

NIST Technical Note 1846

Carbon Monoxide Exposure Analyses in Support of Emission Rate Limits for Portable Generators

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ABSTRACT

The U.S. Consumer Product Safety Commission (CPSC) staff is considering developing a performance standard to address the hazard of acute residential carbon monoxide (CO) exposures from portable gasoline engine-powered generators that result in death or serious and lasting adverse health effects in exposed individuals. As of April 23, 2013, the CPSC databases contain records of at least 739 deaths (involving 552 incidents) from CO poisoning caused by consumer use of a generator in the period of 1999 through 2012. There were an additional 61 CO poisoning deaths (involving 45 incidents) associated with consumer use of both a generator and at least one other CO-producing consumer appliance, for a total of 800 CO poisoning deaths (involving 597 incidents) associated with generators for the same 14-year period. The majority of these deaths occurred when consumers used a generator in an enclosed or partially enclosed space. A smaller percentage occurred when the generator was operated outdoors near an open door, window or vent. A previous computer simulation study by NIST analyzed the effects of generator location and CO emission rate on occupant exposures in single-family residential buildings. This report describes additional analyses of these simulation results to consider other metrics of exposure, including the time to achieve specific levels of carboxyhemoglobin (COHb) as a function of generator location and emission rate.

KEYWORDS: carbon monoxide; CONTAM; emergency generators; multizone airflow model; simulation; test procedure

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1. INTRODUCTION

The U.S. Consumer Product Safety Commission (CPSC) and others are concerned about the hazard of residential carbon monoxide (CO) exposures associated with portable gasoline-powered generators, which can result in death or serious adverse health effects in exposed individuals. As of April 23, 2013, CPSC databases contain records of at least 739 deaths (involving 552 incidents) from CO poisoning caused by consumer use of a generator between 1999 and 2012 (Hnatov 2013). There were an additional 61 CO poisoning deaths (involving 45 incidents) associated with consumer use of both a generator and at least one other CO-producing consumer appliance at the same time, for a total of 800 CO poisoning deaths (involving 597 incidents) associated with the use of generators for the same 14-year period. The majority of these deaths occurred when consumers used a generator in an enclosed or partially enclosed space. A smaller percentage occurred when the generator was operated outdoors near an open door, window or vent. While avoiding the operation of such generators in or near a home is expected to reduce indoor CO exposures significantly, it may not be realistic to expect such usage to be eliminated completely.

Another means of reducing these exposures is to decrease the amount of CO emitted from generators. The magnitude of reductions needed to limit exposures depends on the complex relationship between CO emissions from generators and occupant exposure. This relationship involves interactions between: generator location and operation; house characteristics; occupant location, activity and health status; and, weather conditions. In order to support life-safety based analyses of potential CO emission limits, a computer simulation study was conducted to evaluate indoor exposures as a function of generator source location and CO emission rate (Persily et al. 2013). That simulation study employed the multizone airflow and contaminant transport model CONTAM (Walton and Dols 2005), which was applied to 87 dwellings that are representative of the U.S. housing stock. A total of almost 100 000 individual 24-hour simulations were conducted that cover a range of house layouts and sizes, airtightness levels and weather conditions, as well as generator locations and CO source strengths. The results of the simulations were summarized as frequency distributions of the maximum carboxyhemoglobin (COHb) levels that were reached in the occupied zones of the simulated homes.

Prior to and since the publication of that report, the CPSC has worked to reduce the occurrence of future generator-related CO poisoning incidents, especially those associated with operating a generator indoors. To that end, the CPSC issued an *Advance Notice of Proposed Rulemaking; Request for Comments and Information* in 2006 describing its strategy to reduce generator engine CO emission rates (CPSC 2006). A part of this strategy is the development of a standard test method for determining CO emission rates from portable generators operating in an enclosed space, as well as criteria for assessing the measured emission rates. A draft test method has been developed by NIST (Emmerich and Persily 2014). This report describes additional analyses of the simulation data in Persily et al. (2013) to support the development of the criteria by which measured emission rates could be assessed, but the criteria themselves are not contained in this report. The new analyses include an updated presentation of the frequency distributions of the maximum COHb values as a function of generator location and CO emission rate. New analysis is also included to quantify the elapsed time required to reach key COHb levels, again as a function of location and emission rate. This report is best understood if considered in conjunction with the previous analysis (Persily et al. 2013).

2. DESCRIPTION OF ANALYSIS APPROACH

Previous simulations of residential CO exposure from portable generator operation included close to 100 000, 24-h simulations of CO concentrations in 87 individual houses (Persily et al. 2013). Simulations were performed in each house for three generator locations including a first floor zone, attached garage, and basement; though not all of the houses had garages and basements.

The homes used in these simulations are based on a collection of dwellings that were previously defined by Persily et al. (2006), which includes just over 200 dwellings that together represented 80 % of the U.S. housing stock at the time of their definition. The dwellings are grouped into four housing types: detached (83 homes), attached (53), manufactured homes (4) and apartments (69). This set of dwellings is defined based on the following variables using data in the US Census Bureau's American Housing Survey (AHS) (HUD 1999) and the US Department of Energy's (DOE) Residential Energy Consumption Survey (RECS) (DOE 2005): housing type, number of stories, heated floor area, year built, foundation type, presence of a garage, type of heating equipment, number of bedrooms, number of bathrooms, and number of other rooms. Multizone representations of the dwellings were created in the airflow and contaminant transport model CONTAM for analyzing a range of ventilation and indoor air quality issues.

Only the detached and manufactured home models were used in the previous analysis of CO exposure from generators, for a total of 87 homes. The attached and apartment models were not employed based on challenges in accounting for airflow between units and the lack of air leakage data for the partitions between units. Given the prevalence of single-family dwellings within the U.S. housing stock, these 87 homes represent about 60 % of U.S. dwellings.

Two types of generator CO source profiles were considered: a constant rate lasting for several hours and a short "burst" intended to represent a generator with CO emission control technology (e.g. a shut off device) for which a constant generation rate is not a good assumption. The constant CO generation rates for the first type of source and the mass of CO released by the second used in the simulations covered a range of values based on measurements and analyses conducted by NIST (Emmerich et al. 2013). The source scenarios that were analyzed include the following:

Constant generation rate for 18 hours with the generator in one of the following locations:

- Closed garage (if applicable to the model house)
- Open garage (if applicable to the model house)
- Basement (if applicable to the model house)
- Interior room (on first floor)

Short term burst source with the generator in one of the following locations:

- Closed garage (if applicable to the model house)
- Basement (if applicable to the model house)
- Interior room (on first floor)

The simulated CO emission rates for the constant (in units of g/h) and the burst (total mass released in g) sources are contained in Table 1. For all of the simulations the outdoor CO concentration was assumed to equal zero, since the indoor concentrations of interest are well above typical ambient levels.

Constant sources (g/h)	Burst sources (g)
1000	1000
750	500
500	200
400	100
200	50
100	25
50	15
20	5

Table 1 CO emission rates used in simulation analyses

Each house and generator source combination was analyzed for 28 individual days. Each of the 28 simulations employed a different day of weather conditions, including outdoor temperature, wind speed and wind direction, that varied each day on an hourly basis. These 28 days of weather include two weeks of cold weather, one week of warm and one week of mild.

Each simulation corresponds to one house, one source location and source strength, and one day of weather. The output of each simulation is the CO concentration versus time in each zone of the house. Based on the simulation time step of 5 min, the output consists of 288 concentrations in each zone for each 24-h simulation. COHb levels were calculated for a representative healthy adult in each occupied zone of the house over the 24-h simulation period using the Coburn-Forster-Kane (CFK) equation (Petersen and Stewart 1975, Coburn et al. 1965), assuming an RMV (respiratory minute volume) of 15 L/min and an initial COHb level of 0.0024 ml/ml. The maximum COHb (maxCOHb) value among the occupied zones of each simulation case was used as the output metric for each simulation. The maxCOHb values were considered separately for each source location to generate a frequency distribution for each source/location combination. Fifty-six such distributions were generated from the simulation results, i.e., seven source locations times eight source strengths per location. These distributions are presented in Persily et al. (2013).

2.1 Maximum emissions for burst sources

The frequency distributions presented in Persily et al. (2013) enabled the estimation of the maximum CO source strength from the simulated portable generators that correspond to a fraction of the simulation cases being below a specific value of maxCOHb. Table 2 (excerpted from that reference) presents the maximum source strengths for each source location and type that corresponds to 80 % of the simulated cases having a COHb value below 30 %. For example, for a generator located in the closed garage, a constant CO emission rate of 139 g/h resulted in 80 % of the cases simulated to have a maximum COHb value in the occupied zones of each house that was less than 30 %. Note that the values of 80 % of cases and 30 % maxCOHb are used only for illustrative purposes and are not presented as life-safety based limits to support policy or regulatory decisions. For reference, COHb values of 30 % are associated with dizziness, nausea and convulsions within 45 min and becoming insensible within 2 h (Goldstein 2008).

Source location/type	Maximum source strength
Closed garage/constant	139 g/h
Open garage/constant	646 g/h
Closed garage/burst	443 g
Basement/constant	< 20 g/h*
Basement/burst	123 g
Interior room/constant	< 20 g/h*
Interior room/burst	83 g

* No simulated source strengths result in 80 % of cases having maxCOHb < 30 %.

Table 2 Maximum source strength corresponding to 80 % of the simulated cases with maxCOHb < 30 % (source strengths based on interpolation between simulated values)

In the current study, this analysis of maximum emissions was repeated with the following modifications. First, only the burst cases were considered, and maximum source strengths were estimated for 80 %, 90 % and 95 % of the cases being below 20 % COHb rather than 30 %. Also, in order to better match the house size distributions of actual CO poisoning incidents reported in Hnatov (2013), the simulation cases for the four small manufactured homes were included in the frequency distributions for each source location case five additional times. Table 3 shows the distribution of house sizes in which CO poisoning incidents associated with portable generators occur, for those incidents where house size is known. The percentage of such incidents for the four house size ranges considered is in the second column of the table. The next two columns include the four discrete house sizes considered in the NIST simulations and the number of houses of each size. The percentages of homes simulated for each size are then shown in the next column. The rightmost column shows the percentage of homes after including the results from each of the manufactured homes six times. Comparing the percentages in the second and last columns, the adjustment in the number of homes results in a good match in the distribution of house sizes.

CPSC data from Hnatov (2013)		Houses in NIST simulations			
House size, floor area (m ²)	% of incidents where house size is known	Floor area (m ²)	Number of houses as simulated	% of houses as simulated	% of houses, with manufactured homes entered six times
46 to 93	22	86	4	5	22
> 93 to 139	37	107	37	43	35
> 139 to 186	26	180	30	35	28
>186	15	276	16	18	15

Table 3 Distribution of house sizes associated with CO incidents and in NIST analysis

2.2 Time to reach COHb levels

Additional analyses of the existing simulation results were performed in order to support CPSC consideration of the time available for occupants to first become aware that a problem exists and then take action in response to the elevated CO levels. Awareness of a problem could result from the onset of adverse health symptoms as COHb levels rise, without an individual necessarily understanding the underlying cause, or from the activation of a CO alarm. The previous simulation results for both the burst and constant sources were analyzed to determine the time to reach 10 % COHb for each simulation case. In addition, the incremental times to progress from 10 % to 20 % COHb, from 20 % to 30 %, and from 30 % to 40 % were also determined. For reference, COHb values of 20 % are associated with a slight headache in 2 h to 3 h and a loss of judgment, and levels of 50 % are associated with headache, dizziness and nausea in 5 min to 10 min and death within 30 min (Goldstein 2008). The 40 % value was considered as an intermediate step between 30 % and 50 % COHb. These time analyses also included the results from the four manufactured houses an additional five times to more closely match the house size distributions of the CPSC incident data. This time analysis was performed using the maxCOHb values for all zones in each case and then once again excluding zones in which the generator was located. Since the maxCOHb values only considered occupied zones, the second analysis did not always yield different results. For example, the analysis excluding generator zones for the three garage source locations were not different as the garage was not considered an occupied zone.

