoxin A (OTA) or deoxynivalenol (DON), and EAs [620]; detection of EAs and indole diterpenoids in ergot sclerotia using LC-HRMS/MS diagnostic fragment filtration [621];

1.6.8. Fentanyl-related substances

2019 Differentiation of fentanyl analogues by low-field NMR spectroscopy [622]; evaluation of newly developed lateral flow immunoassays (LFIs) designed for the detection of fentanyl and its derivatives [623]; chromatographic method for the separation of 20 different fentanyl analogues, homologues and positional isomers using ultra high-performance liquid chromatography with photodiode array ultraviolet and mass spectrometry detection [624]; UHPLC-MS/MS method for analysis of furanylfentanyl in different seized blotter papers [625]; wearable glove-based sensor that can detect fentanyl electrochemically on the fingertips towards decentralized testing for opioids [626]; SERS method for trace detection of fentanyl and identification of biological and chemical agents [627]; chromatographic separation of cyclopropylfentanyl and crotonylfentanyl by ultra-high-performance liquid chromatograph [628]; gas chromatography (GC) interfaced with both cold electron ionization mass spectrometric and vacuum ultraviolet detection by the means of a flow splitter for the simultaneous qualitative and quantitative analysis of twenty-four fentanyl analogues, including seven sets of positional isomers [629]; IMS for rapid on-site detection of Fentanyl mixtures [630]; HPLC-DAD method for simultaneous detection and quantification of heroin, fentanyl and ten fentanyl analogues [631]; IMS for the detection of fentanyl and fifteen (15) fentanyl-related compounds (analogues, other opioids, and metabolites) relative to confounding environmental interferents [632]; separation and detection of fentanyl and nine fentanyl analogues from mixtures using gradient elution moving boundary electrophoresis [633]; performance of handheld Raman devices for detecting one hundred opioids and related substances including fentanyl and several analogues [634]; analysis and differentiation of cyclopropylfentanyl from its isomers by LC-MS/MS [635]; characterization and differentiation of cyclopropylfentanyl from E-crotonylfentanyl, Z-crotonylfentanyl, and 3-butenylfentanyl by NMR, GC-MS and FTIR [636]; using multivariate chemical attribution signature analysis, by GC-MS and UHPLC-HRMS, to identify the synthetic methods used to prepare seized fentanyl analogues, independently of the analogues' acyl derivatization [637]; characterization of the chemical properties of fentanyl and its analogues to conduct microfluidic analysis for design optimization and performance evaluation of fentanyl test strips [638]; hyperpolarization of pyridyl fentalogues by signal amplification by reversible exchange (SABRE) [639]; technical-analytical review [640]; method for evaluating IMS for trace detection of fentanyl and fentanyl-related substances [641]; examination of fentanyl and six analogues using density functional theoretical (DFT) calculations and SERS [642]; use of paper SERS and paper spray MS on field-portable and commercial off-the-shelf (COTS) devices for the rapid identification and confirmation of fentanyl and its analogues, enabling in situ analysis at the point of seizure of suspect samples [643]; review of electrochemical sensors for the detection of fentanyl and its analogues [644]; LC-MS/MS-based method for the detection of morphine, fentanyl and their metabolites in limited sample volumes [645]; assessment of the limits of detection, sensitivity and specificity of three devices for checking fentanyl in street-acquired samples [646]; miniature mass spectrometer-based method for the fast and on-site analysis of fentanyl compounds [647]; impurity profiling of alfentanil hydrochloride by LC-QTOF-MS/MS techniques for drug enforcement [648]; UHPLC coupled with quadrupole-orbitrap HRMS for separation and determination of 32 fentanyl-related substances, including seven sets of isomeric fentanyl analogues [649]; machine learning is applied in a systematic manner to identify fentanyl-related functional groups using IR spectra of 632 organic molecules are from National Institute of Standards and Technology (NIST) database [650]; analysis of the fragmentation pathways and characteristic ions of 25 novel fentanyl analogues and 5 novel synthetic opioids by EI and ESI-HR-MS/MS [651]; **2021** examination of a commercially available fentanyl-directed lateral flow immunoassay to determine the presence of synthetic opioids in the field [652]; evaluation of the use of lateral flow immunoassay to detect fentanyl in seized drug samples [653]; use of paper spray mass spectrometry for the screening more than 190 synthetic fentanyl analogues [654]; synthesis of eight fluorinated fentanyl derivatives as pure reference materials and their complete NMR, IR and mass spectral characterization [655]; an on-site analytical protocol using a matrix-assisted ionization and a miniature ion trap mass spectrometer with a custom, expandable mass spec library to investigate the fragmentation patterns for 49 fentanyl analogues [656]; sensor for detection of carboxy-fentanyl [657]; UHPLC-MS/MS method for determination of nine new fentanyl analogues and metabolites (sufentanil and norsufentanil, *cis*-3-methylnorfentanyl, *trans*-3-methylnorfentanyl, metabolites of cis and transmethylfentanyl, beta-phenylfentanyl, phenylfentanyl, para-fluoro furanyl fentanyl, isobutyryl fentanyl and ocfentanil) [658]; analysis of drug seizure data from the National Forensic Laboratory Information System (NFLIS) for fentanyl and fentanyl analogues [659]; use of quantum calculations to obtain the IR spectra of 46 seized synthetic fentanyl analogues [660]; use of LC-QTOF-MS/MS spectra to identify diagnostic ions for detection of the core fentanyl structure in biological matrices [661]; literature review studying the detection and identification of synthetic opioids belonging to the fentanyl class by GC-MS and hyphenated versions of the technique [662]; breakdown and derivatization of a panel of nine fentanyls to yield uniquely tagged products that can be detected by EI-GC-MS [663]; semi-quantitative headspace analysis of fentanyl analogues and confiscated fentanyl exhibits using SPME-GC-MS [664]; LC-MS/MS for the simultaneous determination of 20 fentanyl analogues in collagen peptides, slimming capsules and fentanyl transdermal patches [665]; evaluation of 19 commercially available kits (9 lateral flow assays, 7 heterogeneous immunoassays and 3 homogenous immunoassays) for the detection of 30 fentanyl analogues and metabolites [666]; evaluation of a SERS substrate for use as a drug checking technology for fentanyl analogues in drugs [667]; investigation of fentanyl and carfentanil drug-use patterns in Ontario [668]; SERS method for detection of fentanyl [669]; **2022** DFT to computationally determine the proton affinity and gas-phase basicity of 15 fentanyl compounds [670]; handheld IMS method for vapor detection of fentanyl and related compounds [671]; study of the effect of five environmental conditions on the responses of two laminar flow immunoassay tests and one colorimetric test to six fentanyl analogues and five cross reactivity standards [672]; machine learning classification models as a complementary approach to library matching for detecting fentanyl analogues from mass spectra [673]; computational analyses of the vibrational spectra of fentanyl, carfentanil and remifentanil [674]; increased incidence of Fentanyl-related deaths involving para-fluorofentanyl or metonitazene November 2020–August 2021 [675]; analysis of the geometrical molecular structures, atomic charges, frontier molecular orbitals, and UV–visible electronic data of analgesic drugs carfentanil and acetylfentanyl were computed using quantum chemical code and NMR (H-1 and C-13) chemical shifts, vibrational wavenumbers, and the corresponding vibrational assignments were proposed on the basis of potential energy distribution [676].

1.6.9. Ketamine analogues and Arylcyclohexylamine derivatives

2019 reported cases involving identification of two ketamine analogues, 2-fluoro-deschloroketamine [2-(2-fluorophenyl)-2-methylamino-cyclohexanone] and deschloro-ketamine (2-phenyl-2-methylamino-cyclohexanone) [677]; report of deschloro-N-ethyl-ketamine causing a false positive phencyclidine immunoassay [678]; 2020 Identification of Psychoplastogenic N,N-Dimethylaminoisotryptamine (isoDMT) Analogues through Structure-Activity Relationship Studies [679]; a molecularly imprinted polymer for the SPE of arylcyclohexylamines [680]; case report of emergence of ketamine analogue, 2-fluorodeschloroketamine (2F-DCK); **2021** reported case of two new arylcyclohexylamine derivatives: 2-fluoro-deschloroketamine (2F-DCK) and 3-methoxyeticyclidine (3-MeO-PCE) with identification performed using NMR, HS-GC-FID, LC-MS/MS and LC-HRMS methods [681]; LC-HRMS method using a benchtop Orbitrap instrument for the characterization of the novel ketamine analogues methoxpropamine, 2-fluoro-deschloroketamine and deschloroketamine [682]; SPE-GC-MS method for the detection of 2F-DCK and KET [683]; **2022** analysis of urine and drug powder by LC-MS for quantification of 3-OH-PCP, 3-MeO-PCP, 2F-DCK, N-ethylhexedrone, and CMC followed by building a molecular network to confirm the consumption of powders contained in the bags [684].

