AMBIENT AIR MONITORING AT THE GEYSERS: A HISTORICAL PERSPECTIVE AND CURRENT STATUS

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ABSTRACT

The results of three ambient air monitoring programs performed downwind of The Geysers, California, are described. These studies, conducted since 1976, have monitored the declining ambient air concentrations of hydrogen sulfide (H_2S) in Lake County. During the 13 years of monitoring, geothermal power production has increased from approximately 500 to 2000 megawatts, H_2S emissions from power plants have declined from 1900 to less than 200 lb/hr, and ambient H_2S concentrations have significantly declined. Annual average concentrations of H_2S at four long-term sites have declined by a factor of 2.8, maximum H_2S concentrations have declined by a factor of 3.4, and the frequency of exceedance of the California Air Quality Standard (0.03 ppm) averaged over 1 hour has declined from an average frequency of 52 times per year to less than 1.

INTRODUCTION

Pacific Gas and Electric Company (PG&E) has been a participant in several air monitoring programs for ambient concentrations of hydrogen sulfide (H_2S) in Lake County, California. This area is predominantly downwind of The Geysers, an area producing geothermal steam used to operate power plants generating over 2000 megawatts of electricity. The Geysers is located in the Mayacamas Mountains, 90 miles north of San Francisco.

Three distinct monitoring programs have been conducted since 1976. The first program was initiated in 1976 and was conducted by SRI International. The SRI program was performed for three years and was funded by a consortium of industries. PG&E was the contract manager. Eight sites were monitored using continuous H_2S analyzers. Five of these sites were located in populated areas of Lake County (Kalm Ranch, Pine Summit, Whispering Pines, Anderson Springs, and Sawmill Flats) with two additional sites along the Lake-Sonoma County line (at the ridgeline east of The Geysers and one site west of The Geysers in Sonoma County). This network was complemented with additional meteorological measurements at each of the H_2S sites and along the ridgeline (Figure 1).

The second major program, the Geysers Air Monitoring Program (GAMP), began in August 1983 and continued until July 31, 1987. This program included continuous measurements for ambient H_2S at six sites and meteorological parameters at eleven sites (nine wind direction/speed and temperature/dew point sites and two acoustic sounder sites). H_2S was monitored at Pine Summit, Whispering Pines, Anderson Springs, Glenbrook, Hobergs, Anderson Ridge (1983-1984), and Binckley Ranch (1985-1987). GAMP was supported by a consortium of 15 power companies, steam suppliers, local air pollution control districts, the California Air Resources Board (ARB), and the California Energy Commission. The Northern Sonoma County Air Pollution Control District (NSCAPCD) was the project manager for GAMP. PG&E performed the non-criteria monitoring, H_2S monitoring at two sites, and meteorological monitoring at three sites. The consulting firm, Environmental Systems & Services (ES&S), Kelseyville, California, performed the remainder of the monitoring and issued quarterly data reports to the GAMP consortium. The Lake County Air Quality Management District (LCAQMD) and ARB performed quality assurance activities for GAMP.

The third major program, GAMP II, began on August 1, 1987, at the conclusion of GAMP. GAMP II is basically a modified extension of GAMP. Four of the GAMP H_2S monitoring sites (Whispering Pines, Anderson Springs, Glenbrook, and Pine Summit) were continued along with ridgeline meteorological monitoring at Unit 13 and Unit 17. At the beginning of 1989, the Whispering Pines site was discontinued and the Hobergs site was reactivated. This program is scheduled to continue until December 31, 1990. The monitoring performed in GAMP II is performed solely by PG&E under contract to the NSCAPCD under a similar arrangement as occurred in GAMP. The LCAQMD and ARB continue to provide QA/QC work to the GAMP II consortium.

Between the conclusion of the SRI program and the beginning of GAMP, isolated monitoring occurred at Pine Summit (NSCAPCD), Anderson Springs (LCAQMD), Whispering Pines (PG&E), and Hobergs (PG&E). Each of these sites was operated and maintained

GAMP II: PG&E again uses TECO Model 43 sulfur dioxide analyzers, retrofitted with TECO model 340 hydrogen sulfide to sulfur dioxide converters, to measure ambient H_2S concentrations at The Geysers. Hourly concentrations of H_2S are reported by PG&E to the nearest 1 ppb.

RESULTS OF THE THREE PROGRAMS

Tables 1-4 list maximum concentrations, annual averages, and the number of exceedances of the hourly Ambient Air Quality Standard (AAQS) (0.03 ppm) for 1976-88 at the four sites with the most continuous data records. These sites are Pine Summit, Anderson Springs, Whispering Pines, and Glenbrook (originally Kalm Ranch during the SRI program). Our analysis interprets 25 ppb and greater as an exceedance of the state 0.03 ppm AAQS which is consistent with NSCAPCD and LCAQMD policies.

Tables 1-4 reveal the results of aggressive reduction of H_2S emissions from power plants and steam field activities at The Geysers. From 1976 to date, electric power production capacity has increased from 500 to 2000 megawatts, a factor of 4. In addition, while power production was increasing at The Geysers, H_2S emissions were being abated from existing geothermal facilities (power plants and steam field activities). In 1976, H_2S emissions from electric power plants were estimated to be over 1900 lb/hr; in 1988, the H_2S emissions were estimated to be less than 200 lb/hr including steam field releases (Tolmasoff). Figure 2 shows the number of exceedances of the AAQS versus PG&E annual power production at The Geysers. Again, significant reductions in exceedances have occurred while electric production has increased.

Table 1

Pine Summit Data Summary

year	max. hr. conc. (ppb)	annual avg. (ppb)	no. hrs.> AAQS
1976	75	2.8	79
1977	75	1.9	116
1978	90	1.3	110
1979	55	na	na
1980	30	0.5	1
1981	45	0.5	na
1982	50	0.9	12
1983	38	0.7	10
1984	36	0.5	6
1985	50	1.0	13
1986	22	0.9	0
1987	20	0.6	0
1988	22	0.6	0

Table 2

Anderson Springs Data Summary

year	max. hr. conc. (ppb)	annual avg. (ppb)	no. hrs> AAQS
1976*	35	1.0	6
1977*	60	2.3	58
1978*	30	1.9	8
1979	na	na	na
1980	35	3.8	na
1981	25	0.4	1
1982	28	na**	3
1983	23	na**	0
1984	13	1.0	0
1985	10	1.6	0
1986	8	1.2	0
1987	8	0.9	0
1988	9	0.8	0

* 1976-1978 data collected at Jackass Flats; thereafter, data collected at Recreation Center

** Some of the na data is due to a lower reported limit of 10 ppb which biased the annual averages.

Table 3

Whispering Pines Data Summary

year	max. hr. conc. (ppb)	annual avg. (ppb)	no. hrs> AAQS
1976	40	3.5	79
1977	80	3.1	37
1978	50	2.2	55
1979	na	na	na
1980*	20	na	0
1981	30	0.7	3
1982	18	0.4	0
1983	24	0.8	0
1984	20	0.9	0
1985	25	0.9	3
1986	10	0.7	0
1987	19	0.6	0
1988	8	0.5	0

* 1980 represents half a year of data

AMBIENT AIR MERCURY CONCENTRATIONS AT THE GEYSERS

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ABSTRACT

From June 19 to December 16, 1986, PG&E conducted ambient air mercury measurements at six stations downwind of The Geysers in Lake County. The stations were located in populated areas on the eastern side, within the geothermal field at worst-case locations, and adjacent to geothermal plants and old mercury mining facilities. The mercury measurements were taken for 24 hours on a six-day cycle. The lower detection limit of this technique was approximately 1 ng/m^3 (nanogram per cubic meter) of air.

Overall, the ambient levels of gaseous mercury were low. The average was 5.8 ng/m^3 for the test period, with a maximum concentration of 23.6 ng/m^3. These data are similar to the estimated average atmospheric levels worldwide, 10 ng/m^3.

A statistically significant relationship was determined to exist between ambient mercury and air temperature. A correlation was also evident between rainfall and a decrease of mercury concentrations during the testing period.

INTRODUCTION

The Geysers-Calistoga Known Geothermal Resource Area (KGRA) is located on the eastern Mayacmas Mountain region of Lake and Sonoma counties. This region contains rich deposits of cinnabar ore, the principal ore processed in mercury mining. Mercury mining in this region began around 1861 and continued until about 1944 when the Socrates Mine stopped production. Surface deposits of cinnabar still exist, and the natural outgassing of metallic mercury vapor from these deposits and mercury entrained in the geothermal steam that is ultimately released into the atmosphere have become increasingly of concern. Several researchers have systematically investigated mercury vapor in geothermal steam (Robertson 1977, Crecelius 1976, Vostal 1972) and have followed the path of mercury through the geothermal power plant steam cycle and its ultimate release into the environment.

At The Geysers, three basic mechanisms could account for ambient gaseous mercury. Those processes are: 1) volatilization of mercury vapor from mercury-rich soils (i.e., cinnabar ore and mine tailings) (Robertson 1977), 2) entrainment in geothermal steam and release into the environment by natural venting and wellhead venting or from geothermal power plant cooling towers (Vostal 1972), and 3) volatilization from surface waters exposed to the air (DOI 1970).

In 1982, as part of the PG&E Geysers Unit 18 Public Health Compliance Monitoring required by the California Energy Commission (CEC), the PG&E Air Quality Unit conducted field monitoring of gaseous-metallic and particulate mercury in The Geysers area.

A larger study of the ambient air in the vicinity of The Geysers was undertaken in 1983 by a consortium of industry and local and state agencies including PG&E, the California Air Resources Board, and the CEC. This consortium initiated a study, the Geysers Air Monitoring Program (GAMP), which in 1983 and again in 1986 measured non-criteria pollutants of concern at The Geysers, including gaseous and particulate mercury (Altshuler et al. 1984).

After review of these studies, it was concluded that a more concentrated investigation of ambient metallic mercury vapor at The Geysers was warranted. In June 1986, the PG&E Air Quality Unit began that study.

This report contains the findings and analyses of The Geysers Ambient Air Mercury Program of 1986 and attempts to answer several key questions:

1. What are the ambient levels of mercury at The Geysers?

2. Is there a relationship between air temperature and ambient levels of mercury?

3. Is geothermal steam a major source of gaseous mercury?

4. Does rain have an effect on ambient levels of mercury either through a washing effect (lowering ambient mercury levels) or a process of erosion (exposing new soils to outgassing and thereby increasing ambient mercury levels)?

METHODOLOGY

Sampling Sites

Six sites were established for this study. Three of them were at existing GAMP monitoring stations and three more were established because of their proximity to the geothermal power plants, old mercury mining facilities, or natural meteorological drainage topography. Figure 1 is an area map with the mercury monitoring stations, power plants, and mercury mines indicated. The six stations were:

Anderson Springs. Located in a relatively densely populated area approximately 1 1/2 miles east and 1200 feet below Geysers Unit 13, this site was considered important because of the number of permanent residents living there and because historical data exist for ambient air concentrations of H_2S and mercury. This site was considered relatively clean, and little mercury was expected to be seen there. Abandoned mercury mines are located approximately 1 mile to the west and south of Anderson Springs.

Hobergs. This is a GAMP site located in a residential setting in Cobb, California. It is east of Bottle Rock Road, in a relatively high H_2S area near the crest of the ridge. This site was expected to monitor effects of westerly winds on mercury emissions from Geysers Units 11, 12, and 17.

Glenbrook. This is a GAMP site located at the northern end of The Geysers area. This site was positioned to monitor mercury emissions from the developed portion of the nearby KGRA during southwesterly winds.

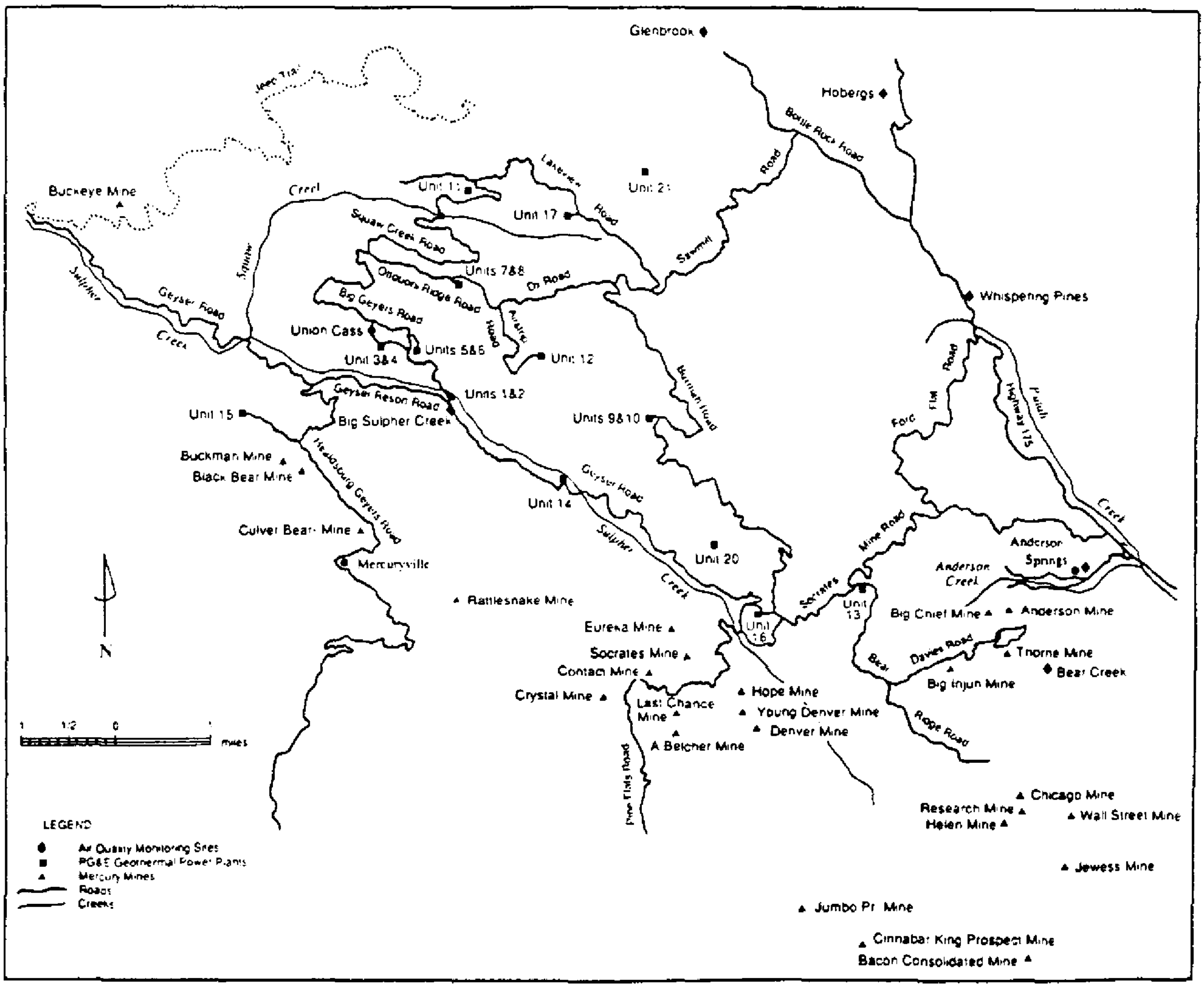

FIGURE 1. Mercury Mines in the Geysers Vicinty

Big Sulphur Creek and Union Chemical Abatement Storage Shed (CASS). These sites, located within the oldest developed area of The Geysers, were considered "worst case" locations. The Big Sulphur Creek site is located immediately south of Geysers Units 1 and 2, and the Union CASS site is between Units 3 and 4 and Units 5 and 6. These sites were located on the Big Sulphur Creek drainage and monitored air parcels that follow the diurnal patterns of wind along the Big Sulphur Creek. Mercury mines across the valley and adjacent to the Healdsburg-Geysers Road potentially influenced ambient mercury at these sites.

