



*Centralia Mine Fire Mercury Study
Final Report*

March 10, 2008

**Commonwealth of Pennsylvania
Department of Environmental Protection
Bureau of Air Quality**

**Edward G. Rendell, Governor
Commonwealth of Pennsylvania**

**Kathleen A. McGinty, Secretary
Department of Environmental Protection**

Executive Summary

The Commonwealth of Pennsylvania (Pennsylvania or Commonwealth) has a well-documented inventory of abandoned coal mining related problems dating from the days before mining activities were regulated. In 2004, the federal Office of Surface Mining (OSM) Abandoned Mine Land Inventory System (AMLIS) identified forty uncontrolled mine fires known to be burning in this Commonwealth. Since the coals burning in mine fires burn are the same coals that are combusted in electrical power generating units (EGUs), concerns were raised concerning the emission of mercury from coal mine fires in Pennsylvania. The Department of Environmental Protection's (DEP's) Bureau of Air Quality (BAQ) and the Bureau of Abandoned Mine Reclamation (BAMR) partnered to conduct a study of mercury emissions from a coal mine fire, with financial support from the United States Environmental Protection Agency (EPA) and OSM. The BAMR selected the Centralia mine fire as the study site. This fire, burning anthracite coal seams located in Columbia County, affects approximately 400 surface acres.

Because pollutants are emitted from the mine fire over a wide area and may increase and decrease over time depending on precipitation, barometric pressure changes and other factors, it was not considered practical to directly measure the emissions as at a point source. Therefore, the goal of the study was to estimate emissions by modeling upwind to downwind mercury concentrations during selected periods with suitable wind conditions. Three ambient monitoring sites were selected, one in the primary downwind direction from the main fire area, one closest to the few remaining residents in the mostly abandoned town, and one background site upwind of the fire. The original study plan called for four monitoring sites. However, subsequent monitoring results negated the need for the fourth site and its associated mercury monitor was then used as collocated sampler at the Main site. This collocation provided the Department with a measurement of the data quality. An on-site meteorological system measured horizontal wind speed, vertical wind speed, wind direction, solar radiation, barometric pressure, precipitation, and air temperatures at two and ten meters in height (to calculate delta T, a measure of atmospheric stability).

The primary downwind site used a Tekran mercury speciation system to measure the total mercury emitted in three different forms: elemental mercury vapor, reactive gaseous mercury and particulate mercury. Due to the high cost of mercury speciation systems, the other sites measured only elemental mercury vapor. The mercury analyzers ran continuously except when they were off-line for service or repairs. In addition to mercury, carbon monoxide, sulfur dioxide, hydrogen sulfide, carbon dioxide and toxic metals in total suspended particulate (TSP) were measured at the Main site. Carbon monoxide, carbon dioxide and TSP were measured at the Town site; and carbon monoxide and carbon dioxide were measured at the Background site. Carbon monoxide, sulfur dioxide, hydrogen sulfide and the toxic metal beryllium were not detected at any levels that exceeded their ambient air quality standard.

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The concentrations of elemental mercury vapor, averaged over the study period from June 2006 to June 2007, were 1.6 nanograms per cubic meter (ng/m^3) at all three sites; and the overall average differences between the sites were within the measurement accuracy. For comparison, the annual average ambient elemental mercury vapor concentration at Lancaster, which is the only other DEP mercury monitoring site, was 1.6 ng/m^3 in 2005 and 2.1 ng/m^3 in 2006. The difference in average mercury concentrations between the Main and Background sites for periods when the wind was blowing from the main fire area (from the west between 1 and 10 mph), was 0.21 ng/m^3 , but for all other periods was 0.07 ng/m^3 . Thus, there are small but detectable mercury emissions from the Centralia coal mine fire area. The average concentrations of reactive gaseous mercury and particulate mercury were 0.016 and 0.009 ng/m^3 , respectively, thus the two forms do not add significantly to the total mercury. The EPA, Integrated Risk Information System (IRIS), Reference Concentration Inhalation for elemental mercury vapor is 300 ng/m^3 . When ambient levels of mercury are below these concentrations, no adverse health effects are expected. Clearly, the elemental mercury vapor levels measured at Centralia are not significant compared to these risk levels.

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Introduction

Background

*“Across the globe, thousands of coal fires are burning. Nearly impossible to reach and extinguish once they get started, the underground blazes threaten towns and roads, poison the air and soil and, some say, worsen global warming. The menace is growing: mines open coal beds to oxygen; human-induced fires or spontaneous combustion provides the spark. The United States, with the world’s largest coal reserves, harbors hundreds of blazes from Alaska to Alabama. Pennsylvania, the worst-afflicted state, has at least 38.”*¹ Mine fires consume a valuable coal resource and produce greenhouse gases. Recently, interest has focused on mercury emissions from coal-fired electricity generating facilities. Since mine fires burn the same coals that are burned in the generating facilities, it is suspected that mine fires also emit mercury. The Department of Environmental Protection’s (DEP’s) Bureau of Abandoned Mine Reclamation (BAMR) contacted the Bureau of Air Quality (BAQ) and expressed an interest in determining the risk to public health and safety posed by the release of mercury from abandoned coal mine fires. If mine fires were significant emitters of mercury, this risk analysis would provide BAMR with a means to prioritize fires for extinguishment utilizing the limited federal funds available to the State through the federal Surface Mine Control and Reclamation Act, P.L. 95-87.