3. RESULTS

This section presents the results of the reanalysis of the burst source strengths corresponding to maxCOHb levels less than 20 % and the analysis of the times to reach key levels of COHb.

3.1 Maximum emissions for burst sources

Table 4 presents the results of the re-analysis of the burst sources to determine the maximum source strength corresponding to less than 80 %, 90 % and 95 % of the simulated cases having maxCOHb values less than 20 %. Compared with the results from the previous analysis in Table 2, the maximum source strengths for 80 % of the cases being below 20 % COHb are all less than the maximum source strengths using 30 % maxCOHb as the criteria. And as expected, the stricter limits of 90 % and 95 % reduce the maximum source strength further. As noted above, these results include the data from the four manufactured houses five additional times, which was not the case for the results in Table 2.

Source location/type	Maximum source strength (g)		
	80 %	90 %	95 %
Closed garage/burst	325	153	103
Basement/burst	96	36	25
Interior room/burst	59	33	22
All burst sources combined	92	42	27

Table 4 Maximum source strength corresponding to 80 %, 90 % and 95 % of simulated burst source cases with maxCOHb < 20 %

3.2 Time to reach COHb levels

As described above, the simulation results from Persily et al. (2013) were reanalyzed to determine the time to reach 10 % COHb for each simulation case. In addition, the incremental times to progress from 10 % to 20 % COHb, from 20 % to 30 %, and from 30 % to 40 % were also determined. These time analyses included the results from the four manufactured houses an additional five times to more closely match the house size distributions in the CPSC incident data. Tables 5a and 5b show the results of these calculations for the interior room burst source, while Figures 1a through 1d show them graphically. This source includes all of the houses simulated, as they all have interior rooms on the first floor. Therefore, the number of houses included in the results includes the 83 single family detached homes plus 24 manufactured homes (4 houses included 6 times each) for a total of 107 homes. Since each source strength was simulated for 28 days of weather, there are 2996 cases for each source strength in the table.

Considering first the time to reach 10 % COHb, the first row in Table 5a shows the number of cases that do not reach that value for each source strength. For a burst source of 1000 g in a first floor room, 1160 cases of the 2996 total cases (38.7 %) do not reach 10 % COHb in the zone with the highest COHb levels. As the burst source mass decreases down to 5 g, the number of cases not reaching 10 % COHb increases, reaching almost 100 % for the lowest mass. The following rows in the table show how many cases reach 10 % maxCOHb in less than 10 min and in subsequent 10 min bins up to more than 120 min. As the source mass decreases from 1000 g to 5 g, for those

cases that do reach 10 % COHb, the time required to reach 10 % increases as expected. This increase can also be seen in the upper graph in Figure 1a, where the fraction of cases for each time interval tends to increase for the higher source strengths as time increases.

The lower half of Table 5a shows the results for the time to get from 10 % to 20 % maxCOHb. The first line of the table shows the number of cases that do not reach 20 % COHb for each source mass released in a first floor room, which is always higher than the number that didn't reach 10 %. The second row shows the number of cases that reached 10 % COHb but did not reach 20 %. Below these two rows, the table shows the number of cases in each time interval for each source mass. Table 5b shows analogous results for the times to get from 20 % to 30 % maxCOHb and from 30 % to 40 % maxCOHb. Note that for the two lowest source masses, none of the 2996 cases reach 30 % maxCOHb. Appendix A of this report contains all of the time analysis results, first for all seven source locations and types considering all occupied zones and then considering only the occupied zones that didn't contain the generator.

Table 6 summarizes all the results for 40 % maxCOHb, including the number of cases that don't reach that value, the number that reach it in less than 30 min, and the number that reach it in more than 30 min. The 40 % maxCOHb and 30 min values are used only in this summary for illustrative purposes and are not suggested as criteria for evaluating CO exposure. As noted earlier, there are 2996 total cases for each source strength for the first floor generator location, as it occurs in all 107 homes considered. Since not all houses have garages and basements, there are a smaller number of cases for those source locations. Specifically there are 1596 cases for the garage sources and 1176 cases for the basement sources. For interior sources (basement and first floor), constant CO rates of less than 50 g/h correspond to significantly less than half of cases reaching 40 % COHb. However, emission rates of 100 g/h or less correspond to less than half of the remaining cases taking more than 30 min to reach 40 % COHb. For the closed garage, the emission rate needs to be less than 500 g/h to have significantly less than half of the cases reaching 40 % COHb and to have most of these that reach 40 % to do so in more than 30 min.

For burst sources in the basement and first floor, the mass emitted needs to be 200 g or less to have a large majority of the cases that reach 40 % COHb. For the burst source in the closed garage, as long as the mass emitted is 1000 g or less, most cases will be below 40 % COHb.

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases reaching 10 % COHb							
Don't reach 10 %	1160	1238	1416	1629	2027	2447	2704	2983
< 10 min	601	510	476	476	346	0	0	0
10 min to 20 min	274	188	46	2	130	172	0	0
20 min to 30 min	148	170	87	15	0	248	28	0
30 min to 40 min	121	107	143	63	3	42	137	0
40 min to 50 min	94	81	91	48	7	4	57	0
50 min to 60 min	112	79	64	76	10	1	27	0
60 min to 70 min	85	67	49	91	27	0	19	0
70 min to 80 min	41	70	47	58	24	0	5	0
80 min to 90 min	43	81	51	45	16	1	0	0
90 min to 100 min	23	50	42	26	27	1	0	0
100 min to 110 min	4	26	18	10	7	0	0	0
110 min to 120 min	20	54	80	39	56	11	0	0
> 120 min	270	275	386	418	316	69	19	13
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	1247	1375	1672	2070	2470	2796	2951	2996
Reach 10 % but not 20%	87	137	256	441	443	349	247	13
< 10 min	923	709	493	474	124	0	0	0
10 min to 20 min	311	264	115	7	303	25	0	0
20 min to 30 min	218	196	208	33	25	64	0	0
30 min to 40 min	101	158	94	46	5	65	2	0
40 min to 50 min	73	118	73	53	3	22	16	0
50 min to 60 min	30	46	74	55	18	15	7	0
60 min to 70 min	27	32	48	45	5	5	7	0
70 min to 80 min	10	28	50	27	9	0	6	0
80 min to 90 min	7	24	61	19	7	0	3	0
90 min to 100 min	19	6	34	39	7	0	3	0
100 min to 110 min	2	5	7	2	0	0	1	0
110 min to 120 min	6	8	20	10	8	0	0	0
> 120 min	22	27	47	116	12	4	0	0

Table 5a Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: first floor burst source

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	1325	1499	1886	2411	2705	2942	2996	2996
Reach 20 % but not 30%	78	124	214	341	235	146	45	0
< 10 min	992	772	491	467	50	0	0	0
10 min to 20 min	349	223	95	4	165	0	0	0
20 min to 30 min	158	185	123	23	34	17	0	0
30 min to 40 min	65	119	81	17	24	12	0	0
40 min to 50 min	31	86	73	19	2	13	0	0
50 min to 60 min	24	28	44	12	0	5	0	0
60 min to 70 min	24	24	33	10	1	6	0	0
70 min to 80 min	11	14	19	7	4	1	0	0
80 min to 90 min	6	25	33	5	4	0	0	0
90 min to 100 min	2	5	9	2	1	0	0	0
100 min to 110 min	1	2	14	1	0	0	0	0
110 min to 120 min	3	6	30	6	0	0	0	0
> 120 min	5	8	65	12	6	0	0	0
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	1412	1634	2210	2504	2838	2983	2996	2996
Reach 30 % but not 40%	87	135	324	93	133	41	0	0
< 10 min	1023	759	487	351	16	0	0	0
10 min to 20 min	305	225	61	89	85	0	0	0
20 min to 30 min	142	128	57	6	37	0	0	0
30 min to 40 min	51	128	45	19	16	0	0	0
40 min to 50 min	26	43	46	9	4	6	0	0
50 min to 60 min	14	26	17	6	0	2	0	0
60 min to 70 min	5	8	9	5	0	5	0	0
70 min to 80 min	2	8	25	2	0	0	0	0
80 min to 90 min	1	8	4	1	0	0	0	0
90 min to 100 min	1	4	3	2	0	0	0	0
100 min to 110 min	0	2	1	0	0	0	0	0
110 min to 120 min	12	3	1	1	0	0	0	0
> 120 min	2	20	30	1	0	0	0	0

Table 5b Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: first floor burst source

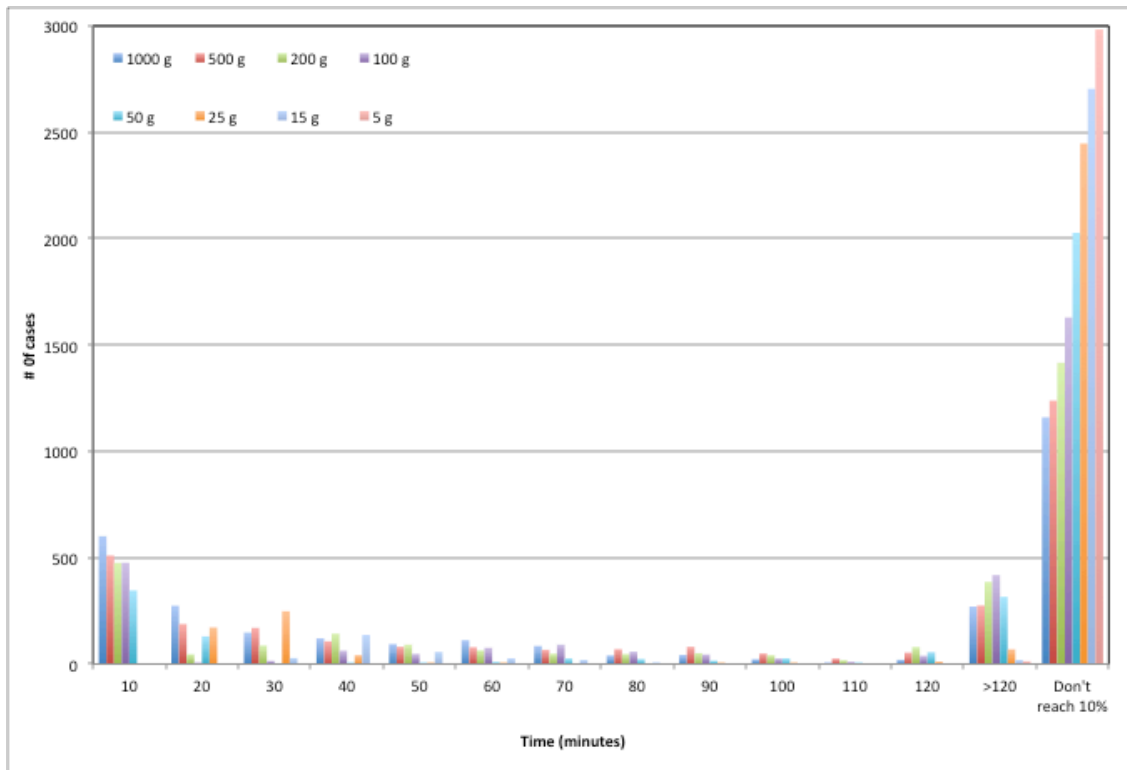


Figure 1a Number of cases sorted by time to reach 10 % COHb: first floor burst source