Bear Creek. This site is located 1 mile east of Geysers Unit 16 and is within 1/2 mile of Thorne and Big Injun mines.

SAMPLING PROTOCOL

The sampling equipment was housed in existing structures, when available. At the Bear Creek site, we used a "cotton region" meteorological shelter. The sample inlets were located approximately 3 meters above ground level and/or 1 meter above the sampler enclosures. Big Sulphur Creek was the exception; the inlet was located about 1 1/2 meters from the side of the building and 10 meters above Big Sulphur Creek at the UNOCAL pump station. In all cases, the sample lines were 3/16-inch (ID) FEP teflon tubing. Inlet line lengths were less than 5 meters and sample flow rates were approximately 0.7 liters per minute, so residence times within the probe were less than 8 seconds. All sites except Bear Creek were able to achieve satisfactory EPA siting guidelines. At Bear Creek, the sampler was located under the forest canopy in a narrow canyon with trees and bushes within 2 meters on two sides.

MERCURY ANALYSIS METHODOLOGY

Airborne mercury vapor was collected and measured using the Jerome gold film technology (McNerney 1983). The samplers drew ambient air across a mercury collection device (gold-coated coil) that absorbed mercury into the coating. The samples were subsequently analyzed on a Jerome Model 301 mercury analyzer.

The Jerome gold film method uses a two-step amalgam technique (sampling followed by analysis) for measuring mercury vapor. First, air passes across a gold-coated coil having a constant collection efficiency. After a pre-selected sampling period, the mercury is volatilized through heating for detection by the Jerome 301 analyzer. The volatilized mercury is collected on a gold film detector (a leg of a Wheatstone bridge) and the resulting change in resistance is proportional to the amount of mercury deposited. This procedure resulted in a detection limit of approximately 1 ng/m^3.

The mercury samplers consisted of sample lines, particulate filters, Mallcosorb filters, rotameters, pumps, dry test meters, and timers in conjunction with the gold coil collectors. Samplers located at sites using a sample distribution manifold (GAMP stations), also included a solenoid valve between the collector coil and the orifice to prevent backflow through the system during non-sampling times. Sites having AC power used a Dayton 7-day dial time switch and a Metal Bellows Model MB-41 air pump. Sites without AC power used an Irri-Trol battery-operated controller and a 12-18 volt DC Brailsford Model TD-4X2S pump. Those pumps were powered by 12-volt lead-acid marine batteries.

Mallcosorb filters removed H_2S (an interference) from the sample stream. The orifice and rotameters were used for setting the flow rates and checking for leaks in the system. The pumps were of a sealed positive displacement design, so the dry test meter recorded the total sample volume. The dry test meter records volume with a resolution of 0.001 ft^3 (2.83 x 10^{-5} m^3).

QUALITY CONTROL

The accuracy of the mercury measurements was maintained by injection of mercury standards into the Jerome 301 analyzer, which (as nearly as possible) duplicated the instrument's response to the 24-hour collection coil response. The 24-hour mercury measurements were based on a new calibration curve each time the collectors were analyzed. The mercury standards were precise volumes of mercury vapor taken from the head space of a vial containing liquid mercury at 0 degrees C (Arcado and Lin 1983b).

RESULTS OF ANALYSES

Data

Ambient gaseous metallic mercury data from the sampling sites were collected from June 19, 1986, to December 16, 1986. These data are presented in Table 1. Overall, the Union CASS site had the highest concentrations of mercury. An average mercury concentration of 8.6 ng/m^3 was monitored there during the sampling period. The high 24-hour value at Union CASS was measured at 17.3 ng/m^3 on August 24 and was the second highest value recorded for all sites. The Big Sulphur Creek site had the next highest mercury concentrations. An average of 7.2 ng/m^3 was measured there over the sampling period.

Hobergs recorded the lowest average ambient mercury concentrations, 4.5 ng/m^3. Interestingly, however, on September 11 the highest single measurement of mercury was recorded at this site, 23.6 ng/m^3. A review of the data and the QC documentation gives no indication that there was an instrument failure or other mishap that might have influenced the measurement. That datum was considered valid.

The average 24-hour mercury measurement for all stations during the sampling period was 5.8 ng/m^3. The

Table 1

GEYSERS MERCURY MONITORING PROGRAM
6-DAY SAMPLING CYCLE
ng/m^3 *
1986

SAMPLING DATE	HOBERGS	GLEN-BROOK	ANDER'N SPRINGS	BIG SUL CREEK	UNION CASS	BEAR CREEK	HIGH VALUE	AVERAGE MERCURY
JUN 19	2.7	4.3	4.0	7.8	7.8	–	7.8	5.3
JUN 25	1.4	7.9	7.0	11.2	13.3	–	13.3	8.2
JUL 1	4.8	9.3	11.2	7.7	7.9	–	11.2	8.2
JUL 7	4.8	7.2	6.3	13.7	11.5	–	13.7	8.7
JUL 13	3.6	6.5	7.5	9.0	13.1	–	13.1	7.9
JUL 19	3.4	4.9	10.3	7.5	8.7	6.0	10.3	6.8
JUL 25	3.8	6.1	9.4	6.8	5.6	6.9	9.4	6.4
JUL 31	3.0	5.3	11.9	5.5	10.2	7.5	11.9	7.2
AUG 6	2.9	7.7	5.7	8.8	10.9	6.6	10.9	7.1
AUG 12	3.7	7.1	4.7	11.5	15.0	5.4	15.0	7.9
AUG 18	2.1	4.6	3.5	4.8	5.5	3.2	5.5	4.0
AUG 24	2.5	5.0	4.3	7.9	17.3	4.8	17.3	6.9
AUG 30	2.2	3.9	4.1	–	6.0	3.4	6.0	3.9
SEPT 5	1.9	4.8	6.8	–	10.0	4.8	10.0	5.6
SEPT 11	23.6	4.9	3.5	4.7	4.1	4.0	23.6	7.4
SEPT 17	2.4	4.3	3.4	-	5.2	3.2	5.1	3.7
SEPT 23	2.4	6.3	3.6	8.0	7.5	4.0	8.0	5.3
SEPT 29	2.0	5.2	3.8	6.7	4.7	3.8	6.7	4.4
OCT 5	1.7	4.3	2.7	4.5	–	3.6	4.5	3.4
OCT 7	–	–	–	–	7.9	–	7.9	7.9
OCT 11	4.0	4.1	3.9	6.9	7.5	4.2	7.5	5.1
OCT 17	1.5	3.8	3.4	4.0	12.3	4.0	12.3	4.8
OCT 23	2.1	4.2	2.6	3.8	8.6	1.8	8.6	3.9
OCT 29	3.8	4.1	3.4	–	9.5	3.8	9.5	4.9
NOV 4	1.1	5.5	5.0	9.7	5.6	13.8	9.7	6.8
NOV 10	4.1	16.0	7.6	7.4	6.8	2.7	16.0	7.4
NOV 16	1.9	6.2	4.1	5.4	6.5	–	6.2	4.8
NOV 22	3.0	4.0	3.6	4.4	4.4	3.1	4.4	3.7
NOV 28	3.1	4.7	3.5	6.7	8.8	3.7	8.8	5.1
DEC 4	1.7	4.2	3.6	4.9	6.6	5.4	6.6	4.4
DEC 10	2.0	4.9	–	4.8	6.6	4.6	6.6	4.6
DEC 16	3.7	5.1	3.5	3.8	3.9	2.9	3.9	3.8
AVERAGES	4.5	5.7	5.3	7.2	8.6	4.7	10.7	5.8

* 24-hour sample.
– missing data.

average of the high mercury measurements was 10.7 ng/m^3. Mercury concentrations were approximately two times greater at Big Sulphur Creek and Union CASS than at the lowest site, Hobergs. However, even at these worst-case locations, ambient air mercury concentrations are considered low when compared to other similar geologic deposition areas and worldwide estimates of mercury.

Mercury concentrations measured at The Geysers during this testing period were low. Ambient air mercury measurements taken by the Pacific Northwest Laboratory in 1975, away from the vicinity of The Geysers, were generally below the detection limit of 1 ng/m^3 but occasionally ranged from 1 to 18 ng/m^3 (Robertson 1977). The U.S. Geological Survey reported mercury concentrations over mercury mines ranging from 24 to 108 ng/m^3 (McCarthy et al. 1970). Other technical reviews on atmospheric mercury levels suggest that the average concentration throughout the world is 20 ng/m^3 (EPA 1980). It was concluded, however, that background levels in the northern hemisphere are about 2 ng/m^3. The EPA assumed that the atmospheric level of total mercury is 10 ng/m^3 in its most recent assessment of mercury health effects.

In a review of H_2S concentrations measured within Big Sulphur Creek Valley (the center of geothermal development at The Geysers), the H_2S concentrations have been observed to be an average of 5 to 10 times greater than those locations east of The Geysers in the populated areas of Lake County (Hobergs, Glenbrook, and Anderson Springs) (Altshuler 1987, SRI International 1980). It appears that there is a greater change of H_2S concentrations than of mercury concentrations with change of location.

ANALYSES

A series of trend analyses were performed to ascertain if relationships existed between gaseous metallic mercury data and other parameters such as ambient temperature, rain, H_2S, and particulate mercury. If significant relationships were found, certain deductions may be reached. For example, if gaseous mercury concentrations are statistically related to ambient temperatures, then soil is probably a source of mercury concentrations. It is known that volatilization of mercury from soils increases with temperature (Vostal 1972).

The statistically significant relationships that were established using the method of least squares and the linear relationship of two unknowns are contained in Table 2.

AIR TEMPERATURE AND GASEOUS MERCURY RELATIONSHIP

Figures 2 and 3 demonstrate the change of average mercury concentration with the change of average air temperature for the entire network and with the high temperature recorded during each individual sample day at any meteorology station. A positive relationship is evident in both cases. We can infer, therefore, that soil temperature and ambient mercury may have a cause-and-effect relationship, although no physical evidence has been established in this study to corroborate that supposition. The instability of cinnabar in a vapor-dominated system (Varekamp and Busick 1984) and the vapor pressure of mercury lend credence to this relationship, however.

We observed that air temperature in excess of 85 degrees F is inversely proportional to changes of ambient mercury (Figure 4). With an increase of air temperature at ground level (air temperature was measured at approximately 10 to 20 feet above the ground), vertical mixing of the atmosphere increases as the warm air rises. This results in the subsequent dilution of airborne pollutants, including mercury. On 5 of the 10 warmer days, no inversion layer was evident. An indication of an inversion layer is a warmer temperature recorded at the Unit 13 meteorology site than recorded at Anderson Springs. They are separated by 1200 feet in elevation and only approximately 1 1/2 miles of horizontal distance.

RAIN AND GASEOUS MERCURY RELATIONSHIP

On November 19, 1983, following a heavy autumn rain at Anderson Springs (one of the first major rain episodes of the season), an elevated mercury concentration was recorded. At that time, it was suggested that the heavy rains exposed fresh mercury rich soils for outgassing. This phenomenon was not witnessed later. In this study, we failed to correlate heavy rains with elevated mercury.

We did, however, correlate an increase of rainfall with a decrease in ambient mercury concentrations. An assumption made in this analysis was that the emissions of mercury are relatively constant and the reduction of mercury with increased rainfall is due to a washout of mercury by rain (Ferrara 1986). A decrease in temperature with weather fronts is another possible explanation, as is reduced escape routes of mercury vapor through rain-moistened soils. Figures 5 and 6 demonstrate the inverse relationship of rain to mercury in two data sets: (1) using all available data, and (2) plotting those sample days where rainfall was >0.01 inches of rain.

Table 2

Relationships of Mercury to Other Measured Parameters

Test of Relationship	Avg. Temp to Avg. Hg	High Temp to Avg. Hg	Temp >85 to Avg. Hg	Rain (in.) to High Hg	Rain >0.01* to Avg. Hg
n	32	32	10	32	16
slope	0.095	0.076	-0.29	-1.45	-1.08
y-intercept	0.05	0.30	32.8	6.2	5.7
Corr. Coeffic. (r)	0.58	0.58	-0.63	-0.44	-0.50
Critical r @ 95% confidence *	0.36	0.36	0.63	0.36	0.50

*Orkin and Drogin, 1975

CONCLUSIONS

In the six-month period from June 19 to December 16, 1986, ambient levels of metallic mercury measured in the vicinity of The Geysers ranged from 1.1 to 23.6 ng/m^3 of air. The overall average mercury concentration was 5.8 ng/m^3. The mercury monitoring site that recorded the highest average ambient mercury concentration was the Union CASS site located east of the Big Sulphur Creek drainage. This site is surrounded by Geysers Units 3, 4, 5, and 6. The Hobergs GAMP site recorded the lowest average levels of mercury during the test period. The higher levels of mercury in the test area, 10 ng/m^3 and greater, were generally associated with northwesterly winds at the Glenbrook and Anderson Springs sites.

A statistically significant relationship was determined to exist between ambient mercury and air temperature. This would indicate that one contributor of the ambient gaseous mercury is outgassing of mercury-laden soils. Above 85 degrees F, mercury concentrations decreased with an increase of temperature. This was probably due to the vertical mixing of the atmosphere and the subsequent dilution of pollutants.

Rain appeared to have an inverse relationship with mercury vapor concentration in ambient air. A weak but statistically significant correlation between an increase of rainfall measured since the last sampling period and a decrease of mercury concentration was established.

REFERENCES

Alder, H. L., and Roessler, E., 1968. Probability and Statistics, 4th ed.

Altshuler, S. L., Arcado, T.D., and Lin, C.I., June 1984. "Concentrations of Non-Criteria Air Pollutants in the Vicinity of the Geysers, California," presented at the 77th Annual Meeting of the Air Pollution Control Association, San Francisco, California.

Altshuler, S. L., 1987. Personal communication re: H_2S data evaluation at The Geysers (1970-1980).

Arcado, T. D., and Lin, C.I., 1983a. "PG&E Unit 18 California Energy Commission Public Health Compliance Monitoring," PG&E (417-83.1).

Arcado, T. D., and Lin, C.I., 1983b. "Procedure for the Determination for Mercury in Ambient Air Using the Jerome 301 Gold Film Mercury Detector." PG&E (Air Quality Unit Procedure).

Code of Federal Regulations, July 1, 1980. 40 Protection of Environmental Parts 53 to 80.

Crecelius, E.A., Robertson, D.E., Fruchter, S.J., and Ludwick, J.D.,1976. "Chemical Forms of Mercury and Arsenic Emitted by a Geothermal Power Plant," in Trace Substances in Environmental Health, A Symposium, p. 287-293.

Orkin, M., and Drogin R., 1975. Vital Statistics, McGraw-Hill Book Company.

Pacific Northwest Laboratory, 1981. "Annual Report for 1980 to the DOE Assistant Secretary for Environment," Part 4, Physical Sciences. Pacific Northwest Laboratory (PNL-3700 PT4/UC-48).

