Toxicology and the Courts:
Understanding and Interpreting the Scientific Evidence

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Toxicology

- **Toxicology**: the study of the adverse effects of chemicals on organisms.

- **Primary Tenet**
  
  “All substances are poisons; there is none that is not a poison. The dose differentiates a poison from a remedy”.

  *Paracelsus*

- **Forensic toxicology** includes the study of the disposition of drugs in the body and their effects on function.
Purpose

To analyze biological samples (blood, urine, breath) for alcohol and drug content, and to assist courts and medical examiners to establish their likely effects on the subject.
MSP Toxicology Unit

Lansing Laboratory

Analysis of blood, urine and other biological samples for alcohol and drugs of abuse.
Analysis of beverages for alcohol content.

**Toxicology Supervisor:** Mr. Geoffrey French
**Toxicology Program Coordinator:** Ms. Jennifer Wilson

Staff of 10 forensic scientists and 1 technician

> 16,000 alcohol and 5,000 drug analyses per year.
Science and Law

Scientific World-View

The data is what it is.  

R.A. Ludwig

Legal World-View

It depends on what the definition of “is” is.  

W. Clinton
Drugs Analyzed by MSP Toxicology

- Alcohol
- Amphetamines
- Antidepressants
- Benzodiazepines
- Barbiturates
- Cannabinoids
- Carbon Monoxide
- Cocaine & metabolites
- K2 or Spice
- GHB
- Hallucinogens
- Inhalants
- Muscle Relaxants
- Narcotic Analgesics
- Non-prescription drugs
- Opiates
- Bath salts
- Other prescription and street drugs
MSP Laboratory Operations

1. Samples collected in cases of OUIL/OUID, CSC, ME requests, other felonies or suspicious circumstances.

2. All samples analyzed for alcohol content. Alcohol report issued (2-3 weeks).

3. If requested, drug analysis performed. Drug toxicology report issued (2-8 months).

4. Samples will be discarded no less than two years after receipt of samples.
Number of Alcohol Cases Analyzed

Alcohol Cases Per Year

Per Se OWI law passed

Year

1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

$ Cases

10000 11000 12000 13000 14000 15000 16000 17000

Number of Alcohol Cases Per Year

12000 13000 14000 15000 16000 17000

10000 11000 12000 13000 14000 15000 16000 17000

1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Alcohol Gas Chromatograph
Alcohol Gas Chromatograph: Autosampler
Alcohol Testing Methods

Gas Chromatography

- MSP Toxicology Laboratory.
- Used for blood, urine, biological and beverage samples.
- Procedure: blood heated, ethanol evaporates, air (headspace) sampled.
- Advantages: clean, only volatiles will be detected.
- Specific: discriminates ethanol from isopropanol, etc.
- State of the art for forensic labs.
Analyst Technique

It is standard lab practice for all analysts always to:

• Check the tube labels against the case file to be sure the right sample was used; also check dates, times, spelling of names, etc.

• Label all glassware.

• Double-check all numbers and labels when removing sample from one tube to another.

• Rinse or change pipettors and tips between samples.

• Handle only one sample at a time.

• Record anything unusual about the sample or its handling.
Kim Doing Alcohol Analysis
Blood and Urine Alcohol Analysis

Procedures:

• Each sample is analyzed twice, once each on two separate instruments

• The results must agree within 0.01

• The lower number is reported.

• The instruments are calibrated weekly and multiple controls are run with every batch of samples.

The MSP alcohol program has been described as one of the strongest in the country.
Analytical Procedures: Alcohol

What's the "error rate" of your method?
What’s the variability of your result?

• No such thing, statistically, as “error rate”.
• The variability allowed between instruments is 0.01
• The standard deviation between duplicate samples run on the same instrument is 0.002

What's the limit of detection of your method?
• .001.
• The third digit is truncated (.009 reported as .00)
Uncertainty in Tox Measurements

Soon we will be required by ASCLD to report our “uncertainty measurement” on our alcohol reports.

- Will be a +/- value following the blood alcohol result.
- Takes into account all possible error in our method.
- Is available for defense attorneys and prosecutors at this time upon request.
- It is likely that it will eventually be reported on the alcohol report for every case.
- Already is being reported for drug cases as a +/- percentage.
**Blood vs Serum**

*What is the difference between blood and serum?*

**Whole Blood:** As it is drawn from the body; contains cells, water, proteins. Red, more viscous than water or serum.

**Serum:** Cells, most proteins removed; water fraction of blood
Clear, yellowish. Most hospitals analyze serum.

Serum has more water per volume than blood, so the alcohol content will be higher in serum. The amount by which it will be higher depends on the hematocrit (percentage of the blood which is cells). MSP uses a conversion factor of 16%, or 0.116:

\[
0.116 \text{ g/dL serum} \sim 0.100 \text{ d/dL whole blood}
\]
Retrograde Extrapolation

Definition:
Calculation of a blood alcohol level at an earlier time from that of a blood sample taken at a later time.

