Forensic Toxicology

By

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- **Toxicology** is the study of the harmful effects of chemicals, substances, or environmental agents on living systems. The word Toxicology is came from Greek word (toxicon), which was used as a poisonous substance in arrowheads.

It is a branch of Chemical Science which deals with

- Properties and toxicity of poison.
- To recognize the symptoms of poisoning and application of proper remedial measures.
- Mode of action, metabolism and routes of elimination of poison in the body system.
- Detection of poison in stomach wash, blood urine, vomit materials if the patient is alive and from the viscera if the patient is dead.

Toxin

- The term “toxin” usually is used when talking about toxic substances produced naturally. A toxin is any poisonous substance of microbial (bacteria or other tiny plants or animals), vegetable, or synthetic chemical origin that reacts with specific cellular components to kill cells, alter growth or development, or kill the organism.

Classification of Toxic Agents: Toxic substances are classified into the following:

A. Heavy Metals
B. Solvents and Vapors
C. Radiation and Radioactive Materials
D. Dioxin/Furans
E. Pesticides
F. Animals and Plant Toxins

- All of these substances may also be further classified according to their:
- Effect on target organs (liver, kidney, hematopoietic system).
- Use (pesticide, solvent, food additive),
- Source of the agent (animal and plant toxins),
- Effects (cancer mutation, liver injury),
- Physical state (gas, dust, liquid),
- Labeling requirements (explosive, flammable, oxidizer),
- Chemistry (aromatic amine, halogenated hydrocarbon),
- # Poisoning potential (extremely toxic, very toxic, slightly toxic)

Branches Of Toxicology

1. OCCUPATIONAL TOXICOLOGY

it is the investigation of the toxicity of chemicals found at the workplace

2. ENVIRONMENTAL TOXICOLOGY

Environmental toxicology, field of study in the environmental sciences that is concerned with the assessment of toxic substances in the environment.

3. ECONOMIC TOXICOLOGY

is the branch of toxicology that investigate the harmful effects of chemicals used to achieve economic or social benefits, such as pesticides

4. CLINICAL TOXICOLOGY

Clinical toxicology deals with the adverse effects of agents such as drugs

- 5. Forensic toxicology is an essential branch of forensic science, providing critical information in legal investigations. It involves the detection and quantification of toxic substances in biological samples, such as blood, urine, and tissues.
- The insights gained from forensic toxicology can influence criminal cases, workplace drug testing, and cause-of-death investigations.
- Understanding the interplay between toxicology and forensic science is crucial for effective analysis and interpretation of results.
- Toxicological analysis can be done to various kinds of samples:

1. A forensic toxicologist must consider the context of an investigation, in particular any physical symptoms recorded.

2. and any evidence collected at a crime scene that may narrow the search, such as pill bottles, powders, trace residue, and any available chemicals.

Principles of Forensic Toxicology

- *1) Absorption, Distribution, Metabolism, and Excretion (ADME)*

The ADME processes are fundamental to understanding how substances affect the body.

a) Absorption: This refers to how substances enter the bloodstream, which can occur through various routes such as oral, inhalation, or injection. The method of absorption influences the onset and intensity of drug effects.

b) Distribution: After absorption, substances are distributed throughout the body via the bloodstream. Factors such as blood flow, tissue permeability, and the binding of substances to proteins affect distribution.

c) Metabolism: The body metabolizes substances primarily in the liver. Metabolism can convert active substances into inactive forms or, in some cases, into more active metabolites. Understanding metabolic pathways is vital for interpreting toxicology results.

d) Excretion: Finally, substances are eliminated from the body, primarily through urine and faeces. The rate of excretion can vary widely depending on the substance and individual factors, such as age and health.

2) Toxicological Thresholds: Establishing toxicological thresholds is critical for determining whether a substance is at a level that could cause impairment or toxicity. Forensic toxicologists use established reference ranges to assess the significance of detected substances. These thresholds can vary by substance, and legal standards may differ across jurisdictions.

Example : Alcohol Thresholds (Blood Alcohol Concentration (BAC) of 0.08% (or 0.8 g/L or 80 mg/100mL)).