Robertson, D. E., et al, June 3, 1977. "Mercury Emissions from Geothermal Power Plants." Science, v. 196, p. 1094-1097.

Schroeder, W. H., 1982. "Sampling and Analysis of Mercury and Its Compounds in the Atmosphere." Environmental Science and Technology, v. 16, no. 7.

Varekamp, J. C., and Buseck, P.R., 1984. "The Specification of Mercury in Hydrothermal Systems, with Applications to Ore Deposition." Geochimica et Cosmochimica Acta, v. 48, p. 177-185.

Vostal, J., 1972. "Transport and Transformation of Mercury in Nature and Possible Routes of Exposure," in Mercury in the Environment: an Epidemiological and Toxicological Appraisal, CRC Press, p. 15-27.

Young, H. D., 1962. Statistical Treatment of Experimental Data, McGraw-Hill Book Company.

Department of the Interior (DOI) GSPP-713, 1970. Mercury in the Environment.

Environmental Protection Agency (EPA), 1976. Quality Assurance Handbook for Air Pollution Measurement Systems, v. 1, 600/9-76-005, Section No. H.

Environmental Protection Agency (EPA), August 7, 1978. "Air Quality Surveillance and Data Reporting," Federal Register, Part II, v. 43, No. 152.

Ferrara, R., et al, 1986. "Mercury Levels in Rain and Air and the Subsequent Washout Mechanism in a Central Italian Region," Atmospheric Environment, v. 20, no. 1.

McCarthy, J. H., Meuschke, J.R., Ficklin, W.H., and Learned, R.E., 1970. "Mercury in the Environment." U.S. Department of the Interior. Geological Survey Professional Paper 713.

McNerney, J. J., Buseck, P.R., and Hanson, R.C., November 10, 1972. "Mercury Detection by Means of Thin Gold Films," Science, v. 178, p. 611-612.

McNerney, R. T., 1983. "Quantitative Analysis of Mercury Vapor by Gold Film Sensors." Presented at the 1983 Meeting of the American Industrial Hygiene Association.

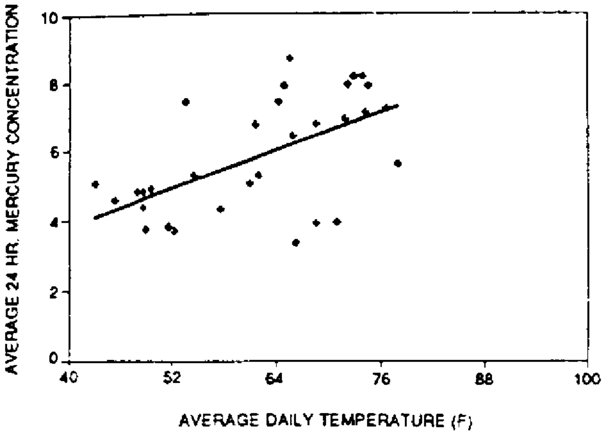

FIGURE 2. Average Daily Temperature and Average Mercury Concentrations

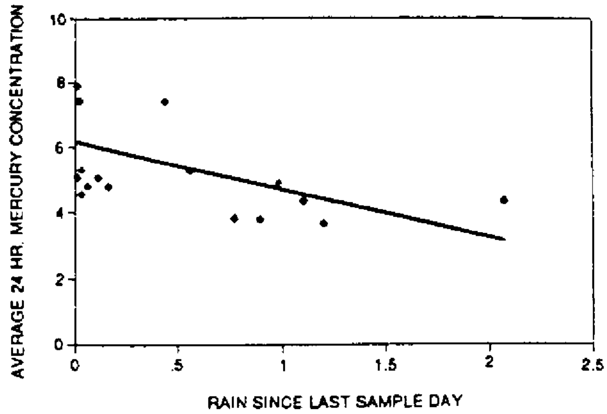

FIGURE 5. Ambient Mercury Concentrations and Rain Since Last Sample Day

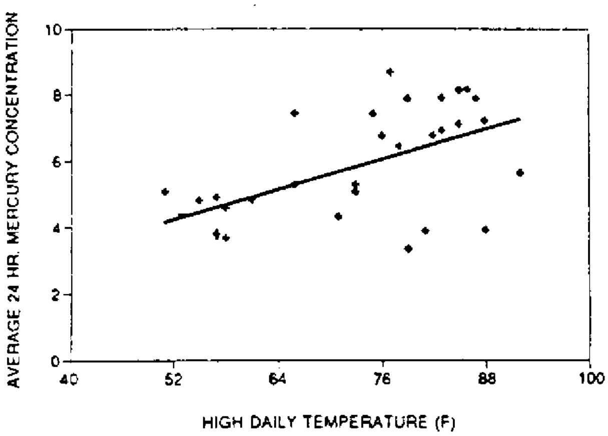

FIGURE 3. Average Ambient Mercury Concentrations and High Daily Temperatures

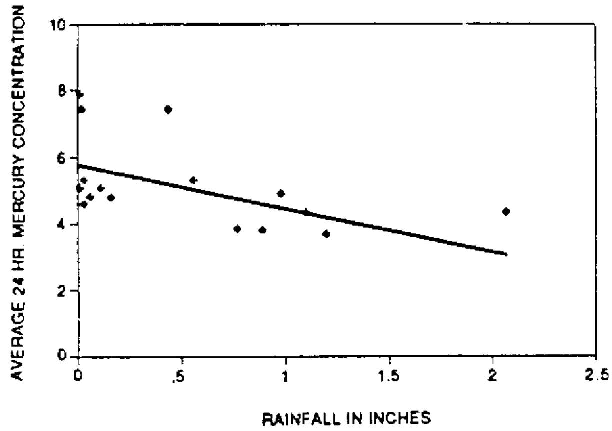

FIGURE 6. Ambient Mercury Concentrations and Rain Episodes Where Amounts are 0.01 Inches or Greater.

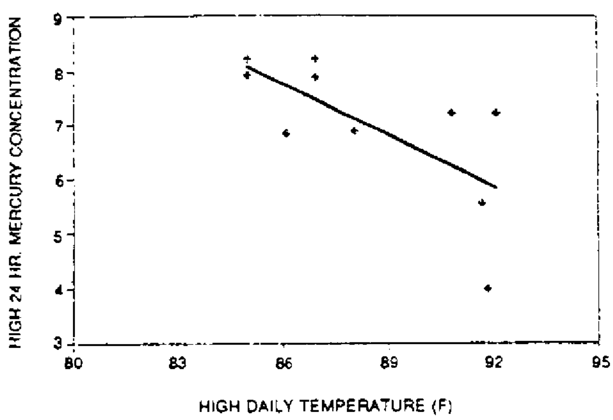

FIGURE 4. Maximum Ambient Mercury Concentrations and Average Air Temperature Above 85 Degrees F

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CONCENTRATIONS OF NON-CRITERIA AIR POLLUTANTS IN THE VICINITY OF THE GEYSERS, CALIFORNIA

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Abstract

Ambient air monitoring for non-criteria pollutants was conducted to assess the impact of geothermal steam utilization on the ambient air at The Geysers. The measurements revealed no exceeds of any ambient air quality standards, state, federal, or foreign. Except for mercury vapor, radon, and ammonia, all of the pollutants were measured at near detection limit concentrations using methods that are state-of-the-art. Mercury vapor seems to be more related to the known geologic cinnabar deposits and past mining operations in the area than to geothermal steam utilization at The Geysers.

Introduction

The Air Quality Unit of Pacific Gas and Electric's (PG&E) Department of Engineering Research conducted ambient air monitoring for non-criteria air pollutants in populated areas of Lake County, . California. This area is predominately downwind of The Geysers, an area producing geothermal steam generating 1300 megawatts of electric power. The Geysers is located in the Mayacmas Mountains, approximately 90 miles north of San Francisco.

The non-criteria air monitoring began in August 1983 and was conducted to the end of July 1984. This program will again resume in August 1986 for one final year of operation. The program is a portion of the larger Geysers Air Monitoring Program (GAMP) which also includes continuous measurements for ambient hydrogen sulfide (H_2S) at six sites and meteorological parameters at eleven sites (nine wind direction/speed and temperature/dewpoint sites and two acoustic sounder sites).

GAMP was created to provide environmental measurements needed by industry and regulatory agencies for assessing the impact of growth of the geothermal industry at The Geysers. GAMP is supported by a consortium of 15 entities including power companies, steam suppliers, local air pollution control districts, the California Air Resources Board (ARB), and the California Energy Commision. The Northern Sonoma County Air Pollution Control District (NSCAPCD) is the project manager for GAMP. PG&E performs all of the non-criteria monitoring, H_2S monitoring at two sites, and meteorological monitoring at three sites. The consulting firm, Environmental Systems & Services (ES&S), Kelseyville, California, performs the remainder of the monitoring for the GAMP consortium. The Lake County Air Pollution Control District (LCAPCD) performs quality assurance activities for GAMP. The ARB also performs quality assurance activities as well as specific chemical analyses at their Haagen-Smit Laboratory in El Monte, California.

The parameters selected for the non-criteria pollutant monitoring programs were chosen based on:

(1) their presence in geothermal steam (mercury, arsenic, benzene, radon, ammonia, boron, and silicon);
(2) their use in H_2S abatement systems at operating power plants (vanadium);and
(3) their formation in the atmosphere as a result of geothermal emissions (sulfate).

This list is believed to cover all emissions from current geothermal steam utilization which are relevant in evaluating public health concerns in nearby populated areas of Lake County. The results of the monitoring program are described herein.

Method of Measurement and Analysis

Methods chosen for the measurement and analysis of the non-criteria pollutants have been selected based on their ability to provide:

1) measurements comparable to ambient air quality standards;
2) the lowest feasible level of detection;
3) the greatest precision; and
4) a cost effective program.

For these reasons, the respirable suspended particulates, sulfate, particulate boron, and ammonia (four 6-hour samples) measurements are performed on a 24 hour basis every sixth day in phase with the ARB's total suspended particulate sampling schedule. Mercury vapor is sampled using a continous (hourly integrated) analyzer to further our understanding about its behavior at The Geysers. Conversely, radon (monthly) and benzene (one, one hour sample per month) are sampled less aggressively. Boron deposition is collected similarly to wet/dry deposition sampling performed elsewhere in acidic deposition monitoring programs.

Measurement Procedures & Accuracies

Table 1 presents the measurement procedures and estimated overall accuracy of each of the measurements. The overall accuracy is assumed to be the sum of the estimated component accuracies (flow, time, analyses, etc.) and, thus, represents a worst case assessment as it does not account for off-setting inaccuracies.

Quality Control/Quality Assurance Activities

Rigorous quality control and quality assurance activities were were maintained throughout the program. These procedures were submitted to the GAMP consortium for approval prior to initiation of field measurements in 1983. These activities include routinely scheduled calibration audits and detailed record keeping of all activities. The results of these activities are reported with the original data.

Results

Table 2 lists the maximum concentrations of the measurement program. The following is a discussion of each of the parameters measured.

(A) Mercury Vapor

Mercury vapor measurements have revealed some of the most interesting data during the program both in magnitude and seasonal trends. Measurements in 1982 were generally an order of magnitude lower thar similar measurements in the same calandar quarter of 1983(1). Mercury vapor data also exhibit a decline in magnitude as each program progressed from their summertime start date, Figure 1. We speculate that this trend can be correlated to ambient temperatures with the belief that mercury vapor is being eluded from known soil deposits of cinnabar in the area. The 1983-84 data show a similar trend with lowest mercury measurements occuring in mid-winter. However, one of the highest mercury vapor measurements, 0.165 ug/m3, at Anderson Springs coincided with one of the first days of extensive rainfall, November 8,1983. We have found no explanation for this phenomenon. Mercury vapor measurements do not correlate with particulate mercury measurements from the dichotomous sampler filters, coarse or fine.

(B) Ammonia

Ammonia concentrations were similar in magnitude to concurrent hydrogen sulfide concentrations at Whispering Pines in 1982(1). A significant relationship was determined for this four month data set. This is not unexpected as ammonia and hydrogen sulfide are usually emitted together in similar concentrations by volume from unabated geothermal activities. However, the ratio of hydrogen sulfide to ammonia emissions may differ from H_2S abated sources(1).

(C) Radon

Monthly radon measurements have been low to date. However, highest radon concentrations (3 to 4 pCi/l) have occurred in December 1983 during an extremely wet month. Conversely radon concentrations ranged from 0.2 to 0.7 pCi/l in January 1984, an extremely dry winter month.

(D) Respirable Suspended Particulates, (RSP)

The RSP measurements uniquely characterize the airborne particulates for the first time at The Geysers. It is significant that near detection limit quantities of particulate mercury, arsenic, and vanadium were measured during the program. Automotive emissions of lead and bromine were measured. Earth elements of iron, titanium, and silicon were commonly measured. Chlorine, believed to be ocean derived, was measured in greater concentrations on days with greater wind velocities coming from the coast. Size wise, coarse particulates (2.5 um to 10 um) dominated the size fraction in the summer of 1983 and more fine particulates (less than 2.5 um) dominate in the winter of 1983-84.

(E) Boron

Ambient particulate boron measurements are low with little relevant interpretation currently discernable. The boron deposition measurements, more useful for vegetation impact assessment than public health, are difficult to interpret. Also, variations in rainfall have affected the reported data. The collection of dew in the dry bucket in the colder months (not uncommon in dry deposition sampling) contributes to the confounding of the results. Thus, these boron deposition data are more qualitative than quantitative.

(F) Benzene

Ambient benzene measurements have been very low and no relevant trends are evident. These data indicate that geothermal benzene emissions appear to have an insignificant effect on air quality in the area of study.

(G) Total Suspended Particulates, (TSP)

TSP concentrations measured to date have all been below the California 24 hour TSP AAQS, 100 ug/m3 and the EPA 24 hour AAQS, 260 ug/m3.

(H) Sulfates

The sulfate data measured using the hi-vol and the dichotomous sampler provide two unique data sets for comparison. The size fractionation of the sulfates in the dichotomous sampler shows that the majority of ambient sulfate is in the fine, less than 2.5 um, size. While the hi-vol and dichotomous data do not correlate statistically, they do show similar measurements both of which are in the range of their detection limits. We believe that the lack of correlation between the two sets of sulfate data is not due to artifact formation on the hi-vol filter paper since the hi-vol sulfate data is not consistently higher than the dichotomous data as it would have to be. Also, very little sulfur dioxide is present in the ambient in this area. Sulfate measurements at the two different sites in 1982 showed a significant relationship indicating area wide uniformity of sulfate concentrations(1).

Comparison of Results with Health Based Criteria

World-wide AAQS's for the non-criteria pollutants measured during the described programs are(2):

1) arsenic, 3 ug/m3 for 24 hours (Czechoslovakia and USSR),
2) mercury, 0.3 ug/m3 for 24 hours (USSR),
3) vanadium pentoxide, 2 ug/m3 for 24 hours (USSR),
4) ammonia, 100 ug/m3 for 24 hours (Czechoslvakia) and 200 ug/m3 for 24 hours (USSR), and
5) benzene, 800 ug/m3 for 24 hours (Czechoslvakia and USSR).