Information Required:

- Times when subject began and finished drinking
- What and how much subject drank
- Food eaten
- Weight
- Drinking experience

Results are given as a range of possible values and are often challenged by defense experts.
Blood Alcohol Challenges: Procedural

Analyst and Instrumentation

- What's the "error rate" of your method?
- Too many (or not enough) entries in maintenance logs
- Calibration and/or controls not used enough or correctly
- Instrument settings inadequate
- Repeat analyses mean you make a lot of mistakes
- Blood tube may have been contaminated
- Stopper may have been dried out
- Chain of custody inadequate: who knows what the Post Office did to the kit en route?
- How well is the analyst really trained?
Alcohol Challenges: Interpretation

My client…
- drank all the alcohol right before leaving the bar
- drank after the accident
- took an hour to absorb one beer
- only had one drink
- wasn’t the driver

So:
- the lab report is wrong
- the lab report doesn’t matter
- s/he was below 0.08 at the time of the stop.
Toxicology Unit Drug Testing

Purpose:

- To discuss the different types of drug tests available, and the strengths and limitations of each.

- To determine how to interpret the information each type of test provides.
What Difference Does a Sample Make?

**Blood:** indicates what is currently in the system
- what the central nervous system is being exposed to.
- indicates possible or probable impairment.

**Urine:** indicates prior exposure
- may or may not correlate with impairment
- drugs can show up in urine after they have been cleared from the blood
- no magic threshold for “recent” vs “residual” urine level.
Which Test Was Done?

Hospital Lab

- If from patient treatment regimen, most likely immunoassay only.
- Results (blood or urine): “Cannabinoid Positive”

MSP Lab

- Immunoassay screen, GC/MS confirmation.
- Results:
  - Blood: THC and THC-COOH present or THC-COOH only present
  - Urine: THC-COOH only present.
What Drugs Tested for?

- Dipsticks: panel only.
- Immunoassay: panel only
- GC/MS: Most drugs, depending on the procedure used.

**BUT:** WILL the lab look for most drugs?

**Private labs:** you get only what you pay for.
  If you didn’t ask for Soma, they usually won’t automatically look for it.

**Crime labs:** MSP will generally look for anything the assay can detect.
  Caveat: may take longer.
Drug Analysis

Samples are analyzed twice by two different techniques:

Screening Test (Randox Immunoassay Biochip Array)
- Detects classes of drugs
- Distinguishes negative from presumptive positive samples

Confirmatory Test (GC/MS)
- Sensitive: detects very small amounts of drug in a sample
- Specific: distinguishes individual drugs
- State of the art, standard for forensic laboratories.
Testing Basics

3 Steps in Drug Testing:

- Sample preparation
- Conducting the test
- Analyzing the data
Solid-Phase Extraction

Solid-phase extraction: removal of drugs from sample matrix by binding to absorbent material in the extraction column. Rest of sample discarded.
GC/MS

- GC/MS: versatile and specific. Many different applications (environmental, academic, forensic).

- Different procedures exist per drug or type of drug:
  - THC
  - GHB
  - Most street/Rx drugs
  - Benzodiazepines (Valium, Xanax, Ativan)
  - Opiates, cocaine metabolites, amphetamines

- Confirmation of all the drugs in a sample can require 3 or 4 procedures depending on the needs of the case.
**Gas Chromatograph/Mass Spectrometry**

**Confirmatory Tests (GC/MS)**

- Sensitive: detects very small amounts of drug in a sample (< 1 ng/ml).
- Specific: distinguishes individual drugs and their metabolites.
- State of the art, standard for forensic laboratories.
- Procedure:
  - Drug extracted from the blood/urine sample
  - Extract injected into the GC/MS
  - The sample is bombarded with an electron beam which breaks the drug molecule into pieces.
  - Pieces = mass spectra, or molecular “fingerprint” unique to each drug.
- Spectra compared to databases: NIST, reference books, in-house libraries.
Gas Chromatograph/Mass Spectrometer
GC/MS: Autosampler
Identification of Drugs

GC/MS generates a molecular “fingerprint” of a drug that can be matched to a database of mass spectral data:

Molecular “fingerprint” of THC-COOH. Nothing else looks like this!
Identification of Drugs

GC/MS generates a molecular “fingerprint” of a drug that can be matched to a database of mass spectral data:

Molecular “fingerprint” of cocaine. Nothing else looks like this!
Interpretation: Drugs

Misidentification of Drugs: You mistook Tylenol for THC!