BAMR proposed to partner with the BAQ to undertake a phased approach to assessing the risk to public health and safety posed by mercury releases from abandoned coalmine fires. Phase I would involve the monitoring around a selected fire that is in close proximity to a downwind population center. After reviewing the status of active fires and conducting limited air sampling, the Centralia mine fire was selected for monitoring. The monitoring program would determine the amount of mercury produced by the subject fire. If a public health and safety risk was identified during Phase I of the Centralia monitoring study, Phase II would expand the study to include approximately five additional fires across the State. Assuming the study identifies measurable risk to the public health from coal-mine-fire-produced mercury, all fires could be ranked and funds could be allocated to extinguish fires in the rank order.

“Surface fires ignited by burning trash, lightning, and forest or bush fires may spread to culm banks or coal seams (DeKok, 1986, p. 20; Discover, 1999). The Centralia, Pennsylvania mine fire (Figure 2), one of the worst underground fires in the United States, has been burning since May 1962 (Gessinger, 1990; Memmi, 2000). The fire began as a surface fire when the Centralia Borough Council decided to ignite trash to reduce the volume of and control rodents in an abandoned strip-mining cut used as an unregulated dump at the edge of town. Burning trash ignited the Buck anthracite seam concealed behind the refuse, and the fire spread along the seam to tunnels beneath Centralia (DeKok, 1986, p. 20; Geissinger, 1990; Memmi, 2000). Today, only about 20

¹ Krajick, Kevin. “Fire in the Hole.” *Smithsonian Magazine*. May 2005.
<http://www.smithsonianmag.com/travel/10013541.html>. Accessed February 2008.

*people in Centralia remain out of approximately 1100 former residents (Schogol, 2001)."*² Figure 1 is a map of Centralia showing the location of the three monitoring sites used in the study and the approximate burn zone as of 2005. The three Centralia sites include a "Background" site located predominately upwind and away from the burn zone, a "Town" site next to the burn zone and the few remaining residents, and a "Main" site that is directly downwind of the main fire area.

Forms of Mercury

Mercury emissions to the atmosphere from the Centralia underground mine fire were expected in several different forms: elemental mercury vapor (Hg^0), reactive gaseous mercury (RGM)(Hg^{2+}) and particulate mercury (HgP). Hg^0 is the predominate form in the atmosphere and is the major component of the global circulation of mercury. RGM is more water-soluble than elemental mercury vapor and readily binds to atmospheric particles to form HgP. Both RGM and HgP are removed from the atmosphere by precipitation over time. A fourth form of mercury, methyl mercury, is the most toxic form and is the main component in mercury bioaccumulation up the food chain. Methyl mercury is mainly created through biological processes in surface waters, lakes, soils, sediments, etc. Because this form is not readily found in the atmosphere, sampling was not conducted for methyl mercury.

² Stratcher, Glen B., Taylor, Tammy P. and Prakash Anumpa. "Coal Fires: A Synopsis of Their Origin, Remote Sensing Detection, and Thermodynamics of Sublimation." *www.Infomine.com*
http://technology.infomine.com/enviromine/case_hist/coal%20fires/Stracher_et_al.html. Accessed February 2008