Presumed safe levels reported at the World Health Organization International Symposium, June 1974, in Paris, France are(3):

1) arsenic, 5.9 ug/m3 for 24 hours,
2) mercury, 0.8 ug/m3,
3) vanadium, 6.8 ug/m3, and
4) boron, 59 ug/m3 for 24 hours.

The Ontario Ministry of the Environment established the standards(4):

1) arsenic, 5 ug/m3 for 24 hours and 15 ug/m3 for 15 minutes,
2) mercury, 2 ug/m3 for 24 hours and 5 ug/m3 for 30 minutes,
3) vanadium, 2 ug/m3 for 24 hours and 5 ug/m3 for 30 minutes, and
4) ammonia, 3600 ug/m3 for 30 minutes, and
5) benzene, 10000 ug/m3 for 24 hours.

Clearly, the measured concentrations of these non-criteria pollutants in Lake County are much less than any of these standards.

Ambient concentrations of sulfate, RSP, and TSP were all less than their respective California AAQS, 25,50, and 100 ug/m3 for 24 hours.

Conclusions

The non-criteria air monitoring program described herein is a progressive program designed to answer today's questions regarding ambient effects of geothermal power plant air emissions. Except for ambient hydrogen sulfide concentrations, all other criteria pollutants downwind of The Geysers are below existing ambient air quality standards in the state of California. Pollutants for which a standard does not currently exist for in California (mercury, arsenic, vanadium, benzene, ammonia, boron, silicon, and radon) are all below standards reported in the literature for other nations. Except for mercury vapor, radon, and ammonia, all of these pollutants were measured at near detection limit concentrations using methods that are state-of-the-art.

Mercury vapor does, however, warrant watching as an apparant increase in ambient concentrations has been measured from 1982 to 1983. These mercury concentrations may be natural to the area and more related to the known geologic cinnabar deposits and past mining operations in the area than due to geothermal steam utilization. The higher December 1983 radon measurements compared to the January 1984 measurements suggest that rainfall patterns have a more measureable effect on ambient radon concentrations than geothermal emissions; more work is required to verify this observation. Ammonia concentrations, while measureable and statistically correlated to ambient H2S measurements in 1982, are, nevertheless, very low when compared to health based criteria.

Data from the 1983-1984 program are providing a valuable baseline to assess future (1986-1987) GAMP data.

Acknowledgements

The authors wish to acknowledge California ARB Haagen-Smit personnel for their assistance in the program by providing chemical analyses.

References

1. Altshuler, S.L., Lin, C., and Arcado, T.D.," Concentrations of Non-criteria Pollutants in the Vicinity of Geothermal Power Plants at The Geysers, California", presented at the 77th Annual Meeting of the Air Pollution Control Association, San Francisco, Calif., June 1984.

2. Stern, A.C., Air Pollution, Vol. III, Sources of Air Pollution and Their Control, 1968.

3. Wilcox, S.L. et. al., "Establishing Safe Ambient Air Quality for Eighteen Hazardous Pollutants", Preprint, World Health Organization, 1974, presented at Organization International Symposium, Paris, France, 1974.

4. Ontario Ministry of the Environment, "Hazardous Substances List and Handbook ", Report Number ARB-TDA-33-76,1976.

TABLE 1
ESTIMATED MEASUREMENT ACCURACIES AND DETECTION LIMITS

Parameter	Analytical Method	Relative Accuracy, %	Detection Limit
Mercury vapor	Jerome analyzer gold film		
-continuous		± 10	10 ppt
-24 hour		± 10	0.004 ug/m3
Radon	Type F, Trachetch	± 50	0.1 pCi/1
Boron (deposit)	ICP analyses	± 50	1 ug/m2-d
TSP	Hi-vol, gravimetric	± 11	1 ug/m3
Sulfate	Hi-vol & turbidimetric	± 15	0.3 ug/m3
RSP, PM 10	Sierra dichotomous gravimetric	± 35	0.3 ug/m3
RSP elements	XRF analyses (As,Hg,V,Si,S)	± 20	0.001 ug/m3
Boron (part.)	Lo-vol & ICP anal.	± 20	0.01 ug/m3
Ammonia	Lo-vol & specific ion	± 25 **	0.2 ug/m3
Benzene	Gas chromatography	± 20	0.1 ppb

TABLE 2
MAXIMUM CONCENTRATIONS (UG/M3)
1983-84 PROGRAM
August 1, 1983 - July 31, 1984

	Anderson Springs	Glen Brook
Mercury vapor, hourly ppt	70	48
Radon, pCi/1	3.95	3.00
Boron wet/dry deposition, ug/m2-day*	<238/<78	<1071/<116
TSP	93	64
Sulfate	3.7	3.1
RSP PM 10	46.1	46.3
- arsenic (fine/coarse)	0.014/0.003	0.004/0.003
- mercury (fine/coarse)	0.005/0.005	0.004/0.008
- vanadium (fine/coarse)	0.002/0.004	0.003/0.002
- silicon (fine/coarse)	1.239/6.806	0.796/3.816
- sulfate (fine/coarse)	3.814/2.074	2.835/0.723
Boron particulate	0.56	0.88
Mercury vapor, 24 hour	0.165	0.273
Ammonia	14.15	17.8
Benzene, ppb	3.6	4.6

*Concentrations are biased high due to effects of rainfall and dew.

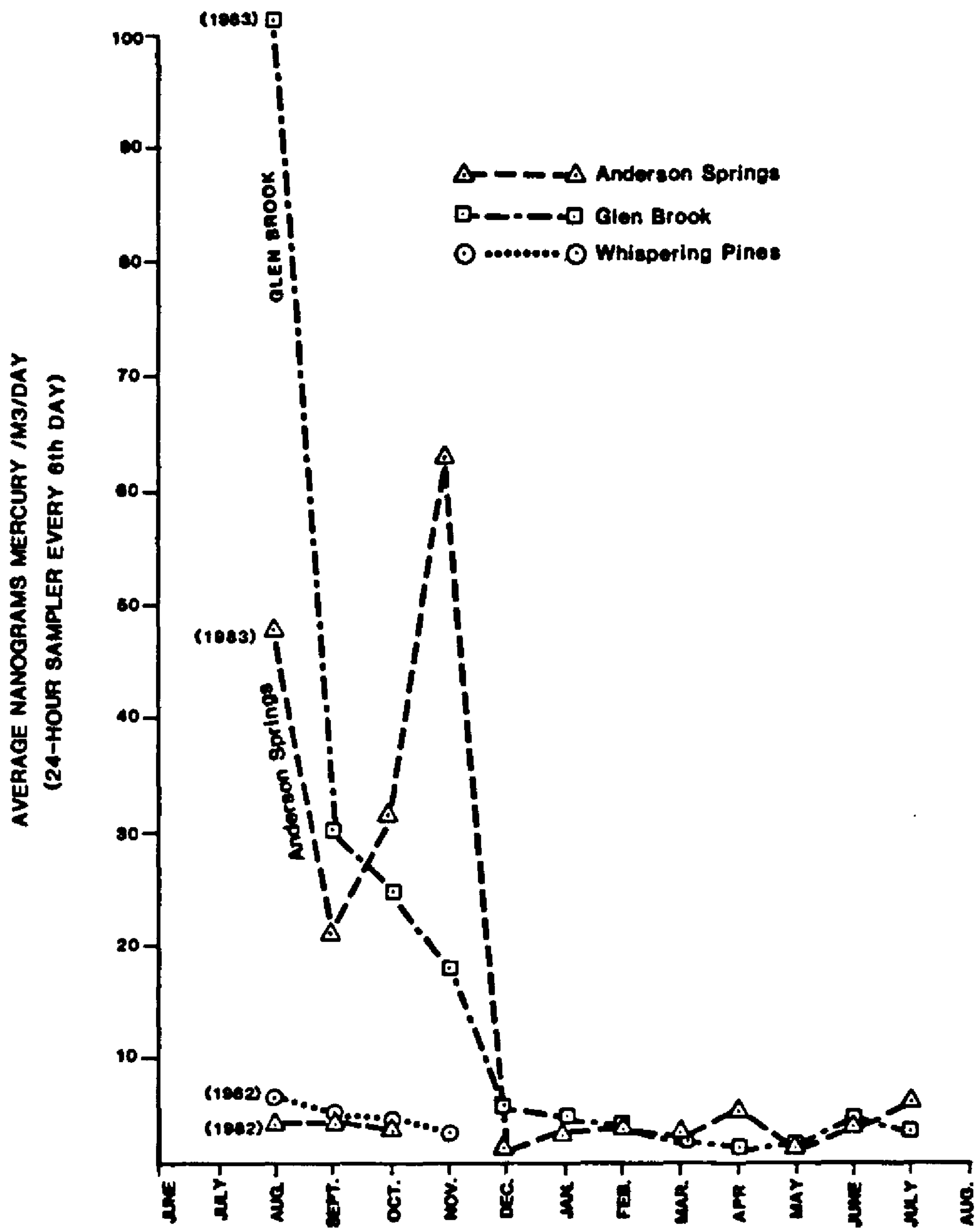

FIGURE 1. Monthly Average Mercury Measurements

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ARSENIC SPECIATION IN ATMOSPHERIC AEROSOLS AT THE GEYSERS

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ABSTRACT

Geothermal energy production in California has been identified as a major source of arsenic by the California Air Resources Board. New regulations have been implemented by the State of California, which require information on ambient levels and emissions of inorganic arsenic. However, these laws consider only total arsenic and do not take into account the potential differences in toxicity and perhaps even carcinogenicity of the different arsenic species present in the ambient atmosphere. In response to that need, atmospheric particulate matter samples were collected at The Geysers geothermal development area in Lake County California over a two month period in 1989. This paper describes those results and provides, for the first time, insight into the atmospheric loadings of the inorganic species of arsenic, As(III) and As(V), at geothermal power facilities.

INTRODUCTION

REGULATIONS AND RISK ASSESSMENT

California's air toxic law (AB 1807), which became effective in January 1984, defines California's air toxic program (California Department of Health Services [DHS] 1984). Under this legislation, a statutory mandate was created for the identification and control of toxic air contaminants found in California.

Ambient concentration is one of the mandated criteria used in the identification process to prioritize compounds that are believed hazardous to human health. The California Air Resources Board (ARB) has developed a list of potentially toxic substances based on this mandated ambient criteria. Inorganic arsenic is required to be on this list, because it has been identified as a hazardous air pollutant under Section 112 of the U.S. Clean Air Act.

Inorganic arsenic is listed by the ARB under Category I: substances under review for the identification as a toxic air contaminant (ARB 1990a). This category describes substances which have been identified as Toxic Air Contaminants by the ARB, pursuant to the provisions of AB1807.

The DHS (ARB 1990c) estimates the number of excess cancer deaths or risk due to airborne inorganic arsenic exposure in California's South Coast and San Francisco Bay Area air basins to be 1-25 cases per ng m^{-3} per million persons. This is based on a 1986 average ambient population-weighted concentration of arsenic equal to 1.9 ng m^{-3} for those two air basins. The lower end of the range (1-2) corresponds to nonsmokers, whereas the upper end (10-25) corresponds to males who smoke heavily. Higher risks may occur near sources. However, the DHS also concludes that it is unlikely that carcinogenic adverse health effects would be caused by current ambient levels of arsenic in California. Statewide concentrations, based on 1986 data, are about 32% lower; therefore, the risk based on the 1986 statewide data would be lower by an equivalent percentage, since a linear model is assumed in calculating the risk assessment.

The risk due to ambient exposures of inorganic arsenic in California, as reported by the DHS, is in the same range as that reported by the Environmental Protection Agency, based on its health assessment of inorganic arsenic (EPA 1984). However, both risk estimates are based on a number of assumptions that are summarized in their respective documents.

Inorganic arsenic also is included in the list of substances under California's Air Toxic "Hot Spots" Information and Assessment Act of 1987 (AB 2588) (DHS 1987). This law became effective in September 1987 and requires the ARB to compile and maintain a list of substances, which are referenced in AB 2588. Arsenic is identified under Category 1: substances required to be on the AB 2588 list by Health and Safety Codes 44321 (c), (d), (e), and (f).

The health effects information and risk assessments for arsenic, however, only consider total arsenic and not the individual species of inorganic arsenic present in the atmosphere (EPA 1984; ARB 1990b, 1990c). The measurement of individual species of inorganic arsenic is particularly important because of the variations in the toxicity and carcinogenicity of the different arsenic compounds found in the environment (Lisk 1971; National Academy of Science 1971; Hernberg 1972; EPA 1978, 1984). Inorganic As(III) is not only more toxic, but also may represent a greater carcinogenic hazard than As(V).

The health effects studies used by the ARB (1990c) to determine risk levels were for occupational exposures where As(III) is believed to be the only arsenic species present; therefore, the current ARB risk assessment (ARB 1990c) may overestimate the actual risk due to inorganic arsenic in the air in California. If a substantial fraction of the arsenic in ambient air is As(V), then the true risk may be lower than the one calculated by assuming all arsenic is As(III).

ATMOSPHERIC ARSENIC

Arsenic is emitted into the atmosphere from anthropogenic and natural sources. Atmospheric concentrations of total arsenic range from about 0.01 to 0.1 ng m^{-3} in clean areas such as Antarctica (Maenhaut et al. 1979) and up to 500 ng m^{-3} near certain industrial sources such as copper smelters (Walsh et al. 1977).

In U.S. urban areas, average ambient arsenic concentrations were reported to be approximately 20 ng m^{-3} (Sawicki 1967). Annual average arsenic values measured by the National Air Sampling Network and conducted by the EPA, ranged from 2.6 to 10.9 ng m^{-3} during 1977-1981. The average over the 5-year period was 7.7 ng m^{-3} (EPA 1984). In 1986, annual average arsenic concentrations in California ranged from 0.7 to 5.0 ng m^{-3}, with an overall mean statewide concentration of 1.5 ng m^{-3}. The average for the eight southern California sites was 2.0 ng/m^3; the average for the 11 northern California sites was 1.2 ng m^{-3} (ARB 1990b). The ARB and EPA data include rural and urban areas.

In the air, arsenic is primarily associated with particles, although it also has been observed at much lower levels in the gas phase (Johnson and Braman 1975; Walsh et al. 1977, 1979; Appel et al. 1984). The predominant forms of arsenic in the atmosphere are the inorganic oxides or oxyacids of arsenic in the +3 and +5 oxidation states. Organic arsenic compounds also have been detected in the air; however, they constitute only a small fraction of the total (Johnson and Braman 1975, Andreae 1980, Nakamura et al. 1989).

Inorganic species of arsenic (As(III) or arsenite and As(V) or arsenate) have been measured in atmospheric particulate matter at two locations: Tucson, Arizona (Solomon 1984), and the City of Industry, Los Angeles County, California (Rabano et al. 1989). The City of Industry site was located within 1 kilometer of a known high temperature source of arsenic (a secondary lead smelter [ARB 1990b]). These measurements were obtained using an analytical method that allows for the species-specific determination of As(III) and As(V) in atmospheric particulate matter with high sensitivity (Solomon 1984). Detection limits of less than 1 ng m^{-3} were achieved for both species.

The As(III)/As(V) ratio varied considerably at both locations. In Tucson, the ratio ranged from 0.04 to 0.97, with an average value of 0.31 ± 0.29. In Los Angeles, the ratio ranged from 0.26 to 2.8, with an average ratio of 1.2 ± 0.7. (A ratio of 1 indicates an equal mixture of both species.) The variations of the ratio at each site and between the two locations are most likely due to the impact of the various sources in the surrounding areas, the age of the aerosol measured at the sampling sites, and/or variations in the effective oxidation-reduction potential of the atmospheric environment (Andreae 1980; Solomon 1984).

