Ten Years Experience of Evidential Breath-Alcohol Testing in Sweden

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Abstract

Ten years have elapsed since the Swedish police began to use breath-alcohol testing for evidential purposes. The Intoxilyzer 5000S, a quantitative infrared analyzer, has been the only instrument approved for legal purposes during the past decade. The statutory alcohol concentration limits for driving in Sweden are 0.20 mg/g in blood or 0.10 mg/L in breath. The concentration of alcohol *per se* is used for prosecution and probable cause and tests of impairment are not necessary. The number of drinking drivers apprehended by the police has decreased appreciably over the past 10 years from about 23,000 in 1989 to 15,000 in 1999. The most common defence argument against the results of evidential breath-alcohol testing concerns the use of various prescription drugs. Other defence tactics include alleged drinking after the offence, problems with the instrument or the operator, presence of interfering substances in breath, illness or disease state such as diabetes or asthma as well as other challenges. The most common interfering volatile substance identified in breath of drunk drivers was acetone derived from the abuse of technical (denatured) alcohol preparations. The mean blood/breath ratio of alcohol in drunk drivers was closer to 2400:1 rather than 2100:1, the value used when setting the *per se* statute. Evidential breath-alcohol testing has been well received by the media, the police, the prosecutors and the courts despite a 50-year tradition in Sweden of only accepting blood-alcohol concentration as evidence of impaired driving. The Intoxilyzer 5000S has proved to be a reliable instrument for enforcing the low breath alcohol concentration threshold in Sweden of 0.10 mg/L.

Introduction

Evidential breath-alcohol testing started to be used in Sweden on a relatively small scale exactly 10 years ago on 1st July 1989. Subsequently, the use of breath-alcohol testing in traffic law enforcement expanded to cover the whole country and about 160 instruments are now being used by the Swedish police (1). For the past 10 years, the Intoxilyzer 5000S, a quantitative infrared breath-alcohol analyser and its ADAMS data collection system, has been the only instrument approved for evidential purposes (1,2).

Operators of the Intoxilyzer 5000 (~3,700) undergo 2 days of instruction on the theory and practice of breath-alcohol testing including hands-on use of the instrument in controlled drinking experiments. In 1999 approximately 10,000 offenders provided specimens of breath for alcohol determination and blood samples were taken from another 5,000 individuals. These figures compare with over 23,000 blood tests made in 1989 and about 250 evidential breath-alcohol tests.

When evidential breath-alcohol testing was introduced in Sweden this broke a 50-year tradition of only accepting blood-alcohol concentration as evidence of impairment at the wheel. Indeed, alcohol concentration *per se* statutes were introduced as early as 1941 first using Widmark's micro-method for analysis of capillary blood samples until the 1950ies when enzymatic oxidation was used and in 1985 headspace gas chromatography became the method of choice for legal purposes. This article deals with various aspects of evidential breath-alcohol testing, which has been used for traffic law enforcement purposes in Sweden for the past 10 years.

Statutory alcohol concentration limits

A two-tier alcohol concentration limit is enforced in Sweden being 0.20 mg/g and 1.00 mg/g in blood or 0.10 mg/L and 0.50 mg/L in breath. The punishment for aggravated drunk driving (0.50 mg/L or 1.00 mg/g) is usually imprisonment for 30 days even for a first offence. However even this severe penalty has done little to deter the hard-core drinking driver because recidivism runs at about 30% within 3 years of a first conviction. The enforcement of concentration *per se* statutes and the stiff sanctions imposed for those found guilty requires that random and systematic variations in the methods of alcohol analysis are considered and allowed for. This requires making a deduction for analytical uncertainty and implementing a rigorous programme of quality assurance of the procedures used for forensic alcohol analysis.

Intoxilyzer 5000S

The Intoxilyzer 5000S is a three filter quantitative infrared analyzer. After a positive roadside screening test with Alcolmeter 400, the suspect makes two separate exhalations into the Intoxilyzer 5000. Refusal to participate in a breath-alcohol test means that a specimen of venous blood will be taken instead and if necessary by force. Table 1 lists the sequence of control checks and specifications during the use of Intoxilyzer 5000S for evidential purposes.

