Epidemiological study of carbon monoxide deaths in Scotland 2007–2016*

Claudia Forés Lisbona,[1,2] M.Sc.; and Hilary J. Hamnett,[1,3] D.Phil.

[1]Forensic Medicine & Science, School of Medicine, Dentistry & Nursing, University of Glasgow, University Place, Glasgow, G12 8QQ, U.K.

[2]Present address: IQVIA, C/Condesa de Venadito 1, 28027 Madrid, Spain.

[3]Present address: Toxicology Unit, Imperial College London, Charing Cross Campus, St Dunstan's Road, London, W6 8RP, U.K.

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Corresponding Author: Hilary J. Hamnett, D.Phil., Toxicology Unit, Imperial College London, Charing Cross Campus, St Dunstan's Road, London, W6 8RP, U.K.; Email: h.hamnett@imperial.ac.uk

ABSTRACT: Carbon monoxide (CO) intoxications are quite frequent in forensic toxicology. Using a sample of 209 CO-positive deaths in Scotland from 2007 to 2016, this study provides ranges of percentage CO saturations (%COHb) according to the CO source, and examines any correlation with age, gender, alcohol and pre-existing disease. It also reports the full toxicological findings, including drug concentrations, in CO-positive cases. The highest numbers of fatalities involved males, occurred during autumn/winter, and the main source of CO was fire. The median %COHb in fire-related cases was significantly lower than in non-fire-related cases such as those involving exhausts, generators and gas supply systems and portable BBQs. There was no relationship between %COHb and age, blood alcohol concentration or the presence of pre-existing cardiovascular and/or respiratory disease. Toxicology results revealed that prescription medications were the most commonly detected drug group, and that the number of cases positive for controlled drugs was small.

KEYWORDS: forensic science, carbon monoxide, suicide, death, fire, drugs

Carbon monoxide (CO) is a colorless, odorless, tasteless and non-irritant gas, which is a product of the incomplete combustion of hydrocarbons. It can be produced endogenously, by natural sources such as forest fires and volcanic eruptions, and by automobile exhausts, house fires, and gases from defective heating systems (1-5). Exposure to CO can lead to toxicity; it is absorbed through the lungs and reacts with the hemoglobin in red blood cells by binding to iron with 200 times higher affinity than O_2. The complex formed is known as *carboxyhemoglobin* (COHb) (1,6,7). Since most CO remains in the blood, the COHb percentage saturation (%COHb) acts as an estimate and a guide to help determine exposure levels (8). The symptoms of poisoning depend on the concentration of CO in the environment, the duration of exposure, the extent of any ventilation, and the presence of pre-existing health conditions (9-11). Table 1 shows how CO poisoning symptoms vary with %COHb (1,12,13), however the %COHb recorded in fatalities can vary greatly due to the specific circumstances of death (2,3,6,14).

<<Table 1 here>>

CO intoxication is a serious public health challenge; 140,490 CO-related deaths were reported in the World Health Organization European Region for the period 1980–2008 (15). Within the U.K., Department of Health estimates for accidental CO poisoning in England suggest that there are 40 deaths, 200 hospital admissions and 4000 Accident & Emergency Department consultations annually (15). In Scotland the number of reported CO-related deaths and hospitalizations is increasing (16).

Unintentional CO home poisonings usually involve faulty gas heating systems, generators, cooking appliances and unattended running vehicles, and occur more frequently in men than in women (17). In addition, these accidents also happen more often in winter (18), due to the increased cold weather and loss of electrical power, which lead to increased use of gasoline-powered generators and alternative heating sources, as well as reduced house ventilation (2,19). The installation of CO alarms can reduce the number of CO poisoning deaths by half (3,19).

Certain groups within the population are at higher risk from exposure to CO. These subpopulations can be categorized by age, gender, genetic variations such as abnormalities in hemoglobin, pregnant women (20), and those with pre-existing diseases that reduce the availability of oxygen to tissues (11). Conditions that impair cardiac efficiency or vascular function may potentially compromise the cardiovascular response to CO by increasing the risk of exposure; diseases involving coronary and/or cerebral circulation are the most critical (21).