ARSENIC AT THE GEYSERS

Arsenic is of interest at The Geysers (Figure 1), because it occurs naturally in the geothermal steam. Therefore, arsenic can be released to the atmosphere through natural venting and as the steam is used to generate power. The final ARB report on inorganic arsenic in California indicates that emissions into the atmosphere from geothermal energy production is one of the largest sources of arsenic in the state (see Table II-2 in ARB 1990b). To arrive at this conclusion, the ARB made a number of assumptions about emission rates from sources at The Geysers, some of which require verification. Therefore, it is necessary to provide regulators with accurate data on arsenic at The Geysers to ensure that imposed regulations and restrictions are justified and needed to protect public health.

The objective of this study is to obtain more accurate ambient concentration data for total arsenic and for the inorganic species of arsenic at The Geysers, which can be used to 1) determine if a long-term study is warranted and 2) advise and influence regulators in their health risk assessment for arsenic. As part of this process, an analytical method (Solomon 1984) to determine the inorganic species of arsenic (arsenite and arsenate) was established and evaluated within PG&E's Technical and Ecological Services (TES). This method was used to determine the species-specific concentrations of arsenite (As(III)) and arsenate (As(V)) in total suspended particulate matter (TSP) samples collected at The Geysers.

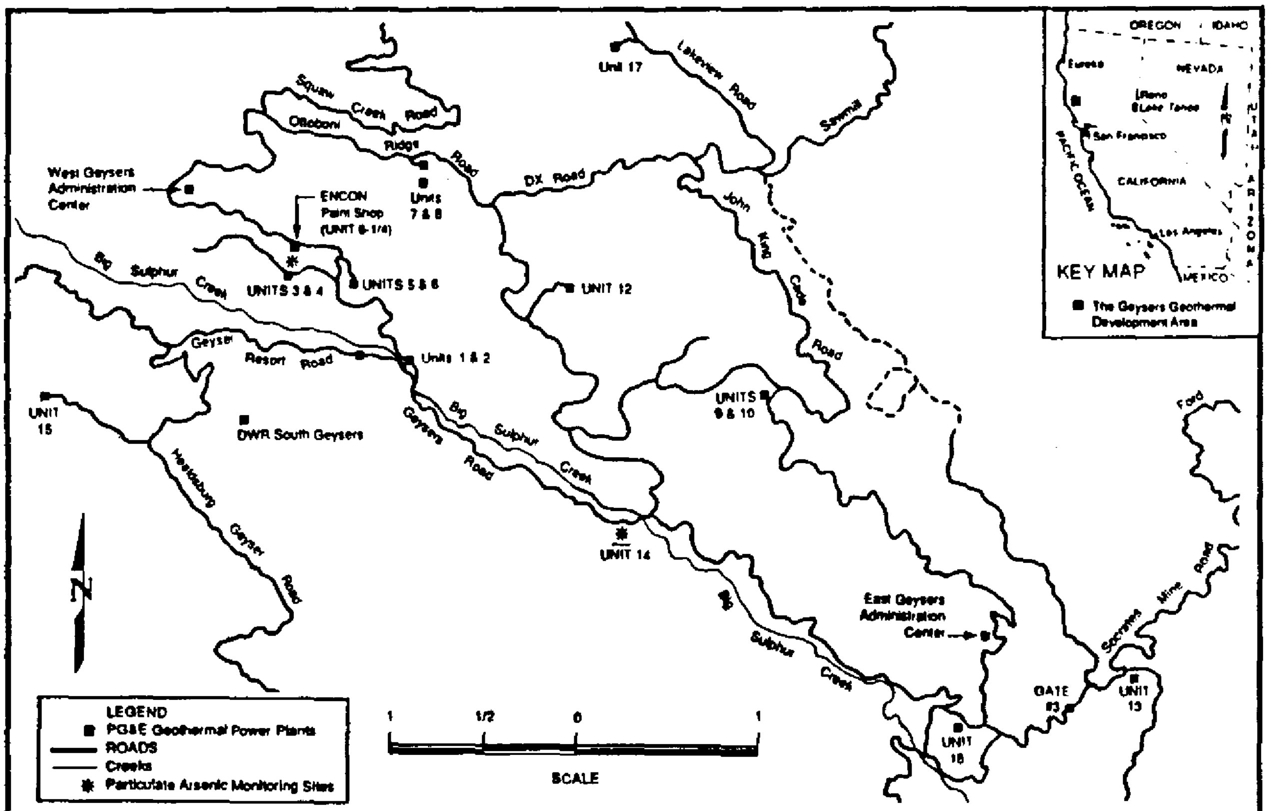

Figure 1. 1989 particulate arsenic monitoring sites at The Geysers.

EXPERIMENTAL

ATMOSPHERIC PARTICULATE MATTER COLLECTION

Atmospheric particulate matter samples were collected at two sites within The Geysers geothermal development area during April and May 1989. One site was located in the East Geysers at Unit 14, and the other was located in the West Geysers near a PG&E paint shop and just north of Units 3 & 4 (Figure 1). The locations of the sites were chosen to maximize filter loadings (i.e., near the valley floor in case an inversion occurred), while avoiding direct impact from steam vents or cooling tower drift. This approach was taken to help ensure that a sufficient amount of sample above the detection limit of the analysis method would be collected, while minimizing the influence from nearby sources.

Unit 14 is at an elevation of about 1,700 ft, which is about 800 ft below the East Geysers administration building and about 50 ft above Big Sulfur Creek, the valley floor. At this site, two samplers were placed just inside the fence perimeter near the front gate and adjacent to the industrial hygiene changing room. During the 2-month study period, Unit 14 was down for maintenance.

The site at the PG&E paint shop is at an elevation of about 2,000 ft, which is about 600 ft above the valley floor and about 300 ft below the West Geysers administration building. At this site, two samplers were placed in a field about 150 ft south of the paint shop and about 1,000 ft north of Units 3 & 4. The samplers were about 100 feet below the elevation of the paint shop and about equal in elevation with the top of the cooling tower stacks of Units 3 & 4.

Two standard high-volume air samplers (Misco Model 680), used to collect total suspended particulates (TSP), were run in sequence at each site. Each sampler employed an 8 x 10-inch quartz fiber filter (QATP, Pallflex Corporation) and was operated at a flow rate of about 1.3 m^3/min (45 cfm) for a sampling period of 48 hours. Samples were not collected if rain was forecasted.

Following sample collection, the loaded filters were folded in half, sealed in their original prelabeled ziplock bag, and stored in a freezer at The Geysers until transferred to PG&E at the end of the study. At PG&E, the samples were stored in a freezer for up to one month, until they were analyzed.

Previous studies of arsenic at The Geysers have measured concentrations of total arsenic in the soil, condensate and cooling tower waters and residues, and in atmospheric aerosols in or near the geothermal development area. Arsenic speciation results were obtained only for the steam condensate and cooling tower waters. A brief summary of these studies was prepared by PG&E (Gans and Solomon 1990).

The atmospheric measurements of arsenic at The Geysers were performed by PG&E as part of The Geysers Air Monitoring Program (GAMP) during 1983/1984 and 1986/1987. GAMP sampling sites were located in Glenbrook and Anderson Springs, two communities situated just outside of The Geysers geothermal development area.

Total (standard high-volume air sampler) and size-fractionated (dichotomous virtual impactor; fine <2.5 µm and coarse 2.5-10 µm aerodynamic diameter particles) 24-hour samples of atmospheric particulate matter were collected at each site every sixth day during two 1-year periods (1983/1984 and 1986/1987).

The high-volume air samples were stored for future analysis, whereas the fine and coarse particle samples were analyzed using x-ray fluorescence spectroscopy (XRF), a method capable of determining only total arsenic and not the individual species. The statistically defined detection limit for the XRF analysis was only about 3 ng m^{-3}, and most of the repo...d data were below this value. Of the 500 fine and coarse samples collected, only 12 (2.4%) were greater than the detection limit and all of those were observed in the fine particle samples: 11 at Anderson Springs and 1 at Glenbrook. The maximum and second highest values reported were 14 and 6 ng m^{-3}, respectively. Depending on how zero values are interpreted (e.g., equal to the detection limit, half the detection limit, or as reported), annual average concentrations of arsenic ranged from less than 1 ng m^{-3} to 3.3 ng m^{-3} at both sites. The ARB summarizes the GAMP data and reports monthly average values ranging from 1-4 ng m^{-3} and annual average values ranging from 1 to 2 ng m^{-3} (ARB 1990b). Applying these concentrations to the unit risk factors reported by the ARB, the estimated number of excess cancer deaths due to airborne inorganic arsenic exposure at The Geysers would be from <1 to 26 cases per ng m^{-3} per million persons. The lower end of the range (1-3) corresponds to nonsmokers, whereas the upper end (11-26) to males who smoke heavily. This risk is greater than one in a million, and therefore, airborne arsenic at The Geysers may concern the ARB.

The ambient average arsenic concentration data collected at The Geysers during GAMP, may be artificially high because of the poor analytical detection limit of the method used to analyze the fine and coarse filter samples. In addition, arsenic speciation data were not obtained during GAMP. This is important because As(III) is more toxic and may represent a greater carcinogenic hazard than As(V), and the ARB and EPA health risk assessments (ARB 1990c, EPA 1984) assume only As(III) is present in ambient aerosols. Therefore, the risk due to airborne inorganic arsenic at The Geysers is probably lower than determined from the GAMP data.

SAMPLE PREPARATION AND ANALYSIS

The analytical method developed by Solomon (1984) was used for determining the concentration of the inorganic species of arsenic (arsenite and arsenate) in atmospheric particulate matter. This sensitive method includes a semimicro sample preparation procedure for extracting the arsenic species from the filter, while maintaining the initial As(III)/As(V) ratio, and a species-specific analysis procedure for determining the concentrations of As(III) and As(V) in the sample extract.

Analysis Procedure

A complete description of the experimental conditions and protocol can be found in the literature (Solomon 1984). The procedure resulted in a routine (day-to-day) detection limit of about 15-25 ng for each species, similar to results reported previously (Solomon 1984, Rabano et al. 1989).

QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance/quality control (QA/QC) procedures were implemented to ensure high quality data. Standard field and laboratory QA/QC procedures were followed and are summarized below.

Field Sampling

Multipoint calibrations of the flow rates for the high-volume air samplers were obtained before and after the study. This helped to ensure that filter clogging or other problems did not occur during the extended sampling period of 48 hours. After collection, samples were stored in their original prelabled ziplock bags at reduced temperatures (below 0°C) until analyzed. At all times, filters were handled with tweezers or talc-free gloves.

Chemical Analysis

The concentrations of all chemical species were determined by comparison to laboratory standards of known concentrations. Aqueous standards were diluted daily from more concentrated solutions prepared bimonthly from ACS-grade analytical reagents. The matrix of the daily standard matched that of the extraction solution.

Teflon vials containing 4.0 ml of 4.25 N HCl and known amounts of arsenite and arsenate (100 ng or 400 ng of each) were extracted and analyzed daily, along with the filter samples, to confirm that the arsenic species were stable and fully recovered throughout the sample extraction and analysis procedure.

For all samples, two identical portions from each filter were extracted in separate Teflon vials and analyzed separately as duplicates to obtain an estimate of the precision for the overall sample preparation and analysis procedure. Replicate analysis of the extract in each sample vial also was performed to ensure accurate and consistent results. Replicate values were first averaged and then duplicate values were averaged to determine the mean loading for an individual filter.

RESULTS AND DISCUSSION

Analytical Methods Evaluation

The sample preparation and analysis method for the determination of the inorganic species of arsenic (arsenite and arsenate) in atmospheric particulate matter (Solomon 1984) was evaluated by the Air Quality Unit at PG&E. The evaluation indicated that the method is capable of determining nanogram levels of As(III) and As(V), while maintaining the initial As(III)/As(V) ratio. The results are summarized in Gans and Solomon (1990).

Effect of Atmospheric Particles

A limited number of samples were analyzed to determine what effect the sample matrix might have on the recovery and stability of the As(III)/ As(V) ratio when atmospheric particles are present on the filter during analysis by the speciation method. The recovery of the standard additions was 60 ± 18% for As(III) and 102 ± 29% for As(V). These results are slightly different from those reported previously (Solomon 1984, Rabano et al. 1989). In the earlier studies, it was apparent that the presence of atmospheric particles on the filter caused 10-20% of the known addition of As(III) to be oxidized to As(V). In this study, it appears that 40% of the As(III), on the average, was lost during the sample preparation and analysis procedure, whereas As(V) was completely recovered. The As(III) values presented in this report were not corrected for this possible matrix effect.

The difference between this study and the previous work may be due to the low As(III) levels encountered at The Geysers or differences in the sample matrix (i.e., particle composition) at the different sampling locations. Further studies will be required to determine the cause of these observed small differences.

ATMOSPHERIC MEASUREMENTS

Atmospheric particulate matter samples were collected at The Geysers during 1989 and analyzed for As(III) and As(V) by the arsenic speciation method. (Solomon 1984).

1989 Total Suspended Particulate Matter (TSP) Samples

Table 1 presents the As(III) and As(V) concentrations (ng/m^3) measured in the TSP samples collected at the East and West Geysers sites during April and May 1989. In this table, the less-than values are equal to the atmospheric detection limit (ADL) calculated for that filter. Based on nominal conditions, the ADL is about 0.23 ng/m^3. It varies because the analytical detection limit, flow rates, and sampling time varied slightly from sample to sample.

The errors listed in Table 1 for values greater than the LOD were determined by propagating the average precision for the analysis and for the sample volume. The overall average analysis precision, defined as the average coefficient of variation and based on the duplicate and replicate analyses, was 12% for As(III) and 13% for As(V). These values reflect the precision near the detection limit of the method, because most of the measurable values are near the LOD of the analysis procedure. The average sample volume precision was estimated to be 3%. For values that were measurable, but less than the detection limit, the stated error is equal to the detection limit for that sample.

In general, As(III) and As(V) levels were higher at the East Geysers site than at the West Geysers. Average concentrations at the East Geysers for As(III) and As(V) were 0.54 ng/m^3 and 2.9 ng/m^3, respectively. At the East Geysers, only two samples had As(III) concentrations greater than 1 ng/m^3, while most As(V) values were greater than 1 ng/m^3. At the West Geysers, average concentrations were generally less than the detection limit for As(III) and about equal to 0.46 ng/m^3 for As(V). Only one sample at the West Geysers was above 1 ng/m^3. The highest (As(III) = 3.08 ng/m^3; As(V) = 6.54 ng/m^3) and second highest (As(III) = 1.51 ng/m^3; As(V) = 5.96 ng/m^3) values for both species were observed at the East Geysers on April 15-16 and on May 18-19, respectively. No unusual conditions were reported for either date.

Time series plots of the As(III) and As(V) concentrations observed at the two monitoring sites indicate differences in arsenic concentrations at both sites.

At the East Geysers, As(III) and As(V) track each other closely (0.83). This observation suggests either similar sources for both species, or more likely, similar variations in meteorologic conditions that are controlling the atmospheric loadings of arsenic in the air. It is not known if a similar situation exists at the West Geysers, since the As(III) concentrations were below the detection limit.