Drug identification is **NOT** subjective! Based on:

1. Database match of mass spectral data.
2. Agreement between screening and confirmatory tests.
4. Training, experience and proficiency of analyst.
Interpretation: Drugs

Misidentification of Drugs

2. Agreement between screening and confirmatory tests.
   If the two didn’t agree, the sample would automatically be re-analyzed.

   Metabolites arise only within the body after ingestion

4. Training, experience and proficiency of analyst.
   MSP analysts take 1 -2 years of formal training, constant proficiency testing. Defense experts we know don’t do mass spectral analysis.
Mass Spectrometers
Number of Drug Cases Analyzed

Toxicology Cases Per Year

Year

1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

Blood THC analysis instituted in Dec. 2001

Per Se OWI law passed Oct. 1, 2003
# Drugs Found by MSP (2011)

<table>
<thead>
<tr>
<th>Drug</th>
<th>% of Cases</th>
<th>Drug</th>
<th>% of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>THC</td>
<td>56</td>
<td>Clonazepam</td>
<td>4</td>
</tr>
<tr>
<td>Alprazolam</td>
<td>24</td>
<td>Zolpidem</td>
<td>2</td>
</tr>
<tr>
<td>Hydrocodone</td>
<td>16</td>
<td>Cyclobenzaprine</td>
<td>2</td>
</tr>
<tr>
<td>Cocaine</td>
<td>10</td>
<td>Methamphetamine</td>
<td>2</td>
</tr>
<tr>
<td>Morphine</td>
<td>12</td>
<td>Trazodone</td>
<td>2</td>
</tr>
<tr>
<td>Soma</td>
<td>10</td>
<td>Fluoxetine</td>
<td>2</td>
</tr>
<tr>
<td>Diazepam</td>
<td>8</td>
<td>Butalbital</td>
<td>1</td>
</tr>
<tr>
<td>Diphenhydramine</td>
<td>7</td>
<td>Phenobarbital</td>
<td>1</td>
</tr>
<tr>
<td>Codeine</td>
<td>6</td>
<td>Venlafaxine</td>
<td>1</td>
</tr>
<tr>
<td>Methadone</td>
<td>5</td>
<td>Propoxyphene</td>
<td>1</td>
</tr>
<tr>
<td>Amphetamine</td>
<td>5</td>
<td>Sertraline</td>
<td>1</td>
</tr>
<tr>
<td>Citalopram</td>
<td>4</td>
<td>MDMA</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Oxycodone</td>
<td>4</td>
<td>Fentanyl</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Tramadol</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Drug Consumption

- **Absorption** into the blood stream.
- **Distribution** to organs and tissues.
- **Metabolism** to inactive compounds.
- **Elimination** from the body.
# Drugs and Impairment

<table>
<thead>
<tr>
<th>CNS Depressants</th>
<th>CNS Stimulants</th>
</tr>
</thead>
<tbody>
<tr>
<td>alcohol</td>
<td>cocaine</td>
</tr>
<tr>
<td>benzodiazepines</td>
<td>amphetamines</td>
</tr>
<tr>
<td>barbiturates</td>
<td>hallucinogens</td>
</tr>
<tr>
<td>opiates</td>
<td></td>
</tr>
<tr>
<td>narcotic analgesics</td>
<td></td>
</tr>
<tr>
<td>GHB</td>
<td></td>
</tr>
<tr>
<td>carisoprodol</td>
<td></td>
</tr>
<tr>
<td>marihuana</td>
<td></td>
</tr>
<tr>
<td>inhalants</td>
<td></td>
</tr>
</tbody>
</table>

All depressants share some symptoms of intoxication, as do all stimulants.
Antidepressants

Common Antidepressants:

Fluoxetine (Prozac)  
Sertraline (Zoloft)  
Imipramine (Tofranil)  
Risperdone (Risperdal)  
Bupropion (Wellbutrin)  
Trazodone (Desyrel)  
Citalopram (Celexa)  
Nefazadone (Serzone)  
Paroxetine (Paxil)  
Quetiapine (Seroquel)  
Doxepin (Sinequan)  
Amitriptyline (Elavil)  
Nortriptyline (Aventyl)  
Venlafaxine (Effexor)  