Table 1. Sequence of tests during use of Intoxilyzer 5000S.

Step	Analysis (test) performed	Tolerance Limits
1	Analysis of room air	± 0.05 mg/L
2	Internal standard check[1]	± 5%
3	Obtain new reference	± 0.05 mg/L for 6s
4	External standard check (0.50 mg/L)[2]	0.47 - 0.53 mg/L
5	Analysis of room air	± 0.05 mg/L
6	Obtain new reference	± 0.05 mg/L for 6s
7	Breath test one (x_{11}) and after 2.4s (x_{12})[3] = MT_1	Minimum exhalation. time 6s
8	Analysis of room air	± 0.05 mg/L
9	Obtain new reference	± 0.05 mg/L for 6s
10	Breath test two (x_{21}) and after 2.4s (x_{22})[3] = MT_2	Minimum exhalation time 6s
11	Analysis of room air	± 0.05 mg/L
12	Obtain new reference	± 0.05 mg/L for 6s
13	External standard check at 0.50 mg/L[2]	0.47 - 0.53 mg/L
14	Analysis of room air	± 0.05 mg/L

[1] The internal standard is a test of the signal amplitude derived from each of the three IR filter channels. [2] The external standard is a wet-bath alcohol simulator at 34°C with a target effluent of 0.50 mg/L. [3] The average of (x_{11} and x_{12}) = MT_1 and (x_{21} and x_{22}) = MT_2 are calculated and truncated to two decimals. Then MT_1 and MT_2 are compared and the absolute difference must not exceed 0.11 mg/L. The mean of MT_1 and MT_2 is truncated to two

decimals and a safety margin of 0.07 mg/L subtracted leaving the BrAC for prosecution.

After a successful test, the mean BrAC reading is truncated to two decimals and an allowance is made to compensate for analytical and sampling variations (1,2). The deduction for uncertainty is currently set at 0.07 mg/L at all concentrations of alcohol in breath. Since 1989 over 120,000 evidential breath-alcohol tests have been made with Intoxilyzer 5000S and after making the deduction for uncertainty about 20% of the results were below the legal limit for driving and no charges were brought against the suspects. These 20% of cases are therefore classified as false positive roadside screening tests and are troublesome for the police because of loss of time and resources. The vast majority of apprehended drivers are in the elimination stage of alcohol metabolism and studies have shown that drunk drivers in Sweden eliminate alcohol at a rate of 0.019 mg/g per hour on average (3). The combined influence of the time difference and the deduction for uncertainty brings many suspects below the legal limit for driving by the time the Intoxilyzer test is made.

Development in number of blood and breath tests

The development in number of blood and breath-alcohol tests in Sweden over the past decade, which also corresponds to the number of individuals apprehended for drunk driving, is shown in table 2. After a slow start, owing to the limited number of Intoxilyzer instruments available for use by the police, the number of evidential breath tests has increased and now accounts for 65-70% of the total. The remaining suspects provide samples of venous blood for quantitative determination of alcohol. Indeed, blood samples will always be necessary because a person cannot be forced to blow into a breath-alcohol analyzer. Some drunk drivers refuse to co-operate with the breath test procedure and fail to provide two successive samples. Other suspects are too drunk to provide an appropriate specimen.

Various other reasons exist for the breath-alcohol test being aborted such as mistakes made by the operator (8%), duplicate results outside tolerance limits (13%), technical problems with simulator or instrument (16%), insufficient breath sample (58%), and refusal to comply with the procedures (5%). In 1999, approximately 10,000 evidential breath samples were analysed and 5,000 blood samples taken. Other reasons for blood samples being taken instead of breath include road-traffic accidents where the driver requires emergency hospital treatment.

Table 2. Development in number of blood and breath samples from apprehended drinking drivers in Sweden 1989-1999.