1.6.10. NBOMe and NBOH compounds

2019 analytical differentiation of the indole ring regioisomeric chloro-1-n-pentyl-3-(1-naphthoyl)-indoles by CG-MS and GC-IR [685]; Simultaneous LC-MS/MS analysis of 2Cs, 25-NBOHs, 25-NBOMes and LSD in seized exhibits [686]; MALDI-MS and MALDI-MSD were coupled to a FT-ICR MS to analyze seven blotter papers of NBOMes containing 25I–NBOH and 251-NBOMe [687]; an electrochemical method using a SPCE for the detection and full differentiation of 25I–NBOMe, 25I–NBOH and 2C–I [688]; four halide derivatives of NBOMe, namely, 2-(4-fluoro-2,5-dimethoxyphenyl)-N-(2-methoxybenzyl)ethan-1-amine, 2-(4-chloro-2,5-dimethoxyphenyl)-N-(2-methoxybenzyl) ethan-1-amine, 2-(4-bromo-2,5-dimet hoxyphenyl)-N-(2-methoxybenzypethan-1-amine, and 2-(4-iodo-2,5-dime thoxyphenyl)-N-(2-methoxybenzyl)ethan-1-amine, were detected and quantified simultaneously using HPLC, and PAD and AD two detection systems were compared [689]; review of the main methods for the analysis of NBOMe in their chemical structures for detection in seized and biological materials for forensic and clinical purposes [690]; analysis of the fragmentation patterns of NBOMe derivatives using LC-QTOF-MS [691]; **2020** Fragmentation challenges in the identification of thermolabile NBOH compounds [692]; comprehensive triple quadrupole MS/MS protocol coupled to LC and GC, for rapid screening and quantitation of NBOMes and NBOHs in seized blotter paper [693]; an additive manufacturing 3D printed wall-jet flow cell for use with HPLC-AD for the detection and quantification of various a NBOMes [694]; use of short analytical columns (4 and 10 m) to decrease compound degradation in the GC oven during chromatographic separation to allow the analysis of non-derivatized 25R–NBOH compounds by GC-MS [695]; synthesis, characterization, and sensing behavior of a hybrid nanodevice for the detection of 25I–NBOMe [696]; Synthesis and determination of analytical characteristics and differentiation of positional isomers in the series of NBOMes using chromatography-mass spectrometry [697]; analysis of blotter paper samples containing 25I–NBOMe and 25C–NBOMe using complementary techniques including micro x-ray fluorescence (mu XRF), LA-ICP-OES, MALDI-MS, and LC-MS [698]; review [699]; review of 25I–NBOMe [700]; review of 25C–NBOMe [701]; identification of a new class of thermolabile psychoactive compounds, 4-substituted 2-(4-X-2, 5-dimethoxyphenyl)-N- [(2-hydroxyphenyl) methyl] ethanamine (25X–NBOH, X = Cl, Br, or I) by GC-MS using chemical derivatization by heptafluorobutyric anhydride (HFBA) [702]; identification and structural elucidation of three NBOHs detected in seized blotter papers (25B–NBOH, 25C–NBOH, and 25E-NBOH) using FTIR, GC-MS, LC-MS/MS and NMR spectroscopy [703]; **2021** chemical color spot test that can selectively identify the presence of 25-NBOMe compounds and related analogues [704]; synthesis method for NBOHs (25H-, 25I- and 25B–NBOH; 9–38% overall yield) and NBOMes (25H-, 25I- and 25B–NBOMe; 7–33% overall yield) to be used as reference standards for forensic purposes [705]; method for synthesis of 25CN–NBOH [706].

1.6.11. Nitrobenzimidazoles (Nitazenes)

2021 identification and full chemical characterization of “etonitazepyne” or “N-pyrrolidino etonitazene” (2-(4-ethoxybenzyl)-5-nitro-1-(2-(pyrrolidin-1-yl)ethyl)-1H-benzo[d]imidazole), a potent NPS opioid of the 5-nitrobenzimidazole class by GC-MS, HRAM LC-MS/MS, H-1 NMR, and FTIR [707]; review [708]; ten nitazenes and four metabolites were synthesized, analytically characterized via HPLC-DAD and LC-QTOF-MS [709]; **2022** in-depth chemical analysis of } Etonitazepipne (N-Piperidinyl etonitazene) in powder via different techniques (LC-HRMS, GC-MS, UHPLC-DAD, FT-IR and pharmacological characterization [710]; LC-MS/MS method for the quantification of analogues and/or metabolites of drugs in the nitazene series (isotonitazene, metonitazene, protonitazene, etonitazene, clonitazene, flunitazene, N-desethyl isotonitazene, and 5-amino isotonitazene) [711].

1.6.12. Opioids

2019 determination of ocfentanil and W-18 in a heroin-like powder using LC-DAD and GC-MS for screening and confirmation by LC-TQMS [712]; multicomponent computational approach to assess the structural and pharmacological similarity of newly identified drugs of abuse to controlled substances with focus on newly emerging illicit opioids [713]; Traceable Opioid Material Kits which provides over 150 opioid reference standards, including over 100 fentanyl analogues [714]; Liquid chromatography-chemiluminescence nitrogen detection (LC-CLND) for quantification of seized synthetic opioids [715]; review on the chemistry and pharmacology of synthetic opioids on the illicit drug market [716]; SERS method for detection of trace amounts of opioids on clothing and packages [717]; **2020** Open Port Interface Mass Spectrometry (OPI-MS) method for detection of opioids on mail and packaging materials [718]; **2021** sensor for detection of opiate drugs in pharmaceutical, clinical and forensic applications [719]; chemiluminescence method coupled with flow injection for determination of nalbuphine hydrochloride in pharmaceutical formulations [720]; analytical method for the simultaneous determination of a broad range of opioids in wastewater [721]; detection of carfentanil and etizolam in opioid samples acquired at a drug checking service using a portable GC-MS [722]; wastewater analysis of opioids [723]; pipette-tip-RSPE of seven opioid analgesics (morphine, codeine, oxycodone, tramadol, nalbuphine, thebaine, and noscapine) followed by HPLC-UV analysis [724]; a SERS method for the detection of trace levels of opioids (fentanyl, hydrocodone, oxycodone, and tramadol) in suspect tablets using two different handheld Raman spectrometers equipped with 785 and 1064 nm lasers [725]; CV to examine the transfer of the protonated forms of several natural and synthetic opioids including fentanyl and its analogues, morphine, heroin and codeine [726]; LC-QTOF-MS/MS and NMR spectroscopy for the identification and structural characterization of synthetic opioids (3,4-methylenedioxy-U-47700 and four fentanyl analogues:o-methyl-acetylfentanyl, benzoylfentanyl, 2-thiophenefentanyl and benzoylbenzylfentanyl) [727]; development of a targeted GC-MS method for the confirmation of synthetic opioids and related compounds [728]; SERS method for detection of opioids [729]; **2022** LCMS analysis of methylenedioxy U-47700, ethylenedioxy U-47700, ethylenedioxy U-51754, U-69593, U-47931E (bromadoline), U-47700, U-48800, U-49900, U-51754, U-50488, propyl U-47700 and isopropyl U-47700 [730]; investigation of the structure activity relationships at the mu- and kappa-opioid receptors of eight U-opioids (U-47700, isopropyl U-47700, U-49900, U-47931E, N-methyl U-47931E, U-51754, U-48520, and U-48800) using a [S-35]-GTP gamma S assay [731]; assessment of opioid surrogates for colorimetric testing [732]; assessment of opioid surrogates for IMS [733]; review of the life cycles of isotonitazene and brorphine on the opioid market in 2019 and 2020, from their earliest synthesis as described in scientific literature to their subsequent rise and fall on recreational markets as an illustration of the new characteristic life cycle of synthetic opioids in the ‘post--fentanyl-analogue’ era [734].

1.6.13. Piperazines

2021 voltammetric profiling of psychoactive piperazine derivatives 1-phenylpiperazine (PhPIP), mCPP, 3-trifluoromethylphenylpiperazine (TFMPP), 4-fluorophenylpiperazine (pFPP) and benzylpiperazine (BZP) [735]; voltammetric determination end electrochemical behavior of aryl piperazines of forensic interest, including 1-(4-methoxyphenyl) piperazine (pMeOPP), 1-(4-chlorophenyl)piperazine (pCPP) and 1-(4-trifluoromethylphenyl)piperazine (pTFPP) [736]; rapid method of detecting piperazine derivatives using LC-MS [737]; **2022** detection and structural elucidation of 1-(4-bromophenyl)piperazine (pBPP), 1-(3-chloro-4-fluorophenyl)piperazine (3,4-CFPP) and methyl 8-methyl-3-phenyl-8-azabicyclo[3.2.1]octane-4-carboxylate (troparil) using LC-HRMS/MS-QTOF, GC-MS and NMR spectroscopy [738].