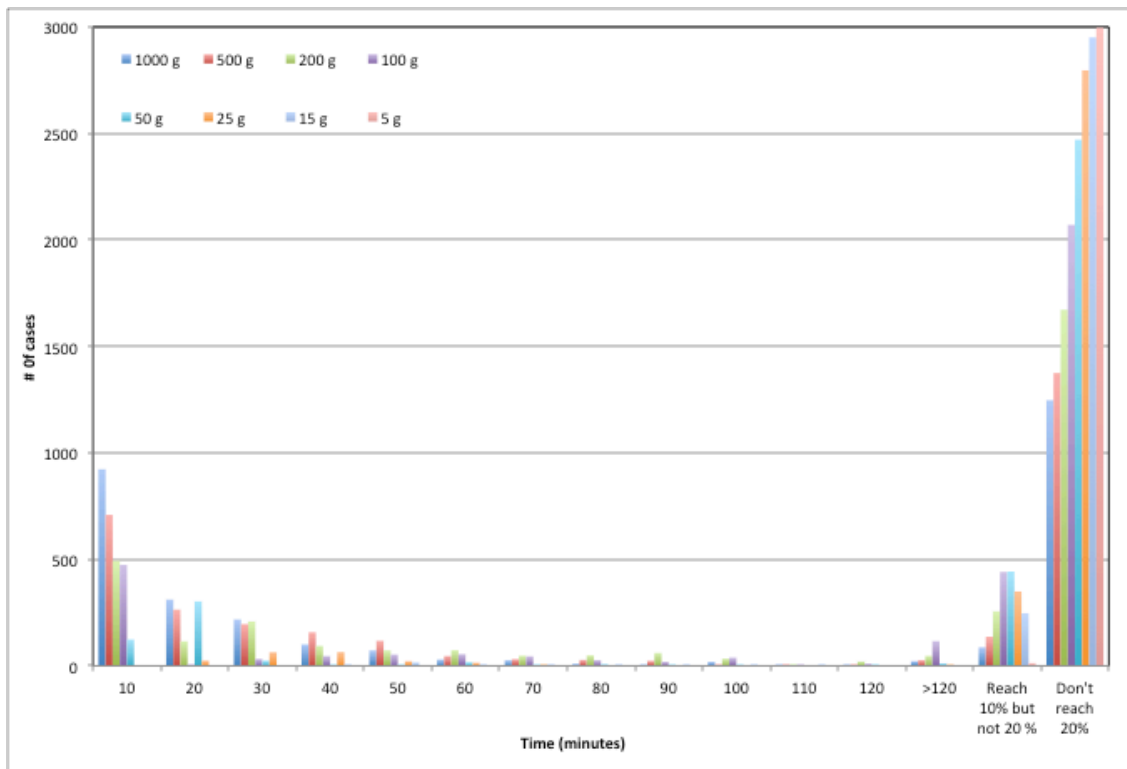


Figure 1b Number of cases sorted by time to progress from 10 % to 20 % COHb: first floor burst source

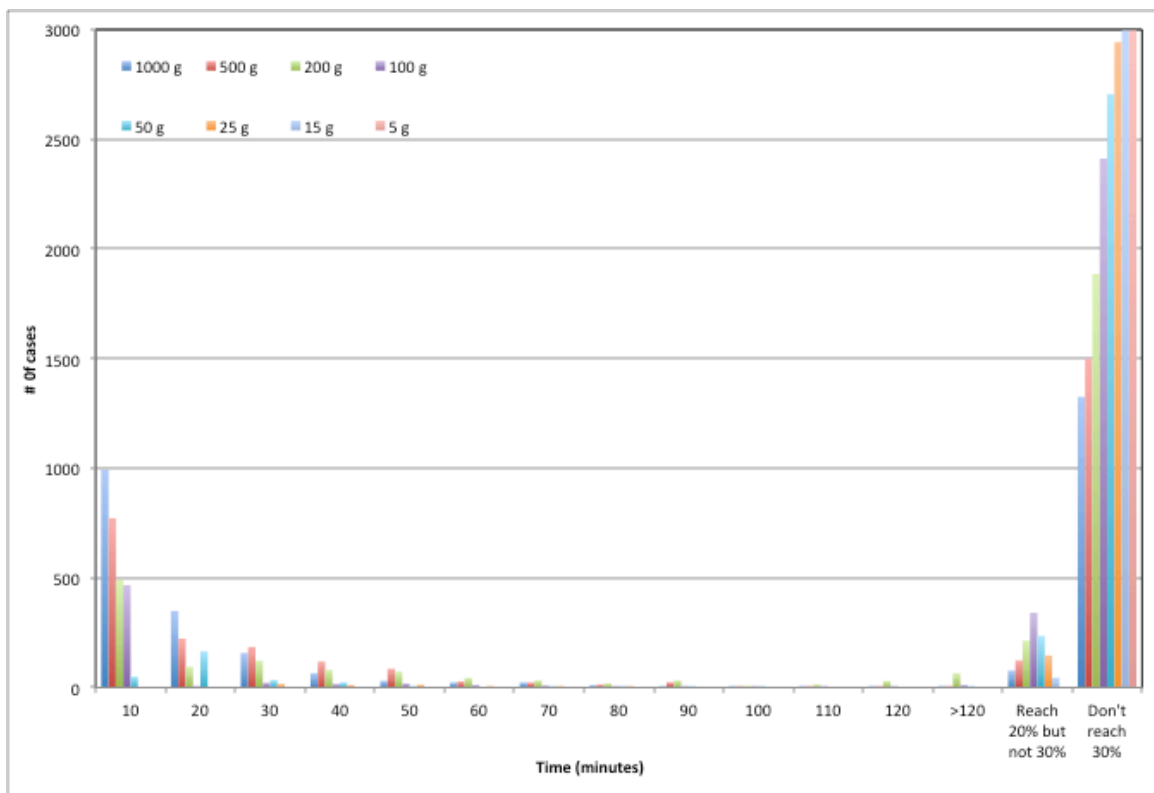


Figure 1c Number of cases sorted by time to progress from 20 % to 30 % COHb: first floor burst source

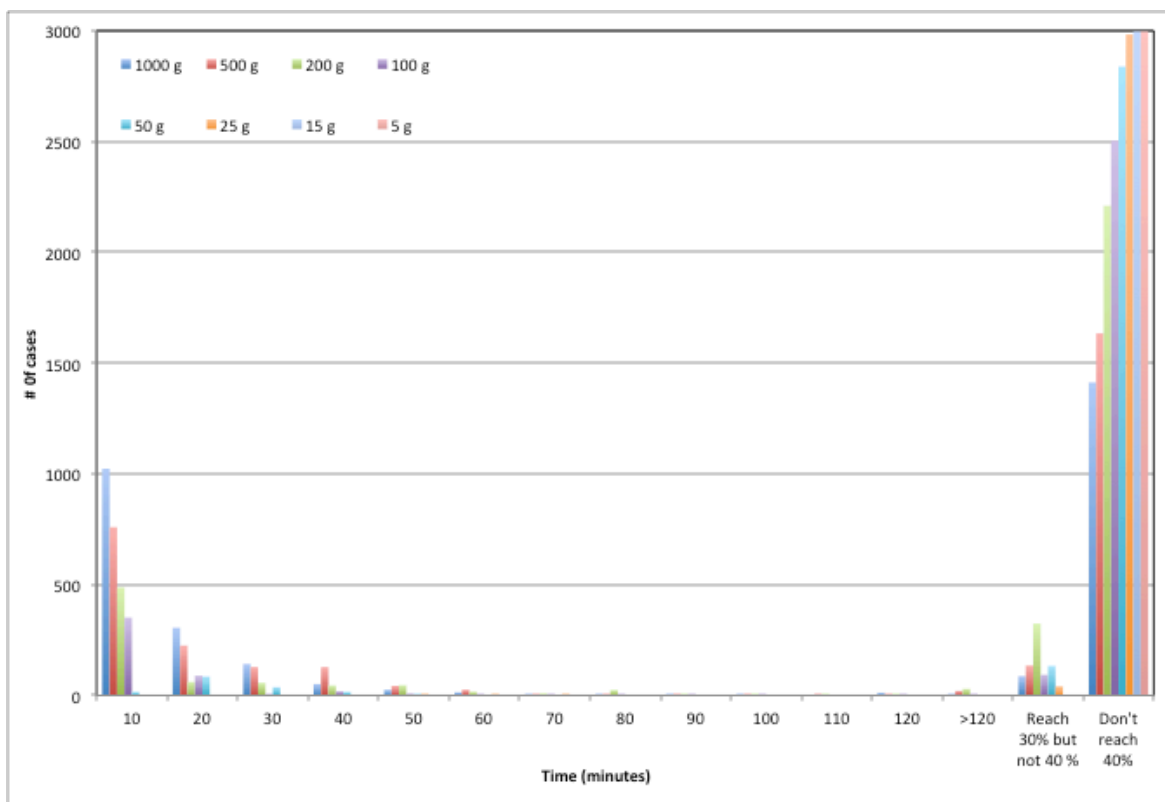


Figure 1d Number of cases sorted by time to progress from 30 % to 40 % COHb: first floor burst source