Year	Number of blood samples (%)	Number of breath samples (%)	Total number of suspects (%)
1989	23,000 (98%)	250 (1%)	23,250 (100%)
1990	17,450 (78%)	4,950 (22%)	22,400 (100%)
1991	8,700 (36%)	15,584 (64%)	24,284 (100%)
1992	7,000 (29%)	16,732 (71%)	23,732 (100%)
1993	6,000 (26%)	17,135 (74%)	23,135 (100%)
1994	5,696 (27%)	15,318 (73%)	20,914 (100%)
1995	5,024 (28%)	12,854 (72%)	17,878 (100%)
1996	4,750 (28%)	12,108 (72%)	16,858 (100%)
1997	4,397 (29%)	10,928 (71%)	15,325 (100%)
1998	4,260 (29%)	10,323 (71%)	14,583 (100%)
1999	5,213 (34%)	10,034 (66%)	15,247 (100%)

Concentration of alcohol in blood and breath of Swedish drinking drivers

The distribution of apprehended drivers according to their blood or breath-alcohol concentration is shown in table 3. The concentrations of alcohol shown are after making the usual deductions for analytical uncertainty. The amounts currently subtracted are 0.07 mg/L from the mean of two breaths (~0.14 mg/g equivalent in blood) compared with 0.06 mg/g for blood samples for concentrations up to 0.5 mg/g and thereafter ~6% of the mean. The amounts subtracted are currently being reviewed and will probably be lowered in the future after new alcohol-testing equipment has been approved.

Table 3. Comparison of alcohol concentrations in blood and breath for drivers apprehended in 1998.

Alcohol concentration in blood (mg/g) or breath (mg/2 L)	Number of blood samples (%)	Number of breath samples (%)
0.00-0.19 mg/g or mg/2 L	668 (16.0%)*	2088 (20.2%)
0.20-0.49 mg/g or mg/2 L	277 (6.5%)	1795 (17.4%)
0.50-0.99 mg/g or mg/2 L	456 (10.7%)	2183 (21.1%)
1.00-1.49 mg/g or mg/2 L	655 (15.4%)	1922 (18.6%)
1.50-1.99 mg/g or mg/2 L	881 (20.7%)	1446 (14.0%)
2.0 mg/g or mg/2 L	1322 (31.0%)	869 (8.4%)

* Includes drivers apprehended for driving under the influence of drugs other than alcohol

The proportion of drivers with high concentrations of alcohol was definitely greater among those offenders who provided blood samples; 31% above 2.0 mg/g compared with just 8.4% of breath-alcohol tests above 2.0 mg/2 L. The alcohol concentration is one indication of the amount people have consumed before driving. The mean concentration of alcohol in blood was 1.43 mg/g compared with a mean of 0.82 mg/2 L in the breath (0.41 mg/L). The higher proportion of individuals at high concentrations of alcohol among blood samples can be explained by over-representation of accident victims and those who were too drunk to fulfil the sampling requirements of the Intoxilyzer 5000S. Moreover, studies have shown that Intoxilyzer 5000S tends to understate venous blood-alcohol concentration when time-adjusted blood-breath comparisons were made (4)

Interfering substances encountered in breath samples

Alleged response of Intoxilyzer 5000S to substances in breath other than ethanol is a common defence challenge although on detailed examination these arguments lack merit (5). Acetone is the only endogenously produced volatile that could theoretically pose a problem with a single wavelength (3.4 µm) breath analyzer. Infrared instruments having two or more analytical wavelength (e.g. 3.38 µm and 3.49 µm) such as Intoxilyzer 5000 flag for an interfering substance being present if the concentration of acetone is > 400 mg/L and the test is aborted. At lower concentrations of acetone, the ethanol signal is automatically adjusted for the amount of acetone present. Experience from Sweden shows that high concentrations of acetone in breath are encountered about 12-15 times a year and the Intoxilyzer 5000 tests are therefore aborted (6). Such cases are dealt with by obtaining blood samples for analysis by headspace gas chromatography. The resulting gas chromatogram confirms the presence of acetone and sometime also isopropanol. These substances are present in the technical alcohol preparations which are consumed by some drunk drivers in Sweden (7). Isopropanol is converted in the body into acetone, which is then expelled in the breath.