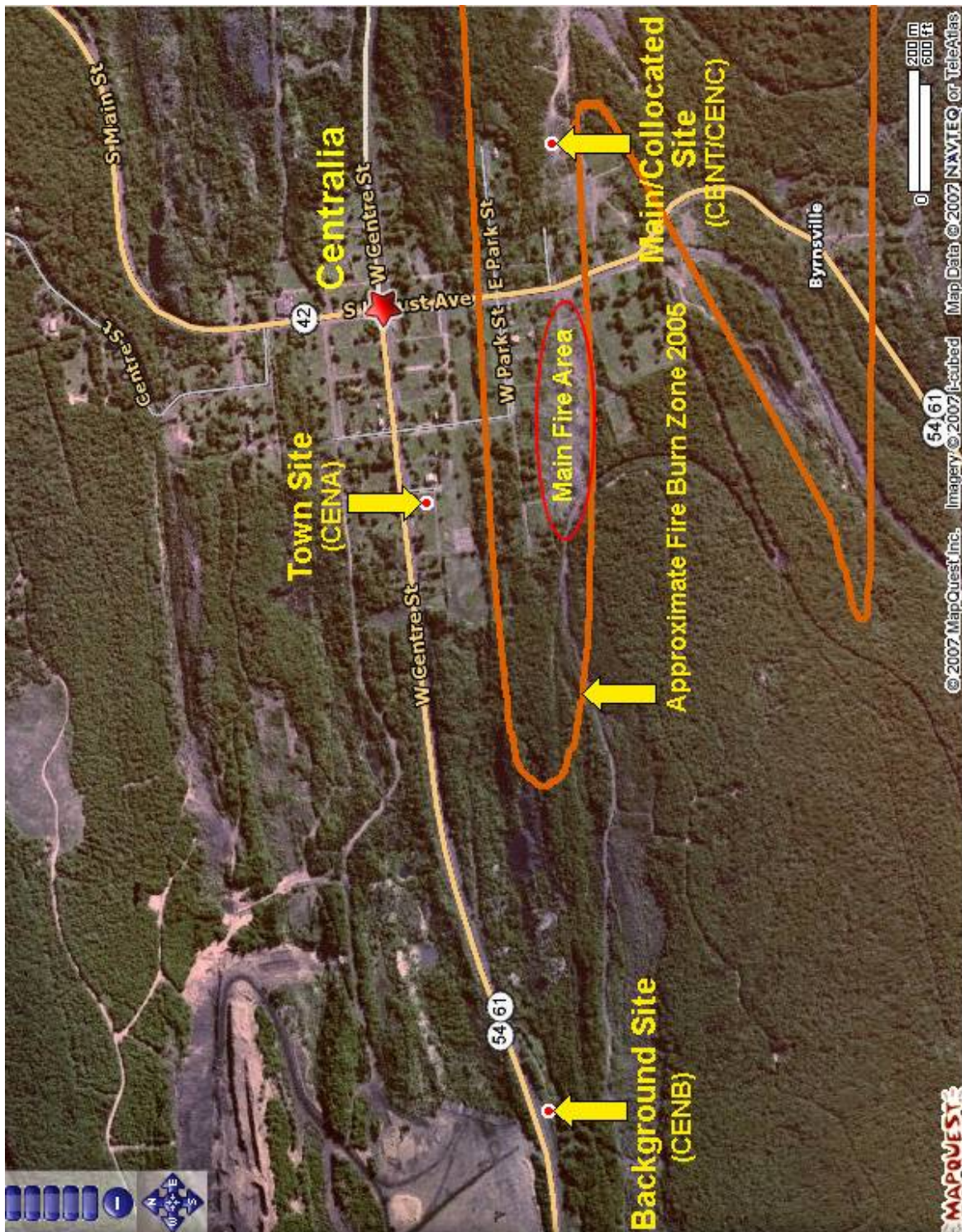


Figure 1 – Map of Centralia monitoring sites and approximate burn area as of 2005.

Mercury Analyzers

The Tekran mercury analyzers used for this study continuously measure Hg^0 with two gold cartridges that alternately adsorb mercury for a 5-minute period, and then are desorbed and analyzed by cold vapor atomic fluorescence. At the Main site, a mercury speciation system was used to measure the three forms of mercury separately. Because RGM and HgP are generally present in the atmosphere at much lower levels, the system operates on a two-hour cycle alternately trapping RGM and HgP for one hour while Hg^0 is measured, then desorbing and converting RGM and HGP to Hg^0 so the same analyzer can measure them. This is a standard method, a manual version of which is detailed in the Environmental Protection Agency's (EPA), Inorganic Compendium Method IO-5 (EPA, 1999). All monitoring and meteorological instruments used in this study are listed in Appendix A.

All of the analyzers experienced problems to some extent with deactivation of the gold cartridges, which gradually causes decreased response from one or both cartridges. Other users of this type of analyzer also have reported this problem. Soda-lime traps were added to the inlet lines to remove other pollutants and desiccant dryers were added to the zero air generators, which greatly reduced the problem during the second half of the study. When results from one cartridge were significantly lower than the other cartridge, the higher value was used, and, therefore, the hourly average was calculated from six five-minute samples. The analyzers are equipped with a mercury source and run an automatic zero and calibration every 24 hours, which can partially correct for the change in response.

Mercury Study Results

Elemental Mercury Vapor

Table 1 summarizes the overall arithmetic mean, standard deviation, maximum and minimum mercury concentration measured by each analyzer. Table 2 shows the average Hg^0 concentrations by the sector the wind was blowing from, which were calculated by grouping and averaging the mercury readings according to the hourly-average vector wind directions measured at the Centralia Main site. This analysis does not take wind speed, precipitation and other factors into account. It appears that the Main site's mercury concentrations were slightly higher when wind was from the west and downwind of the main fire area. The Town site had slightly higher mercury values when it was downwind of the fire with the wind from the south. The difference in average mercury concentrations between the Main and Background sites for periods when the wind was blowing from the main fire area (from the west between 1 and 10 mph), was 0.21 ng/m^3 , but for all other periods was 0.07 ng/m^3 .

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Table 1 – Average, maximum and minimum elemental mercury vapor concentrations at each of the Centralia monitoring sites.

Site	Hg ⁰ Concentrations (ng/m ³)			
	Average	Standard Deviation	Maximum	Minimum
Main	1.64	0.39	20.07	0.58
Collocated	1.56	0.58	72.83	1.03
Town	1.58	0.45	23.20	0.73
Background	1.57	0.24	7.60	0.99

Table 2 – Average elemental mercury vapor concentrations in ng/m³ by wind sector at each of the Centralia monitoring sites.

Wind Blowing From Sector	Average Hg ⁰ Concentration (ng/m ³)		
	Main	Town	Background
N	1.5	1.4	1.4
NNE	1.5	1.4	1.4
NE	1.5	1.5	1.4
ENE	1.6	1.5	1.4
E	1.6	1.6	1.5
ESE	1.7	1.6	1.7
SE	1.6	1.6	1.6
SSE	1.6	1.7	1.6
S	1.7	1.8	1.7
SSW	1.7	1.7	1.6
SW	1.7	1.7	1.5
WSW	1.7	1.7	1.6
W	1.8	1.6	1.6
WNW	1.6	1.5	1.5
NW	1.5	1.5	1.5
NNW	1.5	1.4	1.4

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Elemental mercury data for May 2007, illustrated in Figure 2, show brief periods of higher elemental mercury occurring at monitoring sites near the Centralia mine fire that do not occur at the Background site. This figure is typical for other months.

