Emissions Uncertainty: Focusing on NOx Emissions from Combustion Sources

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Abstract

Emission factors are important for estimating and characterizing emissions from sources of air pollution. An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with said pollutant. These factors are usually expressed as the weight of a pollutant divided by the unit weight, volume, distance, or duration of the activity emitting the pollutant (e. g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i. e., a population average). The objects are as follows… (1) Verify the NOx emission factors from combustion sources with currently available continuous emissions monitor systems (CEMS) data; (2) Develop quantitative uncertainty indicators for A through E rated emission factors on NOx emissions form combustion sources; and (3) Determine the limitations of applying these quantitative uncertainty indicators fto other pollutants and source types

Key Terms

Emissions Uncertainty → the reliability of having an accurate estimate of emissions from a smokestack.

CEMS → Continuous Emission Monitoring Systems: a data collection method for monitoring air pollution.

Emission Factor → a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant.

AP – 42 → this series is the principle means by which the Environmental Protection Agency (EPA) can document its emission factors. In most cases these factors are simply averages of all available data of acceptable quality.

SCC → Source Classification Code: an eight digit number that the EPA uses to classify various sources for purposes of relating to emission factors, grouping common kinds of sources.

WebFIRE → the EPA's online database that catalogs descriptions of SCC's and their emission factors.

Methods

- Input the data into statistical analysis software (SAS) and sorted by the 52 unique SCC's.
- Remove values from May 1st to Sept 30th 2002 – 2007. The remaining data will be a true representation of post combustion uncontrolled emissions.
- Compare the distribution over our ten year period, 1997 – 2007, to the known AP – 42 values for each SCC.
- To reduce variability of our data set we removed the upper and lower 2% of emission factor values for each SCC.
- To reduce data quality issues in our dataset we used an excel sheet using a set of certain criteria as given to us by the USEPA:
  - Boilers with multiple SCCs: This removed 'starter fuels' that released fewer emissions than the main fuel for a boiler, keeping the dominant SCC emissions.
  - Boilers with zero hours of operation.
  - Duplicate entries in database.
- As a result, a few SCC's were fully removed from the data set.
- The relationship of AP – 42 to each SCC is then ranked based on what quartile of the emissions distribution the AP – 42 value falls within.
- By using the as combusted emission factors we can simplify the equation for emission estimations
  - $E = A \times EF \times (1 - ER/100)$
  - $E = A \times EF \times (1 - 0/100)$
  - $E = A \times EF$
- Our true emissions would then be equal to the activity rate multiplied by the emissions factor.
- For phase 2 of this project we focused on three SCC's which were chosen for their massive number of observations and relative normality.
- We used the data from these SCC's to estimate the level of sampling precision associated with different sample sizes.
- In order to achieve a desired level of sampling precision, a given sample size must be found. To estimate the sample size we used the following formula: $n=\sigma^2(Z/MoE)^2$ where n = sample size, sigma = POPULATION standard deviation, Z = standard normal for CI's (ie: 95% CI --> Z = 1.96), and MoE = "margin of error" = (POPULATION mean)*(desired % within mean)

Figure 1. Before 2% Trim

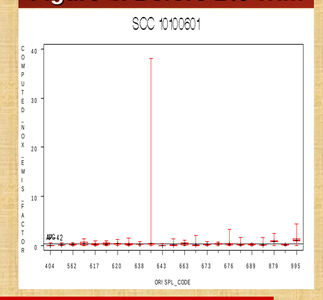
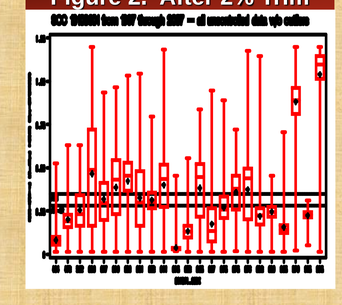


