FORENSIC ANALYSIS OF ILLICIT LIQUOR: A REVIEW

Mahak Gahlawat[1*]

Abstract:
Illicit liquor also known as country-made liquor, is produced and sold illegally, without proper license or permits from government authorities. It is largely unbranded and does not meet the standards that ensure product quality and safety. Illicit liquor contains various adulterants such as methanol, lead, copper, arsenic, and harmful chemicals that can cause toxicity to an individual's health. Consuming illicit liquor that contains several toxic adulterants which causes diseases such as blindness, liver damage, kidney failure, seizures, coma, and even death. The detection of toxicants in illicit liquor aids in an individual's health and crime control. For decades several traditional physical methods are used such as boiling point, density, color, odour, and some chemical tests like the iodoform test, dichromate test, Schiff's reagent test, etc., and some sophisticated techniques are also utilized such as Spectroscopy, chromatography, etc. to detect the concentration of intoxicants in illicit liquor. This review focuses on many physical, and chemical tests, along with instrumental techniques which are generally performed for the detection of different adulterants found in illicit liquor, to assure an individual's health and safety, enforces jurisdiction, generate revenue, and promote well-being of society as whole. The primary focus of this study is about the work accomplished so far in the discipline of analysis and detection of the alcoholic beverages and to expand the horizon of knowledge of adulterants, their toxicity, and their effects by deploying sophisticated techniques that are required to confirm the presence of adulterants in illicit liquor that causes toxicity in humans.

Keywords: Illicit, Liquor, Adulteration, Detection techniques, Forensics.

[1*]M.sc. Student, Department of Forensic Science, Chandigarh University, Punjab, India
email: Mahakgahlawat20@gmail.com

***Corresponding Author:-** Mahak Gahlawat
*M.sc. Student, Department of Forensic Science, Chandigarh University, Punjab, India
email: Mahakgahlawat20@gmail.com

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1. Introduction

Production of unrecorded (illicit) alcoholic beverages, termed illicit liquor, is a worldwide problem in developing countries such as India [1-2]. According to the World Health Organization, illegal alcohol is defined as homemade or informally manufactured alcohol (legal or illegal), smuggled alcohol, alcohol that is not registered and is outside the reach of conventional system of governmental control, alcohol obtained through cross-border shopping (which is recorded in a different jurisdiction)[3] .

Alcoholism is a multidimensional aspect and is contemplated in integrated classes, i.e., physiological, medical, psychological, and on social levels, that is due to its specific circumstances and consequences. Alcohol is a psychotropic substance that affects the parts of the brain and various neural pathways and its effects depend on the dose ingested, genetic factors, and learned experiences of the consumer [4]**.** Alcohol has dependence-producing properties, and deficiencies in nutrition values and this can be a reason for physical or psychological diseases. It is becoming a social challenge in the world, its consumption creates financial problems, poor work performance, limited career opportunities, poor health, offensive behaviour, social ostracism, and other social consequences, and it is a third major factor for diseases and disability. Prolonged enormous alcohol consumption contributes to inflated production of the oxygen radicals that trigger neuroimmune reaction and programmed cell death and necrosis through mitochondrial, protein, lipid peroxidation and DNA [5-6]. Alcohol can harm our mental decision, sensory coordination, concentration reduction, and grasping (observation) capability [7]. Alcohol remains the most widely consumed drug in the world, with a worldwide annual average consumption of 6.5 L (of pure ethanol) per person. It is commonly abused, presenting a global health issue that contributes to over 2.5 million deaths annually. In India, its consumption amounted to about 5 billion litres in 2020 and was evaluated to stretch out to reach about 6.2 billion litres by 2024. [3,8-10]