Source location/type		CO Emission Rate (g/h)							
		1000	750	500	400	200	100	50	20
Closed garage/constant	Don't reach 40 %	755	843	978	1045	1289	1490	1587	1596
	Reach 40 % in < 30 min	574	482	305	218	22	0	0	0
	Reach 40 % in > 30 min	267	271	313	333	285	106	9	0
Open garage/constant	Don't reach 40 %	1349	1529	1596	1596	1596	1596	1596	1596
	Reach 40 % in < 30 min	4	0	0	0	0	0	0	0
	Reach 40 % in > 30 min	243	67	0	0	0	0	0	0
Basement/constant									
All zones	Don't reach 40 %	73	78	78	81	91	185	631	1046
	Reach 40 % in < 30 min	1079	1064	961	929	671	344	89	0
	Reach 40 % in > 30 min	24	34	137	166	414	647	456	130
<i>Non-generator zones</i>	<i>Don't reach 40 %</i>	<i>73</i>	<i>78</i>	<i>78</i>	<i>82</i>	<i>94</i>	<i>193</i>	<i>643</i>	<i>1048</i>
	<i>Reach 40 % in < 30 min</i>	<i>1078</i>	<i>1062</i>	<i>958</i>	<i>927</i>	<i>661</i>	<i>328</i>	<i>81</i>	<i>0</i>
	<i>Reach 40 % in > 30 min</i>	<i>25</i>	<i>36</i>	<i>140</i>	<i>167</i>	<i>421</i>	<i>655</i>	<i>452</i>	<i>128</i>
First floor/constant									
All zones	Don't reach 40 %	48	48	49	49	51	259	1224	2565
	Reach 40 % in < 30 min	2939	2939	2939	2939	2533	1219	242	0
	Reach 40 % in > 30 min	9	9	8	8	412	1518	1530	431
<i>Non-generator zones</i>	<i>Don't reach 40 %</i>	<i>48</i>	<i>48</i>	<i>49</i>	<i>49</i>	<i>51</i>	<i>306</i>	<i>1228</i>	<i>2567</i>
	<i>Reach 40 % in < 30 min</i>	<i>2939</i>	<i>2939</i>	<i>2939</i>	<i>2939</i>	<i>2475</i>	<i>1215</i>	<i>239</i>	<i>0</i>
	<i>Reach 40 % in > 30 min</i>	<i>9</i>	<i>9</i>	<i>8</i>	<i>8</i>	<i>470</i>	<i>1475</i>	<i>1529</i>	<i>429</i>
		CO Emission Mass (g)							
		1000	500	200	100	50	25	15	5
Closed garage/burst	Don't reach 40 %	1187	1333	1549	1596	1596	1596	1596	1596
	Reach 40 % in < 30 min	382	233	3	0	0	0	0	0
	Reach 40 % in > 30 min	27	30	44	0	0	0	0	0
Basement/burst									
All zones	Don't reach 40 %	324	557	949	1087	1126	1176	1176	1176
	Reach 40 % in < 30 min	736	523	210	78	49	0	0	0
	Reach 40 % in > 30 min	116	96	17	11	1	0	0	0
<i>Non-generator zones</i>	<i>Don't reach 40 %</i>	<i>399</i>	<i>680</i>	<i>1145</i>	<i>1167</i>	<i>1176</i>	<i>1176</i>	<i>1176</i>	<i>1176</i>
	<i>Reach 40 % in < 30 min</i>	<i>660</i>	<i>399</i>	<i>14</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>
	<i>Reach 40 % in > 30 min</i>	<i>117</i>	<i>97</i>	<i>17</i>	<i>9</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>
First floor/burst									
All zones	Don't reach 40 %	1412	1634	2210	2504	2838	2983	2996	2996
	Reach 40 % in < 30 min	1470	1112	605	446	138	0	0	0
	Reach 40 % in > 30 min	114	250	181	46	20	13	0	0
<i>Non-generator zones</i>	<i>Don't reach 40 %</i>	<i>1604</i>	<i>1878</i>	<i>2557</i>	<i>2911</i>	<i>2993</i>	<i>2996</i>	<i>2996</i>	<i>2996</i>
	<i>Reach 40 % in < 30 min</i>	<i>1272</i>	<i>859</i>	<i>222</i>	<i>22</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>0</i>
	<i>Reach 40 % in > 30 min</i>	<i>120</i>	<i>259</i>	<i>217</i>	<i>63</i>	<i>3</i>	<i>0</i>	<i>0</i>	<i>0</i>

Table 6 Summary of cases: Number reaching 40 % COHb within or after 30 min

As was done in Persily et al. (2013), the results of the simulations are summarized as frequency distributions of maxCOHb levels in the occupied zones of the simulated homes. Figure 2 is the frequency distribution of the maxCOHb values for all of the constant source cases, i.e. a generator operating for 18 hours, modified relative to the 2013 report by including the results for the four manufactured houses six times. Considering all of the constant source results, the maximum source strength corresponding to 80 % of the cases with the maxCOHb below 30 % is 24 g/h. This value is below the value estimated without increasing the number of manufactured homes, but the difference is only 3 g/h, which is not very large given the 10 % uncertainty associated with these values. Nevertheless, this emission rate is on the low end of those simulated, which indicates that operating a generator for 18 hours as simulated in this study is likely to result in high CO exposures whether the generator is in the house or the garage. Note that the CO emission rates reported in Emmerich et al. (2013) for unmodified generators tended to be above this value.

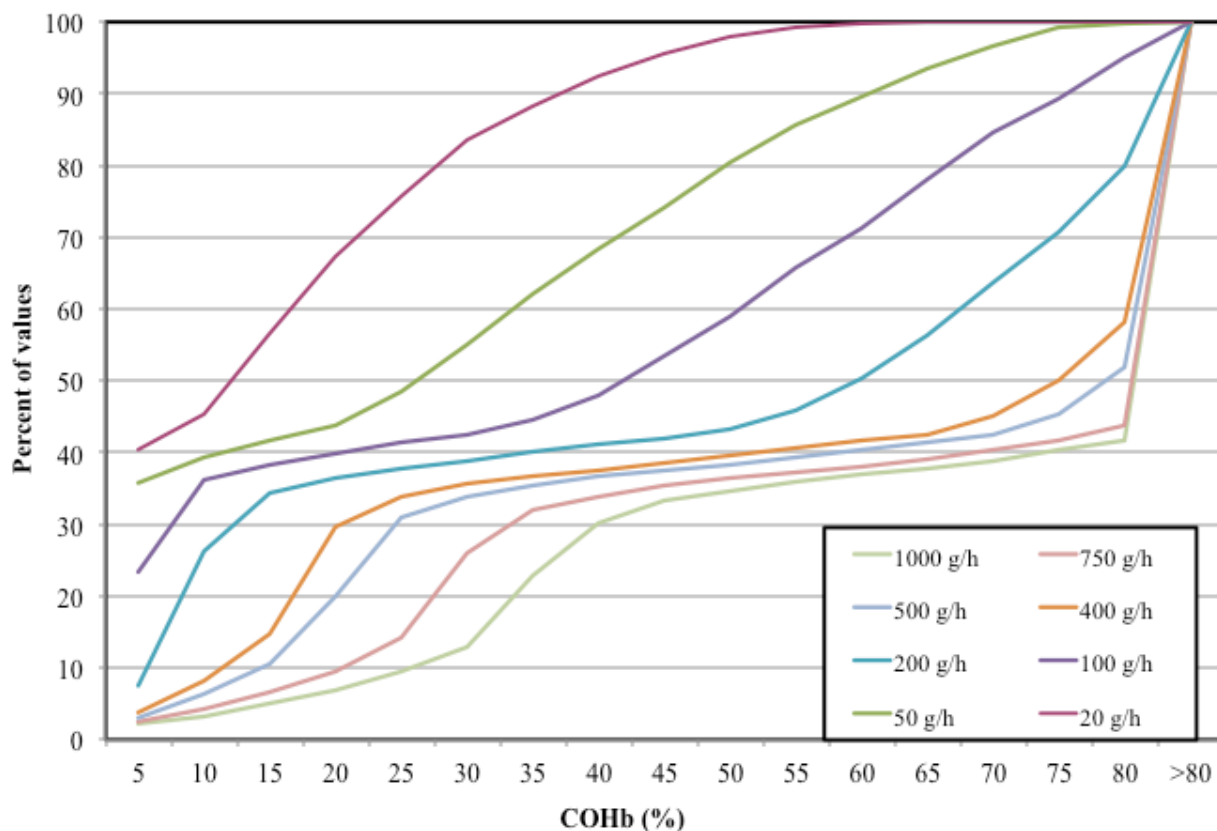


Figure 2 Frequency Distribution of %COHb for All Constant Sources

Figure 3 is the frequency distribution of the maxCOHb values for all of the burst source cases, with the same modification with respect to the additional number of manufactured home results. Considering all of the burst results, the maximum source strength corresponding to 80 % of the cases having a value of maxCOHb below 30 % is 148 g. This value is slightly higher than the values without the extra manufactured homes, 139 g, but the difference is not significant relative to the uncertainty of these estimates. The new estimate is on the higher end of the burst source strengths estimated for prototype generators modified to reduced emissions (Persily et al. 2013), i.e., there were many measurements below this value in the modified generators.

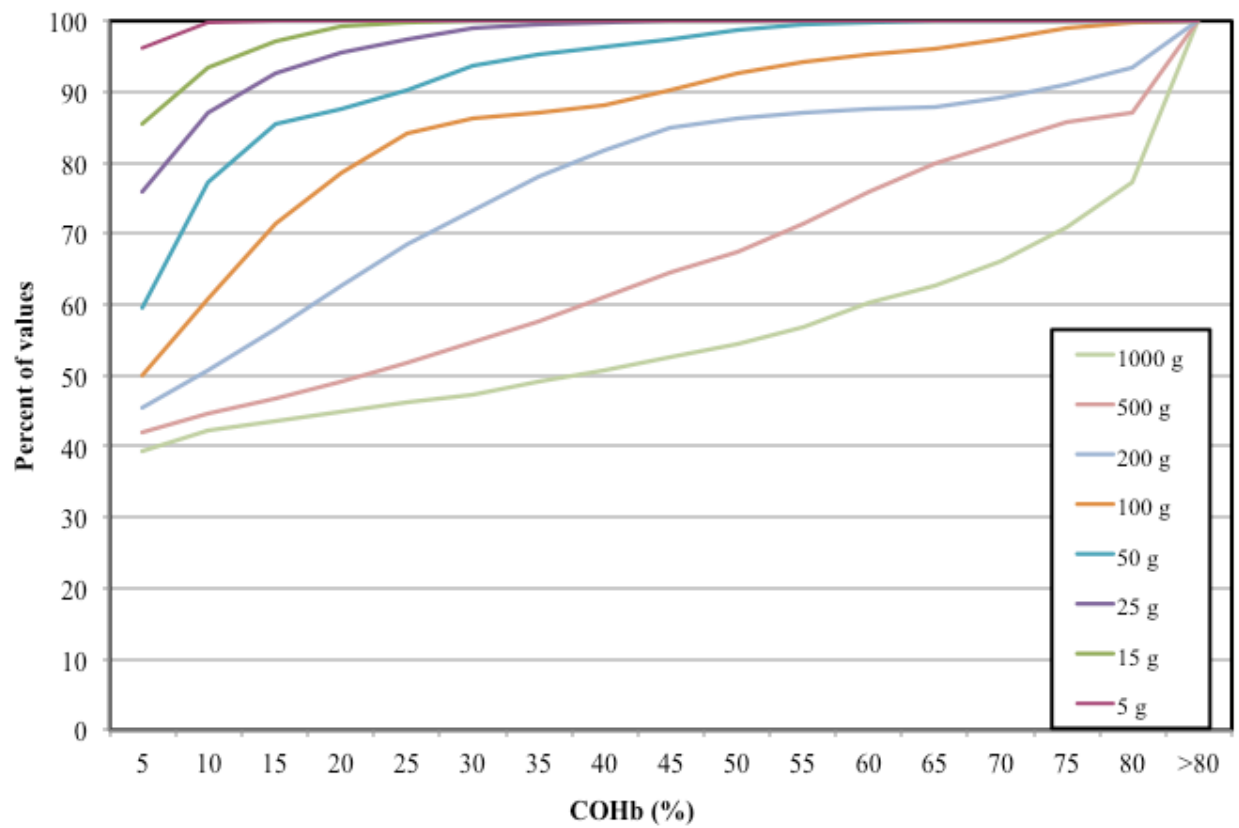


Figure 3 Frequency Distribution of %COHb for All Burst Sources

4. CONCLUSIONS

This report describes additional analyses of the simulation data generated by Persily et al. (2013) to support the development of the criteria to which measured emission rates may be compared, though such criteria are not part of this report. These new analyses include an alternative presentation of the frequency distributions of the maximum COHb values as a function of generator location and CO emission rate and a new analysis of the time to reach key COHb levels, again as a function of location and emission rate.

