Forensic Examination Of Adulterants In Illicit Liquor - Assessing Health Risk And Legal Implication In Chhattisgarh

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Abstract
Illicit or unreported alcohol—commonly referred to as country-made or spurious liquor—poses a significant public health risk globally, with a particularly severe impact in developing countries like India. As the third-largest producer of alcoholic beverages in the world, India faces a growing challenge in controlling the adulteration of alcohol, especially with toxic substances such as methanol. Chhattisgarh, in particular, reports a higher prevalence of alcohol consumption compared to many other Indian states. The present study was conducted to detect adulterants in illicit liquor samples collected from various districts across Chhattisgarh, including Bilaspur, Jangir-Champa, Jashpur, Bastar, Korba, Sarangarh, Ambikapur, Sakti, Mahasamund, and Raigarh. Preliminary analysis of the samples was carried out using a series of qualitative colour tests to identify key constituents. The results indicated the presence of ethanol in all samples. No traces of other toxic adulterants such as furfural, urea, iron, or copper were detected. However, methanol—a highly toxic alcohol—was identified in one sample collected from Bilaspur. Further quantitative analysis was performed using a relative density bottle to determine alcohol content and sample density. Advanced techniques such as Fourier-transform infrared spectroscopy (FTIR) were employed to characterize functional groups and confirm the presence of various chemical components. This study underscores the importance of routine forensic surveillance of illicit alcohol to prevent methanol poisoning and ensure public safety.
Keywords: *Illicit spirits, FTIR spectroscopy, alcoholic beverages, Alcohol poisoning. Forensic analysis*

INTRODUCTION

Over the previous 20 years, there have been indications of rising alcohol consumption in India per capita (APC). One of the primary risk factors for the global burden of sickness is alcohol use. While certain low- and middle-income Southeast Asian countries, like India, started drinking more, high-income countries' alcohol consumption was plateauing during the past ten years. [1] Without a doubt, alcohol addiction is on the rise right now, and it is a more potent risk factor for illness and death globally than it has ever been. [2]

The term "beverage" is derived from Latin "bever" indicating to relax from work. Any liquid other than water that can be taken to satisfy thirst or for some energy can be classified as a beverage. From freshly squeezed juices to chemically laced energy drinks, the list goes on and on. For centuries, there was only one kind of beverage that people were familiar with: Water, Milk or any type of Fruit Juice. Over time the scope extended to Alcohol, Wine, various forms of Tea and Coffee, Cocktails, Cider and Soda. There are various plants that are used to make these beverages. In general, there are two categories of drinks: alcoholic and non-alcoholic. [3]

India is the world's third-largest producer of alcoholic drinks. The two primary categories of liquors are Indian-made foreign liquor (IMFLs) and domestically produced liquor. [4] Alcohol that is produced, sold, or distributed illegally is referred to as illicit spirits. It is frequently untaxed and uncontrolled, and it is occasionally produced in hazardous settings. Illegal (unrecorded) alcohol is a global public health epidemic because it is manufactured without market or regulatory control, putting consumers at greater risk of safety, quality, and adulteration problems. [5]In India, consumption of illegal alcohol has caused hundreds of deaths. Apart from their use in laboratories, ethyl alcohol can also be utilized for drinking by humans. Excessive drinking of illegal liquor can lead to effects like confusion, nausea, vomiting, seizures, slowed or abnormally slow breathing, hypothermia, having trouble remaining awake, decreased physical coordination, etc. Exotic additives are added based on the region of alcohol consumption, but adulteration occurs and legitimate quality controls are circumvented in alcohol strength.[20]

Illicit liquor, also called country-made or unrecorded alcohol, is a significant cause of public concern globally, and particularly in Third World nations like India. This alcohol, prepared outside legal premises, tends to be adulterated with substances that are unhealthy to add to the alcohol, enhance potency, or reduce expense, and is likely to inflict severe health damage, including loss of life.[22]

The main aim of adulteration is to minimize the cost of production. Adulteration of liquors can be achieved in two ways: by diluting the strength or by adding ingredients such as methanol. Other hard material is added independently, including furfural while fermenting, iron and copper while blending, and fuel oil and urea while producing.[4]

The percentage of people who drink alcohol in Chhattisgarh is relatively high when compared to other Indian states. [1] The honey tree, or Madhuca longifolia (Mahua), belongs to the Sapotaceae family. It is a massive deciduous tree that grows extensively in both subtropical and arid tropical climates. The states of Andhra Pradesh, Gujarat, Madhya Pradesh, Odisha, Chhattisgarh, Jharkhand, Bihar, and Uttar Pradesh are home to Madhuca longifolia.