Alcoholic beverages produced all over the world may be categorized into two categories: commercial and non-commercial [11]. Commercial alcohol is alcohol that is formed officially, under law or consumed worldwide while non-commercial alcohol does not come under a record of law(jurisdiction) and they are further categorized into three different types, a) surrogate alcohol that is not proposed for human consumption. b) licit alcohol which is made by licensed breweries and via standard methods. c) illicit alcohol which is produced unlawfully in unlicensed factories [12]. The licit alcohol so produced is standardized, even taxes are imposed on this liquor, and because of this their cost subsequently increases and is not affordable to every section of society. To fulfil the demands, illicit liquor is manufactured that does not follow any standardized method and is produced locally with no product quality and safety. Due to its manufacturing process, toxicants are present such as heavy metals (Pb, As, Cu, Fe, urea, furfural, fuel oil, natural solvents), occasionally narcotic substances like benzodiazepines and barbiturates and other harmful chemicals (methyl alcohol, ethyl alcohol, isopropyl, propanol, butanol, etc.). These adulterants are added to elevate the alcohol concentration and enhance the flavor of alcohol. The adulteration is carried out in two manners either by manipulating the concentration or by putting in a chemical like methanol. The presence of these toxicants in liquor imparts health defects and diseases on an individual's health such as metabolic problems, blindness, kidney failure, and seizures, and even leads to death [13-14].

As stated by WHO, about 25% of all alcohol consumed worldwide is unrecorded, but this figure is complex in some nations [15]. In Europe it is about 21.9% of the total per capita alcohol consumption, in the east Mediterranean, there was an increase of 56.2% and in South East Asia the estimate was 69% [16]. According to the WHO Report 2018, as shown in figure 1, the adverse misuses of alcohol is an elementary factor in greater than 200 disorders and health conditions, and globally 3 million deaths occur every year due to the abuse of alcohol (5.3% of all deaths) [17].

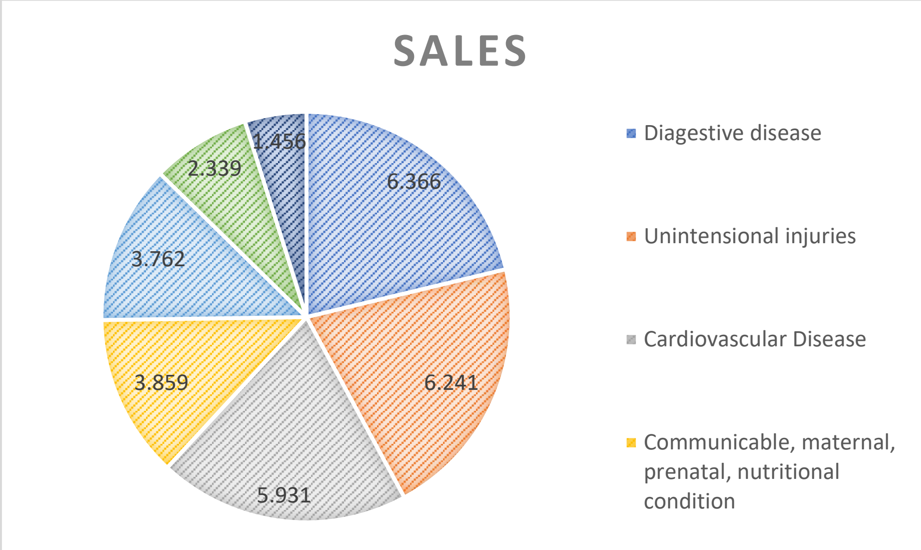

Figure 1: *Representation of diseases in society*

For decades, alcohol or illicit liquor has been the most detected substance in routine forensic analysis, particularly in cases involving violence, sexual assault, and motor vehicle accidents, hooch tragedy [18]. Forensic analysis can be used to identify the particular substance responsible for them and to help prosecute the cause and source for the production and distribution of the liquor. By analysing the chemical composition of illicit liquor, investigators can identify patterns and

trends in the type of substances used, and use this information to operate law enforcement endea-vours and regulatory interventions[19].

