

THE INFLUENCE OF TEMPERATURE AND CO₂ IN EXHALED BREATH

L'INFLUENCE DE LA TEMPÉRATURE ET DE CO₂ DANS L'AIR EXPIRÉ

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Abstract. Breath alcohol analyzers are widely accepted as legal measuring instruments used for determination of the mass concentration of alcohol in exhaled breath. The paper focuses on the following issues: configuration of experimental system; the assurance of traceability at the highest standards; the influence of CO₂ and on the influence of the exhaled breath temperature when the human body's temperature increases up to 38, 39 or, in extreme conditions, up to 40 °C.

Résumé. Ethylomètres sont largement acceptées comme des instruments de mesure légales utilisées pour la détermination de la concentration massique d'alcool dans l'air expiré. Le document met l'accent sur les points suivants: configuration du système expérimental; l'assurance de la traçabilité des étalons; l'influence de CO₂ et l'influence de la température de l'air expiré lorsque la température du corps humain augmente jusqu'à 38, 39 ou, dans des conditions extrêmes, jusqu'à 40 °C..

INTRODUCTION

It is well-known that on the one hand alcohol is a stimulant but on the other hand, from a medical point of view, it is a cellular toxin. After drinking, the alcohol diffuses through the stomach and the small intestine walls, passing via the capillaries into the bloodstream. Due to the ethanol property of being volatile a certain quantity of alcohol, proportional with blood alcohol concentration, transfers from blood to lung alveoli (in the same way that CO₂ goes from blood to the lung alveoli) in order to be eliminated from human body. In accordance with Henry's law, a fixed equilibrium is generated between the mass concentration of alcohol in the blood in the lungs (BAC) and the mass concentration of alcohol in the air in the lungs (BrAC), as a result of diffusion compensation process, as illustrated into the figure 1.

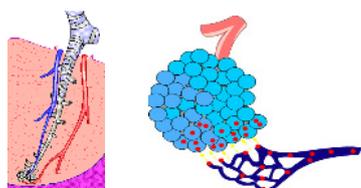


Figure 1– Illustrated exchange of alcohol within the lungs according with the Henry's law

1 EXPERIMENTAL SYSTEM

The experimental system [1], presented in figure 2 [2] consists of:

- CRMs-LNE

Table 1 – CRMs certified by LNE

Mass concentration of alcohol in standard solution		Mass concentration of alcohol in simulated breath	
γ_{eth} [g/L]	U_{eth} [g/L]	γ_{air} [mg/L]	U_{air} [mg/L]
0.2573	0.0005	0.1000	0.0033
0.5146	0.0006	0.1995	0.0033
0.9005	0.0011	0.3500	0.0033
1.0292	0.0012	0.3990	0.0033
1.8011	0.0021	0.6980	0.0033
2.4444	0.0028	0.9500	0.0033
3.8595	0.0044	1.5000	0.0033

- Alcolcal Simulator System - a new wet Bath Simulator System with Depletion Compensation having the traceability to PTB Germany and "3 bubble-train" Mark II, according to OIML R 126

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- Alcotest 9510 breath analyser, which is using a dual IR & EC technology, having the traceability to LNE France.

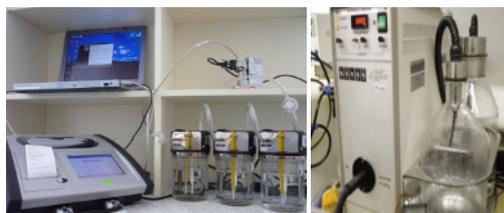


Figure 2- The calibration simulator system

2 THE INFLUENCE OF CO₂

The major components of the inhaled air is Earth's atmosphere: N₂-78 %, O₂-21 % and CO₂ - 0.04 %; while the air humans breathe out has a different concentration: N₂ 78 %, O₂-16 % and CO₂-4.5 %. This major difference in O₂ and CO₂ concentrations depends on human's internal metabolic process and must be correctly evaluated in order to avoid errors which might occur when reporting the final result associated with corresponding uncertainty.

