

CO exposure modelling

R. Bruzzi, P.-O. Droz, D. Vernez

Context: Why modelling ?

Exposure assessment strategy

Measurement

- + Accuracy, objective
- Cost, technical complexity, only current exposure

“Banding” and expert-judgment approaches

- + - Based on an interpretation of observations and interviews
- Subjective

Modelling

- + Predictive, sensitivity analysis,
- Inaccuracy, emission rate estimation and other parameters

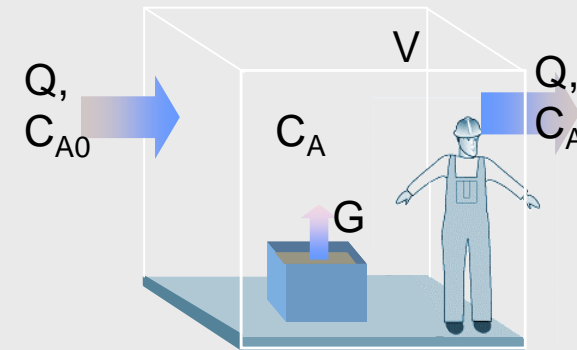
Exposure models

Ideal mixing model

gas ideally mixed in a single compartment

mass balance:

$$V \cdot \frac{dC_A}{dt} = Q \cdot C_{A0} + G - Q \cdot C_A$$



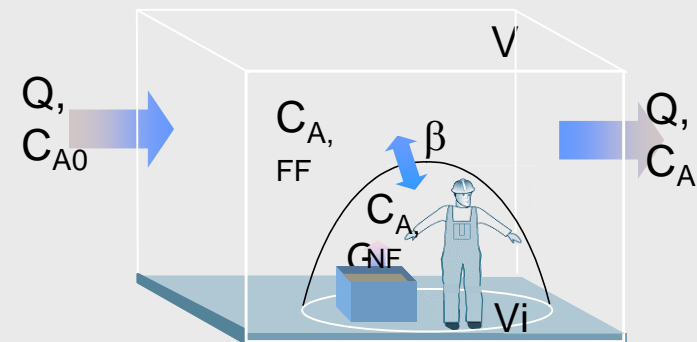
Two - compartments model

Gas ideally mixed in each compartment (Near-Field & Far-Field)

mass balance:

$$\text{NF} \quad V_{NF} \cdot \frac{dC_{A,NF}}{dt} = G + \beta \cdot C_{FF} - \beta \cdot C_{NF}$$

$$\text{FF} \quad V_{FF} \cdot \frac{dC_{A,FF}}{dt} = \beta \cdot C_{NF} - (\beta + Q) \cdot C_{FF}$$



Exposure models

Eddy diffusion model

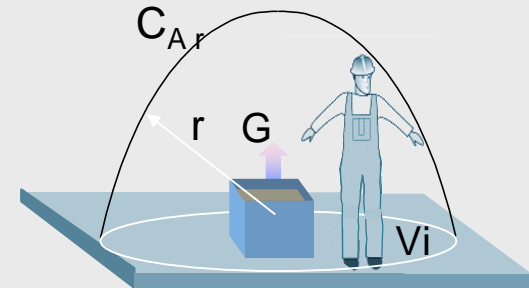
radial mixing of the pollutant through diffusion from a punctual source

$$C_r = \frac{G}{4 \cdot \pi \cdot D \cdot r} \cdot \left[1 - \operatorname{erf} \left(\frac{r}{\sqrt{4 \cdot D \cdot t}} \right) \right]$$

$$C = C(r)$$

$$\operatorname{erf}(a) = \int_0^a \frac{2}{\pi} \exp(-x^2) dx$$

D= Eddy diffusion coefficient ranges from 0.1 to 10 [m²/min]



CO exposure scenario

- a) **Garage**: exposure to car's emissions

- b) **Karting**: exposure in a karting hall

- c) **Chainsaw**: outdoor exposure to chainsaw exhausts

Key parameters affecting motor emission

- the type of engine (catalyst, temperature, fuel used, state of engine)
- mean velocity
- the driving pattern following engine start
- the time interval during which the engine was switched off
- and the ambient temperature

Average emission factors 2005 (OFEFP)

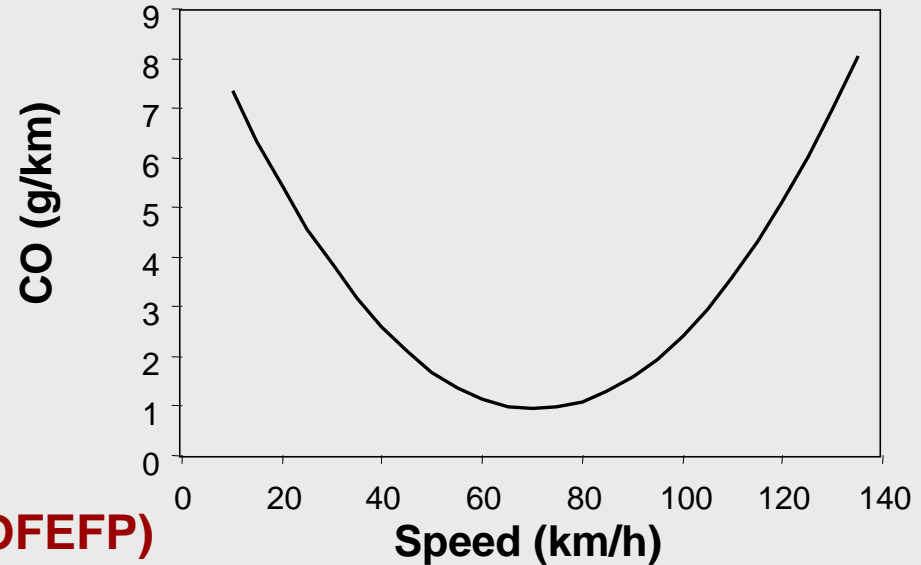
g/km (Including cold start)	2 Strokes		4 Strokes
	<50 cc	>50 cc	
With catalyst	3.4	14	3.5
Without catalyst	11	21	15.8

g/km (Including cold start)	Diesel
car	0.3
truck	2

Key parameters affecting motor emission

Emissions over a trip vary according to the average speed of the trip:

TRL Environment Group:



Average emission factors 2005 (OFEFP)

g/km (Including cold start)	2 Strokes		4 Strokes
	<50 cc	>50 cc	
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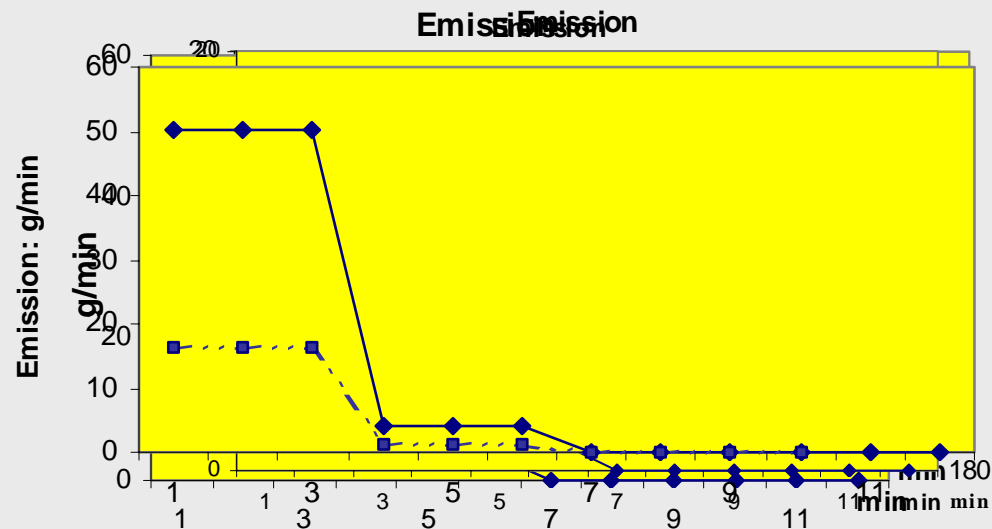
a) Garage

