Report on the Voluntary Effort
To Assess the
Sources and Distribution of Mercury
Lafarge Building Materials, Inc.
Ravena Cement Plant
Ravena, New York

PN 050122.0159

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Revision 2
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List of Revisions

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Date	Identification
03-02-09	Revision 2

- Tables 2 through 14 were modified to recognize that Slurry Production values are reported on a dry weight basis rather than a wet weight basis. This recognition increased the amount of dry solids being feed to the kiln.

- Table 20 was modified to correctly differentiate between the amounts of mercury contributed by coal and coke. This reduced the 2008 mercury emissions by 32.23 pounds.

- Table 20 R-2 was modified to correct a calculation that used metric tons per year as opposed to short tons per year (1,285,725 metric tonne should have been 1,416,869 short). This increased the 2008 mercury emissions by 14.74 pounds.

- The normalized annual clinker production rate was revised from 1,604,418 to 1,604,815 tons based on 5 year historical average. In addition, mathematical differences between averaging mass balances events versus averaging individual components resulted in an increase in the mercury emissions from 146 to 151 lbs/yr using the mass balance technique.

- Tables 21 through 23 were modified to use the actual clinker production rates during the stack test periods versus daily average clinker production rates. This resulted in a minor change in the emission factors associated with the stack tests and a reduction in the new normalized average stack emission number (180lbs/yr versus 188 lbs/yr originally reported).

	Original Stack Emissions Lbs/Yr	**New Stack Emissions Lbs/Yr**
Event # 2 (Table 21)	167.0	166.97
Event # 3 (Table 22)	173.5	173.70
Event # 4 (Table 23)	140.9	140.65
All Events (Table 24)	160.46	160.32
Normalized Emissions at 1604815 tons per year clinker	188.0	180.34

- Figure 12 was modified to reflect the changes to Table 20.

- A new Figure 13 was created to compare the mercury emissions as determined by the mass balance technique (raw materials and slurry) and the stack test derived emission factors technique.

- The text in the report was modified to reflect the changes noted above.

FIGURES

TABLES

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ACRONYMS

AGC	Annual Guideline Concentrations
ASTM	American Society of Testing Materials
BACT	Best Available Control Technology
CKD	Cement Kiln Dust
CVAAS	Cold Vapor Atomic Absorption Spectrometer
CVAFS	Cold Vapor Atomic Fluorescence Spectrometer
DAR	Division of Air Resources
EPA	Environmental Protection Agency
EQ	Environmental Quality Management, Inc
ERP	Emission Rate Potential
ESP	Electro-Static Precipitator
(Hg)	Mercury
(Hg+1)	Mercurous
(Hg+2)	Mercuric
(Hg0)	Elemental Mercury
(Hg^p)	Elemental Mercury Attached Onto or Absorbed Into a Particle
LCS	Laboratory Control Samples
MRL	Method Reporting Limit
MS/MSD	Matrix Spike/Matrix Spike Duplicates
NYCRR	New York Codes, Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
PM	Particulate Matter
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
SEM	Standard Error of the Mean
SGC	Short-Term Guideline Concentration
TON	English short ton (2000 pounds)
TONNE	Metric Long Tonne (2204 pounds)
USEPA	United States Environmental Protection Agency

SECTION 1

EXECUTIVE SUMMARY

In 2008 Lafarge NA decided to conduct a comprehensive study of the origins of mercury in the Portland cement manufacturing process at its Ravena, New York facility. To ensure that the study considered every aspect of the facility, Lafarge:

a) Developed protocols to determine the mercury content of raw material and fuels as well as the concentration in emissions from the stack.

b) Submitted the protocols to the New York State Department of Environmental Conservation ("NYSDEC") for comment and approval. (All of NYSDEC's comments were incorporated into the protocol.)

c) NYSDEC personnel observed sampling efforts during Event 2.

d) Conducted all analyses using Quality Assurance / Quality Control ("QA/QC") procedures established by the United States Environmental Protection Agency ("USEPA") and the New York State Department of Health ("NYSDOH").

1.1 Approach

The sampling protocol consisted of:

a) Thirty days of sampling and analyses of total mercury levels in the raw materials, products, cement kiln dust ("CKD" – byproducts), and fuels (collectively called bulk materials representative of that typically used at the Ravena plant); and

b) The collection and analyses of stack gases on three separate occasions. The primary objective was to try to determine the mercury content of stack gases over a range of operating circumstances.

c) Using a laboratory (RTI Laboratories, Inc. NYSDOH- LABID: 11481) that is experienced in analyzing geological materials via EPA and NYSDOH analytical methods. Ultra low analytical detections limits were needed to achieve the mass balance closure. Sample preparation and analytical Methods 3052 and 1631 E were used to extract the mercury from the non – aqueous samples and to measure the ultralow mercury concentrations in raw materials. The application of these methods to the geologic matrices was innovative.

d) Using a stack testing company (Air Control Techniques, P.C.) that is experienced in collecting mercury emission data from cement manufacturing facilities using U.S. EPA Reference Test Methods 1, 2, 3, 4, and ASTM Method D 6784-02 (Ontario Hydro Method) to quantify the mercury emissions.

1.2 Project Schedule

The initial project schedule indicated that the events would be spread out over a period of eight months and that the final report would be prepared and submitted within 45 days of completing the sampling and analysis efforts. This staggered sampling and analysis schedule recognized that there are multiple sources of the bulk materials (especially bauxite, coal, coke, and fly ash) and that mercury content of the stack gas and CKD may vary as a function of these input parameters. The study sampling efforts were conducted as shown in Table 1.

TABLE 1. SAMPLING EVENTS AND DATES OF PERFORMANCE

Event Number	Sampling Dates[1, 2, 3]	Type of Sampling
1	5-8-08 through 5-22-08	Bulk Material Sampling Only
2	6-23-08 through 7-02-08	Bulk Materials and Stack Testing
3	9-22-08 through 10-06-08	Bulk Materials and Stack Testing
4	10-28-08 through 11-7-08	Bulk Materials and Stack Testing

[1] Regularly scheduled preventive maintenance is conducted on conveyors and shift samples on Wednesdays and samples could not be collected.
[2] Samples were not collected on holidays or weekends.
[3] One or both Kilns were shut down for repairs and/or because of market conditions during the study period. Kiln 1 was not operable during the period 9/29 – 10/2. In order to normalize the annual production and emission rate, it was decided to double the bulk material weights for calculation purposes.

1.3 Principal Findings

a) The calculated 2008 annual mercury emission rate, using mass balance techniques, from the two Ravena kilns is 138.68 pounds (159.21 via stack testing). The kilns were operated 72 percent of the time (6316.5 hours) during 2008.

b) The annual average emission rate for the two kiln operation at the Ravena plant is 151 pounds per year when determined by mass balance techniques using the all event mix design and material concentrations as determined by this study or less than 180 pounds per year when determined by stack testing techniques and the facility produces 1,604,815 tons of clinker (≈85 percent of annual production capacity) and the mercury concentration in the bulk materials (raw material, clinker, CKD, and fuel) are as determined by this study. The average operating hours for the time frame 2004 through 2007 was 7,418 (i.e., 85 percent utilization factor). The 2004 through 2007 utilization factors ranged from 82.9 to 85.8 percent).

c) The average speciated mercury emission rate is 98.7 percent elemental mercury. This speciation of mercury emissions is markedly different than the speciation characteristics reported for other cement plants and raises policy and technical implications which may be unique to the Ravena plant.

d) Mercury emitted during the manufacture of cement is primarily derived from mercury contained in the limestone quarried at the plant. On average mercury derived from fly ash is only 10.44 percent of the amount input and any mix design changes that include substitutes for fly ash (e.g., more bauxite, different Kalkberg/Coeymans limestone ratio, less mill scale, etc.) would still contain mercury. On average, limestone accounts for 56.9 percent and fuel accounts for 27.1 percent of the mercury inputs.

1.4 Additional Findings

a) The small differential between the mass balance and stack testing methodologies is largely attributed to test method variability, concentration flux (change over time), variable processing rates, and timing issues. The concentration in the bulk materials was determined on a daily basis whereas the stack test sampling was conducted during 9 separate two hour periods. The annualized variance between Event 2 runs 1 and 2 for a single stack test was 22.7 pounds of mercury (equivalent to 13% of total). The variance between the mercury emission rates for the three stack tests is 25 pounds (equivalent to 16% of annual total). The daily clinker production rate varied from a low of 3819 tons per day to high of 4,022 tons per day. The 5 year (2004 through 2008) annual average clinker rate is 4,488 tons per day.

b) The major pathways by which mercury leaves the cement kiln system are stack emissions and CKD. CKD is removed from the combustion gas via (“ESP”) precipitators. Although mercury has been measured in the clinker, the mercury measurement was near the method detection limit (2.5 µg/kg-dry). The annualized amount of mercury in the clinker is approximately 4.4 pounds. Approximately 71 percent of the CKD was recycled back to the kiln. The annualized amount of mercury being recycled in the kiln system is 7.8 pounds. The annualized amount of mercury (“Hg”) being disposed or otherwise used as a component of the CKD that is removed from the kiln system 12.03 pounds. Figure 1 displays the annualized amount and percentage of the total Hg inputs by raw material and fuel for all events. Figure 2 displays the annualized amount of Hg emitted and/or included in the wasted CKD and/or the clinker product for all events. Table 2 displays the annualized process rate information. Table 3 displays the annualized mass balance components.

c) The information gathered during this study suggests that Hg emissions are not correlated to inlet temperature of the ESP. Average inlet temperatures to the ESPs during the stack testing events ranged from 506 to 516 degrees Fahrenheit. The range of temperatures was 493 to 536 degrees Fahrenheit. The linear regression correlation coefficient (R^2) was calculated to be 0.0016. Other regression and correlation techniques (e.g., exponential, logarithmic and polynomial) had lower coefficients. R^2 values equal to ± 1 implies a perfect correlation between the data sets.

1.5 Regulatory Implications

The NYSDEC provides 1-hour and annual average guideline concentrations called Short-Term Guideline Concentrations (SGCs) and Annual Guideline Concentrations (AGCs) for regulated compounds. The methodology for assessing ambient air quality impacts due to air toxic emissions is described in Air Guide-1: Guidelines for the Control of Toxic Air Contaminants (DAR-1, NYSDEC, 1991). The information generated by this study effort indicates that the annual average emission rate (151 pounds/year) as determined by mass balance techniques is equal to approximately 0.017 pounds per hour which is 59 times lower than the 1 pound per hour threshold used by the NYSDEC to determine when a Best Available Control Technology ("BACT") analysis must be completed. This study also demonstrates that with an average annual Hg emission rate of 151 pounds per year or 0.02 pounds per hour and with the facility operating 7418 hours per year (85%) the Hg emissions impacts will be 0.11 percent of the AGC and 1.23 percent of the SGC. We also note that the plant's stack gas Hg concentrations are lower that all of the international standards known to Lafarge (see Table 25).

1.6 Quality Assurance

The specified analytical methods met the quality assurance objectives and Hg levels were reliably quantified. We note that the Hg concentration in the clinker samples ranged from 0.0023 ug/kg (below reliable quantitation limit) to 7 ug/kg all on a dry weight basis. The Quality Assurance ("QA") review indicated that the matrix spike recovery values (68 to 132 percent) for some samples of clinker were marginally outside of the targeted QA/QC matrix spike recovery (70 to 130 percent). In order to make the clinker data more robust, it was decided to collect additional clinker samples during events 2, and 3, and 4. Thirty – one clinker samples were collected and analyzed. The number of samples analyzed was significantly greater than the twelve samples that were proposed in the approved work plan. The statistical analysis includes the analytical results from all clinker samples. No spike recovery corrections were made.

Figure 1. All Events Bulk Material Mercury Inputs

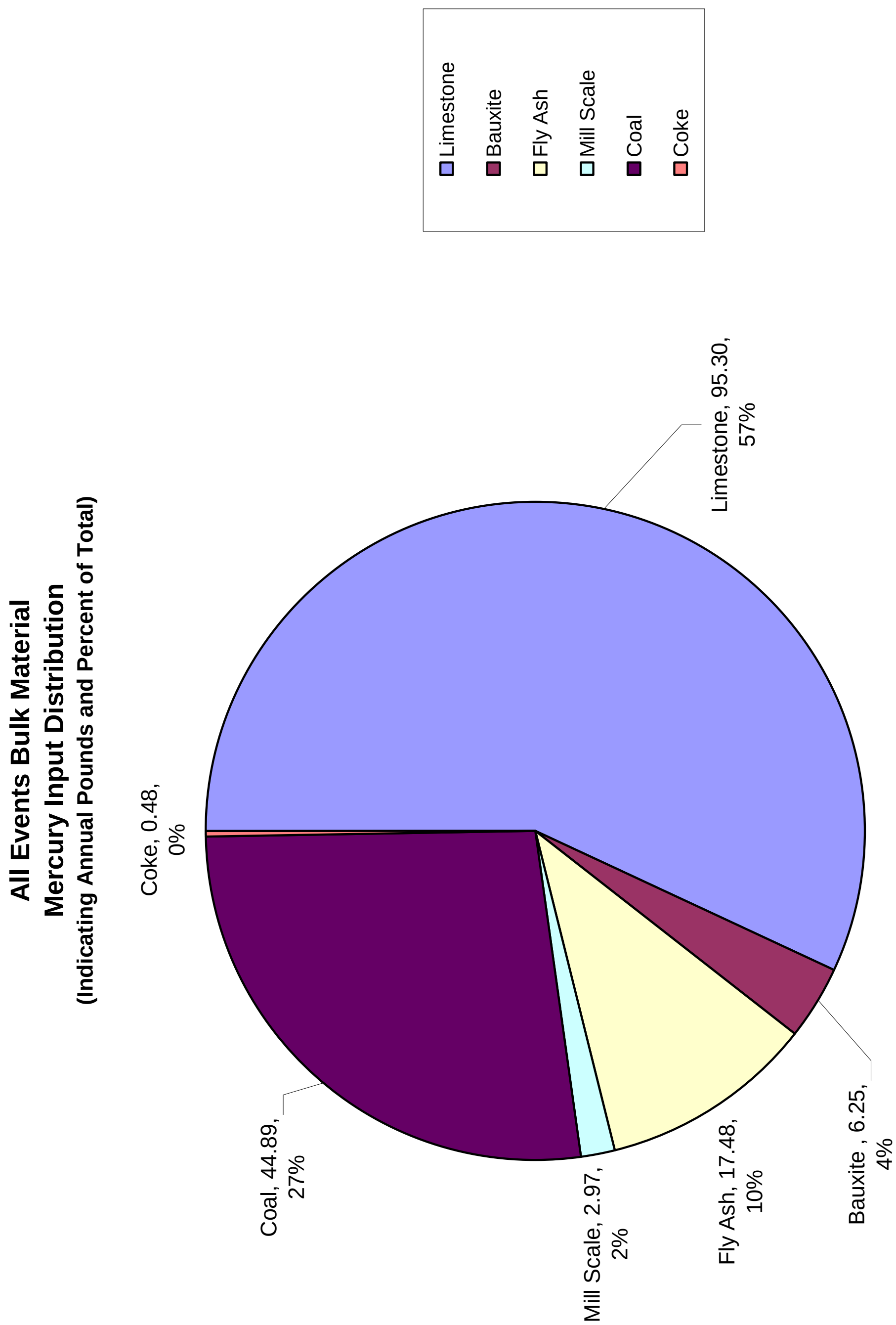

Figure 2. All Events Mercury Emission Distributions Using Mass Balance Techniques

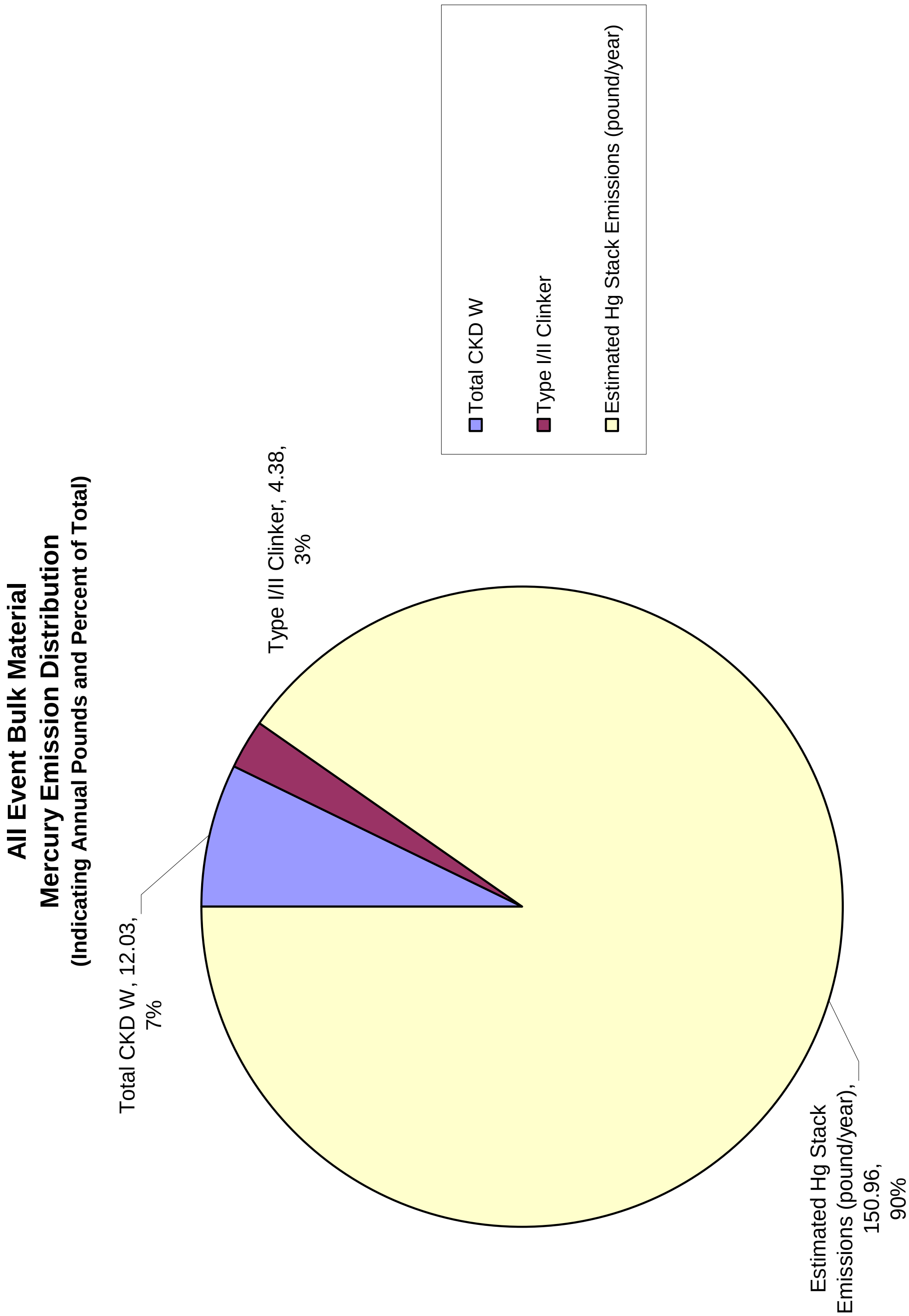

TABLE 2. ALL EVENT ANNUALIZED PROCESS RATE INFORMATION

	Table 2 All Events Production and Process Information					
Product	Average Input (tonne per day)	Average all events	Moisture %	Dry Weight Average Hg Content (PPB)	Dry Metric Tonnes/day	Average Hg LBs per day
Callanan (Kalkberg)	1518.504	20.3%	2.984	11.31	1473.186	0.0405
Coeymans	5685.020	76.0%	2.446	19.28	5545.974	0.2653
Beacraft	34.659	0.5%	6.986	14.86	32.238	0.0013
Bauxite	84.738	1.1%	7.515	100.62	78.370	0.0201
Fly Ash	98.881	1.3%	6.777	245.23	92.180	0.0563
Mill Scale	59.099	0.8%	9.124	86.98	53.707	0.0096
Raw Material Inputs	7480.901	100.0%			7275.654	0.1447
Total CKD R	1150.303		0.00	14.32		
Total CKD W	567.026		0.00	26.33	567.026	0.032906
Product and Byproduct Losses						
Coal	812.270		8.19	80.08	745.774	0.131620
Coke	34.990		8.84	19.35	31.897	0.001361
Fuel Inputs					777.671	0.132981
Type I/II Raw Slurry Mix	7349.524			22	7349.524	0.359178
Type I/II Clinker	4368.202		0.00	1.34	4368.202	0.012910