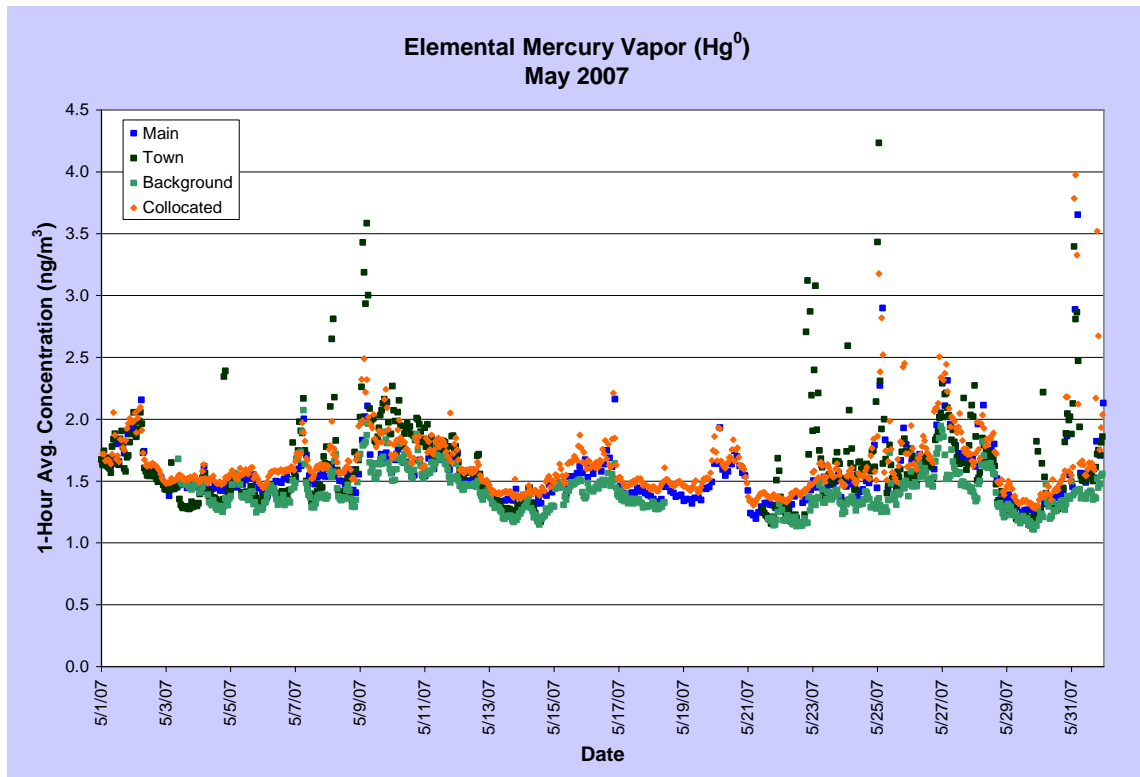


Figure 2 – Elemental mercury vapor concentrations in May 2007 in ng/m³.

Even though there are small but detectable mercury emissions from the fire area, they are in the range of values found at Lancaster, which is the only other DEP mercury monitoring site. Average annual elemental mercury vapor concentrations at Lancaster were 1.6 ng/m³ in 2005 and 2.1 ng/m³ in 2006. (The 2006 average at Lancaster was skewed by unexplained episodes of high mercury concentrations.) Furthermore, the Centralia results are near the reported background concentration of elemental mercury vapor of 1.6 ng/m³, which EPA uses in their 1996 *Mercury Study Report to Congress* (EPA, 1996).

There is no EPA ambient air quality standard for elemental mercury vapor. However, the EPA Integrated Risk Information System (IRIS) Reference Concentration is 300 ng/m³ (EPA, 1995). Also, the Agency for Toxic Substances and Disease Registry, of the U. S. Department of Health and Human Services, Minimal Risk Level for Hazardous

Substances is 200 ng/m³ (DHHS, 2006). When ambient levels of mercury are below these concentrations, no adverse health effects are expected. Clearly, the elemental mercury vapor levels measured at Centralia are not significant when compared to these risk levels.

Reactive Gaseous and Particulate Mercury

Because the only mercury speciation system that DEP has operated was sited in Centralia, no other speciated data in the Commonwealth are available for comparison. The mercury speciation system consists of a Model 1130 RGM unit, a Model 1135 Particulate Mercury Unit and a Model 2537A Mercury Vapor Analyzer. During a one-hour sample period, reactive gaseous mercury is trapped on a quartz annular denuder coated with potassium chloride and particulate matter is collected on a quartz filter. Mercury vapor passes through the traps and is analyzed continuously during the sample period. The traps are then flushed with zero air and heated sequentially to desorb and convert the trapped mercury to elemental mercury that is measured by the same analyzer. This regenerates the traps, which are then cooled and flushed with zero air to be ready for the next cycle.

The speciation system experienced several hardware failures and loss of data due to operator error during initial system operations. The mercury data from the speciation system were invalid from August 20 to September 12, 2006 due to a failure of the zero air generator. The particulate mercury unit had a hardware failure requiring factory repairs, and was out of operation from November 17 to December 28, 2006. After reviewing the data over the entire study, it was noted that particulate mercury values were higher after the factory repair, indicating the unit had not been operating properly. Therefore, in the data analysis only RGM and HgP data was used for the period after repair, from January 1 to June 16, 2007.

Concentrations of RGM and HgP were more variable than those of Hg⁰ as shown in Figure 3 and Figure 4 below. During, and for a few hours after periods of rain, concentrations of both pollutants usually dropped to near zero. In general, ambient air concentrations of RGM and HgP are much lower than concentrations of Hg⁰ and, therefore, are reported in picograms per cubic meter (pg/m³). (A picogram is 10 times smaller than a nanogram.) Table 3 summarizes the overall results for RGM and HgP over the period January 1 to through June 16, 2007. Table 4 shows the averages grouped by the wind sector.

Similarly, RGM and HgP levels measured at Centralia are not significant when compared to the risk levels mentioned in the previous section.