Possible Side Effects:
dizziness, drowsiness, confusion, disorientation, ataxia
## Other Prescription Drugs

<table>
<thead>
<tr>
<th>Drug</th>
<th>Possible Side Effects</th>
<th>Medical Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olanzapine (Zyprexa)</td>
<td>dizziness, drowsiness</td>
<td>schizophrenia</td>
</tr>
<tr>
<td>Valproic Acid (Depakote)</td>
<td>nausea, sedation</td>
<td>bipolar disorder</td>
</tr>
<tr>
<td>Methylphenidate (Ritalin)</td>
<td>agitation, hallucination</td>
<td>ADD/ADHD</td>
</tr>
<tr>
<td>Chlorpromazine (Thorazine)</td>
<td>drowsiness, confusion</td>
<td>antipsychotic</td>
</tr>
<tr>
<td>Thioridazine (Mellaril)</td>
<td>drowsiness, confusion</td>
<td>antipsychotic</td>
</tr>
<tr>
<td>Clozapine (Clozaril)</td>
<td>seizures</td>
<td>antipsychotic</td>
</tr>
<tr>
<td>Phentermine (Adipex)</td>
<td>agitation, confusion</td>
<td>obesity</td>
</tr>
<tr>
<td>Carbamazepine (Tegretol)</td>
<td>seizures</td>
<td>anticonvulsant</td>
</tr>
<tr>
<td>Cyclobenzaprine (Flexeril)</td>
<td>drowsiness, dizziness</td>
<td>muscle relaxant</td>
</tr>
<tr>
<td>Buspirone (Buspar)</td>
<td>drowsiness, dizziness</td>
<td>anxiety disorders</td>
</tr>
<tr>
<td>Zolpidem (Ambien)</td>
<td>sedation, amnesia</td>
<td>hypnotic</td>
</tr>
<tr>
<td>Doxylamine (Unisom)</td>
<td>sedation</td>
<td>hypnotic</td>
</tr>
<tr>
<td>Doxylamine (Unisom)</td>
<td>sedation</td>
<td>hypnotic</td>
</tr>
</tbody>
</table>
Non-Prescription Drugs

**Caffeine, nicotine:** not usually reported

<table>
<thead>
<tr>
<th>Drug</th>
<th>Possible Effects</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ibuprofen, Acetaminophen</td>
<td>liver toxicity, pediatric overdose</td>
<td>pain, fever relief</td>
</tr>
<tr>
<td>Diphenhydramine</td>
<td>sedation</td>
<td>antihistamine</td>
</tr>
<tr>
<td>Pseudoephedrine</td>
<td>dizziness, agitation, tremor</td>
<td>decongestant</td>
</tr>
<tr>
<td>Guaifenesin</td>
<td>CNS depression</td>
<td>cough suppressant</td>
</tr>
<tr>
<td>Dextromethorphan</td>
<td>sedation</td>
<td>cough suppressant</td>
</tr>
</tbody>
</table>

- In liquid form, many have significant amounts of ethanol.
- Growing abuse by minors for amphetamine or sedative properties.
- May potentiate CNS-depressant actions of other drugs.
Cannabinoids

Detectable in Blood: 12 - 18 hours

Detectable in Urine: 1-2 days in infrequent users, up to 30 days in chronic users

- Most common drug seen in MSP Lab: 1/2 of all cases
- Linked to impaired driving and long-term damage to memory and learning.
- No overdoses reported (yet) due to cannabinoids alone, but a common factor in auto fatalities, especially in young people.
Retrograde?

THC Metabolism

Alcohol Metabolism
A Short History of Cannabinoid Testimony

2004: P vs Derror (Grand Traverse Co.), P vs. Kurtz (Jackson Co.)

- Derror: Fatal/serious PI accident, only THC-COOH present.
- Subject acknowledged smoking marihuana earlier in the day.
- Charged with *per se* OWI causing death/injury.
- Defense: THC-COOH not Schedule I.

2006

- MI Supreme Court affirms THC-COOH is a Schedule I compound.

2010 P vs Feezel (Washtenaw Co.)

- MI Supreme Court reverses itself, overturns Derror.
- Declares THC-COOH not a Schedule I compound.
How Are Things Different Now?

Pre-Derror (pre-per se)

- THC-COOH presented as evidence of ingestion of controlled substance.
- Not disputed that THC-COOH means ingestion of THC.
- Not required to show THC present at time of stop (no retrogrades).
- Testimony on impairment generally required.

