Forensic Analysis and Implications of Alcohol Use: ADME Detection, Toxicology, and Legal Perspectives

[1]Himanshu Raj | [1]Himanshu Yadav | [2]Divyanshu Kumar | [2]Dr. Suresh Narayan Baitha

[1]B.Sc Forensic Science, [1]Faculty of Forensic Sciences (Asst.Prof.), [2]Ph.D in Agriculture (Agronomy)[2]Sr.Asst.Prof. & HOD Botany.

[1]Department of Forensic Science. Sharda School of Allied Health Sciences. Sharda University Greater Noida, Uttar Pardesh (201310),India.

[1] Sharda School of Allied Health Sciences. Sharda University Greater Noida, Uttar Pardesh (201310),India.

Abstract

Alcohol (Ethanol) is one of the most used psychoactive drugs worldwide. Its acute and chronic effects on the human body are of significant physiological, legal, and forensic importance. In this study paper, alcohol's chemistry, shapes, and worldwide patterns of use, focusing on the absorption, distribution, metabolism, and excretion (ADME) of ethanol, are discussed. Forensic application, i.e., detection techniques, postmortem analysis, and enforcement in law, particularly drunk driving, is the area of focus. Various testing methods, i.e., blood alcohol concentration, breath, and biomarker-based such as CDT and PEth, are discussed for their use and suitability in forensic research. Signs and symptoms of alcohol poisoning have also been enumerated in the paper along with stages of alcohol intoxication. In light of the multi-disciplinary outlook, the current paper tries to draw the holistic picture of alcohol in relation to interacting with the human body and broader aspects of forensic science and law enforcement.

Keywords- *Forensic Toxicology, Alcohol Metabolism, Blood Alcohol Concentration(BAC), ADME, Alcohol Intoxication Stages, Legal aspect of alcohol consuming, PEth, EtG.*

1. Introduction

Alcohol is a class of chemical substance that contains a special set of atoms known as –OH (hydroxyl group) attached to carbon. The most common one most refer to in everyday life is ethanol, which occurs in beverages such as beer, gin, wine, and whiskey.When an individual consumes alcohol, it enters the bloodstream and begins acting on the brain. Initially, it may make you feel relaxed, happy, or slightly light-headed. That's why some folks feel more sociable after having a drink. But if you continue drinking more and more, it can get you dizzy, lose your balance, or even say and do things you wouldn't ordinarily do. Too much can get you sick, make you have a bad hangover, or lead to bad health problems eventually. Human Typically drinks alcohol for enjoyment and occasionally for relaxation in general alcohol(ethanol) after drinking it first it gets absorbed in blood then distributed throughout body.

After distribution and absorption it comes to metabolic response and it in liver since liver is first organ to metabolise alcohol and assist in breaking down its concentration level of body. Metabolism reaction also vary based on these factors such as age, sex, body weight and quantity of alcohol taken these factors are also impacting the metabolism reaction and through urine excretion it minimises the toxicity or the absorption of alcohol.The physiological laws for ADME of ethanol were established in the 1930s with the fundamental principles of ethanol pharmacokinetics (Widmark, 1932). Time is sole factor that decreases the absorption or hangover of alcohol. Lets comes to the alcohol type(ethanol).

1.1 Alcohol Types

(a) Beer:- Composed of fermenting grains such as barley ,wheat, or rice. Alcohol content percentage in beer:- typically 4-7% alcohol. Types of beer:- Lager, Ale, Stout and Regional/local Beer.

(b) Sprit:- (Whiskey or hard liquor):- Composed of fermented products distilled to obtain higher alcohol. Percentage of alcohol content :- normally 35 - 50% of alcohol. Sometimes it may differ.
Examples of Hard liquor or Sprit:- whiskey, Vodka, Rum, Gin ,brandy, Tequila,Regional/local sprits.

(c) Wine:- Composed of fermented grapes or other fruits percentage of alcohol content:- normally 8-15% of alcohol Types of wine:- Red wine, White wine, sparkling wine like champagne.

1.1.1 From Where Alcohol Beverages Start Consuming

Fermentation of alcohol to produce it dates back to the Neolithic Age, the oldest known being in China around 7000 BCE. Nobody and no organisation was invented or discovered drinking alcohol or alcohol drinks. Different cultures across the globe, through passage of time, developed their own techniques of making alcoholic drinks from various materials, like barley for beer in the Near East and grapes for wine in the Near East.
The world's oldest evidence of man-made alcohol was found in a burial in Raqefet Cave in what is now Haifa, Israel, where Natufians—a hunter-gatherer society in the eastern Mediterranean—were buried. Scientists from Stanford University examine residue on 13,000-year-old stone mortars in the cave and identify traces of beer brewing.