1.6.14. Steroids

2019 Certification of a testosterone calibration standards [739]; Detection of steroids and human growth hormone using color-changing cyclodextrin systems [740]; semi-quantitative determination of designer steroids by HPLC - UV [741]; **2020** analytical approaches applied to the analysis of apprehended formulations of anabolic androgenic steroids [742]; **2021** comparison of four valid analytical methods (LCMS, GC-ECD, TLC and ELISA) for the determination of anabolic steroids (progesterone, testosterone, and estrogen). antibiotics (tetracycline. sulfonamides, gentamycin, and cephalexin), antibacterial compounds (Macrolide, beta-Lactam. Chloramphenicol, Sulfur drugs, and Gentamicin), organochlorine pesticides, dichlorodiphenyldichloroethylene, dichlorodiphenyltrichloroethane, alachlor, and organophosphate in meat products [743]; LC-UV and LC-MS/MS methods for the determination of selected steroid hormones [744]; LC-APPI-MS/MS method for simultaneous determination of endogenous steroids (11-deoxycortisol, 11-ketotestosterone, 17 alpha and 178-estradiol, 17 alpha-hydroxyprogesterone, 17,208-dihydroxyprogesterone, 17,208, 21-trihydroxyprogesterone, androstenedione, cortisol, estriol, estrone, progesterone, and testosterone) [745]; MS method for characterization of anabolic-androgenic steroids in illegal seized samples [746]; GC coupled to isotope ratio MS (GC-C-IRMS) method for analysis of 19-norandrosterone and 19-noretiocholanolone [747]; sensing platform for detection of testosterone [748]; mu ATR-FTIR mapping for forensic analysis of the composition of anabolic steroid tablet [749]; colorimetric aptasensor for the detection of testosterone [750]; CE and UHPLC for determining steroids in water [751]; MALDI-MS method for detection of steroids [752]; **2022** electrochemical probe for trace determination of the Steroid 11-Desoxycorticosterone [753]; aptamer-based assays coupled with electrochemiluminescence sensing for detection of testosterone [754]; LC-HRMSMS for the analysis of ABS TRACT Dehydrochloromethyltestosterone (DHCMT) [755]; HPLC-UV detection of designer steroid 17 beta-hydroxy 5 alpha-androst-1-en-3-one cypionate in an injectable liquid and subsequently characterized using HRAM-MS, NMR spectrometry, and GC-MS [756]; origami paper-based analytical device based on ELISA for testosterone detection [757]; GC-MS/MS method for simultaneous detection of 93 anabolic steroids in dietary supplements [758].

1.6.15. Tryptamines (see also Mushrooms)

2022 qualitative and quantitative analysis of Tryptamines (5-MeO-DMT, 5-MeO-N-methyltryptamine, 5-MeO-tryptamine, 5-MeO-tryptophol, 2-(5-methoxy-1H-indol-3-yl)-acetic-acid (5-MIAA), 5-HO-N-methyltryptamine, bufotenin, DMT and tryptophan) in the poison of Incilius alvarius (Amphibia: Bufonidae) using GC-MS, HPLC-QTOF-HRMS and HPLC-MS/MS [759].

1.7. Synthetic Cannabinoids and Cannabimimetics (SCs) [Notes: compounds are listed either by their acronym or full name as was specified in their respective abstract – no effort was made to transcribe acronyms to full chemical names or vice versa. Articles that include both synthetic cannabinoids and/or cannabimimetics with other drugs are detailed separately.]

1.7.1. Individual synthetic Cannabinoids and Cannabimimetics

2020 GC-MS method for the isolation and quantification of FUB-AMB [760]; electrochemical sensing method for JWH-018 [761]; detection and characterization of APP-BINACA in seized drug material by GC-MS, LC-QTOF-MS, and NMR spectroscopy [762]; **2022** structural characterization of indole-3-acetamide scaffold, N-cyclohexyl-2-(1-pentyl-1H-indol-3-yl)acetamide (CH-PIACA) in a seized material in Denmark using GC-MS, LC-HRMS, and NMR spectroscopy [763];

1.7.2. Multiple synthetic Cannabinoids and Cannabimimetics

2019 analysis using UHPLC-TOF-ESI-MS and GC-MS for detection of six synthetic cannabinoids tested in a smoking simulator [764]; SERS method for detecting synthetic cannabinoids in herbal highs [765]; **2020** solid-state C-13 and F-19 NMR spectroscopy method for the identification of forensically relevant synthetic cannabinoids on herbal substrates [766];

FTIR, NMR, GC/MS and/or LC/MS for detection of synthetic cannabinoids in the unregulated drug supply in Canada - synthetic cannabinoids detected included AMB-FUBINACA, AB-FUBINACA, 5-fluoro-MDMB-PINACA, and 5-fluoro-MDMB-PICA, and often with fentanyl [767]; LC-QTOF-MS assay for the identification of synthetic cannabinoid parent compounds and metabolites, including real-time identification of emergent compounds (including 5F-MDMB-PICA, 4-cyano CUMYL-BUTINACA and 5F-EDMB-PINACA) [768]; **2021** integration of GC-MS and NMR data as a strategy for the identification and confirmation of synthetic cannabinoids (5 napthoylindoles (JWH-018, JWH-073, JWH-122, JWH-210, MAM-2201), APINACA, XLR-11 and CP47,497-C8 and its enantiomer) present in nine seized herbal incenses [769]; electrochemical screening strategy for the detection of synthetic cannabinoids [770]; HPLC-PDA and HPLC-PDA-QTOF-MS methods were applied to 177 infused paper samples seized in Scottish prisons between 2018 and 2020 for detection of synthetic cannabinoid receptor agonists [771]; characterization of analytical profiles and impurities of QMPSB, QMMSB, QMPCB, 2F-QMPSB, QMiPSB, and SGT-233 [772]; review of the challenges of synthetic cannabinoids for forensic chemists [773]; determination of 5F-QUPIC and MDMB-CHMICA in seized plant material by GC-MS, H-1 NMR and HPLC-DAD [774]; synthesis and analysis of 5F-PB-22, NM-2201, UR-144 and AB-CHMINACA by ESI-MS, GC-EI-MS, GC-FID, HPLC, Raman spectroscopy as well as H-1 NMR [775]; detection, activity and toxicity of the pent-4en- and but-3en synthetic cannabinoid analogues including MDMB-4en-PINACA, MMB-4en-PICA and MDMB-3en-BINACA [776]; development of GC-MS and NMR methods for the identification and quantification of synthetic cannabinoids in herbal blends [777]; review of the forensic, clinical, and analytical implications of ADB-FUBINACA and AMB-FUBINACA [778]; evaluation of different TLC methods for detection of cannabinoids and standardization of color nomenclature [779]; LLE-LC-MS method for the extraction and detection of 50 cannabinoids including the cannabis urinary biomarker 11-nor-9-carboxy-Delta (9)-tetrahydrocannabinol (THC-COOH), Delta(9)-tetrahydrocannabinol (THC), cannabidiol (CBD) [780]; method for the detection of synthetic cannabinoids in air using a fixed sequential sampler, alongside personal air sampling units worn by prison officers where air samples were collected onto TD tubes and analyzed via two-dimensional GC x GC-TOF MS [781]; structure elucidation and analytical characterization of Cumyl-BC[2.2.1]HpMeGaClone, Cumyl-BC[2.2.1] HpMINACA, and Cumyl-BC[2.2.1]HpMICA using GC-MS, GC-sIR, solid and neat IR spectroscopy, Raman spectroscopy, LC-ESI-MS, HR-LC-ESI-MS, NMR spectroscopy [782]; LC-MS-MS assay for the simultaneous quantification of 12 cannabinoids and their metabolites in breast milk [783]; development of a targeted GC-MS method for synthetic cannabinoids [784]; detection of synthetic cannabinoids (AMB-FUBINACA, AB-FUBINACA, 5-fluoro-MDMB-PINACA, and 5-fluoro-MDMB-PICA, and fentanyl) using FTIR spectroscopy, quantitative NMR spectroscopy, GC/MS and/or LC/MS [785]; NMR profiles of 13 samples of e-liquids supplied by French customs were collected and quantitative results were obtained for five synthetic cannabinoids detected (JWH-210, 5F-MDMB-PICA, 5F-ADB, 5F-AKB48, and ADB-FUBINACA) with confirmation by conventional GC-MS [786]; **2022** chemical synthesis and spectroscopic characterization of novel 4-, 5-, 6-, and 7-azaindazole analogues of the synthetic cannabinoid MDMB-PINACA using UV, IR, GC-MS, HRMS, 1D- and 2D- NMR and HPLC for the spectroscopic differentiation [787]; evaluation of the use of electrochemistry for screening SCs STS-135 and BB-22 [788]; optimization of an LC-MS/MS method to analyze 8 synthetic cannabinoids and metabolites (in total 16 analytes) in wastewater [789]; detection of ADB-BUTINACA, ADB-4en-PINACA, and ADB-HEXINACA in forensic toxicology casework and infused papers seized in prisons [790]; review the analytical methodologies developed and adopted for the analysis of the SCs in herbal products [791]; application of the linear retention index (LRI) system for the identification of non-psychoactive cannabinoids using a portable LC instrument [792]; screening for synthetic cannabinoids in adulterated low-delta-9-tetrahydrocannabinol products using LC-HRMS [793]; emerging synthetic cannabinoids (ACHMINACA (n = 15), AB-FUBINACA (n = 3), and 4-fluoro-MDMB-BUTINACA (n = 1)) detected in samples analyzed between April and November 2020 by a drug checking service in Toronto, Canada [794]; hydrophobic 1-dodecanethiol-stabilized gold nanoclusters (DT-Au NCs) were prepared for sensing SCs, including UR-144, JWH-018, and AB-PINACA [795].

1.7.3. Synthetic Cannabinoids and Cannabimimetics with other drugs (except when a minor part of a larger study)

2020 Co-detection of the synthetic cannabinoid AMB-FUBINACA, with the piperazine para-fluorophenylpiperazine (pFPP), in plant materials seized in New Zealand in 2017 [796].