Fire deaths are one of the most common causes of CO poisoning. During an 18-month period starting in July 2015, the U.K. National Poisons Information Service recorded 1227 exposures to CO of which the majority of moderate, severe or fatal outcomes were a result of house fires (22). The recorded %COHb levels can vary widely in fire victims. For example, blood samples collected from 87 people in Japan deemed to have died from smoke inhalation as a result of fire had %COHb levels ranging from 37% to 93% (mean 77%) (23).

There are several known methods of suicide by CO poisoning. Suicidal exhaust fume inhalation (SEFI) used to be one of the most frequently used suicide methods in the U.K. (24). However, there has been an approximate 55% decline in such deaths in the last decade (25). A review of 72 cases where death occurred as a result of SEFI reported %COHb levels ranging from 35% to 90% (24). Another method of suicide involves mixing industrial chemicals such as formic and sulfuric acids in order to produce CO via a *death machine* or via *detergent suicide*, with fatal %COHb levels ranging from 64% to 93% reported in the literature (26,27). Charcoal burning suicide, which commonly involves the use of grills or *hibachis*, is also spreading widely, particularly in Asia (28,29). In a review of 79 non-fatal cases of unintentional CO poisoning from charcoal briquettes, the %COHb levels ranged from 3% to 46% (mean 22%) (30). In three fatal cases reported in the literature, the %COHb levels were 65%, 71% and 82% (31).

Although CO is a common source of intoxication, there are very few studies that compare %COHb levels among different types of death and examine the demographics of the individuals. In addition, alcohol, prescription and controlled drugs are related to an increased risk of CO-related poisoning (2,8,32), however there is a lack of information about the presence of drugs in CO-related fatalities, with most studies focusing on alcohol, and only a few on other toxicological findings (33-35). Finally, the most recent study of CO-related fatalities in Scotland was in 1994, which had a small sample size, and covered only one region of the country (24).

The aim of this study was to investigate any relationships between demographic data, sources of CO, blood alcohol concentrations (BACs) and %COHb levels in CO-positive deaths in Scotland between 2007 and 2016. To the best of the authors' knowledge, this study is also the first to report the full toxicological findings in CO-positive deaths, including all available concentrations of controlled and over-the-counter drugs, and prescription medications.

Methods

The Department of Forensic Medicine & Science at the University of Glasgow has a contract with the Crown Office and Procurator Fiscal Service (COPFS) to carry out toxicological analyses for post-mortem cases in the East and West of Scotland and Dundee, analyzing around 3000 cases per year. These analyses allow the identification and quantitation of alcohol, drugs of abuse and prescription or over-the-counter medications, as described previously (36).

This was a retrospective study that examined case data present in an in-house database and in case documentation. All cases positive for CO (%COHb ≥10% as measured by a CO-oximeter as part of routine casework) from January 2007 to May 2016 were examined. The sample size is 209. Case documents were examined for epidemiological parameters, such as date of death, age and gender, as well as some socio-medical factors, including alcohol dependency, prescribed medications and the health status of the deceased. The source of the CO (e.g. fire) and the circumstances of the death (e.g. suspicious) were also recorded. Anonymized data were tabulated in MS Excel and statistical analyses were applied using MS Excel, SPSS version 22.0 and R. Correlation and regression analyses were applied in order to examine any possible association between %COHb levels and BACs or age. A Chi-squared test was used in order to compare the information obtained from the CO-positive cases (gender and age) with census data for Scotland from 2011 (37). The Kruskal–Wallis test was applied in order to determine if the median %COHb was significantly different among the different sources of CO and between populations with and without pre-existing cardiovascular and/or respiratory diseases.

Results and Discussion

Date Distribution

Figure 1 shows the date distribution of the deaths included in this study (the date was not recorded for cases prior to January 2008). The highest numbers of fatalities were recorded in the autumn and winter months (October–March), as seen in previous studies (2).