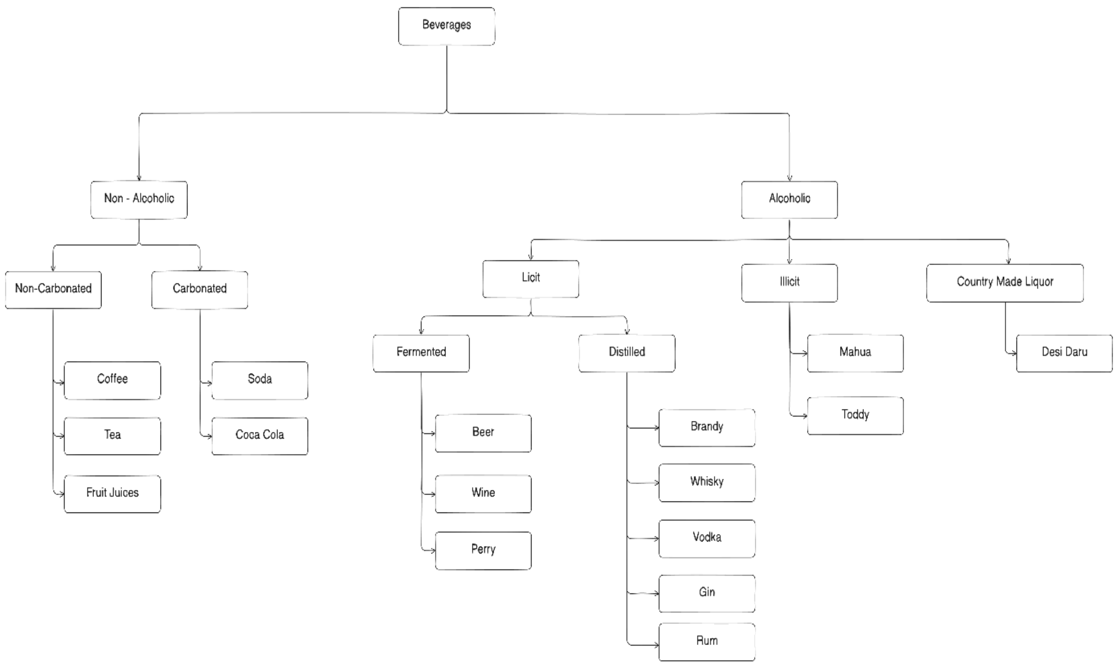
The pH of Madhuca longifolia usually was between 3.5 and 5.5. Prepared from the flowers of the Madhuca longifolia tree, also referred to as the Mahua tree, Mahua spirits is a cultural liquor. It has been part of Chhattisgarh tribal culture for centuries, used in social gatherings, festivals, and ceremonies. In Chhattisgarh, mahua poisoning is a serious issue that is often associated with consumption of contaminated or illegally produced mahua liquor. [6] Though it is an important part of the culture, consumption of mahua liquor has been associated with various health hazards, primarily due to improper fermenting methods and the addition of toxic substances to enhance its strength.[21]

Methanol, a stealthy toxic alcohol, is metabolized primarily to its main metabolic changes within the liver via enzymatic reactions of crucial importance. Methanol, one of the most recognized adulterants in illicit beverages, is one of the most toxic alcohols that can induce metabolic acidosis, visual issues, and death if ingested. Methanol was found in 75% of samples of illegally produced alcoholic drinks in the Antakya area, along with other harmful chemicals such as methylamine and formic acid. [23]

The fatal enzyme alcohol dehydrogenase (ADH) directs methanol conversion to the toxic substance formaldehyde and, as a byproduct, produces NADH. The road continues from here in danger with formaldehyde, extremely well-known for its exceptional toxicity, rapidly being converted into the corrosive formic acid by the catalytic effect of formaldehyde dehydrogenase (FDH), continuing to exacerbate NADH buildup. Then, formic acid undergoes its cycle of transformation, ultimately degrading into its harmless constituents: water and carbon dioxide. Formic acid does this by undergoing a series of enzyme-catalysed reactions, best known of which is formate dehydrogenase. Carbon dioxide produced enroute is removed by the process of respiration, while water is removed by the urinary system. [7]

The identification of the causes of illnesses and fatalities in forensic science depends heavily on the detection of methanol concentration.It also exposes the complex web of links between the production and distribution of illicit liquors and a network of organised crime, encompassing everything from heinous crimes like smuggling and murder to a wide range of smaller offences. [24] Illegal liquors are not only of forensic importance more than simple analysis but also play a significant role in the war against illegal activity, maintaining public safety and health and identifying and detecting individuals involved in illegal liquor-related activities. [18] In forensic science, detection of methanol content becomes a decisive factor in the identification of causes of diseases and deaths. It also reveals the complex web of connections between the manufacture and sale of illegal liquors and a chain of organized crime, ranging from gruesome crimes like murder and smuggling to a host of the other crimes.[24] Beyond such basic revelations, forensic expert expertly dissect the contents of illegal drinks, their origin, production processes, and the range of substances they hide. This realization is crucial in enabling forensic investigator to make strong linkages between various illicit activities and build sound cases against suspects.[19]

1.2 Classification of Beverages



MATERIAL AND METHODOLOGY

For the current research, samples were analyzed using various preliminary color test. After that samples have been examined and and analysed by FTIR (Fourier transform infrared spectroscopy), to determine the adulterants present in the sample.