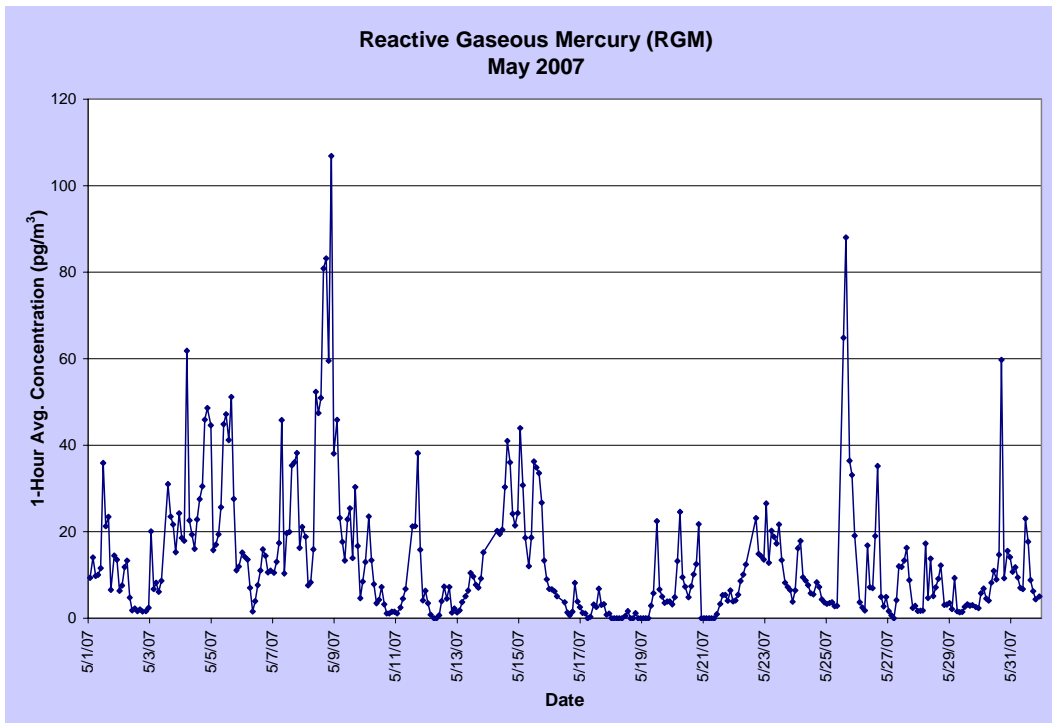


Figure 3 - Reactive gaseous mercury concentrations in May 2007 in pg/m³.

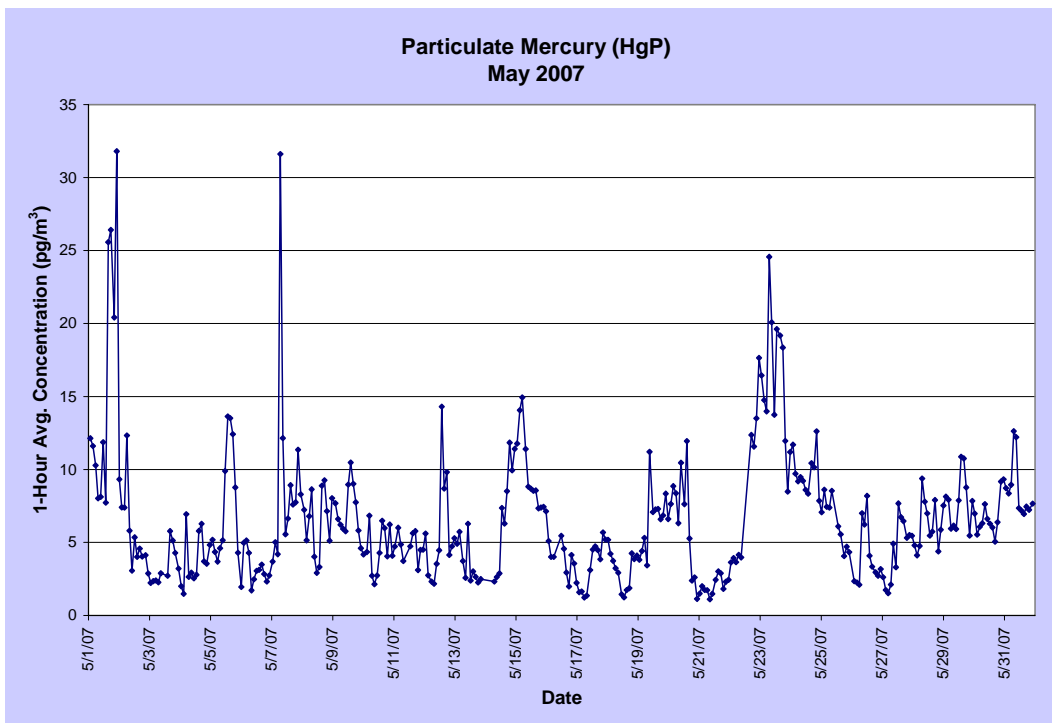


Figure 4 - Particulate mercury concentrations in May 2007 in pg/m³.

Table 3 – Reactive gaseous and particulate mercury summary statistics in pg/m^3 .

Pollutant	Average pg/m^3	Maximum pg/m^3	Standard Deviation pg/m^3
Reactive Gaseous Mercury	15.7	221.6	22.2
Particulate Mercury	9.0	110.4	10.2

Table 4 – Reactive gaseous and particulate mercury concentrations, by wind sector, from January 1 through June 16, 2007, in pg/m^3 .

Wind Blowing From Sector	Average Concentration pg/m^3	
	HgP	RGM
N	4.3	9.2
NE	4.1	8.5
NNE	5.0	8.1
ENE	8.1	15.4
E	8.3	13.9
ESE	10.1	13.8
SE	8.6	10.4
SSE	13.5	14.7
S	12.8	14.0
SSW	10.4	20.6
SW	9.0	23.7
WSW	10.9	14.6
W	10.4	16.4
WNW	9.8	15.1
NW	6.2	20.4
NNW	5.3	15.2

Mercury Quality Assurance

The final calibrations at the end of the study, which are included in Appendix B, show that the errors of all of the analyzers were less than 8% as compared to the reference standard.

