AIRBORNE MERCURY-SAMPLING METHOD DEVELOPMENT

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Project Description

This project is evaluating the effectiveness of using high-altitude weather balloons to sample airborne Hg. The Clean Air Act Amendments of 1990 require the U.S. Environmental Protection Agency (EPA) to examine the potential risks associated with Hg emissions from all air pollution sources in the United States. EPA information collection request data estimate U.S. coal-fired electric utility boilers emit 48 tons (43,584 kg) of Hg and constitute the largest anthropogenic source of Hg emissions in the country. Balloon-based sampling techniques are potentially low-cost alternatives to better characterize Hg transformations and fate during transport downgradient from an anthropogenic source.

Goal

The project goal is to determine the potential for use of high-altitude weather balloons for sampling atmospheric Hg to determine atmospheric distribution, at altitude, downgradient from Hg emission sources.

Rationale

Sampling techniques for atmospheric measurement of Hg include fixed-wing plane sampling, which creates lateral atmospheric profiles, and ground-based samplers positioned downgradient from the source. These sampling methods do not address vertical atmospheric distribution of contaminants and are not well suited for characterizing Hg fate during downgradient transport. Weather balloon methods, while not proven, have the potential to be much more useful for performing atmospheric measurements and evaluating Hg transport reactions.

Approach

The sampling activities for this project were conducted by the High-Altitude Balloon Group at the University of North Dakota (UND). This extracurricular student group has used their past experience in balloon missions to conduct five launches for this project. Initially, it was intended to test three sampling approaches: vertical profiling, stationary sampling, and dynamic sampling, but because of flight logistics and budget and time constraints, only the vertical profiling method was used. In this approach, the balloon and its payload, including a series of gold-coated sand traps, is released to collect samples as a function of time and altitude. However, it should be noted that during one of the balloon missions, unusual atmospheric conditions were encountered that resulted in a neutral buoyancy flight (see Mission 3).

The gold-coated sand traps prepared at the EERC were blanked by heating in a mercury-free argon stream and capped just prior to each mission. The individual 8-mm-O.D. quartz tubes 10 cm long were individually capped with plug septa each with a Teflon membrane at the tube end. The capped tubes were placed into a glass jar lined with gold-plated screen to maintain a mercury-free environment. Just prior to each launch, the tubes were placed onto the manifold and uncapped. Tubes were immediately recapped after each flight, placed back into the protective jar, and analyzed by atomic fluorescence as soon as possible (within a day).

Progress

Two ground-based tests and a total of five balloon missions (including one test flight) were flown as part of this project. A summary of each follows and is shown graphically in Figure 1.

Altitude Chamber/Cold-Weather Testing

Prior to project missions, two separate ground-based tests were performed to determine if sampling pump flow rates would vary under the extreme conditions present at high altitudes. The first test involved the operation of the sample pump for extended periods, 3 to 6 hours, at !26°C (!15°F). The flow rate remained stable throughout this test. The pump was then placed in the high-altitude test chamber located at the UND Aerospace center. Conditions inside the chamber were set to simulate a rise to 10,000 feet (msl) then drop to ground level, followed by a rise to 80,000 feet (msl) and again lowered to ground level. Again,

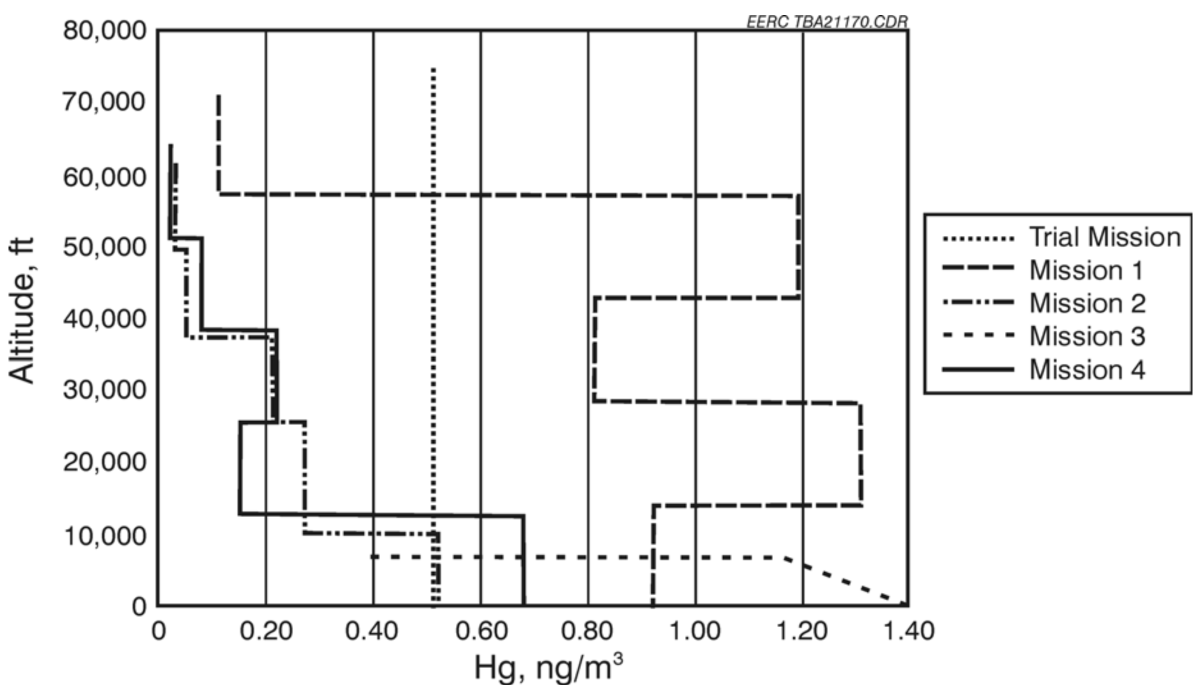

Figure 1. Atmospheric Mercury Distribution

flow rates did not vary. This testing confirmed the suitability of the pump to measure airflow under conditions experienced at altitude and when subjected to the pressure extremes imposed by a balloon flight and release.