<<Fig. 1 here>>

Gender

Information about the gender was available for all 209 cases. A significant difference (p <0.01, Chi-squared) between the percentage of males and females living in Scotland (49% and 51%, respectively) and the percentage of males and females positive for CO (69% and 31%, respectively) was found. This has also been found in previous studies. For example, an analysis of autopsy reports of 311 fire victims conducted at the University of Columbia in 1972, showed that the number of male fire deaths greatly exceeded the number of female fire deaths. The high consumption of alcohol by men, which increases the probability of becoming a fire victim, could be a factor in the difference between genders (32). There is also a higher overall suicide rate among males in the U.K (38).

Age

Information about the age was available for only 179 of the 209 cases. The ages of the deceased ranged from 2–92 years (mean 53 ± 18 years, median 52 years). Figure 2 shows the distribution in CO-positive cases according to age compared to 2011 census data.

<<Fig. 2 here>>

There was a significant difference between the age distribution of the population living in Scotland and the age distribution of CO-positive cases found in this study (p <0.001, Chi-squared). For the age range 0–29 years there were fewer CO-positive cases than might be expected, and for ages >30 years there were more CO-positive cases than might be expected (Figure 2). In a 60-year study of 1233 CO-related deaths in the Czech Republic, CO poisoning predominantly affected the middle-aged population (39). In a study focused on 530 fatalities conducted in Maryland from 1972 to 1977, the distribution of the age of victims in comparison with census data indicated a similar trend to our study; individuals between 10 and 39 years showed a low predisposition to becoming fire victims, whereas individuals between 50 and 60 years showed a higher predisposition (around two times the census expectation) (32). However, other studies have concluded that young children and the elderly are the most susceptible age groups (40), as a consequence of both group's dependency upon others for their care (33), the high oxygen consumption rate and low hemoglobin capacity in children (41), and cognitive impairment, limited mobility and poor socio-economic status in the elderly (39). A correlation between age and %COHb in this study was not detected. A previous study carried out in 1994 in Scotland of %COHb levels resulting from SEFI in 79 cases did not show any correlation between %COHb and age either (24). This may be due to the fact that different individuals are affected by CO exposure to different extents, depending on a variety of factors.

Classification of Cases

Case details were only available for 164 of the 209 cases. Five main types of case were determined according to the source of CO: *fires*, *motor vehicle exhausts*, *generators/gas supply systems*, *portable BBQs and charcoals*, or *other*. The case circumstances were also classified as *unknown*, *suspicious* or *non-suspicious*, and the non-suspicious cases were further subclassified as *undetermined*, *accidental* or *suicide*. This is shown in Table 2.

<<Table 2 here>>

Fires were the most common scenario in this study, followed by motor vehicle exhausts, and generators/gas supply systems. In a 10-year study of 176 CO poisoning deaths in Shanghai, China, 69% were non-fire CO poisoning deaths, and 31% occurred in fires. Within the non-fire CO poisoning deaths, suicides accounted for the majority of the deaths, usually via coal or charcoal burning, whereas only a small number of cases were considered accidental. As for fire-related incidents, only three cases were considered accidental, with the majority being suicides (42). The rate of suicide in our study is much lower (34%), however, there are many more undetermined and unknown cases, so the number of suicides in this study may be an underestimate. In an epidemiological study of 939 CO poisonings in the West Midlands, U.K. from 1988 to 1994, 75.5% of the deaths were suicide, 12.8% were undetermined, and 11.7% were accidental (43). In our study, non-suspicious deaths (accidental deaths and suicides) also accounted for the majority of the cases (71%), although the circumstances were unknown in a high proportion of the cases (26%) and there were also a few cases that occurred in suspicious circumstances (3%).

Sources of CO

A %COHb range was extracted for each source of CO (excluding *other* since that covers many possible circumstances), as can be seen in Table 3. Figure 3 is a box plot showing %COHb according to the source of CO. It can be seen from the figure that the distribution of %COHb in fire cases was significantly lower than in other types of cases.

<<Fig. 3 here>>

<<Table 3 here>>

The difference in median %COHb between the fire cases and each other source of CO was statistically significant (p <0.05, Kruskal–Wallis). There were no statistically significant differences in median %COHb among the non-fire-related cases. Therefore, the cases can be subgrouped in two categories: *fire-related cases* (N = 115) and *non-fire-related cases* (N = 38). The difference is probably due to the fact that in non-fire-related deaths, poisoning by CO is the leading cause of death, whereas in fire-related deaths, burns can also result in fatal injuries, which would lead to death even when the %COHb level is not in the fatal range (13).