Similar to the results contained in Persily et al. (2013), the results presented here reflect the houses simulated, the emission rate and weather conditions considered, and the various assumptions required to perform the analysis. And while the average results of this large number of simulations provide important insight into the issue of CO exposure associated with portable generator operation, the inherent variability among these simulated cases and the complexity of the problem means that considering only one or a small number of buildings under a limited range of conditions may not be adequate to fully understand the levels of CO exposure in residences as a function of generator location and CO emission rate. Additional simulations of more operating scenarios, weather conditions and house configurations could be useful in providing further insight into these issues.

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APPENDIX A: Complete results of time analysis

This appendix contains all of the time analysis results in tabular form, first for all seven source locations and types considering all occupied zones and then for only the occupied zones that didn't contain the generator. The tables in this appendix are as follows:

Table A1-a and A1-b: Closed garage, constant source – all zones

Table A2-a and A2-b: Open garage, constant source – all zones

Table A3-a and A3-b: Closed garage, burst source – all zones

Table A4-a and A4-b: Basement, constant source – all zones

Table A5-a and A5-b: Basement, burst source – all zones

Table A6-a and A6-b: First floor interior room, constant source – all zones

Table A7-a and A7-b: First floor interior room, burst source – all zones

Table A8-a and A8-b: Basement, constant source – zones without generator

Table A9-a and A9-b: Basement, burst source – zones without generator

Table A10-a and A10-b: First floor interior room, constant source – zones without generator

Table A11-a and A11-b: First floor interior room, burst source – zones without generator

	CO Emission Rate (g/h)							
	1000	750	500	400	200	100	50	20
	Cases reaching 10 % COHb							
Don't reach 10 %	91	161	276	379	708	938	1162	1464
< 10 min	0	0	0	0	0	0	0	0
10 min to 20 min	0	0	0	0	0	0	0	0
20 min to 30 min	1	0	0	0	0	0	0	0
30 min to 40 min	83	7	1	0	0	0	0	0
40 min to 50 min	231	145	14	2	0	0	0	0
50 min to 60 min	175	220	126	71	1	0	0	0
60 min to 70 min	142	127	181	120	3	0	0	0
70 min to 80 min	90	115	112	152	37	0	0	0
80 min to 90 min	68	92	93	84	61	2	0	0
90 min to 100 min	48	46	91	84	98	4	0	0
100 min to 110 min	16	25	43	31	50	4	0	0
110 min to 120 min	53	52	65	109	93	58	1	0
> 120 min	598	606	594	564	545	590	433	132
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	315	450	624	758	970	1208	1418	1587
Reach 10 % but not 20%	224	289	348	379	262	270	256	123
< 10 min	7	0	0	0	0	0	0	0
10 min to 20 min	335	227	92	29	0	0	0	0
20 min to 30 min	271	269	212	183	16	0	0	0
30 min to 40 min	102	124	163	157	102	2	0	0
40 min to 50 min	41	71	82	97	66	9	0	0
50 min to 60 min	50	31	50	63	70	34	0	0
60 min to 70 min	64	27	46	37	51	45	1	0
70 min to 80 min	39	29	31	27	66	36	0	0
80 min to 90 min	30	38	22	23	40	22	5	0
90 min to 100 min	43	31	16	33	24	14	2	0
100 min to 110 min	10	17	6	8	16	10	1	0
110 min to 120 min	25	37	16	26	16	25	6	0
> 120 min	264	245	236	155	159	191	163	9

Table A1-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: Closed garage, constant source – all zones

	CO Emission Rate (g/h)							
	1000	750	500	400	200	100	50	20
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	546	691	844	905	1132	1368	1562	1592
Reach 20 % but not 30%	231	241	220	147	162	160	144	5
< 10 min	110	47	4	1	0	0	0	0
10 min to 20 min	366	290	176	119	2	0	0	0
20 min to 30 min	134	175	173	127	45	0	0	0
30 min to 40 min	79	73	113	124	77	1	0	0
40 min to 50 min	39	59	51	78	42	8	0	0
50 min to 60 min	30	40	36	32	33	7	0	0
60 min to 70 min	29	29	20	26	36	35	1	0
70 min to 80 min	33	9	18	18	47	23	0	0
80 min to 90 min	17	17	17	15	27	21	1	0
90 min to 100 min	23	13	22	12	17	8	1	0
100 min to 110 min	10	4	5	10	9	4	2	0
110 min to 120 min	29	14	15	14	18	12	0	0
> 120 min	151	135	102	115	111	109	29	4
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	755	843	978	1045	1289	1490	1587	1596
Reach 30 % but not 40%	209	152	134	140	157	122	25	4
< 10 min	165	79	13	4	0	0	0	0
10 min to 20 min	301	279	171	119	2	0	0	0
20 min to 30 min	108	124	121	95	20	0	0	0
30 min to 40 min	51	64	108	90	61	1	0	0
40 min to 50 min	53	28	46	55	45	2	0	0
50 min to 60 min	25	21	20	37	17	4	0	0
60 min to 70 min	16	23	20	26	23	1	0	0
70 min to 80 min	13	22	12	16	12	5	0	0
80 min to 90 min	8	14	12	14	18	5	0	0
90 min to 100 min	5	7	11	9	15	8	0	0
100 min to 110 min	2	5	4	5	4	3	0	0
110 min to 120 min	11	18	9	18	12	14	1	0
> 120 min	83	69	71	63	78	63	8	0

Table A1-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: Closed garage, constant source – all zones

	CO Emission Rate (g/h)							
	1000	750	500	400	200	100	50	20
	Cases reaching 10 % COHb							
Don't reach 10 %	45	56	80	104	1112	1593	1596	1596
< 10 min	0	0	0	0	0	0	0	0
10 min to 20 min	0	0	0	0	0	0	0	0
20 min to 30 min	0	0	0	0	0	0	0	0
30 min to 40 min	15	0	0	0	0	0	0	0
40 min to 50 min	221	9	0	0	0	0	0	0
50 min to 60 min	372	95	0	0	0	0	0	0
60 min to 70 min	271	304	9	1	0	0	0	0
70 min to 80 min	147	259	17	4	0	0	0	0
80 min to 90 min	90	208	78	8	0	0	0	0
90 min to 100 min	57	133	153	15	0	0	0	0
100 min to 110 min	33	46	106	17	0	0	0	0
110 min to 120 min	34	106	300	83	2	0	0	0
> 120 min	311	380	853	1364	482	3	0	0
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	88	143	725	1304	1596	1596	1596	1596
Reach 10 % but not 20%	43	87	645	1200	484	3	0	0
< 10 min	1	0	0	0	0	0	0	0
10 min to 20 min	11	4	0	0	0	0	0	0
20 min to 30 min	25	7	1	0	0	0	0	0
30 min to 40 min	58	17	3	0	0	0	0	0
40 min to 50 min	146	22	4	1	0	0	0	0
50 min to 60 min	315	44	5	1	0	0	0	0
60 min to 70 min	299	60	13	1	0	0	0	0
70 min to 80 min	229	109	5	3	0	0	0	0
80 min to 90 min	142	114	14	4	0	0	0	0
90 min to 100 min	82	184	13	7	0	0	0	0
100 min to 110 min	25	97	8	4	0	0	0	0
110 min to 120 min	62	266	27	7	0	0	0	0
> 120 min	113	529	778	264	0	0	0	0

Table A2-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: Open garage, constant source – all zones

	CO Emission Rate (g/h)							
	1000	750	500	400	200	100	50	20
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	291	1100	1524	1588	1596	1596	1596	1596
Reach 20 % but not 30%	203	957	799	284	0	0	0	0
< 10 min	0	0	0	0	0	0	0	0
10 min to 20 min	8	0	0	0	0	0	0	0
20 min to 30 min	14	3	0	0	0	0	0	0
30 min to 40 min	16	4	0	0	0	0	0	0
40 min to 50 min	34	14	0	0	0	0	0	0
50 min to 60 min	52	7	0	0	0	0	0	0
60 min to 70 min	67	16	0	0	0	0	0	0
70 min to 80 min	45	11	1	0	0	0	0	0
80 min to 90 min	65	16	1	0	0	0	0	0
90 min to 100 min	96	24	0	0	0	0	0	0
100 min to 110 min	37	12	0	0	0	0	0	0
110 min to 120 min	173	20	0	0	0	0	0	0
> 120 min	698	369	70	8	0	0	0	0
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	1349	1529	1596	1596	1596	1596	1596	1596
Reach 30 % but not 40%	1058	429	72	8	0	0	0	0
< 10 min	0	0	0	0	0	0	0	0
10 min to 20 min	1	0	0	0	0	0	0	0
20 min to 30 min	3	0	0	0	0	0	0	0
30 min to 40 min	7	0	0	0	0	0	0	0
40 min to 50 min	11	1	0	0	0	0	0	0
50 min to 60 min	8	1	0	0	0	0	0	0
60 min to 70 min	17	0	0	0	0	0	0	0
70 min to 80 min	6	0	0	0	0	0	0	0
80 min to 90 min	14	0	0	0	0	0	0	0
90 min to 100 min	17	3	0	0	0	0	0	0
100 min to 110 min	2	1	0	0	0	0	0	0
110 min to 120 min	18	3	0	0	0	0	0	0
> 120 min	143	58	0	0	0	0	0	0

Table A2-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: Open garage, constant source – all zones

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases reaching 10 % COHb							
Don't reach 10 %	1025	1079	1190	1339	1508	1596	1596	1596
< 10 min	24	0	0	0	0	0	0	0
10 min to 20 min	214	93	0	0	0	0	0	0
20 min to 30 min	102	135	13	0	0	0	0	0
30 min to 40 min	86	73	103	0	0	0	0	0
40 min to 50 min	32	49	77	3	0	0	0	0
50 min to 60 min	18	51	45	41	0	0	0	0
60 min to 70 min	11	27	35	53	0	0	0	0
70 min to 80 min	8	14	20	38	0	0	0	0
80 min to 90 min	9	14	19	15	0	0	0	0
90 min to 100 min	8	7	17	23	0	0	0	0
100 min to 110 min	2	0	6	8	9	0	0	0
110 min to 120 min	7	3	20	26	23	0	0	0
> 120 min	50	51	51	50	56	0	0	0
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	1086	1161	1360	1521	1596	1596	1596	1596
Reach 10 % but not 20%	61	82	170	182	88	0	0	0
< 10 min	244	76	0	0	0	0	0	0
10 min to 20 min	134	184	6	0	0	0	0	0
20 min to 30 min	57	56	79	0	0	0	0	0
30 min to 40 min	22	39	61	0	0	0	0	0
40 min to 50 min	9	30	34	5	0	0	0	0
50 min to 60 min	9	15	21	20	0	0	0	0
60 min to 70 min	3	11	12	10	0	0	0	0
70 min to 80 min	9	8	10	13	0	0	0	0
80 min to 90 min	3	7	4	9	0	0	0	0
90 min to 100 min	0	2	2	9	0	0	0	0
100 min to 110 min	2	2	1	1	0	0	0	0
110 min to 120 min	4	0	4	1	0	0	0	0
> 120 min	14	5	2	7	0	0	0	0