Defence challenges against results of evidential breath-alcohol tests

In some countries defending drinking drivers has become a big business for lawyers and the scientific expert witness they engage (5). Many highly imaginative reasons for the alcohol concentration being above the legal limit have been documented (Table 4). Although most challenges are without much substance or simply reflect nit-picking designed to confuse the issue and cast a shadow of doubt on the correctness of the Intoxilyzer instrument all arguments must be seriously considered for the sake of justice. For this purpose, a panel of experts representing medical sciences, technical issues, and police procedures meet regularly to deal with each case on an individual basis and submit a written report.

Table 4. Rank ordering based on 200 defence challenges against results of evidential breath-alcohol tests made in Sweden 1992-1999.

Rank order	Defence challenge
1	Use of prescription drugs or other medication, which has allegedly caused the breath alcohol reading to be over the legal limit.
2	Drinking alcohol after the driving or involvement in a traffic accident thus accounting for the breath-test result – hip flask defence.
3	Questions about the functioning of the instrument or the operator.
4	Various medical problems asthma, diabetes, cirrhosis, kidney failure, fever or alcoholism has accounted for the high result.
5	Someone added alcohol (vodka) to a weaker alcoholic drink usually beer and this laced drink brought the person above the legal limit.
6	Interfering substances in breath (acetone, butane, toluene, gasoline)?
7	Exposure to various organic solvents in the workplace causes the breath-alcohol analyzer to give abnormally high results?
8	Use of breath fresheners or mouth-wash containing alcohol within less than 15 minutes before the test resulting in a mouth-alcohol effect.
9	Something (e.g. tobacco or gum) in the mouth during the breath test.

Compared with countries like USA and UK, rather few defence challenges arise in Sweden in part because of the different systems of justice (5). The adversarial system of justice does not exist in Sweden and the courts operate without juries similar to the French inquisitorial system. A panel of judges decide the case on the basis of the evidence provided. However, if considered necessary the court appoints an expert to advise in scientific matters and trials operate under the code of freedom of evidence evaluation. Between 1992-1999, from a total of 105,458 evidential breath-alcohol tests only 200 challenges were documented which required more detailed evaluation. These were submitted for further investigation to the experts at the Breath Alcohol Control Unit at the National Laboratory of Forensic Sciences.

Problem cases

Two rather troublesome challenges were noted during the past decade and both resulted in acquittals when appealed to the high court. The first was alleged inhalation of gasoline fumes and also accidentally swallowing some of the fuel. The second was alleged consumption of alcohol after taking the drug Antabuse used as aversion therapy for people with alcohol problems.

Gasoline is comprised of a mixture of low-molecular volatile hydrocarbons that absorb infrared energy in the 3.4 µm range used to monitor ethanol. Accordingly, these hydrocarbons in appropriate concentrations cannot easily be distinguished from ethanol with just the two analytical wavelengths used with the Intoxilyzer 5000S. In short, the instrument gives a signal of 0.15-0.30 mg/L that can masquerade as ethanol. Somewhere in this range or higher the instrument will abort the test. Gasoline is a highly poisonous substance and swallowing this liquid would constitute a medical emergency. The suspect in this case was on his way to a physician when he was stopped in a police traffic control. The roadside screening test was positive (>0.1 mg/L) and the Intoxilyzer 5000S gave a result of 0.27 mg/L before making the customary deduction for uncertainty. The man saw his doctor and was remitted to a hospital intensive care unit where he remained for 48 h. The hospital found no proof of gasoline poisoning but the low Intoxilyzer 5000 reading meant that the case was dropped. However details of this case appeared in the daily newspapers and the “gasoline” defence soon became popular with other drunk driving offenders.