Hypothesis:

Volume de la pièce: 600 m³

ACH: 10 h⁻¹

Emission : cold start emission + running emission
50 g CO/start 80 g/h (10 Km/h)



Scenarios:

- I Displacement of a car on a car elevator
- II Simultaneous displacement of 3 cars
- III Tires change in a row on a car elevator

Emission source: 1 car
Duration: 6 minutes

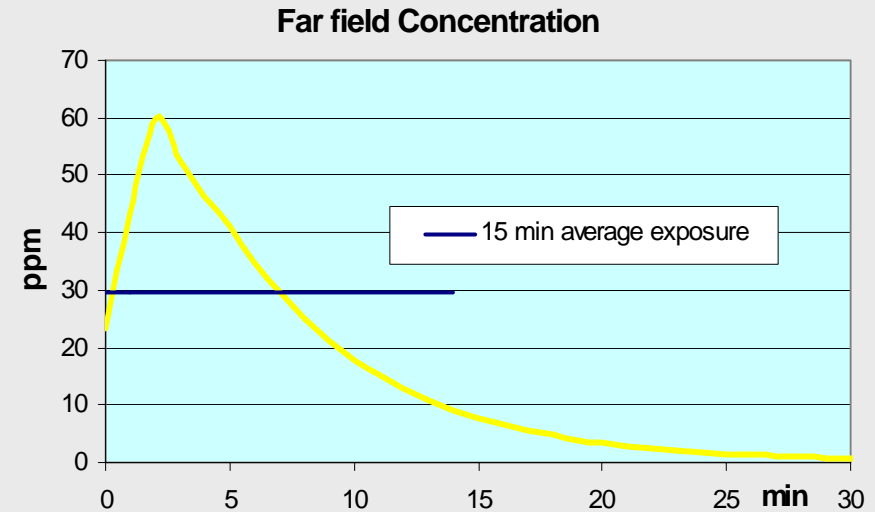
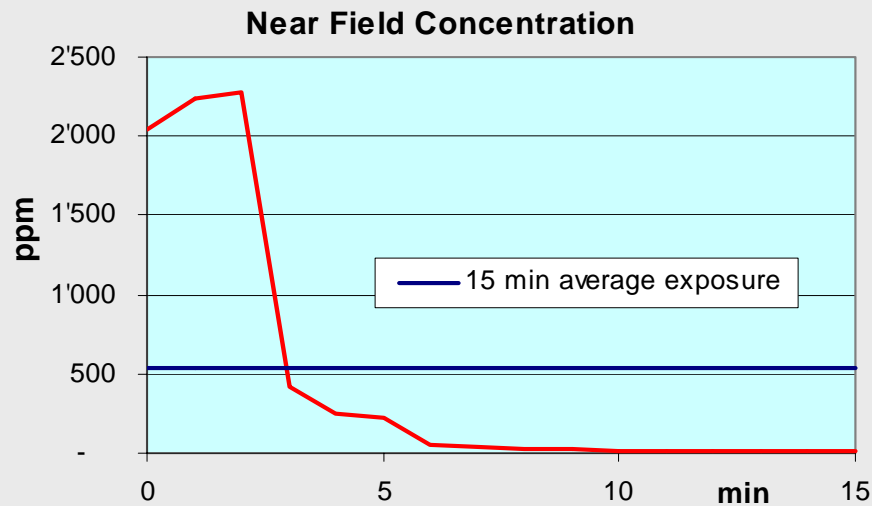
Emission source: 3 cars
Duration: 6 minutes

Emission source: 7 cars
Duration: 6 minutes

*(6 minutes to go on the lift,
and 3 minutes to go down every 25 min.)*

a) Garage

Scenario I : Displacement of a car on a car elevator:



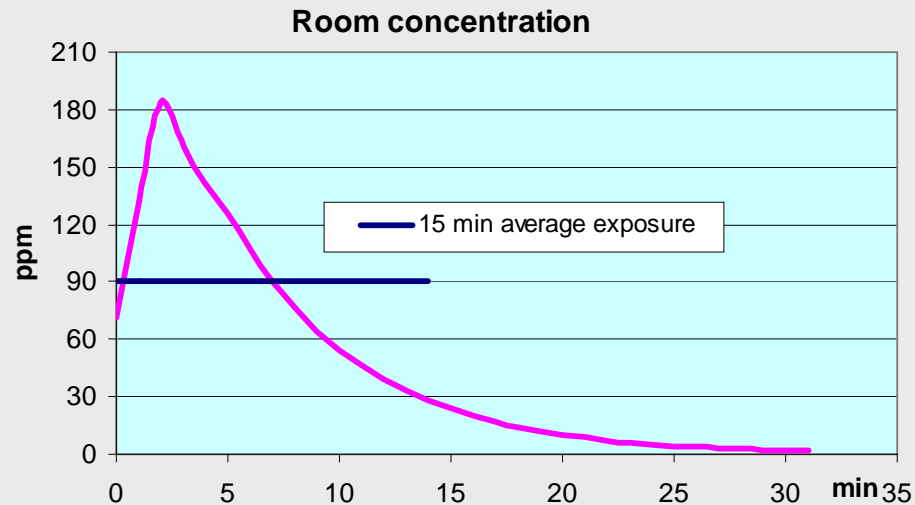
Two zone model

	Near Field	Far Field
Concentration peak:	2300 ppm	60 ppm
[15 min] average exposure :	538 ppm	30 ppm

a) Garage

Scenario I : Displacement of a car on a car elevator:

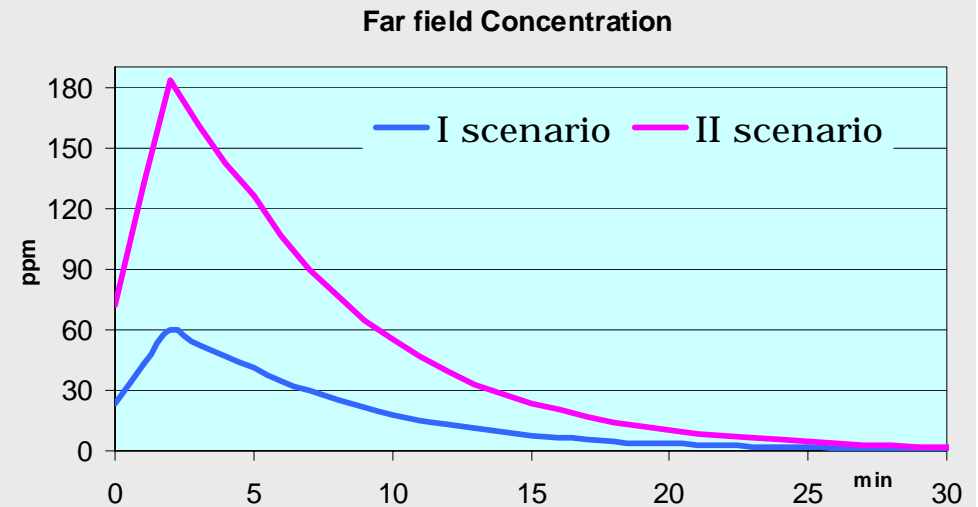
Scenario II : Simultaneous displacement of 3 cars