TABLE 3. ANNUALIZED MASS BALANCE COMPONENTS FOR ALL EVENTS

	Table 3 All Event Mass Balance Components			
Product	Hg LBs per day	Hg/Ton of Clinke	Percent of Inputs	Hg Lb/yr
Callanan (Kalkberg)	0.04052770	0.00000783	7.51%	12.57
Coeymans	0.26534307	0.00005130	49.19%	82.32
Beacraft	0.00130097	0.00000025	0.24%	0.40
All Limestone	0.30717174	0.00005938	0.56941688	95.30
Bauxite	0.02014950	0.00000390	3.74%	6.25
Fly Ash	0.05633065	0.00001089	10.44%	17.48
Mill Scale	0.00958570	0.00000185	1.78%	2.97
Coal	0.14467963	0.00002797	26.82%	44.89
Coke	0.00153244	0.00000030	0.28%	0.48
Raw Material Hg Inputs	0.53944967	0.00010429	156.94%	167.36
Hg inputs per slurry sample results	0.39379206	0.00007613	73.0%	122.17
Raw Material Hg minus fuels Hg	0.39323759	0.00007602	72.9%	122.00
Total CKD W	0.03876108	0.00000749	73%	12.03
Type I/II Clinker	0.01412309	0.00000273	27%	4.38
Estimated Hg Stack Emissions (pound/year)				150.96
Normalized Stack Emissions at 1604815 ton per year				180.34
Percent Difference				19.5%
Emission Factor (pound Hg / ton of Clinker)				0.00011283

Eighty seven (87) percent of the target samples were collected and analyzed. The approved work plan indicates that the QA sampling completeness objective is 85 percent. We note:

a) Twenty – one (21) coal mill samples were not collected. During the project execution it was determined that the kiln coal feed samples had been pulverized, dried, and heated and that the sweep air from the coal mill was used as primary combustion air in the kilns. Hence, collecting coal samples from the kiln feed system would not include Hg that was being volatized in the coal mill but was still passing through the kiln system. In order to assess the effect of the coal mill operations, it was decided that additional coal pile samples would be collected and analyzed and that the existing coal mill data would be compared to the information generated in June 2007 as part of the U.S. EPA information collection request. Twenty – two (22) additional coal pile samples were collected and analyzed. The Hg concentration in the coal mill samples averaged 71.6 ug Hg per kg. The coal pile samples averaged 82.2 ug Hg per kg and ranged from 43 to 180 ug Hg per kg on a dry weight basis. The coal pile samples were used to quantify and assess the Hg inputs discussed elsewhere.

b) There was a shortage of fly ash throughout the project's execution. Fly ash was being consumed almost as soon as it arrived and on several occasions, the fly ash bins did not have any material to sample. Therefore, it was decided to collect samples from each fly ash delivery truck that arrived on site during sampling events 1 through 4. Subsequently, a total of eighty – four (84) fly ash samples were collected and analyzed. This compares to the 63 fly ash samples included in the work plan. The Hg concentration from all samples was used to estimate the amount of Hg associated with fly ash for each event.

c) Twenty – four (24) Becraft Lime samples were not collected. This raw material is used as an additive when balancing the slurry chemistry. The additive was placed in the system sporadically and the sampling team was unaware that the additive was being used and contemporaneous samples were not collected. The Becraft lime was less than 1 percent of the mix design during for all four events. Seven (7) Becraft lime samples were collected from the on-site storage pile during event 3. The Hg concentration from these samples was used to estimate the amount of Hg associated with this material for each event.

1.7 Cost of the Study

The extramural costs for the study, including sampling and analyses, exceeded $250,000.

SECTION 2

PROJECT PURPOSE AND OBJECTIVES

The purpose of this document is to present the information gathered during the sampling and analysis efforts that were designed to reduce the uncertainty and to establish the source inputs and the distribution of Hg exiting the kiln systems at the Lafarge Building Materials Inc. ("Lafarge") Portland cement manufacturing facility located in Ravena, New York. This facility has reported, in accordance with State and Federal reporting requirements, that its emissions contain Hg.

The facility undertook an accelerated process to: 1) determine the Hg content of raw materials and fuel, 2) develop an understanding of the incorporation and removal mechanisms within the cement manufacturing procedures used by Ravena, 3) establish the Hg content of products and byproducts, and 4) verify the Hg content of the stack gas.

Large quantities of materials are processed and a large volume of stack gas is produced during the manufacturing of cement. In order to achieve a high level of agreement on the mass balance between inputs and outputs and to evaluate the incorporation and removal mechanisms, Lafarge used newly available sampling and analysis procedures that are designed to report Hg concentrations at the sub-parts per billion levels. Environmental Quality Management Inc. ("EQ") was contracted by Lafarge to provide technical assistance in the preparation and implementation of this project. EQ provided oversight with the sampling efforts and the QA/QC review of the Laboratory consistent with work plan. This document presents the technical approach used to collect the necessary information and the results of the investigation at the Ravena Cement Plant.

Lafarge voluntarily developed the work plan in consultation with the NYSDEC and obtained its approval prior to implementation. The State approved the work plan on or about March 19, 2008. Appendix A includes a copy of the approval letter.

SECTION 3

BACKGROUND

The Ravena Cement Plant manufactures Portland cement using two nearly identical wet process kilns equipped with ESPs for particulate emissions control. The plant is capable of producing approximately 2 million tons (4,200,000,000 pounds) of cement per year making it one of the largest cement manufacturing facilities in the US. In making this quantity of cement, approximately 2.67 million tons (5,336,010,041 pounds) of raw materials (including slurry water) are processed through the kilns. Information generated during this study indicates that Hg emissions are less than 0.000000003375 percent of the total amount of material being processed. The typical fuel consumption rate is 0.28 million tons (562,891,129 pounds) per year to manufacture 1,699,000 tons (3,398,000,000 pounds) of clinker. In the wet process, each raw material is proportioned to meet a desired chemical composition and is fed to a grinding mill with water. The raw materials are ground into slurry where the majority of the solid materials are less than 75 microns. The slurry is pumped to blending tanks and homogenized to insure the chemical composition of the slurry is correct. Following the homogenization process, the slurry is stored in feed tanks until required. An air sparge and mechanical rake are used to keep the slurry suspended and homogenized. The slurry feed tanks at the Ravena plant hold approximately 2 to 3 weeks of inventory depending on production schedules. The kiln feed is uniform for both kilns and one sample per material is representative of the feed to both kilns. The kiln feed includes water (storm, groundwater, and/or river water depending on weather and production demands), limestone (mined from three distinct formations – Coeymans, Kalkberg, and Becraft) within the quarry, bauxite, iron ore, low carbon fly ash, and low alkali CKD. Within the kiln, the slurry mix is calcined at temperatures of 700 - 900 degree C. It is at this point that the material is decarbonized (or calcined) and CO_2 is evolved. The resulting calcium oxide (lime) reacts with the other silicate, alumina, and iron minerals when the temperature is further increased. At approximately 1350 degree C the process of sintering occurs (i.e. minerals are heated to the liquid phase). The burning and sintering are completed between 1400 degree and 1450 degree C. At this stage the material has acquired a greenish black color and it is commonly referred to as clinker. After cooling the clinker is ground and mixed with up to 5 percent gypsum to create the finished product known as Portland cement. This product meets the strict American Society of Testing Materials (ASTM) C150 - 07 Standard Specification for Portland cement.

Mercury is an element and naturally present in the raw materials and fuels that must be used in the cement manufacturing process. The element's atomic mass is 200.59 grams per mole and its specific density is 13.5 times that of water. Hg has a melting point of -38.9°C, a boiling point of 357.3°C, and is the only metal to remain in liquid form at room temperature. Hg is 67th in natural abundance in crustal rocks. Hg has a relatively high vapor pressure and the highest volatility of any metal. When vaporized it becomes a colorless, odorless gas. The metal is a fair conductor of electricity, but a poor conductor of heat. Hg's atomic number is 80. In nature, Hg has three possible conditions of electrical charge, or valence states. Elemental Hg (Hg^0) has no electric charge. Hg is also found in two positively charged, or cationic, states, Hg^{+2} (mercuric) and Hg^{+1} (mercurous). The mercuric cation is more stable and is generally associated with inorganic molecules, such as sulfur (in the mineral cinnabar), chlorine (mercuric chloride), oxygen and hydroxyl ions. Hg^{+2} is also found in organic (carbon based) substances like dimethylmercury (Me_2Hg). Since Hg can be adsorbed onto small particles of matter, it is common to use the notation Hg^p to represent elemental Hg attached onto or absorbed into a particle. Because it is an element, Hg is not biodegradable. It is converted among its various forms through a range of processes in the environment.

Historically, the State of New York controls the ambient levels of air toxics from emission sources through the use of recommended guideline concentrations in the New York Code, Rules and Regulations (6 NYCRR Part 212). These "non-criteria air pollutants" include carcinogens, as well as non-carcinogenic compounds and irritants. The NYSDEC provides 1-hour and annual average guideline concentrations called Short-Term Guideline Concentrations (SGCs) and Annual Guideline Concentrations (AGCs) for regulated compounds. The methodology for assessing the impact due to air toxic emissions is described in Air Guide-1: Guidelines for the Control of Toxic Air Contaminants (DAR-1, NYSDEC, 1991). It should also be noted that SGCs and AGCs are guideline concentrations rather than standards because they have not undergone the rigorous regulatory scrutiny that would be afforded proposed Federal or State ambient air quality standards. Annual guideline concentrations in particular, are developed to protect the public health from the effects associated with long-term continuous, exposure to a contaminant via inhalation. The AGCs and SGCs contained in Air Guide-1 were developed to be protective of public health and are based on the toxicological information that was available at the time of promulgation. These values were updated after a comprehensive review by the New York State Department of Health (NYSDOH) in December 2003. The SGCs were developed to protect the general population from 1-hour exposures that can result in adverse acute health effects. The AGCs were developed to protect the general population from annual exposures that can result in adverse chronic health effects that include cancer and non-cancer endpoints. These guidelines are intended to protect the general public including sensitive subpopulations from adverse health effects that may be induced by exposure to ambient air contaminants. The procedures that are used by the Department to derive these guidelines are contained in Appendix C of the NYSDEC Air Guide-1 policy.

Reportedly, NYSDEC is evaluating the need to assign an "A" rating to mercury emissions under the criteria in Table 1 of 6 NYCRR § 212.9(a). As stated in the regulations, an "A" rating is assigned to "... an air contaminant whose discharge results, or may result, in serious adverse effects on receptors or the environment. These effects may be of a health, economic, or aesthetic nature or any combination of these. …" An "A" rating would remove mercury compounds from Part 220 applicability as provided in Subdivision 212.7(b). The degree of air cleaning required for "A" rated emissions is found in Table 2 of Section 212.9. Specifically, for an "A"-rated air contaminant, where a facility's Emission Rate Potential ("ERP") is greater than 1 pound/hour, the degree of air cleaning required is 99 percent or BACT; where a facility's ERP is less than 1 pound/hour, the control level is left to the Commissioner's discretion. The Department has informally indicated that it believes that Lafarge's emissions of mercury compounds should be controlled with BACT as defined in Subdivision 200.1(j). One of the reasons this study was undertaken was to determine the hourly emission rate. The facility historically has on average operated the kilns 7418 hours per year or 85 percent of the available hours. This study also demonstrates that with an average annual mercury emission rate of 146 pounds per year or 0.0197 pounds per operating hour and with the facility operating 7418 hours per year (85%) the mercury emissions impacts will be 0.11 percent of the AGC and 1.23 percent of the SGC. We also note that the plant's in stack mercury concentrations are lower that all of the international standards known to Lafarge. The administrative record associated with Lafarge's air permit to utilize tire derived fuel and to emit more than 500 pounds per year of mercury at the Ravena plant indicates that,

> “ … Lafarge (the applicant) conducted an Air Guide-1 evaluation in accordance with the Department's policy to assess the potential public health impacts associated with the proposed modification (the use of tire derived fuel) of the Ravena facility. With respect to air emissions upwind or downwind from the Ravena facility in terms of ambient air quality impacts, particularly downwind, the dispersion modeling of the air toxic emissions was conducted by Lafarge per Appendix B of the DEC Air Guide-1 policy. This analysis provides a very conservative estimate (i.e. tends to over predict) of ambient impacts irrespective of wind speed or direction or specific location. It simulates impacts as if all locations are downwind of the facility. The results provided by the applicant and verified by the Department indicated that the emissions impacts were predicted to be below 10% of the applicable health based annual guideline concentrations (AGCs) and short-term guideline concentrations (SGCs) used by the Department to assess public health impacts.
>
> In addition, the Department conducted a more refined dispersion modeling analysis using the EPA ISCLT2 model and predicted lower maximum emission impacts which were less than 1% of the applicable health based annual guideline concentrations (AGCs) and short-term guideline concentrations (SGCs) used by the Department to assess public health impacts. In summary, the dispersion modeling indicates that the predicted impacts of all the metal emissions are considerably below the SGCs/AGCs even when considering the worst-case scenario and maximum potential impact. …”

If the annual Hg emission rate is 180 pounds, as determined by the stack testing methodology and the facility operating 7418 hours per year the ambient air Hg emissions impacts will be less than 0.15 percent of the AGC and less than 1.58 percent of the SGC.

SECTION 4

METHOD OF APPROACH

The purpose of this project is to determine the input sources and the distribution exiting the kiln of Hg from the production of Portland cement at the Ravena Plant. Lafarge conducted three different stack tests. The testing schedule and study design were established in recognition that the slurry mix design may vary from time to time. The study effort could not interfere with the plant's ability to produce high quality Portland cement while remaining in compliance with all applicable regulations and permit limitations. The plant's ability to obtain fly ash was and is wholly dependent on the four (4) power plants that are under contract. Each of these suppliers generates fly ash at different and variable rates and they make it available to Lafarge when it is convenient and cost effective for them to do so. The Ravena plant has limited fly ash storage capabilities and having substantive quantities from each vendor on any given day is a rare event. Fly ash is used primarily as a source of alumina and the slurry mix design is established only after sufficient quantities are accumulated. The slurry tanks provide approximately 10 to 14 days of feed material, hence choreographing and coordinating the cement production schedule, the slurry mix design, and the schedules of various third parties (e.g., fly ash vendors, stack tester, laboratory, and QA team) required significant effort. Two of the stack test events (i.e., Events 2 and 3) were conducted when substantial quantities of fly ash had been incorporated into the mix design. During Event 4 limited quantities of fly ash was incorporated into the mix design and bauxite was the primary source of alumina.

The information obtained was based on: 1) thirty days of sampling and analyses of total Hg levels in the raw materials, products, byproducts, and fuels (collectively called bulk materials); and 2) the collection and analysis of stack gases on three separate occasions. The stack gas was sampled and analyzed for elemental, oxidized, particle-bound, and total Hg.

Lafarge initiated the project within 15 days of receiving approval of the work plan by NYSDEC. Bulk material samples were collected in four campaigns and stack testing was conducted over three campaigns. Event 1 bulk material samples were collected for 9 days. The second, third and fourth set of bulk material samples were collected over seven-day campaigns; each one was initiated after the analytical results of the prior set were obtained from the laboratory. Stack testing was conducted during the three seven-day bulk material sampling campaigns. Stack testing was conducted three days into the bulk materials sampling campaign. The study sampling efforts were conducted as shown in Table 1.

The staggered sampling and analysis schedule recognized that there are multiple sources of the bulk materials (especially bauxite, coal, coke, and fly ash) and that Hg content of the stack gas and CKD may vary as a function of these input parameters. This approach allowed us to approximate the Hg content of the materials Lafarge is currently and will be using in the future. By combining Hg concentration data with mix design and production process information, Hg mass inputs were correlated with Hg mass outputs. Correlation of the Hg inputs and outputs may provide a basis for future evaluation of control strategies or technologies. However, the evaluation of different control options and strategies is outside the scope of this work effort.

4.1 Quality Assurance

The Quality Assurance Project Plan ("QAPP") documents established the planning, implementation, and assessment procedures for the project, as well as any specific quality assurance and quality control activities. Quality assurance ("QA") and quality control ("QC") integrates all the technical and quality aspects of the project in order to obtain the type and quality of environmental data and information needed for a specific decision or use.

The precision of particle-bound, oxidized, and elemental, Hg-sampling method data is influenced by many factors: flue gas concentration, source, procedural, and equipment variables. Strict adherence to the method is necessary to reduce the effect of these variables. To ensure precise results are achieved, it is necessary that the system be leak free; all indicated system components accurately calibrated; proper sampling locations selected; glassware thoroughly cleaned; and prescribed sample recovery, preparation, and analysis procedures followed. The stack testing contractor, Air Control Techniques, P.C. did not encounter any problems during the test program and no changes were made to the standardized procedures.

The effects of particulate matter ("PM") on Hg speciation can be significant when the sampling train filter has the potential to collect a high loading of PM from the flue gas. The speciated Hg (Hg) measurement can be biased in two ways. The particulate on the filter can adsorb gaseous Hg from the flue gas as it passes through the filter. Reactive particulate can also oxidize gaseous Hg^0 entering the filter. When adsorption and/or oxidation occur across the filter, they alter the distribution of total Hg and/or gaseous Hg measured. For example, if particles on the filter adsorb gaseous Hg, the filter will contain a greater amount of Hg^p than if no adsorption had taken place; in this case, the sampling-train Method will overestimate the amount of Hg^p in the flue gas and underestimate the gaseous Hg, thus, the total distribution of Hg will be altered. Alternatively, fly ash on the filter can oxidize gaseous Hg^0 to Hg^{+2} (without adsorption) overestimating the amount of Hg^{+2} in the flue gas. Thus, the distribution of gaseous Hg will be altered. The rates of these transformations are dependent on the properties of the raw materials and particulate, the amount of particulate, the temperature, the flue gas composition, and the sampling duration. As a result, the magnitude of these biases may vary significantly and cannot be uniformly assessed. In an effort to minimize this source of variability, each stack testing effort was replicated by consistently operating the kiln system and the air pollution control equipment during the testing event. Since more than 98 percent of the emitted Hg was in the form of elemental Hg, it is apparent that on filter oxidation or catalytic reaction was not occurring. Lafarge did not meet the target production level of 4888 ton of clinker per day during Event 1. Lafarge did not need to repeat any stack test runs because the average production rate was greater than 4888 ton-clinker per day (203 ton-clinker per hour) during Events 2 through 4.