1.8. Polydrug A: mixed or unrelated individually named compounds or substances

2020 Electrochemical sensor for determination of morphine in the presence of tramadol [797]; electrode for detection of LSD, MDMA and MA [798]; SERS method for simultaneous detection of ketamine and amphetamine [799]; a four-channel paper microfluidic device (mu PAD) that uses colorimetric sensors to detect cocaine, codeine and MA [800]; **2021** validation of an immunochromatography screening method and a GC-MS confirmation method for the detection of MA and amphetamine [801]; LCMS analysis of four illicit stimulants: 3,4-methylenedioxymethamphetamine (MDMA), 3,4-methylenedioxyamphetamine (MDA), cocaine and MA and three new psychoactive substances (NPS): ethylone, mephedrone and N-ethylpentylone for monitoring wastewater over the Christmas-New Year period in South Australia from 2016 to 2019 [802]; LC-HRMS method to detect two novel stimulants, mephedrone and ethylphenidate, and selected metabolites [803]; study on the emergence of N-methyl-2pyrrolidone in GBL-containing liquids in New Zealand [804]; GC-MS, HPLC-UV and LC-Q-ToF analysis of seized heroin and cocaine samples by Luxembourg Police and Customs in 2019–2020 [805]; sensor for electrochemical profiling of oxymorphone and heroin [806]; DFT study on the sensing properties of Al- and Si-doped HBC nanostructures toward GBL in presence of GBH and ecstasy [807];

HS-SPME-IMS method for determination of ketamine and midazolam [808]; magnetic dispersive SPME coupled with GC-MS for simultaneous determination of tramadol and fluoxetine in water and biological samples [809]; ultrasound-assisted dispersive SPME technique for simultaneous preconcentration and determination of ultra-trace amount of carbamazepine and phenobarbital [810]; review focusing on the sensing of DFSA drugs (Rohypnol, flunitrazepam, GHB and ketamine) and potential limitations for real life implementations of the sensors [811]; optimization and validation of a dried blood spot microwave-assisted extraction LC-MS method for the determination of selected substances from the date-rape drugs group: ketamine, benzodiazepines and cocaine [812]; simultaneous voltammetric determination of noscapine and lorazepam [813]; **2022** CV with portable Raman spectroscopy for determination of mephedrone (4-MMC) and 4-methylethcathinone (4-MEC) [814]; ion-selective electrodes for cocaine, tropane, atropine, and scopolamine [815]; electrochemical sensor for the simultaneous detection of morphine and methadone [816]; HPLC method for simultaneous detection of four sedative-hypnotic drugs (diazepam, ketamine, nimetazepam, and xylazine) recovered from spiked beverages [817]; Vortex-assisted dispersive liquid-liquid microextraction-gas chromatography (VADLLME-GC) determination of residual ketamine, nimetazepam, and xylazine from drug-spiked beverages in liquid, droplet, and dry forms [818]; LC-MS-MS screening method for MA, AMP, MDMA, MDA, paramethoxymethamphetamine (PMMA), ephedrine, pseudoephedrine, ketamine, deschloroketamine (DCK), 2-fluorodeschloroketamine (2-F-DCK) and 2-oxo-PCE [819]; enrichment bag-based liquid-phase microextraction (EB-LPME) system to isolate and enrich AMP, MA, MDMA, ketamine, codeine and fentanyl from wastewater [820].

2. Instrument focus

Forensic Chemists must maintain familiarity with updates in current instrumental techniques and become versant in new, improved methods of analysis. Improved/existing and new technologies are reviewed and applied to both routine and specialized analyses of drugs. In cases where improved performance is observed, case reports are generated for the forensic community.

2.1. Polydrug B: mixed or unrelated groups of compounds or substances

2.1.1. Named groups of compounds

2020 solutions for the selective electrochemical analysis for the detection of cocaine in speedball-like polydrug samples adulterated with heroin and codeine [821]; review of electrochemical detection of illicit drugs (such as cocaine, heroin, and (meth)amphetamine), their precursors and derivatives in different matrices [822]; an approach to identify and estimate the purity of white powders as amphetamine, cocaine, ketamine or others using spectroscopic techniques hyphenated with partial least squares (PLS) modelling [823]; electron ionization (EI) and electrospray ionization (ESI) high-resolution mass spectrometry fragmentation pathways and characteristic ions of 25 novel fentanyl analogues and 5 novel synthetic opioids to provide a reference for the identification of these compounds [651]; **2021** UHPLC-MS/MS method to determine the designer benzodiazepines (clonazolam, deschloroetizolam, nifoxipam, flubromazolam and meclonazepam), and the Z-hypnotics (zolpidem, zaleplon and zopiclone) [824]; an ultrasonic cutter-assisted non-thermal desorption (non-TD) method for ultra-trace level detection of different types of nonvolatile compounds such as drugs of abuse, explosives, pharmaceuticals, spinosad, cholesterol, rhodamine B, glucose and amino acids [825]; HR-EIS-QTOF-MS comparison study of in-source versus beam-type collision-induced dissociation for fentanyl analogues and synthetic cathinones [826]; ATR-FTIR method used with PCA, Fisher discriminant analysis (FDA), and K nearest neighbor analysis (KNN) to develop a method for differentiating barbiturates, benzodiazepines, and phenothiazines [827]; H-1 and F-19 NMR spectroscopy method for the dection, discrimination and quantification of amphetamine, cathinone and nor-ephedrine regioisomers [828]; validated UHPLC-ESI-MS/MS method for determination of 19 psychoactive substances, including nine amphetamine-type stimulants and 10 synthetic cathinone derivatives [829]; review of the research on chiral separation of amphetamines, ketamine, cathinones [830]; **2022** Comparison of two seized drug workflows for the analysis of synthetic cannabinoids, cathinones, and opioids that includes color tests for screening with GC-FID and GC-MS analyses for confirmation verus DART-MS screening with class-specific (targeted) GC-MS [831].

2.1.2. Abused substances illegally added to licit pharmaceuticals, herbal medications, health supplements, foodstuffs, cosmetics

2019 Rapid detection of adulteration of dehydroepiandrosterone in slimming products by competitive indirect enzyme-linked immunosorbent assay and lateral flow immunochromatography [832]; screening method for detection of illegal adulterants in ginseng pills by profiling analysis of HPLC multi-dimensional fingerprints [833]; **2020** identification of tert-butyl-4-anilinopiperidine-1-carboxylate (4-anilinopiperdine-t-BOC or 4-AP-t-BOC) in seized falsified 'Xanax' tablets and suspected heroin seizures [834]; 20 herbal mixtures containing Cumyl-PEGACLONE were quantitatively analyzed by HPLC-DAD after an initial screening by gas chromatography mass spectrometry [835]; simultaneous and reliable determination of 20 pharmaceutical compounds in adulterated health food products using liquid chromatography with electrospray ionization tandem mass spectrometry (LC-ESI-MS/MS) and liquid chromatography with quadrupole-time-of-flight mass spectrometry (LC-QTOF-MS) [836]; MALDI-MS method for analysis of illegal drugs and doped substances added in supplements [837]; **2021** voltammetric method for analyzing weight loss products adulterated amphetamine [838]; development and validation of an HPLC-MS/MS system for the analysis of 16 chemical drugs illegally added to dietary supplements for weight-loss in a capsule form [839]; quantification of pharmaceuticals or prescription medications (fluoxetine, phenolphthalein, and sibutramine illegally added to herbal weight loss supplements by RP-HPLC-MS/MS [840]; IMS qualitiative screening method for illicit additives (ibuprofen, nitrazepam, nitrendipine, indomethacin, phenobarbital, sibutramine, diclofenac sodium, diazepam, estazolam, melatonin, phenolphthalein, prednisone acetate, betamethasone, metformin HCl, glibenclamide, and tadalafil) in herbal pharmaceuticals and health foods with quantification by HPLC [841]; UPLC-PDA and LC/EIS-MS/MS methods for simultaneously screening for 25 anti-hyperlipidemic substances illegally added to dietary supplements [842]; HPLC-DAD method for the identification and quantification of sexual stimulants and anabolic steroids in the adulterated dietary supplements [843]; MALDI-MS method for the analysis of illegally added and doped substances added to medicines or food [837]; **2022** mixed-mode sorbent for SPE of hydrophobic and hydrophilic illegal additives from food sample followed by analysis by RPLC/HILIC-MS/MS [844]; analytical techniques and metrological principles in studying dietary supplement products and ingredients, particularly medicinal plants and other botanicals [845]; a membrane-protected micro-SPE method based on molecular imprinting and its application to the determination of local anesthetics illegally added to cosmetics [846]; application of predicted fragmentation pathways and fragment ion structures with LC-QTOF-MS for the analysis of 15 steroids and 20 selective androgen receptor modulators in dietary supplements [847]; development of an atmospheric pressure solids analysis probe coupled with single-quadrupole mass spectrometer (ASAP-MS) to rapidly screen 42 common illegal additives in six categories of functional food and analysis of 21 batches of seized unknown samples by ASAP-MS and confirmed by LC-MS/MS (QQQ) [848].

2.1.3. "Hallucinogens", "Hypnotics" (and similar generic terms)

2019 SERS method for screening spiked beverages for various hypnotics [849]; **2021** survey of socio-demographics, preferences, experiences and attitudes associated with hallucinogen use in Slovakia [850]; review of different hallucinogens [851].