3) Methodologies in Forensic Toxicology*:* Forensic toxicology employs various analytical techniques, each with its strengths and limitations.

1) Immunoassays: Immunoassays are commonly used for preliminary screening of biological samples. These tests are quick and cost-effective (Affordable , low cost), allowing for the detection of specific classes of drugs. However, they can produce false positives or negatives, necessitating confirmatory testing (**May give inaccurate results**, so additional tests are required to confirm.).

2) Gas Chromatography-Mass Spectrometry (GC-MS): GC-MS is a widely used confirmatory method in forensic toxicology. It separates compounds based on their mass-to-charge ratio and provides a high level of sensitivity and specificity. This technique is particularly effective for volatile substances and is considered the gold standard for confirming drug presence in forensic cases.

3) Liquid Chromatography-Mass Spectrometry (LC-MS): LC-MS is increasingly utilized for its ability to analyze a wide variety of substances, including non-volatile and polar compounds. It is particularly useful for complex biological matrices, offering sensitivity and versatility in toxicological analyses.

4) High-Performance Liquid Chromatography (HPLC): HPLC is another valuable technique that separates components of a mixture and is often used for quantifying substances. It is particularly useful for pharmaceuticals and can be coupled with mass spectrometry for enhanced analysis.

How Do Toxic Chemicals Affect the human Body

- 1. Recurrent exposure even in small doses, which can trigger **chronic intoxications**. The common effects of this are: asthma, eczema, cancer, kidney failure, fertility problems, etc.

  2. Short-term exposure, which has an almost instantaneous effect on our bodies. This is known as an **acute intoxication**. The best-case outcomes of this are usually burning, irritation, itching, or vomiting. The worst-case outcomes include drunkenness, loss of consciousness, convulsion تشنج, coma, respiratory or cardiac arrest, etc.

- 4) Application of forensic toxicology

- *1.Criminal Investigations:* Forensic toxicologists play a pivotal role in criminal investigations by analyzing biological samples from suspects and victims. Toxicology reports can provide evidence in cases of overdose, poisoning, and drug-related offenses. Determining the presence and concentration of substances can help establish timelines and intentions, crucial for legal proceedings.

- *2. Workplace Drug Testing:* Many organizations implement workplace drug testing programs to promote safety and compliance. Forensic toxicology provides the analytical methods to detect and quantify drugs in employees, helping to mitigate risks associated with substance abuse.
- *3. Death Investigations:* In cases of suspicious or unexplained deaths, forensic toxicology is instrumental in determining the cause of death. Toxicologists analyze samples to identify potentially lethal substances, aiding in autopsy conclusions and criminal investigations.
- *4. Sports Doping:* Forensic toxicology also plays a significant role in sports, where anti-doping agencies use toxicological methods to detect prohibited substances. The integrity of competitive sports relies on fair practices, and toxicology helps uphold these standards.

Challenges in Forensic Toxicology:

- Despite advancements in forensic toxicology, several challenges persist:

1. *Emerging Psychoactive Substances:* The introduction of novel psychoactive substances poses a significant challenge for toxicologists. These new drugs often evade detection using traditional methods, requiring the development of new analytical techniques and reference standards.

2. *Interpretation of Results:* Interpreting toxicological results is complex due to individual variability. Factors such as metabolic rates, co-administered substances, and pre-existing health conditions can influence results. Toxicologists must exercise caution in drawing conclusions, especially in legal contexts where the stakes are high.

3. *Quality Assurance and Standardization:* Ensuring the accuracy and reliability of toxicological analyses is paramount. Laboratories must adhere to strict quality assurance protocols and standards to maintain credibility. Discrepancies in testing methods or interpretation can lead to significant legal repercussions.