4.2 Sampling Procedures

During the first 9-day bulk material sampling event (Event 1): 4 daily samples (3 sub-samples and the composite sample) of fly ash, coal, and bauxite were analyzed for Hg. These results were used to calculate descriptive statistics for the sub-samples and the composite samples. This information was used to assess the homogeneity of the materials being sampled. It was determined that the materials are sufficiently homogeneous that composite samples could be used for the balance of the study. Only new pre-cleaned sample containers were used and no on-site efforts were needed to meet the applicable method criteria. During the project it was determined that one 4 ounce sample as opposed to a 16 ounce samples would be collected for the bulk material every sampling day. Each daily composite sample consisted of equal portions of three sub-samples collected every 8 hours (± 2hr). Each daily grab sample was collected during the day shift or in the case of fly ash when it is delivered. A technician made a sampling round once during each shift, or approximately every eight hours. Technicians collected samples only if the bulk material was being consumed at the time of the sampling visit. Technicians noted whether or not material is being consumed during the sample visit. Lafarge tracked consumption quantities for each material. Segregation sampling error was minimized by taking 3 increments (~1/3 of sample container each time) in the immediate vicinity of the sampling location and combining them into the final collected sub-sample. The daily composite sample consisted of 3 sub-samples that in and of themselves consisted of 3 increments. Simple random sampling was used because the population of interest is relatively homogeneous (i.e., there are no major patterns or "hot spots" expected). The 8-hour samples were collected in containers that meet the requirements of EPA Method 1669. Lafarge's on – site laboratory personnel were responsible for assuring that the materials could pass through a 5 mesh screen (4000 micron or 0.0157 inch opening). Existing laboratory crushing equipment was used, if needed, to meet these criteria. Prior to its use, the crushing equipment was decontaminated and no less than 200 grams of each sub-sample was processed through the crusher before the composite sample is assembled. The 8-hour sub-samples were composited by Lafarge laboratory personnel to develop each daily sample. The daily samples were placed in containers that meet the requirements of Method 1669. Each sample container (daily composite, grab and/or sub-sample) was labeled with a sample ID number, collection date, matrix, and analyses requested (Hg). Field preservation of the samples was not part of the procedures.

The stack gas Hg sampling and analysis was conducted in accordance with all applicable sampling and quality assurance requirements of ASTM D6784-02. Particle bound Hg was collected in the front half of the sampling train including the filter and the rinses of the nozzle, probe and front-half of the filter holder. Oxidized Hg was collected in impingers 1-3 containing a chilled aqueous potassium chloride solution. Elemental Hg was collected in subsequent impingers (impinger 4 containing a chilled aqueous acidic solution of hydrogen peroxide and impingers 5-7 containing a chilled aqueous acidic solution of potassium permanganate). Samples were recovered, digested, and analyzed for Hg using cold vapor atomic fluorescence spectroscopy (CVAFS). Samples were withdrawn isokinetically (100% ±10%) from the source using an Ontario Hydro sampling train. The test runs were two hours in duration. The sampling train consisted of a glass nozzle, a heated glass probe with an S-type Pitot tube attached, a filter, eight chilled impingers, and a metering console. The first three impingers contained 100 milliliters of a potassium chloride solution, the fourth impinger contained 100 milliliters of a nitric acid/hydrogen peroxide solution, the fifth through seventh impingers contained 100 milliliters of a potassium permanganate/sulfuric acid solution, and the eighth contained preweighed silica gel. The filter were removed from the filter holder and placed in a labeled Petri dish. The nozzle, probe, and front-half of the filter holder were rinsed with 0.1 N HNO_3 into a glass jar. The mass of each impinger was weighed and recorded for moisture content determination. The filter housing and connecting glassware was rinsed with 0.1 N HNO_3. A 5 percent (w/v) $KMnO_4$ solution was added to each KCl impinger until a purple color was obtained. The impingers were left to sit for 15 minutes to ensure the purple color persists. The contents of the impingers were transferred into a sample container. The impingers and connecting glassware were rinsed with 10% (v/v) HNO_3. The solution in the sample container was checked after 90 minutes to ensure that the color remains. A final rinse of these three impingers and connecting glassware were completed with 0.1 N HNO_3 and added to the sample container. The content of the fourth impinger was transferred into a sample container. The impinger and connecting glassware was rinsed two times with 0.1 N HNO_3 into the sample container. The contents of the fifth through seventh impingers were transferred into a sample container. The impingers and connecting glassware was rinsed two times with 0.1 N HNO_3. The rinses were added to the sample container. A third rinse with 0.1 N HNO_3 and enough 10% (w/v) hydroxylamine solution was added to remove brown deposits from the surface of the impingers. This rinse was added to the sample container. A final rinse with 0.1 N HNO_3 was conducted and added to the sample container.

4.3 Sample Distribution

Eighty – seven (87) percent of the target samples were collected and analyzed. The approved work plan indicated that the QA sampling completeness objective is eighty – five (85) percent. We note:

- Twenty – one (21) coal mill samples were not collected. During the project execution it was determined that the kiln coal feed samples had been pulverized, dried, and heated and that the sweep air from the coal mill was used as primary combustion air in the kilns. Hence, collecting coal samples from the kiln feed system would not include Hg that was being volatized in the coal mill but was still passing through the kiln system. In order to assess the affect of the coal mill operations, it was decided that additional coal pile samples would be collected and analyzed and that the existing coal mill data will be compared to the information generated in June 2007 as part of the U.S. EPA information collection request. Twenty – two (22) additional coal pile samples were collected and analyzed. The Hg concentration in the coal mill samples averaged 71.6 ug Hg per kg and ranged from 53 to 88 ug Hg per kg on a dry weight basis. The coal pile samples averaged 84.6 ug Hg per kg and ranged from 49 to 180 ug Hg per kg on a dry weight basis. The coal pile samples were used to quantify and assess the Hg inputs discussed elsewhere.

- Thirty – six (36) fly ash bin samples were not collected. There was a shortage of fly ash throughout the projects' execution. Fly ash was being consumed almost as soon as it arrived and on several occasions, the fly ash bins did not have any material to sample. Therefore, it was decided to collect samples from all fly ash delivery trucks that arrived on site during sampling events 1 through 4. Subsequently, a total of 84 fly ash samples were collected and analyzed. The original work plan total indicated that 96 fly ash samples would be collected. It is also noted that a fourth fly ash vendor began making deliveries during the summer.

- Twenty – four (24) Becraft lime samples were not collected. This raw material is used as an additive when balancing the slurry chemistry. The additive was placed in the system sporadically and the sampling team was unaware that the additive was being used and contemporaneous samples were not collected. The Beacraft lime was less than 1 percent of the mix design during for all four events. Seven (7) Becraft Lime samples were collected from the on-site storage pile during event 3. The Hg concentration from these samples was used to estimate the amount of Hg associated with this material for each event.

4.4 Analytical Procedures

Method 3052 was used to extract the Hg from the non – aqueous samples. This method contains a sequential extraction and separation procedure that is used in conjunction with a determinative method to analyze for extractable Hg that is present in soils, sediments and other digestible materials. For the determination of extractable Hg, a representative sample aliquot is extracted with an appropriate volume of solvent at elevated temperatures. Following initial extraction the resultant extracts were separated from the remaining sample matrix for analysis of extractable Hg by an appropriate technique.

Method 1631, Revision E is for determination of Hg (Hg) in filtered and unfiltered water by oxidation, purge and trap, desorption, and cold-vapor atomic fluorescence spectrometry (CVAFS). This reference method is for use in EPA's data gathering and monitoring programs associated with the Clean Water Act, the Resource Conservation and Recovery Act, the Comprehensive Environmental Response, Compensation and Liability Act, and the Safe Drinking Water Act. Since all of the bulk samples are digestate, this analytical method is being used to achieve the lowest detection limits. This method is for determination of Hg in the range of 0.5–100 ηg/L. Application may be extended to higher levels by selection of a smaller sample size or by calibration of the analytical system across a higher range. For measurement of blank samples, the method may be extended to a lower level by calibration to a lower calibration point. Method 1631 was used on the following sample matrices:

Aqueous Trip	Coke
Bauxite	Coeymans ("CYMN") Lime
Becraft ("BCFT") Lime	Iron/Mill Scale
CKD recycled	Kalkberg ("KLK") Lime
CKD wasted	Slurry
Clinker	

Method 7471, in the SW-846 methods manual, is designed for the cold-vapor atomic absorption spectrometric (CV-AAS) determination of total Hg in aqueous (extracts, wastewater, ground water, etc.) and solid (soils, sediments, sludges, etc.) materials, respectively. Solid samples are heated in an autoclave with sulfuric acid, nitric acid and permanganate. The mercuric ions in the digests are then reduced with hydroxylamine, and the elemental Hg is aerated into the AAS cell where the absorption at 253.7 nm is determined. Method 7471 was used to analyze the matrices that were known to contain Hg concentrations that were quantifiable via this method. Method 7471 was used to quantify the amount of Hg in the following sample matrices:

Bauxite	Fly Ash
Coal	

4.5 Quality Control

4.5.1 Field Quality Control

Quality control samples were collected in the field to allow evaluation of data quality. Field QA/QC samples for bulk material samples include equipment rinse blanks, and the collection of duplicate samples. For bulk material samples, field QA/QC samples were generated at the rate of 1 per every 20 environmental samples or one per sampling day when less than 20 samples were collected. A random number generator was used to identify the initial date upon which the QC sample would be collected for each bulk material. Subsequent QC samples were collected in a manner to assure that at least one duplicate sample was collected for each material.

4.5.2 Laboratory Quality Control

QA/QC samples prepared in the laboratory included method blanks, laboratory control samples (LCS), matrix spikes, and duplicates. Performance evaluation samples were not included. Method blanks were prepared and analyzed by the RTI Laboratories at a rate of at least one per analytical batch. Method blanks consisted of laboratory-prepared blank water processed along with the batch of environmental samples including all manipulations performed on actual samples. The method blank was prepared and analyzed before analysis of the associated environmental samples. LCS was analyzed at the rate of 5% or one per sample batch of up to 20 samples. Laboratory control spikes consist of laboratory-fortified method blanks. Matrix spikes were run at a rate of 5 percent or 1 per sample batch up of up to 20 samples. Duplicate samples of the bulk materials were run at a rate of 5 percent or 1 per sample batch up of up to 20 samples. A blind duplicate sample was collected in the field to facilitate this requirement.

4.5.3 Data Verification/Validation

Sample analysis and batch quality control results was delivered in a Microsoft Excel© compatible electronic format for batch loading into the project database. Analytical results for all samples were provided as a full data package in a scanned electronic media (Adobe® Acrobat /.pdf file). Automated electronic data verification was performed on 100% of the data using the batch quality control results provided by the laboratories in the excel spread sheets. The specific measures evaluated during verification and the associated criteria included:

- Holding times
- Accuracy (by evaluating laboratory control sample (LCS) recovery)
- Matrix spike/matrix spike duplicate (MS/MSD) recoveries
- Precision (by evaluating laboratory duplicate results)
- Field duplicate sample precision
- Blank contamination (laboratory method blanks and field generated blanks)

The data validator prepared a narrative entitled Overall Assessment for each group of samples. The objective of the assessment was to ensure that the reported sample quantitation results are accurate. It was appropriate for the data reviewer to make professional judgments and express concerns, as well as to comment on the validity of the overall data. The reviewer had the responsibility to inform the user concerning data quality and data limitations to assist the user in avoiding inappropriate use of the data, while not precluding any consideration of the data. If qualifiers other than those listed below were necessary to describe or qualify the data, the data validator thoroughly explained the additional qualifiers used. Upon completion of data verification, the data was validated to identify the usability of the data for conducting assessments required to satisfy project objectives. Data validation involves identifying the technical usability of the data for making decisions pertaining to satisfying the project objectives. Based upon the quality assurance review of the analytical data, specific codes were placed next to results in the database to provide and indication of the quantitative and qualitative reliability of the results. The laboratory was required to use the reporting procedures as described in the NATIONAL FUNCTIONAL GUIDELINES FOR INORGANIC DATA REVIEW (OSWER 9240.1-45 EPA 540-R-04-004 October 2004) to validate the data generated by the laboratory. The applicable qualifiers were:

- U: The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
- J: The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
- J+: The result is an estimated quantity, but the result may be biased high.
- J-: The result is an estimated quantity, but the result may be biased low.
- R: The data are unusable.
- UJ: The analyte was not detected above the sample quantitation limit. The reported quantitation limit, however, is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

- I: The method reporting limit (MRL) is elevated due to matrix interference. This is a laboratory-applied qualifier and is left for the convenience of the user. These qualifier codes will serve as an indication of qualitative and quantitative reliability.

SECTION 5

SUMMARY OF BULK SAMPLING EVENTS

To help visualize and summarize the data, the project team calculated basic statistical quantities for each event and material being sampled or analyzed. The following parameters were calculated:

- 95% confidence interval
- Maximum
- Mean
- Minimum
- Standard deviation
- Standard error
- Variance

The descriptive statistics analysis generated a summary report that provided information about the central tendency and variability of the data. Within this summary report the following terms and meaning are used:

- The confidence interval is a range of values. The sample mean, x, is at the center of this range and the range is x ± CONFIDENCE. For example, if x is the sample mean of Hg concentration in Bauxite, x ± CONFIDENCE is a range of population means. For any population mean, μ_0, in this range, the probability of obtaining a sample mean further from μ_0 than x is greater than alpha; for any population mean, μ_0, not in this range, the probability of obtaining a sample mean further from μ0 than x is less than alpha. In other words, assume that we use x, standard deviation, and population size to construct a two-tailed test at significance level alpha of the hypothesis that the population mean is μ_0. Then we will not reject that hypothesis if μ_0 is in the confidence interval and will reject that hypothesis if μ_0 is not in the confidence interval. The confidence interval does not allow us to infer that there is probability 1 – alpha that our next sample with an unknown Hg concentration is in the confidence interval.
- The standard deviation is a measure of how widely values are dispersed from the average value (the mean). The standard deviation assumes that its arguments are a sample of the population. The standard deviation is calculated using the unbiased or "n-1" method.

- The mode is the most frequently occurring, or repetitive, value in an array or range of data. Like median and average, MODE is a location measure.
- Kurtosis characterizes the relative peakedness or flatness of a distribution compared with the normal distribution. Positive kurtosis indicates a relatively peaked distribution. Negative kurtosis indicates a relatively flat distribution.
- Skewness characterizes the degree of asymmetry of a distribution around its mean. Positive skewness indicates a distribution with an asymmetric tail extending toward more positive values. Negative skewness indicates a distribution with an asymmetric tail extending toward more negative values.
- The median is the number in the middle of a set of numbers; that is, half the numbers have values that are greater than the median, and half have values that are less.
- The mean (arithmetic average) is the sum of the values divided by the number of values. It is a measure of location and the center of a normally distributed population.
- The standard error of the mean (SEM) is an unbiased estimate of expected error in the sample estimate of a population mean, is the sample estimate of the population standard deviation (sample standard deviation) divided by the square root of the sample size (assuming statistical independence of the values in the sample). Decreasing the uncertainty in your mean value estimate by a factor of two requires that you acquire four times as many samples. Worse, decreasing standard error by a factor of ten requires a hundred times as many samples.
- The data sets were checked for normality by using whisker plots. All results were found to be normally distributed. No outliers were identified and no data substitution techniques were needed or used.

Tables 4 through 8 summarize the results of the bulk material sampling and analytical efforts. Tables 9 through 14 summarize the process rate information used to perform the mass balance calculations. Tables 15 through 20 summarize the mass balance components. Appendix B includes the laboratory reports for each of the 4 sampling events.

Figures 3 through 7 present the annualized Hg inputs for each event using mass balance techniques. Figures 8 through 12 present the annualized Hg emission distributions for each event.

