ESTIMATING SMOG PRECURSOR EMISSIONS FROM IDLING VEHICLES IN THE CHICAGO METROPOLITAN AREA

Riyaz Shipchandler

Jim Janssen

Gary Miller*

Illinois Sustainable Technology Center

Institute of Natural Resources Sustainability

University of Illinois at Urbana-Champaign

October, 2008

Submitted to the

Metropolitan Mayors Caucus
177 North State Street, Suite 500
Chicago, Illinois 60601

* Corresponding author: Dr Gary Miller, Acting Director of the Illinois Sustainable Technology Center. He can be reached by phone at (217) 333-8940 or by email at gmiller@istc.illinois.edu.

Estimating emissions from idling vehicles can be helpful in securing organizational support for idling reduction programs. The development of these programs is discussed in a companion paper entitled, *Idling Reduction Programs for the Chicago Metropolitan Area*. Section I of this paper provides an overview of smog precursor emissions in the Chicago region, and Section II shows how emission calculations can be tailored to specific situations, such as determining emissions from idling vehicles near a school.

I: OVERVIEW OF EMISSIONS FROM IDLING VEHICLES

Determining the total quantity of emissions produced from idling vehicles in the Chicago metropolitan area is difficult due to the lack of scientific data. However, using reasonable assumptions, idling emissions can be estimated.

A. Vehicle Emissions

Vehicles are a significant source of air pollution. In fact, emissions from on-road vehicles are estimated to be the largest source of anthropogenic (man-made) smog precursors in the Chicago region according to the Illinois Environmental Protection Agency (Figure 1).[1] In 2002, on-road vehicles emitted 578 tons per day of smog precursors in the Chicago metropolitan area or 31.4% of total anthropogenic emissions. Heavy-duty trucks, passenger vehicles and light duty trucks (pickup trucks, SUV's, vans, minivans, etc.) emitted 240, 181 and 153 tons per day of smog precursors, respectively. Therefore, reducing emissions from vehicles (either while moving or idling) can lead to a significant improvement in air quality.

B. Idling Emissions

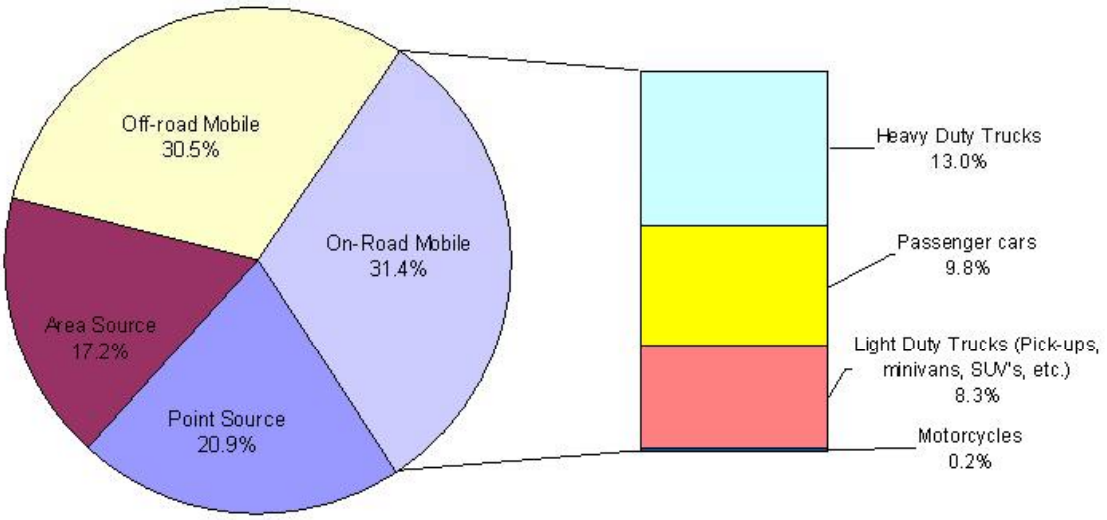
Determining emissions from idling vehicles is tricky because of the lack of scientific data on the length of time that various classes of vehicles idle. However, with reasonable assumptions, idling emissions can be estimated.

Smog Precursor Emissions in the Chicago area

- ✓ On-road vehicles were responsible for 578 tpd (31.4%) of total anthropogenic emissions
- ✓ Eliminating truck idling could reduce smog precursor emissions by 21.9 tpd.
- ✓ Reducing passenger vehicle idling by 5 minutes per day per could reduce emissions by 25.5 tpd.