Trends in Suicides

There were a total of 40 suicides, which accounted for 34% of the 117 non-suspicious cases or 19% of the total. The most common method of suicide was SEFI, followed by portable BBQs and charcoals, fires, and others. The use of generators/gas supply systems was the least popular method. The overall study female-to-male ratio was 1:2. However, the ratio of suicide cases in females to males was 1:7. Therefore, there was a much higher number of men using CO in completed suicides in comparison to women. Busuttil *et al.* (24) observed that the majority of their cases concerned men (90%). The most common methods in this study for men were motor vehicle exhausts (40%), BBQs and charcoals (40%), and fires (20%), whereas for women they were motor vehicle exhausts (40%), fires (23%), and BBQs and charcoals (23%).

In their study of CO poisonings in Wuhan, China, Li *et al*. (44) also found a high proportion of suicides, almost 33%. The study by Wilson *et al*. (43) as well as reporting a high percentage (76%) of completed suicides, also reported 701 patients admitted to hospital due to CO intoxication, 49% of which were attempted suicides. In the study by Janík *et al*. (39), 40% of the cases examined were suicides. The proportion of CO-positive suicides in relation to all CO-positive deaths in Scotland is therefore lower than in other areas.

Alcohol

Analysis for alcohol was carried out in 207 out of the 209 cases, and was positive (≥10 mg/100 mL) in 143 (69%) and negative in 64 (31%) cases. This is consistent with previous studies where, for example, in a study of 39 fire victims, alcohol was found in 80% (32). The BAC could only be determined for 128 of the alcohol-positive cases; the remaining 15 cases were positive for alcohol in the urine or vitreous humour only. BACs ranged from 10 to 447 mg/100 mL (mean 170 mg/100 mL, median 162 mg/100 mL). In 16 cases the BAC was <30 mg/100 mL and therefore we cannot exclude the possibility that some of the alcohol detected was a result of post-mortem bacterial production (45). A correlation between BAC and %COHb was not found in this study, however alcohol reduces the ability to react and the capacity to escape a fire (46). This is consistent with Janík *et al*. (39) who also found no statistically significant relationship between BAC and %COHb. Some studies have shown that the lethal %COHb level is higher in the presence of alcohol, suggesting that ethanol may provide some protection from CO. In contrast, other studies suggest that both substances have additive effects, increasing mortality (46).

Drugs

Information about drug analyses was collected for all 209 cases, with 108 cases (52%) testing positive. This is higher than a previous study examining the prevalence of drugs in CO-related deaths in Cleveland, Ohio, in which 41% of cases were positive (33). Forty-nine cases were positive for one or more drug(s) or active metabolite(s) in the blood, but had no alcohol in the blood (findings of inactive metabolites, acetone, beta-hydroxybutyrate and drugs administered during emergency medical treatment were excluded). Fifty-nine cases were positive for both alcohol and one or more drug(s) or active metabolite(s). Simultaneous use of ethanol and drugs potentially increases the risk of death by CO poisoning due to impaired judgement (33). A high percentage (69%) of cases was positive for more than one drug or active metabolite, with 19% positive for two, 21% positive for three, 10% positive for four, and 19% positive for five or more. Drugs were equally prevalent in suicides and accidents (63%) in this study, but less prevalent in suspicious deaths (40%). This compares to 61% of suicides, 33% of accidents, and 43% of homicides being drug-positive in the study by Przepyszny and Jenkins (33).

<<Fig. 4 here>>

<<Table 4 here>>

Figure 4 shows the drug families identified in this study. A case was considered ‘positive’ for that drug family if the blood contained one or more drug or active metabolite from that group. Many cases contained more than one member of the same drug group. As can be seen from the figure, *other prescription drugs* were the most commonly detected group (of which antidepressants were the most common), followed by *benzodiazepines* and *opioids*. The number of cases positive for controlled drugs was small. Table 4 shows the identity of the drugs found in this study. Although amphetamine was the most prevalent controlled drug, the inactive metabolites of cocaine (benzoylecgonine and ecgonine methyl ester) were present in some cases without active cocaine. This may reflect the use of cocaine some time prior to death by the deceased, or the breakdown of cocaine in post-mortem blood (47). Cocaine was the most common controlled drug detected in the study by Przepyszny and Jenkins (33). The designer benzodiazepine etizolam (48) (not prescribed in the U.K.) was detected in seven cases.