Comparison of the elemental mercury vapor results in May 2007 from the Main and Collocated analyzers is graphed in Figure 5. Linear regression indicates a near one to one relationship (Slope = 0.9494) between the two analyzers with good reliability ($R^2 = 0.9238$). The differences between the two data sets can most likely be attributed to calibration accuracy and differences between the two “set ups” (the Main site was measuring RGM and particulate mercury as well).

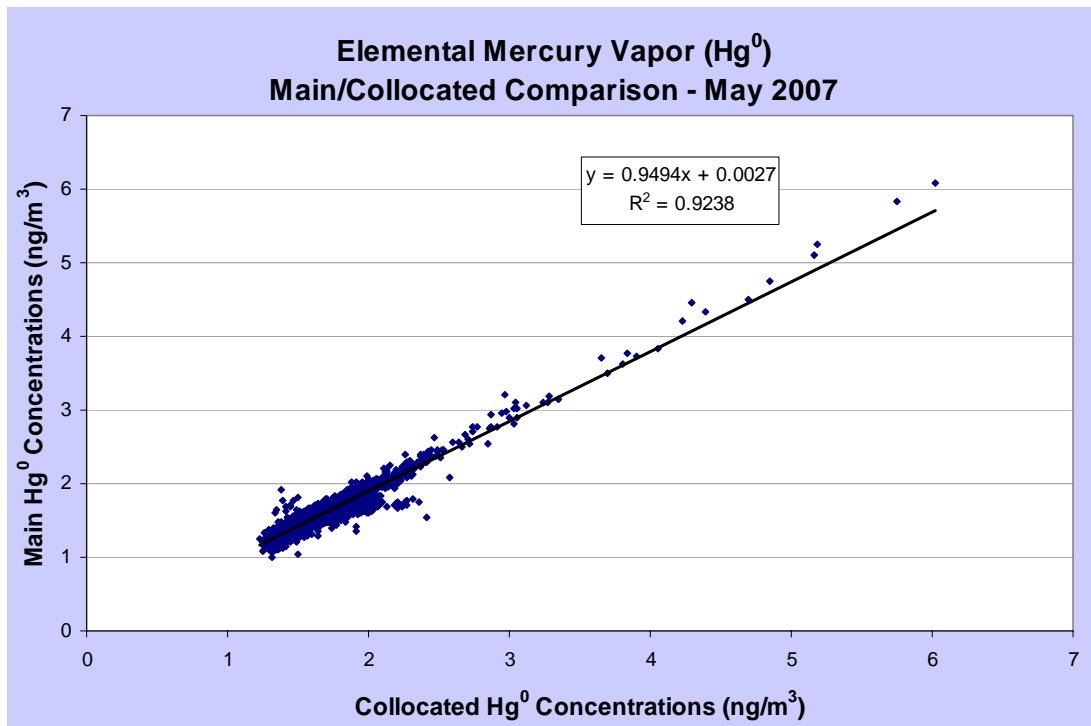


Figure 5 – Comparison of the elemental mercury vapor results in May 2007 between the Main and Collocated site analyzers.

Ancillary Measurements

In addition to mercury, carbon monoxide (CO), sulfur dioxide (SO₂), hydrogen sulfide (H₂S), carbon dioxide (CO₂) and toxic metals in total suspended particulate (TSP) were measured during the study. All of these pollutants are emitted when coal is burned. These pollutants were measured to provide additional information on the impact of the mine fire to the surrounding air quality. See Table 5 for the parameters measured by site.

Table 5 – Ancillary measurements at each of the three Centralia sites.

Site	Carbon Monoxide	Sulfur Dioxide	Hydrogen Sulfide	Carbon Dioxide	TSP/Metals
Main	X	X	X	X	X
Town	X			X	X
Background	X			X	

Table 6 provides a comparison of carbon monoxide concentrations in parts per million at Centralia from April 2006 to June 2007 with national standards and other monitoring sites. As set forth in Table 6, CO concentration averages at all sites in Centralia fell well below National Ambient Air Quality Standards (NAAQS) values. Furthermore, CO averages at Centralia were below the ranges obtained from the 22 sites in Pennsylvania for which CO concentrations were measured as part of the Commonwealth of Pennsylvania Air Monitoring System (COPAMS) in 2006.

Table 6 – Comparison of carbon monoxide concentrations in parts per million at Centralia from April 2006 to June 2007 with national standards and other monitoring sites.

Type of Average	Sites	Centralia CO Concentration	NAAQS ^{1,2}	Concentration Range from COPAMS Sites ³
8-hour	Main	0.3	9	0.9 – 2.2
	Town	0.5		
	Background	0.3		
1-hour	Main	0.4	35	1.3 – 3.3
	Town	0.9		
	Background	0.4		

¹ The 8-hour CO NAAQS is based on the second highest non-overlapping average.

² The 1-hour CO NAAQS is based on the second highest 1-hour average.

³ From January through December, 2006.

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As shown in Table 7, all SO₂ concentration averages fell well below NAAQS standards, and were comparable to the averages obtained from the 33 sites in Pennsylvania for which SO₂ concentrations were measured in 2006. The 1-hour maximum average of 0.273 parts per million (ppm) of SO₂ that occurred in September 2006 was neither sustained nor repeated during the 14-month study. All other 1-hour maximum concentrations obtained were less than one third of that level.