The American Transportation Research Institute conducted a survey of companies representing 55,000 trucks. The survey showed that sleeper cabs idle an average of 28 hours per week (1,456 hours annually) and day cabs idle an average of 6 hours per week (312 hours annually)[2]. Trucks often idle while waiting for shipments to be loaded or unloaded and to run heating, air conditioning, communication or entertainment devices. Some trucks are equipped with technologies to reduce idling, such as direct-fired heaters, battery powered air conditioners and auxiliary power units/ generator sets. Assuming that a gallon per hour of fuel is consumed during idling and that diesel fuel costs $5 per gallon, then idling costs an average of $7,280 and $1,560 per year for sleeper cabs and day cabs, respectively.

Figure 1: Smog Precursor Emissions in the Metropolitan Chicago Area for 2002.



Based on the results from the American Transportation Research Institute's survey, it is estimated for the Chicagoland area that 21.9 tons per day of smog precursors are emitted from idling trucks or 9% of the total smog precursor emissions from heavy-duty trucks. A similar estimate can be made for passenger vehicles. If all passenger vehicles (passenger cars and light duty trucks) in the Chicagoland area reduced idling by 5 minutes per day, then total smog precursor emissions would be cut by 25.5 tons per day (6% of total emissions from passenger vehicles). These estimates show that reducing idling can have a significant impact on air quality. Complete assumptions and calculations for these estimates are shown in Appendix B.

II. ESTIMATING EMISSION AND GASOLINE USAGE FROM IDLING VEHICLES

Emissions from idling vehicles can be estimated using the data and formulas given in this section. The sample calculations at the end of the section demonstrate that the estimates can be tailored to the focus of the idling reduction program depending on the types and number of vehicles concerned.

For these estimates, an emission factor methodology should be used. A generalized formula is shown below.

Emissions = Number of vehicles x Idle Time x Emission Factor

The United States Environmental Protection Agency Office of Mobile Sources has conducted tests to determine emission factors for various vehicles (Table 1)[3]. The emission factors

represent national averages for all vehicles as of July 1, 1998. Emissions from idling vehicles are affected by a number of factors including fuel formulation, local temperature and pressure, and vehicle age and condition. However, these emission factors can be used for general estimating purposes.

Table 1: Emission Factors

	Winter Emissions				Summer Emissions		
	VOC (g/hr)	**CO (g/hr)**	**NOx (g/hr)**		**VOC (g/hr)**	**CO (g/hr)**	**NOx (g/hr)**
Passenger Cars (Gasoline)	21.1	371	6.16		16.1	229	4.72
Light-Duty Trucks (Gasoline)	30.7	487	7.47		24.1	339	5.71
Heavy-Duty Trucks (Gasoline)	44.6	682	11.8		35.8	738	10.2
Passenger Cars (Diesel)	3.63	10.1	6.66		3.53	9.97	6.50
Light-Duty Trucks (Diesel)	4.79	11.5	6.89		4.63	11.2	6.67
Heavy-Duty Trucks (Diesel)	12.6	94.6	56.7		12.5	94.0	55.0
Motorcycles	20.1	388	2.51		19.4	435	1.69

Notes:

- g/hr = grams per hour
- Passenger vehicles weigh up to 6,000 lbs.
- Light-duty trucks (pick-up trucks, minivans, passenger vans and SUV's) weigh up to 8,500 lbs.
- Heavy-duty vehicles weigh greater than 8,501 lbs.

Fuel Usage

The fuel consumed by idling vehicles has been estimated to be:

Heavy Duty Trucks: 1 gallon per hour[4]
Passenger Vehicles: 0.5 gallons per hour[5]

Like emissions, fuel consumption is affected by a number of factors including fuel formulation, local temperature and pressure, and vehicle age and condition.

SAMPLE PROBLEM 1: IDLING EMISSIONS AT A SCHOOL

PROBLEM STATEMENT

Calculate the VOC emissions from idling vehicles at a school on a summer day. Assume that there are:

- 50 gasoline powered passenger cars that each idle for 15 minutes
- 10 diesel-powered school buses that each idle for 15 minutes
- 2 gasoline-powered, light-duty maintenance trucks that each idle for 20 minutes

ANSWER

I. Emission Factor

Use Table 1 on page 3 to determine emission factors

Gasoline-powered passenger cars: 16.1 g/hr
Diesel-powered school buses (heavy duty trucks): 12.5 g/hr
Gasoline-powered light-duty trucks: 24.1 g/hr

II. Calculations

Passenger Cars

VOC Emissions = # of Vehicles x Idling Time x Emission Factor

$$= \frac{50}{\text{day}} \left| \frac{15\ \cancel{min}}{} \right| \frac{16.1\ \text{g}}{\cancel{hr}} \left| \frac{}{60\ \cancel{min}} \right.$$

= 201.3 g / day

School Buses

VOC Emissions = # of Vehicles x Idling Time x Emission Factor

$$= \frac{10}{\text{day}} \left| \frac{15\ \cancel{min}}{} \right| \frac{12.5\ \text{g}}{\cancel{hr}} \left| \frac{}{60\ \cancel{min}} \right.$$

