# LEACHING CHARACTERISTICS OF FLY ASH–ACTIVATED CARBON FROM MERCURY CONTROL TECHNOLOGIES

**Final Report**

*Prepared for:*

Mr. Jim Stieritz

Cinergy
Room 552 Annex
139 East Fourth Street
Cincinnati, OH 45202

*Prepared by:*

Debra F. Pflughoeft-Hassett

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202-9018

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## INTRODUCTION

When coal is consumed to generate electricity, coal combustion by-products (CCBs), such as fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) material are inevitably formed. CCBs have been the subject of numerous characterization, research, development, demonstration, and commercialization efforts. It has been well documented that CCBs contain trace elements in varying concentrations, including mercury and other air-toxic elements. Proposed regulation of mercury emissions from coal-fired power plants has led to emission control technologies designed specifically to reduce mercury emissions associated with coal combustion. These emerging technologies have a significant potential to impact the concentrations of mercury in CCBs.

Mercury emission-control technologies will be installed on many U.S. coal-fired power plants in the future. When mercury is removed from the flue gas by activated carbon injection, captured mercury will be associated with the activated carbon. The activated carbon used for mercury removal is expected to be normal, sulfur-impregnated, or halogenated. This report focuses on fly ash–activated carbon mixtures collected at various demonstrations of mercury emission control technologies. Cinergy will generate this material at the power plant where installation of mercury emission controls is planned.

To assess the stability of mercury present in fly ash-activated carbon mixtures, two primary leaching methods were used. The report includes summaries of these methods, the samples evaluated, and the leaching data assembled to date.

## METHODOLOGY

### Description of Leaching Tests

The TCLP (toxicity characteristic leaching procedure) (EPA, 1992) is frequently applied to CCBs. The TCLP uses a 20:1 liquid-to-solid (L/S) ratio (mass/mass, m/m), and rotating the mixture for 18 ± 2 hr at 30 rpm. The Environmental Protection Agency (EPA) now recognizes that the TCLP is an inappropriate test for use with CCBs.

The SGLP–LTL (synthetic groundwater leaching procedure–long-term leaching) is a procedure developed at the EERC (Hassett, 1998). The SGLP–LTL was designed to use a synthetic groundwater or distilled deionized water for the leaching solution to more closely simulate environmental conditions, and to include longer-term leaching time frames for reactive CCBs. The complete SGLP–LTL usually includes leaching times of 18 hours, 30 days, and 60 days. However, LTL is only necessary for alkaline samples (pH >10), because CCB samples with pH values below 10 do not undergo long-term hydration reactions that impact leachate characteristics.

It is important to note that when distilled, deionized water is used as the leaching solution in the 18-hour SGLP leaching test, that test is equivalent to American Society for Testing and Materials (ASTM) D3987 Standard Test Method for Shake Extraction of Solid Waste with Water (ASTM, 2004). The SGLP with distilled, deionized water uses the same 18-hour time frame, 20:1 L/S ratio, and end-over-end agitation at approximately 30 rpm. In this report, the results are reported as SGLP–LTL because several of the CCB samples evaluated required the long-term leaching time frames, but the first data set in the series is equivalent to the ASTM D3987.

## SAMPLES

The sample set for which leaching data are presented is a subset of the samples collected and evaluated under an EERC project that examined the release of mercury from CCBs. Table 1 summarizes the types of fly ash samples that the EERC has assembled for evaluating mercury releases. These include samples of typical fly ash from full-scale and demonstration facilities firing various U.S. coals and using standard combustion technologies and particulate collection devices. Most samples for the overall project have been collected from typical PCDs during operation without and with mercury emission controls in place, and a small number have been collected from post-PCD systems specially designed for mercury emission reduction. The samples for which data has been included in this report (see Table 2) were limited to samples of fly ash–activated carbon from demonstrations of mercury emission controls that utilize activated carbon for mercury removal. Table 2 includes the source of coal, the particulate collection device, the pH, total concentration of mercury, and leachate concentrations of mercury using the TCLP and SGLP-LTL tests.