Drug concentrations in blood were reportable for 99 cases, and are also given in Table 4. In some instances, an accurate concentration could not be determined due to the level being either above or below the calibration curve for the analysis. In others, the blood sample condition precluded accurate quantification, and the drug(s) and/or active metabolite(s) were reported only as ‘Present’. It should be noted that post-mortem drug concentrations do not always represent those present at the time of death, due to phenomena such as post-mortem redistribution (e.g. for fluoxetine) (49), drug instability (e.g. for cocaine) (47), and post-mortem bacterial production (e.g. for GHB) (50).

It is well known that individuals who commit suicide may ingest large quantities of drugs and subsequently expose themselves to CO, and that these types of cases can have high drug concentrations combined with low %COHb levels (33,34). There were 13 cases in this study where one or more drug(s) was present at a concentration consistent with previous overdose fatalities. In these cases, the median %COHb was 39% (range 10–75%) and the types of cases were fire (5), unknown (3), vehicle exhaust (3), portable BBQ (1) and generator (1). Therefore, as found in a previous study, the presence of a potentially fatal concentration of a drug does not appear to affect %COHb (33). The 13 cases described above may not represent all drug-related deaths in this study, as some could have resulted from the combination of several drugs, each present at toxic or even therapeutic concentrations.

Possible interactions among particular drugs and CO could not be determined, as the majority of the cases positive for drugs had different types of drugs as well as alcohol, in addition to other factors, such as pre-existing disease.

Influence of Disease

Medical histories were only available for 134 cases. Twenty-seven cases had pre-existing *cardiovascular disease* (e.g. angina), with a mean and median %COHb of 37%. Twelve cases had pre-existing *respiratory disease* (e.g. asthma), with a mean and median %COHb of 43% and 52%, respectively. Eighty-seven cases had *neither* disease, with a mean and median %COHb of 48% and 51%, respectively. Seven cases had a history of *both* disease types, with a mean and median %COHb of 42% and 30%, respectively. Figure 5 is a box plot that shows the %COHb level according to the presence of pre-existing disease. There was no statistically significant correlation between %COHb and any of the disease states.

<<Fig. 5 here>>

Forty-nine cases had a history of alcoholism or alcohol dependency, with a mean and median %COHb of 48% overall. Excluding those with a history of cardiovascular and/or respiratory disease, there were 38 cases with a mean and median %COHb of 46% and 47%, respectively.

Limitations

There are several important limitations to this study. Firstly, this study does not cover all the regions of Scotland, as data from the far Northern regions were not included. For the regions where data were available, it was not possible to account for concomitant policies that may have caused differences in the numbers of CO-related deaths (e.g. local fire safety or CO alarm campaigns). Secondly, detailed case circumstances were not available in all instances, leading to a high number of unknown/undetermined classifications. The suicide cases in this study were also only considered *apparent* at the time the case was submitted to the laboratory, and may have been reclassified following completion of the death investigation. Thirdly, the presence of COHb in post-mortem blood is not the same as a causal factor, and the majority of the cases had different factors or circumstances that may have influenced the %COHb, which makes it difficult to determine the role of specific factors in CO toxicity. As the official cause of death was not recorded for all cases, there may have been instances where death was unrelated to CO (e.g. drug overdose or a fall from height). Fourthly, in terms of the toxicology, in some cases the %COHb level was low (~10%), which is consistent with normal %COHb levels in some smokers (51). Pre-analytical conditions such as the post-mortem interval and sample condition, and loss of CO from the headspace of sample vials in some cases could have led to %COHb levels that did not reflect those present at the time of death (52). Other toxic fire gases such as HCN or CO_2 that could have contributed to the fire deaths in this study were also not analyzed (13,21,53), and the same range of drug tests was not carried out in every case due to differences in requests by the submitting pathologists, influenced by the individual case circumstances as well as financial constraints. Where a deceased was positive for more than one drug group, drug–drug interactions were not considered.