Table A3-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: Closed garage, burst source – all zones

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	1129	1229	1479	1595	1596	1596	1596	1596
Reach 20 % but not 30%	43	68	119	74	0	0	0	0
< 10 min	272	90	0	0	0	0	0	0
10 min to 20 min	101	146	0	0	0	0	0	0
20 min to 30 min	41	58	36	0	0	0	0	0
30 min to 40 min	24	18	29	0	0	0	0	0
40 min to 50 min	9	19	23	0	0	0	0	0
50 min to 60 min	8	19	16	0	0	0	0	0
60 min to 70 min	4	6	4	0	0	0	0	0
70 min to 80 min	2	9	3	0	0	0	0	0
80 min to 90 min	1	0	5	0	0	0	0	0
90 min to 100 min	0	0	1	0	0	0	0	0
100 min to 110 min	1	1	0	0	0	0	0	0
110 min to 120 min	2	1	0	0	0	0	0	0
> 120 min	2	0	0	1	0	0	0	0
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	1187	1333	1549	1596	1596	1596	1596	1596
Reach 30 % but not 40%	58	104	70	1	0	0	0	0
< 10 min	266	69	0	0	0	0	0	0
10 min to 20 min	72	116	0	0	0	0	0	0
20 min to 30 min	44	48	3	0	0	0	0	0
30 min to 40 min	21	19	14	0	0	0	0	0
40 min to 50 min	4	7	14	0	0	0	0	0
50 min to 60 min	2	3	9	0	0	0	0	0
60 min to 70 min	0	1	4	0	0	0	0	0
70 min to 80 min	0	0	0	0	0	0	0	0
80 min to 90 min	0	0	1	0	0	0	0	0
90 min to 100 min	0	0	0	0	0	0	0	0
100 min to 110 min	0	0	0	0	0	0	0	0
110 min to 120 min	0	0	1	0	0	0	0	0
> 120 min	0	0	1	0	0	0	0	0

Table A3-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: Closed garage, burst source – all zones

	CO Emission Rate (g/h)							
	1000	750	500	400	200	100	50	20
	Cases reaching 10 % COHb							
Don't reach 10 %	51	54	65	67	72	78	86	139
< 10 min	218	196	0	0	0	0	0	0
10 min to 20 min	342	309	352	254	3	0	0	0
20 min to 30 min	28	82	213	295	291	0	0	0
30 min to 40 min	5	2	23	39	229	241	0	0
40 min to 50 min	70	35	1	1	57	174	16	0
50 min to 60 min	112	88	45	10	7	117	125	0
60 min to 70 min	88	86	67	69	2	44	167	0
70 min to 80 min	59	77	80	67	13	9	138	4
80 min to 90 min	41	48	86	58	62	1	80	21
90 min to 100 min	58	35	37	81	36	3	36	51
100 min to 110 min	13	34	16	16	21	4	5	43
110 min to 120 min	9	44	51	48	68	61	9	38
> 120 min	82	86	140	171	315	444	514	880
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	66	69	71	74	78	87	117	618
Reach 10 % but not 20%	15	15	6	7	6	9	31	479
< 10 min	603	585	556	451	72	0	0	0
10 min to 20 min	238	171	147	204	479	115	0	0
20 min to 30 min	154	182	173	134	85	313	66	0
30 min to 40 min	72	116	81	135	100	164	122	0
40 min to 50 min	23	25	99	88	115	29	118	10
50 min to 60 min	2	8	15	50	75	68	100	32
60 min to 70 min	2	3	15	16	33	62	99	48
70 min to 80 min	4	0	2	11	79	81	43	44
80 min to 90 min	4	6	0	2	24	51	47	23
90 min to 100 min	1	2	3	1	11	36	34	20
100 min to 110 min	0	1	0	0	8	15	14	12
110 min to 120 min	2	1	3	0	10	38	42	32
> 120 min	5	7	11	10	7	117	374	337

Table A4-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: Basement, constant source – all zones

	CO Emission Rate (g/h)							
	1000	750	500	400	200	100	50	20
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	70	71	78	78	85	100	323	908
Reach 20 % but not 30%	4	2	7	4	7	13	206	290
< 10 min	710	648	587	556	140	1	0	0
10 min to 20 min	237	255	203	178	447	196	9	0
20 min to 30 min	115	144	152	178	97	228	94	0
30 min to 40 min	25	32	115	72	119	140	82	3
40 min to 50 min	3	13	21	83	115	60	84	7
50 min to 60 min	5	0	13	18	38	56	60	22
60 min to 70 min	3	3	2	8	71	64	40	28
70 min to 80 min	2	1	1	0	25	83	28	34
80 min to 90 min	1	2	0	1	10	31	32	16
90 min to 100 min	1	2	0	2	18	26	35	17
100 min to 110 min	0	0	0	0	3	11	20	8
110 min to 120 min	1	1	0	1	3	30	36	17
> 120 min	3	4	4	1	5	150	333	116
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	73	78	78	81	91	185	631	1046
Reach 30 % but not 40%	3	7	0	3	6	85	308	138
< 10 min	769	697	617	595	207	14	0	0
10 min to 20 min	244	238	220	160	386	186	11	0
20 min to 30 min	66	129	124	174	78	144	78	0
30 min to 40 min	14	24	103	78	116	104	69	0
40 min to 50 min	0	5	23	59	88	88	34	4
50 min to 60 min	2	1	5	18	56	56	33	4
60 min to 70 min	2	0	1	7	46	39	44	5
70 min to 80 min	2	0	2	0	53	52	22	20
80 min to 90 min	0	1	0	1	13	51	22	15
90 min to 100 min	1	1	0	0	7	20	16	10
100 min to 110 min	0	1	0	0	1	12	8	5
110 min to 120 min	0	0	0	0	17	25	16	9
> 120 min	3	1	3	3	17	200	192	58

Table A4-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: Basement, constant source – all zones

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases reaching 10 % COHb							
Don't reach 10 %	254	260	316	501	928	974	1096	1176
< 10 min	197	196	196	84	72	0	0	0
10 min to 20 min	94	5	0	172	124	11	0	0
20 min to 30 min	127	108	2	24	0	141	0	0
30 min to 40 min	128	78	32	0	0	40	41	0
40 min to 50 min	130	76	70	2	0	2	24	0
50 min to 60 min	49	115	61	8	0	2	7	0
60 min to 70 min	46	86	41	40	1	0	3	0
70 min to 80 min	53	32	48	24	1	0	4	0
80 min to 90 min	33	38	42	15	0	0	0	0
90 min to 100 min	15	25	49	17	4	0	0	0
100 min to 110 min	1	13	24	12	3	0	0	0
110 min to 120 min	6	34	53	41	6	0	0	0
> 120 min	43	110	242	236	37	6	1	0
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	261	300	587	893	979	1118	1171	1176
Reach 10 % but not 20%	7	40	271	392	51	144	75	0
< 10 min	398	253	196	84	0	0	0	0
10 min to 20 min	236	216	7	41	165	0	0	0
20 min to 30 min	109	113	72	60	23	28	0	0
30 min to 40 min	43	69	59	39	4	21	0	0
40 min to 50 min	54	69	88	23	0	7	0	0
50 min to 60 min	40	30	62	4	0	2	0	0
60 min to 70 min	4	17	26	10	0	0	0	0
70 min to 80 min	4	15	12	9	1	0	2	0
80 min to 90 min	2	7	11	1	1	0	1	0
90 min to 100 min	11	7	11	0	1	0	2	0
100 min to 110 min	2	5	5	1	0	0	0	0
110 min to 120 min	5	31	4	1	1	0	0	0
> 120 min	7	44	36	10	1	0	0	0

Table A5-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: Basement, burst source – all zones

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	273	425	858	1019	1096	1165	1176	1176
Reach 20 % but not 30%	12	125	271	126	117	47	5	0
< 10 min	485	274	196	82	7	0	0	0
10 min to 20 min	184	206	6	2	51	0	0	0
20 min to 30 min	86	94	16	20	17	0	0	0
30 min to 40 min	24	42	18	31	4	0	0	0
40 min to 50 min	26	39	22	6	0	2	0	0
50 min to 60 min	49	28	11	5	0	1	0	0
60 min to 70 min	25	16	11	4	0	4	0	0
70 min to 80 min	3	22	13	4	0	2	0	0
80 min to 90 min	3	11	8	1	0	2	0	0
90 min to 100 min	1	9	7	1	0	0	0	0
100 min to 110 min	0	1	2	1	0	0	0	0
110 min to 120 min	1	2	6	0	0	0	0	0
> 120 min	16	7	2	0	1	0	0	0
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	324	557	949	1087	1126	1176	1176	1176
Reach 30 % but not 40%	51	132	91	68	30	11	0	0
< 10 min	502	266	196	40	0	0	0	0
10 min to 20 min	138	157	4	34	32	0	0	0
20 min to 30 min	96	100	10	4	17	0	0	0
30 min to 40 min	28	33	4	0	1	0	0	0
40 min to 50 min	18	15	2	0	0	0	0	0
50 min to 60 min	6	10	2	5	0	0	0	0
60 min to 70 min	1	13	2	4	0	0	0	0
70 min to 80 min	8	6	0	1	0	0	0	0
80 min to 90 min	11	3	3	1	0	0	0	0
90 min to 100 min	12	1	2	0	0	0	0	0
100 min to 110 min	8	1	0	0	0	0	0	0
110 min to 120 min	10	6	0	0	0	0	0	0
> 120 min	14	8	2	0	0	0	0	0

Table A5-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: Basement, burst source – all zones

	CO Emission Rate (g/h)							
	1000	750	500	400	200	100	50	20
	Cases reaching 10 % COHb							
Don't reach 10 %	45	45	45	46	48	49	51	145
< 10 min	753	228	0	0	0	0	0	0
10 min to 20 min	1531	1837	1564	820	26	0	0	0
20 min to 30 min	609	819	764	1288	746	28	0	0
30 min to 40 min	38	47	563	649	1048	428	0	0
40 min to 50 min	0	0	40	146	513	715	214	0
50 min to 60 min	1	0	0	28	342	684	131	0
60 min to 70 min	1	1	0	0	228	319	272	6
70 min to 80 min	3	1	0	0	25	261	528	86
80 min to 90 min	3	6	2	1	3	199	494	115
90 min to 100 min	0	0	2	1	0	208	309	86
100 min to 110 min	0	0	4	1	0	56	116	21
110 min to 120 min	1	0	0	5	2	25	254	187
> 120 min	11	12	12	11	15	24	627	2350
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	45	46	47	48	49	51	89	1166
Reach 10 % but not 20%	0	1	2	2	1	2	38	1021
< 10 min	2585	2353	1540	1251	248	0	0	0
10 min to 20 min	350	579	1326	1358	1419	339	33	0
20 min to 30 min	5	7	73	329	813	900	225	0
30 min to 40 min	1	1	0	1	402	674	345	18
40 min to 50 min	5	2	0	0	58	462	400	59
50 min to 60 min	1	4	1	0	0	267	341	59
60 min to 70 min	1	0	3	1	0	148	251	104
70 min to 80 min	0	0	3	3	1	122	206	145
80 min to 90 min	1	0	0	1	1	24	189	129
90 min to 100 min	1	1	0	1	1	3	161	78
100 min to 110 min	0	0	0	0	0	0	59	33
110 min to 120 min	0	1	0	0	2	3	167	144
> 120 min	1	2	3	3	2	3	530	1061