In forensics several simple and traditional methods such as colour test, flame test, boiling point, density, smell test, and taste tests were utilized for the presence of adulterants but they do not give precise and accurate results. These traditional methods are still used today, although they are supplemented with more advanced analytical techniques such as gas chromatography (GC), High-performance liquid chromatography (HPLC), FTIR, and mass spectrometry (MS).

2. Production of Illicit liquor:

Alcohol is manufactured by the process of fermentation of sugars, starches, molasses, grains, and fruit juices. These products are found to be less fermented in illicit liquor and confer the individuality of liquor. In the process of manufacturing of liquor, glucose is formed that ferments down to produce two ethanol and two carbon-dioxide molecules [20-21].

$C6H12O6 \rightarrow 2C2H5OH + 2CO2$

In illicit liquor, the composition varies due to unregulated conditions or frequent adulteration leading to variation in concentration and its configuration and toxicity are subject to what they are formed from and how cautiously precise the process is. Adulterants such as methanol, furfural, copper, iron, and urea, are intentionally or unintentionally added at different stages during production. Copper and iron are not added manually or by manufacturing procedure but can be found due to the preservation canisters, fuel oil and urea present during fermentation as a by-product of the liquor production[22-24].

Illicit liquor is manufactured by different steps such as raw material preparation, home fermentation, and distillation.

2.1 Raw Material Preparation: Raw materials such as grain, fruits, sugarcane, etc are shown in Table 1 with alcohol yield and starch percentage. Preparation involves cleaning, crushing, and boiling the raw material to extract the necessary sugars and flavours[25].

Table 1: *Raw material used in manufacturing illicit liquor*

Sr. No	Raw Material	Fermentable Carbohydrates (Starch%)	Alcohol Yield (Lit. of Alcohol/ml)
1.	Rice	62-67	380-418
2.	Sorghum	62-65	380-410
3.	Wheat	62-65	380-410
4.	Potato	19-20	127-134
5.	Malt	58-59	389-395
6.	Maize	62-65	380-410

2.2 Home Fermentation: It is the process of fermenting foods or beverages in the household environment, usually for personal consumption. It is a natural procedure that is being used for 1000 years to preserve food and create new flavours and textures. It involves the use of micro-organisms such as yeast and bacteria to break down sugar in food or beverages for producing alcohol, lactic acid, or other organic acids[26].

2.3 Distillation: The distillation process involves the separation and concentration of the alcohol from the fermented mixture, and if it's not done properly it can result in the yield of methanol or other harmful substances that can be lethal to consume[27].

2.4 Toxicants in illicit liquor:
Toxicants are constituents that cause harm to living organisms when they are exposed to them for a longer duration. Illicit liquor contains a range of toxicants that can be dangerous to human health. Some of the toxicants commonly found in illicit liquor include- Methanol, ethylene glycol, heavy metals, isopropyl alcohol, urea, 1-propanol (n-propyl alcohol), 1-butanol (n-butyl alcohol), 2-butanol (sec. butyl alcohol), iso-butanol (2-methyl-1-propanol) and isoamyl alcohol (3-methyl-1-butanol) and other contaminants. The use of ethylene-glycol and methanol raises the alcohol concentration and improves the flavour of liqour. Methanol is usually intentionally added to increase the profit and potency as its cheap to manufacture and it has the maximum potential to cause impairment to an individual. The presence of these intoxicants in liquor might lead to an increased incidence of cancer, liver diseases and abnormalities [28-31].

Toxicants that found in illicit liquor such as methanol, lead, cadmium, and other heavy metals are shown in Table 2. Illicit liquor is often produced under unregulated conditions and can contain a variety of toxic substances that can pose serious health risks to consumers.