**Table 1. Summary of Complete Project Fly Ash Sample Set**

| Sample Type | No. of Samples | Total Hg Range, µg/g | pH Range |
|---|---|---|---|
| Fly Ash (no Hg control) | 40 | 0.005–2.03 | 4.15–13.00 |
| Fly Ash–Activated Carbon (Hg control, collected in primary PCD) | 22 | 0.147–5.8 | 8.44–12.64 |
| Activated Carbon–Fly Ash (Hg control, collected after primary PCD) | 5 | 17.7–120 | 3.54–9.43 |

**Table 2. Summary of Leaching Data on Samples of Fly Ash–Activated Carbon**

| ID No. | Coal Type | Particulate Collection | Sample pH | Hg, µg/g | TCLP Hg, µg/L | SGLP (ASTM D3987) Hg, µg/L | LTL 30-day Hg, µg/L | LTL 60-day Hg, µg/L |
|---|---|---|---|---|---|---|---|---|
| 02-004 | PRB[a] sub.[b] | ESP-CS[c] | 11.47 | 5.50 | <0.01 | <0.01 | <0.01 | <0.01 |
| 02-005 | PRB sub. | ESP-CS | 10.65 | 4.73 | <0.01 | <0.01 | <0.01 | <0.01 |
| 02-069 | Low-S e. bit.[d] | ESP-CS | 8.94 | 0.526 | 0.07 | 0.03 | | |
| 02-071 | Low-S e. bit. | ESP-CS | 9.59 | 0.595 | <0.01 | 0.01 | | |
| 02-076 | Low-S e. bit. | ESP-CS | 9.93 | 0.400 | <0.01 | 0.02 | | |
| 03-009 | Low-S e. bit | ESP-CS | 11.79 | 0.198 | <0.01 | <0.01 | | |
| 03-010 | Low-S e. bit. | ESP-CS | 10.34 | 0.371 | <0.01 | <0.01 | | |
| 03-011 | | | 8.44 | 0.618 | 0.14 | <0.01 | | |
| 03-012 | | | 11.58 | 1.09 | <0.01 | <0.01 | | |
| 03-013 | | | 10.39 | 0.362 | <0.01 | <0.01 | | |
| 03-014 | | | 9.95 | 1.21 | <0.01 | 0.02 | | |
| 03-015 | | | 10.52 | | <0.01 | <0.01 | | |
| 03-017 | ND lignite | ESP-CS | 12.57 | 0.225 | | | | |
| 03-018 | ND lignite | ESP-CS | 12.57 | 0.289 | | | | |
| 03-019 | ND lignite | ESP-CS | 11.74 | 2.22 | | | | |
| 03-060 | Sub/TDF[e] | AHPC[f] | 11.32 | 1.86 | | <0.01 | <0.01 | <0.01 |
| 03-062 | ND lignite | ESP-CS | 12.57 | 0.490 | | <0.01 | <0.01 | <0.01 |
| 04-030 | ND lignite | ESP-CS | 11.51 | 0.147 | | <0.01 | <0.01 | <0.01 |
| 04-031 | ND lignite | ESP-CS | 11.60 | 0.174 | | 0.01 | <0.01 | 0.03 |
| 04-033 | ND lignite | ESP-CS | 10.70 | 1.43 | | <0.01 | <0.01 | <0.01 |
| 04-036 | ND lignite | ESP-CS | 12.64 | 0.287 | | 0.02 | <0.01 | <0.01 |

[a] Powder River Basin
[b] Subbituminous
[c] Electrostatic precipitator–cold side
[d] Eastern bituminous
[e] Tire-derived fuel
[f] Advanced Hybrid particulate collector

## LEACHING RESULTS

Direct leaching of components present in CCBs frequently is used to evaluate appropriate management options for these materials. The evaluation of mercury release from CCBs by leaching is ongoing at the EERC, and some data have not yet been collected. Leaching data for mercury from 12 samples of fly ash–activated carbon using both the TCLP and SGLP (ASTM D3987) short-term leaching tests are included in Table 2. Table 2 also summarizes leachate data from the SGLP–LTL tests applied to fly ash–activated carbon samples exhibiting pH > 10 (eight samples). For all leaching procedures the majority of the results are below the reporting limit of 0.01 µg/L. As noted by Kim (2004), the national Primary Drinking Water (PDW) limit for mercury is 2.0 µg/L, and even the highest leachate concentration reported here (0.14 µg/L) is more than an order of magnitude less than the PDW limit for mercury.

