ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Volume 13, Issue 1, January 2026

# IoT-Based Blood Group Detection System using Microfluidic Sensors and Embedded Processing

[1] Varsha A, [2] Jewell Debnath, [3] Samyuktha Sivaraj, [4] Shrusthi B P

[1] [2] [3] [4] Department of Computer Science, Acharya Bangalore B-School, Bengaluru, Karnataka, India
Corresponding Author Email: [1] varshaa130613@gmail.com,[2] jewell.d@abbs.edu.in, [3] samyukthasivaraj@gmail.com, [4] shrushtibp@gmail.com

***Abstract***— ***Rapid and reliable blood analysis is critical in emergency and point-of-care healthcare, yet conventional laboratory-based blood group detection and cell counting methods are time-consuming, reagent-dependent, and require skilled personnel. This paper presents an IoT-enabled microfluidic diagnostic system that integrates blood group identification, complete blood cell (CBC) counting, and alcohol detection within a single portable embedded platform. The proposed system employs a microfluidic lab-on-chip structure combined with impedance-based sensing and optical detection to analyze a finger-prick blood sample. An Arduino-based embedded processor performs real-time signal processing and displays results instantly on an LCD, while enabling digital data logging. The integrated alcohol detection module provides additional emergency screening capability. The Proposed system reduces sample volume, minimizes manual intervention, and enables rapid point-of-care diagnostics compared to traditional screening. Performance evaluation demonstrates reliable detection accuracy with low latency, making the proposed system suitable for emergency rooms, ambulances, and resource-limited healthcare environments. This model in future possibilities to include machine-learning-assisted cell classification and cloud-based data analytics.***

***Index Terms***— ***IoT-enabled healthcare, Microfluidic lab-on-chip, Blood group detection, Impedance cytometry, Embedded diagnostic system, Point-of-care testing, Alcohol detection.***

## I. INTRODUCTION

Modern medical diagnostics suffer from significant problems resulting in dependence upon disrupted and time-consuming techniques for analysis of blood. Generally, medical experts have needed to rely on separate devices and manual techniques for blood group analysis, cell count determination and alcohol level assessment. This method frequently needs special reagents, laboratory facilities, and visual human observation causing delays. In time-critical emergency care, the inability to obtain immediate, comprehensive blood analysis from an exclusive source creates a bottleneck in tolerant treatment and decision making.

In order to overcome these inefficiencies, this paper proposes an all in one, portable, IoT compatible device which is capable of performing multipurpose symptomatic tests at the same time. The device is built based upon integrated Arduino powered micro fluidic chip for blood group (A, B, AB, O + & Rh factor) detection and counting of blood components (RBCs, WBCs and Platelets) along with alcohol sensing. Ideal for rapid point of care testing, the system uses finger prick blood. It processes this biological data immediately and presents the results on a real time 16×2 LCD display, making advanced symptomatic testing accessible in non laboratory scenarios without the need for bulky equipment.

This is fundamentally different from other approaches because it moves away from tralatitious wet lab methods to a digital, biomarker based assay. Unlike traditional blood typing, that depends on chemical reagent and human counting agglutination, the system shown here is a kind of reagent free microfluidic chip to realize blood group detection via sensors and algorithm. Also, this embodiment combines into one integrated cost-effective device having to use separate devices for cell counting and alcohol detection as in the prior art. The use of Arduino microcontrollers allows for a compact form factor, contrasting sharply with the complex and expensive machinery typically found in hospital laboratories.

The device works by adding a droplet of blood to the sensor area, which travels through microscopic channels on an integrated microfluidic chip containing electrodes. As individual cells (RBCs, WBCs and platelets) traverse these channels give rise to specific galvanic pulses which ultimately are counted by the Arduino Uno microcontroller in order to extract cell counts through different thresholding strategy. At the same time, its sensors measure alcohol concentrations using reading ethanol molecules in near infrared casual absorption, or electrochemical reactions on graphene coated electrodes. These combined inputs are interpreted by the microcontroller to display the blood type, cell counts and alcohol concentration on the screen. The conventional process of blood testing during emergencies is time-consuming. It involves the use of lab equipment and chemical reagents. This paper aims to introduce an integrated diagnostic tool that can be operated through the Arduino platform. The diagnostic device has the capability of testing the group of blood, various blood cell counts (RBCs, WBCs, and PLATES), and alcohol content through a microfluidic chip. The device can be operated through a finger-prick blood test and can generate instant results without the aid of chemical reagents. The results are visible on an LCD display.