Well mixed model

Room Concentration peak: 184 ppm

[15 min] average exposure: 90 ppm

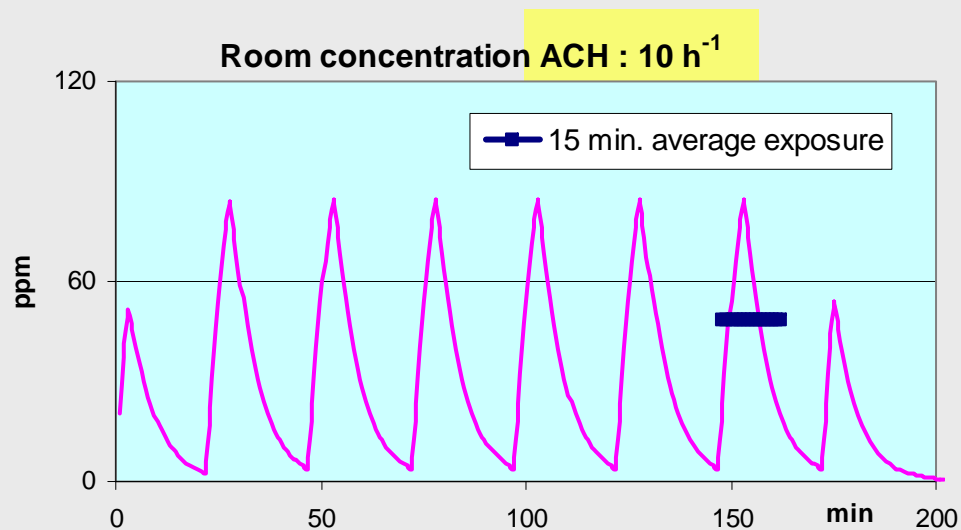


a) Garage

Scenario I : Displacement of a car on a car elevator:

Scenario II : Simultaneous displacement of 3 cars

Scenario III : Tires change in a raw on a car elevator



Well mixed model (ACH: 10 h⁻¹)

Room Concentration peak: 85 ppm

Average exposure: 28 ppm

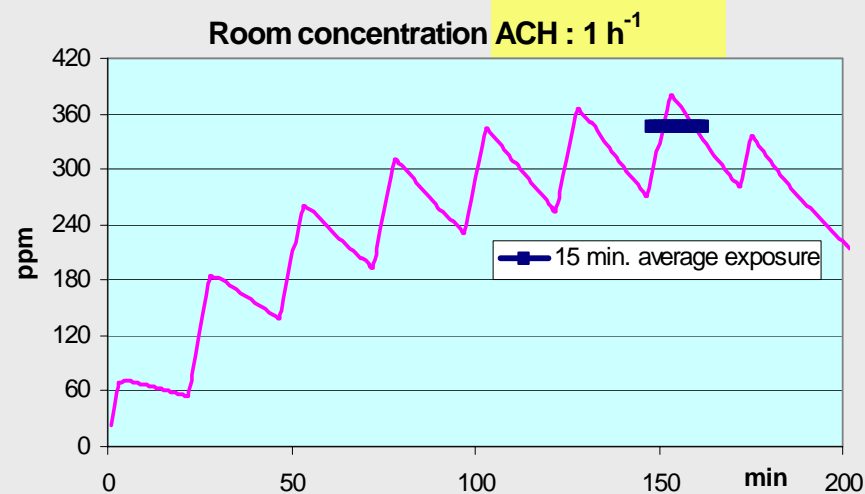
15 min. average exposure: 50 ppm

a) Garage

Scenario I : Displacement of a car on a car elevator:

Scenario II : Simultaneous displacement of 3 cars

Scenario III : Tires change in a raw on a car elevator



Well mixed model (ACH: 1 h⁻¹)

Room Concentration peak: 380 ppm

Average exposure: 243 ppm

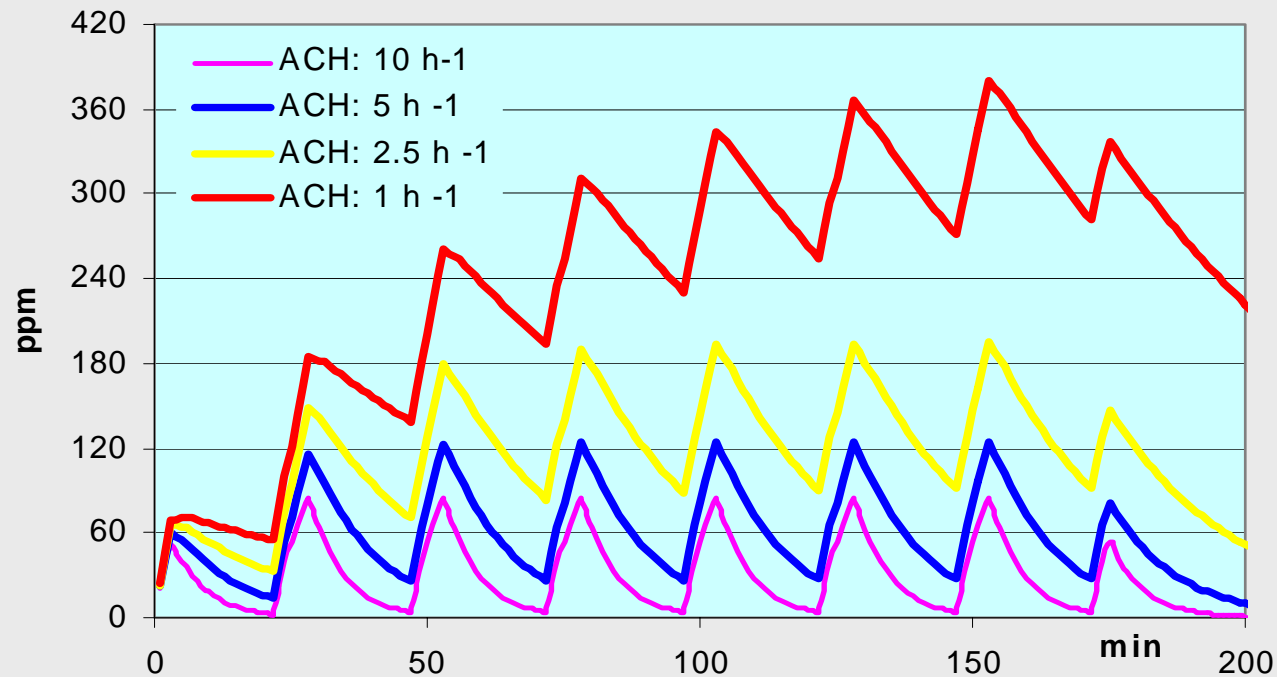
15 min. average exposure: 300 ppm

a) Garage

Scenario I : Displacement of a car on a car elevator:

Scenario II : Simultaneous displacement of 3 cars

Scenario III : Tires change in a row on a car elevator



a) Garage - exposure values in the literature

		Min [ppm]	Max [ppm]	Mean [ppm]	
Average exposure	Average exposure profile mechanic workshop - n.6	14	500	221	IST
	Average exposure [4 h] private garage - n.16	14	256		National Institute of Standards and Technology
	Average exposure [8 h] private car repair shops - n.25	1	50	19	http://www.baua.de
	Average exposure [1 h] private garage - n.7	31	84		National Technical University of Athens
	Average exposure [8 h] private garage - n.7	43	64		National Technical University of Athens

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	Average exposure profile	28	243		MODEL

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Peak exposure	Average exposure profile	28	243	(135)	MODEL
	Peak exposure mechanic workshop	70	900	70	IST
	Peak exposure	57	120		National Technical University of Athens

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Peak exposure	Average exposure profile	28	243	(135)	MODEL
	Peak exposure mechanic workshop	70	900	70	IST
	Peak exposure	57	120		National Technical University of Athens
	Peak exposure	60	380	120	MODEL

b) Karting Hall

Hypothesis:

Engine type:	two strokes engine
Emission factor:	15 g/km (including cold start)
Hall volume:	21000 m ³
Average speed:	45 Km/h
ACH:	5 h ⁻¹
Max kart running:	14

Scenarios:

I Normal

II Low season

III High season

b) Karting Hall

Hypothesis:

Engine type: two strokes engine

Emission factor: 15 g/km

Hall volume: 21000 m³

Average speed: 45 Km/h

ACH: 5 h⁻¹

Max kart running: 14

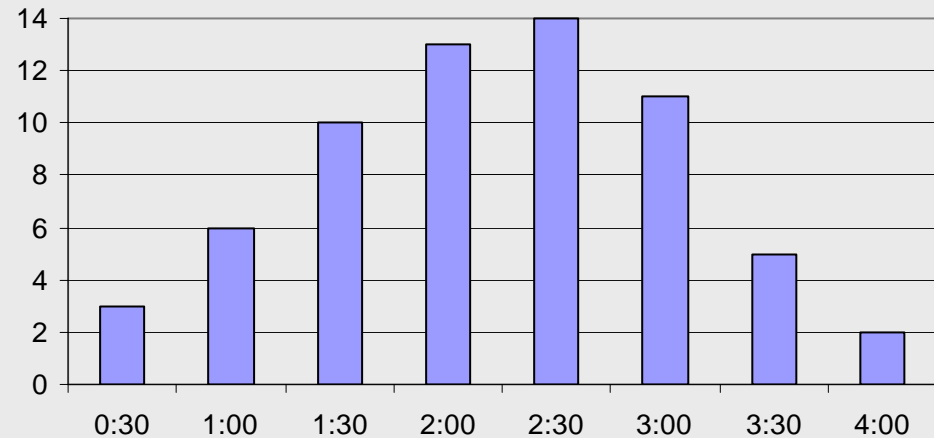
Scenarios:

I Normal

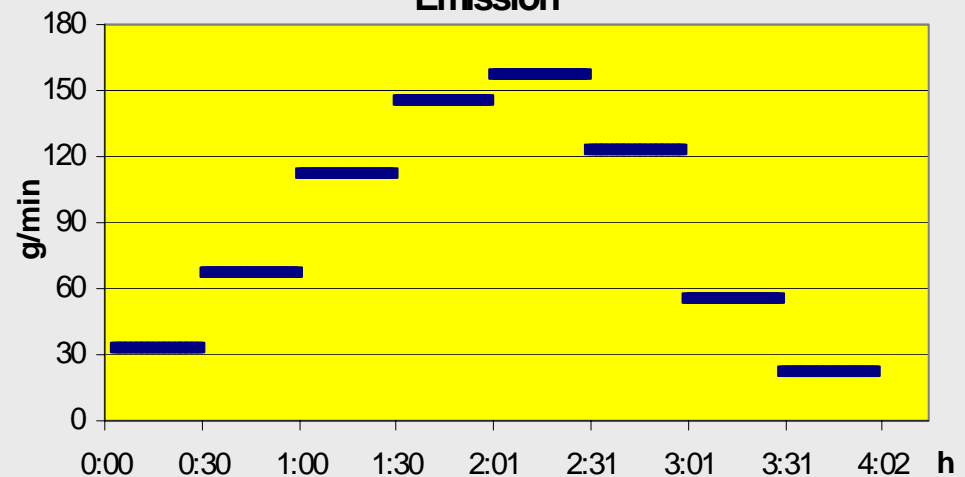
II Low season

III High season

n° kart running



Emission



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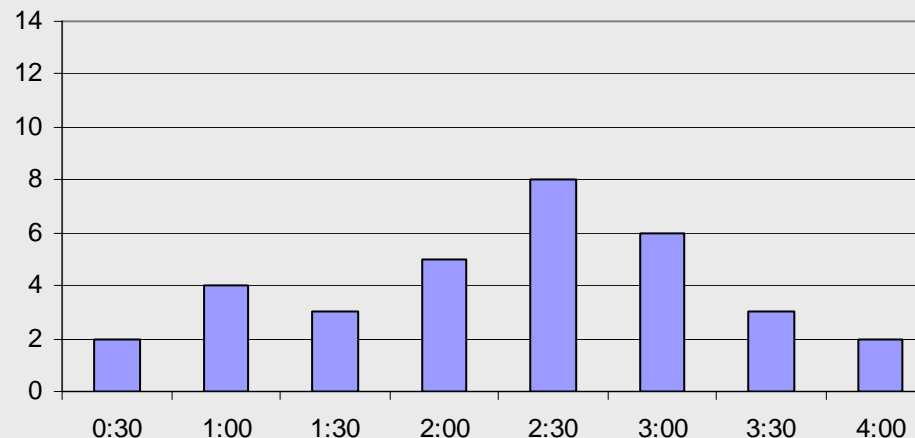
Scenarios:

I Normal

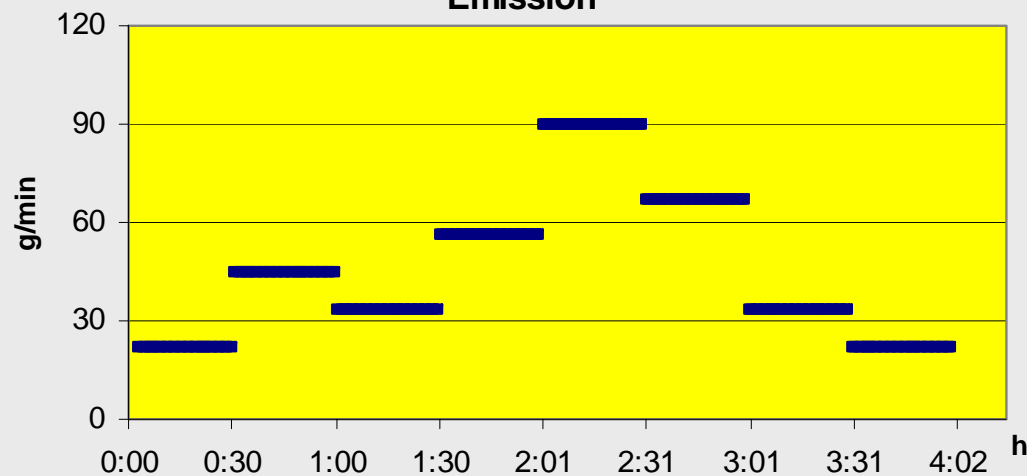
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n° kart running



