

# EXTRACTION AND ANALYSIS OF A COMPREHENSIVE QUANTITATIVE DRUG PANEL IN HAIR SAMPLES BY UHPLC-MS/MS FOR FORENSIC TOXICOLOGY

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## INTRODUCTION

The use of hair as a matrix for forensic toxicology continues to increase in popularity. As a specimen, hair offers several benefits. Sample collection is simple and easily supervised, and once collected, hair can be easily transported and stored at room temperature prior to analysis. Hair also provides an extended window of detection for drug exposure, enabling detection months and even years after use. This makes analysis of illicit drugs and pharmaceuticals in hair useful for situations where other samples may not be appropriate or available for analysis such as determining drug exposure in post-mortem toxicology, drug facilitated sexual assault (DFSA), or for other forensic testing in which long-term monitoring is desired.

The objective of this work was to develop, optimize and validate a method for the extraction and quantification of a comprehensive panel of drugs in hair to satisfy the confirmation cut-off values recommended by the Society of Hair Testing (SoHT)<sup>1</sup>. This was accomplished by optimizing pulverization, incubation conditions, the analytical workflow and solid phase extraction (SPE). The sample preparation protocol resulted in consistent recoveries and well-controlled matrix effects. The resulting method was linear, accurate and precise for all target compounds and easily met the SoHT cut-off criteria for all target analytes.

## METHODS

**Chemicals:** Certified reference materials and internal standards were from Millipore Sigma and Cayman Chemical.

**Reagents:** Reference standard and quality control (QC) solutions of analytes were used to prepare working multi-analyte calibrator and QC solutions in methanol. External quality control samples were acquired from Comedical (It) and consisted of authentic hair with drugs incorporated into the keratin matrix with assigned values.

**Sample preparation:** Samples were decontaminated by sequential washing with aqueous buffer and solvents. Bulk hair samples were pulverized using a Precellys Tissue Homogenizer and 2 mL CKMix Lysing Kits (Bertin Technologies, Montigny-le-Bretonneux, FR) for 6 x 6400 rpm for 40 seconds each. Figure 1 shows a schematic of the pretreatment workflow. Samples were then extracted using Waters Oasis™ MCX 30 mg Plates. 2  $\mu$ L were injected on the UHPLC system. Figure 2 summarizes the SPE procedure.

**UHPLC-MS/MS analysis:** A Waters ACQUITY™ UPLC™ I-Class (FTN) System was interfaced with a Xevo™ TQ Absolute Tandem Mass Spectrometer detector. Chromatography was performed using a Waters UPLC BEH™ C18 Column (1.7  $\mu$ m, 2.1 x 100 mm) with a column temp. of 40°C. Mobile phase A was 0.1% formic acid in water and mobile phase B was 0.1% formic acid in LC-MS grade acetonitrile; flow rate was 0.6 mL/min. The LC gradient started at 2% B rising linearly to 67% B by 3.3 minutes, then 90% B by 3.5 minutes before returning to 2% B from 3.6 to 4.0 minutes. Injection volume was 2  $\mu$ L. Mass spectrometer conditions were: source temperature 150°C, capillary voltage 1.0 kV desolvation gas (at 1000 L/h, 500°C) and cone gas (at 10 L/h). Data was processed with MassLynx™ Software and QUAN Review Application in the waters\_connect™ platform.

