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TECHNICAL NOTE

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Effect of Eight Solvents on Ethanol Analysis by Dräger 7110 Evidential Breath Analyzer*

ABSTRACT: The Dräger 7110 MK III FIN Evidential breath analyzer is classified as a quantitative analyzer capable to provide sufficient evidence for establishing legal intoxication. The purpose of this study was to evaluate ethanol specificity of this instrument in the presence of other solvents. Effects of eight possible interfering compounds on ethanol analysis were determined in a procedure simulating a human breathing. Most of the compounds studied had either a negligible effect on ethanol analysis (acetone, methyl ethyl ketone, and methyl isobutyl ketone) or were detected in very low concentrations before influencing ethanol readings (methanol, ethyl acetate, and diethyl ether). However, 1-propanol and 2-propanol increased the ethanol readings significantly. Thus, Dräger ethanol readings should be interpreted carefully in the presence of propanol.

KEYWORDS: forensic science, forensic medicine, breath tests, ethanol, solvents, spectrophotometry, infrared, electrochemistry, false positive reactions, Dräger 7110 Evidential

Breath tests are widely used in screening and indicating drunken drivers. The infrared absorption method (IR) is fast and convenient to use for breath-ethanol analysis. However, some other volatile compounds may absorb the infrared beam in the same wavelength regions and, therefore, they may interfere the ethanol analysis. That could be of practical importance, because a significant interference may lead to an erroneous judgment for driving under the influence (DUI). Moreover, even a possibility of interference may lead to claims alleging that true analysis results are erroneous and hence, not valid as evidence.

In addition to single wavelength (9.5 μm) IR, the Dräger 7110 MK III FIN Evidential breath analyzer benefits from electrochemical detection (EC) in order to make the analyzer more specific to ethanol (1). This instrument is classified as a quantitative evidential analyzer capable to provide sufficient data for proving a legal intoxication. The aim of this study was to evaluate the ethanol specificity of this instrument in the presence of other solvents.

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Material and Methods

Simulator Design

The breath simulator consisted of two parallel Gasmet Calibrators (Temet Instruments, Helsinki, Finland) and a water bubbling system (Fig. 1). A close imitation of exhaled breath was achieved by using 5% carbon dioxide (CO_2) in 5.0 nitrogen (99.999% N_2) as a carrying gas (AGA, Espoo, Finland). Water was vaporized into the system by bubbling CO_2–N_2 gas through water warmed to 37°C. Ethanol (96.1%, Primalco ltd, Helsinki, Finland) and possible interfering compounds were added to the system from separate calibrators in order to avoid interference in a liquid phase.

The Gasmet Calibrator incorporated a syringe pump (Cole-Parmer 74900 series, Cole-Parmer Instrument Company, Vernon Hills, Illinois), a manual needle valve, a mass flow meter (Aalborg GFM17, Aalborg Instruments & Controls, Orangeburg, New York), and a stainless steel injection chamber (Fig. 2). The syringe pump injected precise amounts of liquid or gas into a heated CO_2–N_2 gas flow in the injection chamber. Hamilton 25, 50, or 100 μL syringes (Hamilton 1700-series™, Hamilton Company, Reno, NV) were used, depending on the target concentration. The injected liquid was rapidly vaporized, and a continuous flow of the sample gas was produced. The chamber was heated to the temperature 2°C below the boiling point of each component. In order to avoid swaying, the syringe pumps were operated at a high speed and the sample gas was conducted through a heated 1.0 L integrator.