Emission



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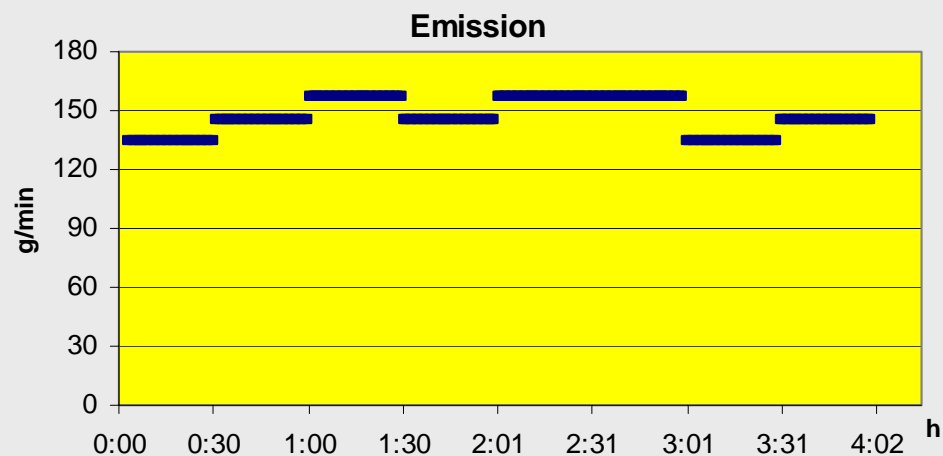
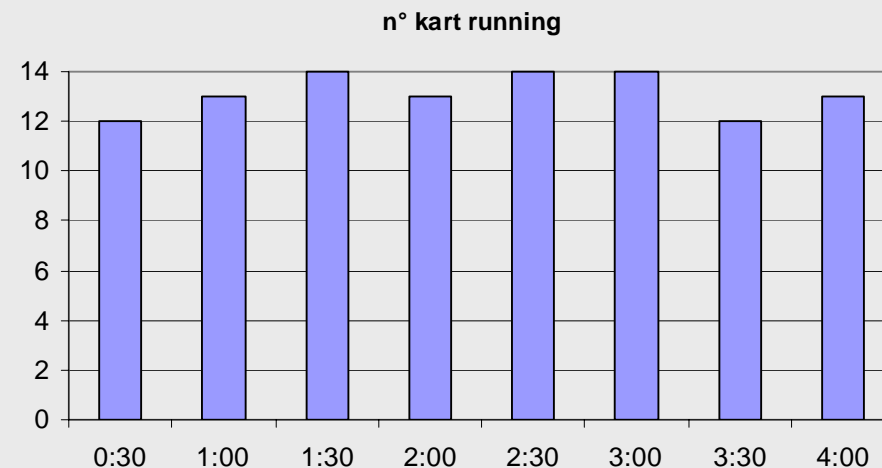
Max kart running: 14

Scenarios:

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II Low season

III High season



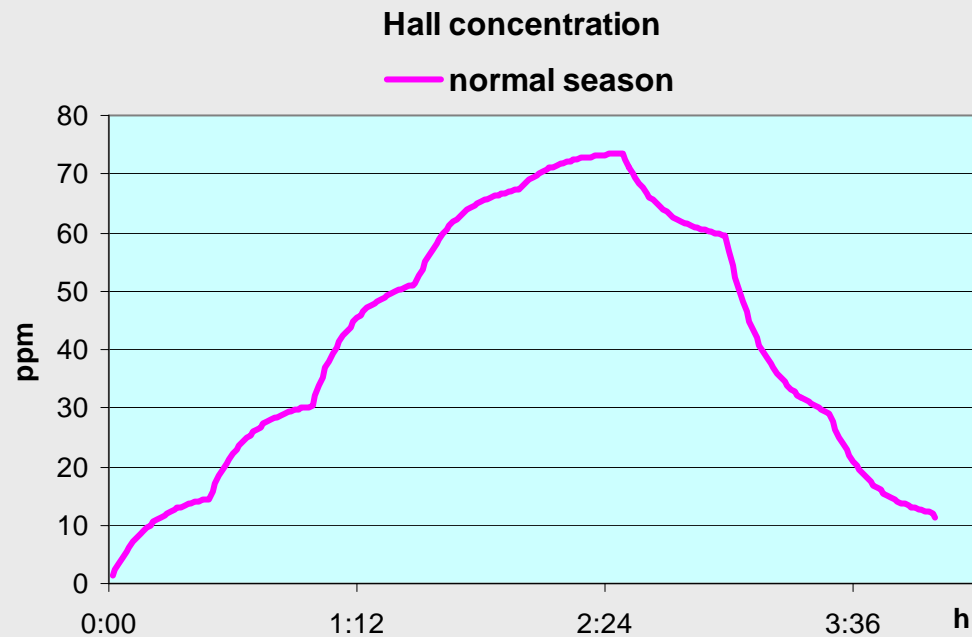
b) Karting Hall – exposure concentration

Well mixed model (Normal season)

Room Concentration peak: 74 ppm

Average exposure: 42 ppm

15 min. average exposure: 73 ppm



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Well mixed model (Normal season)

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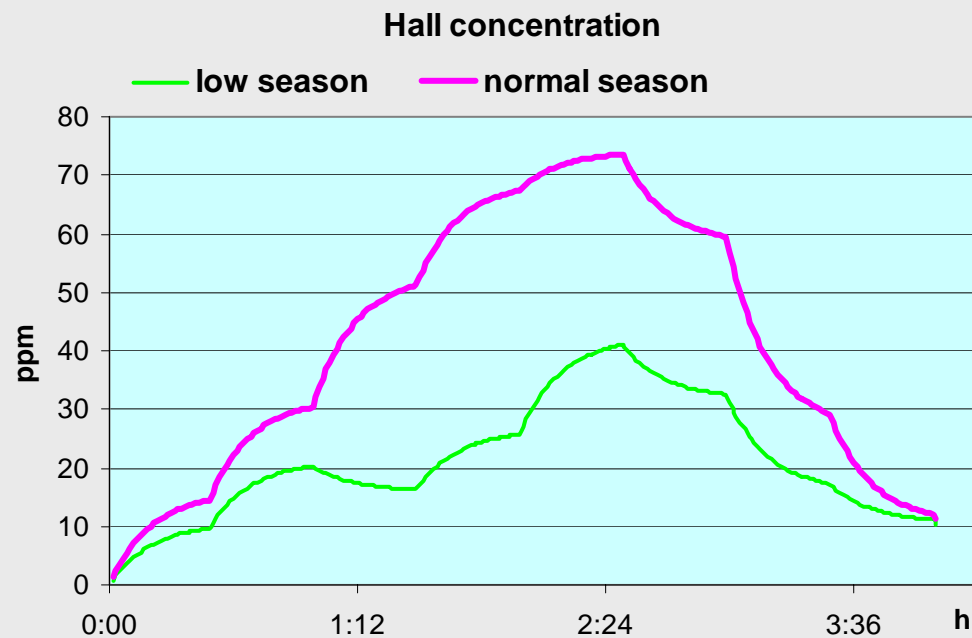
15 min. average exposure: 73 ppm