The differences in arsenic concentrations observed between the two sites may be due to local meteorology (e.g., the East Geysers site may have been below the inversion layer more often because it was 50 ft above the valley floor, whereas the West Geysers site was 600 ft above the valley floor) or the impact of the different sources in the area. Other reasons also may exist; however, the reasons for the differences cannot be determined from this limited data set.

Total arsenic, equal to the sum of As(III) and As(V), ranged from less than the detection limit to 9.6 ng/m^3, with an average value of 2.8 ng/m^3 at the East Geysers and 0.69 ng/m^3 at the West Geysers. These averages include less-than values as equal to the stated detection limit for that sample. Total arsenic concentrations observed in April and May during the 1983/1984 and 1986/1987 GAMP program ranged from less than the detection limit to 6 ng/m^3. It is difficult to define an average for these samples, because most of the samples were less than the detection limit of 3 ng/m^3.

Atmospheric levels of arsenic observed during this study appear to be similar to those observed during GAMP (i.e., most samples were less than 3 ng/m^3, with only a few values greater than 3 ng/m^3). However, it should be remembered that the 1989 samples were collected within The Geysers geothermal development area, whereas the GAMP samples were collected near two communities outside The Geysers. In addition, the 1989 samples were collected to maximize filter loadings by not sampling when rain was forecasted and by locating the samplers at sites expected to be below the inversion layer, if one developed. Therefore, the 1989 data likely represents a maximum for arsenic concentrations in the area during the study period. Additional sampling at sites within and external to The Geysers geothermal development area could define what differences exist between the various locations.

The averages reported here are consistent with averages reported by the ARB (ARB 1990b, 1990c) for the State of California. The ARB reports a statewide average of about 1.5 ng/m^3, and northern and southern California averages of 1.2 and 2.0 ng/m^3, respectively.

The ratio of As(III)/As(V) is presented in Table 1. The average ratio for the East Geysers was 0.21 with a maximum value of 0.47. An average value for the West Geysers could not be calculated, because most of the As(III) values were below the detection limit of 0.2 ng m^{-3}. These results are similar to those observed previously (Solomon 1984, Rabano et al. 1989) and indicate that both As(III) and As(V) are present in the atmospheric aerosol. More important, these results indicate that most arsenic at The Geysers is in the +5 (i.e., As(V)) oxidation state or in the potentially less toxic form.

Table 1. As(III) and As(V) Concentrations at East and West Geysers sampling sites.[a]

Site	Date	As(III) ng/m^3	As(V) ng/m^3	As(III)/As(V)
East Geysers	890411	0.17 ± 0.23	1.68 ± 0.22	0.10
	890413	0.47 ± 0.06	4.26 ± 0.56	0.11
	890415	3.08 ± 0.40	6.54 ± 0.86	0.47
	890417	0.23 ± 0.31	3.94 ± 0.52	0.06
	890419	0.46 ± 0.06	2.31 ± 0.30	0.20
	890421	0.17 ± 0.17	0.84 ± 0.11	0.20
	890423	0.17 ± 0.21	0.70 ± 0.09	0.24
	890429	0.06 ± 0.21	0.51 ± 0.07	0.12
	890501	0.46 ± 0.06	1.22 ± 0.16	0.38
	890503	0.14 ± 0.21	1.14 ± 0.15	0.12
	890505	0.18 ± 0.31	0.96 ± 0.13	0.19
	890508	0.52 ± 0.07	2.20 ± 0.29	0.24
	890511	0.29 ± 0.32	1.13 ± 0.15	0.26
	890513	0.22 ± 0.22	1.24 ± 0.16	0.18
	890515	0.08 ± 0.32	1.39 ± 0.18	0.06
	890518	1.51 ± 0.20	5.96 ± 0.79	0.25
	890520	0.98 ± 0.13	2.99 ± 0.39	0.33
	x ± σ	0.54 ± 0.75	2.29 ± 1.84	0.21 ± 0.11
West Geysers	890405	< 0.18	0.30 ± 0.04	-
	890407	< 0.25	0.35 ± 0.04	-
	890410	0.08 ± 0.18	0.74 ± 0.09	0.11
	890412	< 0.22	1.30 ± 0.17	-
	890414	0.09 ± 0.19	0.95 ± 0.12	0.09
	890416	0.19 ± 0.22	0.68 ± 0.09	0.28
	890418	< 0.24	0.17 ± 0.24	-
	890420	< 0.28	0.18 ± 0.28	-
	890422	< 0.24	0.26 ± 0.03	-
	890426	< 0.23	0.41 ± 0.05	-
	890428	< 0.30	0.59 ± 0.08	-
	890502	< 0.25	0.35 ± 0.04	-
	890504	< 0.30	0.08 ± 0.30	-
	890507	< 0.28	0.84 ± 0.11	-
	890509	< 0.24	0.27 ± 0.03	-
	890511	< 0.07 ± 0.24	0.21 ± 0.24	0.33
	890513	< 0.26	0.29 ± 0.04	-
	890517	< 0.25	0.28 ± 0.04	-
	890519	< 0.27	0.46 ± 0.06	-
	x ± σ[b]	0.22 ± 0.07	0.46 ± 0.32	0.20 ± 0.12
	x ± σ[c]	0.02 ± 0.05	———	———

[a]For less-than values (<), the error represents the detection limit for that sample. For samples where the error is greater than the sample value, the sample value was detected, but less than the detection limit (defined as twice the baseline noise), which is given as the error for that sample. Other errors are calculated based on the propagation of the analysis and sampling precisions.

[b]Upper limit, includes less-than values (<) as equal to the value given (i.e., the detection limit for that sample); all other values are included as given. For the AS(III)/As(V) ratio, the average includes only the value given.

[c]Lower limit, includes less-than values (<) as equal to zero; all other values are included as given.

CONCLUSIONS

The enactment of new regulations regarding air toxics along with ARB's report entitled "Public Exposure to Airborne Inorganic Arsenic In California" suggests that geothermal energy producers in California must remain aware of the current atmospheric levels of arsenic at The Geysers. These producers must also be able to provide evidence of the species-specific nature of the airborne arsenic if the regulatory climate changes to include the inorganic species of arsenic in health risk assessment calculations.

A method for the determining the inorganic species of arsenic (arsenite, As(III) and arsenate, As(V)) was evaluated and found to be capable of determining sub-nanogram levels of As(III) and As(V) in atmospheric particulate matter, while maintaining the initial As(III)/As(V) ratio in the aerosol collected on the filter. An atmospheric detection limit of approximately 0.2 ng/m^3 was obtained for both species.

It was determined that the aerosol matrix (i.e., composition of the collected particles) appears to interfere with the procedure by reducing the As(III) response by an average of about 40%. This effect can be compensated for by applying the method of standard additions. The As(V) response appears unaffected.

Arsenic(III) concentrations ranged from less than the detection limit (0.2 ng m^{-3} to about 3 ng/m^3, with an overall average for both sites of about 0.26-0.46 ng/m^3 depending on how values less than the detection are included in the calculation. The lower limit assumes less-than values as equal to zero and the upper limit assumes less-than values as equal to the detection limit. Arsenic(V) concentrations ranged from less than the detection limit (0.2 ng m^{-3}), but measurable, to about 6.5 ng/m^3, with an overall average for both sites of about 1.3 ng/m^3. Concentrations of both species were higher at the East Geysers site than at the West Geysers site.

Total arsenic concentrations ranged from the detection limit (0.2 ng m^{-3}) to about 9.6 ng/m^3, with an average for both sites equal to about 1.6 ng/m^3. This average value is very close to the statewide average of 1.5 ng/m^3, as determined by the ARB (ARB 1990b). These data would therefore suggest that The Geysers may not be an area of significant concern with regard to atmospheric arsenic concentrations, relative to the rest of California.

The average As(III)/As(V) ratio at the East Geysers was 0.21. The ratio was variable and ranged up to 0.47. An average ratio for the West Geysers site could not be determined, because most As(III) values at that site were below the detection limit of the method. These data indicate that As(V) was the dominant arsenic species and on the average equal to greater than 83% of the total arsenic measured. This may be important if future health risk assessments are based on the individual species of arsenic and not on total arsenic, as was recently done by the California Department of Health Services (ARB 1990c). One result of such a change may be to allow exemptions or amendments to some of the operations at The Geysers, which could reduce the financial impact of compliance on energy producers using geothermal power plants. It is suggested that this preliminary study be considered as a baseline to provide an indication of concentration levels. These results also can be used to support recommendations for a long-term study of arsenic at The Geysers, if the regulatory climate changes from requiring total to species-specific data on arsenic in the atmosphere.

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REFERENCES

Anderson, D., 1986. Review and evaluation of arsenic at The Geysers, Phase A: Summary of current information. Prepared by Steam Generation Department. Prepared for Research, Development, and Demonstration. Pacific Gas and Electric Company, San Ramon, CA.

Andreae, M. O., 1980. Arsenic in rain and the atmospheric mass balance of arsenic. J. Geophys. Res. 85:4512.

Appel, B. R., Y. Tokiwa, and E. M. Hoffer, 1984. Efficiency of filter sampling for arsenic in the atmosphere. Atmos. Environ. 18:219.

California Air Resources Board, 1990a. Status of Toxic Air Contaminant Identification. California Air Resources Board, Sacramento, CA.

California Air Resources Board, 1990b. Public exposure to airborne inorganic arsenic in California, final report to the Air Resources Board on Inorganic Arsenic, Part A. California Air Resources Board, Sacramento, CA.

California Air Resources Board. 1990c. Health Effects of Arsenic Compounds, final report to the Air Resources Board on Inorganic Arsenic, Part B. California Air Resources Board, Sacramento, CA.

California Department of Health Services. 1984. Health and Safety Code, Sections 39650 et seq., Food and Agriculture Code Sections 14021 et seq. California State Law Library, Sacramento, CA.

California Department of Health Services. 1987. Health and Safety Code, Sections 44321 et seq., California State Law Library, Sacramento, CA.

Environmental Protection Agency. 1971. National primary and secondary ambient air quality standards. Environmental Protection Agency. Federal Register, 36:8186.

Environmental Protection Agency. 1978. An Assessment of the Health Effects of Arsenic Germane to Low-Level Exposure. Environmental Protection Agency, Office of Research and Development. Washington, D.C.

Environmental Protection Agency. 1984. Health Assessment Document for Inorganic Arsenic, Report No. EPA-600/8-83-021F.

Gans, C. D. and P.A. Solomon. 1990. Arsenic Speciation in Atmospheric Aerosols at The Geysers. Environment, Health & Safety, No. 009.1-89.3, Department of Research and Development, Pacific Gas and Electric Company, San Ramon, CA.

Geysers Air Monitoring Program. 1982. Memorandum of understanding for The Geysers Air Monitoring Program. Northern Sonoma County Air Quality Management District.

Hemberg, S. 1972. Origins of human cancer. Vol. 4. Ed. by H. H. Hiatt. Cold Spring Harbor Laboratories, New York, p. 147.

Johnson, D. L. and R. S. Braman. 1975. Alkyl- and inorganic arsenic in air samples. Chemosphere 8:333.

Lisk, D. J. 1971. Ecological aspects of metals. N.Y. St. J. Med. 71:2541.

Maenhaut, W., W. H. Zoller, R. A. Duce, and G. L. Hoffman. 1979. Concentration and size distribution of particulate trace elements in the south polar atmosphere. J. Geophys. Res. 84:2421.

Nakamura, M., Y. Matsuzono, S. Tanaka, and Y. Hashimoto. 1989. Chemical form of arsenic compounds and distribution of their concentrations in marine atmospheres. The Chemical Society of Japan. 2:227.

National Academy of Science. 1971. Medical and Biological Effects of Environmental Pollutants: Arsenic. National Academy of Science, Washington, D.C. p. 117, 195.

Rabano, E. S., N. T. Castillo, K. J. Torre, and P. A. Solomon. 1989. Speciation of arsenic in ambient aerosols collected in Los Angeles, J. Air Pollution Control Assoc. 39:76.

Sawicki, E. 1967. Airborne carcinogens and allied compounds. Arch. Environ. Health. 14:46.

Solomon, P. A. 1984. Collection and Analysis Techniques for Studies of Atmospheric Arsenic Species. Ph.D. thesis, Department of Chemistry, University of Arizona, Tucson, Arizona.

Walsh, P. R., R. A. Duce, and J. L. Fasching. 1977. Impregnated filter sampling system for collection of volatile arsenic in the atmosphere. Environ. Sci. and Technol. 11:163.

Walsh, P. R., R. A. Duce, and J. L. Fasching. 1979. Tropospheric arsenic over marine and continental regions. J. Geophys, Res. 84:1710.

VERSION (REPRINT) of 1989 paper presented @ GRC This is to go INTO Geysers Monograph This is a paper

AMBIENT AIR H_2S MONITORING AT THE GEYSERS: FROM NONATTAINMENT TO ATTAINMENT

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ABSTRACT

The results of three ambient air monitoring programs performed downwind of The Geysers, California, are described. These studies, conducted since 1976, have monitored the declining ambient air concentrations of hydrogen sulfide (H_2S) in Lake County. During the 13 years of monitoring, geothermal power production has increased from approximately 500 to 2,000 MW, H_2S emissions from power plants have declined from 1,900 to less than 200 lb/hr, and ambient H_2S concentrations have significantly declined. Annual average concentrations of H_2S at four long-term sites have declined by a factor of 3.0, maximum H_2S concentrations have declined by a factor of 3.6, and the frequency of violation of the California Air Quality Standard (0.03 ppm) averaged over 1 hour has declined from an average frequency of 52 times per year to almost 0. The area has not had a recorded violation of the air quality standard since August 1987. As such, the area has gone 3 years without a violation was classified by the California Air Resources Board as "attainment" during their November 1990 review process.

INTRODUCTION

Pacific Gas and Electric Company (PG&E) has been a participant in several air monitoring programs for ambient concentrations of hydrogen sulfide (H_2S) in Lake County, California. This area is predominantly downwind of The Geysers, an area producing geothermal steam used to operate power plants generating over 2,000 MW of electricity. The Geysers is located in the Mayacamas Mountains, 90 miles north of San Francisco.

Three distinct monitoring programs have been conducted since 1976. The first program was initiated in 1976 and was conducted by SRI International. The SRI program was performed for 3 years and was funded by a consortium of industries. PG&E was the contract manager. Eight sites were monitored using continuous H_2S analyzers. Five of these sites were located in populated areas of Lake County (Kalm Ranch, Pine Summit, Whispering Pines, Anderson Springs, and Sawmill Flats) with two additional sites along the Lake-Sonoma County line (at the ridgeline east of The Geysers and one site west of The Geysers in Sonoma County). This network was complemented with additional meteorological measurements at each of the H_2S sites and along the ridgeline (Figure 1).

The second major program, The Geysers Air Monitoring Program (GAMP), began in August 1983 and continued until July 31, 1987. This program included continuous measurements for ambient H_2S at six sites and meteorological parameters at eleven sites (nine wind direction/speed and temperature/dew point sites and two acoustic sounder sites). H_2S was monitored at Pine Summit, Whispering Pines, Anderson Springs, Glenbrook, Hobergs, Anderson Ridge (1983-1984), and Binckley Ranch (1985-1987). GAMP was supported by a consortium of 15 power companies, steam suppliers, local air pollution control districts, the California Air Resources

Board (ARB), and the California Energy Commission. The Northern Sonoma County Air Pollution Control District (NSCAPCD) was the project manager for GAMP. PG&E performed the noncriteria monitoring, H_2S monitoring at two sites, and meteorological monitoring at three sites. The consulting firm, Environmental Systems & Services (ES&S), Kelseyville, California, performed the remainder of the monitoring and issued quarterly data reports to the GAMP consortium. The Lake County Air Quality Management District (LCAQMD) and ARB performed quality assurance activities for GAMP.