Dräger 7110 MK III FIN Evidential Breath Analyzer

A Dräger 7110 MK III FIN Evidential breath analyzer determines the breath alcohol concentration using an electrochemical

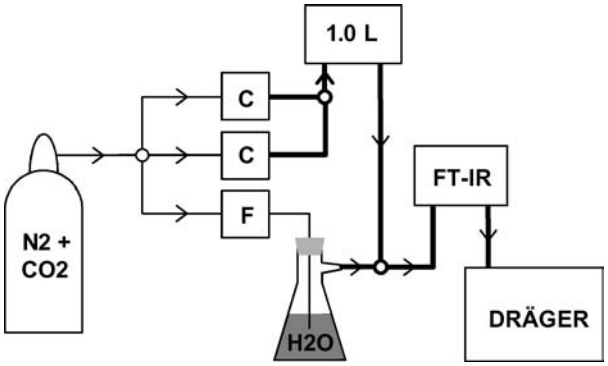

FIG. 1—*Breath simulator design. Mixture of 5% CO_2 in 5.0 N_2 was used as carrier gas at total flow of 4 L/min. One L/min flow was directed to both calibrators (C) and 2 L/min flow was lead to water bubbler (H_2O). A mass flow controller (F) controlled the flow to bubbler, which was heated to 37°C. Integrator (1.0 L) was added to system to reduce swaying of syringe pumps. Function of the infrared analyzer (FT-IR) was to control the stability of sample concentrations. All lines and spaces after calibrators and bubbler were heated to 50°C to avoid condensing (bold lines).*

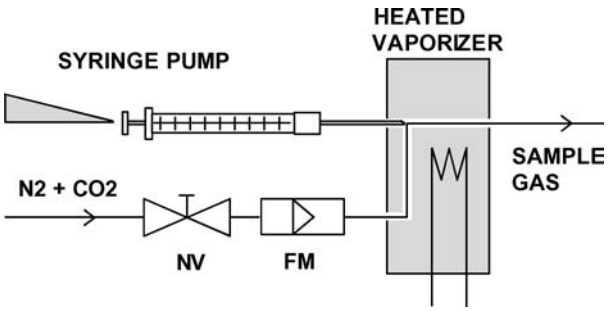

FIG. 2—*Calibrator design. Flow of carrier gas (mixture of 5% CO_2 in 5.0 N_2) was controlled with a needle valve (NV) and a mass flow meter (FM). The sample solvent was vaporized to the gas flow in a heated stainless steel vaporizer unit. The solvent flow was controlled by a syringe pump.*

sensor (EC) in addition to infrared sensor (IR). The infrared sensor functions in the wavelength of 9.5 μm, especially in order to avoid the effect of acetone. The idea is that as there are two different measuring systems used, the analyzer would be able to detect an interfering component, discard the analysis and display an "interfering compound" message. Measurements are considered acceptable only if results provided by both sensors are within tight limits. (1)

In order to ensure alveolarity of the samples, a minimum volume of breath is required. Flow sensors measure the volume of air blown into the instrument. Two temperature sensors record the temperature of the exhaled airflow at a mouthpiece end of the breath hose. Results from the breath-ethanol analysis are standardized to a fixed exhalation temperature of 34°C (1). The analyzer measures the ambient air ethanol concentration and automatically checks the calibration with a reference gas sample in the course of each measuring event. Prior to the laboratory-testing period, the Dräger instrument was serviced and calibrated in accordance with the manufacturer's instructions.

Gasmet FT-IR Gas Analyzer

A FT-IR spectrometer (Gasmet™, Temet Instruments Oy, Helsinki, Finland) was used in controlling stability of the sample concentrations and in determining the appropriate analysis period for the Dräger (Fig. 1). The volume of the FT-IR gas cell was 200 mL, the temperature was set to 50°C and the scanning time to 5 s at 10 scans/s. The analyzer was equipped with a multi-component analysis software (Calcmet™, Temet Instruments Oy, Helsinki, Finland) (2).

Possible Interfering Compounds

A possible interfering compound must have a sufficient vapour pressure to pass from the blood into the breath. The resulting breath concentration must be high enough to cause a significant error in analysis, but relevant in relation to toxic and lethal limits. A solvent is able to interfere with the Dräger ethanol analysis only in cases where it both activates the EC-detector and absorbs infrared radiation at 9.5 μm region. IR absorption at 9.5 μm is not specific to ethanol (3). Neither is an EC detector specific for ethanol, because other alcohols and aldehydes become also oxidized at the electrode, although with different reaction rates.

