Forensic Sci Rev 38:129–149
July 2026

Distribution of Ethanol Between Blood and Alternative Biological Specimens in Life and After Death. Part I: Importance of Body Water

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REFERENCE: Jones AW: Distribution of ethanol between blood and alternative biological specimens in life and after death. Part I: Importance of body water; *Forensic Sci Rev* 38:129; 2026.

ABSTRACT: Measuring the concentration of ethanol in blood and other biological specimens provides important forensic information whenever alcohol-related crimes and alcohol-related deaths are investigated. A dose-response relationship holds between a person's blood-alcohol concentration (BAC) and the degree of impairment of the central nervous system (CNS): When their BAC reaches 0.3–0.5 g/L, most people feel less inhibited and experience mild euphoria, while heavy drinking resulting in a BAC of 3.0–4.0 g/L is sufficient to cause death by depression of respiratory centers in the brainstem. After the consumption of alcoholic beverages, the ethanol they contain is distributed into the total body water (TBW) compartment without significant binding to plasma proteins or other macro-molecules. When absorption and distribution are complete, the concentrations of ethanol in blood and other body fluids and tissues depend on their relative water contents. Other factors influencing BAC are the dose ingested and the rate of drinking, as well as the person's age, sex, body weight, ethnicity, and degree of adiposity. Concentration-time profiles of ethanol in the blood also depend upon the route of administration (oral or intravenous) and upon whether ingested as a bolus dose or through repetitive drinking over several hours. Factors influencing gastric emptying are also important considerations, such as whether the ethanol was consumed on an empty stomach or after a meal. Blood is the most important biological specimen in forensic casework, because BAC serves as a proxy for the concentration of ethanol influencing the brain. This forensic science review deals with the distribution of ethanol between the blood and the total body water compartment, and the role played by body composition (obesity), which is an important consideration when blood-alcohol calculations are performed.

KEYWORDS: Analysis, biological fluids, blood-ethanol, body mass index, forensic toxicology, volume of distribution, water content.

INTRODUCTION

Forensic toxicology is a branch of legal medicine mainly concerned with the identification and quantitative analysis of drugs and toxins (xenobiotics) in biological specimens. The analytical results are important for the investigation of alcohol- and drug-related crimes and when poisoning is suspected as a cause of death [15,72]. The toxicologist is also expected to interpret the analytical results and opine whether a particular combination of drugs and/or the concentrations of various substances determined in blood might explain any observed signs and symptoms of intoxication or are compatible with an overdose death.

Laboratory methods for the analysis of ethanol in small volumes of blood (80–100 μL) have been available since the 1920s, which therefore marked the start of forensic blood-alcohol research [126,127]. Ethanol first needed to be separated from the biological matrix by distillation or diffusion before a mixture of potassium dichromate and sulfuric acid (chromic acid) was added as an oxidizing agent. The quantitative determination of ethanol was accomplished by volumetric titration (iodometry); this method allowed measuring BAC as low as 0.02–0.05 g/L with acceptable accuracy and precision. This prompted some countries to introduce statutory blood-alcohol limits for driving a motor vehicle on public roads, as exemplified by Norway in 1936 and Sweden in 1941 [44].

The analytical methods for the determination of ethanol in blood and other biological specimens have since undergone enormous improvements in accuracy, precision, specificity, and ease of use [16,40,47]. In the 1950s, enzymatic oxidation methods were developed that utilized alcohol dehydrogenase (ADH) extracted from liver or yeast, and these were more selective than the older chemical oxidation methods [8,10].

Furthermore, using enzymatic oxidation, the laboratory routines could be automated (Technicon AutoAnalyzer), thus streamlining workflow and improving the accuracy and precision of the final results [10]. In today's forensic laboratories, the gold standard method of blood-alcohol analysis is gas chromatography (GC) with a flame ionization detector (FID) and/or mass spectrometric (MS) detector [47,117]. Identification of ethanol is done by measuring its retention time (RT) in comparison with known standard reference substances [79], and if GC-MS methods are used, by its fragmentation pattern [7]. The evolution of analytical methods for the determination of ethanol in blood for clinical and forensic purposes was the subject of a recent review article [47].

ABOUT THE AUTHOR

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A. Wayne Jones was born in Wales (UK) and obtained his B.Sc. and Ph.D. degrees from the University of Wales (Cardiff, UK), although most of his career has been spent living and working in Sweden. In 2013 he retired from his appointment as senior scientist at Sweden's National Laboratory of Forensic Genetics and Forensic Toxicology (Linköping). However, he continues to write and publish scientific papers as guest professor at the University of Linköping (Department of Biomedical and Clinical Sciences).

Since his first publication in 1974, Dr. Jones's bibliography now lists 530 items, including journal articles, review papers, book chapters, commentary, and letters to the editor. His name appears as sole author on more than half of these contributions and stands as first and/or corresponding author on most of the others. The scientific papers authored by Dr. Jones have appeared in over 100 peer-reviewed journals, including *Journal of Analytical Toxicology* (1983–2024, $n = 49$), *Forensic Science International* (1978–2025, $n = 49$), *Journal of Forensic Sciences* (1978–2024, $n = 25$), and *Clinical Chemistry* (1979–2001, $n = 14$). According to Google Scholar, Dr. Jones's current H-index is 72 and his papers have been cited over 16,000 times. His composite citation score (up to the end of 2024) was 3.978, making him the fifth most cited scientist worldwide in the discipline of legal and forensic medicine.

Prof. Jones has served as peer reviewer of articles submitted for publication to more than 100 academic journals and has belonged to the editorial boards of a dozen others. Dr. Jones has received peer recognition for his contributions to forensic alcohol research and toxicology by awards from professional organizations, such as the International Councel on Alcohol, Drugs and Traffic Safety (ICADTS), the American Academy of Forensic Sciences (AAFS), International Association of Chemical Testing (IACT), and The International Association of Forensic Toxicologists (TIAFT). Besides hundreds of appearances as an expert witness in Swedish courts, in alcohol- and drug-related cases, Dr. Jones has testified as an expert witness in several other countries, including USA and UK.