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CHEMICAL-TOXICOLOGICAL ANALYSIS OF ALCOHOL POISONING USING A GAS CHROMATOGRAPH (CRYSTALLUX-4000M)

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Abstract. This article presents a modern methodological approach to the chemical-toxicological assessment of alcohol poisoning through the use of gas chromatography, with a focus on the CrystalLux-4000M system. Given the high incidence of acute ethanol intoxication in both forensic and clinical practice, the need for accurate, reproducible, and legally defensible methods for ethanol detection in biological samples is paramount. The article describes in detail the principles of headspace gas chromatography, sample preparation procedures, calibration methods, and forensic interpretation of ethanol concentrations in blood, urine, and vitreous humor. The analytical reliability and sensitivity of the CrystalLux-4000M platform are evaluated in relation to its role in toxicological diagnostics and medicolegal investigations.
Keywords: Alcohol poisoning, ethanol, gas chromatography, CrystalLux-4000M, forensic toxicology, blood alcohol concentration.

INTRODUCTION

Ethanol is one of the most frequently encountered substances in forensic toxicology due to its legal availability, widespread use, and high potential for misuse. Acute alcohol poisoning can lead to central nervous system depression, respiratory failure, hypothermia, hypoglycemia, and death, depending on the blood alcohol concentration (BAC) and individual tolerance. From a forensic perspective, determining the type, concentration, and source of ethanol in the body is essential for reconstructing the events leading up to death or impairment.

Traditional methods such as enzymatic assays and colorimetric tests, though useful for screening, often lack the specificity and evidentiary rigor required in court. Gas chromatography (GC), especially with headspace sampling, has emerged as the gold standard for ethanol detection. The CrystalLux-4000M, a modern Russian-manufactured chromatographic instrument, offers high precision and rapid analysis capabilities, making it ideal for routine forensic evaluation of alcohol intoxication.

MATERIALS AND METHODS

Ethanol is a small, water-soluble molecule that is rapidly absorbed from the gastrointestinal tract and distributed throughout body fluids. Following ingestion, peak BAC typically occurs within 30–90 minutes. The liver metabolizes the majority of ethanol via alcohol dehydrogenase and the microsomal ethanol-oxidizing system. In overdose situations, metabolic capacity is exceeded, leading to systemic toxicity [1].

Ethanol depresses the central nervous system in a dose-dependent manner:

0.2–0.5 ‰ (g/L): euphoria, decreased inhibition

0.5–1.5 ‰: impaired coordination and reaction time

1.5–3.0 ‰: severe intoxication, stupor

3.5 ‰: possible coma and death

Forensic analysis is therefore critical not only for confirming ethanol presence but for establishing whether BAC levels are consistent with fatal intoxication or merely contributory.

RESULTS AND DISCUSSION

The headspace gas chromatography technique is the preferred method for volatile compounds like ethanol. The method involves the analysis of the vapor (headspace) above the liquid biological matrix, eliminating matrix interference and improving accuracy [2].

Sample preparation protocol:
Biological specimens: whole blood, urine, vitreous humor (preferably refrigerated)
1–2 mL of specimen is mixed with an internal standard (e.g., n-propanol)
Sample is sealed in a vial and heated to 60–70°C in a thermostatic headspace unit
The gas phase is injected into the GC column for analysis
This method reduces contamination risk and enhances reproducibility. CrystalLux-4000M's integrated headspace sampler ensures minimal sample handling and automated throughput for up to 80 samples per batch.
The CrystalLux-4000M gas chromatograph offers reliable thermal stability and precise quantification of volatile substances. Optimized settings for ethanol detection include:

- Column: Capillary column HP-INNOWax (30 m × 0.32 mm × 0.25 µm)
- Carrier gas: Nitrogen or helium at a constant flow
- Oven temperature: Isothermal at 40–45°C
- Injector/detector temperature: 150°C
- Detector: Flame ionization detector (FID)
- Internal standard: n-Propanol (retention time separation ~0.5–1.0 min from ethanol)

With these settings, ethanol peaks are highly symmetrical, with minimal baseline drift and excellent separation from interfering substances like methanol, acetone, or isopropanol [3].
Validation studies have confirmed linearity of ethanol detection across 0.1–4.0 g/L with correlation coefficients exceeding 0.999. Repeatability (CV < 3%) and recovery (>95%) render the method suitable for both clinical and postmortem toxicology.
Forensic interpretation involves not only quantification but contextualization:
Endogenous ethanol production must be ruled out in decomposed bodies by comparing blood and vitreous levels
Postmortem redistribution is minimized in vitreous humor, making it a preferred matrix
Timing of ingestion can be inferred using ethanol/metabolite ratios or serial sampling
The CrystalLux-4000M's precision supports robust expert conclusions in criminal cases (e.g., DUI, negligent homicide), insurance claims, and occupational safety investigations [4].

CONCLUSION

The application of headspace gas chromatography using the CrystalLux-4000M system represents an essential advancement in the forensic evaluation of alcohol poisoning. Its methodological accuracy, rapid throughput, and reproducibility make it the instrument of choice for toxicological laboratories dealing with ethanol-related fatalities and impairments. In forensic contexts, reliable measurement of ethanol concentration is not only a scientific necessity but also a legal imperative. As patterns of alcohol use continue to evolve, the integration of validated analytical platforms like the CrystalLux-4000M ensures that forensic toxicology remains both responsive and scientifically credible.

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