In order to assure the traceability and to have a very good understanding regarding the influence of CO₂ in the measurements of mass concentration of alcohol in exhaled breath also, a number of 7 standard solutions with traceability to LNE France [7], [8] and a recipient under the pressure having a volume fraction of 5.0 % CO₂ in synthetic air was used. A number of 10 measurements were made with and without CO₂ [9]. The results are presented in table 2 and the graphical representation is presented in figure 3.

Table 2. The influence of CO₂ at different mass concentrations of alcohol in exhaled breath [10]

γ_{CRM} [mg/L]	γ_m (- CO ₂) [mg/L]	γ_m (+ CO ₂) [mg/L]	RSD [%]
0.1000	0.0884	0.1003	11.90
0.1995	0.1915	0.2044	6.47
0.3500	0.3421	0.3585	4.69
0.3990	0.3947	0.4108	4.04
0.6980	0.7048	0.7217	2.42
0.9500	0.9564	0.9740	1.85
1.5000	1.5420	1.5575	1.03

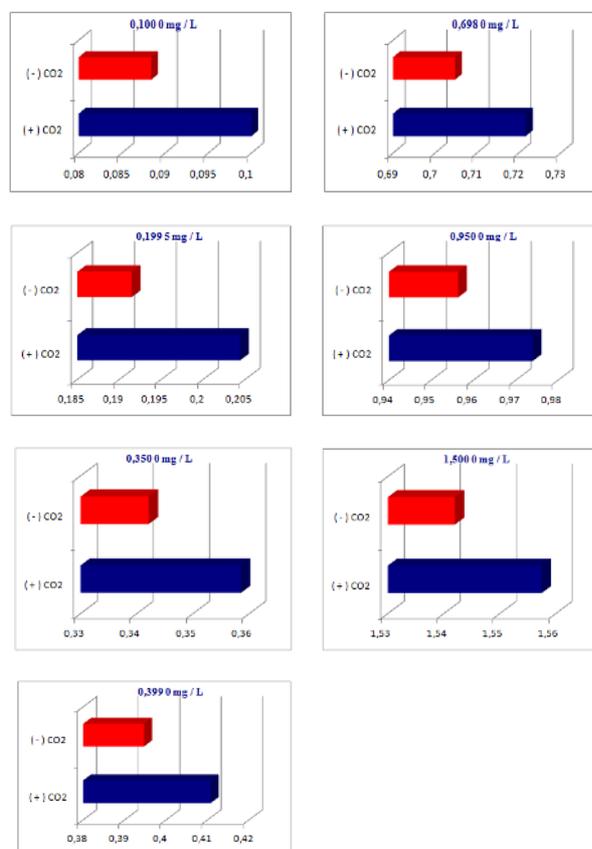


Figure 3–Influence of CO₂-graphical representation

3 THE INFLUENCE OF TEMPERATURE

The experimental studies made on health human beings showed that the temperature human breath varies between 33.3 and 34.4 °C. The temperature of a healthy human being is about 37 degrees Celsius while the exhaled breath temperature varies around 34 degrees Celsius. Taking into consideration that the body's temperature can have in

extreme conditions about 40 degrees Celsius which means that a difference of about 3 degrees Celsius was found between the air temperature [4], [5], [6] from alveoli and the breath exhaled temperature. For this study a number of 20 repeated measurements were made for 6 levels of CRMs at 32, 33, 34, 35 and 36 °C and a prediction for 37 °C [3] was calculated. The results are presented in tables 3 and 4

Table 3. The mass concentration of alcohol with 1 °C & 2 °C variation of breath temperature. Prediction for 3 °C [3]