Sample Collection

The convenience sampling method was used to collect the samples. Three-three samples of illicit spirits were gathered from different Chhattisgarh districts. The samples were homemade and collected from different villages.

Samples collected from different districts of Chhattisgarh are given below in [table1]:

Fig1: Sample collected in bottles

Table:1 Shows the list of samples.

S.NO	Samples	Sample Code	Districts
1.	Sample 1	S1A-S1C	Raigarh
2.	Sample 2	S2A-S2C	Sakti
3.	Sample 3	S3A-S3C	Mahasamund
4.	Sample 4	S4A-S4C	Bilaspur
5.	Sample 5	S5A-S5C	Janjgir-Champa
6.	Sample 6	S6A-S6C	Jashpur
7.	Sample 7	S7A-S7C	Bastar
8.	Sample 8	S8A-S8C	Korba
9.	Sample 9	S9A-S9C	Sarangarh
10.	Sample 10	S10A-S10C	Ambikapur

Collection method

All the samples were obtained from small plastic bottles from various districts of Chhattisgarh. The bottles are sealed and packed properly to avoid the evaporation of alcohol. Every bottle of sample is marked with the information (geographical area and sample number).

Procedure

Colour test

Different colour test has been performed for the detection of presence of various compounds like ethanol, methanol, urea, furfural, copper and iron. Colour test for detection of compounds were taken from DFS Manual along with some modifications.

Test for ethanol

Iodoform test: 1ml of sample has been taken in a test tube and 1ml of 5% NaOH solution has been added in the same test tube. Iodine solution is then added to the tube until dark brown colour appears (20g of potassium iodide and 10g of iodine is mixed in distilled water). Excess of iodine is removed by using dilute NaOH and equal amount of water. Appearance of yellow crystalline precipitate indicates the presence of ethanol.

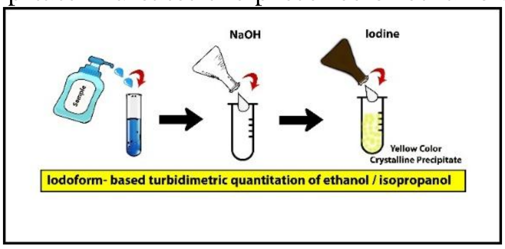


Fig 2: Iodoform test for ethanol

Dichromate test: 1ml of sample has been taken in a test tube and 0.2ml of KMnO4 solution was added to it. After that concentrated H2SO4 was added which change the yellow colour of dichromate to bluish green colour indicating the presence of ethanol.

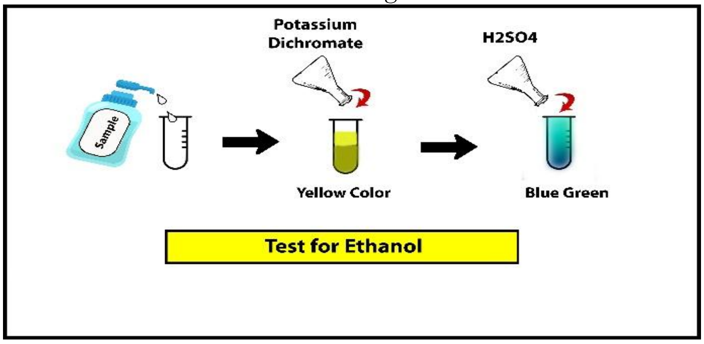


Fig 3: Dichromate test for ethanol

Test for methanol

Schiff's test: 1ml of sample has been taken in a test tube and 2ml of 2% potassium permagnate solution id added to it. After that 2ml of phosphoric acid was added to it and allow solution to stand for 10min. After that add 1ml of 10% oxalic acid solution, then add 5ml of schiffs reagent to it. Appearance of purple colour shows that methanol was present in the sample.