Trial Mission

A sampling apparatus/payload was constructed to accommodate one sample port for a test launch held on August 2, 2001. The mission included a 1-hour rise time and a one-half hour decent time, attaining a maximum altitude of 75,400 feet. The pump was allowed to run for the entire flight in an effort to test the sampling apparatus.

The resulting bulk sample contained 0.510 pg of Hg/L from a total volume sampled (at STP) of 564.3 L air. This is slightly lower than expected as ambient values are typically about 2 ng/m^3, but was most likely caused by a poor connection between the sand trap and the sample port. This connection was modified for future missions.

Mission 1

A five-port sampler was constructed to sample Hg as a function of time and altitude. A 1-hour rise time was selected with each port remaining open for 12 minutes. Flow rates were set at 3 L per minute for a total sample volume of 36 L per trap. The rise rate was approximately 1200 feet per minute with a maximum altitude of 71,066 feet. Flight time was 60 minutes over northern Minnesota. Results are summarized in Table 1.

Table 1. Mission 1 Results

Trap	Altitude, ft	pg Hg (total)	Hg, ng/m^3
1	0–14,400	33	0.92
2	14,401–28,800	47	1.31
3	28,801–43,200	29	0.81
4	43,201–57,600	43	1.19
5	57,601–71,066	4	0.11

Mission 2

During this mission, which was also over northern Minnesota, the flow rate was increased to 6 L per minute for a total sample volume of 108 L per trap. Sample volume was increased by increasing flight time (90 minutes) and open-port time (18 minutes per trap). The rise rate was slowed to approximately 700 feet per minute with a maximum altitude of 60,000 feet. Results are summarized below in Table 2.

Mission 3

The objective of this mission was to duplicate the conditions of Mission 2. The balloon rose at 700 feet per minute, as planned, but due to atmospheric anomalies, it leveled off (stratified) at 7000 feet. Therefore, Samples 2–5 were collected at this altitude. Although it was the original intention of this project to conduct a neutral buoyancy balloon flight, logistical concerns eliminated that method. However, Mission 3 provided the conditions necessary to collect samples at a constant altitude, as would be the advantage of a neutral buoyancy flight. Results are summarized below in Table 3.

Table 2. Mission 2 Results

Trap	Altitude, ft	pg Hg (total)	Hg, ng/m^3
1	0–10,263	55.71	0.52
2	10,264–25,857	29.32	0.27
3	25,858–37,341	22.56	0.21
4	37,342–49,617	5.87	0.05
5	49,618–61,675	2.95	0.03

Table 3. Mission 3 Results

Trap	Altitude, ft	pg Hg (total)	Hg, ng/m^3
1	0–7000	151	1.4
2	7000	81	0.75
3	7000	42	0.39
4	7000	74	0.69
5	7000	126	1.17

Mission 4

Mission 4 was launched immediately next to the coal-fired steam plant located on UND campus property. It also traveled over northern Minnesota. Once launched, the balloon traveled directly through the visible plume emanating from the plant stack. Flight time was 90 minutes with an open-port time of 18 minutes. Flow rates were set at 4 L per minute for a total sample volume of 72 L per trap. The rise rate was approximately 711 feet per minute with a maximum altitude of 64,000 feet. Results are summarized below in Table 4.

Table 4. Mission 4 Results

Trap	Altitude, ft	pg Hg (total)	Hg, ng/m^3
1	0–12,800	41	0.68
2	12,801–25,600	8	0.15
3	25,601–38,400	14	0.22
4	38,401–51,200	7	0.08
5	51,201–64,000	2	0.02

The total amounts of mercury collected in each of the flights were extremely small. The lower level of quantitation of the instrument used for this research was between 1 and 3 picograms depending on conditions. A problem experienced during most of the flights is that the blank traps were contaminated and therefore were not subtracted from the total taken during the flights. The extremely low concentrations of mercury as measured at ground level are somewhat troubling but not out of range for the pristine environments where the launches took place. All of this taken into consideration does not invalidate the data however. Trends are evident for the most part, and considerable information on sampling and analyses of the traps were gained. Clearly, improvements on the manifold holding the sampling tubes, slower ascent rates, and higher pumping rates for larger air volumes would greatly enhance future efforts of this kind.

Status

The balloon flights for this project have been completed. Additional activities to conclude this project include the analyses of all data collected from the balloon missions flown and preparation of the final report.

Potential Users/Technology Transfer

The project's results will benefit atmospheric researchers as the potential for a new low-cost method to attain vertical profiles of contaminant concentrations in the atmosphere is realized. Additional testing will be required to perfect the method, but initial results are promising.

Bibliography

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