Figure 3. Event 1 – Annualized Mercury Inputs Using Mass Balance Techniques

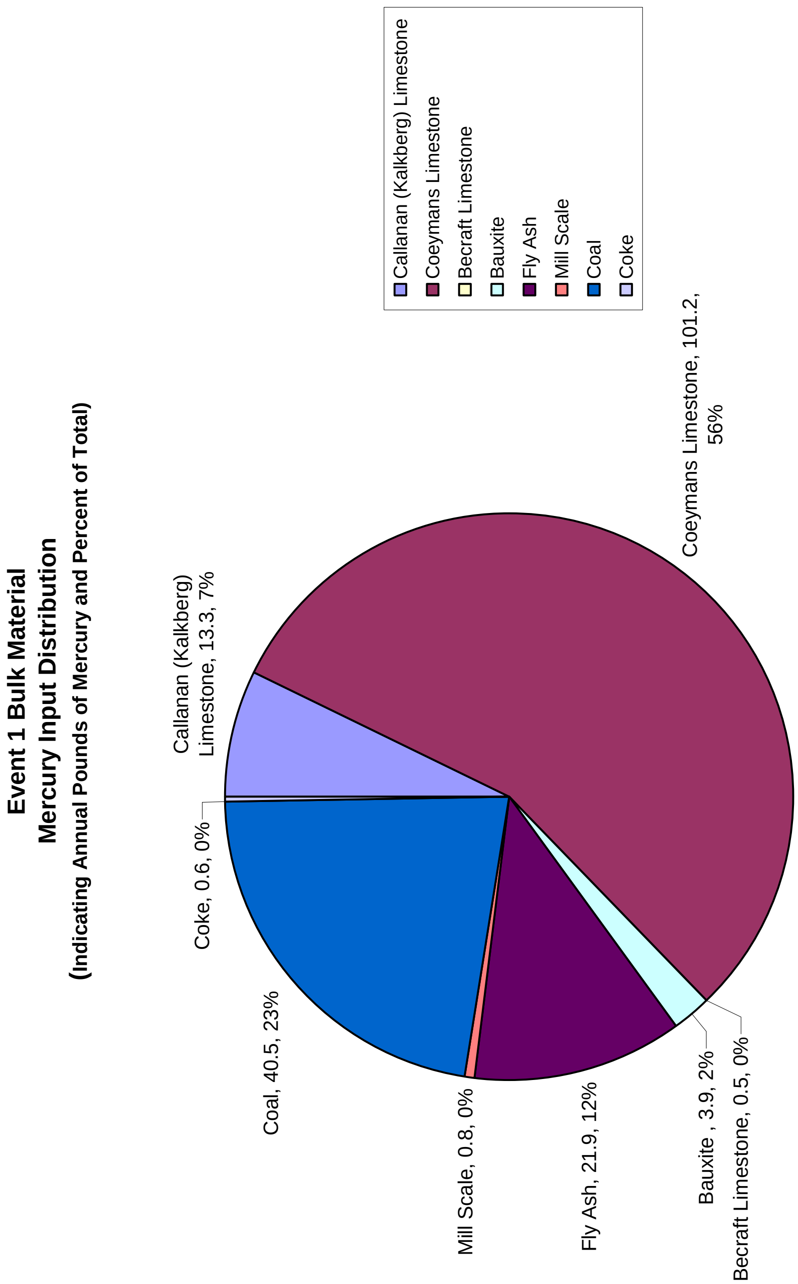

Figure 4. Event 2 – Annualized Mercury Inputs Using Mass Balance Techniques

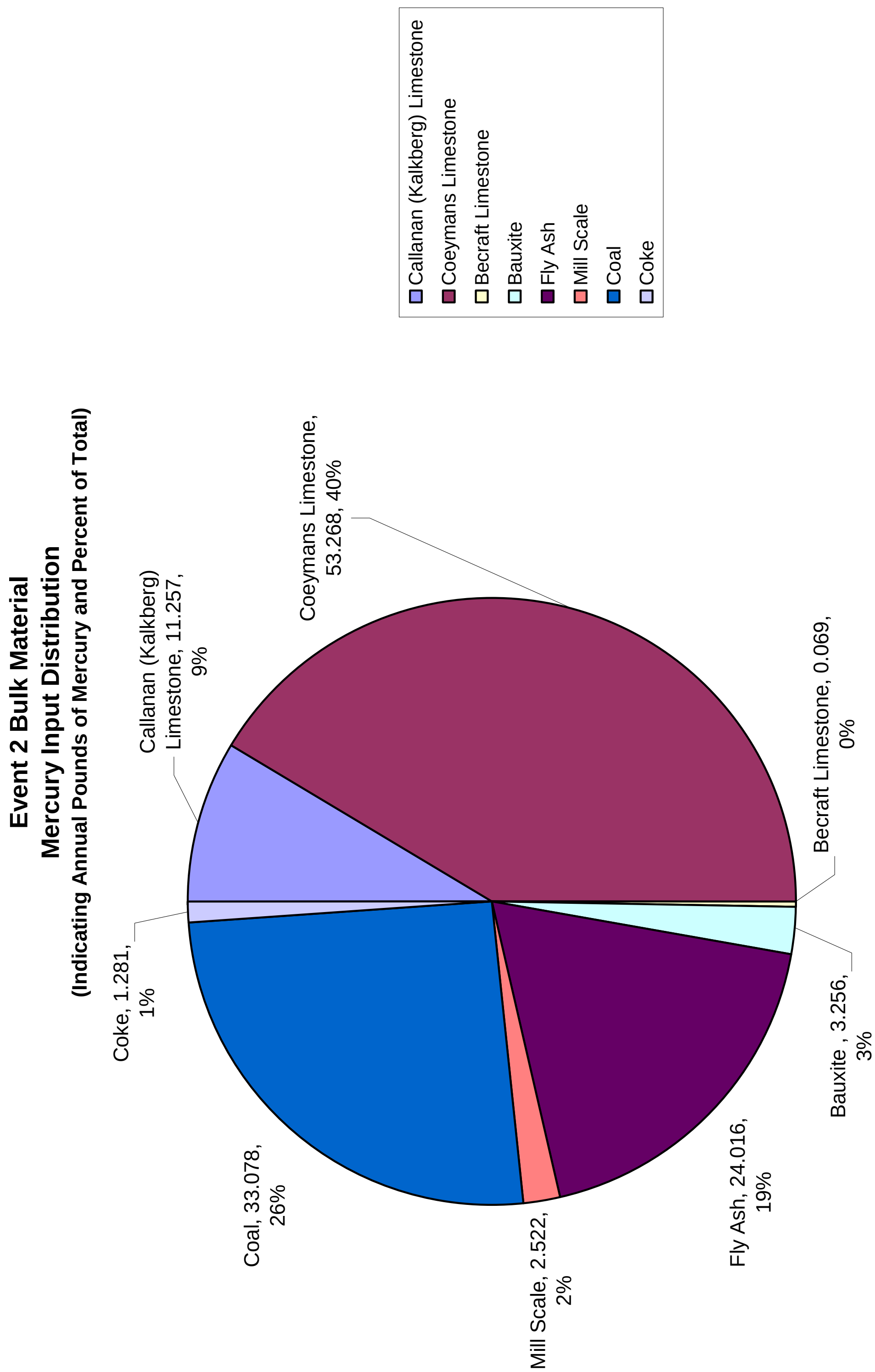

Figure 5. Event 3 – Annualized Mercury Inputs Using Mass Balance Techniques

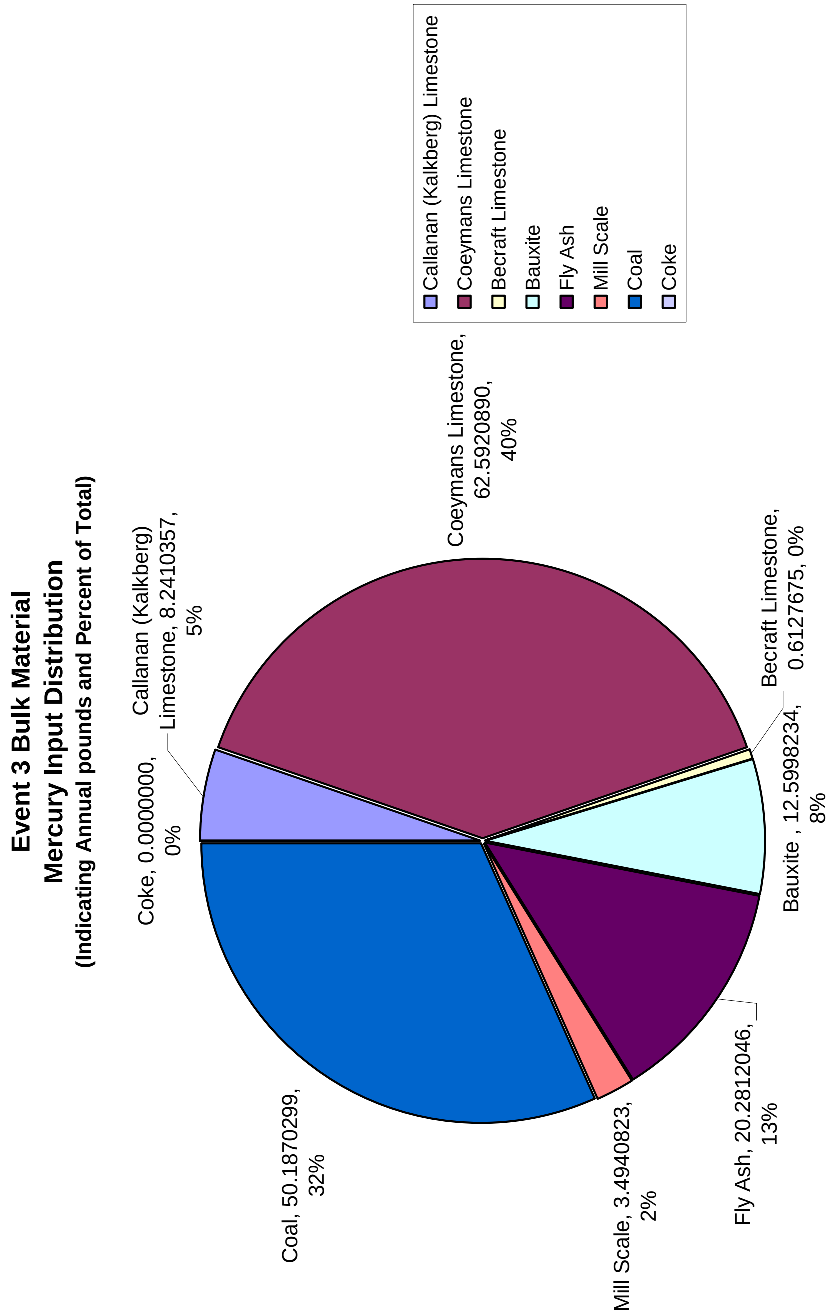

Figure 6. Event 4 – Annualized Mercury Inputs Using Mass Balance Techniques

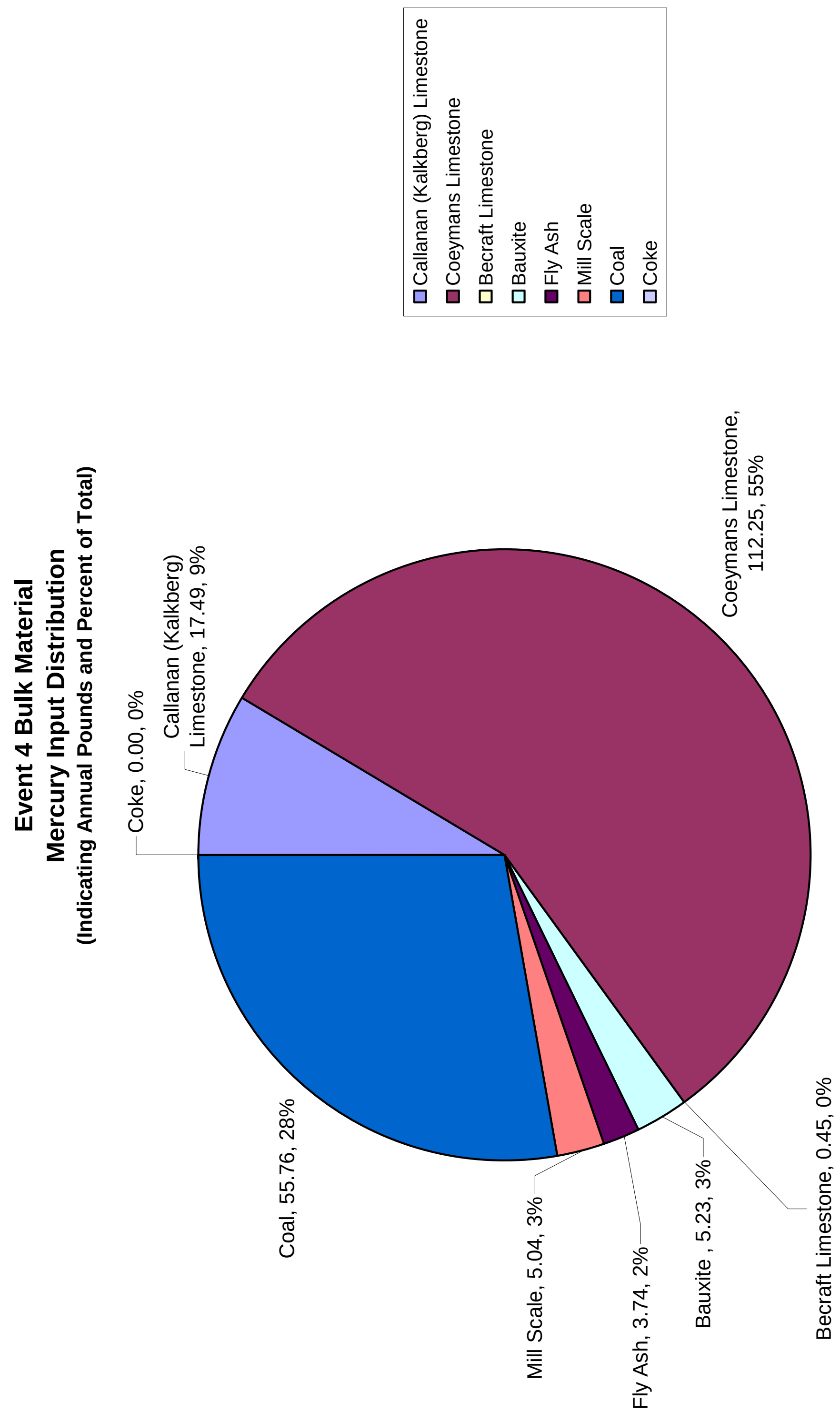

Figure 7. 2008 Inputs Using Mass Balance Techniques

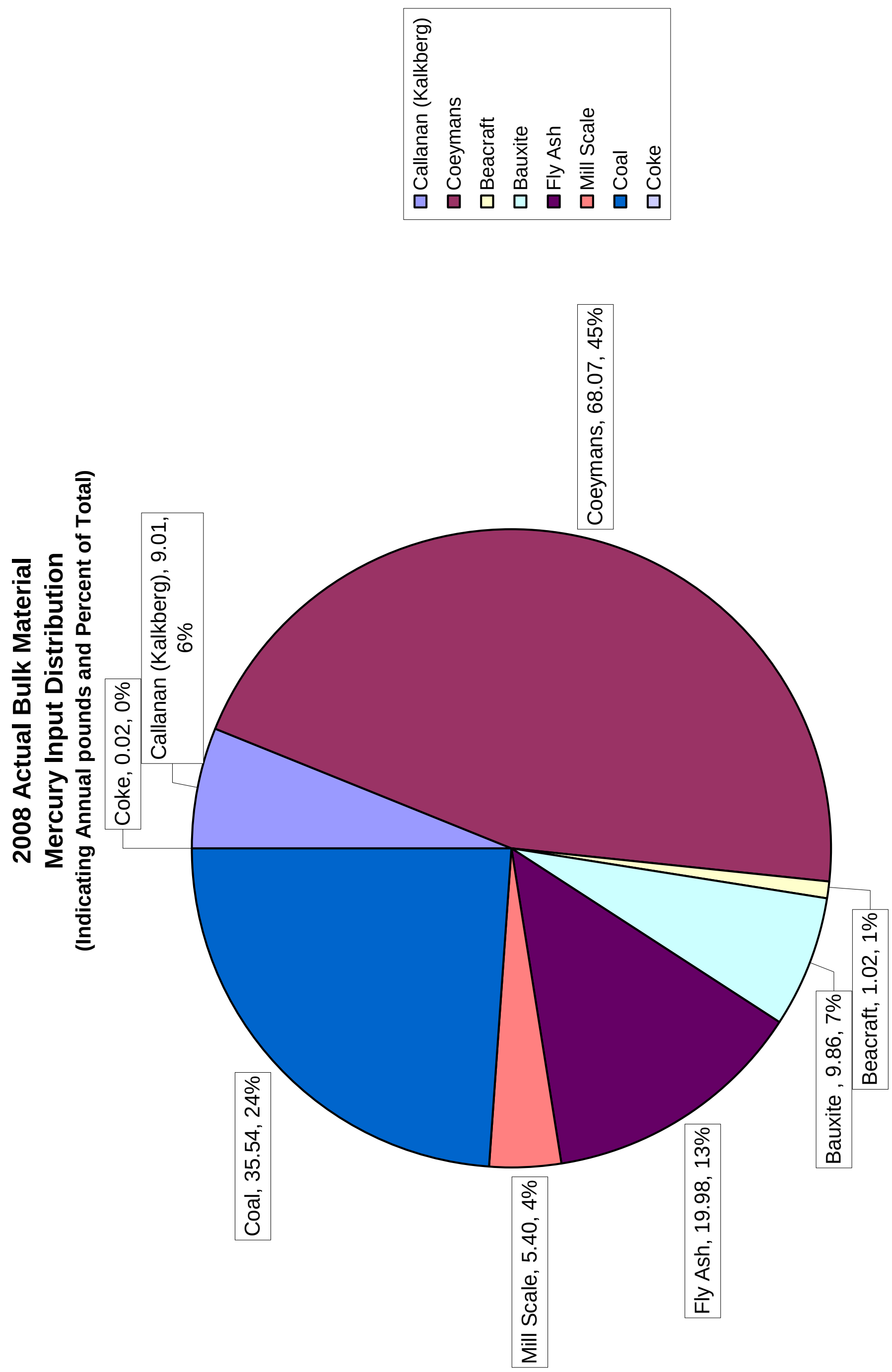

Figure 8. Event 1 – Annualized Mercury Emission Distribution Using Mass Balance Techniques

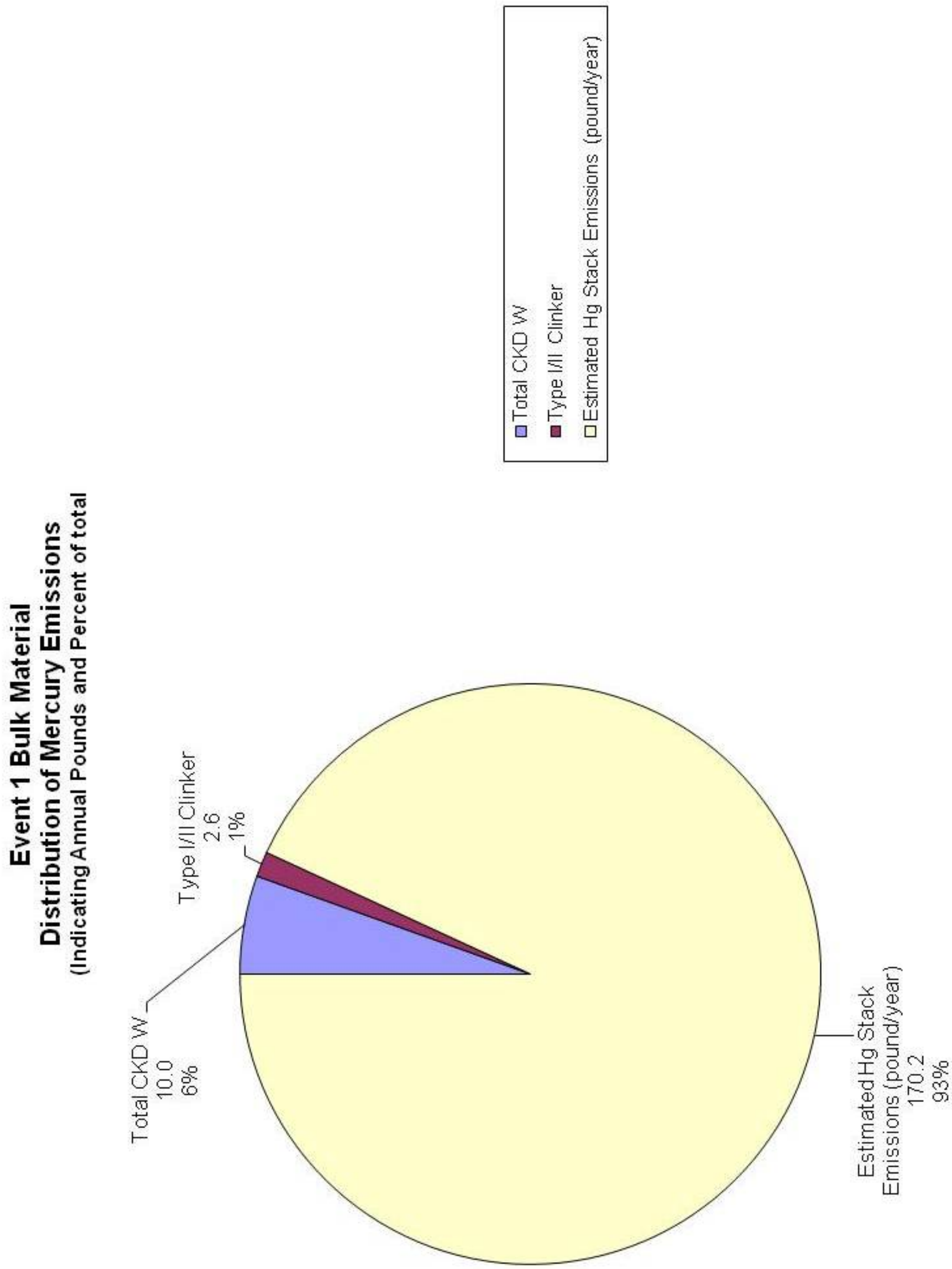

Figure 9. Event 2 – Annualized Mercury Emission Distribution Using Mass Balance Techniques