2.1.4. "Illicit drugs" (including "Controlled Substances," "Drugs of Abuse," "Illegal Drugs," "Narcotics," "Seized Drugs," "Street Drugs" and similar generic terms)

2019 separation with Magneto-Archimedes levitation (MagLev), followed by characterization by FTIR-ATR of powdered mixtures of illicit drugs (cocaine, MA, heroin, fentanyl, and its analogues), adulterants, and diluents based on density, for the presumptive identification of individual components [852]; SERS for the detection of illegal injectables [853]; study investigates the prevalence of drugs of abuse detected from 2011 to 2015 through forensic drug testing of illicit drug seizures from law enforcement agencies [854]; ambient mass spectrometry and LC-MS/MS for the rapid detection and identification of multiple illicit street drugs [855]; rapid analytical method using an Orbitrap mass spectrometer for identification of 32 illicit drugs in marketed products was developed (included benzodiazepine-, synthetic cannabinoid-, amphetamine- and benzylpiperazine-type drugs) [856]; Thermal Desorption Direct Analysis in Real Time Mass Spectrometry (TD-DART-MS) for the simultaneous detection of rodenticides and drugs in seized drug mixtures [857]; Capillary Microextraction-Mass Spectrometry (CME-MS) method for the analysis of Illicit Drugs [858]; LC-MS/MS method for designer drugs that combines synthetic cannabinoids and synthetic cathinones, etizolam, a designer benzodiazepine and mitragynine (kratom) [859]; review of the epidemiology, chemistry, pharmacophysiology, clinical effects, laboratory detection, and clinical treatment for newly emerging drugs of abuse in the following classes: (1) opioids (2) cannabinoids (3) stimulants and hallucinogens (4) dissociative agents and (5) sedative-hypnotics [860]; type and purity analysis of seizured illicit substances (screened by GC-MS and LC-MS/MS followed by GC-FID for quantitative analyses) [861]; TD acetone-assisted photoionization miniature ion trap mass spectrometer was developed for on-site and rapid identification of illegal drugs at checkpoints [862]; a synchronized flash-thermal-desorption purging and ion injection (SFTDPI) method to increase the sensitive and rapid screening of volatile and nonvolatile illegal drugs for miniature ion trap mass spectrometry (ITMS) [863]; vacuum filtration-paper chromatography-SERS (VF-PC-SERS) for field analysis of illicit materials [864]; **2020** Evaluation of seized performance enhancing drugs in Isreaal from 2012 to 2017 [865]; integration of SERS and PSI-MS to enable on-site chemical analysis by two independent methods for on-site illicit drug confirmation [866]; feasibility study to examine creating mutant protein arrays capable of detecting drugs of abuse in solution or in vapor phase [867]; high-resolution Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS) applying different ionization sources such as paper spray ionization (PSI) and electrospray ionization (ESI) in the evaluation of seized drugs samples on blotter paper ($n = 79$) and tablet ($n = 100$) [868]; two paper electrospray ionization quadrupole-orbitrap mass spectrometer screening procedures for detection of drugs of abuse, pharmaceuticals and chemical warfare agents in soil by direct analysis [869]; raman spectroscopy and ambient ionization mass spectrometry for bulk analysis of over-the-counter drugs using benchtop instruments, as well as trace analysis of illicit drugs utilizing corresponding portable instruments [870]; screening analysis by GC-MS and confirmatory analysis by LC-QTOF of 357 used syringes suspected of containing illicit drugs of abuse [871]; development and validation of a screening method using a portable quadrupole-based gas chromatography mass spectrometer (FLIR Griffin (TM) G510) to identify drugs of abuse and adulterants in seized material, and compared to GC-MS (method was validated for the identification of alprazolam, amphetamine, aminopyrine, benzocaine, caffeine, cocaine, codeine, diltiazem, ephedrine, fentanyl, fenethylline, furanylfentanyl, heroin, hydroxyzine, levamisole, lidocaine, MA, morphine, noramidopyrine (a marker of metamizole), phencyclidine, phenacetin, procaine, strychnine and xylazine) [872]; determination of drug residues in used syringe needles [873]; MALDI-HRMS method for the high-throughput qualitative and quantitative analysis of drug samples [874]; XRPD to analyze samples seized on the black market (heroin, cocaine, mephedrone, ephylone, butylone, JWH-073, and naphyrone) [875]; analytical method for the analysis of active ingredients in pharmaceutical products and illegal drugs, based on benchtop NMR spectroscopy [876]; quadrupole Orbitrarp (TM) mass spectrometer for identification of illicit drugs in marketed products [877]; raman spectroscopy in conjunction with the characteristic peaks method for the qualitative analysis of seized drug samples [878]; sensor for detection of psychoactive drugs (cocaine, methylphenidate, ampheatimen, heroin) in water [879]; IMS and APCI-ITMS for screening passport documentation for forensic drug intelligence purposes [880]; non-contact screening for illicit substances via vapor collection followed by TD [881]; evaluation of the solvent effects for the TD of illegal drugs on a polytetrafluoroethylene (PTFE) swab [882]; enzyme-based test method for lactose in illicit drugs [883]; nanoscale colorimetric probe for discriminating illegal drugs from other substances of common use [884]; GC-FTIR spectroscopy method for identification of analysis of complex mixtures of illicit drugs [885]; **2021** GC-MS and LC-MS analysis of drug seizures in Kuwait from 2015 to 2018 [886]; descriptive study of psychoactive substances seized in Jordan from 2014 to 2018 [887]; review of prior research on illicity supply-chain netrowrks, procedures for detection and disruption [888]; SERS method for detection and monitoring of drugs of abuse [889]; development of a low-barrier system for monitoring the contents of drugs in the unregulated street supply [890]; a national wastewater campaign was performed for the first time to get more insight on the consumption of illicit drugs within Spain [891]; identification of the anti-coagulant rodenticide coumatetralyl in seized tablets [892]; assessment of FTIR spectroscopy as a test method for seized drugs [893]; Raman SORS technology for rapid identification of narcotics in a range of concentrations including the pure form to street forms that are cut with adulterants [894]; analysis of the content of used syringes collected in 7 European cities in 2017 and 2018 using GC-MS and (U)HPLC -MS analytical techniques [895]; review of sample preparation techniques and instrumentation methods for the analysis of illicit drugs in solid, liquid, and gas samples [896]; LC-MS/MS method for simultaneous determination of multiclass illicit drugs (cocainoids, opiates, amphetamines, and cannabinoids) and psychoactive pharmaceuticals (anxiolytics, hypnotics, antipsychotics, antidepressants, and antiparkinsonian) in wastewater [897]; evaluation of a portable, 785 nm, Raman spectroscopy system for screening of seized drug samples followed by DART-MS [898]; identification of synthetic drugs on seized blotter papers validated on dataset of 158 seizures using ATR-FTIR and PLS-DA [899]; electrochemical detection of illicit drugs and common adulterants found in street samples [900]; analysis of drug residue (fentanyl, heroin, cocaine, MA, diphenhydramine, sylazine and etizolam) from used needle-exchange syringes [901]; validated SPE-GC-MS method for detection and quantification of nineteen drugs of abuse [902]; study of the thermal decomposition of the volatile products in street samples of cocaine and MA over the temperature range of 350–650° by high-resolution FTIR spectrometry with theoretical examination by quantum-chemical calculations [903]; evaluation of a colorimetric test and a GC-MS method for drug checking [904]; wastewater epidemiology for monitoring illicit drugs, alcohol and tobacco consumption [905]; review of the application of monitoring illegal drugs by air [906]; preliminary investigation where the exterior of illicit drug capsules were sampled after they had been handled to determine if informative DNA profiles could be generated [907]; UHPLC-PDA/MS method for the routine screening of a wide variety of illicit drugs using a single quadrupole MS with ESI [908]; qualitative analysis strategy for illicit drugs using Raman spectroscopy an examination of the suitability of the characteristic peaks method for analyzing large amounts of seized illegal drugs, including 72 MA hydrochloride (concentration range of 13.9%–99.4%), 68 ketamine hydrochloride (17.7%–99.8%), 176 heroin hydrochloride (5.2%–79.5%), 51 cocaine hydrochloride (21.1%–94.5%), and 33 cocaine base (30.9%–92.5%) samples [909]; study using wastewater analysis to trace precursors and patterns of illicit drug use [910]; analytical method for the analysis of drugs of abuse and metabolites in river sediment [911]; comparison of the measured and recommended acceptance criteria for the GC-MS analysis of seized drugs [912]; detection of illicit drugs in surface water following a music festival [913]; GC-MS and Orbitrap-MS, combined with statistical analyses, to chemically and geographically map drugs of abuse from blotter papers seized by the Civil Police of Rio de Janeiro State between 2006 and 2019 [914]; validated LC-MS/MS method for the simultaneous quantitative determination of 37 narcotic substances as well as commonly used excipients/adulterants found in seized illicit material [915]; comparison of the capabilities of two methods for extraction and chromatographic determination of narcotic drugs and psychotropic substances (N-methylephedrine, methamphetamine, amphetamine, methadone, dihydrocodeine, hydrocodone, oxycodone, ketamine, cocaine zolpidem, fentanyl, harmine, harmaline) in various matrices (syrups, ointments, tablets, herbal mixtures, etc.) [916]; commercially produced paper with a pressure-sensitive adhesive coating was utilized for the collection and analysis of trace drug residues by paper spray mass spectrometry [917]; application of NIR spectroscopy and chemometrics for the analysis of illicit drugs [918]; QuEChERS and solid phase extraction cleanup with detection based on LC-MS/MS for 16 compounds grouped into four different classes (pharmaceutically active chemicals, phenolic endocrine disrupter compounds, estrogenic hormones, and pesticides) [919]; assessment of the operational capability of a dual approach (deterministic and Bayesian frameworks) in evaluating similarity scores between illicit drug profiles [920]; statistical optimization of a Gas Chromatography-Vacuum UV Spectroscopy (GC-VUV) method for analysis of cocaine and other drugs of abuse [921]; a derivatization approach that introduces formaldehyde in the measuring conditions in order to achieve methylation, via an Eschweiler-Clarke mechanism, of illicit drugs containing primary and secondary amines, using amphetamine (AMP) and methamphetamine (MET) as model molecules [922]; characteristics of illicit drug seizures in the Neapolitan area from 2013 to 2018 [923]; study of the effects of substrate-solvent composition on signal intensity, blank signal intensity, and signal-to-blank ratio for a variety of pharmaceutical drugs, illicit drugs, chemical warfare agent (CWA) simulants, and CWA hydrolysis products [924]; overview of the qualitative and quantitative uses of LC- SFC-DAD within forensic science from 2010 to 2020 for the analysis of seized drugs, toxicology samples, explosives, inks, and dyes [925]; review [926]; UPLC-MS/MS analysis of metabolic residues of licit drugs (nicotine and alcohol), medications of abuse (morphine, codeine and methadone) and illicit drugs (cannabis, cocaine, amphetamine, methamphetamine, ecstasy and heroin) in wastewater [927]; SPE-UHPLC-MS/MS method for determination of 12 illicit drugs (methamphetamine, amphetamine, morphine, codeine, 6-monoacetylmorphine, benzoylecgonine, 3,4-methylenedioxymethamphetamine, 3, 4-methylenedioxyamphetamine, cocaine, ketamine, norketamine, and methcathinone) in wastewater [928]; simultaneous enantioselective analysis of illicit drugs in water by chiral LC-MS/MS [929]; rapid identification of 22 illegal drugs and seven explosives using resonance excitation in miniaturized photoionization ion trap mass spectrometry [930]; colorimetric immuno-microarrays for the quantitation and direct visual determination of multiple illicit drugs [931]; rapid characterization of drugs in biological fluid and seized material using thermal-assisted carbon fiber IMS [932]; **2022** review of the drugs that are involved in sexual assaults, the many conventional techniques for detecting illicit drugs (UV, MS, TLC, IMS, IR, Raman, Xray diffraction, microcrystalline tests, spot/color tests and immunoassay) [933]; identification of polymer-bounded illicit drugs on a fabric surface using GCMS and FTIR [934]; machine learning algorithms with portable Raman instruments to classify single compounds, binary, ternary, and quaternary mixtures by the compound name, and the compound's class in seized drugs and common diluents [935]; analysis of illicit drugs in purchased and seized electronic cigarette liquids by GC-MS [936]; micro-extraction tube injection with GC-MS/MS for the determination of illicit drugs (methamphetamine, ketamine, norketamine and cocaine) in wastewater [937]; identification of illicit substances in low purity seized drugs with swept-source Raman spectroscopy [938]; LC-HRMS/MS with molecular networking and metabolite annotation applied to illicit drug seizures for the establishment of composition and natural origin [939]; a polystyrene-divinylbenzene sorbent with weak cation-exchange character for the selective extraction of illicit drugs in environmental water [940]; electrochemical device for the electrochemical profiling of several illicit drugs by square-wave voltammetry (SWV) [941]; evaluation of using latent fingerprints for drug screening [942]; GC-MS screening of "Dirty Sprite" too identify illicit pharmaceuticals (codeine, dihydrocodeine, promethazine and impurities of cocaine) [943]; application of portable Raman spectroscopy associated with principal component analysis (PCA) and interval principal component analysis (iPCA) to analyze trends in samples of cocaine (n = 40), crack (n = 33), and their main adulterants (n = 5) and diluents (n = 5), tablets of ecstasy (n = 14), designer drugs papers (n = 27), and alcoholic solutions adulterated with benzodiazepines (alprazolam and diazepam) [944]; evaluation of tetracaine as an internal standard for qualitative DART-MS analysis of seized drugs [945]; inkjet-printed paper-based SERS sensors for the detection of narcotics [946]; nonlinear time-varying sigmoid transfer function in binary whale optimization algorithm for descriptors selection in drug classification [947].