4. Legal and Ethical Considerations: Forensic toxicologists must navigate a landscape of legal and ethical challenges. The admissibility of toxicology evidence in court is subject to scrutiny, and professionals must be well-versed in legal standards and practices

- Part 2

Types of Forensic Toxicology

The field of forensic toxicology involves three main sub-disciplines:

1. postmortem forensic toxicology

is the analyses of illegal and medicinal drugs in biological samples from deceased individuals. Such investigations are important in forensic cases to determine the cause of death, e.g. identifying possible overdoses. Interpretation of postmortem toxicological results requires caution, due to various factors that can influence drug concentrations after death. For example, drug concentrations in blood can increase after death, because of redistribution of some drugs from internal organs to blood. Therefore, samples for toxicological analyses are usually collected from peripheral blood, which is located far from internal organs.

Example

- Gamma-Hydroxybutyrate (GHB) is a substance that can be formed in the body after death. It is important to distinguish whether GHB detected in a deceased person is a result of intake of GHB or postmortem formation. In this project, postmortem toxicology data are linked to official causes of deaths, and we try to estimate the amount of postmortem formation of GHB that occurs at each concentration level of GHB. Additionally we evaluate whether the urine/blood concentration ratio is suitable to differentiate between GHB intake and postmortem formation.

2. Human performance toxicology:

Human performance toxicology deals with the effects of alcohol and drugs on human performance and behavior, and the medico-legal consequences of drug and alcohol use.

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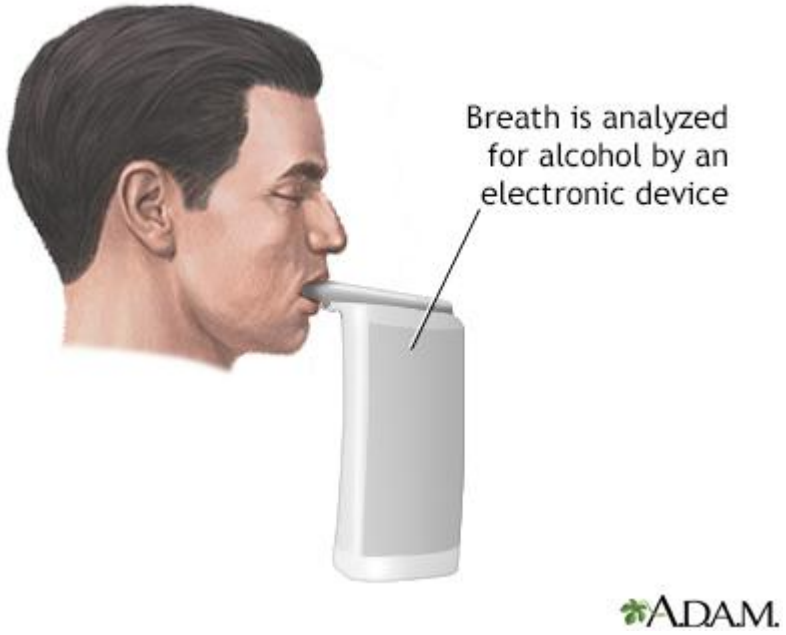
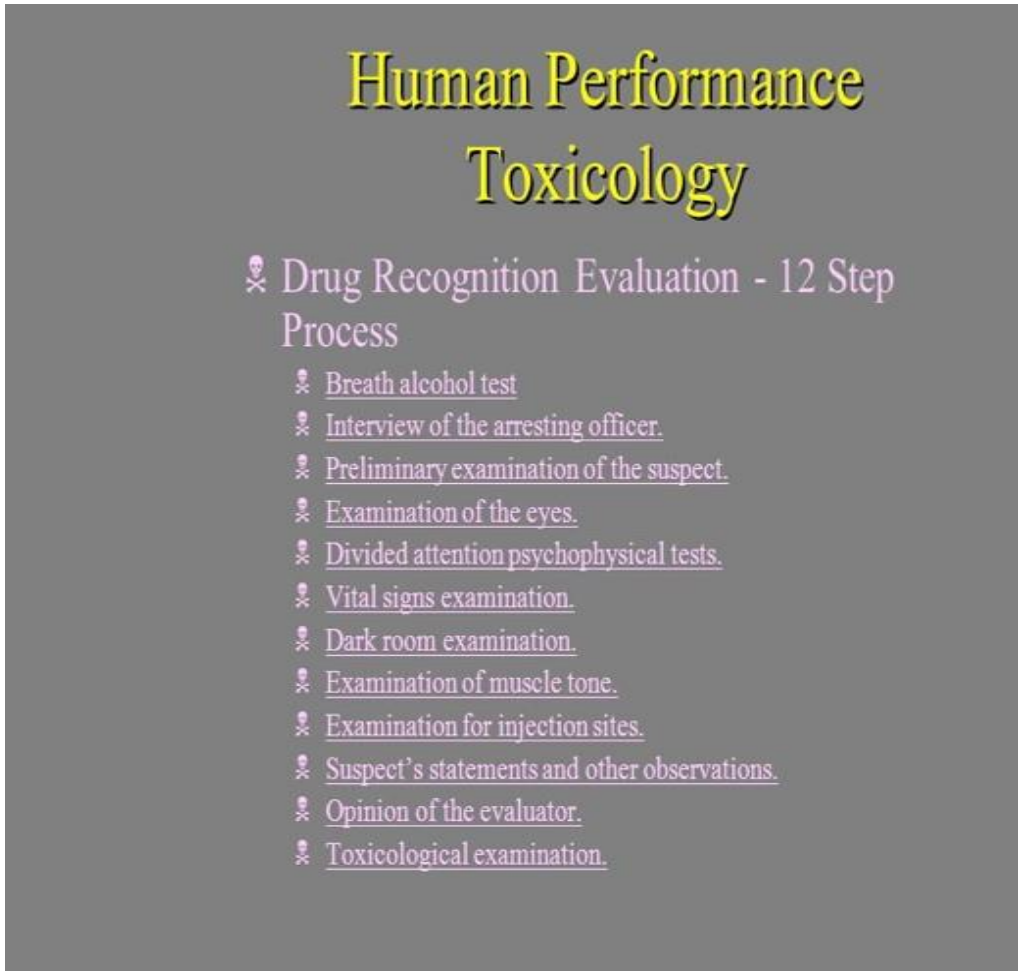
1. Breath alcohol test