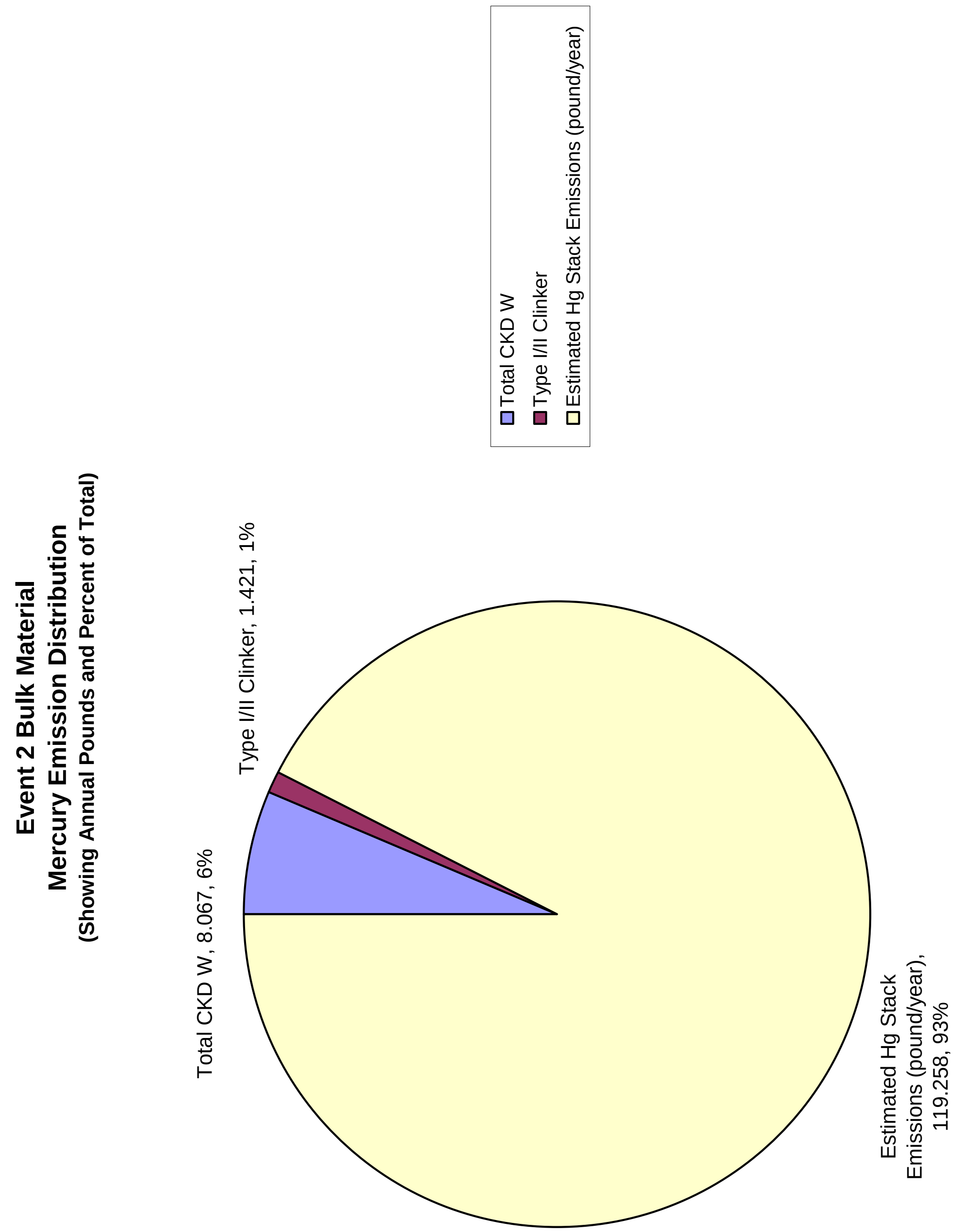

Figure 10. Event 3 – Annualized Mercury Emission Distribution Using Mass Balance Techniques

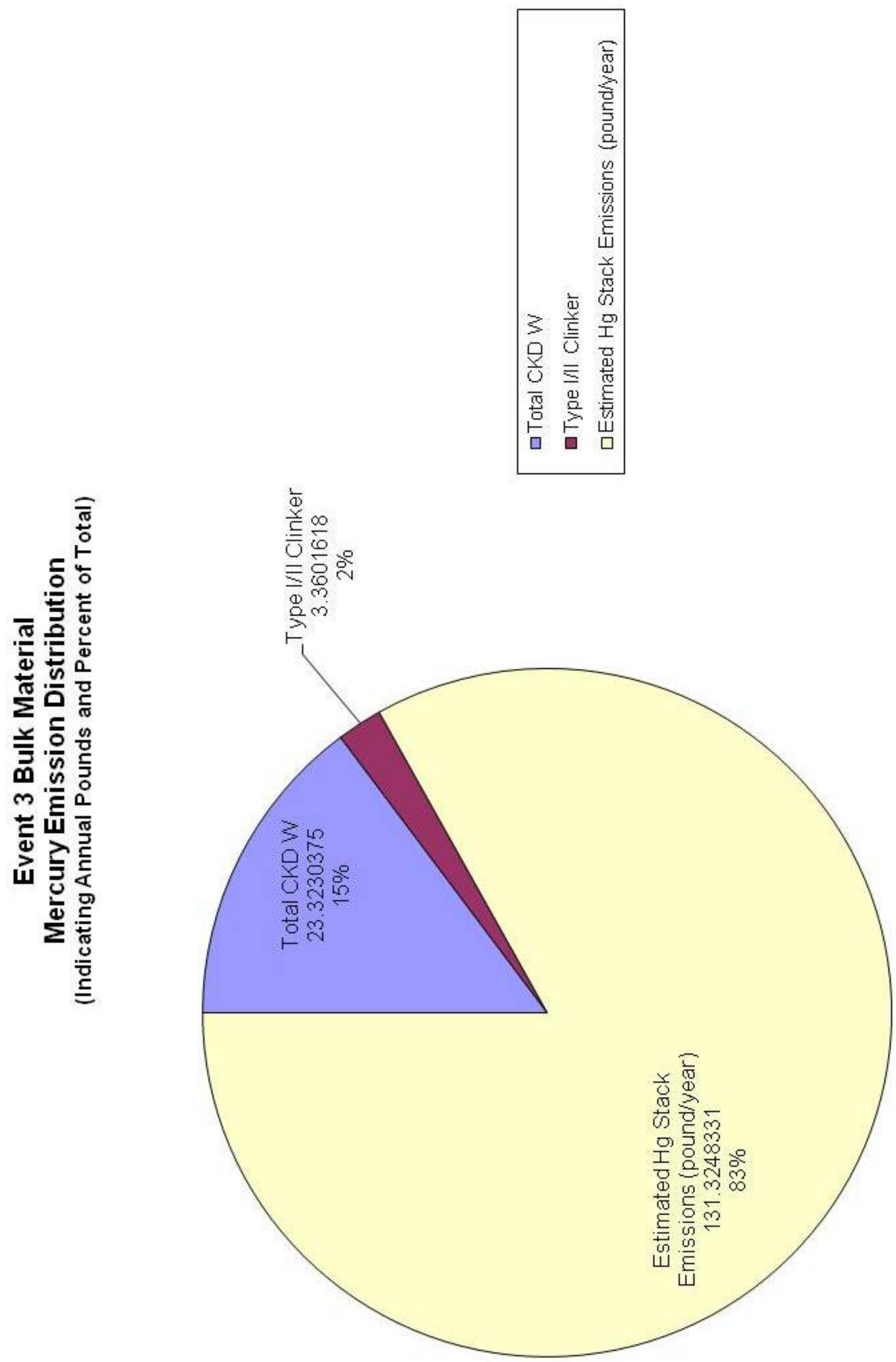

Figure 11. Event 4 – Annualized Mercury Emission Distribution Using Mass Balance Techniques

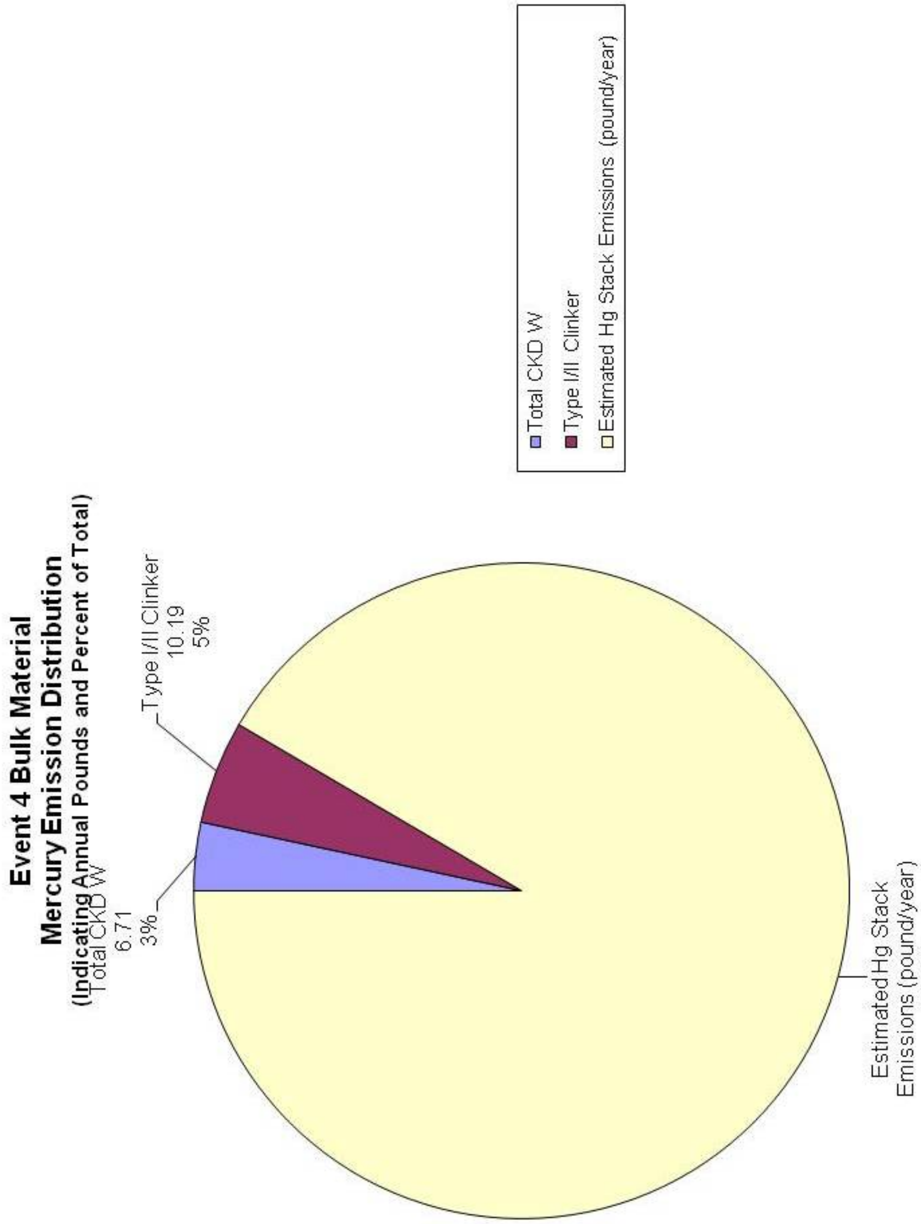

Figure 12. 2008 Mercury Emissions Distribution Using Mass Balance Techniques

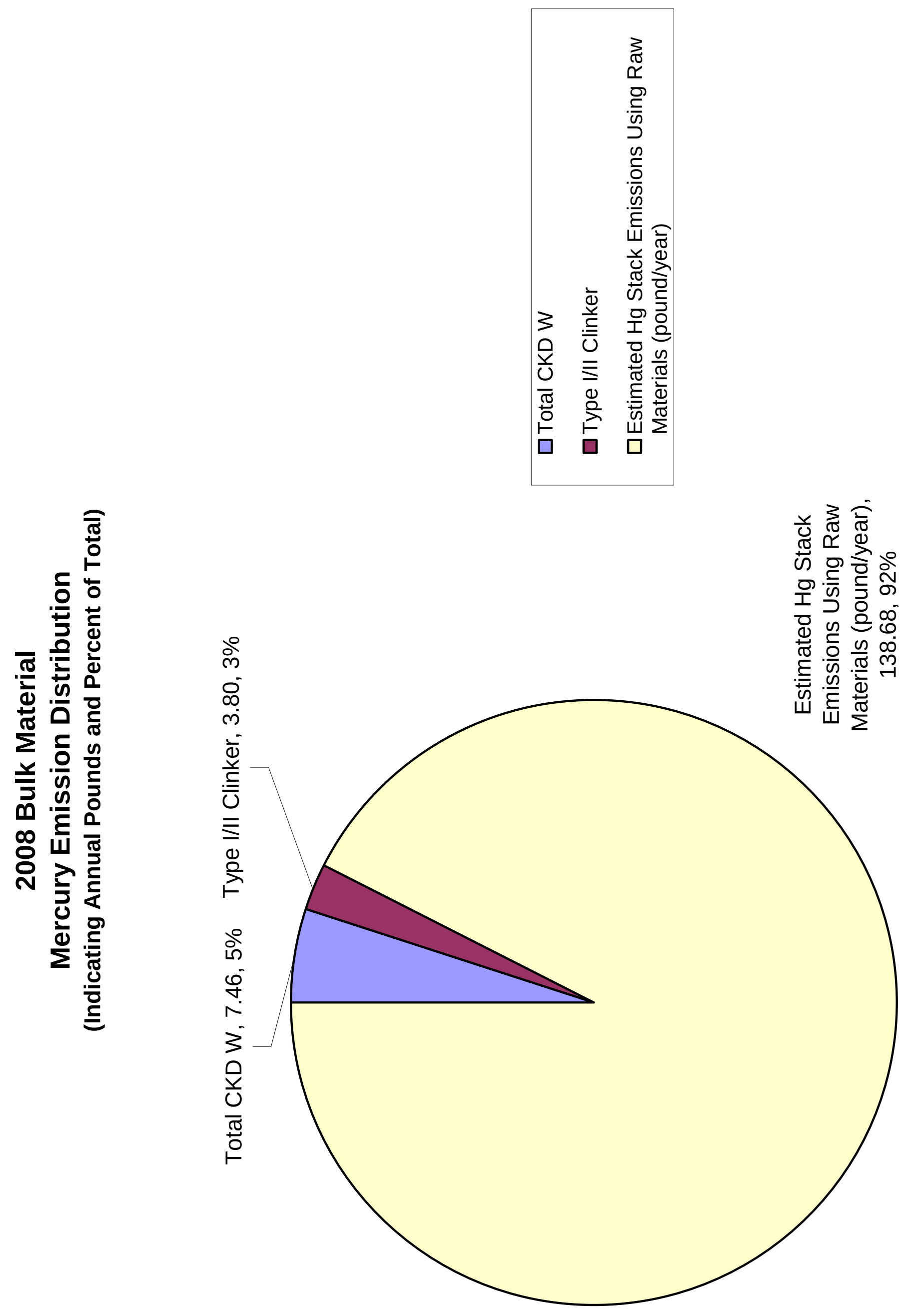

TABLE 4. STATISTICAL SUMMARY OF EVENT 1

Bauxite Event 1	
Mean	73.16667
Standard Error	3.451133
Median	75.5
Mode	65
Standard Deviation	20.7068
Sample Variance	428.7714
Kurtosis	-0.306933
Skewness	0.375791
Range	80
Minimum	40
Maximum	120
Sum	2634
Count	36
Largest(1)	120
Smallest(1)	40
Confidence Level(95.0%)	7.006172

CKD R Event 1	
Mean	16.1
Standard Error	2.592682
Median	15.5
Mode	10
Standard Deviation	8.19878
Sample Variance	67.22
Kurtosis	0.693437
Skewness	0.851409
Range	27.8
Minimum	5.2
Maximum	33
Sum	161
Count	10
Largest(1)	33
Smallest(1)	5.2
Confidence Level(95.0%)	5.865054

Coke Event 1	
Mean	15.70833
Standard Error	3.189791
Median	14
Mode	#N/A
Standard Deviation	11.04976
Sample Variance	122.0972
Kurtosis	-1.337024
Skewness	0.297612
Range	32
Minimum	1
Maximum	33
Sum	188.5
Count	12
Largest(1)	33
Smallest(1)	1
Confidence Level(95.0%)	7.020683

Coeymans Limestone Event 1	
Mean	21.46364
Standard Error	4.056135
Median	19
Mode	#N/A
Standard Deviation	13.45268
Sample Variance	180.9745
Kurtosis	1.501506
Skewness	1.031171
Range	46.5
Minimum	5.5
Maximum	52
Sum	236.1
Count	11
Largest(1)	52
Smallest(1)	5.5
Confidence Level(95.0%)	9.037632

Fly Ash vendor 4 Event 1	
Mean	160
Standard Error	21.60247
Median	150
Mode	#N/A
Standard Deviation	57.15476
Sample Variance	3266.667
Kurtosis	4.089796
Skewness	1.889606
Range	170
Minimum	110
Maximum	280
Sum	1120
Count	7
Largest(1)	280
Smallest(1)	110
Confidence Level(95.0%)	52.85934

Event 1 Kalkberg	
	Hg
Mean	11.75556
Standard Error	2.110497
Median	9.3
Mode	#N/A
Standard Deviation	6.331491
Sample Variance	40.08778
Kurtosis	0.487981
Skewness	1.172456
Range	19.3
Minimum	4.7
Maximum	24
Sum	105.8
Count	9
Confidence Level(95.0%)	4.866815

Table 4 (continued)

CKD W Event 1	
Mean	27.57273
Standard Error	4.32086
Median	28
Mode	24
Standard Deviation	14.33067
Sample Variance	205.3682
Kurtosis	-1.017767
Skewness	-0.166361
Range	44
Minimum	5
Maximum	49
Sum	303.3
Count	11
Largest(1)	49
Smallest(1)	5
Confidence Level(95.0%)	9.627477

Clinker Event 1	
Mean	0.795922
Standard Error	0.340392
Median	0.27
Mode	#N/A
Standard Deviation	1.021177
Sample Variance	1.042802
Kurtosis	3.933222
Skewness	1.905242
Range	3.1977
Minimum	0.0023
Maximum	3.2
Sum	7.1633
Count	9
Largest(1)	3.2
Smallest(1)	0.0023
Confidence Level(95.0%)	0.784946

Fly Ash Bin Event 1	
Mean	240.2667
Standard Error	23.67789
Median	240
Mode	160
Standard Deviation	91.70408
Sample Variance	8409.638
Kurtosis	-0.829265
Skewness	0.077736
Range	296
Minimum	84
Maximum	380
Sum	3604
Count	15
Largest(1)	380
Smallest(1)	84
Confidence Level(95.0%)	50.78403

No Fly Ash V-1 Event 1

Mill Scale Iron Event 1	
Mean	29.15455
Standard Error	5.340435
Median	22
Mode	12
Standard Deviation	17.71222
Sample Variance	313.7227
Kurtosis	-1.485725
Skewness	0.469411
Range	47.3
Minimum	9.7
Maximum	57
Sum	320.7
Count	11
Largest(1)	57
Smallest(1)	9.7
Confidence Level(95.0%)	11.89923