Finally, there is a lack of a control group for the study, for example, in order to determine if alcohol or alcohol dependency is found at a higher frequency in CO-positive cases than in other types of incidents, these data should be compared with a control dataset from non-CO-positive cases.

Conclusions

This study has examined 209 post-mortem CO-positive cases from Scotland between 2007 and 2016 for correlation between the %COHb and epidemiological factors such as the source of CO, the presence of alcohol, and a history of pre-existing disease. Other parameters such as the date of death, age and gender were also investigated. It was the first study to examine the full toxicological findings in CO-positive cases and report all available concentrations of prescription, over-the-counter and controlled drugs. The highest numbers of fatalities were recorded in the autumn and winter months (October–March), and the main sources of CO were fire, followed by vehicle exhausts, portable BBQs, and generators/gas supply systems. The majority of cases were classified as non-suspicious, with the number of apparent suicides being higher than the number of accidental deaths. Males accounted for the majority of the suicides, with motor vehicle exhausts being the main source of CO in these types of case. Those under the age of 30 were under-represented in comparison to census data. The median %COHb in fire-related cases was significantly lower than in non-fire-related cases, but there was no relationship between %COHb and age, blood alcohol concentration or the presence of pre-existing cardiovascular and/or respiratory disease. Examination of the toxicology results revealed that prescription medications (antidepressants, benzodiazepines and opioids) were the most commonly detected drug group in CO-positive cases, and that the number of cases positive for controlled drugs was small. Over-the-counter drugs, such as paracetamol were also detected.

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TABLE 1—*Effects of CO in humans according to %COHb (1,12).*

%COHb	Effects in humans
<1	Endogenous CO: neuroprotective effects
1–9	Chest pain, possibly slight headache, decrease in exercise duration
15–20	Headache, visual problems
20–30	Severe headache, fatigue, nausea, dizziness
30–40	Severe headache, nausea, vomiting, hypotension, increased heart and respiratory rate, loss of consciousness
40–50	Hypotension, seizures, coma, possible death
60–70	Lethal

TABLE 2—*Classification of cases.*

	Fires	Motor vehicle exhausts	Generators/gas supply systems	Portable BBQs and charcoals	Other*	Total (%)
Unknown	34	2	3	0	3	42 (26)
Suspicious	5	0	0	0	0	5 (3)
Non-suspicious	77	17	6	10	7	117 (71)
Total (%)	116 (71)	19 (12)	9 (5)	10 (6)	10 (6)	164
Non-suspicious cases						
Undetermined	52	1	4	0	4	61 (52)
Accidental	16	0	0	0	0	16 (14)
Suicide	9	16	2	10	3	40 (34)
Total non-suspicious	77	17	6	10	7	117

*Other circumstances involved petrol chainsaws and propane canisters among others.

TABLE 3—*%COHb ranges for different sources of CO.*

Source of CO	*N* cases	Range of %COHb	Mean %COHb ± SD	Median %COHb
Fires	115	10–84	42 ± 20	40
Vehicle exhausts*	19	24–84	60 ± 20	69
Generator/gas supply systems*	9	36–74	62 ± 12	66
Portable BBQs and charcoals*	10	50–80	68 ± 9	69

*Grouped as *non-fire-related* cases.

TABLE 4—*Drugs detected in this study and their concentrations in post-mortem blood.*