2. *Interview of the Arresting Officer*

The DRE (Drug Recognition Evalution) begins the investigation by reviewing the BrAC test (Breath Alcohol Concentration) results and discussing the circumstances of the arrest with the arresting officer. The DRE asks about the subject's behavior, appearance, and driving.

- 3. *Preliminary Examination and First Pulse*
- The DRE conducts a preliminary examination, in large part, to ascertain whether the subject may be suffering from an injury or other condition unrelated to drugs. Accordingly, the DRE asks the subject a series of standard questions relating to the subject's health and recent ingestion of food, alcohol, and drugs, including prescribed medications. The DRE observes the subject's attitude, coordination, speech, breath and face.

4. *Eye Examination*

The DRE examines the subject for HGN, vertical gaze Nystagmus (VGN), and a lack of convergence.

Horizontal gaze nystagmus (**HGN**) is the involuntary jerking of one's eye when it gazes to the side. Alcohol use exaggerates this jerking motion.

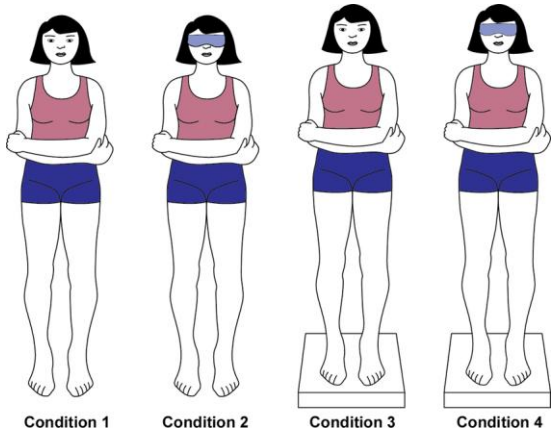
lack of convergence

Vertical Gaze Nystagmus (VGN) is an involuntary jerking of the eyes, both up and down, that occurs when the eyes are held at maximum upward elevation.