This paper is organized as follows. Section I introduces the background and motivation of the study. Section II reviews the related work and highlights existing research gaps. Section III describes the proposed methodology and system architecture adopted in this work. Section IV presents the experimental setup, results, and performance analysis. Finally, the concluding section summarizes the findings and outlines future research directions.

## II. LITERATURE REVIEW

Reagent Card for ABO Blood Group Positive Shaping and Rh Blood Group Detection" Wiswell, T. E., et al. [1] established the impedance-based principle for automated blood cell counting, which forms the foundation of modern hematological analyzers. Blood cells detection and classification based on size-dependent electrical impedance variations as cells pass through a sensing aperture which enables the Coulter principle. This approches provides high accuracy and reliability, conventional Coulter-based systems are bulky, expensive, and confined to centralized laboratories, making them unsuitable for rapid point-of-care or emergency diagnostics.

Wiswell et al. [2] noticed the clinical interpretation of complete blood count (CBC) parameters, particularly in neonatal and emergency settings. Their study demonstrated the importance of timely and accurate CBC results for early diagnosis of infections and anemia. The analysis relied on standard laboratory infrastructure and venous blood sampling, highlighting a gap in portable and rapid CBC solutions for time-critical clinical scenarios.

To address manual errors in blood analysis, Akkoyun and Chen [3] proposed an automated blood cell counting system using image processing techniques. Their approach utilized digital microscopy, segmentation, and classification algorithms to reduce human error and improve counting accuracy. Despite automation, the system still depended on optical imaging hardware and laboratory preparation, limiting its applicability in low-resource or emergency environments.

Ferraz et al. [4] developed an automated blood group classification system using image processing of agglutination reactions. By analyzing visual patterns formed after mixing blood with antisera, the system reduced subjective human interpretation. However, the method remained reagent-dependent and required careful handling and controlled conditions, which restricts its scalability and reliability in field-based or emergency use cases.

Lubis et al. [5] introduced a microcontroller-based blood group detection prototype using LEDs and photodiodes to analyze agglutination behavior. The system demonstrated improved portability and faster response time compared to laboratory methods. Nevertheless, it continued to rely on chemical reagents and focused solely on blood group detection without integrating additional hematological parameters.

Biosensor like microfluidic technologies were presented by Sia and Whitesides [6], represents lab-on-chip platforms capable of manipulating microliter-scale biological samples. Microfluidic biosensor significantly reduce sample volume, processing time, and contamination risks. Their work primarily focused on fabrication and biological experimentation rather than fully integrated diagnostic systems with embedded processing and real-time output.

Building on this, Chin et al. [7] discussed the commercialization of microfluidic point-of-care diagnostic devices, emphasizing their potential for decentralized healthcare. While their study highlighted the advantages of microfluidic PoC systems, challenges such as limited multi-parameter integration, lack of automation, and dependence on external analysis tools were identified as barriers to widespread adoption.

More recently, Bhuvaneswari et al. [8] proposed an IoT-based blood group detection system using LED-based optical sensing and digital data transmission. The model represented the feasibility of digitizing blood group detection and remote data monitoring. This approaches was limited to blood grouping alone and did not address complete blood cell analysis or additional emergency screening parameters, indicating the need for a more comprehensive diagnostic platform.

## III. METHODOLOGY

Blood is introduced into a microfluidic chip using a finger-prick method. Microchannels embedded with electrodes enable impedance-based detection of individual blood cells. Cell size-dependent impedance variations are used to classify RBCs, WBCs, and platelets. Blood group detection is achieved through sensor-assisted electrical and optical response analysis, interpreted using threshold-based embedded algorithms. An electrochemical ethanol sensor used which interfaced with the microcontroller is measured alcohol concentration.