Table A6-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: First floor interior room, constant source – all zones

	CO Emission Rate (g/h)							
	1000	750	500	400	200	100	50	20
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	46	47	48	49	51	59	570	2066
Reach 20 % but not 30%	1	1	1	1	2	8	481	900
< 10 min	2885	2653	2265	1868	379	45	0	0
10 min to 20 min	54	286	669	1025	1594	532	80	0
20 min to 30 min	1	0	5	46	670	795	241	1
30 min to 40 min	4	1	0	0	263	434	294	16
40 min to 50 min	2	4	1	1	34	365	286	36
50 min to 60 min	0	2	1	0	3	239	280	29
60 min to 70 min	0	0	3	2	2	154	148	27
70 min to 80 min	1	0	1	1	0	89	130	142
80 min to 90 min	0	0	2	3	0	82	122	71
90 min to 100 min	1	0	0	0	0	48	99	70
100 min to 110 min	0	0	1	1	0	27	34	39
110 min to 120 min	0	0	0	0	0	42	97	66
> 120 min	2	3	0	0	0	85	615	433
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	48	48	49	49	51	259	1224	2565
Reach 30 % but not 40%	2	1	1	0	0	200	654	499
< 10 min	2928	2779	2398	2113	632	89	0	0
10 min to 20 min	11	160	541	800	1265	521	75	0
20 min to 30 min	0	0	0	26	636	609	167	0
30 min to 40 min	5	1	0	1	236	326	263	7
40 min to 50 min	2	4	0	0	125	281	131	12
50 min to 60 min	0	2	1	1	34	184	185	18
60 min to 70 min	0	2	1	0	10	105	123	10
70 min to 80 min	0	0	4	1	2	106	76	17
80 min to 90 min	0	0	1	0	1	68	75	12
90 min to 100 min	0	0	0	2	2	65	107	57
100 min to 110 min	0	0	0	1	0	19	11	21
110 min to 120 min	0	0	1	1	2	58	113	54
> 120 min	2	0	0	1	0	306	446	223

Table A6-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: First floor interior room, constant source – all zones

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases reaching 10 % COHb							
Don't reach 10 %	1160	1238	1416	1629	2027	2447	2704	2983
< 10 min	601	510	476	476	346	0	0	0
10 min to 20 min	274	188	46	2	130	172	0	0
20 min to 30 min	148	170	87	15	0	248	28	0
30 min to 40 min	121	107	143	63	3	42	137	0
40 min to 50 min	94	81	91	48	7	4	57	0
50 min to 60 min	112	79	64	76	10	1	27	0
60 min to 70 min	85	67	49	91	27	0	19	0
70 min to 80 min	41	70	47	58	24	0	5	0
80 min to 90 min	43	81	51	45	16	1	0	0
90 min to 100 min	23	50	42	26	27	1	0	0
100 min to 110 min	4	26	18	10	7	0	0	0
110 min to 120 min	20	54	80	39	56	11	0	0
> 120 min	270	275	386	418	316	69	19	13
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	1247	1375	1672	2070	2470	2796	2951	2996
Reach 10 % but not 20%	87	137	256	441	443	349	247	13
< 10 min	923	709	493	474	124	0	0	0
10 min to 20 min	311	264	115	7	303	25	0	0
20 min to 30 min	218	196	208	33	25	64	0	0
30 min to 40 min	101	158	94	46	5	65	2	0
40 min to 50 min	73	118	73	53	3	22	16	0
50 min to 60 min	30	46	74	55	18	15	7	0
60 min to 70 min	27	32	48	45	5	5	7	0
70 min to 80 min	10	28	50	27	9	0	6	0
80 min to 90 min	7	24	61	19	7	0	3	0
90 min to 100 min	19	6	34	39	7	0	3	0
100 min to 110 min	2	5	7	2	0	0	1	0
110 min to 120 min	6	8	20	10	8	0	0	0
> 120 min	22	27	47	116	12	4	0	0

Table A7-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: First floor interior room, burst source – all zones

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	1325	1499	1886	2411	2705	2942	2996	2996
Reach 20 % but not 30%	78	124	214	341	235	146	45	0
< 10 min	992	772	491	467	50	0	0	0
10 min to 20 min	349	223	95	4	165	0	0	0
20 min to 30 min	158	185	123	23	34	17	0	0
30 min to 40 min	65	119	81	17	24	12	0	0
40 min to 50 min	31	86	73	19	2	13	0	0
50 min to 60 min	24	28	44	12	0	5	0	0
60 min to 70 min	24	24	33	10	1	6	0	0
70 min to 80 min	11	14	19	7	4	1	0	0
80 min to 90 min	6	25	33	5	4	0	0	0
90 min to 100 min	2	5	9	2	1	0	0	0
100 min to 110 min	1	2	14	1	0	0	0	0
110 min to 120 min	3	6	30	6	0	0	0	0
> 120 min	5	8	65	12	6	0	0	0
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	1412	1634	2210	2504	2838	2983	2996	2996
Reach 30 % but not 40%	87	135	324	93	133	41	0	0
< 10 min	1023	759	487	351	16	0	0	0
10 min to 20 min	305	225	61	89	85	0	0	0
20 min to 30 min	142	128	57	6	37	0	0	0
30 min to 40 min	51	128	45	19	16	0	0	0
40 min to 50 min	26	43	46	9	4	6	0	0
50 min to 60 min	14	26	17	6	0	2	0	0
60 min to 70 min	5	8	9	5	0	5	0	0
70 min to 80 min	2	8	25	2	0	0	0	0
80 min to 90 min	1	8	4	1	0	0	0	0
90 min to 100 min	1	4	3	2	0	0	0	0
100 min to 110 min	0	2	1	0	0	0	0	0
110 min to 120 min	12	3	1	1	0	0	0	0
> 120 min	2	20	30	1	0	0	0	0

Table A7-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: First floor interior room, burst source – all zones

	CO Emission Mass (g/h)							
	1000	750	500	400	200	100	50	20
	Cases reaching 10 % COHb							
Don't reach 10 %	51	54	65	67	72	78	88	144
< 10 min	22	0	0	0	0	0	0	0
10 min to 20 min	538	501	190	58	0	0	0	0
20 min to 30 min	28	86	375	491	98	0	0	0
30 min to 40 min	5	2	23	39	421	55	0	0
40 min to 50 min	70	35	1	1	61	238	16	0
50 min to 60 min	105	82	45	10	7	227	50	0
60 min to 70 min	92	86	60	68	2	56	124	0
70 min to 80 min	61	81	81	58	13	9	150	4
80 min to 90 min	42	49	90	64	61	1	141	21
90 min to 100 min	58	35	37	82	28	3	67	21
100 min to 110 min	13	35	17	15	21	4	13	27
110 min to 120 min	9	44	52	51	74	60	15	74
> 120 min	82	86	140	172	318	445	512	885
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	66	69	71	74	78	89	121	633
Reach 10 % but not 20%	15	15	6	7	6	11	33	489
< 10 min	601	585	541	386	46	0	0	0
10 min to 20 min	238	168	150	265	484	109	0	0
20 min to 30 min	155	183	182	134	102	276	61	0
30 min to 40 min	73	118	82	137	98	182	124	0
40 min to 50 min	23	25	99	88	118	48	112	10
50 min to 60 min	2	8	16	50	76	66	79	32
60 min to 70 min	2	3	15	17	33	62	93	39
70 min to 80 min	4	0	3	11	79	84	36	38
80 min to 90 min	4	6	0	2	24	51	46	38
90 min to 100 min	1	2	3	2	11	38	37	18
100 min to 110 min	0	1	0	0	8	15	19	14
110 min to 120 min	2	1	3	0	10	38	46	32
> 120 min	5	7	11	10	9	118	402	322

Table A8-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: Basement, constant source – zones without generator

	CO Emission Mass (g/h)							
	1000	750	500	400	200	100	50	20
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	70	71	78	78	87	103	356	910
Reach 20 % but not 30%	4	2	7	4	9	14	235	277
< 10 min	710	642	587	539	146	1	0	0
10 min to 20 min	235	259	198	190	424	193	9	0
20 min to 30 min	116	144	155	181	106	189	88	0
30 min to 40 min	26	33	115	72	120	136	88	3
40 min to 50 min	3	13	21	84	117	73	83	7
50 min to 60 min	5	1	15	18	40	69	55	22
60 min to 70 min	3	3	2	8	72	69	35	28
70 min to 80 min	2	1	1	0	25	86	27	23
80 min to 90 min	1	2	0	2	10	32	22	22
90 min to 100 min	1	2	0	2	18	30	31	10
100 min to 110 min	0	0	0	0	3	11	15	4
110 min to 120 min	1	1	0	1	3	32	36	25
> 120 min	3	4	4	1	5	152	331	122
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	73	78	78	82	94	193	643	1048
Reach 30 % but not 40%	3	7	0	4	7	90	287	138
< 10 min	762	692	613	575	201	14	0	0
10 min to 20 min	249	241	220	175	351	183	11	0
20 min to 30 min	67	129	125	177	109	131	70	0
30 min to 40 min	14	25	105	78	116	91	74	0
40 min to 50 min	1	6	23	59	91	77	37	4
50 min to 60 min	2	1	5	18	58	53	32	4
60 min to 70 min	2	0	1	8	46	39	40	5
70 min to 80 min	2	0	2	0	53	54	23	20
80 min to 90 min	0	1	0	1	13	50	23	15
90 min to 100 min	1	1	0	0	8	28	16	10
100 min to 110 min	0	1	0	0	1	10	7	5
110 min to 120 min	0	0	0	0	17	25	16	9
> 120 min	3	1	4	3	18	228	184	56

Table A8-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: Basement, constant source – zones without generator