1.2 Forensic Applications of Alcohol

(1) Alcohol Detection

Biological Samples are ideal samples to detection of alcohol

Blood alcohol concentration (BAC) :- It is most popular test/technique to detection of alcohol through blood, urine, breath or saliva.

Breathlyzer Test:- Detection of alcohol on roads by police in this technique through breath alcohol is identified. When intoxicated person will breathe in into the machine (Breathlyzer), the alcohol vapour in your breath is trapped.

Gas Chromatography: Applied to detect and measure alcohol content in blood and tissues.

Urinalysis: It is not very accurate compared to blood or breath. It shows consumption of alcohol over a period of time.

(2) Postmortem Analysis

(a)Bacteria-created alcohol after death assist in identifying.
(b) It also have role in autopsy to confirm the alcohol have role in cause of dearth or not.
(c)Fermentation by bacteria assists in distinguishing between postmortem and antemortem ingestion.

(3) Legal and Investigating Applications(Legal action)

(a) Drink and drive legal blood alcohol content (BAC) limit is 0.08% in the majority of countries.
(b) Examine BAC and provide testimony in court of law by forensic toxicologists.

(c) In India now due to Urbanisation and growing affluence. Drunk driving or driving under the influence (DUI) is a criminal offence in India under the Motor Vehicle Act.

(d) In India the legal drinking age is from 18 years to 25 years state to stare like in Haryana, Delhi legal drinking age is 25 Years.

1.2.1 Motor Vehicle (Amendment) Bill 2016

The Union Cabinet led by Prime Minister Shri Narendra Modi recently approved Motor Vehicle (Amendment) Bill 2016. Amendment bill aims at increasing the safety on roads and provides a greater level of fines and penalty for drunk driving. Drunk driving penalty in Motor Vehicle (Amendment) Bill 2016 has been increased from Rs.2000 to Rs.10,000. (stats from government of Assam transport

1.3 Table of Common Test For Alcohol Detection

Test Type	Sample	Use Case	Pros	Cons
Breathalyzer	Breath	DUI	Non-invasive, quick	Less accurate
Immunoassay	Urine	Screening	Fast	False positives
GC-MS	Blood	Legal, postmortem	High accuracy	Expensive
EtG/EtS	Urine	Screening	Chronic use	Long detection window