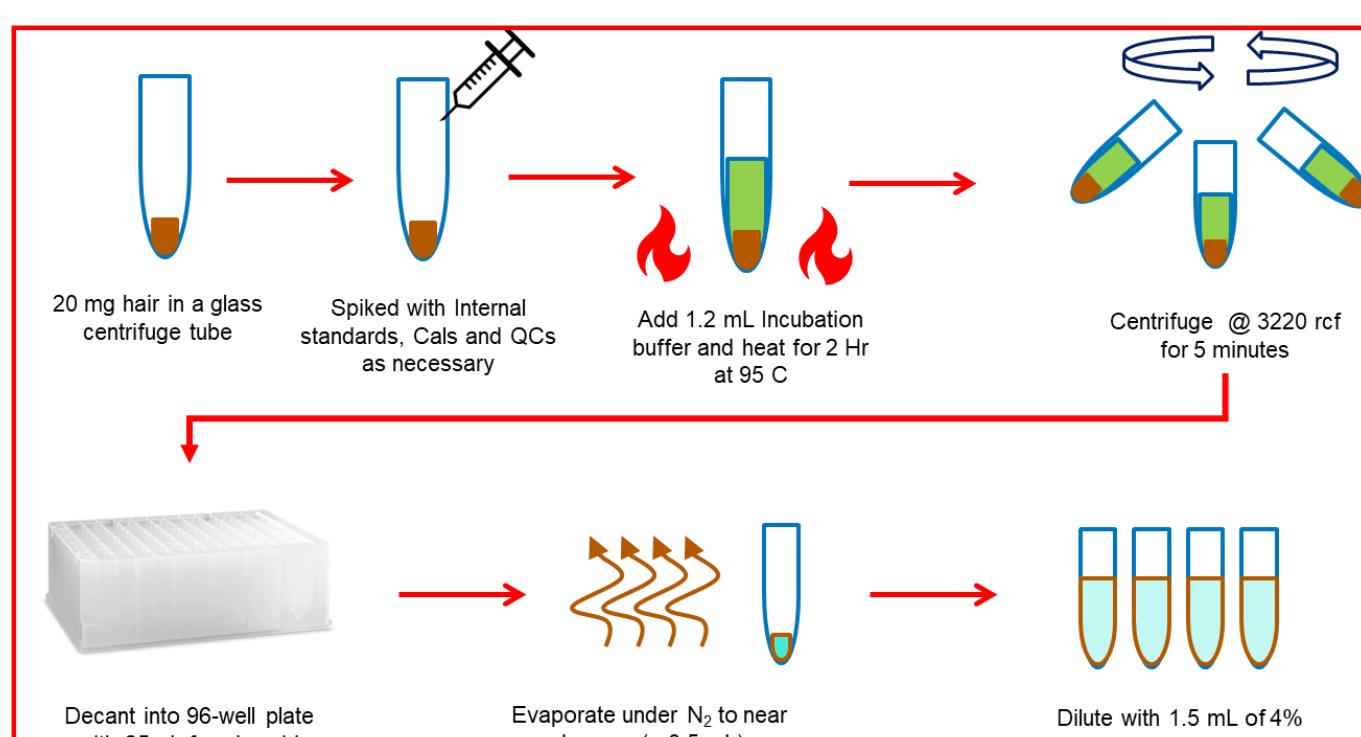


Figure 1. Graphical schematic of the pretreatment workflow



Figure 2. Solid Phase Extraction procedure

Analyte	RT	R <sup>2</sup>	Analyte	RT	R <sup>2</sup>
Morphine	0.89	0.998	Meperidine	1.82	0.999
Oxymorphone	0.94	0.999	Norpseudoephedrine	1.89	0.996
Hydromorphone	1.02	0.999	Chlorizepoxide	1.92	0.998
Dihydrocodeine	1.20	0.997	Trazodone	1.96	1.000
Naloxone	1.2	0.998	Cocathylene	1.99	0.999
Codeine	1.23	0.999	Phencyclidine	2.06	0.999
Noroxycodone	1.29	0.997	N-Pyrrolidino Etonitazaine	2.17	0.994
Amphetamine	1.31	0.995	Fentanyl	2.12	0.996
Naltrexone	1.26	0.994	α-Hydroxyalprazolam	2.12	0.996
Oxycodone	1.27	0.999	Midazolam	2.15	0.998
6-acetyl morphine	1.28	0.996	Etonitazaine	2.21	0.996
MDA	1.29	0.995	Flurazepam	2.20	0.999
Metadesnitazine	1.36	0.998	Buprenorphine	2.24	0.996
Hydrocodone	1.33	0.997	MDMA	2.34	0.999
O-desmethyl			Methadone	2.55	0.996
Tramadol	1.32	0.999			
Methamphetamine	1.35	0.998	6-acetyl morphine	0.841	2.68
MDMA	1.36	0.997	MDA	0.394	6.58
Phentermine	1.41	0.996	Methamphetamine	0.516	2.57
MDEA	1.47	0.999	MDMA	0.661	9.37
Ritalinic acid	1.48	0.998	Benzoylengonine	0.653	7.35
Norfentanyl	1.53	0.999	Tramadol	0.500	4.07
Benzoylengonine	1.52	1.000	Cocaine	0.434	2.18
7-aminoclonazepam	1.71	0.999	Norpseudoephedrine	0.862	3.61
Tramadol	1.67	0.999	Chlorizepoxide	0.876	3.80
N-desmethyltramadol	1.68	0.999	Fentanyl	0.224	3.17
Methylphenidate	1.69	0.999	Buprenorphine	0.065	4.78
7-aminoflunitrazepam	1.71	0.999	EDDP	0.546	4.17
Cocaine	1.79	1.000	Methadone	0.866	8.91
Norpseudoephedrine	1.80	0.999	Lorazepam	0.198	3.18
Diazepam			Alprazolam	0.255	4.23