Eight possible interfering components were selected, namely: acetone (>99.5%, Prolabo, Briare, France), methanol (>99.8%, Labscan ltd, Dublin, Ireland), 1-propanol (>99.5%, Fluka Chemie GmbH, Deisenhofen, Germany), 2-propanol (>99.5%, Acros Organics, Geel, Belgium), methyl ethyl ketone (>99.5%, Riedel-de Haën AG, Seelze, Germany), methyl isobutyl ketone (>99%, Riedel-de Haën AG, Seelze, Germany), diethyl ether (>99.5%, Merck KgaA, Darmstadt, Germany) and ethyl acetate (>99.5%, Merck KgaA, Darmstadt, Germany) (Fig. 3).

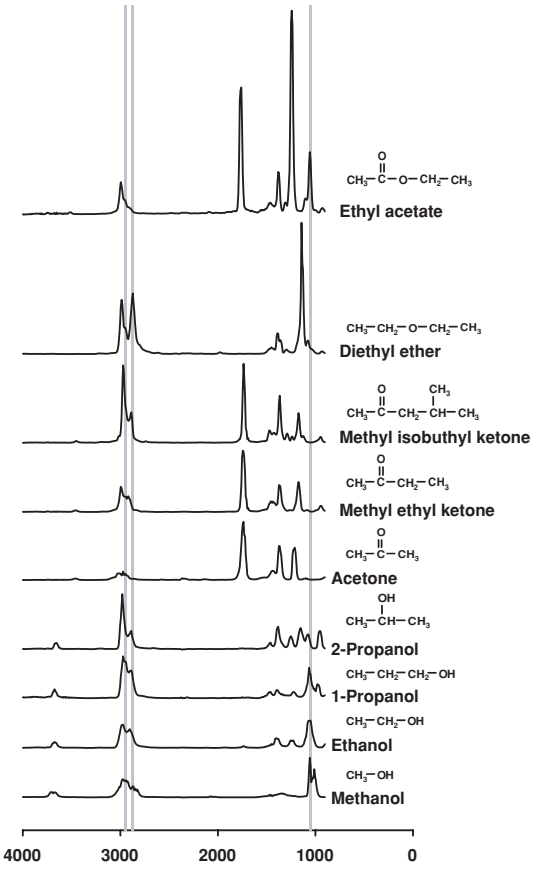

FIG. 3—*Infrared spectra of solvents studied on a wavenumber scale (cm^{-1}). The spectra were measured by the used FT-IR analyzer at 8 cm^{-1} resolution. The grey lines represent 3.39, 3.48 and 9.50 μm wavelengths commonly used in breath ethanol analyzers.*

TABLE 1—*Effect of interferents on the breath ethanol reading.*

EtOH Concentration (mg/L)	Interferent	Coefficient (C_x)*	Max. interf. conc.† (mg/L)	Reading‡ (mg/L)	Error§ (%)
0	1-Propanol	0.58	0.17	0.09	
0.24	MeOH	1.35	0.019	0.26	+8
	Acetone	0.017	1.8‖	0.27	+13
	Ethyl acetate	0.54	0.052	0.27	+13
	Diethyl ether	¶	0.044	0.25	+4
	Methyl ethyl ketone	0.025	0.86‖	0.26	+8
	Methyl isobutyl ketone	0.018	1.2‖	0.26	+8
	2-Propanol	0.26	0.17	0.28	+17
	1-Propanol	0.60	0.48	**0.52**	**+117**
0.60	Ethyl acetate	0.65	0.10	0.67	+12
	2-Propanol	0.25	0.60	**0.74**	**+23**
	1-Propanol	0.59	1.4‖	**1.40**	**+133**

* Biasing power of an interferent on the ethanol reading (see text for details).
† Highest observed concentration of a possible interfering compound not to trigger the "interfering compound" sign.
‡ Analysis result at the maximum interference level.
§ Relative difference between the true ethanol concentration and the reading.
‖ Higher concentrations were not tested.
¶ Regression not relevant due to a small number of observations.