1.4 Sequence of events in a typical case of drunken driving.

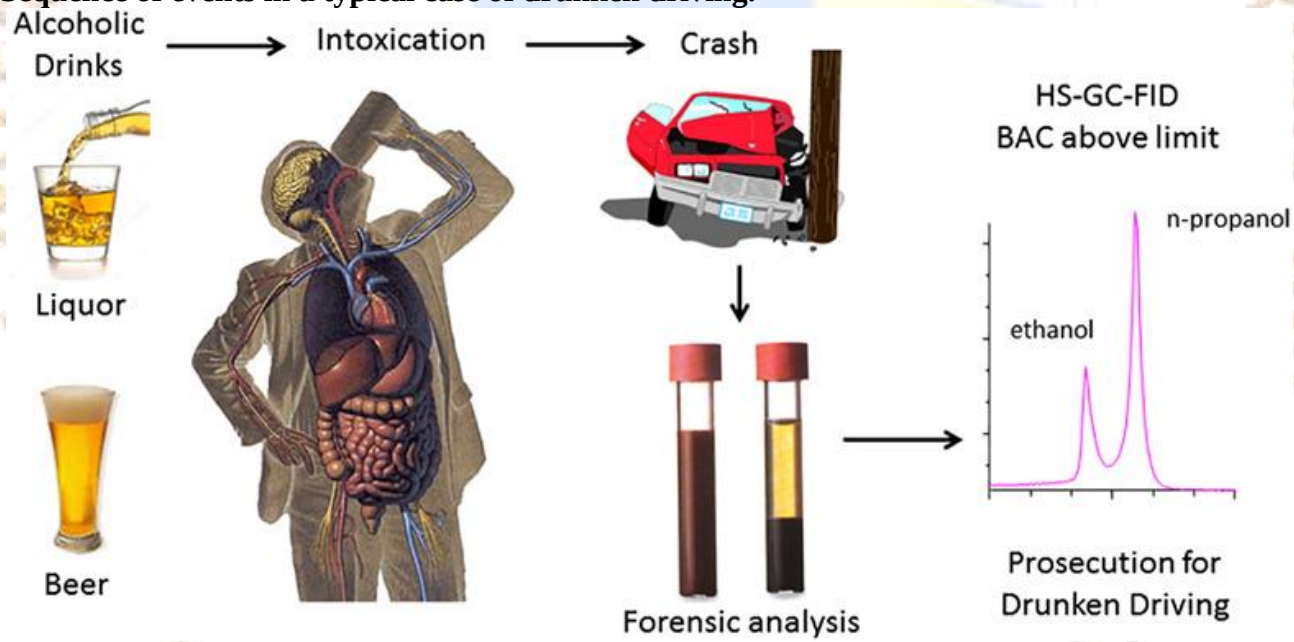


Fig 1

1.5 Consumption of Alcohol or Alcohol Beverages Top 7 Countries

Rank	Country	Avg. Alcohol Consumption (Liters per capita/year)	Alcohol-Related Deaths	Drink & Drive Issues & Measures	Gender Differences in Drinking
1	Latvia	13.19	High risk, linked to health issues	Drink driving laws in place; enforcement ongoing	Men drink significantly more than women
2	Moldova	12.85	Significant alcohol-related deaths	Issues with enforcement in rural areas	Men drink more, cultural stigma for women
3	Germany	12.79	1 death per ~5,849 people	Strict drink-driving laws, breathalyzer tests	Men consume more alcohol, women increasing
4	Lithuania	12.78	High alcohol mortality rate	Enforcement of drink-driving laws improving	Men drink more; women's drinking rising
5	Ireland	12.75	Elevated alcohol-related mortality	Drink-driving laws enforced strictly	Men consume more alcohol than women
6	Spain	12.67	Moderate alcohol-related deaths	Drink-driving campaigns ongoing	Men drink more, but women's consumption rising
7	Uganda	12.48	Alcohol abuse linked to deaths	Challenges with illegal alcohol affecting safety	Men drink more; cultural norms significant

1.6 ADME (Absorption, Distribution, Metabolism, Excretion)

When you drink alcohol also known as ethanol such as wine, beer, whiskey etc. First it gets absorbed into your blood stream then after distribution of alcohol into your body/bloodstream. After distribution and absorption Metabolism occurs and responds in body finally by excretion all harmful products/removal of waste products.

Absorption

Routes of administration

Four important routes of administration:-

1.Ingestion by direct administration into the bloodstream
2.Dermal application on the skin or any wound/cut mark.
3.Ingestion via the digestive tract.
4.Inhalation through the respiratory system

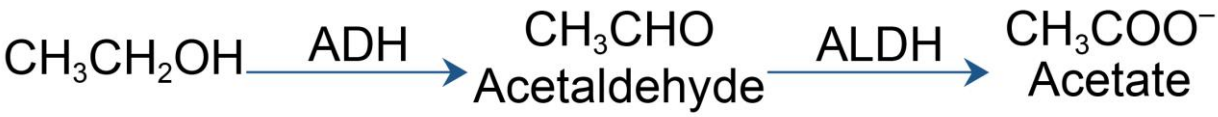
Distribution

Drugs have been absorbed and travel from absorption site to tissue throughout the body or bloodstream.Distribution may be occurred from one body part to another by bloodstream**.**

Metabolism

Alcohol is metabolised in the body based on the body type and other factors. First alcohol consumed by the body reaches the stomach and is absorbed by it. Then is absorbed by the body through blood. When blood runs through nephrons, the alcohol is eliminated from the blood.

The scientific name for alcohol is ethanol (CH3CH2OH). The body metabolizes and eliminates ethanol in a series of distinct steps. Enzymes, chemicals, assist in dismantling the ethanol molecule into other substances (or metabolites), which the body can process more efficiently. Some of these intermediate metabolites are toxic.



Excretion

Excretion is the method by which the metabolized drug compound departs the body.Scientists are interested in the rate of drug elimination from the body and by what route it is done. Most drug excretion comes as faces or urine. Excretion also takes place through the lungs or in sweat through the skin. Molecular charge and size dictate the route of excretion.

1.7 Blood alcohol detection test

There are various blood alcohol tests. The most common form is one that shows the amount of alcohol an individual has drunk in the recent past. This is known as blood alcohol content (BAC). There are others used to measure chronic alcohol consumption and the buildup of alcohol biomarkers in the body.

They include:

(a)**Carbohydrate-deficient transferrin (CDT):** CDT is a parameter that may detect heavy drinking. A high level of CDT shows that one has been consuming alcoholic drinks on a daily basis.

(b) **Phosphatidylethanol (PEth):** PEth body levels depend on alcohol intake for 3 to 4 weeks.

(c) **Ethyl glucuronide/ethyl sulfate (EtG/EtS):**These compounds are typically tested

Trusted Source for in urine after use, but can also be tested for in the blood.

The most common type of blood alcohol test is a BAC test. It's the one utilized for the majority of legal, medical, and employment testing to detect alcohol.

1.8 Alcohol Poisoning and Its Symptoms

Alcohol is addictive if we take it in large quantities and it also leads to sleepiness which is extremely dangerous for our body.Alcohol is digested and absorbed in your body, the alcohol is delivered to your bloodstream.