CRM	[g/L]	0.257 3	0.514 6	0.900 5	1.029 2	1.801 1	2.444 4
$\gamma_{CRM_{34}}$	[mg/L]	0.100 0	0.199 5	0.350 0	0.399 0	0.698 0	0.950 0
T_{34}	[°C]	33.94	34.08	34.04	34.01	33.92	33.99
γ_{34}	[mg/L]	0.086 5	0.191 3	0.344 1	0.393 6	0.699 0	0.955 8
T_{35}	[°C]	34.98	35.02	35.30	34.97	35.08	35.12
γ_{35}	[mg/L]	0.094 3	0.205 4	0.374 9	0.422 2	0.756 3	1.031 8
T_{36}	[°C]	36.21	36.06	36.06	36.03	36.46	36.23
γ_{36}	[mg/L]	0.098 6	0.220 1	0.394 9	0.451 3	0.828 9	1.096 7
$T_{35}-T_{34}$	[°C]	1.04	0.95	1.26	0.96	1.16	1.13
$\gamma_{35}-\gamma_{34}$	[mg/L]	0.0078	0.014 1	0.030 8	0.028 6	0.055 3	0.076 1
$\Delta\gamma, 1^{\circ}\text{C more}$	[%]	0.75	1.48	2.44	2.99	4.76	6.75
$T_{36}-T_{34}$	[°C]	2,27	2.02	2.02	1.90	2.54	2.24
$\gamma_{36}-\gamma_{34}$	[mg/L]	0.012 1	0.028 8	0.050 8	0.057 8	0.129 9	0.141 0
$\Delta\gamma, 2^{\circ}\text{C more}$	[%]	1.07	2.86	5.01	6.08	10.21	12.57
Prediction γ_{37}	[mg/L]	0.1049	0.2293	0.4182	0.4758	0.8739	1.1671
$\Delta\gamma, 3^{\circ}\text{C more}$	[%]	1.84	3.80	7.41	8.22	17.49	21.14

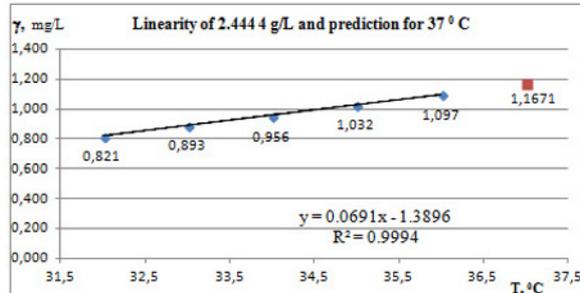
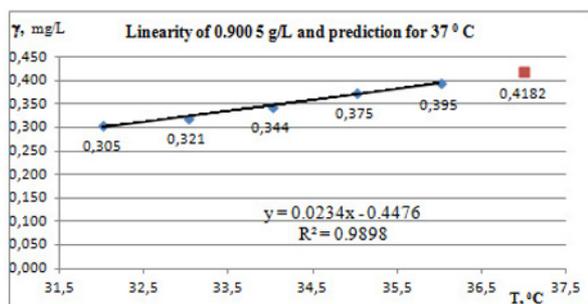
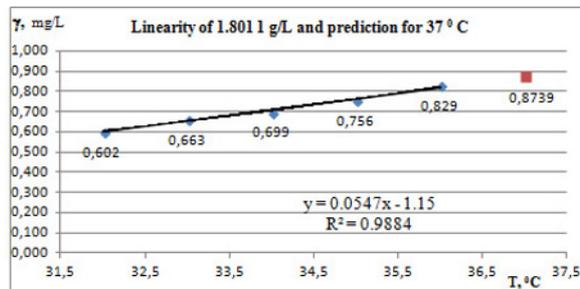
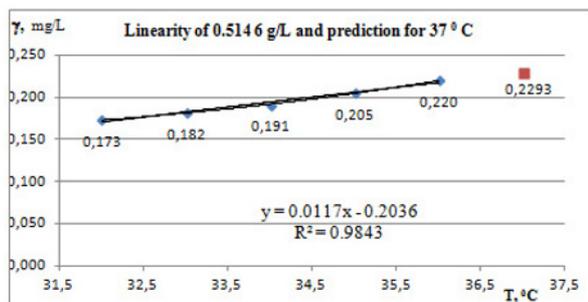
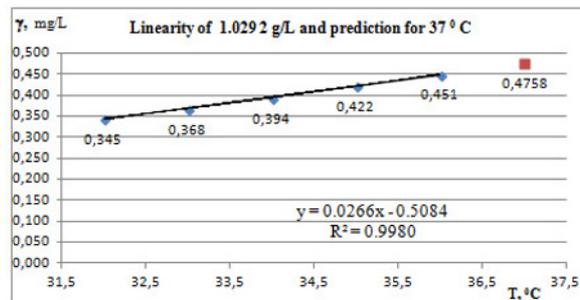
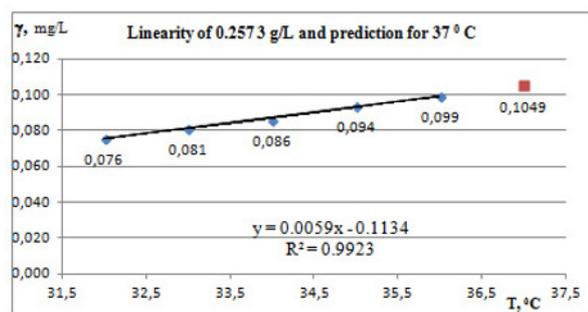