2.1.5. *"Novel Psychoactive Substances" (NPSs)*

2019 application of 2D-LC for the separation of isomeric and structurally related complex mixtures of NPS [948]; analysis of 1357 narcotics confiscated by the police identified eighteen members of synthetic cannabinoid group, six cathinone compounds, three different tryptamine compounds, and two compounds from the phenethylamine group [949]; analysis of 70 doses of blotter papers coming from forensic cases, identified mixtures of drugs, such as DOB, 25I–NBOMe, MDMA and 25I–NBOMe imine were identified using CG-MS [950]; Raman spectroscopy and surface-enhanced Raman scattering (SERS) combined with chemometrics approaches, for rapid and portable quantitative detection and discrimination of a wide range of novel psychoactive substances (methcathinone and aminoindane derivatives) [951]; Raman spectroscopy for the identification and classification of seized Customs samples into three NPS families. [952]; **2020** low-voltage paper spray ionization coupled with QTOF-MS method was developed and employed for the qualitative analysis of NPS in street drug blotter samples [953]; GC-MS analysis to evaluate the presence, chemical composition and profile of NPS in blotters seized in the State of Santa Catarina, Brazil, over the period of 2011–2017 [954]; analytical strategies and MS instruments used for the analysis of NPS compounds [955]; novel application of the atmospheric solids analysis probe (ASAP) using medical swabs has coupled to a triple quadrupole mass analyzer under a data-dependent acquisition mode to perform a suspect screening of NPS in different types of samples as well as on surfaces [956]; determination of the chiral status of fifty-one chiral different NPS purchased from online vendors via the Internet [957]; an enantioselective HPLC-UV method with applicability to a broad spectrum of NPS [958]; derivatization for GC-MS-based NPS identification [959]; IR of 301 new psychoactive substances (NPS) reference substances, including 100 synthetic cannabinoids, 81 synthetic cathinone, 42 phenethylamines, 9 tryptamines, 5 piperazines, 7 phencyclidine-type substances, 2 aminoindanes, 55 other types were analyzed [960]; review of currently available analytical methodologies for the identification and quantification of NPS [961]; GC-NCD-APCI-QTOFMS method for fast quantitative estimation of stimulant-type NPS [962]; quantitative H-1 NMR (H-1-qNMR) method for quantification of twelve NPS is seized samples [963]; analysis of tap water for investigation of 23 psychoactive substances [964]; analysis of samples using HPLC-DAD and SFC-MS/MS for detection of NPS in biological and seized samples [965]; quantitative analysis of NPSs by IR including the IR spectra of 301 NPS reference substances (100 synthetic cannabinoids, 81 synthetic cathinone, 42 phenethylamines, 9 tryptamines, 5 piperazines, 7 phencyclidine-type substances, 2 aminoindanes, 55 other types) [960]; UHPLC-QTOF-MS method used with an online mass spectral database (HighResNPS.com) for searching the exact mass of the precursor ion and evaluating the fragmentation profile of NPS compounds in seized drugs [966]; **2021** evaluation of the utility of drug use forums as an early indicator of new NPS compounds or predictor of impending intoxications [967]; research to determine whether Google Trends and drug discussion forum data can be used to complement early warning systems for NPS [968]; review [969]; review of the suitability of ambient ionization MS for analysis of NPS for forensic and clinical toxicology applications [970]; the role of MS for investigation of NPS compounds [971]; a complete LC-MS/MS workflow from the detection of a regional NPS threat to its implementation in a method accredited under the ISO 17025:2017 that includes 55 NPS and metabolites (31 Novel Synthetic Opioids (NSO), 22 NSO metabolites and 2 designer benzodiazepines) [972]; review of analytical techniques for detection of NPS in wastewater and global trends [973]; investigation of the electroanalytical behavior of NPS compounds (25B–NBOMe, benzylpiperazine, 1-(3-chlorophenyl)piperazine (mCPP), and DMT) using DVP [974]; review of detection rates of new psychoactive substances and challenges for drug analysis [975]; analysis of psychoactive substances in wastewater by SPE-LC-MS/MS with detection of Morphine, MDMA, MA, ketamine and norketamine [976]; GC-solid deposition-FTIR spectroscopy as a complementary technique for NPS identification in multi-drug mixtures [977]; overview of cases involving Beta-keto-methylenedioxyamphetamines (novel psychoactive substances with names ending in "ylone") [978]; non-enantioselective and enantioselective chromatographic methods for quantification of illicit psychoactive drugs [979]; development and validation of an indirect GC-MS method using a chiral derivatization reagent for enantiomeric quantification of amphetamine, MA, MDMA, norketamine, buphedrone, butylone, 3,4-DMMC), 3-methylmethcathinone, and quantification of 1-benzylpiperazine and 1-(4-metoxyphenyl)-piperazine [980]; review of different classes of NPS drugs and methods for identification [981]; UHPLC-HRMS/MS method combined with a methanolic extraction for detection of NPSs including ketamine, arylcyclohexylamines (deschloroketamine, 3-MeO-PCP and methoxetamine); and cathinones (methyl--metcathinone and N-ethyl-pentylone) [982]; forensic applications of high-resolution NMR spectroscopy for the identification of NPSs and the quantitation of MA [983]; quantification of 33 illicit and prescribed psychotic drug residues (out of target 36) and five NPS (out of target 40) in wastewater, using UHPLC-MS/MS [984]; study of existing workflows for monitoring, communication and management of analytical data regarding the structural elucidation and chemical identification of NPS seized in EU by member states [985]; fully validated LC-MS/MS screening method for the simultaneous detection of 163 substances (120 NPS and 43 other drugs) [986]; GC-MS and HPLC-HRMS analysis of packages seized during the year 2020, and suspected to contain NPS but did not react with standard field test kits (synthetic cathinones, 3-MMC, 5F-MDMB-PICA, 2-FDCK, 1cp-LSD and 1P-LSD) [987]; UHPLC-QTOF-MS method used with an online mass spectral database (HighResNPS.com) for identification of NPS in seized materials by searching the exact mass of the precursor ion and evaluating the fragmentation profile [966]; development and validation of a non-target GC/MS analytical method based on linear retention indexes for the identification of NPS without the need of analytical standards [988]; review of NPS compounds and their typical classifications based on either effects (hallucinogens, stimulants or depressants), origin (natural, synthetic, or semisynthetic), or legality (lawful, illicit, or unregulated) [989]; **2022** screening of wastewater samples from music festivals for 98 psychoactive substances and/or their metabolites [990]; study of the application of electrochemiluminescence sensors for forensic investigations as a viable technique for detection of NPSs [991]; GC-IMS method for analysis of NPS [992]; review of the applications of HRMS for the analysis of NPS [993]; overview of the pharmacology, legal aspects, and risks of NPS consumption [994]; systematic literature review on the detection of NPS in prison settings including the most frequently reported NPS classes, the routes and forms used for smuggling, and the detection methods of NPS in biological (i.e., LC-HRMS/MS) and non-biological samples (i.e., LC-HRMS/MS and GC-MS) [995].