Your blood alcohol content (BAC) begins to rise. Alcohol is metabolized by your liver to remove it from your body because it's a toxin. But when your BAC is higher, your liver can't get rid of the toxins quickly enough. The extra alcohol in your system is a depressant. It slows down your body's normal processes. If you continue drinking (and drinking quickly), your BAC keeps rising. The depressant effect gets stronger and stronger.

When the depressant effect begins to interfere with the vital functions of your body, like your breathing and level of consciousness, that's alcohol poisoning. Everyone is unique, so we don't know your limit for how much you can drink before you're at risk for alcohol poisoning. So you should always drink slowly and not too much.

1.8.1 Risk Factor for alcohol poisoning:

(1)Drinking fast always maintain at least 10-15 minutes of interval.(According to an article by Cleveland Clinic, A woman drinks four or a man drinks five in roughly two hours.)

(2)Medical conditions such as consuming anti-anxiety drugs may raise the alcohol overdose and it can be dangerous at one place & also decelerate your CNS (Central Nervous System).

(3) Age also play a significant role in alcohol poisoning & alcohol drinking habit. Unless you eat food before or while drinking alcohol, you are likely to have alcohol poisoning. Alcohol gets absorbed most quickly in your small intestine. The longer the alcohol stays in your stomach, the more slowly your body will be able to absorb it.

(4)If you don't eat before or while drinking alcohol, you are more likely to become alcohol poisoned. Alcohol is absorbed most quickly in your small intestine. The longer alcohol sits in your stomach, the slower it will be absorbed into your body.

1.8.1 Normal signs of alcohol poisoning include:

(1). Slowed responses and confusion.

(2). Inability to walk or loss of coordination.

(3). Trouble staying conscious.

(4). Nausea.

(5). Vomiting.

(6). Delayed or absent gag reflex, which can lead to choking on vomit.

(7). Bradycardia.

(8). Low body temperature.

(9). become unable to control your bladder and leak urine.

1.9 Stages of Alcohol Intoxication

The increasingly additive effects of alcohol intoxication as blood alcohol concentration rises can be extrapolated to project just what increasing levels of alcohol would do to the body and the individual's judgement and behavior.It must be understood that the same quantity of drinks won't produce the same BAC in everybody. Your size, metabolism, ethnicity, etc., might influence how alcohol affects this individual.

(1)30-100mg%-

Stage of excitement -Slowed information, loss of fine motor skills, talkativeness, sexual desires etc.

(2)100-300mg%

Stage of incoordination- Incoordination of thought, Speech, Impaired judgment, Vomit, Nausea, Dilated Pupil, Criminal offence are committed, etc.

(3) Above 300mg%

Stage of narcosis- Deep sleep, Rapid pulses, hypothermia, contracted pupils, Coma & Death

Result

This research combined evidence from a number of forensic and medical sources to assess the impacts of alcohol consumption on the justice system and the human body. Some of the key findings are:

Detection Techniques: Blood alcohol continues to be the gold standard but newer biomarkers like CDT and PEth are increasingly being employed for identifying chronic use.Postmortem Processes: Ethanol can be created postmortem through microbial fermentation, and forensic toxicologists have to distinguish between antemortem and postmortem ethanol presence.Legal Limits and Penalties: Most countries have a BAC legal threshold for driving at 0.08%, with escalating penalties for DUI offenses.

Legal drinking age and enforcement in India are state-dependent, and drunk driving fines have risen drastically under new laws.Toxicological Impact: Metabolism of alcohol is influenced by age, sex, weight, and other medications taken concurrently. Consumption of alcohol quickly greatly increases the risk of alcohol intoxication.Stages of Intoxication: As BAC increases, symptoms become more pronounced, from mild euphoria and uninhibited behaviour to gross loss of coordination, coma, and even death.These findings highlight the critical role played by forensic science in detecting alcohol consumption, examining toxicological evidence, and aiding legal process.

Conclusion

Drinking, as socially tolerated in the majority of cultures, is of significant health and legal interest when it is abused.Forensic analysis of ethanol is paramount in the interpretation of its pharmacokinetics, especially in forensic cases of alcohol-related driving, accidental or suspicious death. Alcohol elimination and metabolism are determined by a number of variables such as age, gender, and body composition and must be considered during forensic examination. Assessment methods like BAC tests, gas chromatography, and novel biomarker tests provide credible criteria for forensic toxicologists to quantify acute and chronic alcohol use. In addition, an understanding of the physiological action of alcohol, from intoxication through poisoning, is also critical to both medical and legal professionals. As alcohol-related problems and urbanization rise further, national forensic consciousness and legislative intervention are crucial to alcohol harm reduction in society

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