= 31.3 g / day

Maintenance Vehicles

VOC Emissions =

$$\frac{\text{\# of Vehicles}}{} \times \frac{\text{Idling Time}}{} \times \frac{\text{Emission Factor}}{}$$

$$= \frac{2}{\text{day}} \left| \frac{20 \text{ ~~min~~}}{} \right| \frac{24.1 \text{ g}}{\text{~~hr~~}} \left| \frac{\textit{~~hr~~}}{\textit{60 ~~min~~}} \right.$$

= 16.1 g

Total Emissions

$$= \frac{(201.3 + 31.3 + 16.1) \text{ ~~g~~}}{\text{day}} \left| \frac{\textit{lbs}}{\textit{453.593 ~~g~~}} \right.$$

= 0.55 lb of VOC emissions /day

Note: Conversion factors are shown in italics

SAMPLE PROBLEM 2: EMISSIONS AND FUEL USAGE FROM IDLING PASSENGER VEHICLES

PROBLEM STATEMENT

Estimate the VOC, NOx and fuel savings that would occur if all passenger vehicles in the Chicagoland area reduced their idling time by 5 minutes per day.

ANSWER

I. Number of Vehicles

According to the U.S. Department of Transportation's Research and Innovative Technology Administration, there were 135,399,345 registered passenger vehicles in the United States in 2006.[6]

According to the U.S. Census Bureau, 2.8% of the United States population lives in the Chicagoland area.[7,8] Assume that 2.8% of the registered passenger vehicles in the country are in the Chicagoland area.

Passenger vehicles in the Chicagoland area = 135,399,345 * 0.028

= 3,791,182

II. Emission Factor

Determine emission factors from Table 1 on page 3. Assume that all passenger vehicles are powered by gasoline. Only a small percentage of passenger cars in the country run on diesel. The summer and winter emission factors for NO_x and VOC have been averaged.

NO_x : 5.44 g/hr
VOC : 18.6 g/hr
Gasoline: 0.5 gallons per hour

III. Calculations

NOx

NO_x Emissions =

# of Vehicles x Idling Time x Emission Factor

=

$$3{,}791{,}182 \left| \frac{5\ \cancel{min}}{day} \right| \frac{5.44\ \cancel{g}}{\cancel{hr}} \left| \frac{\cancel{hr}}{60\ \cancel{min}} \right| \frac{\cancel{lbs}}{453.593\ \cancel{g}} \left| \frac{ton}{2000\ \cancel{lbs}} \right.$$

= 1.89 tons/ day

VOC

VOC Emissions = # of Vehicles x Idling Time x Emission Factor

$$= \frac{3{,}791{,}182 \mid 5\ \cancel{min} \mid 18.6\ \cancel{g} \mid \cancel{hr} \mid \cancel{lbs} \mid ton}{\mid \cancel{day} \mid \cancel{hr} \mid 60\ \cancel{min} \mid 453.593\ \cancel{g} \mid 2000\ \cancel{lbs}}$$

= 6.5 tons / day

Total Smog Precursors

= 1.89 + 6.5 (tons/day)

= 8.395 tons/day

Gasoline

Gasoline Usage = # of Vehicles x Idling Time x Emission Factor

$$= \frac{3{,}791{,}182 \mid 5\ \cancel{min} \mid 0.5\ gal \mid \cancel{hr}}{\mid \cancel{day} \mid \cancel{hr} \mid 60\ \cancel{min}}$$

= 158,000 gallons of gasoline per day

Note: Conversion factors are shown in italics.

SAMPLE PROBLEM 3: EMISSIONS FROM TRUCKS IN THE CHICAGO AREA

PROBLEM STATEMENT

Estimate the daily VOC and NOx emissions from trucks in the Chicago area.

ANSWER

I. Number of Vehicles

According to the U.S. Census Bureau, there were 62,400 sleeper trucks and 229,1000 day trucks registered in Illinois in 2002.[9]

Also according to the U.S. Census Bureau, 65% of the Illinois's population lives in the Chicagoland area.[10] Assume that 65% of the registered trucks in the state are in the Chicagoland area.

Cab with sleepers: 62,400 * 0.65 = 40,560
Cabs without sleepers: 229,1000 * 0.65 = 148,915

II. Idling Time

According to the American Transportation Research Institute, on average, sleeper trucks idle 28 hours per week and day cabs idle 6 hours per week.

III. Emission Factor

Determine the emission factors for heavy-duty diesel vehicles using Table 1 on page 3. The summer and winter emission factors for NO_x and VOC have been averaged to determine a year-round factor.