2.1.6. Nyaope

2019 study to evaluate the stability of the cannabinoid, opiate, and antiretroviral components of nyaope during storage following seizure [996]; **2021** validated method for GC-MS analysis of nyaope [997].

2.1.7. Pharmaceuticals/Counterfeits (with a focus on differentiation of legitimate versus counterfeit products, or for monitoring quality control for legitimate pharmaceutics)

2019 analytical method for the analysis of active ingredients in pharmaceutical products and illegal drugs, based on benchtop NMR spectroscopy [998]; HPLC method on RP-C18 core-shell particulate and monolithic columns for simultaneous analysis of avanafil, sildenafil, apomorphine, trazodone, yohimbine, tramadol and dapoxetine in pharmaceutical dosage forms, counterfeit products and human plasma [999]; **2020** low-wavenumber Raman spectral database of pharmaceutical excipients for qualitative and quantitative analysis, counterfeit detection and pharmaceutical process control [1000]; review of the implications of counterfeit medications and the current technological approaches that are used to detect counterfeited pharmaceuticals [1001]; **2021** HPLC-UV and UPLC-MS/MS methods for the simultaneous analysis of sildenafil, vardenafil, and tadalafil and their counterfeits dapoxetine, paroxetine, citalopram, tramadol, and yohimbine in 50 commercial products including honey sachets, instant coffee and pharmaceutical products [1002]; Time-Domain Nuclear Magnetic Resonance (TD-NMR) method to detect adulterated pharmaceutical materials [1003]; electrochemical sensor for determination of acetaminophen in pharmaceutical formulations [1004]; electrochemical sensor for determination of pharmaceutical compounds [1005]; paper spray ionization (PSI) coupled to fourier transform ion cyclotron resonance mass spectrometry (FT-ICR-MS) for determining the chemical profiling of 92 samples of counterfeit medicines and ecstasy tablets [1006]; qualitative and quantitative analyses of pharmaceutical and dietary supplements seized from the black market between January 2016 and December 2019 using GC-MS and LC-HRMS [1007]; development and validation of a UHPLC-UV method to quantify sildenafil and tadalafil in the presence of six degradation products in the pharmaceutical analysis of genuine and seized medicines [1008]; NMR method for verifying drug compliance, drug identity, purity and quality [1009]; ion beam analysis (IBA) procedure to characterize authentic Viagra (R) tablets and sildenafil-based illegal products [1010]; ATR-FTIR and DSC for the quick detection of counterfeit medicines through the polymer analysis of blister packaging materials [1011]; discrimination of counterfeit erectile dysfunction medicines using an Ultra-Compact Raman Scattering Spectrometer for the analysis of tadalafil (Cialis), vardenafil (Levitra), and sildenafil (Viagra) tablets purchased on the internet [1012]; **2022** analytical strategy which enables the structural identification, comprehensive characterization and quantification of monoclonal antibodies in potentially counterfeit samples [1013].

2.2. Instrument focus

2.2.1. General overviews and reviews, and articles covering multiple techniques

2020 review of the applications of SPME in forensic context from January 1995 to June 2018 - majority of the reviewed articles (40/133) aimed to identify drugs (cannabinoids, cocaine, opiates, amphetamines, simultaneous detection of different drugs of abuse, prescribed drugs) [1014]; review of the substances used in drug facilitated crimes and the analytical methods used for detection [1015]; **2021** review of spectroscopic methods including GC-MS, LC-MS, SERS, magnetic resonance imaging, Positron Emission Tomography, IR Spectroscopy, and UV Spectroscopy [1016]; **2022** novel applications of microextraction techniques focused on biological and forensic analyses [1017].

2.2.2. Direct Analysis in Real Time (DART-MS)

2021 a prototype of a new Inverted Library-Search Algorithm (ILSA) that enhances presumptive identifications of mixture components using a series of in-source collision-induced dissociation mass spectra collected through DART-MS (https://github.com/asm3-nist/DART-MS-DST) [1018]; creation and release of the new NIST DART-MS Forensics Database and the steps taken to automate the data evaluation process [1019]; **2022** review of the application of DART-MS in forensic science [1020].

2.2.3. Gas chromatography

2021 GC-FID method of simultaneously determining the commonly abused prescription drugs in “lean cocktail” [1021];

2.2.4. Infrared Spectroscopy (IR)

2019 ATR-FTIR method for fast qualitative analysis of MA, ketamine, heroin, and cocaine [1022]; 2020 combined laboratory and theoretical investigation focused on a suite of crystalline phenethylamine-class molecules of forensic interest using far-IR: amphetamine sulfate, levo- and dextro-MA hydrochloride, MDMA hydrochloride, MDAhydrochloride, and the hydrochloride salts of two substituted (4-fluoro and 4-methyl) methcathinones [1023]; **2021** IR spectroscopy with partial least squares-discriminant analysis for the onsite identification of the composition of white powders (amphetamine, cocaine, ketamine and others) [1024].

2.2.5. Ion Mobility Spectroscopy (IMS)

2021 Sonic-spray introduction of liquid samples to hand-held IMS for the analysis of narcotic substances (cocaine, amphetamine and methamphetamine) and explosive compounds [1025].

2.2.6. “Lab-on-a-Chip” (Microfluidics)

2019 fabrication technique for generating custom capillary ampules for containing small volumes of chemical reagents that is compatible with microfluidic devices, a platform that has shown to be advantageous for field use [1026]; **2021** systematic review of lab-on-a-chip approaches for the detection of 28 different controlled drugs including NPSs [1027].

2.2.7. Lateral-flow immunoassay test strips

2021 review of the production process of antibodies against drugs of abuse used in lateral flow immunoassays as detection molecules, with a focus on the components, the principles, the formats, and the mechanisms of reaction of these assays as well as the advantages of monoclonal antibodies over the polyclonal [1028].

2.2.8. Liquid chromatography

2019 Two HPLC methods for analysis of paracetamol, codeine, guaifenesin and pseudoephedrine or phenylephrine quaternary mixtures [1029]; tuning retention and selectivity in reversed-phase liquid chromatography by using functionalized multi-walled carbon nanotubes for separation and analysis of barbiturates, steroid hormones and alkaloids [1030]; **2021** systematically evaluation of the impact of different scan numbers on quantitation analysis using both LC triple quadrupoles mass spectrometry and LC-HRMS as applied to pharmaceutical, environmental, forensic, toxicological, and biotechnological fields of testing [1031].

2.2.9. Mass spectrometry

2019 a nano-atmospheric pressure chemical ionization (nAPCI) source was developed that allowed direct mass spectrometry analysis of complex mixtures [1032]; two-dimensional tandem mass spectrometry (2D MS/MS) scan for the linear quadrupole ion trap for analyzing a broad range of structurally related precursor ions, including chemical warfare agent simulants, fentanyls and other opioids, amphetamines, cathinones, antihistamines, and tetracyclic antidepressants [1033];

2020 paper spray ionization mass spectrometry (PS-MS) for chemometric differentiation of legal and illegal cigarette samples [1034]; **2021** review of commercially available and fieldable mass spectrometry systems that have been deployed for on-site analysis of seized drugs, chemical warfare agents, explosives, and other analytes of interest to the forensic and security communities [1035]; a MasSpec pen integrated with sub-atmospheric pressure chemical ionization (sub-APCI) for forensic applications [1036]; SPE-ESI for complex sample analysis [1037]; **2022** paper spray mass spectrometry for quantitative drug checking [1038]; a systematic characterization of paper spray ionization-mass spectrometry (PSI-MS) performance under variable environmental conditions on a field-deployable MS system [1039].