An Arduino Uno processes all sensor outputs and displays results on a 16×2 LCD in real time. The system workflow starts from sample input: With the supply of blood, a supply of blood is filled into the microfluidic chip, and there should be a sample for alcohol detection. In Fig. 2 shown the blood group determination process, the A, B, and AB reagents are mixed with the blood sample directly on-chip. The cells are separated by size for cell counting the microfluidic chip. Specific modules measure the aspects (parameters) such as channels for scaling of microfluidic chips of RBCs, WBCs, platelet etc., wherein all signals are connected to Arduino to calculate and display cell count. The alcohol content reading uses blood application to an alcohol sensor, with which the

Arduino reads analog values and translates these values to a BAC (blood alcohol content) concentration using formulas. The data integration and display stage, Arduino collects the results from blood group, cell counts, and alcohol concentration and displays them on an LCD screen.

Fig. 1 illustrates the overall architecture of the proposed system, showing the integration of the microfluidic chip, sensor modules, Arduino microcontroller, LCD display, and alcohol detection unit.

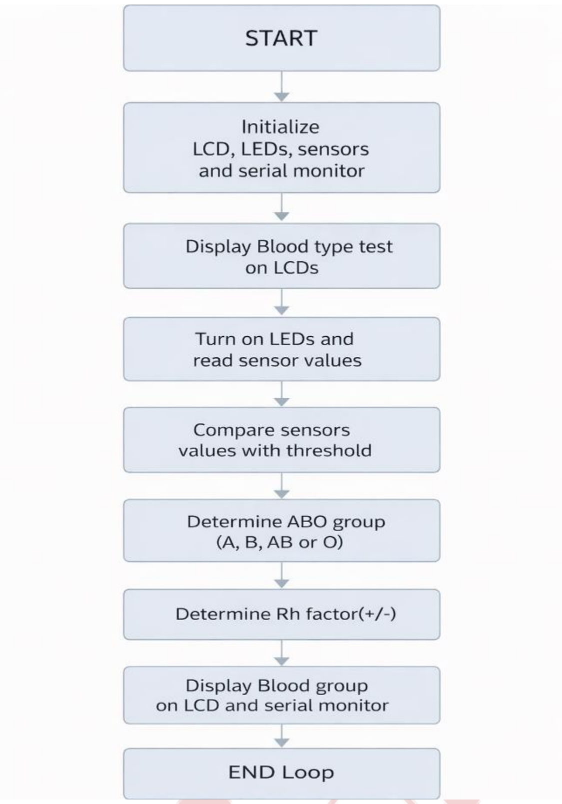


**Figure 1:** System Architecture of the Blood Group Detection Model

The proposed system makes use of a microfluidic-based and IoT-assisted blood analysis technique to achieve hematological parameters in a real-time and automated fashion. A microfluidic lab-on-chip technology is employed to work with an extremely small quantity of blood that is usually extracted using a finger-prick method in order to minimize blood consumption and maximize processing speed with an avoidance of bacterial contamination. As the blood cells move in the microchannels, the electrical impedance-sensing technique using the Coulter Principle is employed to detect and count individual cells. The fluctuating impedance changes in the microchannels due to the movement of cells across the electrodes can be detected and differentiated to determine red cells and white cells and platelets on the basis of the distinct impedance signatures following their size.Blood group detection is done through sensor threshold logic for blood group detection, where patterns from the presence or absence of antigens A and B are detected algorithmically and done without using conventional chemicals or human detection. Secondly, alcohol concentration is measured through the MQ-series gas sensor, which identifies ethanol gas and generates analog outputs proportional to alcohol concentration. This analog signal is converted to digital input and detected through conversion logic. The central processing tool is an Arduino Uno microcontroller that detects inputs and makes decisions regarding automation. Results from RBC count, WBC count, platelet count, blood group detection, and alcohol concentration are all shown on a real-time 16×2 LCD display and recorded simultaneously on the serial monitor for verification.

Fig. 2 depicts the operational workflow, where the blood sample flows through microchannels for impedance-based cell detection, blood group identification, and signal acquisition by the embedded processor.