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases reaching 10 % COHb							
Don't reach 10 %	320	326	389	567	1124	1170	1175	1176
< 10 min	1	0	0	0	0	0	0	0
10 min to 20 min	94	5	0	88	0	0	0	0
20 min to 30 min	212	110	2	108	0	0	0	0
30 min to 40 min	165	161	32	0	0	0	0	0
40 min to 50 min	132	106	74	2	0	0	0	0
50 min to 60 min	53	115	129	8	0	0	0	0
60 min to 70 min	45	97	73	40	1	0	0	0
70 min to 80 min	52	34	62	24	1	0	0	0
80 min to 90 min	33	37	43	15	0	0	0	0
90 min to 100 min	18	24	47	30	4	0	0	0
100 min to 110 min	1	13	25	14	3	0	0	0
110 min to 120 min	6	34	58	50	6	0	0	0
> 120 min	44	114	242	230	37	6	1	0
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	328	373	744	1006	1171	1176	1176	1176
Reach 10 % but not 20%	8	47	355	439	47	6	1	0
< 10 min	302	61	0	0	0	0	0	0
10 min to 20 min	262	330	7	13	0	0	0	0
20 min to 30 min	110	111	72	74	0	0	0	0
30 min to 40 min	43	72	62	17	0	0	0	0
40 min to 50 min	56	71	113	23	0	0	0	0
50 min to 60 min	40	30	72	10	0	0	0	0
60 min to 70 min	4	17	31	11	0	0	0	0
70 min to 80 min	4	17	12	9	1	0	0	0
80 min to 90 min	2	7	10	1	1	0	0	0
90 min to 100 min	11	7	10	0	1	0	0	0
100 min to 110 min	2	5	4	1	0	0	0	0
110 min to 120 min	5	31	3	1	1	0	0	0
> 120 min	7	44	36	10	1	0	0	0

Table A9-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: Basement, burst source – zones without generator

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	342	503	1054	1107	1175	1176	1176	1176
Reach 20 % but not 30%	14	130	310	101	4	0	0	0
< 10 min	403	79	0	0	0	0	0	0
10 min to 20 min	192	316	6	0	0	0	0	0
20 min to 30 min	89	96	16	14	0	0	0	0
30 min to 40 min	25	46	18	33	0	0	0	0
40 min to 50 min	27	40	22	8	0	0	0	0
50 min to 60 min	49	28	11	5	0	0	0	0
60 min to 70 min	25	16	11	2	0	0	0	0
70 min to 80 min	3	22	13	4	0	0	0	0
80 min to 90 min	3	11	8	1	0	0	0	0
90 min to 100 min	1	9	7	1	0	0	0	0
100 min to 110 min	0	1	2	1	0	0	0	0
110 min to 120 min	1	2	6	0	0	0	0	0
> 120 min	16	7	2	0	1	0	0	0
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	399	680	1145	1167	1176	1176	1176	1176
Reach 30 % but not 40%	57	177	91	60	1	0	0	0
< 10 min	423	70	0	0	0	0	0	0
10 min to 20 min	141	207	4	0	0	0	0	0
20 min to 30 min	96	122	10	0	0	0	0	0
30 min to 40 min	28	32	4	0	0	0	0	0
40 min to 50 min	19	16	2	0	0	0	0	0
50 min to 60 min	6	11	2	3	0	0	0	0
60 min to 70 min	1	13	2	2	0	0	0	0
70 min to 80 min	8	6	0	3	0	0	0	0
80 min to 90 min	11	3	3	1	0	0	0	0
90 min to 100 min	12	1	2	0	0	0	0	0
100 min to 110 min	8	1	0	0	0	0	0	0
110 min to 120 min	10	6	0	0	0	0	0	0
> 120 min	14	8	2	0	0	0	0	0

Table A9-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: Basement, burst source – zones without generator

	CO Emission Rate (g/h)							
	1000	750	500	400	200	100	50	20
	Cases reaching 10 % COHb							
Don't reach 10 %	45	45	45	46	48	49	51	173
< 10 min	308	28	0	0	0	0	0	0
10 min to 20 min	1977	2039	1486	407	26	0	0	0
20 min to 30 min	608	817	844	1707	403	28	0	0
30 min to 40 min	38	47	561	643	1390	308	0	0
40 min to 50 min	0	0	40	146	514	612	214	0
50 min to 60 min	1	0	0	28	342	836	121	0
60 min to 70 min	1	1	0	0	228	389	209	6
70 min to 80 min	3	1	0	0	25	262	511	86
80 min to 90 min	3	6	2	1	3	199	451	115
90 min to 100 min	0	0	2	1	0	208	325	86
100 min to 110 min	0	0	4	1	0	56	131	20
110 min to 120 min	1	0	0	5	2	25	322	171
> 120 min	11	12	12	11	15	24	661	2339
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	45	46	47	48	49	51	106	1172
Reach 10 % but not 20%	0	1	2	2	1	2	55	999
< 10 min	2585	2354	1500	1221	248	0	0	0
10 min to 20 min	350	578	1366	1388	1356	344	33	0
20 min to 30 min	5	7	73	329	863	881	225	0
30 min to 40 min	1	1	0	1	415	634	341	18
40 min to 50 min	5	2	0	0	58	439	402	59
50 min to 60 min	1	4	1	0	0	308	339	59
60 min to 70 min	1	0	3	1	0	167	240	102
70 min to 80 min	0	0	3	3	1	128	207	150
80 min to 90 min	1	0	0	1	1	33	188	123
90 min to 100 min	1	1	0	1	1	4	153	81
100 min to 110 min	0	0	0	0	0	0	56	32
110 min to 120 min	0	1	0	0	2	3	161	140
> 120 min	1	2	3	3	2	4	545	1060

Table A10-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: First floor interior room, constant source – zones without generator

	CO Emission Rate (g/h)							
	1000	750	500	400	200	100	50	20
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	46	47	48	49	51	63	593	2073
Reach 20 % but not 30%	1	1	1	1	2	12	487	901
< 10 min	2885	2653	2241	1765	358	45	0	0
10 min to 20 min	54	286	693	1128	1560	539	80	0
20 min to 30 min	1	0	5	46	695	776	241	1
30 min to 40 min	4	1	0	0	291	432	295	16
40 min to 50 min	2	4	1	1	35	352	285	36
50 min to 60 min	0	2	1	0	4	223	276	29
60 min to 70 min	0	0	3	2	2	135	150	27
70 min to 80 min	1	0	1	1	0	101	129	140
80 min to 90 min	0	0	2	3	0	84	118	73
90 min to 100 min	1	0	0	0	0	56	101	71
100 min to 110 min	0	0	1	1	0	25	34	36
110 min to 120 min	0	0	0	0	0	43	90	67
> 120 min	2	3	0	0	0	122	604	427
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	48	48	49	49	51	306	1228	2567
Reach 30 % but not 40%	2	1	1	0	0	243	635	494
< 10 min	2928	2779	2357	2054	653	45	0	0
10 min to 20 min	11	160	582	859	1207	539	75	0
20 min to 30 min	0	0	0	26	615	776	164	0
30 min to 40 min	5	1	0	1	255	432	264	7
40 min to 50 min	2	4	0	0	147	352	131	12
50 min to 60 min	0	2	1	1	39	223	181	18
60 min to 70 min	0	2	1	0	17	135	127	10
70 min to 80 min	0	0	4	1	6	101	70	17
80 min to 90 min	0	0	1	0	1	84	81	12
90 min to 100 min	0	0	0	2	2	56	105	57
100 min to 110 min	0	0	0	1	0	25	12	21
110 min to 120 min	0	0	1	1	2	43	113	54
> 120 min	2	0	0	1	1	122	445	221

Table A10-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % 40 %: to First floor interior room, constant source – zones without generator

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases reaching 10 % COHb							
Don't reach 10 %	1324	1404	1608	1888	2358	2865	2964	2996
< 10 min	190	42	0	0	0	0	0	0
10 min to 20 min	425	288	53	2	0	0	0	0
20 min to 30 min	210	280	162	18	0	0	0	0
30 min to 40 min	134	162	209	102	3	0	0	0
40 min to 50 min	101	89	150	91	12	0	0	0
50 min to 60 min	120	87	105	108	16	0	0	0
60 min to 70 min	85	73	67	109	48	0	0	0
70 min to 80 min	41	76	50	83	48	2	0	0
80 min to 90 min	43	81	55	66	39	1	0	0
90 min to 100 min	23	51	45	41	45	8	0	0
100 min to 110 min	4	27	18	12	15	3	0	0
110 min to 120 min	20	55	82	47	70	23	0	0
> 120 min	276	281	392	429	342	94	32	0
Cases increasing from 10 % COHb to 20 % COHb								
Don't reach 20 %	1413	1565	1950	2406	2883	2986	2996	2996
Reach 10 % but not 20%	89	161	342	518	525	121	32	0
< 10 min	708	380	22	0	0	0	0	0
10 min to 20 min	340	381	205	12	0	0	0	0
20 min to 30 min	225	209	254	66	0	0	0	0
30 min to 40 min	105	160	122	74	2	0	0	0
40 min to 50 min	76	118	91	92	19	0	0	0
50 min to 60 min	31	46	77	71	30	0	0	0
60 min to 70 min	28	32	50	49	11	0	0	0
70 min to 80 min	10	30	51	30	10	0	0	0
80 min to 90 min	9	26	63	24	8	0	0	0
90 min to 100 min	19	6	35	40	9	0	0	0
100 min to 110 min	3	5	7	3	0	0	0	0
110 min to 120 min	7	8	21	10	8	3	0	0
> 120 min	22	30	48	119	16	7	0	0

Table A11-a: Number of cases sorted by time to reach 10 % COHb and time to progress from 10 % to 20 %: First floor interior room, burst source – zones without generator

	CO Emission Mass (g)							
	1000	500	200	100	50	25	15	5
	Cases increasing from 20 % COHb to 30 % COHb							
Don't reach 30 %	1509	1702	2216	2812	2968	2996	2996	2996
Reach 20 % but not 30%	96	137	266	406	85	10	0	0
< 10 min	783	446	28	0	0	0	0	0
10 min to 20 min	364	318	172	8	0	0	0	0
20 min to 30 min	161	204	163	51	0	0	0	0
30 min to 40 min	66	123	89	26	0	0	0	0
40 min to 50 min	33	88	77	25	0	0	0	0
50 min to 60 min	25	30	44	18	6	0	0	0
60 min to 70 min	24	24	33	13	1	0	0	0
70 min to 80 min	11	14	20	11	5	0	0	0
80 min to 90 min	6	26	33	8	8	0	0	0
90 min to 100 min	3	5	9	4	1	0	0	0
100 min to 110 min	1	2	14	1	0	0	0	0
110 min to 120 min	3	6	30	7	1	0	0	0
> 120 min	7	8	68	12	6	0	0	0
	Cases increasing from 30 % COHb to 40 % COHb							
Don't reach 40 %	1604	1878	2557	2911	2993	2996	2996	2996
Reach 30 % but not 40%	95	176	341	99	25	0	0	0
< 10 min	811	423	27	0	0	0	0	0
10 min to 20 min	318	284	97	1	0	0	0	0
20 min to 30 min	143	152	98	21	0	0	0	0
30 min to 40 min	53	133	66	32	0	0	0	0
40 min to 50 min	26	44	53	11	0	0	0	0
50 min to 60 min	17	26	22	7	0	0	0	0
60 min to 70 min	6	8	10	5	0	0	0	0
70 min to 80 min	2	8	27	3	0	0	0	0
80 min to 90 min	1	10	4	1	0	0	0	0
90 min to 100 min	1	4	3	2	2	0	0	0
100 min to 110 min	0	2	1	0	1	0	0	0
110 min to 120 min	12	3	1	1	0	0	0	0
> 120 min	2	21	30	1	0	0	0	0

Table A11-b: Number of cases sorted by time to progress from 20 % to 30 % COHb and from 30 % to 40 %: First floor interior room, burst source – zones without generator