5. Divided Attention Psychophysical Tests

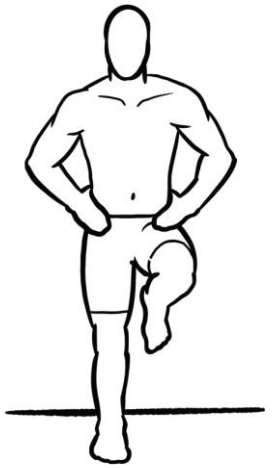
The DRE administers four psychophysical tests: the Modified Romberg Balance, the Walk and Turn, the One Leg Stand, and the Finger to Nose test.

the Modified Romberg Balance

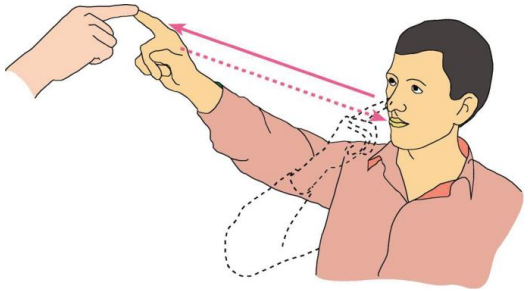


Walk and Turn

One Leg Stand



Finger to Nose test

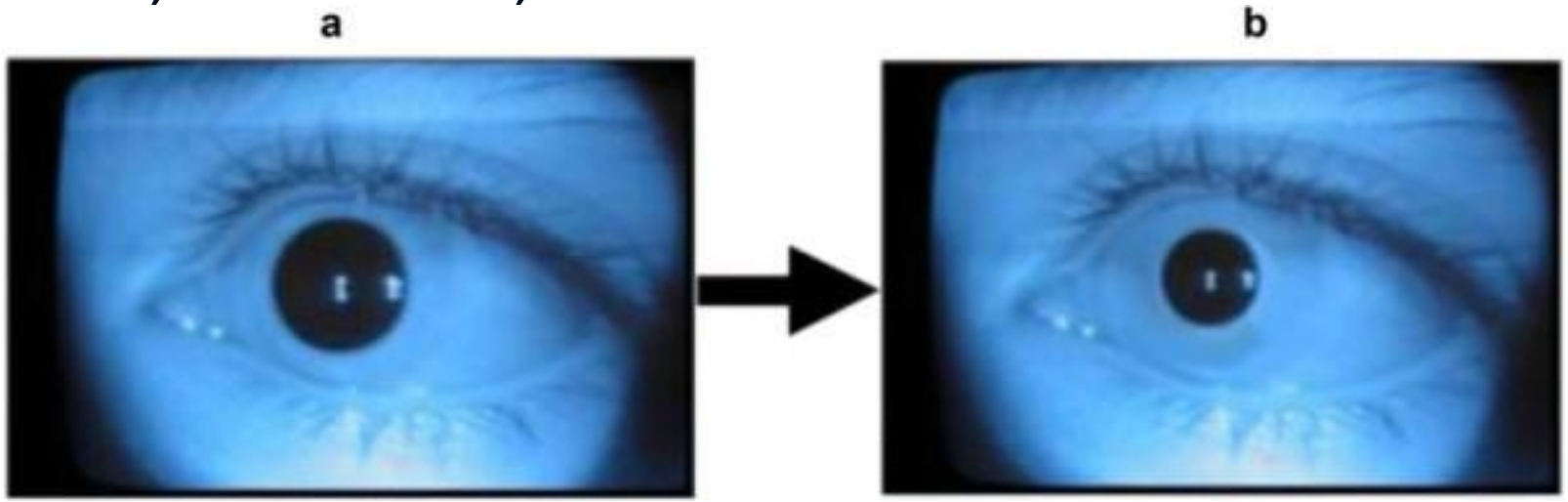


6. *Vital Signs and Second Pulse*

The DRE takes the subject's blood pressure, temperature, and pulse.

7. *Dark Room Examinations*

The DRE estimates the subject's pupil sizes under three different lighting conditions with a measuring device called a pupilometer. The device will assist the DRE in determining whether the subject's pupils are dilated, constricted, or normal.