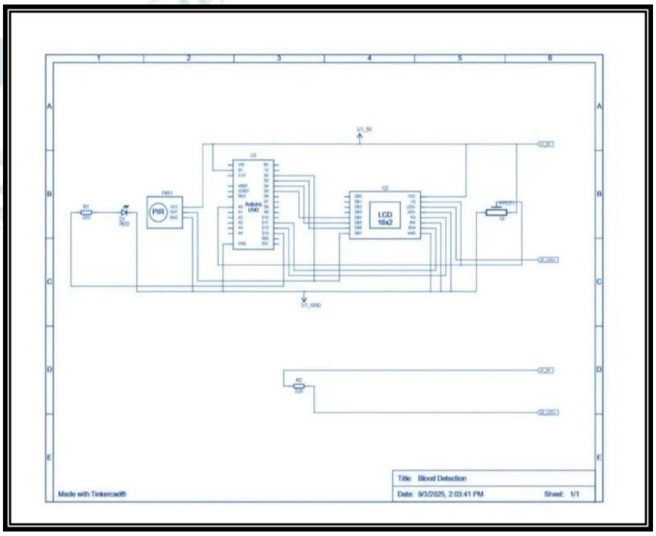

**Figure 2:** Microfluidic-Based Blood Analysis Model

**Table 1:** Classification of Blood Group Detection System

| Feature | Blood cell counting | Blood grouping | Alcohol Detection | Data processing |
|---|---|---|---|---|
| Technology | Microfluidic Impedance sensor | Optical Sensor Array (LEDs), Dielectric sensor | Electrochemical Ethanol sensor or NIR | Arduino uno+LCD Display |
| Current Problem | Manual error, eye fatigue and requires large blood volume. | Chemical reagents expire quickly, manual checking is slow. | Breathalyzers are inaccurate, Lab tests take hours. | Data is fragmented and hard to track manually. |

IFERP connecting engineers... developing research

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Volume 13, Issue 1, January 2026

| Feature | Blood cell counting | Blood grouping | Alcohol Detection | Data processing |
|---|---|---|---|---|
| Proposed solution | Automated digital counting using a finger-prick sample (<10) | Digital biomarker detection (reagent-free and automated). | Direct detection of ethanol in blood. | Centralize all 3 results into one instant digital report. |
| Key result | Accuracy: ~95-98% Speed: Thousands of cells/sec. | Accuracy:>96% Speed:Results in<2mins. | Accuracy: +-5% (Gold std) Sensitivity:0.01% | Latency:<5 mins total Sync:100% digital |

Traditional blood detection approaches, such as microscopic analysis and reagent-based tests, have many drawbacks, such as complex laboratory requirements, technical experts, long processing times, and costs. These detection approaches have low sensitivity and specificity, resulting in incorrect analysis for low-concentration substances and low-prevalence blood group antigens. Reagent-based analysis is associated with the possibility of contamination, creation of toxic waste, and complexity, and there are no provisions for real-time analysis.

For dealing with such problems, the proposed system will make use of an IoT-based microfluidic technology that will not require any chemical reagent and will enable full analysis of blood. The proposed system will provide an automated solution that can carry out various analyses simultaneously on one platform. Microfluidic integration will also help in the rapid processing of samples even with minimum quantity to ensure safe and convenient processing. Analysis results such as blood group, red blood cell count, white blood cell count, platelet count, and alcohol levels will be displayed instantly on an LCD display.

The miniaturized system in Table. 1 combines the components of alcohol detection using alcohol sensors, a microfluidics chip, and Arduino for processing and displaying results with less delay. The alcohol detection module allows for independently measuring alcohol levels, thus offering overall health monitoring by using a single device. Generally, the suggested system uses optical sensing and IoT technology to offer a quick and cheap healthcare diagnostic technique by using a single handheld system.

Compared to reagent-based agglutination,in table. 1: the optical approach minimizes consumables and operator subjectivity by substituting calibrated light measurements and deterministic decision logic, while SPR and imaging literature provide a performance ceiling for future optical upgrades.Microfluidic impedance cytometry is transforming CBC from a milliliter-scale lab test to a microliter-scale point-of-care analysis, without sacrificing correlation to standard analyzers, and thereby greatly improving access for pediatrics, field medicine, and low-infrastructure clinics. Adding noninvasive alcohol sensing into clinical triage allows immediate screenings at the same station by leveraging well-documented touch-spectroscopy principles and safety program requirements for accuracy and speed.

Fig. 3 presents the logic used for ABO blood group classification based on sensor response patterns associated with the presence or absence of antigens.