The third major program, GAMP II, began on August 1, 1987, at the conclusion of GAMP. GAMP II is basically a modified extension of GAMP. Four of the GAMP H_2S monitoring sites (Whispering Pines, Anderson Springs, Glenbrook, and Pine Summit) were continued along with ridgeline meteorological monitoring at Unit 13 and Unit 17. At the beginning of 1989, the Whispering Pines site was discontinued and the Hobergs site was reactivated. This program was continued as GAMP III with 3 sites in early 1991. The monitoring performed in GAMP II is performed solely by PG&E under contract to the NSCAPCD under a similar arrangement as occurred in GAMP. The LCAQMD and ARB continue to provide quality assurance/quality control (QA/QC) work to the GAMP II consortium. GAMP III will be a three station H_2S monitoring network, plus ridgeline meteorological monitoring, lasting 3 years.

Between the conclusion of the SRI program and the beginning of GAMP, isolated monitoring occurred at Pine Summit (NSCAPCD), Anderson Springs (LCAQMD), Whispering Pines (PG&E), and Hobergs (PG&E). Each of these sites was operated and maintained independently with no uniform QA/QC procedures in use among the sites. In addition, each of these sites began operation at different times using different analyzers. As such, data collected from these sites were not as well controlled as the data collected during the larger programs. The LCAQMD also performed monitoring at Kelseyville, independently from GAMP, during the latter part of GAMP.

For this paper, we have collected all of the original H_2S monitoring data and entered it into a computer. For the SRI data, we were able to obtain magnetic tapes of the data from SRI. For the GAMP data that ES&S reported, we manually keypunched the data and then entered the data into the computer. The PG&E GAMP and GAMP II data were already in a computer database as a result of our data

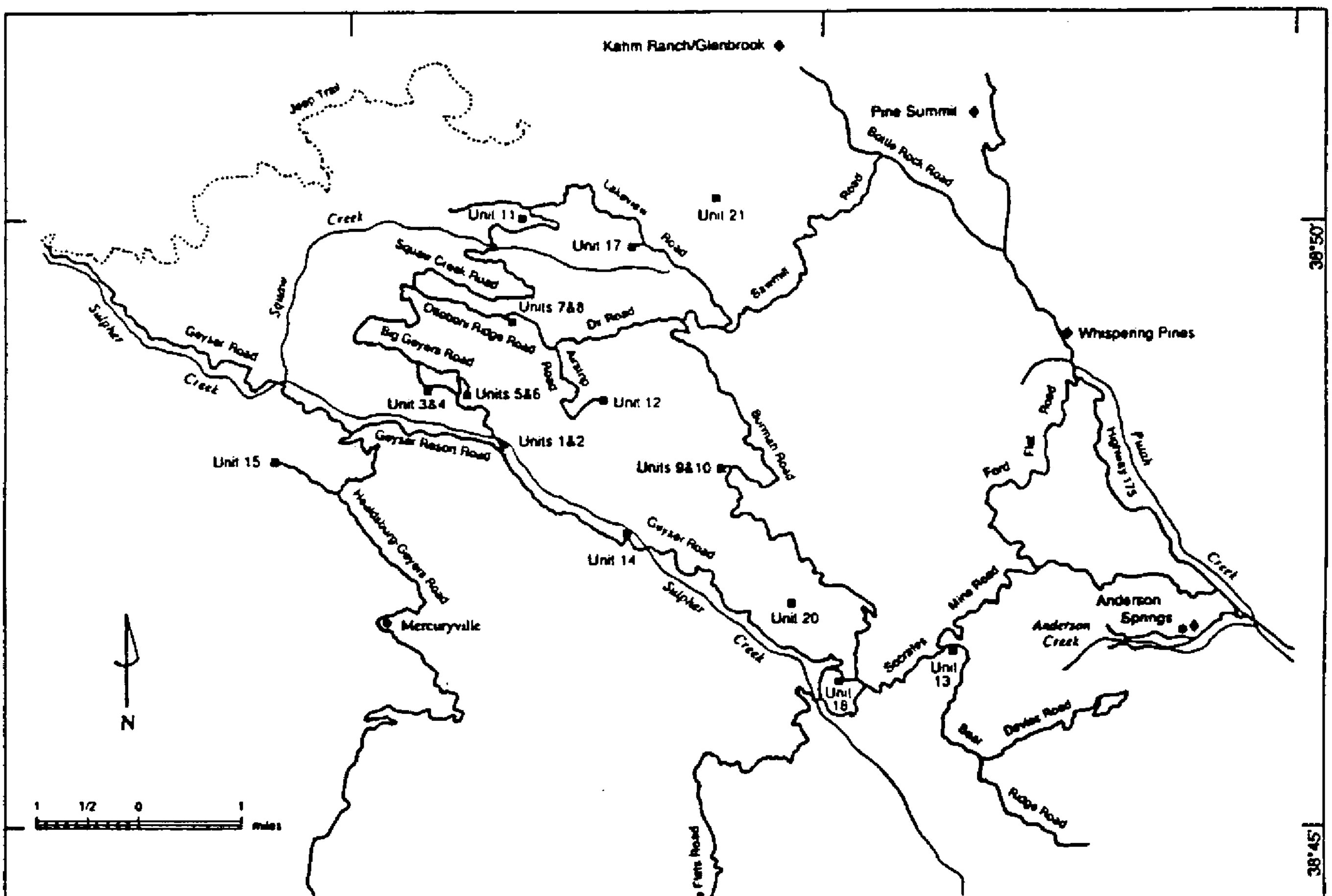

Figure 1. Air monitoring stations at The Geysers.

processing activities. Once compiled, we analyzed the data using PG&E software to generate the desired statistics and analyses.

METHODS FOR MEASUREMENT AND ANALYSIS OF HYDROGEN SULFIDE

SRI Program: SRI deployed an H_2S monitoring network of six Houston Atlas and two Tracor analyzers. The Tracor analyzers were sited at Pine Summit and Anderson Springs, with the Houston Atlas analyzers at the remaining six sites. The Houston Atlas analyzer used a lead acetate impregnated paper tape for detection of H_2S. The Tracor analyzer used gas chromatography and flame photometry to measure H_2S and sulfur dioxide. H_2S data were reported to the nearest 5 ppb.

GAMP: Meloy and Monitor Labs flame photometric analyzers and Thermo Electron (TECO) Model 45 pulsed fluorescence analyzers were used by ES&S at its four monitoring sites. PG&E used TECO Model 43 sulfur dioxide analyzers retrofitted with TECO Model 340 hydrogen sulfide to sulfur dioxide converters to measure ambient H_2S concentrations at The Geysers. Sulfur dioxide scrubbers were also used to prevent its interference. H_2S data were reported by ES&S to the nearest 1 ppb with a lower detection limit of 4 ppb.

GAMP II: PG&E again used TECO Model 43 sulfur dioxide analyzers, retrofitted with TECO model 340 hydrogen sulfide to sulfur dioxide converters, to measure ambient H_2S concentrations at The Geysers. Hourly concentrations of H_2S were reported by PG&E to the nearest 1 ppb.

RESULTS OF THE THREE PROGRAMS

Tables 1 through 4 list maximum concentrations, annual averages, and the number of violations of the hourly Ambient Air Quality Standard (AAQS) (0.03 ppm) for 1976-89 at the four sites with the most continuous data records. These sites are Pine Summit, Anderson Springs, Whispering Pines, and Glenbrook (originally Kalm Ranch during the SRI program). Our analysis interprets 25 ppb and greater as an exceedance of the state 0.03 ppm AAQS, which is consistent with NSCAPCD and LCAQMD policies.

Tables 1 through 4 reveal the results of aggressive reduction of H_2S emissions from power plants and steam field activities at The Geysers. From 1976 to date, electric power production capacity has increased from 500 to 2,000 MW, a factor of 4. In addition, while power production was increasing at The Geysers, H_2S emissions were being abated from existing geothermal facilities (power plants and steam field activities). In 1976, H_2S emissions from electric power plants were estimated to be over 1,900 lb/hr; in 1988, the H_2S emissions were estimated to be less than 200 lb/hr including steam field releases (Tolmasoff,

Table 1. Pine Summit Data Summary

Year	Max. Hr. Conc. (ppb)	Annual Avg. (ppb)	No. Hrs.> AAQS
1976	75	2.8	79
1977	75	1.9	116
1978	90	1.3	110
1979	55	na	na
1980	30	0.5	1
1981	45	0.5	na
1982	50	0.9	12
1983	38	0.7	10
1984	36	0.5	6
1985	50	1.0	13
1986	22	0.9	0
1987	20	0.6	0
1988	22	0.6	0
1989	17	0.6	0

Table 2. Anderson Springs Data Summary

Year	Max. Hr. Conc. (ppb)	Annual Avg. (ppb)	No. Hrs.> AAQS
1976*	35	1.0	6
1977*	60	2.3	58
1978*	30	1.9	8
1979	na	na	na
1980	35	3.8	na
1981	25	0.4	1
1982	28	na**	3
1983	23	na**	0
1984	13	1.0	0
1985	10	1.6	0
1986	8	1.2	0
1987	8	0.9	0
1988	9	0.8	0
1989	9	1.2	0

* 1976-1978 data collected at Jackass Flats; thereafter, data collected at Recreation Center

** Some of the na data are due to a lower reported limit of 10 ppb, which biased the annual averages.

personal communication, ????). Figure 2 shows the number of violations of the AAQS versus PG&E annual power production at The Geysers. Again, significant reductions in the number of violations have occurred while electric production has increased.

Close examination of Tables 1 through 4 reveals that annual average H_2S concentrations generally reached low and consistent levels in the early 1980s while peak hourly concentrations occasionally exceeded the AAQS. During the mid 1980s, increased control over steam field releases and power plant breakdown/upset conditions resulted in elimination of the few remaining vagrant hours of violation of the AAQS.

Table 5 summarizes the results of Tables 1 through 4. Except for the column of maximum hourly concentrations, all annual statistics are averages of data contained in the tables. Furthermore, 1976-1978 and 1987-1989 have been grouped and averaged to show the 10-year trend. Annual maximum hourly concentrations and average annual concentrations dropped by a factor of 3.6 and 3.0, respectively over the 10-year period. This reduction is consistent with the reduction in H_2S emissions occurring from geothermal facilities at The Geysers, which experienced a factor of 10 reduction. The average number of violations of the AAQS fell much more dramatically: the 1987-1989 period averaged almost 0 violations among the four monitoring sites. Since August 1987, no violations of the AAQS have been recorded at any monitoring site. As such, the area has gone

Table 3. Whispering Pines Data Summary

Year	Max. Hr. Conc. (ppb)	Annual Avg. (ppb)	No. Hrs.> AAQS
1976	40	3.5	79
1977	80	3.1	37
1978	50	2.2	55
1979	na	na	na
1980*	20	na	0
1981	30	0.7	3
1982	18	0.4	0
1983	24	0.8	0
1984	20	0.9	0
1985	25	0.9	3
1986	10	0.7	0
1987	19	0.6	0
1988	8	0.5	0
1989	discontinued		

* 1980 represents half a year of data.

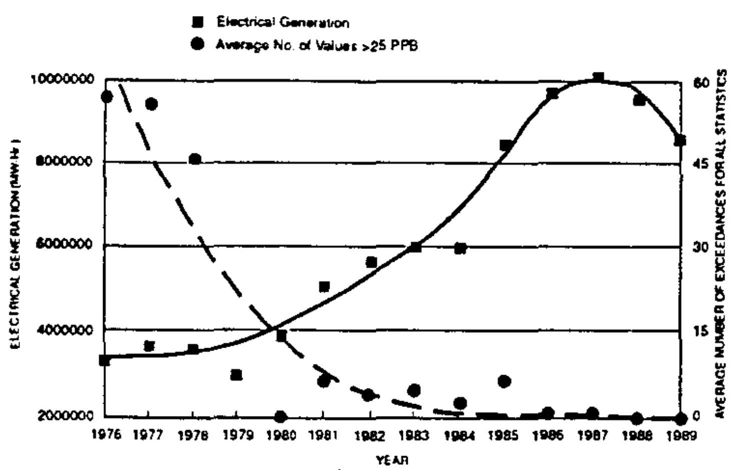

Figure 2. PG&E electrical generation and exceedances of the AAQS.

Table 4. Glenbrook Data Summary

Year	Max. Hr. Conc. (ppb)	Annual Avg. (ppb)	No. Hrs.> AAQS
1976*	65	2.1	63
1977*	50	2.0	12
1978*	75	2.0	10
1979	na	na	na
1980	na	na	na
1981	na	na	na
1982	na	na	na
1983**	42	na	7
1984	40	1.0	4
1985	38	1.2	5
1986	27	1.4	0
1987	27	0.5	2
1988	24	0.8	0
1989	16	0.8	0

* 1976-1978 data collected at SRI site Kahm Ranch, which is near the current Glenbrook site.

** 1983 represents about a half year.

Table 5. Summary Table, Average of Tables 1-4

Year	Max. Hr. Conc. (ppb)	Annual Avg. (ppb)	No. Hrs.> AAQS
1976	75 \	2.4 \	57 \
1977	80 = 82	2.3 = 2.2	56 = 53
1978	90 /	1.8 /	46 /
1983	42	0.8	4
1984	40	0.8	2
1985	50	1.2	5
1986	27	1.0	<1
1987	27 \	0.6 \	<1 \
1988	24 = 23	0.7 = 0.7	0 = <<1
1989	17 /	0.9 /	0 /

over 3 years without a violation of the AAQS and was designated as "attainment" by the ARB in their November 1990 review process.

CONCLUSIONS

The three programs described herein were progressive programs designed to assess the impact of geothermal steam utilization at The Geysers. The first program was initiated at the time of rapid development at The Geysers. From 1976 to 1989, electric power production increased four-fold, from 500 to 2,000 MW. During this same period, overall emissions of H_2S from power plants, including emissions from new sources, declined by about an order of magnitude from about 1,900 lb/hr to less than 200 lb/hr. Ambient concentrations of H_2S in the populated areas of Lake County, as evidenced by measurements at four sites with the longest and most continuous data set, showed a decline in the annual average by a factor of 3.0 and a decline in the peak hourly concentrations by a factor of 3.6. In comparing the 1976-1978 period with the 1987-1989 period, violations of the state AAQS declined from an average of 52 per year to almost 0. No violations have been recorded at any air monitoring site since August of 1987. As such, the area has gone 3 years since a violation of the AAQS was recorded. ARB designated the area as "attainment" in their November 1990 review process.

ACKNOWLEDGEMENTS

Bob Reynolds (APCO, LCAQMD), Mike Tolmasoff (APCO, NSCAPCD), Al Viesca (UNOCAL) and other members of industry should be acknowledged for their efforts in helping to create the two GAMP programs. Earlier, Carl Weinberg (PG&E) was instrumental in establishing the original SRI program.