Slurry	
Mean	23.82
Standard Error	3.459152
Median	24
Mode	25
Standard Deviation	10.9388
Sample Variance	119.6573
Kurtosis	-0.386164
Skewness	0.323527
Range	34.8
Minimum	7.2
Maximum	42
Sum	238.2
Count	10
Largest(1)	42
Smallest(1)	7.2
Confidence Level(95.0%)	7.825146

Table 4 (continued)

Coal Mill Event 1	
Mean	71.6
Standard Error	4.284857
Median	72.5
Mode	#N/A
Standard Deviation	13.54991
Sample Variance	183.6
Kurtosis	-1.843013
Skewness	-0.156124
Range	35
Minimum	53
Maximum	88
Sum	716
Count	10
Largest(1)	88
Smallest(1)	53
Confidence Level(95.0%)	9.69302

Coal Pile Event 1	
Mean	84.55556
Standard Error	5.59598
Median	78
Mode	80
Standard Deviation	33.57588
Sample Variance	1127.34
Kurtosis	2.316687
Skewness	1.610175
Range	131
Minimum	49
Maximum	180
Sum	3044
Count	36
Largest(1)	180
Smallest(1)	49
Confidence Level(95.0%)	11.36044

Fly Ash Vendor 2 Event 1	
Mean	226.9231
Standard Error	22.22797
Median	240
Mode	180
Standard Deviation	80.1441
Sample Variance	6423.077
Kurtosis	0.216833
Skewness	0.646243
Range	280
Minimum	120
Maximum	400
Sum	2950
Count	13
Largest(1)	400
Smallest(1)	120
Confidence Level(95.0%)	48.4306

Fly Ash Vendor - 3 Event 1	
Mean	264.4444
Standard Error	15.55556
Median	240
Mode	240
Standard Deviation	46.66667
Sample Variance	2177.778
Kurtosis	1.020094
Skewness	1.146358
Range	150
Minimum	210
Maximum	360
Sum	2380
Count	9
Largest(1)	360
Smallest(1)	210
Confidence Level(95.0%)	35.87118

Slurry Moisture	*(%wt)*
Mean	20.6
Standard Error	1.431394
Median	20.5
Mode	21
Standard Deviation	4.526465
Sample Variance	20.48889
Kurtosis	-0.27414
Skewness	0.065774
Range	15
Minimum	13
Maximum	28
Sum	206
Count	10
Largest(1)	28
Smallest(1)	13
Confidence Level(95.0%)	3.238038

Event 1 Trip	
Mean	2.016923
Standard Error	0.937169
Median	0.92
Mode	0.5
Standard Deviation	3.379012
Sample Variance	11.41772
Kurtosis	11.49824
Skewness	3.323969
Range	12.5
Minimum	0.5
Maximum	13
Sum	26.22
Count	13
Confidence Level(95.0%)	2.041917

TABLE 5. STATISTICAL SUMMARY OF EVENT 2

Bauxite Event 2	
Mean	56.81818
Standard Error	4.859336
Median	53
Mode	38
Standard Deviation	22.79231
Sample Variance	519.4892
Kurtosis	1.651328
Skewness	1.322724
Range	91
Minimum	29
Maximum	120
Sum	1250
Count	22
Largest(1)	120
Smallest(1)	29
Confidence Level(95.0%)	10.10554

CKDR - event 2	
Mean	11.625
Standard Error	1.322032
Median	12
Mode	12
Standard Deviation	3.73927
Sample Variance	13.98214
Kurtosis	2.566656
Skewness	-1.007224
Range	13
Minimum	4
Maximum	17
Sum	93
Count	8
Largest(1)	17
Smallest(1)	4
Confidence Level(95.0%)	3.126108

Coke Pile Event 2	
Mean	23
Standard Error	2.5
Median	23
Mode	23
Standard Deviation	7.071068
Sample Variance	50
Kurtosis	-0.469463
Skewness	0.494571
Range	21
Minimum	14
Maximum	35
Sum	184
Count	8
Largest(1)	35
Smallest(1)	14
Confidence Level(95.0%)	5.911561

Coeymans Limestone Event 2	
Mean	14.4875
Standard Error	1.996912
Median	13.5
Mode	#N/A
Standard Deviation	5.648119
Sample Variance	31.90125
Kurtosis	4.058602
Skewness	1.7078
Range	19.1
Minimum	7.9
Maximum	27
Sum	115.9
Count	8
Largest(1)	27
Smallest(1)	7.9
Confidence Level(95.0%)	4.721946

No Fly Ash V-4 Samples

Kalkberg Lime Event 2	
Mean	9.55
Standard Error	0.69949
Median	9.05
Mode	#N/A
Standard Deviation	1.978455
Sample Variance	3.914286
Kurtosis	-0.317989
Skewness	0.985138
Range	5.3
Minimum	7.7
Maximum	13
Sum	76.4
Count	8
Largest(1)	13
Smallest(1)	7.7
Confidence Level(95.0%)	1.65403

Table 5 (continued)

CKDW event 2	
Mean	21.125
Standard Error	1.787231
Median	22
Mode	19
Standard Deviation	5.055054
Sample Variance	25.55357
Kurtosis	1.456011
Skewness	-1.10606
Range	16
Minimum	11
Maximum	27
Sum	169
Count	8
Largest(1)	27
Smallest(1)	11
Confidence Level(95.0%)	4.226131

Clinker Event 2	
Mean	0.442857
Standard Error	0.074856
Median	0.44
Mode	#N/A
Standard Deviation	0.19805
Sample Variance	0.039224
Kurtosis	-1.67173
Skewness	1.84E-05
Range	0.53
Minimum	0.18
Maximum	0.71
Sum	3.1
Count	7
Largest(1)	0.71
Smallest(1)	0.18
Confidence Level(95.0%)	0.183166

Fly Ash Bin Event 2	
Mean	296.5
Standard Error	46.16185
Median	360
Mode	370
Standard Deviation	113.073
Sample Variance	12785.5
Kurtosis	0.821905
Skewness	-1.412561
Range	271
Minimum	99
Maximum	370
Sum	1779
Count	6
Largest(1)	370
Smallest(1)	99
Confidence Level(95.0%)	118.6628

Fly Ash Vendor 1 Event 1	
Mean	352
Standard Error	32.85659
Median	415
Mode	420
Standard Deviation	103.9017
Sample Variance	10795.56
Kurtosis	-0.884414
Skewness	-1.09794
Range	240
Minimum	180
Maximum	420
Sum	3520
Count	10
Largest(1)	420
Smallest(1)	180
Confidence Level(95.0%)	74.32677

Iron Mill Scale Event 2	
Mean	39.25
Standard Error	2.710759
Median	39
Mode	#N/A
Standard Deviation	7.667184
Sample Variance	58.78571
Kurtosis	0.480176
Skewness	-0.68747
Range	24
Minimum	25
Maximum	49
Sum	314
Count	8
Largest(1)	49
Smallest(1)	25
Confidence Level(95.0%)	6.409926

Slurry Event 2	
Mean	25.875
Standard Error	3.043949
Median	25.5
Mode	18
Standard Deviation	8.609588
Sample Variance	74.125
Kurtosis	2.461823
Skewness	1.399083
Range	26
Minimum	18
Maximum	44
Sum	207
Count	8
Largest(1)	44
Smallest(1)	18
Confidence Level(95.0%)	7.197795

Table 5 (continued)

No Coal Mill

Coal Pile Event 2	
Mean	69.75
Standard Error	4.173685
Median	71.5
Mode	#N/A
Standard Deviation	11.80496
Sample Variance	139.3571
Kurtosis	-1.575559
Skewness	-0.01346
Range	30
Minimum	55
Maximum	85
Sum	558
Count	8
Largest(1)	85
Smallest(1)	55
Confidence Level(95.0%)	9.869196

162 - Fly Ash V2 G1 270

Fly Ash V-3 Event 2	
Mean	230
Standard Error	10
Median	240
Mode	240
Standard Deviation	17.32051
Sample Variance	300
Kurtosis	#DIV/0!
Skewness	-1.732051
Range	30
Minimum	210
Maximum	240
Sum	690
Count	3
Largest(1)	240
Smallest(1)	210
Confidence Level(95.0%)	43.02653

Slurry Moisture Event 2	
	% wt
Mean	23.375
Standard Error	1.625
Median	23.5
Mode	18
Standard Deviation	4.596194
Sample Variance	21.125
Kurtosis	-1.263157
Skewness	0.243687
Range	12
Minimum	18
Maximum	30
Sum	187
Count	8
Largest(1)	30
Smallest(1)	18
Confidence Level(95.0	3.842514

TABLE 6. STATISTICAL SUMMARY OF EVENT 3

Event 3 Bauxite	µg/Kg-dry
Mean	168.0000
Standard Error	55.5257
Median	105.0000
Mode	#N/A
Standard Deviation	157.0505
Sample Variance	24664.8571
Kurtosis	2.4175
Skewness	1.7375
Range	455.0000
Minimum	45.0000
Maximum	500.0000
Sum	1344.0000
Count	8.0000
Confidence Level(95.0%)	131.2975

Event 3 Becraft	ug/kg-dry
Mean	16.1429
Standard Error	2.4537
Median	13.0000
Mode	13.0000
Standard Deviation	6.4918
Sample Variance	42.1429
Kurtosis	4.5527
Skewness	2.0782
Range	19.0000
Minimum	11.0000
Maximum	30.0000
Sum	113.0000
Count	7.0000
Confidence Level(95.0%)	6.0039

Event 3 Coeyman	ug/kg
Mean	14.4000
Standard Error	2.2271
Median	13.0000
Mode	13.0000
Standard Deviation	6.2992
Sample Variance	39.6800
Kurtosis	2.9719
Skewness	1.7478
Range	18.8000
Minimum	9.2000
Maximum	28.0000
Sum	115.2000
Count	8.0000
Confidence Level(95.0%)	5.2663

Event 3 Fly Ash Bin	ug/kg
Mean	138.6667
Standard Error	36.4478
Median	170.0000
Mode	#N/A
Standard Deviation	63.1295
Sample Variance	3985.3333
Kurtosis	#DIV/0!
Skewness	-1.6833
Range	114.0000
Minimum	66.0000
Maximum	180.0000
Sum	416.0000
Count	3.0000
Confidence Level(95.0%)	156.8224

Event 3 Iron	ug/kg
Mean	134.1500
Standard Error	34.3394
Median	115.0000
Mode	#N/A
Standard Deviation	97.1265
Sample Variance	9433.5514
Kurtosis	4.4187
Skewness	1.6611
Range	340.8000
Minimum	9.2000
Maximum	350.0000
Sum	1073.2000
Count	8.0000
Confidence Level(95.0%)	81.1998

Event 3 Slurry	ug/kg
Mean	18.6250
Standard Error	1.6790
Median	18.5000
Mode	#N/A
Standard Deviation	4.7491
Sample Variance	22.5536
Kurtosis	0.9056
Skewness	0.2366
Range	16.0000
Minimum	11.0000
Maximum	27.0000
Sum	149.0000
Count	8.0000
Confidence Level(95.0%)	3.9703

Table 6 (continued)

Event 3 CKD R	ug/kg
Mean	14.4429
Standard Error	2.5446
Median	19.0000
Mode	19.0000
Standard Deviation	6.7325
Sample Variance	45.3262
Kurtosis	-2.4441
Skewness	-0.4214
Range	15.2000
Minimum	5.8000
Maximum	21.0000
Sum	101.1000
Count	7.0000
Confidence Level(95.0%)	6.2265

Event 3 CKDW	ug/kg
Mean	33.0000
Standard Error	4.1748
Median	30.5000
Mode	#N/A
Standard Deviation	11.8080
Sample Variance	139.4286
Kurtosis	2.7969
Skewness	1.4487
Range	39.0000
Minimum	19.0000
Maximum	58.0000
Sum	264.0000
Count	8.0000
Confidence Level(95.0%)	9.8717

Event 3 Fly Ash V-1	ug/kg
Mean	111.0000
Standard Error	14.6401
Median	100.0000
Mode	#N/A
Standard Deviation	25.3574
Sample Variance	643.0000
Kurtosis	#DIV/0!
Skewness	1.5847
Range	47.0000
Minimum	93.0000
Maximum	140.0000
Sum	333.0000
Count	3.0000
Confidence Level(95.0%)	62.9914

Event 3 Fly Ash V-2	ug/kg
Mean	156.6667
Standard Error	27.2845
Median	140.0000
Mode	#N/A
Standard Deviation	47.2582
Sample Variance	2233.3333
Kurtosis	#DIV/0!
Skewness	1.3896
Range	90.0000
Minimum	120.0000
Maximum	210.0000
Sum	470.0000
Count	3.0000
Confidence Level(95.0%)	117.3958

Event 3 Equipment and Trip blanks	ng/L
Mean	3.1700
Standard Error	0.4837
Median	2.6500
Mode	#N/A
Standard Deviation	1.5297
Sample Variance	2.3401
Kurtosis	-1.5330
Skewness	0.3628
Range	4.2000
Minimum	1.3000
Maximum	5.5000
Sum	31.7000
Count	10.0000
Confidence Level(95.0%)	1.0943

Table 6 (continued)

Event 3 Clinker	
	ug/kg
Mean	0.9500
Standard Error	0.1342
Median	0.9400
Mode	1.3000
Standard Deviation	0.3795
Sample Variance	0.1440
Kurtosis	-1.1458
Skewness	-0.4075
Range	1.0100
Minimum	0.3900
Maximum	1.4000
Sum	7.6000
Count	8.0000
Confidence Level(95.0%)	0.3172

Event 3 Coal Pile	
	µg/Kg-dry
Mean	76.0000
Standard Error	8.9821
Median	71.0000
Mode	110.0000
Standard Deviation	25.4053
Sample Variance	645.4286
Kurtosis	-1.5047
Skewness	0.3711
Range	65.0000
Minimum	45.0000
Maximum	110.0000
Sum	608.0000
Count	8.0000
Confidence Level(95.0%)	21.2394

Event 3 Fly Ash V-3	
Mean	213.3333
Standard Error	8.8192
Median	210.0000
Mode	#N/A
Standard Deviation	15.2753
Sample Variance	233.3333
Kurtosis	#DIV/0!
Skewness	0.9352
Range	30.0000
Minimum	200.0000
Maximum	230.0000
Sum	640.0000
Count	3.0000
Confidence Level(95.0%)	37.9458

Event 3 Kalkburg Lime	
	ug/kg
Mean	8.9250
Standard Error	1.0215
Median	9.9500
Mode	11.0000
Standard Deviation	2.8893
Sample Variance	8.3479
Kurtosis	1.4615
Skewness	-1.5492
Range	7.9000
Minimum	3.1000
Maximum	11.0000
Sum	71.4000
Count	8.0000
Confidence Level(95.0%)	2.4155

TABLE 7. STATISTICAL SUMMARY OF EVENT 4

Event 4 Bauxite	
	µg/Kg-dry
Mean	104.5
Standard Error	6.568322
Median	99.5
Mode	#N/A
Standard Deviation	18.57802
Sample Variance	345.1429
Kurtosis	0.863797
Skewness	0.942597
Range	59
Minimum	81
Maximum	140
Sum	836
Count	8
Confidence Level(95.0%)	15.53161

Event 4 CKD R	
	ug/kg
Mean	15.1
Standard Error	1.779647
Median	13.5
Mode	#N/A
Standard Deviation	5.033601
Sample Variance	25.33714
Kurtosis	-1.082145
Skewness	0.54282
Range	14.2
Minimum	8.8
Maximum	23
Sum	120.8
Count	8
Confidence Level(95.0%)	4.208196

4146 FLY BIN COMP	
	µg/Kg-dry
	460

Fly Ash V-1	
	µg/Kg
Mean	380
Standard Error	20
Median	380
Mode	#N/A
Standard Deviation	28.28427
Sample Variance	800
Kurtosis	#DIV/0!
Skewness	#DIV/0!
Range	40
Minimum	360
Maximum	400
Sum	760
Count	2
Confidence Level(95.0%)	254.1241

Event 4 Mill Scale	
	ug/kg
Mean	145.375
Standard Error	20.22104
Median	140
Mode	#N/A
Standard Deviation	57.19375
Sample Variance	3271.125
Kurtosis	-0.370879
Skewness	0.330882
Range	177
Minimum	63
Maximum	240
Sum	1163
Count	8
Confidence Level(95.0%)	47.81517

Event 4 Slurry	
	ug/kg
Mean	20.375
Standard Error	1.426002
Median	19.5
Mode	20
Standard Deviation	4.033343
Sample Variance	16.26786
Kurtosis	-0.418636
Skewness	0.959347
Range	11
Minimum	16
Maximum	27
Sum	163
Count	8
Confidence Level(95.0%)	3.371959

Table 7 (continued)

Event 4 Coal Pile	
	µg/Kg-dry
Mean	90
Standard Error	9.432088
Median	89
Mode	89
Standard Deviation	26.67797
Sample Variance	711.7143
Kurtosis	2.650814
Skewness	0.209104
Range	97
Minimum	43
Maximum	140
Sum	720
Count	8
Confidence Level(95.0%)	22.30334

Event 4 Coeyman Limestone	
	ug/kg
Mean	26.75
Standard Error	4.177961
Median	22
Mode	19
Standard Deviation	11.81706
Sample Variance	139.6429
Kurtosis	-0.077268
Skewness	1.306101
Range	30
Minimum	17
Maximum	47
Sum	214
Count	8
Confidence Level(95.0%)	9.879308

4402 FLY V-4 GRAB 2 (Cayuga)	
	µg/Kg
	87

Event 4 Kalkberg Lime	
	ug/kg
Mean	15
Standard Error	0.906327
Median	14.5
Mode	12
Standard Deviation	2.56348
Sample Variance	6.571429
Kurtosis	-0.914367
Skewness	0.407055
Range	7
Minimum	12
Maximum	19
Sum	120
Count	8
Confidence Level(95.0%)	2.143123

Table 7 (continued)

Event 4 Coal Pile	
	µg/Kg-dry
Mean	90
Standard Error	9.432088
Median	89
Mode	89
Standard Deviation	26.67797
Sample Variance	711.7143
Kurtosis	2.650814
Skewness	0.209104
Range	97
Minimum	43
Maximum	140
Sum	720
Count	8
Confidence Level(95.0%)	22.30334

Event 4 Coeyman Limestone	
	ug/kg
Mean	26.75
Standard Error	4.177961
Median	22
Mode	19
Standard Deviation	11.81706
Sample Variance	139.6429
Kurtosis	-0.077268
Skewness	1.306101
Range	30
Minimum	17
Maximum	47
Sum	214
Count	8
Confidence Level(95.0%)	9.879308

4402 FLY V-4 GRAB 2 (Cayuga)	
	µg/Kg
	87

Event 4 Kalkberg Lime	
	ug/kg
Mean	15
Standard Error	0.906327
Median	14.5
Mode	12
Standard Deviation	2.56348
Sample Variance	6.571429
Kurtosis	-0.914367
Skewness	0.407055
Range	7
Minimum	12
Maximum	19
Sum	120
Count	8
Confidence Level(95.0%)	2.143123