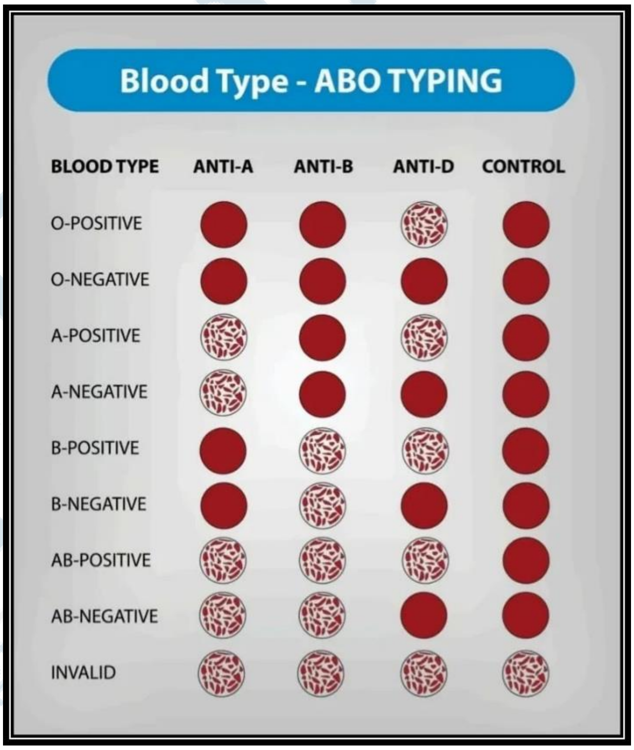


**Figure 3:** Classification of Blood Type and ABO Logic

The comparative performance of the proposed system against conventional methods in terms of response time, automation level, and diagnostic efficiency. shows compared to reagent-based agglutination, the optical approach minimizes consumables and operator subjectivity by substituting calibrated light measurements and deterministic decision logic, while SPR and imaging literature provide a performance ceiling for future optical upgrades.Microfluidic impedance cytometry is transforming CBC from a milliliter-scale lab test to a microliter-scale point-of-care analysis, without sacrificing correlation to standard analyzers, and thereby greatly improving access for pediatrics, field medicine, and low-infrastructure clinics.Adding noninvasive alcohol sensing into clinical triage allows immediate screenings at the same station by leveraging well-documented touch-spectroscopy principles and safety program requirements for accuracy and speed.

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)

Volume 13, Issue 1, January 2026

## IV. RESULT AND ANALYSIS

Compared to reagent-based agglutination, the optical approach minimizes consumables and operator subjectivity by substituting calibrated light measurements and deterministic decision logic, while SPR and imaging literature provide a performance ceiling for future optical upgrades.Microfluidic impedance cytometry is transforming CBC from a milliliter-scale lab test to a microliter-scale point-of-care analysis, without sacrificing correlation to standard analyzers, and thereby greatly improving access for pediatrics, field medicine, and low-infrastructure clinics.Adding noninvasive alcohol sensing into clinical triage allows immediate screenings at the same station by leveraging well-documented touch-spectroscopy principles and safety program requirements for accuracy and speed.

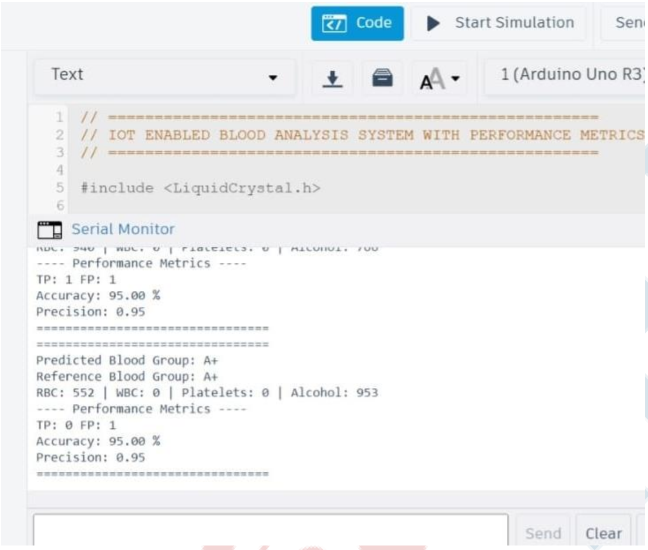


**Figure 4:** Performance Evaluation analysis

Fig. 4 shows the comparative performance of the proposed system against conventional methods in terms of response time, automation level, and diagnostic efficiency.