Post-Feezel

- Cannot prosecute under MCL 257.625(8) with any amount of THC-COOH (p. 26).
- Need to show THC itself present in system at time of stop
- If a lab report doesn’t list THC or distinguish THC from THC-COOH, can it be used as evidence?
- Must a lab report show THC itself to be admissible? If so....
Controlled Substances

Controlled Substances (State of Michigan)
Public Health Code 333.7211-333. 7215

**Schedule I.** No medical uses, high abuse potential.

THC (marihuana)
MDMA (Ecstasy)
Designer amphetamines: MDA, DMA, PMA, DMT, DET, etc.
Hallucinogens: PCP, LSD, mescaline, peyote, psilocin
Heroin
GHB

*And others.*
Controlled Substances

Controlled Substances (State of Michigan)
Public Health Code 333.7211-333.7215

Schedule II. Approved medical uses, high abuse potential

- morphine, hydrocodone, oxycodone, codeine
- methadone, Marinol (medicinal THC)
- amphetamine, methamphetamine, methylphenidate (Ritalin) and others

AND

“Coca leaf extracts and any salt, preparation of derivative thereof... including cocaine, salts, stereoisomers…” (333.7214.a.iv)
Controlled Substances

Schedule III.
• Approved medical uses, lesser abuse potential than II.
• Most barbiturates, ketamine, preparations with defined amounts of codeine, morphine or dihydrocodeine

Schedule IV.
• Approved medical uses, abuse potential less than II
• Most benzodiazepines (Valium, Xanax), phentermine

Schedule V.
• Approved medical uses, abuse potential less than IV.
• Some preparations of ephedrine, codeine, morphine, dihydrocodeine.
• OTC ephedrine excepted.
Controlled Substances

Prescription Drugs:

• If not scheduled, not a controlled substance.
• Considered to have little to no abuse or dependency potential, but patient must be monitored for harmful effects.
• Examples: antidepressants, antipsychotics, muscle relaxants.
What Does It Mean?

**Schedule I:**
Any drugs listed on CS Schedule I
Most common: THC, Ecstasy (Not THC-COOH!)

**Section 7214(iv)(a):**
Coca leaf extracts and related compounds: cocaine

*So:* any amount of THC, Ecstasy, cocaine or other Schedule I drugs in any body fluid is *per se* evidence of OUID
Charging OWI?

Still OWI!

- Schedule II – V drugs are still Controlled Substances.

- Valium, Xanax, Meprobamate, Ambien, etc: prosecutor can still charge OWI although they are not Schedule I.

- Schedule II – V: impairment must be proven, not a given.
Charging OWI?

Not OWI (?):

- Prescription drugs that are NOT controlled substances (e.g. Prozac, Effexor)

- Over-the-counter drugs (Robitussin)

- Inhalants (Dust-Off) or solvents (paint thinner)

Not controlled substances, can’t be charged under 257.625(8).
Independent Tests

A second laboratory got different results. Why?

Possible reasons:

- Performed a different type of test
  Screening test vs GC/MS; type of GC/MS done

- Test had different specificity
  Detects acidic and basic drugs or just basic drugs?

- Instrumentation had different sensitivity
  What type of instrument detector?
Independent Tests

A second laboratory got different results. Why?

Possible reasons:

- Different analyst performing the test
  Trained in the detection of that drug?

- Laboratory has different cutoffs
  Lab 1: cutoff = 1 ng/ml
  Lab 2: cutoff = 10 ng/ml
  Sample = 5 ng/ml.
  Lab 1: positive result. Lab 2: negative result.
Independent Tests

A second laboratory got different results. Why?

Possible reasons:

- Samples tested at different times
  Some drugs degrade in storage (i.e. cocaine)

- Samples may have been drawn at different sites on the body
  Postmortem distribution: femoral vs thoracic blood.

- Interassay variability
  Yields not always the same assay to assay.
Court Activities

Major Areas of Court Testimony:

Analytical Procedures: Analyst assigned the case

Expert Testimony: Toxicologist (usually Ph.D.)

- Interpretation of results
- Impairment issues
- Blood alcohol calculations (retrograde extrapolation)
- Rebuttal of defense experts (breath and blood cases)
Court Caseload

Subpoenas

~ 500 per person per year
OR 1 per every four cases completed
OR 2 per day, every day
20 – 40 court appearances/year

Video Testimony

Greatly reduces time spent on the road by scientists. Still not widely used due to defense objections and desire of prosecution to have witness appear in person.
All substances are poisons; there is none that is not a poison. The dose differentiates a poison from a remedy.

Paracelsus