TABLE 8. STATISTICAL SUMMARY OF ALL EVENTS

All Events Bauxite	
Mean	81.946
Standard Error	7.212
Median	73.500
Mode	100.000
Standard Deviation	62.039
Sample Variance	3848.819
Kurtosis	30.338
Skewness	4.960
Range	471.000
Minimum	29.000
Maximum	500.000
Sum	6064.000
Count	74.000
Confidence Level(95.0%)	14.373

All Events Becraft lime	
	ug/kg-dry
Mean	16.143
Standard Error	2.454
Median	13.000
Mode	13.000
Standard Deviation	6.492
Sample Variance	42.143
Kurtosis	4.553
Skewness	2.078
Range	19.000
Minimum	11.000
Maximum	30.000
Sum	113.000
Count	7.000
Confidence Level(95.0%)	6.004

All Event Coke	
Mean	18.025
Standard Error	2.269
Median	17.500
Mode	23.000
Standard Deviation	10.146
Sample Variance	102.951
Kurtosis	-1.003
Skewness	0.050
Range	34.000
Minimum	1.000
Maximum	35.000
Sum	360.500
Count	20.000
Confidence Level(95.0%)	4.749

All Event Coeyman	
Mean	19.463
Standard Error	1.870
Median	17.000
Mode	13.000
Standard Deviation	11.062
Sample Variance	122.361
Kurtosis	1.940
Skewness	1.420
Range	46.500
Minimum	5.500
Maximum	52.000
Sum	681.200
Count	35.000
Confidence Level(95.0%)	3.800

Table 8 (continued)

All Events CKD R	
Mean	14.421
Standard Error	1.087
Median	13.000
Mode	14.000
Standard Deviation	6.241
Sample Variance	38.956
Kurtosis	0.950
Skewness	0.738
Range	29.000
Minimum	4.000
Maximum	33.000
Sum	475.900
Count	33.000
Confidence Level(95.0%)	2.213

All Events CKD W	
Mean	26.437
Standard Error	2.038
Median	24.000
Mode	24.000
Standard Deviation	12.059
Sample Variance	145.418
Kurtosis	0.432
Skewness	0.746
Range	53.000
Minimum	5.000
Maximum	58.000
Sum	925.300
Count	35.000
Confidence Level(95.0%)	4.142

All Event Fly Ash	
Mean	245.232
Standard Error	11.184
Median	240.000
Mode	240.000
Standard Deviation	101.280
Sample Variance	10257.612
Kurtosis	-0.891
Skewness	0.300
Range	394.000
Minimum	66.000
Maximum	460.000
Sum	20109.000
Count	82.000
Confidence Level(99.0%)	29.504

All Event Kalkberg	
Mean	10.988
Standard Error	0.822
Median	10.500
Mode	11.000
Standard Deviation	4.792
Sample Variance	22.968
Kurtosis	1.134
Skewness	0.481
Range	24.000
Minimum	0.000
Maximum	24.000
Sum	373.600
Count	34.000
Confidence Level(95.0%)	1.672

Table 8 (continued)

All Event Clinker	
Mean	1.352
Standard Error	0.274
Median	0.900
Mode	1.300
Standard Deviation	1.548
Sample Variance	2.396
Kurtosis	5.917
Skewness	2.302
Range	6.998
Minimum	0.002
Maximum	7.000
Sum	43.263
Count	32.000
Confidence Level(95.0%)	0.558

All Event Coal Pile	
Mean	82.167
Standard Error	3.839
Median	77.500
Mode	110.000
Standard Deviation	29.735
Sample Variance	884.175
Kurtosis	2.829
Skewness	1.557
Range	137.000
Minimum	43.000
Maximum	180.000
Sum	4930.000
Count	60.000
Confidence Level(95.0%)	7.681

All Event Mill Scale	
Mean	82.026
Standard Error	12.693
Median	51.000
Mode	12.000
Standard Deviation	75.090
Sample Variance	5638.503
Kurtosis	3.660
Skewness	1.722
Range	340.800
Minimum	9.200
Maximum	350.000
Sum	2870.900
Count	35.000
Confidence Level(95.0%)	25.794

All Event Slurry	
Mean	22.271
Standard Error	1.378
Median	20.000
Mode	20.000
Standard Deviation	8.035
Sample Variance	64.562
Kurtosis	1.463
Skewness	1.019
Range	36.800
Minimum	7.200
Maximum	44.000
Sum	757.200
Count	34.000
Confidence Level(95.0%)	2.804

All Event Trip Blanks	
Mean	2.850
Standard Error	0.477
Median	1.800
Mode	0.500
Standard Deviation	3.166
Sample Variance	10.023
Kurtosis	5.750
Skewness	2.399
Range	13.820
Minimum	0.180
Maximum	14.000
Sum	125.380
Count	44.000
Confidence Level(95.0%)	0.963

TABLE 9. EVENT 1 ANNUALIZED PROCESS RATE INFORMATION

Table 9 Event 1 Production and Process Information						
Product	Average Input (tonne per day)	Event 1 Mix Design Percentage	Moisture %	Dry Weight Average Hg Content (PPB)	Dry Metric Tonnes/day	Hg LBs per day
Callanan (Kalkberg)	1,141	18.51%	2.238	11.756	1,115.90	0.029
Coeymans	4,811	78.04%	3.425	21.464	4,646.44	0.220
Beacraft	32	0.52%	6.986	16	29.56	0.001
Bauxite	55	0.89%	4.287	73.167	52.80	0.009
Fly Ash	94	1.53%	6.777	245.232	87.89	0.048
Mill Scale	31	0.50%	8.450	29.155	28.48	0.002
Raw Material Inputs	6,165				5,961.07	0.308
Total CKD R	799		0.000	16.100		
Total CKD W	358		0.000	27.57273	357.53	0.022
Product and Byproduct Losses						
Coal	506		6.683	84.556	472.39	0.088
Coke	42		8.042	15.708	38.98	0.001
Fuel Inputs					511.37	0.089
Type I/II Raw Slurry Mix	5,247			23.820	5,247	0.275
Type I/II Clinker	3,163.67			0.796	3,163.67	0.006

TABLE 10. EVENT 2 ANNUALIZED PROCESS RATE INFORMATION

	Table 10 Event 2 Production and Process Information					
Product	Average Input (tonne per day)	Event 2 Mix Design Percentage	Moisture %	Dry Weight Average Hg Content (PPB)	Dry Metric Tonnes/day	Hg LBs per day
Callanan (Kalkberg)	1,938	23.44%	3.700	9.550	1,866.71	0.039
Coeymans	5,946	71.92%	2.083	14.488	5,822.54	0.186
Beacraft	7	0.09%	6.986	16	6.78	0.000
Bauxite	98	1.18%	7.323	56.818	90.76	0.011
Fly Ash	166	2.01%	6.777	245.232	155.08	0.084
Mill Scale	112	1.35%	9.050	39.250	101.73	0.009
Raw Material Inputs	8,268	100%			8,043.60	0.329
Total CKD R	1,099		0.000	11.625		
Total CKD W	605		0.000	21.125	604.71	0.028
Product and Byproduct Losses						
Coal	826		9.050	69.750	750.99	0.115
Coke	98		9.638	23.000	88.17	0.004
Fuel Inputs					839.16	0.120
Type I/II Raw Slurry Mix	8,533			25.875	8,533	0.487
Type I/II Clinker	5,082.71		0.000	0.443	5,082.71	0.005

TABLE 11. EVENT 3 ANNUALIZED PROCESS RATE INFORMATION

	Table 11 Event 3 Production and Process Information					
Product	Average Input (tonne per day)	Event 3 Mix Design Percentage	Moisture %	Dry Weight Average Hg Content (PPB)	Dry Metric Tonnes/day	Hg LBs per day
Callanan (Kalkberg)	1,179	16.96%	2.675	8.925	1,147.46	0.023
Coeymans	5,473	78.72%	1.313	14.400	5,401.59	0.171
Beacraft	51	0.73%	6.986	16	47.17	0.002
Bauxite	104	1.49%	10.075	168.000	93.20	0.035
Fly Ash	110	1.59%	6.777	245.232	102.77	0.056
Mill Scale	36	0.51%	9.371	134.150	32.37	0.010
Raw Material Inputs	6,953	100%			6,824.56	0.295
Total CKD R	1,426		0.000	14.443		
Total CKD W	878		0.000	33	878.29	0.064
Product and Byproduct Losses						
Coal	890		7.825	76.000	820.62	0.137
Coke	0				0.00	0.000
Fuel Inputs					820.62	0.137
Type I/II Raw Slurry Mix	7,620			18.625	7,620	0.313
Type I/II Clinker	4,395.43			0.950	4,395.43	0.009

TABLE 12. EVENT 4 ANNUALIZED PROCESS RATE INFORMATION

	Table 12 Event 4 Production and Process Information					
Product	Average Input (tonne per day)	Event 4 Mix Design Percentage	Moisture %	Dry Weight Average Hg Content (PPB)	Dry Metric Tonnes/day	Hg LBs per day
Callanan (Kalkberg)	1,815	21.26%	3.325	15.000	1,754.79	0.058
Coeymans	6,509	76.24%	2.963	26.750	6,316.17	0.372
Beacraft	49	0.57%	6.986	15	45.44	0.001
Bauxite	82	0.96%	8.375	104.500	75.33	0.017
Fly Ash	25	0.29%	6.777	245.232	22.97	0.012
Mill Scale	58	0.68%	9.625	145.375	52.16	0.017
Raw Material Inputs	8,538	100%			8,266.87	0.478
Total CKD R	1,276		0.000	15.100	1,276.43	0.042
Total CKD W	428		0.000	23.625	427.57	0.022
Product and Byproduct Losses						
Coal	1,027		9.188	90.000	932.51	0.185
Coke	0				0.00	0.000
Fuel Inputs					932.51	0.185
Type I/II Raw Slurry Mix	7,998			20.375	7,998	0.359
Type I/II Clinker	4,831.00		0.000	3.175	4,831.00	0.034

TABLE 13. AVERAGE ANNUALIZED PROCESS RATE INFORMATION (ALL EVENTS)

	Table 13 All Events Production and Process Information					
Product	Average Input (tonne per day)	Average all events	Moisture %	Dry Weight Average Hg Content (PPB)	Dry Metric Tonnes/day	Average Hg LBs per day
Callanan (Kalkberg)	1518.504	20.3%	2.984	11.31	1473.186	0.0405
Coeymans	5685.020	76.0%	2.446	19.28	5545.974	0.2653
Beacraft	34.659	0.5%	6.986	14.86	32.238	0.0013
Bauxite	84.738	1.1%	7.515	100.62	78.370	0.0201
Fly Ash	98.881	1.3%	6.777	245.23	92.180	0.0563
Mill Scale	59.099	0.8%	9.124	86.98	53.707	0.0096
Raw Material Inputs	7480.901	100.0%			7275.654	0.1447
Total CKD R	1150.303		0.00	14.32		
Total CKD W	567.026		0.00	26.33	567.026	0.032906
Product and Byproduct Losses						
Coal	812.270		8.19	80.08	745.774	0.131620
Coke	34.990		8.84	19.35	31.897	0.001361
Fuel Inputs					777.671	0.132981
Type I/II Raw Slurry Mix	7349.524			22	7349.524	0.359178
Type I/II Clinker	4368.202		0.00	1.34	4368.202	0.012910

TABLE 14. ACTUAL 2008 PROCESS RATE INFORMATION

	Table 14 2008 Average Hg Concentration					
Product	**Average Input (tonne per day)**	**Average Pooled Data and 2009B Mix Design**	**Moisture %**	**Dry Weight Average Hg Content (PPB)**	**Dry Metric Tonnes/day**	**Hg LBs per day**
Callanan (Kalkberg)	1021.337	0.17	2.98	11.31	991	0.025
Coeymans	4499.685	0.76	2.45	19.28	4,390	0.186
Beacraft	91	0.02	6.99	14.86	85	0.003
Bauxite	131.718	0.02	7.51	100.62	122	0.027
Fly Ash	108.638	0.02	6.78	245.23	101	0.055
Mill Scale	84.899	0.01	9.12	86.98	77	0.015
Raw Material Inputs	5937.690	1.00			5,766	0.311
Total CKD R	878.756		0.00	14.32		
Total CKD W	352.2328767		0.00	26.33	352	0.020
Product and Byproduct Losses						
Coal	600.975		8.19	80.08	552	0.097
Coke	1.648		8.84	19.35	2	0.000
Fuel Inputs					553	0.097
Type I/II Raw Slurry Mix	5820.797			22.17	5,821	0.284
Type I/II Clinker	3522.534		0.00	1.34	3,522.53	0.010

TABLE 15. EVENT 1 MASS BALANCE COMPONENTS

Product	Hg LBs per day	lb Hg/Ton of Clinker	Percent of Inputs	Hg Lb/yr
	Table 15 Event 1 Mass Balance Components and Comparisons			
Callanan (Kalkberg) Limestone	0.029	0.000008	7.3%	13.3
Coeymans Limestone	0.220	0.000063	55.4%	101.2
Becraft Limestone	0.001	0.0000003	0.3%	0.5
Bauxite	0.009	0.0000024	2.1%	3.9
Fly Ash	0.048	0.0000136	12.0%	21.9
Mill Scale	0.002	0.0000005	0.5%	0.8
Coal	0.088	0.0000253	22.2%	40.5
Coke	0.001	0.0000004	0.3%	0.6
Raw Material and Fuel Hg Inputs	0.397	0.0001139	100.0%	182.7
Hg inputs per slurry sample results	0.275	0.0000790	69.4%	126.8
Raw Material Hg minus fuels Hg	0.308	0.0000882	77.5%	141.6
Total CKD W	0.022	0.0000062	79.7%	10.0
Type I/II Clinker	0.006	0.0000016	20.3%	2.6
Estimated Hg Stack Emissions (pound/year)				170.2
Normalized Stack Emissions at 1604815 ton per year				NA
Percent Difference				#VALUE!
Emission Factor (pound Hg / ton of Clinker)				0.000134

TABLE 16. EVENT 2 MASS BALANCE COMPONENTS

	Table 16 Event 2 Mass Balance Components and Comparisons			
Product	Hg LBs per day	Hg/Ton of Clinker	Percent of Inputs	Hg Lb/yr
Callanan (Kalkberg) Limestone	0.03929	0.00001	0.08744	11.257
Coeymans Limestone	0.18592	0.00003	0.41374	53.268
Becraft Limestone	0.00024	0.00000	0.00054	0.069
Bauxite	0.01137	0.00000	0.02529	3.256
Fly Ash	0.08382	0.00001	0.18654	24.016
Mill Scale	0.00880	0.00000	0.01959	2.522
Coal	0.11545	0.00002	0.25692	33.078
Coke	0.00447	0.00000	0.00995	1.281
Raw Material Hg Inputs	0.44935	0.00008	1.00000	128.747
Hg inputs per slurry sample results	0.48665	0.00009	1.08300	139.432
Raw Material Hg minus fuels Hg	0.32944	0.00006	0.73313	94.388
Total CKD W	0.02816	0.00001	0.85019	8.067
Type I/II Clinker	0.00496	0.00000	0.14981	1.421
Estimated Hg Stack Emissions (pound/year)				119.258
Normalized Stack Emissions at 1604815 ton per year				182.500
Percent Difference				34.65%
Emission Factor (pound Hg / ton of Clinker)				0.00011

TABLE 17. EVENT 3 MASS BALANCE COMPONENTS

	Table 17 Event 3 Mass Balance Components and Comparisons			
Product	**Hg LBs per day**	**Hg/Ton of Clinker**	**Percent of Inputs**	**Hg Lb/yr**
Callanan (Kalkberg) Limestone	0.0226	0.0000051	5.2%	8.241
Coeymans Limestone	0.1714	0.0000390	39.6%	62.592
Becraft Limestone	0.0017	0.0000004	0.4%	0.613
Bauxite	0.0345	0.0000079	8.0%	12.600
Fly Ash	0.0555	0.0000126	12.8%	20.281
Mill Scale	0.0096	0.0000022	2.2%	3.494
Coal	0.1375	0.0000313	31.8%	50.187
Coke	0.0000	0.0000000	0.0%	0.000
Hg inputs per Raw Material and Fuel	0.4328	0.0000985	100.0%	158.008
Hg inputs per slurry sample results	0.3128	0.0000712	72.3%	114.203
Raw Material Hg minus fuels Hg	0.2953	0.0000672	68.2%	107.821
Total CKD W	0.0639	0.0000145	87.4%	23.323
Type I/II Clinker	0.0092	0.0000021	12.6%	3.360
Estimated Hg Stack Emissions (pound/year)				131.325
Normalized Stack Emissions at 1604815 ton per year				196.339
Percent Difference between Raw materials and fuel minus CKD and Normalized stack emissions				33.11%
Emission Factor (pound Hg / ton of Clinker)				0.00011

TABLE 18. EVENT 4 MASS BALANCE COMPONENTS

Table 18 Event 4 Mass Balance Components and Comparisons				
Product	Hg LBs per day	Hg/Ton of Clinker	Percent of Inputs	Hg Lb/yr
Callanan (Kalkberg) Limestone	0.058013	0.000011	0.0875	17.49
Coeymans Limestone	0.372382	0.000070	0.5614	112.25
Becraft Limestone	0.001488	0.00000028	0.0022	0.45
Bauxite	0.017350	0.000003	0.0262	5.23
Fly Ash	0.012417	0.000002	0.0187	3.74
Mill Scale	0.016712	0.000003	0.0252	5.04
Coal	0.184974	0.000035	0.2789	55.76
Coke	0.000000	0.000000	0.0000	0.00
Hg Input via Raw Material and Fuel Hg Inputs	0.6633	0.000125	1.0000	199.96
Hg inputs per slurry sample results	0.3592	0.000067	0.5415	108.27
Raw Material Hg minus fuels Hg	0.4784	0.000090	0.7211	144.20
Total CKD W	0.0223	0.000004	0.3971	6.71
Type I/II Clinker	0.0338	0.000006	0.6029	10.19
Estimated Hg Stack Emissions (pound/year)				183.06
Normalized Stack Emissions at 1604815 ton per year				162.17
Percent Difference				-12.88%
Emission Factor (pound Hg / ton of Clinker)				0.0000835

TABLE 19. ALL EVENT MASS BALANCE COMPONENTS (ALL EVENTS)

	Table 19 All Event Mass Balance Components			
Product	**Hg LBs per day**	**Hg/Ton of Clinke**	**Percent of Inputs**	**Hg Lb/yr**
Callanan (Kalkberg)	0.04052770	0.00000783	7.51%	12.57
Coeymans	0.26534307	0.00005130	49.19%	82.32
Beacraft	0.00130097	0.00000025	0.24%	0.40
All Limestone	0.30717174	0.00005938	0.56941688	95.30
Bauxite	0.02014950	0.00000390	3.74%	6.25
Fly Ash	0.05633065	0.00001089	10.44%	17.48
Mill Scale	0.00958570	0.00000185	1.78%	2.97
Coal	0.14467963	0.00002797	26.82%	44.89
Coke	0.00153244	0.00000030	0.28%	0.48
Raw Material Hg Inputs	0.53944967	0.00010429	156.94%	167.36
Hg inputs per slurry sample results	0.39379206	0.00007613	73.0%	122.17
Raw Material Hg minus fuels Hg	0.39323759	0.00007602	72.9%	122.00
Total CKD W	0.03876108	0.00000749	73%	12.03
Type I/II Clinker	0.01412309	0.00000273	27%	4.38
Estimated Hg Stack Emissions (pound/year)				150.96
Normalized Stack Emissions at 1604815 ton per year				180.34
Percent Difference				19.5%
Emission Factor (pound Hg / ton of Clinker)				0.00011049

TABLE 20. 2008 MASS BALANCE COMPONENTS

	Table 20 Actual 2008 Mass Balance			
Product	**Hg LBs per day**	**Hg/Ton of Clinker**	**Percent of Inputs**	**Hg Lb/yr**
Callanan (Kalkberg)	0.025	0.000006	6.05%	9.01
Coeymans	0.186	0.000048	45.71%	68.07
Beacraft	0.003	0.000001	0.68%	1.02
Bauxite	0.027	0.000007	6.62%	9.86
Fly Ash	0.0547	0.000014	13.42%	19.98
Mill Scale	0.0148	0.000004	3.63%	5.40
Coal	0.0974	0.000025	23.87%	35.54
Coke	0.00006	0.00000002	0.02%	0.02
Raw Material Hg Inputs	0.41	0.000105	100.00%	148.90
Hg inputs per slurry sample results	0.284	0.000073	69.73%	103.83
Raw Material Hg minus fuels Hg	0.311	0.000080	76.11%	113.34
Total CKD W	0.0204	0.00000527	66.26%	7.46
Type I/II Clinker	0.0104	0.00000268	33.74%	3.80
Estimated Hg Stack Emissions Using Raw Materials (pound/year)				138.68
Stack Emissions at 1285725 tonne (1416868.95 ton) per year				159.2154
Percent Difference				12.90%
Emission Factor (pound Hg / ton of Clinker)				0.0001124

SECTION 6

SUMMARY OF STACK SAMPLING EFFORTS

Air Control Techniques, P.C. measured stack gas Hg concentrations. The objective of the test program was to determine the elemental, oxidized, particle-bound, and total Hg emissions. Stack testing was conducted on June 26, September 25, November 3, and, November 4, 2008. The test program included U.S. EPA Reference Test Methods 1, 2, 3, 4, and ASTM Method D 6784-02 (Ontario Hydro Method) to quantify the Hg emissions. The measured Hg emissions are summarized in Tables 21, 22, and 23. Copies of the complete stack testing reports are included in Appendix C. It should be noted that the clinker rates shown on the bottom of Tables 21 through 24 were used to produce the emission factors used to develop the pound per year emitted from the stack.