Figure 4-Prediction for 37 °C

CONCLUSIONS

The experiments conducted for the purpose of this article have been performed with the following equipments: CRMs prepared by gravimetric method, AlcoCal wet simulator system with depletion compensation of alcohol and Alcotest 9510 configured with a dual IR & EC technology. The measurements results, presented in tables 2 - 3 and figures 3 - 4, prove our good capabilities in the field of mass concentration of alcohol in exhaled breath. Table 2 and figure 3 demonstrate the fact that is mandatory to use a mixture of air and CO₂ in simulator system or to take into consideration its contribution to the final result of measurements. The temperature of a healthy human being is about 37 degrees Celsius, while the exhaled breath temperature varies around 34 degrees Celsius. Taking into consideration a difference of about 3 degrees of exhaled breath temperature, figure 4 is focused on the influence of the exhaled breath temperature when the human body's temperature increases up to 38, 39 or, in extreme conditions, up to 40 degrees Celsius.

The measurement results shows that a variation of temperature by 1 degree Celsius produces a variation of alcohol mass concentration, corresponding to each CRM, with the following percentages: 0.75 %; 1.48 %; 2.44 %; 2.99 %; 4.76 %; 6.75 %; while, the variation of temperature by 2 Celsius degrees results in a variation of alcohol mass concentration as follows: 1.07 %; 2.86 %; 5.01 %; 6.08 %; 10.21 %; 12.57 %.

The results have been extended for 37 °C using prediction tools. The temperature of a healthy human being is about 37 degrees Celsius while the exhaled breath temperature

varies around 34 degrees Celsius. That means that a difference of about 3 degrees Celsius was found between the air temperature from alveoli and the breath exhaled temperature. Taking into consideration that the body's temperature can have in extreme conditions about 40 degrees Celsius, the experiment has been conducted for 5 different temperatures. Using the measurement results, the calibration curves were drawn for each of these 5 temperatures and a prediction for 37 degrees Celsius was calculated. The measurement results are presented in figure 4. The predictions of mass concentrations of alcohol for an exhaled breath temperature about 37 degrees Celsius have been: 0.1049 mg/L (for 0.2573 g/L); 0.2293 mg/L (for 0.5146 g/L); 0.4182 mg/L (for 0.9005 g/L); 0.4758 mg/L (for 1.0292 g/L); 0.8739 mg/L (for 1.8011 g/L) and 1.1672 mg/L (for 2.4444 g/L). For each CRM used, the predicted value clearly fitted into the corresponding calibration curve.

A variation of exhaled breath temperature by 3 degrees Celsius, from 34 to 37 degrees Celsius, generates a significant variation in mass concentration of alcohol with: 1.84 % (for 0.2573 g/L); 3.80 % (for 0.5146 g/L); 7.41 % (for 0.9005 g/L); 8.22 % (for 1.0292 g/L); 17.49 % (for 1.8011 g/L) and 21.14 % (for 2.4444 g/L).

The linear equations for the variation of mass alcohol concentration with temperature are presented. The value of the correlation factor, close to 1 for all mass alcohol concentrations, proves a dependency of mass alcohol concentration on the temperature of the subject tested with these modern, non-invasive analysis methods used by breath alcohol analyser.

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