Table 7 - Comparison of sulfur dioxide concentrations in parts per million at the Centralia Main site from May 2006 to June 2007 with national standards and other monitoring sites.

Type of Average	NAAQS ¹	Centralia Concentration	Concentration Range from COPAMS Sites ²
Annual	0.030	0.004	0.002 – 0.011
24-hour	0.14	0.017	0.011 – 0.147
3-hour	0.5	0.045	0.024 – 0.256
1-hour	none	0.273	0.036 – 0.423

¹ The 24 and 3-hour SO₂ NAAQS are based on the second highest 24 and 3-hour average.

² From January through December, 2006.

Table 8 provides a comparison of hydrogen sulfide concentrations in parts per million at the Centralia Main site from May 2006 to June 2007 with Pennsylvania standards and other monitoring sites. As shown below in Table 8, all H₂S concentration averages fell well below the Pennsylvania Ambient Air Quality Standard (PAAQS), and were comparable to the averages obtained from five other sites in Pennsylvania for which H₂S concentrations were measured in 2006.

Table 8 - Comparison of hydrogen sulfide concentrations in parts per million at the Centralia Main site from May 2006 to June 2007 with Pennsylvania standards and other monitoring sites.

Type of Average	PAAQS	Centralia Concentration	Concentration Range from COPAMS Sites ¹
24-hour	0.005	0.003	0.000 – 0.008
1-hour	0.1	0.003	0.000 – 0.041

¹ From January through December, 2006.

As shown in Figure 6, CO₂ levels in the atmosphere have a diurnal fluctuation, mainly due to plant photosynthesis during the daylight hours and respiration at night. These naturally-occurring fluctuations make it difficult to discern the effects of the mine fire on CO₂ levels, but in any case, concentrations never exceeded 576 ppm. For reference, background CO₂ concentration has been estimated to be between 375 and 400 ppm and the National Institute for Occupational Safety and Health has a 10-hour workplace standard of 5,000 ppm to protect health.

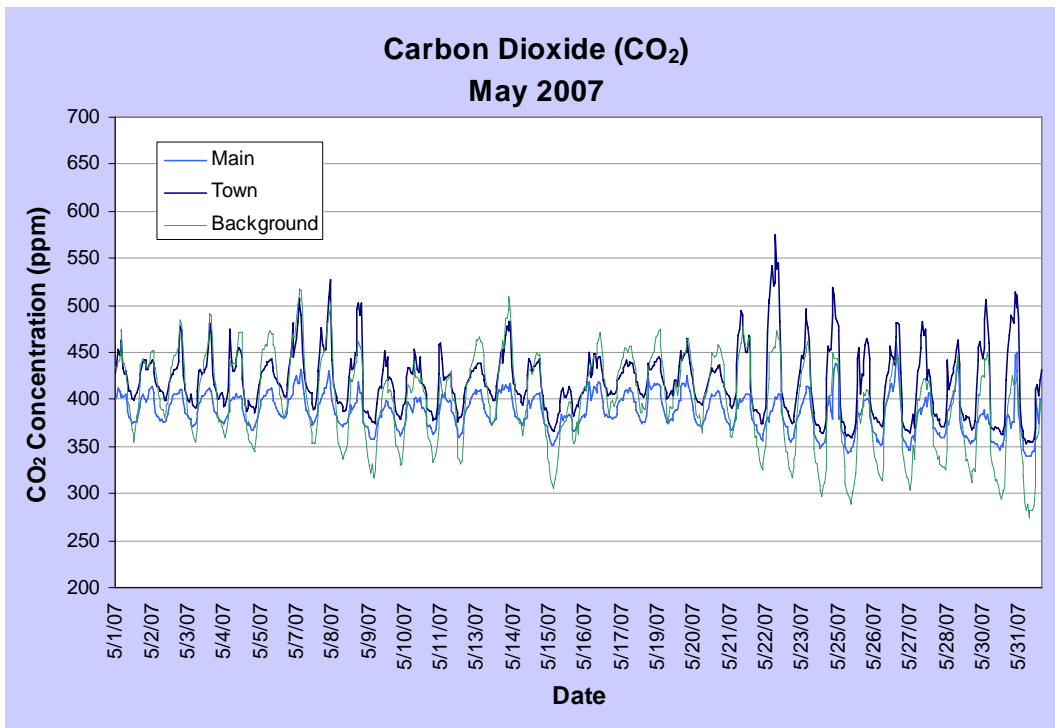


Figure 6 – Carbon dioxide concentrations in May 2007 at all three Centralia monitoring sites.

The monitoring at the Centralia Main and Town sites for particles and toxic metals produced the results found in Table 9 and 10. The results are compared to another toxic metal monitoring site in Lewisburg, PA, about 30 miles to the west of Centralia. The Lewisburg site is characterized as a small town site surrounded by farmland and forest. As can be seen in Table 10, the comparison shows little difference in values between the two areas which suggests the effects of the underground fire at Centralia on ambient toxic metal concentrations tends to be minimal. Note the beryllium concentrations never approached the PAAQS 30-day average standard of 0.01 micrograms per cubic meter.

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Table 9 - Total suspended particulate matter summary in micrograms per cubic meter from June 2006 to June 2007.

Site	Number Of 24-Hr Samples	TSP (ug/m ³)				
		Annual Mean	Maximum 24-Hr Mean	Date	Minimum 24-Hr Mean	Date
Main	59	21	80	05/12/07	4	9/2/06
Town	61	24	53	04/30/07	4	11/13/06

Table 10 – Comparison of the toxic metals results at Centralia with the Lewisburg site from June 2006 to June 2007.