Well mixed model (Low season)

Room Concentration peak: 41 ppm

Average exposure: 22 ppm

15 min. average exposure: 40 ppm



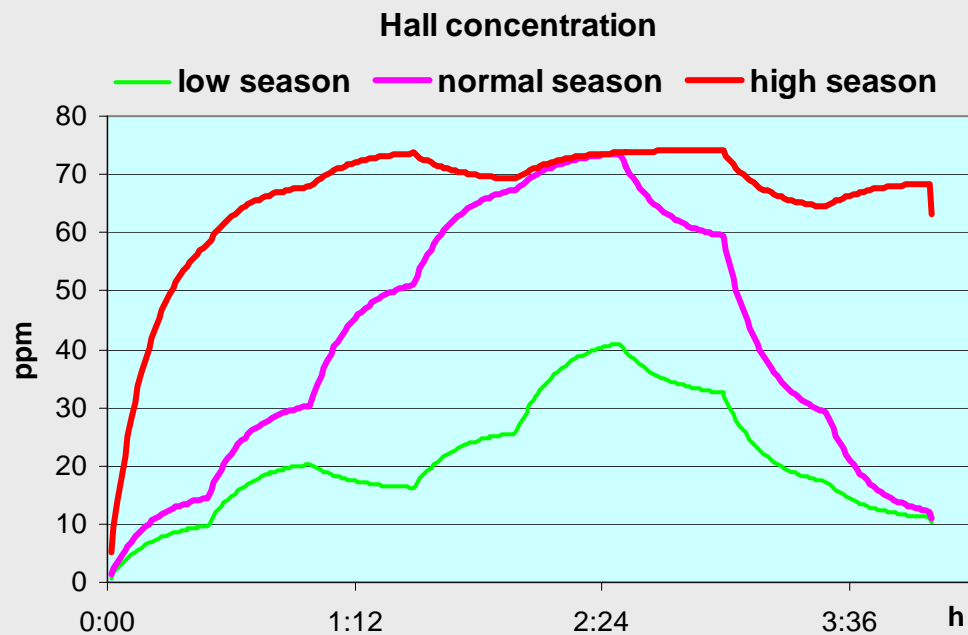
b) Karting Hall – exposure concentration

Well mixed model (Normal season)

Room Concentration peak: 74 ppm
Average exposure: 42 ppm
15 min. average exposure: 73 ppm

Well mixed model (Low season)

Room Concentration peak: 30 ppm
Average exposure: 12 ppm
15 min. average exposure: 28 ppm



Well mixed model (High season)

Room Concentration peak: 74 ppm
Average exposure: 66 ppm
15 min. average exposure: 74 ppm

b) Karting Hall – exposure values in the literature

Average exposure	> 30 ppm			SECO
	45 ppm			Insitut national de santé publique du Québec

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Average exposure	> 30 ppm			SECO
	45 ppm			Insitut national de santé publique du Québec
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	22	66	43	

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Average exposure	> 30 ppm			SECO
	45 ppm			Insitut national de santé publique du Québec
	Min [ppm]	Max [ppm]	Mean [ppm]	MODEL
	22	66	43	
Peak exposure	> 50 ppm			SECO
	85 ppm			Insitut national de santé publique du Québec

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Average exposure	> 30 ppm			SECO
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	22	66	43	
Peak exposure	> 50 ppm			SECO
	85 ppm			Insitut national de santé publique du Québec
	Min [ppm]	Max [ppm]	Mean [ppm]	MODEL
	41	74	63	

c) Chainsaw

Emission factor?

Operating a chainsaw for **1 hour** produces the same amount of exhaust emissions as driving an automobile for approximately **1000 kilometres**.

The U.S. Environmental Protection Agency

Emission testing of Engine of Non-Road Mobile Machinery :

Emission Factor: 224.5 g/kwh (power 2.3 kw)

European commission, Directorate - General XI Environment,

Nuclear Safety And Civil Protection

c) Chainsaw

Hypothesis:

engine type: two stroke

power: 2.3 kw

emission factor: 515 g CO/h

outdoor exposure

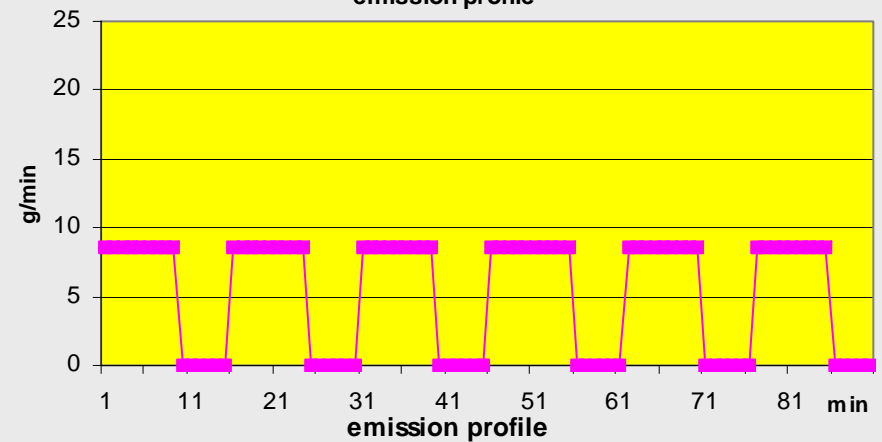
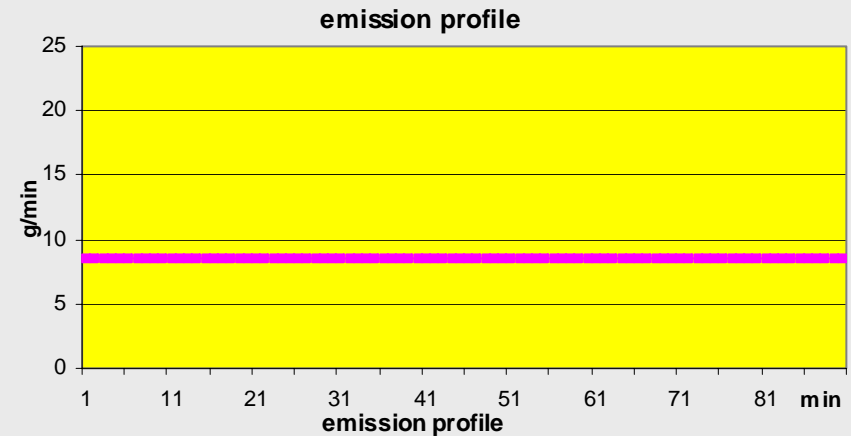
Scenarios:

I Constant emission

II Pulse emission

III With cold start

IV Different source distances



c) Chainsaw - Eddy diffusion model ($D = 2 \text{ m}^2/\text{sec}$, $r = 0.8 \text{ m}$)