Drug group	Drug	Concentration (mg/L) Mean (*n* of cases, range)*
Benzodiazepines	Chlordiazepoxide	0.12
	Diazepam	0.24 (*n* = 30, range 0.01–1.3)
	Nordiazepam	0.20 (*n* = 27, range 0.05–0.62)
	Etizolam	0.06 (*n* = 7, range 0.006–0.11)
	Lormetazepam	0.08
	Oxazepam	0.05, 0.07
	Temazepam	0.10 (*n* = 5, range 0.03–0.27)
Opioids	Buprenorphine	175
	Norbuprenorphine	3, 82
	Codeine	0.49 (*n* = 10, range 0.03–2.6)
	Dihydrocodeine	0.69 (*n* = 9, range 0.03–3.0)
	Methadone	1.02 (*n* = 4, range 0.51–1.4)
	Morphine	0.12 (*n* = 7, range 0.03–0.23)
	Tramadol	3.50 (*n* = 6, range 0.75–7.2)
Other prescription Antidepressants	Amitriptyline	0.89 (*n* = 7, range 0.09–3.8)
	Nortriptyline	—
	Citalopram	0.31 (*n* = 14, range 0.06–0.83)
	Desipramine	—
	Dothiepin	0.65
	Duloxetine	—
	Fluoxetine	0.95 (*n* = 10, range 0.17–2.0)
	Norfluoxetine	0.70 (*n* = 10, range 0.18–1.6)
	Mirtazapine	0.26 (*n* = 12, range 0.02–0.79)
	Sertraline	0.22, 0.06, 0.36
	Trazodone	—
	Venlafaxine	0.64, 0.71
Antipsychotics	Clozapine	1.1
	Olanzapine	0.25
	Risperidone and 9-*OH*-risperidone	—
Anticonvulsants	Carbamazepine	4.98 (*n* = 4, range 2.6–10)
	Pregabalin	1.8
Other	Atenolol	0.36, 0.43, 0.69
	Cyclizine	0.09, 0.66, 0.80
	Lignocaine	0.38
	Procyclidine	0.06, 0.11
	Promethazine	0.11, 1.0
	Propranolol	0.16, 0.18
	Quinine	0.35
	Trimethoprim	—
	Zopiclone	0.27 (*n* = 7, range 0.13–0.65)
Over-the-counter Analgesics	Ibuprofen	6.4
	Paracetamol	61 (*n* = 15, range 11–206)
Antihistamines	Chlorpheniramine	0.02
	Diphenhydramine	0.05, 0.85
Controlled Stimulants	Amphetamine	0.45 (*n* = 8, range 0.1–1.2)
	Cocaethylene	0.15
	Cocaine	0.15, 1.4

Drug group	Drug	Concentration (mg/L) Mean (*n* of cases, range)*
Other	Δ^9-Tetrahydrocannabinol (THC)	20 (*n* = 5, range 6–39) ng/mL
	γ-Hydroxybutyrate (GHB)	57, 62
	MDMB-CHMICA (synthetic cannabinoid)	—

*Where three or fewer concentrations are reported, all values are given. *n* is the number of cases with a reportable concentration.

Figure Legends

FIG. 1—*Distribution of cases according to date.*

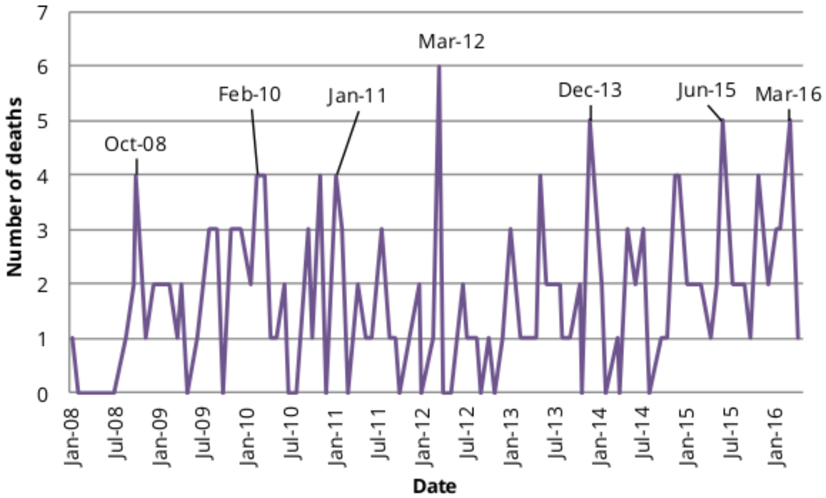

FIG. 2—*Distribution of cases according to age, comparison with 2011 census data.*