Metal	Average (ug/m ³)		
	Centralia Main Site	Centralia Town Site	Lewisburg Site
Arsenic	0.00056	0.00055	0.00059
Beryllium	0.00010	0.00010	0.00010
Cadmium	0.00015	0.00018	0.00017
Chromium	0.00321	0.00313	0.00283
Lead	0.00353	0.00391	0.00363
Manganese	0.00591	0.00639	0.00636
Nickel	0.00116	0.00118	0.00117
Zinc	0.01900	0.02271	0.01960
TSP	21	24	20

With mercury concentrations near background ambient levels, no attempt was made to correlate mercury measurements with ancillary data. The raw data for the ancillary measurements, as well as for mercury, are available upon request.

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Appendices

Appendix A: Equipment

Tekran 2537A Mercury Vapor Analyzer
Tekran 1130 Reactive Gaseous Mercury Unit
Tekran 1135 Particulate Mercury Unit
Tekran 2505 Mercury Vapor Calibration Source
Tekran 1100 Zero Air Generator
Environmental Systems Corporation (ESC) Model 8816 Datalogger
Vaisala GMP222 Carbon Dioxide Transmitter
API Model 300 Carbon Monoxide
API Model 101E Hydrogen Sulfide
API Model 199A Sulfur Dioxide
Thermo Environmental Permeation Oven SO₂ and H₂S Zero/Span
Certified Carbon Monoxide Standards, Scott Specialty Gases
RM Young Model 200-8100 3-axis Ultrasonic Wind Sensor
Nova Lynx Model 230-701-V5 Barometric pressure sensor
RM Young Motor-aspirated shield with platinum RTD temperature probe
Nova Lynx Model 240-150 Silicon Cell Pyranometer
Nova Lynx Model 260-2500E 8" heated tipping bucket rain gauge
Met Tower 10-meter
Ekto Equipment Shelter with Ace Glass air sampling cane, manifold and blower

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**Appendix B:
Flow and Perm Tube Checks**

Site	Main	Date	6/28/07
Operator	G/D	Serial #	216

Flow Check

Cart.	Temp (C)	Atm Pres (in Hg)	Flow (ml/min)			%Diff
			Measured	Standard	Set	
A	23.0	28.26	1187	1004	1000	0.4

Perm Source

Cartridge	Perm				
	Zero Area	Area	Adj Area	Amnt (pg)	Area/pg
A			643251	128.9	4990
B			640503	128.9	4969

Injection Source

Adj Area	A		B		
	Amnt (pg)	Area/pg	Adj Area	Amnt (pg)	Area/pg
115822	23.5	4929	115162	23.5	4901
496519	93.9	5288	534377	93.9	5691
453208	93.9	4826	466020	93.9	4963
Average		5014	Average		5185

% Difference

Cartridge	Perm Area/pg	Injection Area/pg	%Diff
A	4990	5014	-0.5
B	4969	5185	-4.2

Site	Collocated	Date	6/21/07
Operator	GL	Serial #	217

Flow Check

Cart.	Temp (C)	Atm Pres (in Hg)	Flow (ml/min)			%Diff
			Measured	Standard	Set	
A	20.9	28.65	1425	1237	1250	-1.0
B	20.9	28.65	1410	1224	1250	-2.1

Perm Source

Cartridge	Perm				
	Zero Area	Area	Adj Area	Amnt (pg)	Area/pg
A	0	462421	462421	131.3	3522
B	0	485182	485182	131.3	3695

Injection Source

Adj Area	A		B		
	Amnt (pg)	Area/pg	Adj Area	Amnt (pg)	Area/pg
322562	94.0	3432	351544	94.0	3740
			351071	94.0	3735
Average		3432	Average		3737

% Difference

Cartridge	Perm Area/pg	Injection Area/pg	%Diff
A	3522	3432	2.6
B	3695	3737	-1.1

Site	Town	Date	6/25/07
Operator	G/D	Serial #	218

Flow Check

Cart.	Temp (C)	Atm Pres (in Hg)	Flow (ml/min)			%Diff
			Measured	Standard	Set	
A	22.0	28.66	1456	1256	1250	0.4
B	22.0	28.66	1456	1256	1250	0.4

Perm Source

Cartridge	Perm				
	Zero Area	Area	Adj Area	Amnt (pg)	Area/pg
A	0	393596	393596	130.9	3007
B	0	397549	397549	130.9	3037

Injection Source

Adj Area	A		B		
	Amnt (pg)	Area/pg	Adj Area	Amnt (pg)	Area/pg
276690	94.0	2944	291032	94.0	3096
286497	94.0	3048			
Average		2996	Average		3096

% Difference

Cartridge	Perm Area/pg	Injection Area/pg	%Diff
A	3007	2996	0.4
B	3037	3096	-1.9

Site	Background	Date	6/26/07
Operator	G/D	Serial #	212

Flow Check

Cart.	Temp (C)	Atm Pres (in Hg)	Flow (ml/min)			%Diff
			Measured	Standard	Set	
A	24.0	28.50	1431	1214	1250	-2.9
B	24.0	28.50	1431	1214	1250	-2.9

Perm Source

Cartridge	Perm				
	Zero Area	Area	Adj Area	Amnt (pg)	Area/pg
A	0	345935	345935	138.0	2507
B	0	329619	329619	138.0	2389

Injection Source

Adj Area	A		B		
	Amnt (pg)	Area/pg	Adj Area	Amnt (pg)	Area/pg
214929	94.0	2286	213021	94.0	2266
223158	94.0	2374	214714	94.0	2284
Average		2330	Average		2275

% Difference

Cartridge	Perm Area/pg	Injection Area/pg	%Diff
A	2507	2330	7.6
B	2389	2275	5.0