Trace amounts of acetaldehyde (AcH) are produced during the metabolism of ethanol and this volatile substance is expelled in the breath. The drug Antabuse blocks the enzyme responsible for converting acetaldehyde into acetate so if someone taking the drug drinks alcohol the concentration of AcH increases in blood and breath (8). This triggers a host of unpleasant reactions, among others, warm flushes in the face, tachycardia, difficulties in breathing. low blood pressure, nausea and vomiting. The highest concentration of AcH in breath coincides with the most intense signs and symptoms that last for about 60 min after end of drinking. The elevated breath acetaldehyde allegedly increases the response on the Intoxilyzer 5000 because of the similarity between the molecules ethanol and acetaldehyde and how they absorb infrared radiation. However, studies have shown that even during the most intense flush-reaction, the concentrations of breath AcH are too low to cause an interference problem on a single wavelength infrared analyzers (8). Despite this well documented research, a man was acquitted of drunk driving by the high court after showing a doctor’s prescription for Antabuse tablets. The acquittal was based on the fact that police instructions required a blood sample to be taken if a suspect was using Antabuse. The individual concerned was adamant that nobody asked him about his medication and once again this case made it into the daily newspapers and similar defences escalated. The police authorities have investigated the problem and re-written their operating rules and regulations for conducting evidential breath-alcohol tests.

Blood-breath ratios of alcohol

A population average blood-breath conversion factor of 2100:1 was adopted by the legislator when the threshold breath-alcohol concentration of 0.10 g/L was set. This was derived from the pre-existing blood-alcohol limit 0.20 mg/g (0.21 mg/mL/2100 = 0.10 mg/L). The 2100:1 blood/breath ratio has been used in USA and elsewhere and tends to understate the coexisting venous blood-alcohol concentration. Some years ago we had the opportunity to evaluate blood/breath ratios of alcohol in 799 drunk drivers being those who failed to provide two consecutive Intoxilyzer test results. Thus, available for evaluation was one breath-alcohol test comprised of a deep exhalation for at least 6 seconds and a specimen of venous blood obtained 15-60 minutes later (4). After making an adjustment for elimination of alcohol at a rate of 0.19 mg/mL per hour between the time of sampling the two media, we found a time-mean adjusted blood/breath ratio of alcohol of 2400:1, being 14% higher than the assumed blood-breath ratio of 2100:1. This suggests a considerable advantage for those who are tested with Intoxilyzer 5000S compared with blood sampling. However, this advantage might not be so much if the person tested was in the elimination phase of alcohol kinetics when Intoxilyzer 5000 test was aborted and if the blood sample was then taken several hours later. Over this time the concentration of alcohol in blood decreases.

Concluding remarks

Many people were apprehensive about switching from blood to breath testing for legal purposes owing to problems for the courts in understand a new (for Sweden) system of forensic alcohol analysis. The need to appreciate the reliability of two independent analytical methods utilising different concentration units and principles was considered prohibitive. Also the fact that the police were responsible for conducting the breath-alcohol tests as opposed to forensic scientists who make the blood-alcohol analysis was also considered a potential problem. However experience has shown that the switch from blood to breath-alcohol testing went smoothly and has been much appreciated by police forces responsible for traffic safety. The evidence of drunk driving from use of Intoxilyzer 5000S is seldom challenged in the courts and few acquittals have been recorded. The Intoxilyzer 5000S has been successful in the enforcement of a low threshold alcohol concentration of 0.10 mg/L.

In the future, the Swedish police are planning to conduct evidential breath-alcohol test much closer to the time of driving. The approved instrument and portable computer will be placed in a police car at the roadside. Problems with mouth-alcohol influencing the results and ways to ensure on-site calibration control still need to be solved. Also whether wide fluctuations in temperature, humidity and purity of ambient air will cause problems needs to be investigated. One advantage of roadside evidential breath testing will be fewer false-positive screening test results. About 20 % of current evidential tests are below the legal alcohol limit of 0.1 mg/L after making a deduction for uncertainty (currently 0.07 mg/L) despite obtaining a positive roadside screening test result.

Although the practice of conducting evidential breath-alcohol tests at the roadside is unlikely to deter drinking drivers it should enhance police effectiveness and hopefully increase prosecution rates. Specifications already exist for a new generation of breath-testing instruments suitable for mobile and stationary use and several devices are currently being evaluated. Multiple wavelength infrared spectrometry seems to be the most reliable analytical principle for quantitative analysis of ethanol in breath of drinking drivers.

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