Figure 2. After 2% Trim



Results: Phase I

SCC and Corresponding AP-42 Ranking

SCC	Fuel Type	# of Obs.	# of Plants	Mean	Median	Letter Grade	New Rating
10100101	Anthracite Coal	107,389	1	12.81	12.88	B	18
10100201	(Sub)Bituminous Coal	2,066,852	20	16.05	14.49	D	31
10100202	(Sub)Bituminous Coal	16,040,745	160	11.69	11.04	A	12
10100203	(Sub)Bituminous Coal	2,029,758	28	22.36	21.74	A	33
10100204	(Sub)Bituminous Coal	144,337	4	8.48	7.55	C	11
10100211	(Sub)Bituminous Coal	128,492	1	6.47	6.9	E	14
10100212	(Sub)Bituminous Coal	9,890,025	90	10.45	10.04	A	10
10100215	(Sub)Bituminous Coal	256,878	2	20.19	15.1	A	31
10100217	(Sub)Bituminous Coal	126,097	2	6.75	6.9	D	15.2
10100218	(Sub)Bituminous Coal	19,075	1	4	3.71	D	5
10100221	(Sub)Bituminous Coal	294,735	3	7.54	8.02	E	24
10100222	(Sub)Bituminous Coal	5,426,296	56	7.41	6.91	A	7.4
10100223	(Sub)Bituminous Coal	455,553	13	13.27	14.06	C	17
10100224	(Sub)Bituminous Coal	14,719	1	6.41	5.88	B	8.8
10100226	(Sub)Bituminous Coal	3,642,723	37	5.8	5.68	A	7.2
10100301	Lignite Coal	741,616	8	4.74	4.48	C	6.3
10100302	Lignite Coal	322,862	6	4.59	4.74	A	7.1
10100303	Lignite Coal	320,759	3	9.49	10.61	C	15
10100306	Lignite Coal	EXC.	EXC.	EXC.	EXC.	C	5.8
10100317	Lignite Coal	EXC.	EXC.	EXC.	EXC.	C	3.6
10200204	(Sub)Bituminous Coal	15,813	1	9.08	8.71	B	11
10200219	(Sub)Bituminous Coal	19,219	1	9.9	9.92	U	15
10100401	Residual Oil	549,312	31	1.56	1.53	A	1.97
10100404	Residual Oil	295,913	16	1.77	1.77	A	1.34
10100501	Distillate Oil	150,293	14	2.11	1.8	D	1.01
10100504	Distillate Oil	3,133	1	0.75	0.72	B	1.97
10100801	Petroleum Coke	30,193	4	10.5	11.56	A	21
10101201	Solid Waste	EXC.	EXC.	EXC.	EXC.	U	3.8
10101302	Liquid Waste	EXC.	EXC.	EXC.	EXC.	C	0.8
10200501	Distillate Oil	EXC.	EXC.	EXC.	EXC.	D	1.01
20100101	Distillate Oil (Diesel)	28,960	2	0.02	0.01	C	0.88
20100901	Kerosone/Naphtha (Jet Fuel)	EXC.	EXC.	EXC.	EXC.	C	0.88
20300102	Distillate Oil (Diesel)	EXC.	EXC.	EXC.	EXC.	C	0.88
10100601	Natural Gas	5,117,185	126	0.22	0.19	A	0.19
10100602	Natural Gas	122,234	4	0.31	0.28	B	0.1
10100604	Natural Gas	1,737,279	37	0.15	0.14	A	0.17
10100711	Landfill Gas	EXC.	EXC.	EXC.	EXC.	U	0.07
10101002	Liquified Petroleum Gas	EXC.	EXC.	EXC.	EXC.	E	0.8
10200601	Natural Gas	118,924	3	0.18	0.14	A	0.19
10200602	Natural Gas	1,350	1	0.08	0.04	B	0.1
10200604	Natural Gas	564	1	0.25	0.28	A	0.17
10200704	Process Gas	EXC.	EXC.	EXC.	EXC.	U	0.02
10200707	Process Gas	EXC.	EXC.	EXC.	EXC.	U	0.08
10300601	Natural Gas	135,332	2	0.41	0.38	A	0.19
10300811	Landfill Gas	EXC.	EXC.	EXC.	EXC.	U	0.07
10500106	Natural Gas	55,847	1	0.15	0.16	U	0.1
20100201	Natural Gas	1,451,941	42	0.1	0.04	A	0.32
20200201	Natural Gas	105,344	3	0.33	0.32	A	0.32
20200203	Natural Gas	99,887	2	0.02	0.01	A	0.32
20300202	Natural Gas	EXC.	EXC.	EXC.	EXC.	A	0.32

LEGEND

AP-42 mean b/w 25% - 75% of CEMS obs.	AP-42 mean b/w 10% - 90% of CEMS obs.	AP-42 mean b/w 5% - 95% of CEMS obs.	AP-42 mean outside 5% - 95% of CEMS obs.	SCC EXCLUDED due to data quality issues