2.2.10. Portable instruments

2021 review of portable separation devices and novel methods in chromatographic and electrophoretic separations detailing how they are implemented in forensic analysis, as well as current and future applications in the fields of seized drug analysis, drugs in bodily fluids, explosives and fire scenes, chemical warfare, cosmetics and commercial products, and environmental wastewater analysis [1040].

2.2.11. Raman spectrophotometry

2019 spectra of 39 drugs of current interest to aid in the development of current and future SERS [1041]; SERS method for detection of fentanyl in binary mixtures with cocaine [1042]; analysis strategy for quantitation of low concentrations of three analytes (MA, cocaine, and papaverine) by SERS [1043]; SERS method for detecting fentanyl at low concentrations in the presence of heroin [1044]; SERS method to classify fentanyls from morphines [1045]; **2021** inkjet-printed SERS sensors that are designed to work with field portable Raman analyzers for the detection of chemical and biological agents [1046]; Paper-based SERS sensors for field applications [1047]; iodide functionalized paper-based SERS sensors for improved detection of narcotics such as fentanyl, heroin and cocaine [1048]; **2022** an inverse spatially offset Raman spectroscopy (ISORS) which illuminates a sample of interest with an annular beam of light and collects Raman scattering from the center of the ring, thereby retrieving the chemical signature of the contents while suppressing signal from the container to allow for identification of the contents within a sealed container [1049]; SERS method for drug classification [1050].

2.2.12. Supercritical fluid chromatography

2020 investigation of the elution characteristics of polar and ionic compounds using SFC combined with tandem mass spectrometry- GHB, gamma-butyrolactone, GHB-glucuronide, ethyl sulfate, ethyl glucuronide, meldonium and gamma-butyrobetaine [1051]; **2022** coupling of chiral and achiral stationary phases in supercritical fluid chromatography to improve retention prediction behavior of analytes on a coupled column system [1052].

3. Miscellaneous Topics

3.1. Adulterated beverages

2019 GC-FID, HPLC-PAD, GC/MS for detection of pharmaceutical additives in illicit alcoholic beverages [1053,1054], **2021** Atropine determination in beverages using 3D-printing electrode as a new mechanism for use in forensic electrochemistry [1055]; immunochromatographic test strip for the simultaneous detection of phenacetin and paracetamol is spiked beverages [1056].

3.2. Canines

2019 Randomized trial comparing the effect of intramuscular versus intranasal naloxone Reversal of intravenous fentanyl on odor detection in working dogs [1057]; ability of narcotic detection canines to detect illegal synthetic cathinones [1058]; **2020** review of canine detection training aids [1059]; **2021** canine detection proficiency to odor mixtures and the use of mixture training to improve proficiency [1060]; **2022** a polymer that imitates the odor of cocaine HCl using molecular printing technology intended for the conditioning of drug detection dogs [1061].

3.3. Clandestine laboratories – appraisals and safety

2021 review focused on the medicinal chemistry precedents utilized by clandestine laboratories to develop new NPS in three compound classes identified as synthetic opioids, synthetic amphetamines, and synthetic cannabinoids [1062]; a comparison between three analytical techniques (immunoassay, IMS, ambient pressure laser desorption) that can be applied for on-site analysis of traces at clandestine drug laboratories [1063].

3.4. Cutting agents

2019 GC-MS followed by LC-QTOF for detection of cutting agents in drug-positive seized exhibits within the United States [1064];

3.5. Cryptomarket, Dark Web and online forums

2019 availability of fentanyl, fentanyl analogues, and other non-pharmaceutical opioids on cryptomarkets [1065]; **2020** web analytics and predictive models study of illicit online pharmacies [1066]; **2021** machine learning classification models to identify fentanyl risk [1067]; multi-view attention-based deep learning system to distil large-scall datsets collected from online platforms (Facebook) to detect content associated with marijuana [1068]; extraction of open-source data on ecstasy pills from the website www.pillreports.net for intelligence purposes [1069]; analysis of 64, 420, 376 drug-related posts made between January 2011 and December 2018 on Reddit using diachronic word embeddings of substances discussed on social media [1070].

3.6. Drug checking

2021 review of studies of drug checking at dance festivals to determine the generalizability of findings [1071]; **2022** literature review of drug checking services with a focus on the following domains: (a) the influence of drug checking services on the behavior of people who use drugs; (b) monitoring of drug markets by drug checking services; and (c) outcomes related to models of drug checking services [1072].

3.7. Extraction techniques

2021 review of the synthesis and applications of molecularly imprinted polymers for the extraction of drug compounds [1073].

3.8. Immunoassays

2021 development of an upconverting nanoparticle based lateral-flow immunoassay for the point-of-care quantitative detection of THC [1074].

3.9. Impurities and impurity profiling

2021 UHPLC method for separation and determination of impurities in a bilayer table dosage form of codeine [1075].

3.10. Nanomaterials

2022 review of novel nano polymers and nanomaterials provided by material science and the various forensics areas that have been benefitted by employing innovative materials, functional polymers, and nanomaterials for crime prevention [1076].

3.11. Precursors

2019 ATR-FTIR method for fast qualitative analysis of 13 precursor chemical [1077]; **2020** quick detection and quantification of Acetic anhydride in air, the key chemical used as acetylation agent in producing the illegal drugs heroin and methaqualone using photoionization detection and IMS [1078]; identification and characterization of chemically masked derivatives of pseudoephedrine, ephedrine, MA, and MDMA using NMR, GC-MS, FTIR, high-resolution LC-MS/MS to provide updated compound spectral libraries [1079]; study on the illicit production of ephedrine/pseudoephedrine as precursors for MA [1080]; **2021** sensor for detecting benzyl methyl ketone, a precursor for amphetamine production [1081]; UPLC method for the separation and detection of 2,6-dimethylaniline and isomers (precursors used in the synthesis of many classes of drugs) [1082]; sensor for the detection of benzyl methyl ketone a precursor for AMP [1083].

3.12. Quality

2020 Implementation of a blind quality control (QC) program in the Toxicology, Seized Drugs, Firearms, Latent Prints (Processing and Comparison), Forensic Biology, and Multimedia (Digital and Audio/Video) sections of a forensic laboratory [1084]; **2021** assessment of measurement uncertainty using longitudinal HPLC-MS/MS calibration data in the forensic context [1085].

3.13. Safety

2019 characterization of the risk associated with unintentional occupational exposure to drugs for law enforcement officers [1086];

3.14. Scheduling and legal issues

2019 Review of the scheduling of Cathinones and other amphetamine analogues [1087]; **2021** considerations and unintended consequences of a class-wide ban on fentanyl analogues [1088]; the importance of a class-based scheduling strategy [1089]; the current situation and initiative for rational scheduling of NPSs in Taiwan [1090]; study aimed to identify changes in codeine supply before and after the February 2018 implementation of up-scheduleding over-the-counter codeine products to prescription only in Australia [1091].

3.15. Sensors (biological and instrumental)

2019 sensors for the detection of illicit drugs [1092]; electrochemical sensor for detection of clonazepam in pharmaceutical formulations [1093]; sensor for the detection of ephedrine in pharmaceutical samples [1094]; colorimetric aptamer-based sensor for visual detection of illicit drugs and toxins in various sample matrices [1095]; **2020** review of advancements in electrochemical detection of drugs of abuse [1096]; **2021** sensor for simultaneous determination of paracetamol, diclofenac, and tramadol [1097]; sensor for electrochemical determination of naloxone [1098]; **2022** review of the advances in the field of biosensors for the detection of commonly abused drugs, both prescribed (codeine and morphine), and illegal narcotics (cocaine) [1099]; a novel setup for single-color reflectometry optical biosensor applications [1100].

3.16. Vaping products

2022 GCMS method for quantifying squalane and squalene in aerosol emissions of electronic cigarette, or vaping, products [1101].

3.17. Other

2020 Analysis of fingerprints using LC-HRMS to distinguish between dermal contact and administration of heroin [1102]; comparison of the use of paper spray-mass spectrometry (PS-MS) and LC-MS/MS for analyzing the distribution of mephedrone and its metabolites in fingerprints [1103]; cocaine detection in a fingerprint to distinguish between contact and ingestion of cocaine [1104]; study of the use of synthetic substances in France and across Europe [1105].

Prefacing remarks

1. With the exception of synthetic cannabinoids and cannabimimetics, all references are subdivided by individual drug, drug group/class, or general topic, then chronologically (year only) within each subsection, then alphabetically by first author within each year. Synthetic cannabinoids and cannabimimetics are in a separate category (1.D), and are subdivided as individual compounds, groups of compounds, and finally as groups with other drugs.
2. Some citations included in this report are dated prior to June of 2019, because they had not yet been abstracted prior to the 2019 report.
3. All citations are formatted in accordance with Uniform Requirements for Manuscripts Submitted to Biomedical Journals.
4. No restricted articles are cited in this report.

[2] Contains some citations published prior to June 1, 2019 – see Prefacing Remarks.

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