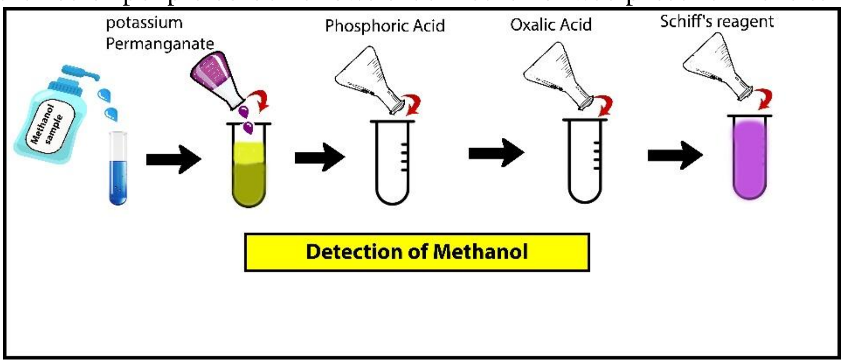


Fig 4: Schiff's test for methanol

Test for copper and iron

Take 5ml of sample in a test tube and add 1 drop of nitric acid to it. Then 0.025M potassium ferrocyanide was added. No colour changes indicate the absence of copper and iron in the sample.

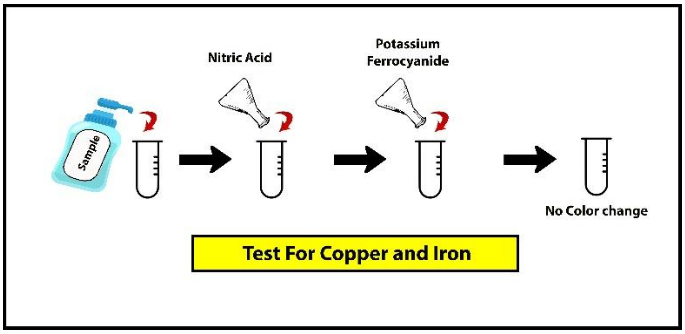


Fig 5: Test for copper and iron

Test for furfural

5ml of sample has been taken in a test tube and 1 drop nitric acid was added in the same tube. After that 0.025M potassium ferrocyanide was added to it. No change in colour indicates that copper and iron are absent in the sample.

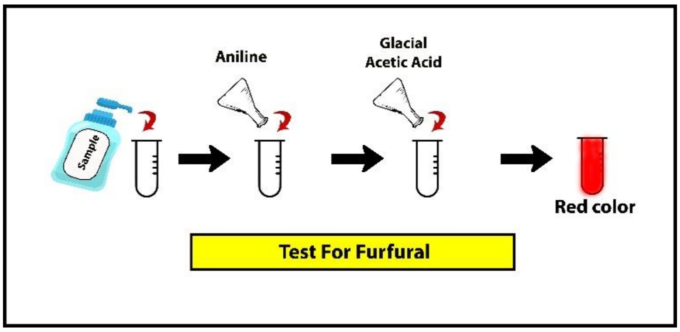


Fig 6: Test for furfural

Test for Urea

Biuret Test

5ml of sample has been taken in a test tube and 1% of potassium hydroxide or sodium hydroxide was added to it. After that add few drops of CuSo4 solution in the tube. Appearance of purple colour indicates the presence of urea in the sample.

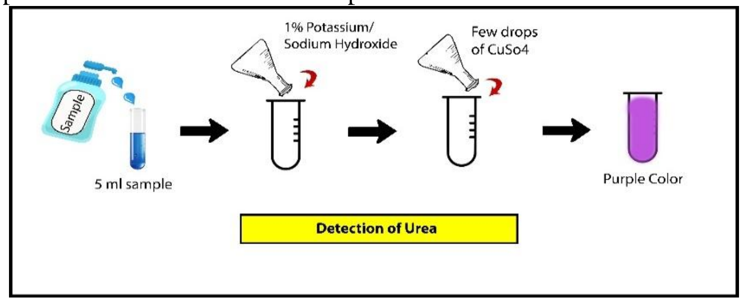


Fig 6: Test for Biuret Test

FTIR

Fourier Transform Infrared (FTIR) Spectroscopy of brunker company is utilized. An established method of analytical chemistry, infrared spectroscopy is utilized to a very great extent in qualitative and quantitative research.[12] The major advantage of the FTIR technique compared to other spectroscopic methods is that almost all chemicals exhibit characteristic absorption or emission in the infrared region such that both qualitative as well as quantitative analysis is possible. [13] The functional groups in the analyte determine the infrared spectra, which typically consist of complex multiplets of peaks and minima. [12]

For the analysis of functional groups in organic molecules, specifically alcohols, Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy is currently a fast and dependable method.[14] By ATR-FTIR, this research aims to identify and measure primary, secondary, and tertiary alcohol peak absorbances. For identifying O-H stretching frequencies and comparing hydrogen bonding and molecular differences, spectra of ethanol, isopropanol, and tert-butanol were examined. [15][24]