Procedure

Simulated breath ethanol concentrations used in this study were determined according to Finnish legal breath-ethanol concentration limits for DUI (driving under the influence): 0.25 mg/L (drunken driving) and 0.60 mg/L (aggravated drunken driving). Prior to the measurement with an interfering solvent, plain ethanol was measured in a simulated breath in order to calculate the specific interference effect. Concentration of the interfering compound was raised until the "interfering compound" message was displayed, and the analysis was rejected. Due to the volume of the integrator and the FT-IR cell, it took a few minutes for the simulator system to stable after any change made in the settings. Measurements with the Dräger were started only when the FT-IR analyzer indicated the concentrations to be stable. Measurements at threshold levels were repeated with an intention to reduce random errors. In addition to the absolute and relative errors in the results from the ethanol analysis at the maximal interferent level, a coefficient C_x was determined from the following equation:

$$EtOH_{app} = C_x \times Interf_x + EtOH_{act},$$

where $EtOH_{app}$ = apparent EtOH concentration displayed by Dräger, $Interf_x$ = concentration of the possible interfering component X in the sample, $EtOH_{act}$ = actual EtOH concentration of the sample. The coefficient C_x describes the biasing power of interfering compounds in ethanol readings.

Statistics

Linear regression line equations and squared Pearson correlation coefficients (R^2) were calculated with SPSS for Windows 11.0 software for the effect of different solvents on the ethanol analysis.

Results

Effects of other compounds on ethanol recordings are summarized in Table 1. Correlation between the influence and concentration of the substance seemed to be mainly linear (Fig. 4). Most of the possible interfering compounds studied had either a negligible effect on ethanol analysis (small coefficient (C_x); acetone, methyl ethyl ketone and methyl isobutyl ketone) or were detected in very low concentrations (methanol, ethyl acetate and diethyl ether). 1-propanol and 2-propanol had a significant impact on ethanol readings. 1-propanol had a more pronounced effect in comparison with 2-propanol, the coefficients being 0.60 and 0.26, respectively.

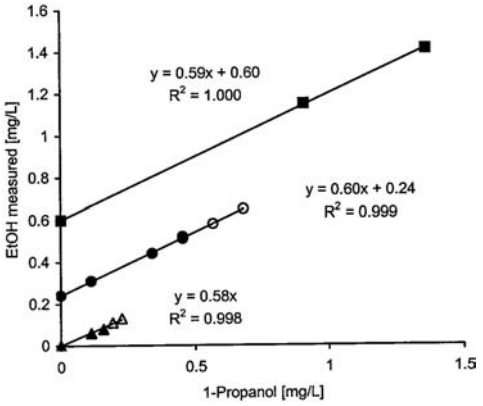

FIG. 4—*Effect of 1-propanol on ethanol analysis at different breath ethanol concentrations (squares 0.60 mg/L, circles 0.24 mg/L and triangles 0 mg/L). Solid symbols represent accepted analyses. Shown are analysis results before the safety reduction.*

Discussion

The main finding of this study was that propanols may significantly interfere ethanol analysis by Dräger 7110 MK III FIN Evidential. The effect of 1-propanol on ethanol readings was more than two times stronger than that of 2-propanol. The Dräger did not even detect considerably high concentrations of 1-propanol, which caused a marked effect on ethanol analysis. In a previous study (4) performed with a similar Dräger instrument, a maximal error due to 2-propanol on ethanol results in an ethanol concentration of 0.55 mg/L was 0.1 mg/L. There was no reference made to the exact 2-propanol concentration used.

According to our results, a significant interference by 1-propanol requires a simultaneous existence of ethanol. 0.1 mg/L of

1-propanol alone caused only a negligible apparent ethanol reading (0.05 mg/L). Interference was detected at higher levels.