TABLE 21. EVENT 2 MERCURY EMISSIONS - KILNS #1 & # 2 COMMON EXHAUST STACK

Event 2 Mercury Emissions - Kilns #1 & # 2 Common Exhaust Stack Test Program Conducted: June 26, 2008				
	Run Number			
Parameter	OH-1	OH-2	OH-3	Average
Test date	6/26/2008	6/26/2008	6/26/2008	N/A
Test time (Eastern Daylight Time)	0755-1011	1027-1242	1251-1509	N/A
Mercury Emissions (mg/Nm^3)				
Elemental	16.9900	20.2500	19.4500	18.8900
Oxidized	0.1790	0.1890	0.2310	0.2000
Particle-Bound	0.0210	<0.014	0.0130	<0.016
Total	17.2000	20.4000	19.6800	19.0900
Mercury Emissions (mg/Nm^3 @ 7% O_2)				
Elemental	16.2800	19.5500	18.6400	18.1600
Oxidized	0.1720	0.1830	0.2210	0.1920
Particle-Bound	0.0200	<0.014	0.0130	<0.015
Total	16.4800	19.6900	18.8700	18.3500
Mercury Emissions (g/hour)				
Elemental	10.8200	12.4700	12.3100	11.8700
Oxidized	0.1140	0.1170	0.1460	0.1260
Particle-Bound	0.0130	<0.009	0.0080	<0.010
Total	10.9500	12.5600	12.4600	11.9900
Total Mercury Emissions				
Pounds per hour	0.0241	0.0277	0.0275	0.0264
Pounds per year[1]	152.2277	174.9671	173.7038	166.9662
Pounds per ton of clinker	0.0001045	0.0001166	0.0001201	0.0001137
Volumetric flue gas rate, DSCFM	374822.0000	362408.0000	372643.0000	369958.0000
Volumetric flue gas rate, DNm^3/minute	10614.0000	10262.0000	10552.0000	10476.0000
Stack temperature, °F	457.5000	457.1000	454.7000	456.4000
Stack temperature, °C	236.4000	236.1000	234.8000	235.8000
Clinker Production, tons per hour	234.5000	234.6000	234.4000	234.5000
Revised Clinker Production, tons per hour	230.6200	237.6400	228.9800	232.4133

[1] Based on 6,316.5 operating hours

TABLE 22. EVENT 3 MERCURY EMISSIONS - KILNS #1 & # 2 COMMON EXHAUST STACK

Event 3 Mercury Emissions – Kilns #1 & # 2 Common Exhaust Stack Test Program Conducted: September 25, 2008				
	Run Number			
Parameter	OH-4	OH-5	OH-6	Average
Test date	9/25/2008	9/25/2008	9/25/2008	N/A
Test time (Eastern Daylight Time)	0739-0954	1002-1218	1227-1442	N/A
Mercury Emissions (mg/Nm^3)				
Elemental	16.9400	19.9300	18.2300	18.3700
Oxidized	0.1930	0.3200	0.4590	0.3240
Particle-Bound	<0.009	<0.010	<0.010	<0.009
Total	17.1000	20.2700	18.6600	18.6800
Mercury Emissions (mg/Nm^3 @ 7% O_2)				
Elemental	17.1900	20.2200	18.2300	18.5500
Oxidized	0.1960	0.3250	0.4590	0.3270
Particle-Bound	<0.009	<0.010	<0.010	<0.010
Total	17.3500	20.5700	18.6600	18.8600
Mercury Emissions (g/hour)				
Elemental	11.6200	13.0500	12.1000	12.2600
Oxidized	0.1330	0.2100	0.3040	0.2160
Particle-Bound	<0.006	<0.006	<0.006	<0.006
Total	11.7300	13.2700	12.3800	12.4600
Total Mercury Emissions				
Pounds per hour	0.0259	0.0293	0.0273	0.0275
Pounds per year[1]	163.5974	185.0735	172.4405	173.7038
Pounds per ton of clinker	0.0001170	0.0001290	0.0001208	0.0001223
Volumetric flue gas rate, DSCFM	403797.0000	385265.0000	390495.0000	393186.0000
Volumetric flue gas rate, DNm^3/minute	11434.0000	10910.0000	11058.0000	11134.0000
Stack temperature, °F	446.6000	448.6000	453.8000	449.7000
Stack temperature, °C	230.3000	231.4000	234.3000	232.0000
Clinker Production, tons per hour	220.6000	222.1000	219.2000	220.6000
Revised Clinker Production, tons per hour	221.3300	227.0600	225.9400	224.7767

[1] Based on 6,316.5 operating hours

TABLE 23. EVENT 4 MERCURY EMISSIONS - KILNS #1 & # 2 COMMON EXHAUST STACK

Event 4 Mercury Emissions - Kilns #1 & # 2 Common Exhaust Stack Test Program Conducted: November 3-4, 2008				
	Run Number			
Parameter	OH-7	OH-8	OH-9	Average
Test date	11/3/2008	11/4/2008	11/4/2008	N/A
Test time (Eastern Standard Time)	1641-1854	0814-1049	1106-1322	N/A
Mercury Emissions (mg/Nm^3)				
Elemental	14.3500	14.3100	15.2600	14.6400
Oxidized	0.1650	0.1490	0.2170	0.1770
Particle-Bound	<0.006	0.0110	0.0130	<0.010
Total	14.5200	14.4700	15.4500	14.8100
Mercury Emissions (mg/Nm^3 @ 7% O_2)				
Elemental	14.9900	14.7400	15.6000	15.1100
Oxidized	0.1730	0.1530	0.2220	0.1830
Particle-Bound	<0.007	0.0110	0.0140	<0.011
Total	15.1700	14.9000	15.7900	15.2900
Mercury Emissions (g/hour)				
Elemental	9.9700	9.5700	10.4600	10.0000
Oxidized	0.1150	0.1000	0.1490	0.1210
Particle-Bound	<0.004	0.0070	0.0090	<0.007
Total	10.0900	9.6700	10.5800	10.1200
Total Mercury Emissions				
Pounds per hour	0.0222	0.0213	0.0233	0.0223
Pounds per year[1]	140.2263	134.5415	147.1745	140.6474
Pounds per ton of clinker	0.0001021	0.0000974	0.0001031	0.0001010
Volumetric flue gas rate, DSCFM	409132.0000	393451.0000	403220.0000	401934.0000
Volumetric flue gas rate, DNm^3/minute	11585.0000	11141.0000	11418.0000	11382.0000
Stack temperature, °F	447.1000	444.6000	448.7000	446.8000
Stack temperature, °C	230.6000	229.2000	231.5000	230.4000
Clinker Production, tons per hour	219.8000	216.4000	216.1000	217.4000
Revised Clinker Production, tons per hour	217.3700	218.7400	225.9400	220.6833

[1] Based on 6,316.5 operating hours

TABLE 24. ALL EVENT STACK TESTING AVERAGES

All Event Mercury Emissions - Kilns #1 & # 2 Common Exhaust Stack Test Program Conducted: June 26 through November 4, 2008				
	Composite Run Number			
Parameter	1	2	3	Average
Test date	Various	Various	Various	N/A
Test time (Eastern Standard Time)	Various	Various	Various	N/A
Mercury Emissions (mg/Nm^3)				
Elemental	16.0933	18.1633	17.6467	17.3011
Oxidized	0.1790	0.2193	0.3023	0.2336
Particle-Bound	0.0210	0.0110	0.0130	0.0150
Total	16.2733	18.3800	17.9300	17.5278
Mercury Emissions (mg/Nm^3 @ 7% O_2)				
Elemental	16.1533	18.1700	17.4900	17.2711
Oxidized	0.1803	0.2203	0.3007	0.2338
Particle-Bound	0.0200	0.0110	0.0135	0.0148
Total	16.3333	18.3867	17.7733	17.4978
Mercury Emissions (g/hour)				
Elemental	10.8033	11.6967	11.6233	11.3744
Oxidized	0.1207	0.1423	0.1997	0.1542
Particle-Bound	0.0130	0.0070	0.0085	0.0095
Total	10.9233	11.8333	11.8067	11.5211
Total Mercury Emissions				
Pounds per hour	0.0241	0.0261	0.0260	0.0254
Pounds per year[1]	152.0353	164.5139	164.4049	160.3180
Pounds per ton of clinker	0.0001079	0.0001143	0.0001147	0.0001123
Volumetric flue gas rate, DSCFM	395917.0000	380374.6667	388786.0000	388359.2222
Volumetric flue gas rate, DNm^3/minute	11211.0000	10771.0000	11009.3333	10997.1111
Stack temperature, °F	450.4000	450.1000	452.4000	450.9667
Stack temperature, °C	232.4333	232.2333	233.5333	232.7333
Clinker Production, tons per hour	224.9667	224.3667	223.2333	224.1889
Revised Clinker Production, tons per hour	223.1067	227.8133	226.9533	225.9578

[1] Based on 6,316.5 operating hours

CONCLUSIONS

The annual average Hg emission rate is estimated to be between 151 and 180 pounds per year when the production rate is 1,604,815 tons of clinker per year. The difference between the annual average Hg emission rates as determined via stack testing methodologies and the calculated annual average mass balance Hg emission rate is 29 pounds of Hg or approximately 19.5 percent. The difference is largely attributed to test method variability, concentration flux (change over time), variable processing rates, and timing issues. The concentration in the bulk materials was determined on a daily basis where as the stack test sampling was conducted during 9 separate two hour periods. For example, the difference between Event 2 runs 1 and 2 of the stack test was 22.7 pounds per year or 13 percent of the annual total. The cumulative variance between the first runs of each event and average of all events is less than 5.2 percent. The cumulative variance between the second runs of each event and the average of all events is less than 2.8 percent. The cumulative difference between runs 3 and the average of all events is less than 2.5 percent. The difference between the average Hg emission rates for the three stack test is less than 5 percent of the annual total. We also note that the daily clinker production rate varied from a low of 3819 tons per day to high of 4022 tons per day. On average Hg derived from fly ash is only 10.4 percent of that input and any mix design changes that include substitutes for fly ash (e.g., more bauxite, different Kalkberg/Coeymans limestone ratio, less mill scale, etc.) would still contain Hg. On average, limestone accounts for 56.94 percent and fuel accounts for 27.1 percent of the Hg inputs.

The major pathways by which Hg leaves the cement kiln system are stack emissions and CKD. Although Hg has been measured in the clinker, the Hg measurement was near the method detection limit. The annualized amount of Hg in the clinker is less than 4.38 pounds.

CKD is removed from the combustion gas via ESPs. The wasted CKD is collected in the rear chambers of the ESPs and constant speed screws remove the CKD from the ESP. The amount of CKD reaching the last two fields is a function of combustion gas velocity, particle size, particle weight, and alkali metal content of the mix. Each of these parameters may change as a function of the mix design and burnability of the mix. Seventy – one percent of the CKD was recycled back to the kilns. The annual average amount of Hg being recycled in the kiln system is approximately 7.8 pounds. The annual average amount of Hg being disposed or otherwise used as a component of the CKD that is removed from the Kiln system is approximately 12.03 pounds. Figure 13 compares the estimated annual mercury emission rate as determined using the mass balance techniques and the stack test derived emission factors.

The information gathered during this study suggests that Hg emissions are not correlated to inlet temperature of the ESP. Average inlet temperatures to the ESPs during the stack testing events ranged from 506 to 516 degrees Fahrenheit. The range of temperatures was 493 to 536 degrees Fahrenheit. The linear regression correlation coefficient (R^2) was calculated to be 0.0016. Other regression and correlation techniques (e.g., exponential, logarithmic and polynomial) had lower coefficients. R^2 values equal to ± 1 implies a perfect correlation between the data sets.

The average speciated Hg emission rate is 98.7 percent elemental Hg. Elemental Hg is highly volatile and insoluble in water and therefore not easily captured by ESP, baghouse and/or wet scrubber technologies. EPA [4] has indicated that elemental Hg oxidizes slowly under atmospheric conditions, and it becomes part of the global Hg cycle. Under these conditions localized depositional impacts are minimal.

The Plant's stack gas Hg concentrations are lower that all of the international standards known to Lafarge. Table 25 displays the international standards for various countries.

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[4] Human Health Risk Assessment Protocol EPA530-R-05-006 September 2005 Chapter 2: Facility Characterization – The Mercury Global Cycle

Figure 13. Comparison of Mercury Emissions

Hg Emissions using Mass Balance Technique and Raw Materials,

		Clinker Rate (ton per year) for Normalization		
		1,604,815.05		
	Emissions factor (lb ton of Clinker) based on ingredients, CKD, and fuel	Annual Mercury Emission Rate	Variance compared to Mass Balance via Slurry	Variance Compared to Normalized Stack Test
All Event Average	0.00009407	150.9569	-3.02%	-19.46%

Hg Emissions using Mass Balance technique and Slurry, CKD, Clinker and Fuel

		Clinker Rate (ton per year) for Normalization	
		1,604,815.05	
	Emissions factor (lb ton of Clinker) based on slurry, CKD and fuel	Annual Mercury Emission Rate	Variance Compared to Normalized Stack Test
All Event Average	0.000096903	155.51	-15.96%

HG Emissions via Stack Test Derived Emission

		Average Clinker Rate During Testing (ton per year)	Clinker Rate Event 1 (ton/year)	Clinker Rate Event 2 (ton/year)	Clinker Rate Event 3 (ton/year)	Normalizing Clinker Rate (ton/year)
		1,427,262.30	1,468,038.82	1,419,801.82	1,393,946.28	1,604,815.05
	Emission Factor per stack testing (lb/ton of Clinker)	Annual Average Mercury Emission Rate via Stack Testing Results	Normalized Annual Mercury Emission Rate			
All Event Average	0.00011237	160.50	180.34			

TABLE 25. MERCURY LIMITS FOR VARIOUS COUNTRIES

MERCURY EMISSION LIMITS FOR CEMENT PLANTS IN VARIOUS COUNTRIES [A]					11/14/2008
Country/Locality	Local Limit	Local Units[1] & O2 Correction	Measured Emission or Regulatory Limit as US Std [2] ug/dscm @ 7% O2	Averaging Period	Notes
Ravena Event 2		$\mu g/Nm^3$ @ 7% O_2	14	1-hour	2
Ravena Event 3			18	1-hour	2
Ravena Event 4			17	1-hour	2
Ravena All			16	1-hour	2
USA, applicable to new cement plants constructed after December 20, 2006. Thre is no applicable standard for existing cement plants.	41	ug/dscm @ 7% O2	41	1-hour	
Germany	0.03	mg/Nm3 @ 11% O2	39	8-hour	
Austria	0.05	mg/Nm3 @ 10% O2	59	0.5-hour	
Germany	0.05	mg/Nm3 @ 11% O2	65	0.5-hour	
Mexico	0.07	mg/Nm3	83		6
Ecuador	0.1	mg/Nm3 @ 7% O2	93		
Chile	0.1	mg/Nm3 @ 10% O2	119		
Turkey	0.1	mg/Nm3 @ 10% O2	119	0.5-hour	
Korea	0.1	mg/Nm3 @ 13% O2	164		
Netherlands	0.15	mg/Nm3 @ 10% O2	178	0.5-hour	4
Canada	0.15	mg/Rm3 @ 11% O2	214		3,4
Bangladesh	0.2	mg/Nm3	238		6
Belgium	0.2	mg/Nm3 @ 10% O2	238	0.5-hour	4
France	0.2	mg/Nm3 @ 10% O2	238	0.5-hour	4
Hungary	0.2	mg/Nm3 @ 10% O2	238	0.5-hour	4
India	0.2	mg/Nm3	238		6
Italy	0.2	mg/Nm3 @ 10% O2	238	0.5-hour	4
Portugal	0.2	mg/Nm3 @ 10% O2	238	0.5-hour	5
Romania	0.2	mg/Nm3 @ 10% O2	238	0.5-hour	4
Slovenia	0.2	mg/Nm3 @ 10% O2	238	0.5-hour	4
Switzerland	0.2	mg/Nm3 @ 10% O2	238	0.5-hour	4
Brazil	0.2	mg/Nm3 @ 11% O2	262		4
Indonesia	5	mg/Nm3 @ 7% O2	4,659		
Philippines	5	mg/Nm3	5,941		6
Malaysia	10	mg/Nm3 @ 12% O2	14,552		

Notes:

[A] For comparison purposes this table does not include standards applicable to cement plants that burn hazardous waste

[1]Normal reference temperature (metric convention) is 0 degrees Celcius

[2]Standard reference temperature (USEPA convention) is 68 degrees Fahrenheit

[3]Canada reference temperature is 25 degrees Celcius

[4]Limit is the sum of Hg, Cd, and Tl emissions

[5]Limit is the sum of Hg and Cd emissions

[6]Oxygen correction not specified (normalized limits may vary)