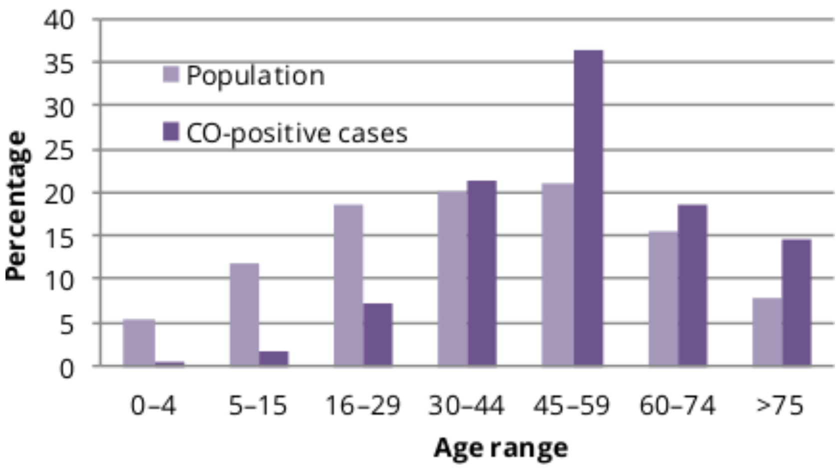

FIG. 3—*Box plot of the %COHb according to the source of CO (circles indicate outliers).*

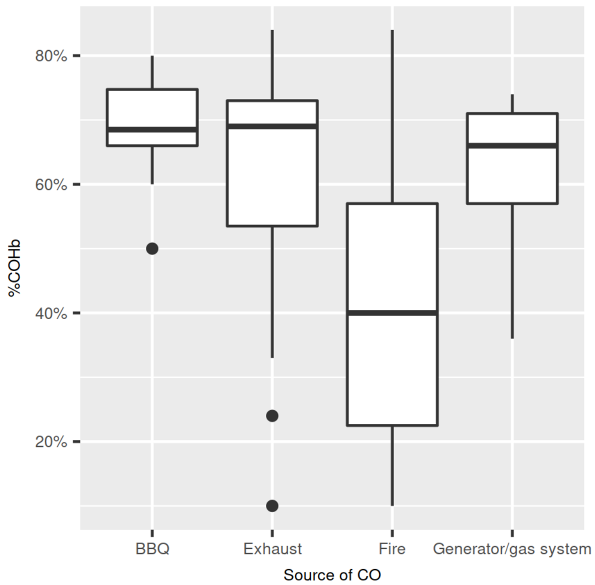

FIG. 4—*Distribution of the drug families detected in the cases in this study.*

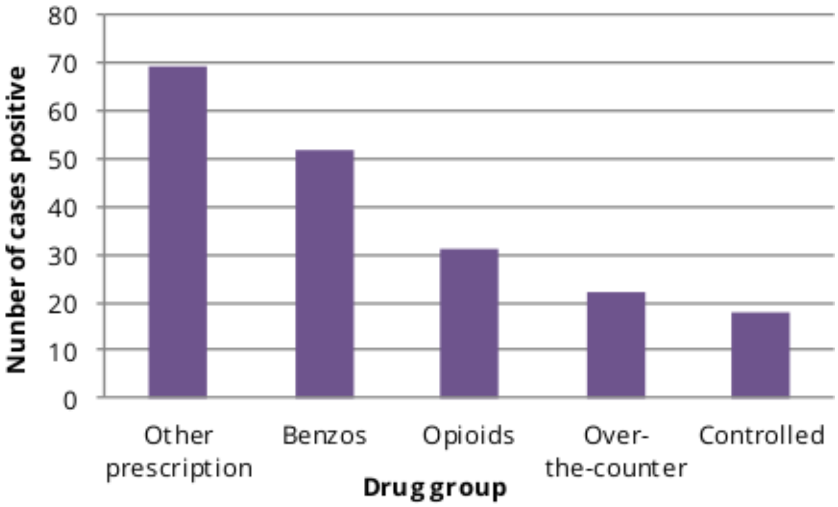

FIG. 5—*Box plot of the %COHb according to the presence of pre-existing disease.*