Table 2: *Toxicants identified in illicit liquor with their signs and symptoms.*

Sr. No	Toxicant	Properties	Signs and symptoms	Reference
1.	Methanol	It is toxic alcohol that can cause sightlessness or death if ingested in large amounts.	Nausea and vomiting, abdominal pain, visual disturbances, seizures, and coma.	[13]
2.	Heavy metals (lead, arsenic etc.)	It can leach into the alcohol from lead-based solder used in the production process.	Irritability, joint pain, memory loss, anaemia, and seizures.	[13]
3.	Ethylene glycol	Ethylene glycol is a toxic substance that is sometimes added to illicit liquor to increase the alcohol content.	Nausea and vomiting, abdominal pain, kidney failure, seizures, and coma.	[32]
4.	Acetaldehyde	Acetaldehyde is a by-product of the fermentation process and it is expected to found in both legal and illegal alcohol.	Headache, nausea, vomiting, sweating, rapid heartbeat, and difficulty breathing.	[33]
5.	Iron and Copper	the equipment used in the production process is made of these metals, they can potentially contaminate the liquor.	Nausea and vomiting, abdominal pain, diarrhoea, jaundice, anaemia, and liver damage.	[34]
6.	Isopropyl Alcohol	It is sometimes added to illicit liquor as a cheap substitute for ethanol. It also known as rubbing alcohol	Skin irritation and respiratory problems if inhaled.	[28] [34]

3. Medicolegal Purpose:

Gradually over years and on a day-to-day basis a lot of people are affected by these intoxicants, adulterants and poisoning cause deaths and their cause of death is not known which poses a dilemma for the forensic examiner in cases of hooch tragedies and domestic violence. Several stringent laws were made such as The Narcotic Drugs and Psychotropic Substances Act (1985). It was passed to consolidate and amend the laws and to make stringent provisions for the control and regulation of operations relating to psychotropic substances[35].

The Madhya Pradesh Hooch Tragedy had significant medicolegal implications, hooch tragedy is a misfortune accident in which the individual dies due to the ingestion of illicit liquor which was manufactured from the denatured spirit that was procured from a pharmacy along with 100 litres of sanitizer, a sedative, and isopropyl which caused poisoning and this resulted in the death of at least 23 people and hospitalization of many others[36].

Liquor is considered as the main cause of accidents and aggression, in India 70% of road accidents are due to drunken driving which costs 1.34 lakh lives each year. Alcohol inflicts harmful effects on a number of aspects of human cognition and performance. The analysis of drunken drive cases is done on the spot with the help of a breathalyser [37-38].

4. Forensic Analysis of illicit liquor:

The forensic examination of illicit liquor is an important field of study that seeks to identify and characterize the chemical composition of bootleg alcohol. The complete analysis is crucial in detecting and prosecuting those involved in the production and distribution of illicit liquor, as well as in identifying the specific health risks associated with consuming these products[39].

The examination of illicit liquor can be performed by the following steps:

4.1 Physical Examination: The physical examination of the samples involves observation of the colour, odour, and appearance of the sample. It also involves the measurement of density, pH, and refractive index.

4.1.1 Density Test: Illicit liquor samples may have a lower density than standard alcoholic beverages due to the presence of water or other diluents[40].

4.1.2 Flame Test: Illicit liquor samples may produce a colored flame due to the presence of impurities or adulterants such as methanol.

4.1.3 Chloroform Test: Illicit liquor samples may produce a cloudy or hazy appearance due to the presence of oil or other impurities [41].

4.1.4 Ph Test: This test estimates the acidity and alkalinity of the sample and can give an indication of the presence of certain acids or bases that may be used in the production of illicit liquor[42].

4.1.5 Breathalyzer: It is used to assess the person's blood alcohol concentration (BAC) from a breath of an individual in drunken drive cases. (There is no internationally accepted standard method for analysing liquor samples in forensic cases along with any type of database)[43-44].

4.2 Chemical Analysis: Chemical tests are utilized to distinguish and recognize specific components in illicit liquor. Some of the most common chemical tests used in the analysis of illicit liquor are listed in Table 3.

Table 3: Adulterants are identified by different chemicals test.