NO_x Emissions: 55.85 g/hr
VOC Emissions: 12.55 g/hr

IV. Calculations

Sleeper Cabs

NO_x Emissions =

# of Vehicles x Idling Time x Emission Factor

=

$$\frac{40{,}560 \;\left|\; \frac{28\ \text{hr}}{\text{wk}} \right.\; \left|\; \frac{55.85\ \text{g}}{\text{hr}} \right.\; \left|\; \frac{\text{wk}}{7\ \text{days}} \right.\; \left|\; \frac{\text{lbs}}{453.593\ \text{g}} \right.\; \left|\; \frac{\text{ton}}{2000\ \text{lbs}} \right.}{}$$

= 10.0 tons / day

VOC Emissions =

# of Vehicles x Idling Time x Emission Factor

=

40,560	28 ~~hr~~ / ~~wk~~	12.55 ~~g~~ / ~~hr~~	~~wk~~ / *7 days*	~~lbs~~ / *453.593 ~~g~~*	*ton* / *2000 ~~lbs~~*

= 2.2 tons / day

Day Cabs

NO_x Emissions =

# of Vehicles x Idling Time x Emission Factor

=

148,915	6 ~~hr~~ / ~~wk~~	55.85 ~~g~~ / ~~hr~~	~~wk~~ / *7 days*	~~lbs~~ / *453.593 ~~g~~*	*ton* / *2000 ~~lbs~~*

= 7.9 tons / day

VOC Emissions =

# of Vehicles x Idling Time x Emission Factor

=

148,915	6 ~~hr~~ / ~~wk~~	12.55 ~~g~~ / ~~hr~~	~~wk~~ / *7 days*	~~lbs~~ / *453.593 ~~g~~*	*ton* / *2000 ~~lbs~~*

= 1.8 tons / day

Total Smog Precursors

= 10.0 + 2.2+ 7.9 + 1.8 (tons/day)

= 21.9 tons/day

ENDNOTES

---

[1] Illinois Environmental Protection Agency. *Illinois Base Year Ozone Inventory for 2002: Draft.* Springfield, IL: IL Environmental Protection Agency, 2006. [cited July 17, 2008]. Available from World Wide Web: <http://www.epa.state.il.us/air/sip/il-base-o3-inventory-2002.pdf>.

[2] U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics. *National Transportation Statistics.* Washington D.C.: U.S. Department of Transportation, 2008. Table 1-11. [cited July 17, 2008]. Available from World Wide Web: <http://www.bts.gov/publications/national_transportation_statistics>.

[3] U.S. Environmental Projection Agency Office of Mobile Sources. *Idling Vehicle Emissions.* Ann Arbor, MI: United States Environmental Projection Agency, 1998. [cited July 17, 2008]. Available from World Wide Web: <http://www.epa.gov/otaq/consumer/f98014.pdf >.

[4] U.S. Environmental Protection Agency Region 1. *Idling* [Online]. Boston, MA: U.S. Environmental Protection Agency Region 1, 2008. Updated May 30, 2008. [cited July 17, 2008]. Available from World Wide Web: < http://www.epa.gov/region1/eco/diesel/idling.html>.

[5] ASME Florida Section. *Virtual Mythbusters by American Society of Mechanical Engineers Florida Section* [Online]. Florida: American Society of Mechanical Engineers Florida Section, undated. [cited 7 July 2008]. Available from World Wide Web: <http://sections.asme.org/florida/ASME%20Fla%20Section%20Virtual%20Mythbusters.html >.

[6] U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics. *National Transportation Statistics.* Washington D.C.: U.S. Department of Transportation, 2008. See Table 1-11. [cited July 17, 2008] Available from World Wide Web: <*http://www.bts.gov/publications/national_transportation_statistics/*>.

[7] U.S. Census Bureau, Population Division. *County Population Estimates* [Online]. Washington, D.C.: U.S. Census Bureau, 2008. Last Modified: March 20, 2008. [cited July 17, 2008]. Available from World Wide Web: < http://www.census.gov/popest/counties/CO-EST2007-01.html>.

[8]U.S. Census Bureau, Population Division. *National and State Population Estimates* [Online]. Washington, D.C.: U.S. Census Bureau, 2008. Last Modified: June 26, 2008. [cited July 17, 2008]. Available from World Wide Web: <http://www.census.gov/popest/states/NST-ann-est.html>.

[9] U.S. Census Bureau, *2002 Economic Census Vehicle Inventory and User Survey (Illinois).* Washington D.C.: U.S. Census Bureau, 2004. [cited July 17, 2008]. Available from World Wide Web: <http://www.census.gov/svsd/www/vius/2002.html>.

[10] U.S. Census Bureau, Population Division. *County Population Estimates* [Online]. Washington, D.C.: U.S. Census Bureau, 2008. Last Modified: March 20, 2008. [cited July 17, 2008]. Available from World Wide Web: < http://www.census.gov/popest/counties/CO-EST2007-01.html>.