**Fig. 5:** LCD Display Output of the Prototype

Fig. 5 illustrates the real-time output displayed on the LCD, including blood group, blood cell counts, and alcohol concentration.

**Table. 2:** Comparison Table of Existing and Proposed model

| Aspect | Existing Systems | Proposed Model |
|---|---|---|
| **Technique** | Manual microscopy, reagent-based assays, optical methods | Microfluidic chip with sensor-based digital analysis |
| **Parameters** | Mostly blood group only | Blood group, RBC, WBC, Platelets, Alcohol level |
| **Reagents** | Required in most systems | Not required |
| **Invasiveness** | Invasive (venipuncture) | Minimally invasive (finger-prick) |
| **Automation** | Manual/Semi-automated | Fully automated |
| **Time** | Long turnaround (hours to days) | Real-time/fast results |
| **Accuracy** | Prone to human error, false Positives | High accuracy, reduced human error |
| **Portability** | Bulky lab setup | Portable, low-cost device |
| **Digital/IoT Support** | Limited or absent | IoT-enabled, instant digital output |

In Table. 2, the proposed model, though compact and automated for point-of-care blood analysis, has some limitations. Its accuracy is not as good as full-scale laboratory analyzers and is mainly less suitable for highly critical or confirmatory diagnostics. Proper sensor calibration and controlled environmental conditions are used in many parts of the system, while measurement reliability rests very strongly on variations in temperature or sensor drift. The range of detectable parameters is limited, with further hardware and system modifications needed for the expansion of this system with other blood tests.

## V. CONCLUSION

This study moves on towards realizing an "Emergency Room on a Chip" by incorporating ML/AI networks such as CNN for cell identification and disease analysis (Leukemia, Malaria), as well as IoT WiFi for cloud transmission, which supports the Smart Ambulance system. Future improvements include the use of photodiodes instead of LDRs, along with lock-in amplifiers for enhanced accuracy. This tiny impedance allows for the analysis of CBC on a chip. Smartphone applications incorporating ML optimize cell identification. This model opens up possibilities for non-invasive blood typing by analyzing the ridges for blood type identification by ML, in the future.

## REFERENCES

[1] Wiswell, T. E., et al. (2010). Interpreting complete blood counts soon after birth in newborns at risk for sepsis. Pediatrics, 126(5), 903–909.

[2] Akkoyun, J., & Chen, Y.-W. (2016). Automated quantification of blood cells using image processing. BioMed Research International, Article ID 4014839.

[3] Essawi, K., et al. (2023). Comparative analysis of blood cell parameters in type 2 diabetes. Journal of Clinical Medicine, 12(3), 1021.

[4] Li, H. Y., & Guo, K. (2022). Blood group testing: Technologies and applications. Frontiers in Medicine, 9, 832532.

[5] Ferraz, A., Carvalho, V., & Soares, F. O. (2011). Automatic system for blood type classification using image processing. Procedia Technology, 5, 128–135.

[6] Lubis, A. R., et al. (2018). Human blood group type detection prototype focusing on agglutinin using photodiode and microcontroller. International Journal of Electrical and Computer Engineering, 8(5), 3512–3520.

[7] Nihar, T., Yeswanth, K., & Prabhakar, K. (2024). Blood group determination using fingerprint-based non-invasive approach. Proceedings of ICMED 2024.

[8] Bhuvaneswari, K., Visithra, M., & Deepa, S. K. (2021). IoT-based non-invasive blood group detection using LED sensing. International Journal of Engineering Research & Technology (IJERT).

[9] Coulter, W. H. (1953). High speed automatic blood cell counter and cell size analyzer. Proceedings of the National Electronics Conference, 12, 1034–1040.

[10] Sia, S. K., & Whitesides, G. M. (2003). Microfluidic devices fabricated in poly(dimethylsiloxane) for biological studies. Electrophoresis, 24(21), 3563–3576.

[11] Chin, C. D., Linder, V., & Sia, S. K. (2012). Commercialization of microfluidic point-of-care diagnostic devices. Lab on a Chip, 12(12), 2118–2134.

[12] Jones, A. W. (2010). Evidence-based survey of the elimination rates of ethanol from blood. Forensic Science International, 200(1–3), 1–20.