Table 1. Target analytes, retention times and R<sup>2</sup> values from calibration curves

## RESULTS AND DISCUSSION

### Recovery and Matrix Effects

### Recovery and ME

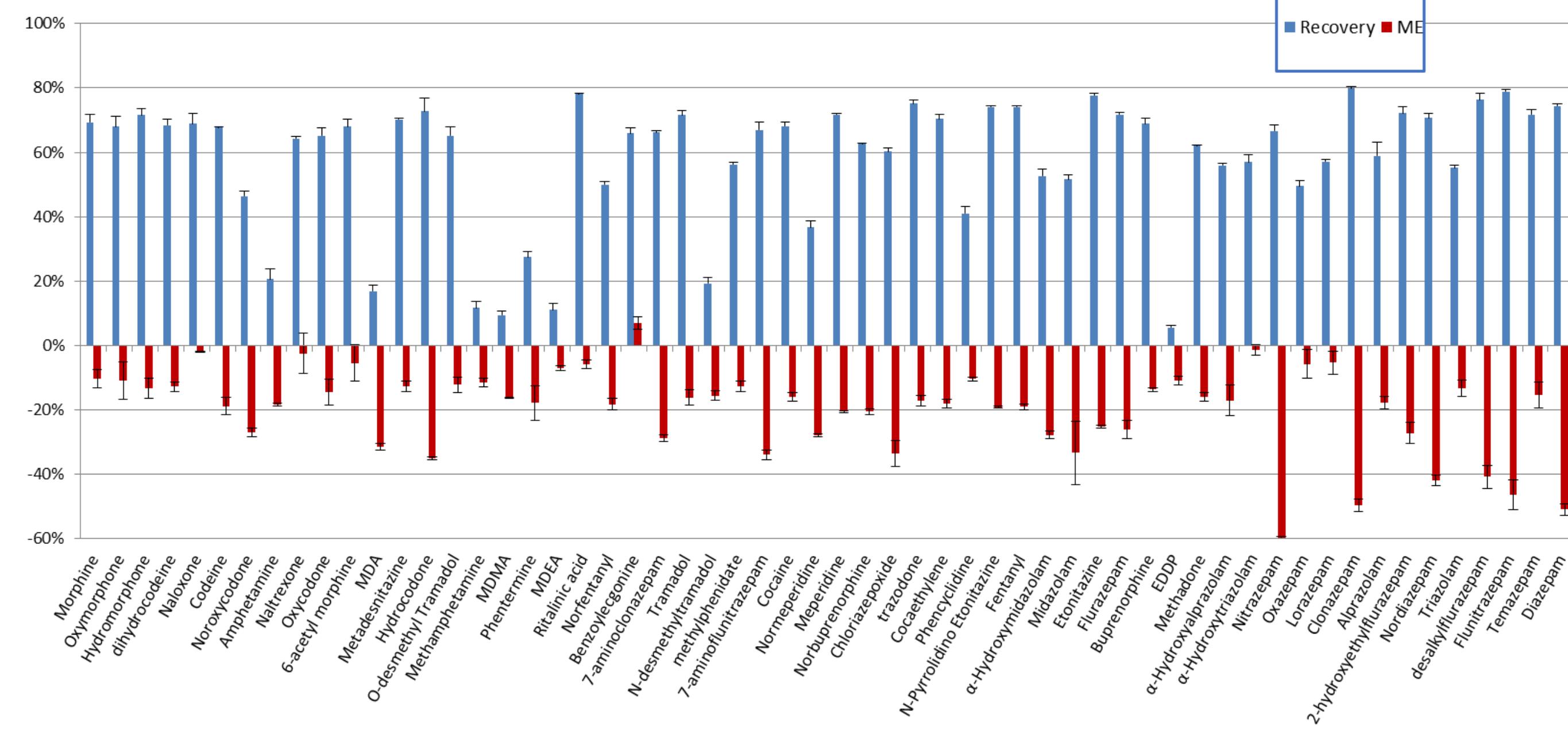


Figure 3. Recovery and matrix effects for all compounds in the multi-drug panel.