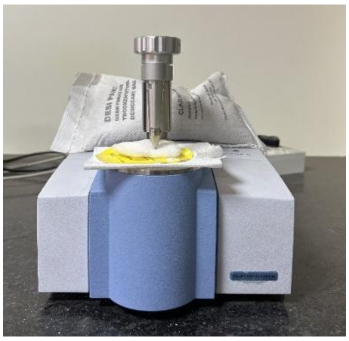


Fig 7: ATR (Attenuated Total Reflectance)

Specific Gravity

The proportion of the density of a substance to that of a reference substance is referred to as specific gravity.[16] The method is an old, tried and tested method of determining precisely how much alcohol there is in liquid samples. It involves the use of a Relative Density (RD) or pycnometer bottle. This technique relies on the premise that ethanol and water are of different densities and that the concentration-dependent changes in density of their mixtures are predictable. The ethanol content of a sample can be approximated by determining its specific gravity and using reference tables or calibration curves.[17]

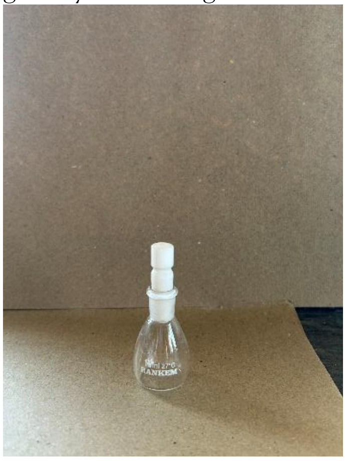


Fig 8: Relative density bottle

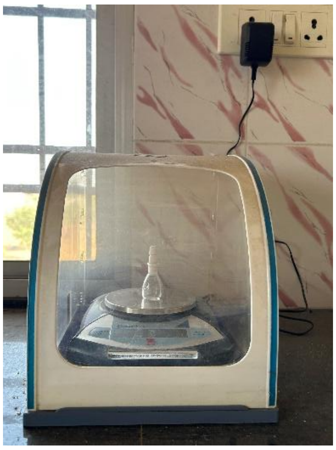


Fig 9: Weighing machine

pH of alcohol

As per the observation the pH of sample S3 is 3, while the other all samples pH lies between 4 to 5. This observation indicates that the mahua liquor is acidic in nature, which is due to the byproducts of fermentation like organic acids.

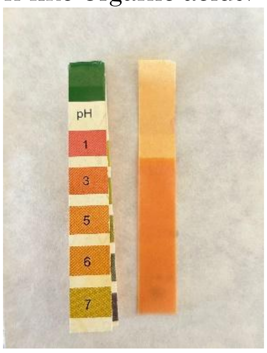


Fig 10: pH of alcohol sample.

Observation

In this research we have taken 30 samples from various districts of Chhattisgarh. S1A-S1C samples were taken from Raigarh, S2A-S2C from Sakti, S3A-S3C Mahasamund, S4A-S4C Bilaspur, S5A-S5C Janjgir-champa, S6A-S6C Jashpur, S7A-S7C Bastar, S8A-S8C korba, S9A-S9C Sarangarh, S10A-S10C Ambikapur. All the samples were examined by primary colour test for alcohol. According to author Abhilash Thakur et.al and Rohit Kumar Verma et.al and stranded DFS Manual, Iodoform test provides yellow colour crystalline precipitates and Dichromate test provides blue-green colour and indicates the presence of ethanol. It is revealed that the sample S1A to S10C all the sample provides positive results for ethanol. While the test for copper, iron, furfural and urea negative for all the samples. Schiff"s test provides purple colour for the presence of methanol and the sample S4A(Bilaspur) provides purple colour for the presence of methanol in the sample, but the other samples don't include methanol.

All samples have been passed through RD bottle. Specific gravity of all the samples has been calculated using the formula (Weight of empty bottle-weight of sample/Weight of empty bottle-weight of distilled water) and gravity is being compared with the density table for determining the density of alcohol sample. It has been found that following analysis alcohol present in sample S1A-S1C varies from 17% to 18% and the density varies from0.9756 to 0.9762. Sample S2A-S2C have 15% and density varies between 0.9784 to 0.9788. Sample S3A-S3C have 19% to 20% and the density 0.9734 to 0.9737. Sample S4A-S4C have 17% to 18% alcohol and density varied from 0.9755 to 0.9757. Sample S5A-S5C have 17% and density 0.9761 to 0.9765. Sample S6A-S6C have 12% and density 0.9824 to 0.9831. Sample S7A-S7C have 8% to 9% and density 0.9869 to 0.9872. Sample S8A-S8C have 16% and density 0.9778 to 0.9771. Sample S9A-S9C have 14% to 15% and density 0.9789 to 0.9793. Sample S10A-S10C have 14% and density 0.9803 to 0.9801. Therefore, the study reveals that among 30 samples, sample S3A-S3C have highest alcohol content and the sample S6A-S6C have highest density of 0.9831 to 0.9824.