Sr. No	Test	Reagent	Sample	Result	Reference
1.	Iodoform Test	NaoH +KI + I	Ethanol	Yellow-colour, Hexagonal-crystal indicates presence of ethanol.	[34]
2.	Sulpho-Molybdic Acid	Molybdic acid + conc.H2So4	Ethanol	Deep blue colour indicates the presence of ethanol.	[34]
3.	Dichromate Test	Sample + K2Cr2O7 + conc. H_2SO_4	Ethanol	Blue or Green Colour indicates the presence of ethanol.	[45]
4.	Chromotrophic Acid	KMnO4 + H_3PO_4 + NaHSO3	Methanol	Violet colour indicates the presence of methanol.	[34]
5.	Schiff's Reagent Test	Sample + KMnO4 +Phosphoric acid+ C2H2O4 + H_2SO_4+reagent	Methanol and aldehydes	Purple colour indicates the presence of methanol.	[46]
6.	Potassium ferrocyanide test	Sample + HNO3 + $K_4[Fe(CN)_6]$	Copper and Iron	Blue colour indicates the presence of Fe. Chocolate colour indicate the presence of Cu.	[33]
7.	Biurets test	Sample+NaOH+CuSo4	Urea	Brown colour indicates presence of urea.	[46]

4.3 Instrumental Analysis: Instrumental analysis is a crucial aspect of the forensic analysis of illicit liquor. It involves the use of advanced analytical instrumental techniques to identify and quantify the chemical compounds present in the sample[47]. Some of the commonly used instrumental techniques for the examination of illicit liquor include Gas Chromatography-Mass Spectrometry (GC-MS), High-Performance Liquid Chromatography (HPLC), and FTIR (Fourier Transform Infrared Spectroscopy). The instruments give reference peaks for components and level of detection, each component has an individual peak. The peaks and levels of detection of adulterants are represented in Table 4.

Table 3: Peak and Level of detection of adulterants in different instruments.

Sr. No	Adulterant	Instrument	Peak	LOD (mg/L)	Reference
1.	Methanol	Gas Chromatography-Mass spectroscopy.	_	0.79*	[48]
2.	Ethanol	ATR-FTIR	1043-1085/cm	_	[49]
3.	Methanol	ATR-FTIR	2785-2912/cm	_	[49]
4.	Methanol	Spectroscopy (Raman)	1035/cm	_	[50]
5.	Ethanol	Spectroscopy (Raman)	881/cm	_	[50]
6.	2-propanol	GC-MS	-	0.319	[51]
7.	Acetaldehyde	GC-MS	-	0.289	[51]
8.	n-butanol	GC-MS	-	0.267	[51]
9.	Ethyl-acetate	GC-MS	-	0.322	[51]
10.	2-propanol	GC-MS	-	0.319	[51]
11.	Isobutyl alcohol	GC-MS	-	0.235	[51]
12.	Isoamyl alcohol	GC-MS	-	0.276	[51]

*LOD-level of detection

5. Conclusion:

The analysis of alcoholic beverages constitutes a major area in forensic cases. Illicit liquor is a main contributor to hooch tragedies because of the toxicants present. As we know, it is manufactured in small unlicensed breweries, cheap in price, made by raw material and their alcoholic content varies from one sample to another. The production and distribution of illicit liquor are often driven by the demand for cheap alcohol and the desire for profit and can be particularly prevalent in areas where legal alcohol is heavily taxed or difficult to obtain. Illicit liquor can be manufactured from a range of substances, including industrial alcohol and even toxic chemicals, which can make it extremely dangerous to consume. This paper has drawn together academic, contemporary, and historic evidence on the impact of illicit liquor production, distribution, and consumption. This review focuses on liquor which is homemade or country-made alcohol to assess the intoxicants that are present in liquor through physical tests, chemical tests, and instrumental techniques. The identification of intoxicants endures an interesting and extensive sphere of study in the future.

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