Recoveries and matrix effects (ME) for all analytes are shown in Figure 3. Recoveries ranged from 6-79% with 49/58 > 40%. All %RSDs were under 17%. Amine stimulants and EDDP had lower recoveries than other analytes, but they were consistent and enabled accurate quantification even at the lowest concentrations. Matrix effects ranged up to -59% with only 6 compounds exceeding 40% ion suppression. They were also consistent with all S.D. values <10%. Phentermine and metadesnitazine were subject to some endogenous interferences which interfered with their quantification. All other compounds were well controlled.

### Quantitative Analysis

Calibration curves ranged from 0.01-1.0 ng/mg for most drugs, with a few exceptions. Norfentanyl and 6-acetyl morphine ranged from 0.002-0.2 ng/mg and fentanyl ranged from 0.001-0.1 ng/mg. Table 1 lists R<sup>2</sup> values for all analyte calibration curves. Table 2 lists the intra-batch statistics for all the analytes in the panel. With the exception of phentermine and metadesnitazine, all compounds met validation criteria for accuracy and precision, both for intra-batch results (shown) and inter-batch results. Table 2 also shows the cut-offs recommended by SoHT. All compounds satisfied the designated cut-off concentrations listed.

Table 2. Mean accuracy and precision for within batch QC results, along with lower limits of quantification (LLOQ) and SoHT cut-offs

	Within Batch Statistics					LLOQ	SoHT Cut-Off	
	Low	Med	High	LLOQ	SoHT Cut-Off			
Morphine	101.3	4.2	105.1	5.8	93.4	5.6	0.01	0.20
Oxymorphone	98.6	2.7	100.4	1.1	96.4	3.3	0.01	0.20
Hydromorphone	98.2	2.6	101.5	1.2	97.3	4.2	0.01	0.20
Dihydrocodeine	98.1	2.5	101.5	1.8	97.2	4.8	0.01	0.20
Naloxone	91.6	5.1	100.8	4.5	94.2	4.4	0.01	0.20
Codeine	92.0	8.5	98.4	0.7	94.5	4.3	0.01	0.20
Noroxycodone	94.7	7.7	99.5	5.8	94.0	4.3	0.01	0.20
Amphetamine	117.6	10.9	101.5	2.5	95.8	2.1	0.01	0.20
Naltrexone	102.5	4.7	98.8	3.3	91.6	4.5	0.01	0.20
Oxycodone	96.4	2.5	103.6	1.9	97.4	3.6	0.01	0.20
6-acetyl morphine	93.3	5.4	103.1	5.6	94.8	2.4	0.002	0.20
MDA	99.2	10.0	102.7	3.3	96.4	5.3	0.03	0.20
Metadesnitazine	95.9	4.1	97.6	2.3	86.9	3.4	—	—
Hydrocodone	98.2	4.1	103.5	1.6	94.5	3.6	0.01	0.20
O-desmethyl Tramadol	96.8	4.1	103.1	0.8	96.2	3.5	0.01	0.20
Methamphetamine	96.5	3.0	103.7	3.5	94.6	5.7	0.01	0.20
MDMA	96.2	6.1	102.0	5.1	97.8	6.9	0.01	0.20
Phentermine	ND	44.0	85.5	92.3	7.2	—	0.20	—
MDEA	96.7	8.0	101.8	3.8	97.8	4.6	0.01	0.20
Ritalinic acid	82.7	9.0	94.7	7.1	94.3	5.1	0.01	n/a
Norfentanyl	91.5	4.3	101.4	2.8	105.8	5.1	0.002	0.20
Benzoylengonine	100.5	3.2	100.9	1.5	94.5	2.8	0.01	0.05
7-aminoclonazepam	100.8	3.0	97.5	2.8	92.0	2.7	0.01	0.05
Tramadol	97.8	1.5	103.2	2.4	98.3	2.6	0.01	0.20
N-desmethyltramadol	96.5	5.5	105.2	3.4	96.0	3.0	0.01	0.20
Methylphenidate	99.3	1.5	101.0	1.6	95.5	2.7	0.01	—
7-aminoflunitrazepam	96.4	4.2	100.9	1.8	95.3	3.1	0.01	0.05
Cocaine	99.7	3.2	101.3	2.3	96.0	4.2	0.01	0.50
Norpseudoephedrine	97.2	4.1	102.4	1.6	96.7	3.2	0.01	0.01

### External Assessment

Figure 4. Correlation between the nominal values and our observed values. Each point represents a different analyte, the overall slope of 1.05 indicates the excellent overall agreement with the assigned values.