Fourier Transform Infrared (FTIR) Spectroscopy was employed to examine the sample of spurious alcohol. Different spectra of samples have been produced and explained for each samples individually. Stranded peaks for alcohol's functional groups in FTIR are:

The O-H (hydroxyl) has a large peak at 3300 cm-1 and a strong link through H-bonding. C=O (aldehyde) has a peak between 1730 and 1740 cm-1, while C-H (alkane) has a medium band extending peak between 1250 and 1300 cm-1, with a significant peak between 1050 and 1150 cm-1. The stretching peak of C-O (alcohol/ether) is between 2850 and 2950 cm-1. C=C extending from 1640.04 cm-1. The investigation revealed that all 30 samples had a band at about 3300 cm-1, indicating the presence of a significant O-H (hydroxyl) group. A band between 1044 cm-1 and 1089 cm-1 is displayed by the C-O group in S6A, S7A, S7C, S8A, S8B, S9A, S9B, S9C, S10A, and S10C. The chemical is anhydride.

The existence of conjugated alkene is confirmed by the band between 1635 and 1640 cm-1 that is present in all samples from S1 to S10. Sample S7 is an alkene compound with a C=C bending value of 877.51 cm-1.4

RESULT

Colour tests

In the current research preliminary colour test was performed for the detection of adulterants present in the alcohol sample, as a result dichromate and iodoform test was positive for each sample indicating the presence of ethanol in each sample. And one sample from Bilaspur that is S4B was positive for Schiff"s test indicating the presence of methanol. Whereas copper, iron, urea and furfural was absent in the sample. [Table 2].

Table:2 Shows the results of colour test:

Sample no.	Iodoform test	Dichromate test	Schiff"s test	Biuret Test	Test for Cu, Fe	Test for Furfural
S1A	Positive	Positive	Negative	Negative	Negative	Negative
S1B	Positive	Positive	Negative	Negative	Negative	Negative
S1C	Positive	Positive	Negative	Negative	Negative	Negative
S2A	Positive	Positive	Negative	Negative	Negative	Negative
S2B	Positive	Positive	Negative	Negative	Negative	Negative
S2C	Positive	Positive	Negative	Negative	Negative	Negative
S3A	Positive	Positive	Negative	Negative	Negative	Negative
S3B	Positive	Positive	Negative	Negative	Negative	Negative
S3C	Positive	Positive	Negative	Negative	Negative	Negative
S4A	Positive	Positive	Negative	Negative	Negative	Negative

S4B	Positive	Positive	Negative	Negative	Negative	Negative
S4C	Positive	Positive	Negative	Negative	Negative	Negative
S5A	Positive	Positive	Negative	Negative	Negative	Negative
S5B	Positive	Positive	Negative	Negative	Negative	Negative
S5C	Positive	Positive	Negative	Negative	Negative	Negative
S6A	Positive	Positive	Negative	Negative	Negative	Negative
S6B	Positive	Positive	Negative	Negative	Negative	Negative
S6C	Positive	Positive	Negative	Negative	Negative	Negative
S7A	Positive	Positive	Negative	Negative	Negative	Negative
S7B	Positive	Positive	Negative	Negative	Negative	Negative
S7C	Positive	Positive	Negative	Negative	Negative	Negative
S8A	Positive	Positive	Negative	Negative	Negative	Negative
S8B	Positive	Positive	Negative	Negative	Negative	Negative
S8C	Positive	Positive	Negative	Negative	Negative	Negative
S9A	Positive	Positive	Negative	Negative	Negative	Negative
S9B	Positive	Positive	Negative	Negative	Negative	Negative
S9C	Positive	Positive	Negative	Negative	Negative	Negative
S10A	Positive	Positive	Negative	Negative	Negative	Negative
S10B	Positive	Positive	Negative	Negative	Negative	Negative
S10C	Positive	Positive	Negative	Negative	Negative	Negative

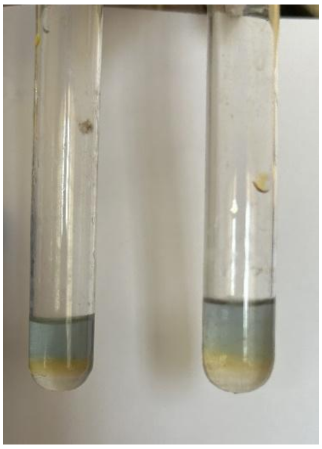


Fig 11(a): positive result for ethanol.