Observations and the Interrelationship Between Ranking and Letter Grade

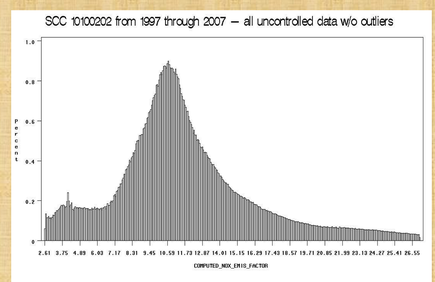
Letter Grade	Ranking: Green	Yellow	Orange	Red	Totals	Excluded
A	74.39%	12.44%	2.79%	1.13%	90.75%	37.74%
B	0.00%	0.06%	0.21%	0.24%	0.51%	0.31%
C	0.00%	2.58%	0.00%	0.67%	3.25%	6.19%
D	0.04%	0.00%	4.26%	0.24%	4.54%	52.94%
E	0.00%	0.00%	0.00%	0.81%	0.81%	1.62%
U	0.00%	0.00%	0.00%	0.14%	0.14%	1.20%
Totals	74.43%	15.08%	7.25%	3.24%	100.00 %	100.00%

Results: Phase II

Ex. SCC 10100202

SCC 10100202		CHANCE SAMPLE MEAN WILL BE WITHIN X% OF TRUE MEAN				
		20%	15%	10%	5%	1%
LEVEL OF CONFIDENCE	80%	7	11	27	99	2466
	90%	11	19	41	163	4073
	95%	15	26	58	232	5782
	99%	25	45	100	400	9979

Mean	Standard Deviation	coefficient of variation	n
11.69	4.535	0.388	16,040,745



SCC 10100202		
Margin of Error = 10%		
A	25	19.7%
B	10	41.5%
C	5	56.4%
D	3	65.6%
E	1	79.5%

Phase III

In order to accomplish phase III of our project a dataset from a pervious study by RTI was obtained. This dataset was also used for analysis of emissions uncertainly and contained emission factors for 44 different pollutant and source category combinations. Phase III demonstrated according to our findings that a different approach is needed when addressing multiple pollutant sources and category combinations. This is illustrated by the wide rages of uncertainty values in the chart of uncertainty ranges from all pollutants and source categories in the following section.

Conclusions

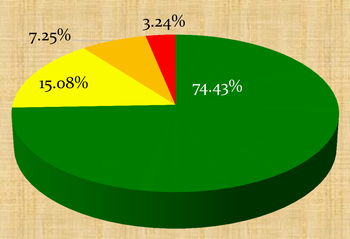
The results from Phase I were mixed:

- Over half of all observations came from 3 SCC's, all of which had an "A" letter grade and green rating: 10100202, 10100212 and 10100601
- However, over half of the SCC's are either "red" or "excluded"

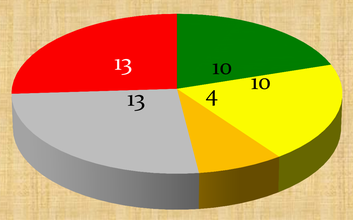
For Phase II we determined the sample sizes necessary to achieve a predetermined level of precision, as well estimated the level of uncertainty of the AP-42 letter grades.

The table for Phase III is below the Phase II results.

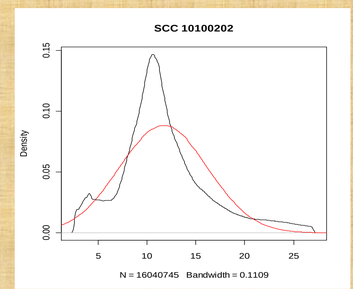
Count of Observations by Rating



Counts of SCCs by Rating



Normal Curve vs. Histogram Curve for Scc10100202



Overall Uncertainty of AP-42 Letter Grades

AVERAGE		SAMPLE SIZE: 25	10	5	3	1
SAMPLING PRECISION	20%	0.068	0.155	0.265	0.360	0.559
	10%	0.226	0.395	0.522	0.605	0.748
	5%	0.482	0.632	0.723	0.778	0.866
	1%	0.866	0.914	0.939	0.953	0.973

Uncertainty Ranges from All Pollutant and Source Categories

A Uncertainty (n=25)	B Uncertainty (n=10)	C Uncertainty (n=5)	D Uncertainty (n=3)	E Uncertainty (n=1)
25-50%	45-65%	60-75%	65-80%	80-90%

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