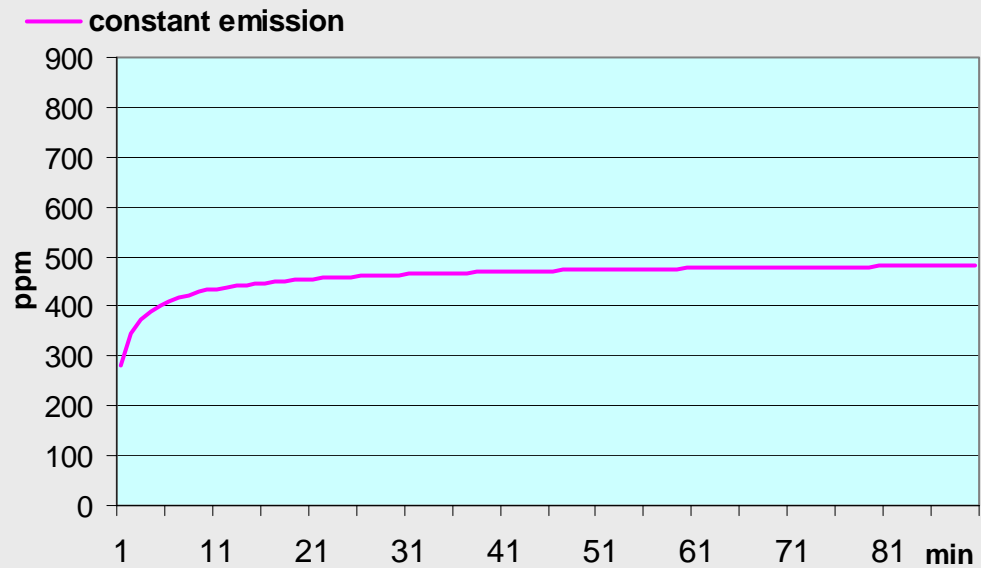
Scenarios I : Constant emission

Peak exposure: 481 ppm

average exposure (1h30): 460 ppm

15 min average exp: 481 ppm

CO concentration



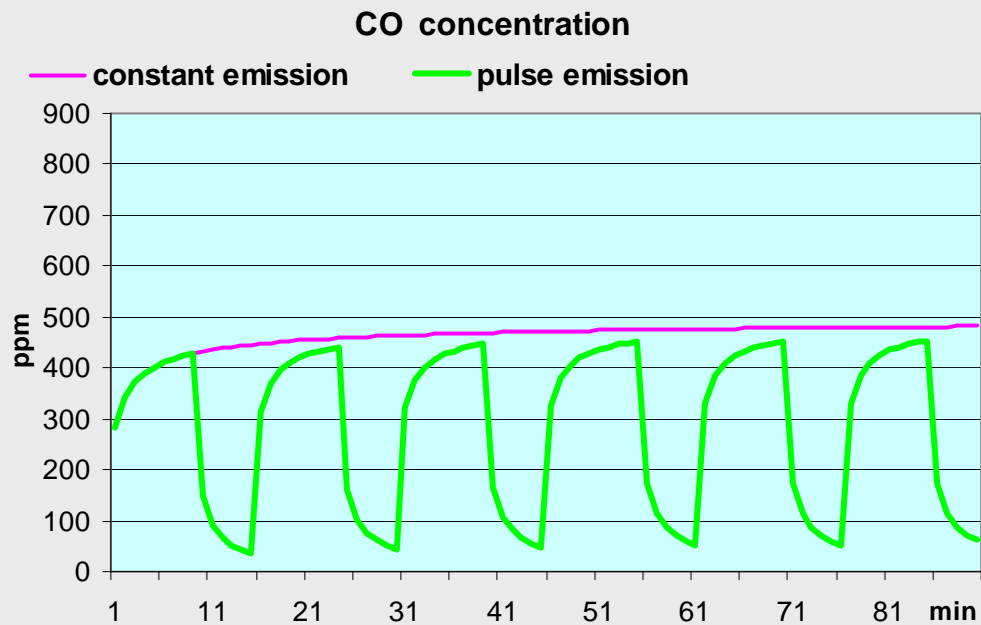
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Scenarios I : Constant emission

Peak exposure: 481 ppm
average exposure (1h30): 460 ppm
15 min average exp: 481 ppm

Scenarios II : pulse emission

Peak exposure: 453 ppm
average exposure (1h30): 284 ppm
15 min average exp: 288 ppm