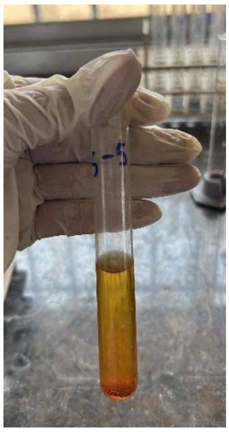


Fig 11(b): positive result for ethanol

Fig11(c): Showing positive result for schiff"s test

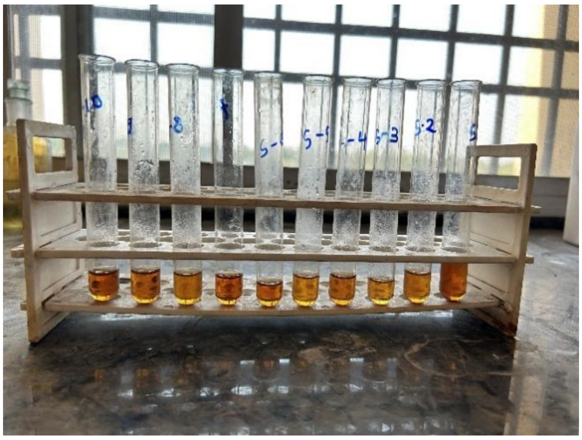
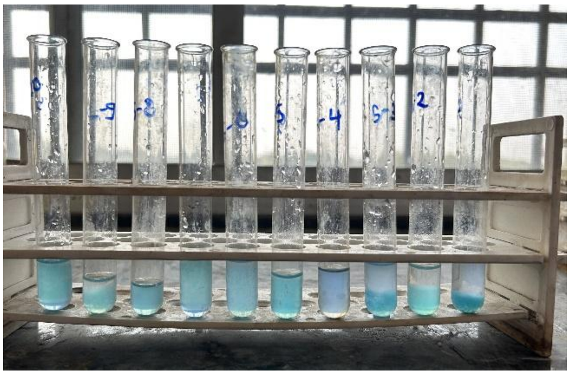


Fig11(d): Showing negative results for furfural



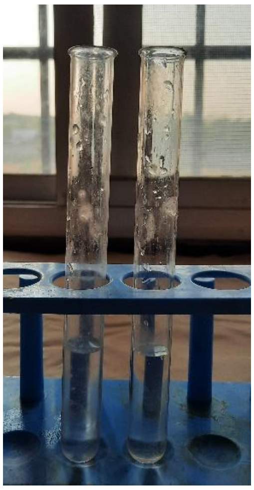


Fig11(e): Negative results for urea test. **Fig11(f):** Negative result for Cu and Fe.

Specific Gravity

30 total samples were collected from 10 districts of Chhattishagrh. Three-three samples were collected from each district. All samples were tested by Relative density Bottle. Specific gravity is calculated based on the stranded formula and matched with the specific gravity of library. Alcohol content in samples ranged from 8.97% to 19.84%. It should be mentioned that in all the samples S3A-S3C (Mahasamund) have the highest alcohol and highest density (19.29%,19.84%,19.53%). Findings have been presented in [Table 3].

Table:3 Shows the density and alcohol percentage of the sample:

Sample. No	Density @36°	Alcohol(V/V%)
S1 A	0.9756	17.80%
S1 B	0.97652	17.10%
S1 C	0.97612	17.41%
S2 A	0.9784	15.61%
S2 B	0.9788	15.31%
S2 C	0.9782	15.76%
S3 A	0.9737	19.29%
S3 B	0.9730	19.84%
S3 C	0.9734	19.53%
S4 A	0.9756	17.80%
S4 B	0.9752	18.12%
S4 C	0.9755	17.80%
S5 A	0.9765	17.10%
S5 B	0.9761	17.41%
S5 C	0.9764	17.17%
S6 A	0.9831	12.01%
S6 B	0.9829	12.16%
S6 C	0.9824	12.55%
S7 A	0.9872	8.97%
S7 B	0.9871	8.91%
S7 C	0.9869	9.11%
S8 A	0.9775	16.32%
S8 B	0.9771	16.63%
S8 C	0.9778	16.08%

S9 A	0.9793	14.91%
S9 B	0.9789	15.23%
S9 C	0.9795	14.76%
S10 A	0.9803	14.15%
S10 B	0.9801	14.30%
S10 C	0.9803	14.15%

FTIR

Fourier Transform Infrared (FTIR) Spectroscopy was utilized to scan the sample of illicit liquor. For this study total 30 samples were obtained from various districts of chhattishgarh. Various spectra of the sample have been developed and interpreted for each samples respectively. The investigation revealed that all 30 samples had a band at about 3300 cm-1, indicating the presence of a significant O-H (hydroxyl) group. The results achieved are discussed in [Table 4].