8. Examination for Muscle Tone

The DRE examines the subject's skeletal muscle tone. Certain categories of drugs may cause the muscles to become rigid. Other categories may cause the muscles to become very loose and flaccid.

9. Check for Injection Sites and Third Pulse

The DRE examines the subject for injection sites, which may indicate recent use of certain types of drugs. The DRE also takes the subject's pulse for the third and final time.

10. Subject's Statements and Other Observations

The DRE typically reads *Miranda*, if not done so previously, and asks the subject a series of questions regarding the subject's drug use.

11. *Analysis and Opinions of the Evaluator*

Based on the totality of the evaluation, the DRE forms an opinion as to whether or not the subject is impaired. If the DRE determines that the subject is impaired, the DRE will indicate what category or categories of drugs may have contributed to the subject's impairment.

12. *Toxicological Examination*

The toxicological examination is a chemical test or tests that provide additional scientific, admissible evidence to support the DRE's opinion.

3. Forensic drug testing: Forensic drug analysis deals with the identification and quantification of illegal drugs. Forensic drug tests are generally carried out in two steps: screening and confirmation.

4. Clinical toxicology

is a subspecialty of toxicology dealing with the bedside management of poisoned patients, including definitive toxicological diagnosis, assessment of immediate severity and long-term prognosis, and selection of treatments including antidotes.

TYPES OF CASES:

- • Suspected drug intoxication cases.
- • Fire deaths.
- • Homicides.
- • Driver and pilot fatalities.
- • Sudden infant death (SIDS).

Case report : A case of thallium intoxication by walking in a field

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- Thallium intoxications are a rare occurrence in forensic sciences. This paper reports a case of chronic thallium poisoning in a couple hospitalized in Milan, Italy, in which toxicological analyses were performed by the Institute of Legal Medicine of Milan on the request of the Judicial Authority.

- Preliminary analyses confirmed the presence of thallium in the blood and urine samples of the couple. After positive results were obtained from the biological samples, the Judicial Authority learned that the son of the couple used thallium powder illegally in his field and that the father helped his son in that field almost every day.

- Therefore, the Judicial Authority suspected that the man had accidentally contaminated the house environment, thus intoxicating his wife. Consequently, they requested the seizing of multiple items from their residency to verify this hypothesis. Each object was sampled internally (content or internal surface) and externally (surface of the container) and the concentrations of thallium were evaluated using ICP-MS analyses. Positive results of items indicate a thallium contamination caused by an external vector. Indeed, they suggest that none of the elements analyzed was the contaminant responsible for the intoxication but the examination of the soles of the man's shoes argued in favor of an external contamination (the son's field), suggesting that he was the accidental mean of transportation of the heavy metal into the house. This paper presents a rare case of chronic thallium intoxication in a domestic setting where contamination occurred from an illegal usage of thallium in a field.

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Case2

- A **17-year-old male** became **apneic** **انقطاع تنفس** **and unresponsive** while on his way to school. A bystander administered **4 mg intranasal naloxone**, after which he was transported to the emergency department.

Clinical observations:
– Heart rate: 125 b/min (↑)
– Respiratory rate: 18 br/min (↑)
– Oxygen saturation: 100%
– Pupils 4 mm in diameter
– Neurologic exam: nonfocal
• Blood and urine samples collected for toxicology testing – GC-MS: Caffeine only

- Individual reported snorting “crushed Xanax”
- – Received from a friend
- – Crushed pill fragments
- – Negative for alprazolam
- - Denied use of opioids مواد افيونية

Xanax is a brand-name prescription medication that contains the active ingredient alprazolam. This medication is a type benzodiazepine (or benzo) which induces a tranquilizing effect that calms the brain’s central nervous system (CNS).

Expanded toxicology testing for NPS(Because of inconsistent findings, **expanded toxicology testing** for novel psychoactive substances (NPS) was performed. It detected:

– Caffeine – U-47700 (282.4 ng/mL)
– U-47700 Metabolites – Naloxone
Conclusion:
The patient’s symptoms were due to **opioid toxicity from U-47700**, a synthetic opioid misrepresented as “Xanax.” The clinical response to naloxone and toxicology results confirm the diagnosis.