These preliminary data do not allow a direct comparison of total mercury concentrations or leachability from pre- and post-mercury control samples from a given site, but as shown in Table 1, the total mercury content of fly ash (with no Hg control) and fly ash–activated carbon (with mercury control) can fall into the same concentration range. The highest total mercury concentrations for the fly ash–activated carbon are only approximately 2 times higher than those in fly ash alone.

Figure 1 shows a comparison of the total mercury concentrations versus the leachate concentrations. Data presented in the tables and figures show that leachate mercury concentrations are extremely low regardless of the total mercury content of the sample. Only 10 of 40 leachates exhibited mercury concentrations greater than or equal to the reporting limit of 0.01 µg/L, and all of the leachate concentrations fell well below the PDW limit of 2.0 µg/L for mercury. Pflughoeft-Hassett et al. (2004) and Kim (2004) both reported the lack of correlation between the total mercury concentration and leachable mercury at the DOE–NETL Mercury Control Technology R&D Program Review.

## SUMMARY

The data included in this report are presented with the pH of the sample as a key component of data tables. Fly ash that Cinergy is likely to generate using eastern bituminous coal is expected to have a pH of 8–10. Based on the limited data available, the EERC concludes the following:

- Total mercury concentrations in fly ash–activated carbon samples are often only slightly elevated over fly ash obtained with no mercury controls in use.

- Leachate mercury concentrations have been found to be extremely low regardless of the total mercury content of the sample. Most leachates exhibited mercury concentrations less than the LLQ of 0.01 µg/L. All leachate concentrations fell well below the PDW limit of 2.0 µg/L for mercury as well as the limit at 30× PDW (60 µg/L) and 100× PDW (200 µg/L). Even the highest leachate concentration reported here (0.14 µg/L) is more than an order of magnitude less than the PDW limit for mercury.

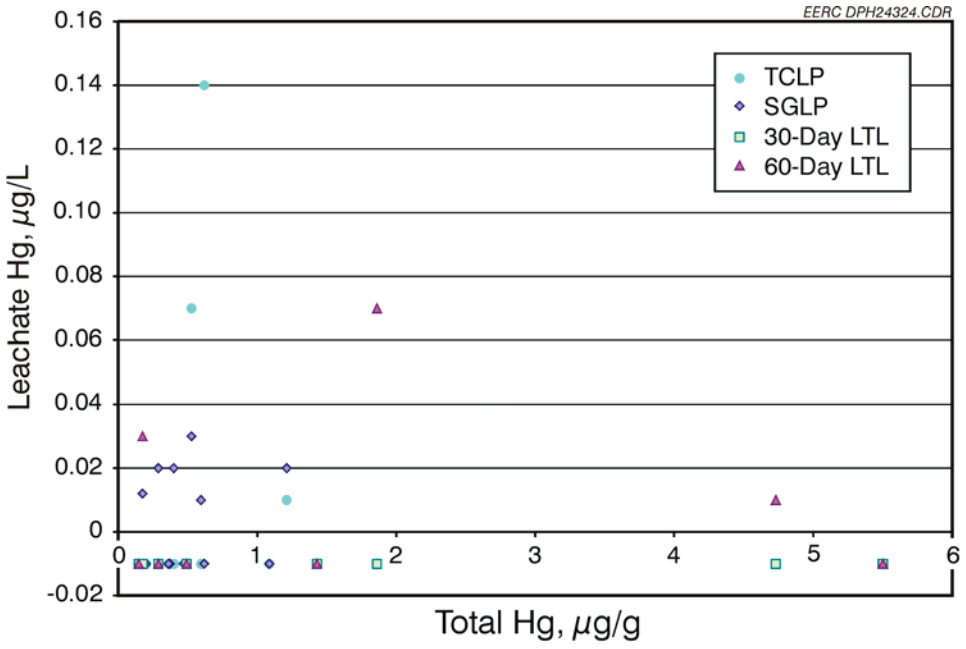


Figure 1. Comparison of total mercury concentrations and leachate concentrations.

- Mercury leachate concentrations are equivalent for short- and long-term leaching procedures and usually similar for TCLP and SGLP (ASTM D3987).

- Total and leachate mercury concentrations reported here are consistent with work reported by DOE–NETL (Kim, 2004).

## REFERENCES

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