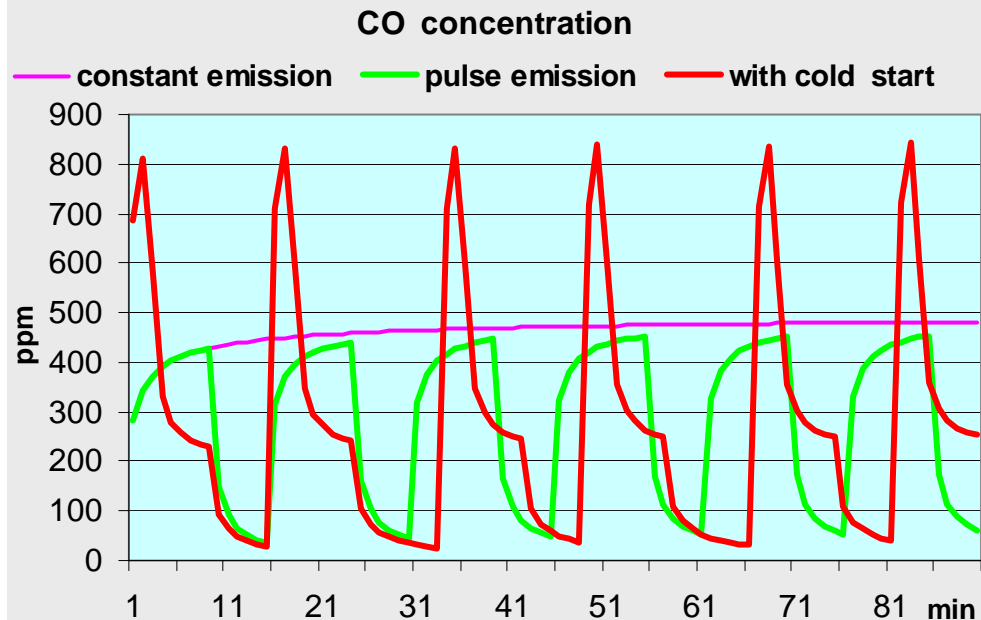
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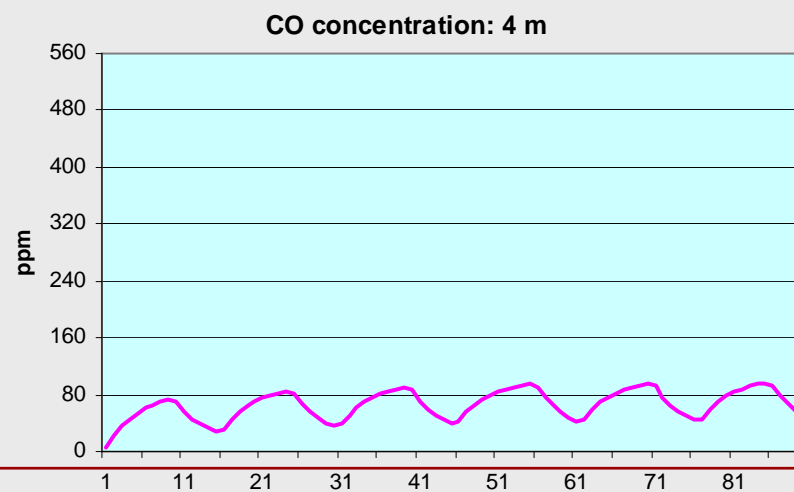
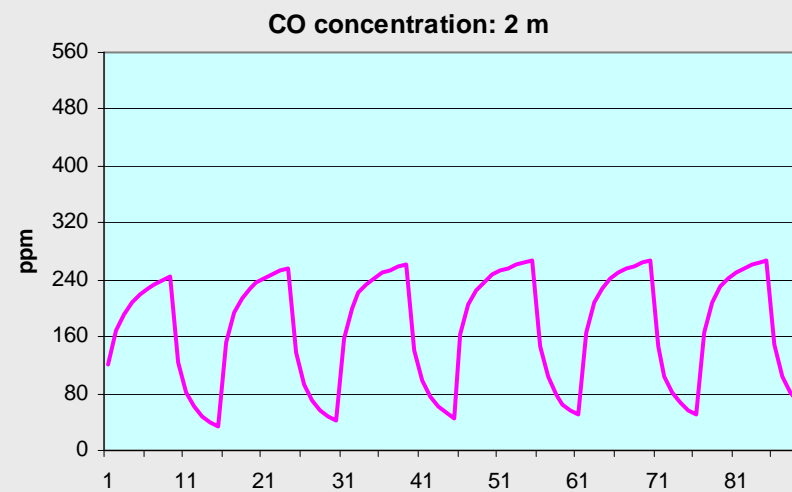
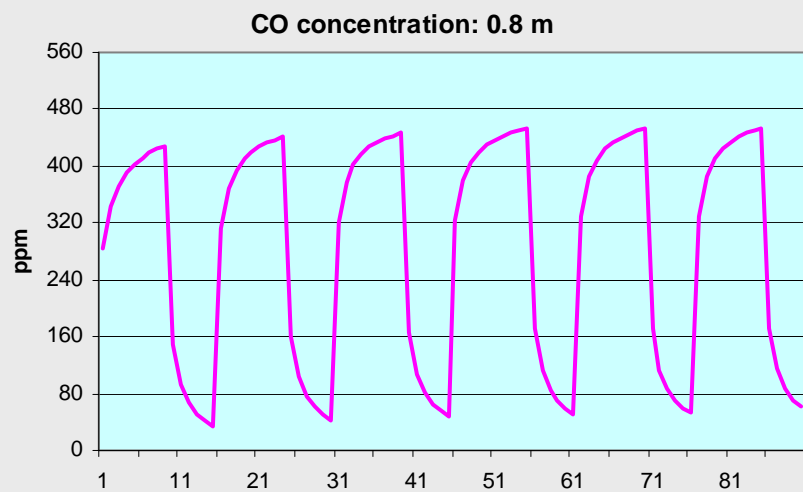
Peak exposure: 453 ppm
average exposure (1h30): 284 ppm
15 min average exp: 288 ppm



Scenarios III : with cold start

Peak exposure: 843 ppm
average exposure (1h30): 276 ppm
15 min average exp: 286 ppm

c) Chainsaw - Scenarios IV : Different source distance



c) Chainsaw – exposure values in the literature

Average exposure	Sample time: 4 h	17 ppm			NIOSH
	time-weighted average (8h)	Min [ppm]	Max [ppm]	Mean [ppm]	Biinger et al, Am. Ind. Hyg. Ass. J. 58:747-75 1 [1997]
		16.2	24.3	21.4	

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Peak exposure	504 ppm			NIOSH	
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	Min [ppm]	Max [ppm]	Mean [ppm]	MODEL	
	453	843	592		



Merci
de votre attention !!

c) Chainsaw

Some CO exposure values in the literature:

- short-term exposures > 500 ppm
a time-weighted average (8h) 24.3 , 16.2 and 23.7 ppm

Biinger et al, Am. Ind. Hyg. Ass. J. 58:747-75 1 [1997]

Conclusion

cold start emission

50 g CO/start

a) Garage

Some CO exposure values in the literature:

- 14 -256 ppm (during cold start test, 4 h average concentration)

National Institute of Standards and Technology, U.S. Department of Housing and Urban Development Office of Lead Hazard Control and Healthy Homes

- 1 - 43 ppm CO, median 16 ppm (n = 25 in private car repair shops 8 h-TWA)

<http://www.baua.de>

50 ppm in some garage following a car displacement

<http://www.nonsoloaria.com>

cold start emission

50 g CO/start

(Swedish road & Transport research):

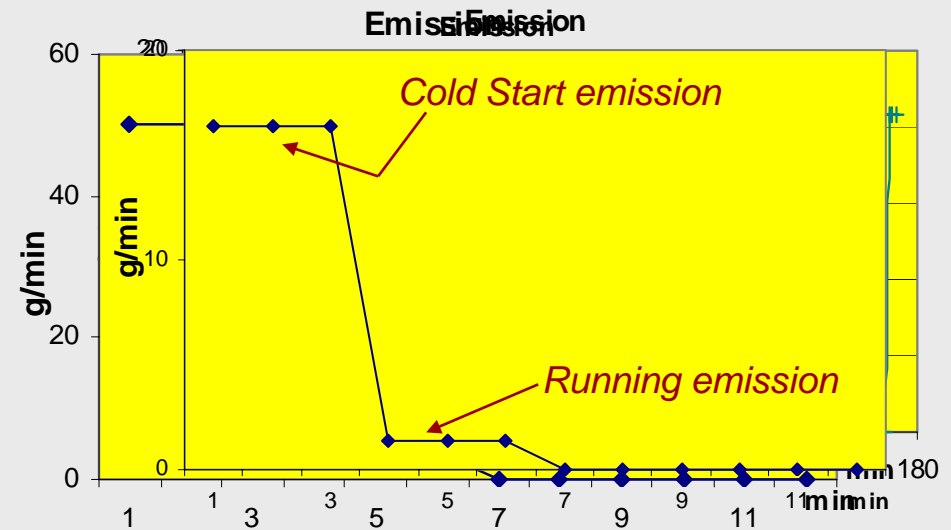
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Volume de la pièce: 600 m³

ACH: 10 h⁻¹

Emission : cold start emission + running emission
50 g CO/start 80 g/h (10 Km/h)



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Duration: 6 minutes

Emission source: 3 cars
Duration: 6 minutes

Emission source: 7 cars
Duration: 6 minutes

*(6 minutes to go on the lift,
and 3 minute to go down every 25 min.)*

b) Karting Hall

Some CO exposure values in the literature:

- peak exposure 85 ppm (4 h average concentration: 45 ppm)

Institut national de santé publique du Québec

- peak exposure > 50ppm (3 h average concentration: > 30 ppm)

SECO Direction du travail

a) Garage

Some CO exposure values in the literature:

14-500 ppm (min-max average value on 6 measure with main value 220)

70-900 ppm (min-max peak value)

Ist – Occupational exposure Database

http://www.iurst.ch/ist-bin/ist_nuisances_db.pl

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