Table:4 Shows the peaks of alcohol in FTIR:

FTIR SAMPLE	**SPECTRUM**			
	C-O	C-H	C=C	O-H
Stranded	1000–1260	2850–2960	1640.06	3260-3300
S1A			1638	3285
S1B			1637	3275
S1C			1638	3277
S2A			1638	3260
S2B			1635	3290
S2 C			1639	3298
S3 A			1635	3280
S3 B			1638	3279
S3 C			1639	3289
S4 A			1638	3266
S4 B			1639	3271
S4 C			1635	3269
S5 A			1633	3263
S5 B			1636	3288
S5 C			1638	3289
S6 A	1044		1638	3277
S6 B			1636	3283
S6 C			1635	3279
S7 A	1046		1643	3283
S7 B			1639	3287
S7 C	1098		1638	3278
S8 A	1040 1089		1638	3261
S8 B	1056		1637	3271
S8 C			1636	3269
S9 A	1044 1082		1638	3276
S9 B	1088		1638	3281
S9 C	1058			3289
S10 A	1044		1638	3264

	1089			
S10 B			1638	3270
S10 C	1089 1056		1639	3275

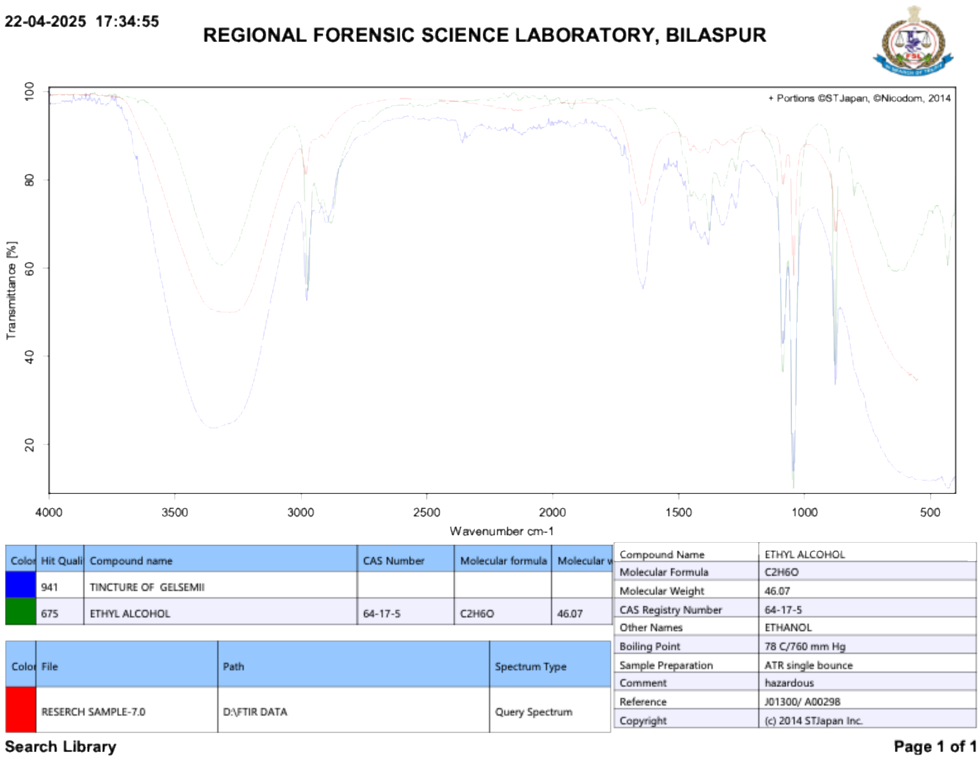


Fig 12: Graph showing the presence of ethyl alcohol.

CONCLUSION

The main purpose of this research was to ascertain the quality of the illegal alcoholic beverages. To determine any dangerous ingredients in the sample, such as methanol, copper, iron, furfural, and urea, a test was conducted prior. According to the results, there is one Bilaspur sample containing methanol but no chemicals in other samples. Methanol is a poisonous, wicked alcohol that is subject mainly to metabolic transformations in the liver, mediated by extremely important enzymic activities. Methanol is an extremely poisonous alcohol which, when taken orally, can result in metabolic acidosis, visual disturbances, and death. Alcohol percentage and density of the samples were determined by analysis using Relative density Bottle. More dangous samples are those of greater density. Contemporary techniques like Fourier-transform infrared spectroscopy (FTIR) are used to determine other components and the functional components present. The results show that the sample contains alcohol along with other compounds like halo alkene, aldehyde, and anhydride.

Acknowledgements- I would like to express my sincere gratitude to the **Regional Forensic Science Laboratory, Chhattisgarh**, for providing the necessary facilities and technical support required for the completion of this study, Lastly, I acknowledge the role of the **journal editorial team** for their constructive feedback and for considering this work for publication.

Conflict of Interest -There is no conflict of interest from author's side

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