A toxic blood concentration of propanols is 0.04 to 0.08 % w/v, corresponding 0.3 to 0.6 mg/L in breath (5). The minimum concentration needed for a falsely elevated ethanol analysis result corresponds to 0.02 % w/v 1-propanol with 0.05 % w/v ethanol in the blood. No doubt, a habitual alcohol user could tolerate that kind of combination. On the contrary, the highest tested combination of 2-propanol and ethanol (blood concentrations 0.06 and 0.12 % w/v, respectively) would lead to a very strong CNS depressing effect. Even though propanols in the above-mentioned concentrations have an effect on an individual's performance more than it can be anticipated on the basis of the error in the ethanol reading, the interference may cause disagreement in the process of prosecution, because illegal concentrations of 1- or 2-propanol are not set.

When considering the importance of these findings, it has to be underlined that the Dräger instrument is designed specifically for analyzing ethanol concentrations in breath in suspected DUI cases. Individuals are subjected to Dräger measurements only after a roadside screening with handheld instruments and without exception, they are thus drivers of vehicles in traffic. A significant concentration of propanols can only be obtained by drinking relatively high amounts of denaturated alcohol. It is highly improbable that alcoholics relying on denaturated alcohol are confronted by the police in a routine traffic control.

The Finnish ethanol-breath test procedure consists of two acceptable breath samples. The final test result (R) is the mean of these samples (M) subtracted by a "safety reduction":

$$R = M - 0.03\,\text{mg/L} - 0.07 \times M$$

The reason for this safety reduction is to avoid false positive analysis results. Nevertheless, both 1- and 2-propanol raised erroneously the ethanol level more than the safety reduction could compensate (bold face type values in Table 1). Due to the safety reduction, the interference caused by 2-propanol was significant only in higher ethanol concentrations.

A detection of volatile compounds other than ethanol might in some rare cases reveal poisoning. Regarding methanol, it could be of vital importance. Methanol had a very strong relative effect on ethanol reading (coefficient 1.35), but the interference was detected in very low concentration, before influencing the results from ethanol analysis. However, Dräger is not intended or equipped to qualify the interfering component and, therefore, the suspicion of severe methanol intoxication is relied on clinical signs and symptoms.

Normal metabolism generates hundreds of volatile compounds that can be measured in exhaled breath. Concentrations of the most of them are so small that they cannot interfere with ethanol analysis (6). Acetone and methane are potential interferences based on their concentrations in exhalation, but they do not absorb infrared radiation at 9.5 μm and thus, they are unlikely to interfere with the Dräger ethanol analysis.

Acetone, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK) were tested, because they are abundant components in the breath of an alcoholic drinking denaturated alcohol. The results confirmed the theoretical assumption that they would not have any significant effect on the Dräger ethanol analysis. None of the ketones triggered the "interfering compound" sign even in very high concentrations.

In a previous study by Bell et al. (7), a volunteer's breath containing 0.77 mg/L diethyl ether was analyzed by a Dräger Alcotest 7110 that was not equipped with an EC sensor. The apparent blood ethanol concentration was 0.27% w/v. In our study, discrepancy in EC and IR sensors triggered the "interfering compound" sign in a low concentration, not causing any effect on an individual (5). In that concentration, diethyl ether had an insignificant effect on the result from the ethanol analysis.

Ethyl acetate also has a C–O bond with a strong IR absorbency at 9.5 μm. It had a strong effect on ethanol reading (coefficient 0.6), but triggered the "interfering compound" sign in a low concentration. Due to a minimal effect on the analysis results at 0.24 mg/L breath ethanol level, ethyl acetate was also tested at a higher (0.60 mg/L) breath ethanol level. The effect remained relatively low at the both levels.

Conclusions

The Dräger 7110 MK III FIN Evidential breath analyzer was able to detect most of the potential interfering common solvents in concentration levels, which did not significantly affect ethanol analysis. On the other hand, 2- and especially 1-propanol caused notable analysis errors that were not entirely compensated by the safety reduction.

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