The authors also wish to acknowledge the assistance of Jan Diaz, Bill Neesan, and R.L. Mulder for their work in preparing the data, and Larry Boardman for his field activities in providing a sound data base to build this paper.

Mike Tolmasoff and his staff at the NSCAPCD provided historical emission estimates.

7

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

P. O. BOX 621
HONOLULU, HAWAII 96809

WILLIAM W. PATY, CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES

DEPUTIES

KEITH W. AHUE
MANABU TAGOMORI
DAN T. KOCHI

AQUACULTURE DEVELOPMENT PROGRAM
AQUATIC RESOURCES
CONSERVATION AND ENVIRONMENTAL AFFAIRS
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION PROGRAM
LAND MANAGEMENT
STATE PARKS
WATER RESOURCE MANAGEMENT

REF:WRM-LN

NOV 13 1991

TO: Dr. John Lewin, Director of Health

FROM: William W. Paty

SUBJECT: Memorandum of Understanding Regarding Puna Geothermal Venture Noise Standards

Subsequent to the June 12, 1991 uncontrolled venting incident at Puna Geothermal Venture's well KS-8, new drilling and environmental standards have been adopted as promulgated in the State/County Geothermal Management Plan.

This memorandum of understanding is to clarify the role of the Department of Health and the Department of Land and Natural Resources in imposing and enforcing new noise standards applicable to the Puna Geothermal Venture's operations.

It is our understanding that proposed standards submitted by PGV shall be subject to approval by the State of Hawaii Department of Health and the County of Hawaii and will be added to the Puna Geothermal Venture Plan of Operations as an amendment.

Notwithstanding the fact that these noise guidelines will be attached to the Plan of Operations approved by our Department, enforcement and regulation of the noise levels shall be the sole responsibility of the Department of Health.

Rev. 11/90

DIVI N OF WATER RESOURCE MANA(ÆENT

FROM: ____________ DATE: ____________ FILE IN: ____________

TO: INITIAL: PLEASE: REMARKS:

TO	INITIAL	NAME	PLEASE
___	______	G. AKITA	____ See Me
___	______	L. Nanbu	✓ Take Action By______
			____ Route to Your Branch
___	______	E. Sakoda	✓ Review & Comment
___	______	G. Matsumoto	____ Draft Reply____
___	______	E. Lau	____ Acknowledge Receipt
___	______	L. Chang	____ Xerox ____copies
___	______	Y. Shiroma	____ File
___	______	______________	____ Mail
✓	______	______________	
___	______	______________	
___	______	______________	FOR YOUR:
___	______	______________	
___	______	______________	____ Approval
___	______	______________	____ Signature
___	______	______________	____ Information
___	______	M. TAGOMORI	
___	______	S. Kokubun	

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

JOHN C. LEWIN, M.D.
DIRECTOR OF HEALTH

RECEIVED
92 JAN 17 P 3:33
DIV. OF WATER & LAND DEVELOPMENT

In reply, please refer to:
File:

January 6, 1992

TO: Honorable William W. Paty, Chairperson
Department of Land & Natural Resources

FROM: John C. Lewin, M.D., Director
Department of Health

SUBJECT: Puna Geothermal Venture (PGV) Plan of Operations Noise Addendum

Attached is the amended Noise Addendum for the Puna Geothermal Venture Plan of Operations. The Geothermal Noise Control Program was finalized following numerous meetings and discussions with Maurice Richard of PGV.

Should there be any questions, please contact Jerry Y. Haruno, Chief, Noise and Radiation Branch, at 586-4701.

NOISE CONTROL PROGRAM
PUNA GEOTHERMAL VENTURE

A. ALLOWABLE NOISE LEVELS

1. Drilling and Well Testing Operations

55 dBA	Daytime (7:00 a.m. to 7:00 p.m.)
45 dBA	Nighttime (7:00 p.m. to 7:00 a.m.)

1.1. Allowable noise levels shall apply to any point along the boundary of Puna Geothermal Venture project site.

2. Drilling and Well Testing Operations (Well Pad "E")

55 dBA	Daytime (7:00 a.m. to 7:00 p.m.)
47 dBA	Daytime (7:00 p.m. to 7:00 a.m.)

2.1. Allowable noise levels shall apply to any residential property boundary (exterior) which may be impacted by the noise from the operations.

3. Power plant and steam field operations

53 dBA	Daytime (7:00 a.m. to 7:00 p.m.)
44 dBA	Nighttime (7:00 p.m. to 7:00 a.m.)

3.1. Allowable noise levels shall apply to any point along the boundary of Puna Geothermal Venture project site.

4. Construction Operations and General Activities

55 dBA	Daytime (7:00 a.m. to 7:00 p.m.)
45 dBA	Nighttime (7:00 p.m. to 7:00 a.m.)

4.1. Allowable noise levels shall apply at any point along the boundary of Puna Geothermal Venture project site.

5. Noise levels shall not exceed the allowable noise levels for more than ten per cent of the time within any twenty-minute period.

6. If sound measurements indicate levels exceeding the allowable noise levels specified above, the activity creating the excessive noise levels shall be terminated **OR** immediate mitigative measures shall be implemented.

7. The allowable noise levels shall be waived in cases of emergencies. An emergency is defined as an accident, imminent loss of equipment or unforeseen event requiring immediate action to protect public health, safety or welfare. All such emergencies shall be reported to the Noise and Radiation Branch as soon as possible.

8. The allowable noise levels shall be waived for a specified duration of 4 hours for authorized open geothermal well venting from all wells and for steam pipeline cleanout periods.

B. Conditions

1. Impact type noise shall be restricted to daytime hours (7:00 a.m. to 7:00 p.m.) whenever possible and safe. Impact noise means any sound with a rapid rise and decay of sound pressure level, lasting less than one second, caused by sudden contact between two or more surfaces, or caused by a sudden release of pressure.

2. Puna Geothermal Venture shall design project components generally consistent with the best available control technology (BACT) noise abatement measures.

3. Mitigation plans shall be submitted to the Noise and Radiation Branch prior to commencement of each phase of operation, in order to minimize noise emissions and insure compliance with the allowable noise levels. The Noise and Radiation Branch shall determine and insure BACT for each operational phase consistent with available technical resource information and recommendation.

4. The Noise and Radiation Branch or authorized representative shall have jurisdiction over noise investigations, enforcement procedures and noise monitoring.

GODDARD & GODDARD ENGINEERING

Environmental Studies

Dean Nakano
Department of Land and Natural Resources
Tom Arizumi, Chief Environmental Management
Paul Aki, Chief Clean Air Branch
Wendell Sano, Environmental Health Specialist
Clean Air Branch, Department of Health
State of Hawaii

July 10, 1991

Dear Dean, Tom, Paul and Wendell:

The data package covering items 3, 6, 7, 8, 9, 11 and 12 arrived yesterday. This information will be very helpful in our analysis.

I have talked to Dick Thomas, Chief of State of California, DOG and to Jim Moore about the Element I report. Dick suggests, and I concur, that the information would be very helpful in answering item 5 of my data request which characterizes the initial and continuing venting emissions. Dick suggested that the mud drilling logs would be helpful in establishing the estimated concentrations of hydrogen sulfide and carbon dioxide in the initial blow-out.

Please send a copy of the draft Element I report and the drilling logs to us for inclusion in the micrometeorological air quality impact analysis.

Item 4 of my data request concerns surveying those affected by the venting exposure. Jane Hedtke, Secretary of the Kapoho Community Association, has informed me of two surveys which have been circulated. I have asked Ms. Hedtke to plot the time and location of each respondent upon hourly maps so that we may compare health effect symptoms to the estimates of local hydrogen sulfide concentrations. It would be very helpful if some of your local staff could assist in this data request since it is a time consuming task. Ms. Hedtke can be reach at 808-965-7299 and FAXed at 808-965-8049.

As you know, time is of the essence since we must have our draft report completed by July 15, 1991.

Please make every effort to send the data requests by over-night mail or by FAX. We look forward to receiving items 1., 2., 4., 5. and 10. as well as any other information which you feel would assist in our report. Thank you for your assistance.

Sincerely,

Wilson B. Goddard, Ph.D.
Principal

Copies: Robert L. Reynolds, LCAQMD; Dr. Bruce Anderson, DOH; Ms. Hedtke

6870 Frontage Rd., Lucerne, CA 95458-8504 (707) 274-2171

June 30, 1991

Mr. Robert L. Reynolds
7467 Evergreen Drive
Kelseyville, CA 95451

Dear Mr. Reynolds:

This Letter of Agreement ("Agreement") sets forth the terms, conditions, mutual understandings, and provisions under which the Department of Health ("DOH") of the State of Hawaii ("State") engages your services as an independent consultant and participant in a third-party review of an incident of unplanned steam release ("incident") which occurred on June 12 and 13, 1991 at the plant site of Puna Geothermal Venture ("PGV") in Kapoho, Puna District, Island of Hawaii. The review is being coordinated jointly by (1) the State and (2) the County of Hawaii ("County"), with DOH serving as lead agency for the State and the County Planning Department serving as lead agency for the County.

1. Scope of Services. The review will focus on the adequacy of the State and County's air quality and noise monitoring programs in view of the incident. You shall serve as one of two members of a team which will: (1) review the existing noise and air quality monitoring programs; and (2) make recommendations for any appropriate changes in monitoring equipment, procedures, and sites. Data on air quality and noise impacts resulting from the incident will be provided by to you by DOH. A list of suggested tasks is attached herewith as a preliminary guideline. You may modify or add to this list as you deem appropriate. This Agreement requires timely submission of a written report ("report") further described herein.

2. Term. The aforedescribed services shall commence on July 1, 1991, and shall be completed on or before July 22, 1991, unless a delay is caused by DOH's failure to review the draft report in a timely manner, in which case an extension of time equal to the length of the delay shall be permitted.

3. Reimbursement for Costs. DOH agrees to compensate you for your time and daily expenses in Hawaii based on a daily rate (per diem) of $150.00. DOH agrees to reimburse you for the cost of your air travel to and from Hawaii. DOH agrees to compensate you for any additional

time you spend writing, editing, and finalizing the required report after you have completed the interviews and site inspection(s) in Hawaii and have returned home to the mainland, based on an hourly rate of $75.00. Payment shall be made by DOH upon receipt from you of a written statement or invoice.

4. Clerical Support, Office Space, Interisland Travel. Clerical assistance, office space, telephone access, ground transportation, and interisland air travel shall be provided by DOH at no cost to you while you are in Hawaii to participate in the review.

5. Independent Contractor. In the performance of the services required under this Agreement, you shall be an independent contractor with the authority to control and direct the performance and details of the work.

6. Review Team Cooperation and Interaction. The review team shall consist of yourself and Mr. Wilson B. Goddard. You shall cooperate with Mr. Goddard by sharing with him in a timely manner the information and data you obtain on the incident and on the State and Countys' noise and air quality monitoring programs. You shall cooperate with Mr. Goddard in the preparation of the report. Each of you shall exercise your considered professional judgment, reaching independent conclusions based on the facts as you discern them after objectively and thoroughly evaluating the evidence. To the extent that the conclusions and judgments of you and Mr. Goddard differ, these differences shall be reflected in the report.

7. Submission of Report. You shall submit the required report in draft form to DOH no later than 4:30 P.M. Hawaii Standard Time, July 15, 1991, either by mail, courier service or facsimile transmission. The report shall consist of: (1) an analysis of air and noise monitoring data compiled by DOH; (2) a presentation of conclusions drawn from site inspections and interviews with staff; and (3) recommendations for changes in the air and noise monitoring programs. Provided that DOH has approved the draft report or made comments by phone to you no later than 12:00 P.M. Hawaii Standard Time on July 17, 1991, you shall finalize and submit the final report to DOH by mail, courier or facsimile transmission no later than 12:00 P.M. Hawaii Standard Time on July 22, 1991. To the extent that DOH's approval or comments by

phone on the draft report are delayed past 12:00 P.M. Hawaii Standard Time on July 17, 1991, you may delay submission of the final report by the same amount of time.

8. Agreement to Provide Follow-Up Services if Requested. You agree, subject to your availability and upon receiving at least fifteen days prior notice from the State, and based on additional compensation acceptable to you, to travel to Hawaii in the future, if requested by the State or County, to discuss the report with officials and/or to provide testimony on the report in a public hearing or other public forum.

9. Hold Harmless and Defense Agreement. You and DOH each agree to hold the other harmless, and DOH agrees to defend you from any claim arising out of your performance under this Agreement or the submission or dissemination of the report.

10. Modification. Any modification of this Agreement shall be made only by written supplemental agreements executed by the parties.

If the terms, conditions and mutual understandings specified above meet with your approval, please indicate acceptance thereof by affixing your signature in the space below, and return the original of this Agreement to DOH, care of Dr. Bruce Anderson. A duplicate copy is enclosed for your records.

Very truly yours,

John C. Lewin, M.D.

ACCEPTED:

____

Date: ______________________

JCL/DRA:rr63091.ctr

June 30, 1991

Mr. Wilson B. Goddard
6870 Frontage Road
Lucerne, CA 95458

Dear Mr. Goddard:

This Letter of Agreement ("Agreement") sets forth the terms, conditions, mutual understandings, and provisions under which the Department of Health ("DOH") of the State of Hawaii ("State") engages your services as an independent consultant and participant in a third-party review of an incident of unplanned steam release ("incident") which occurred on June 12 and 13, 1991 at the plant site of Puna Geothermal Venture ("PGV") in Kapoho, Puna District, Island of Hawaii. The review is being coordinated jointly by (1) the State and (2) the County of Hawaii ("County"), with DOH serving as lead agency for the State and the County Planning Department serving as lead agency for the County.

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3. Compensation. DOH agrees to compensate you for your time in an amount not to exceed $4,000.00. based on an hourly billing rate of $100.00. Payment shall be made by DOH upon receipt from you of a written statement or invoice.

4. Independent Contractor. In the performance of the services required under this Agreement, you shall be an independent contractor with the authority to control and direct the performance and details of the work.

5. Review Team Cooperation and Interaction. The review team shall consist of yourself and Mr. Robert L. Reynolds. You shall cooperate with Mr. Reynolds in reviewing the noise and air quality data provided by the State and County, by discussing with him the adequacy of the State and County's air quality and noise monitoring programs in light of the incident, and in preparing the report. Each of you shall exercise your considered professional judgment, reaching independent conclusions based on the facts as you discern them after objectively and thoroughly evaluating the evidence. To the extent that the conclusions and judgments of you and Mr. Reynolds differ, these differences shall be reflected in the report.

6. Submission of Report. You and Mr. Reynolds shall submit the required report in draft form to DOH no later than 4:30 P.M. Hawaii Standard Time, July 15, 1991, either by mail, courier service or facsimile transmission. The report shall consist of: (1) an analysis of air and noise monitoring data compiled by DOH; (2) a presentation of conclusions drawn from site inspections and interviews with staff; and (3) recommendations for changes in the air and noise monitoring programs. Provided that DOH has approved the draft report or made comments by phone to you no later than 12:00 P.M. Hawaii Standard Time on July 17, 1991, you shall finalize and submit the final report to DOH by mail, courier or facsimile transmission no later than 12:00 P.M. Hawaii Standard Time on July 22, 1991. To the extent that DOH's approval or comments by phone on the draft report are delayed past 12:00 P.M. Hawaii Standard Time on July 17, 1991, you may delay submission of the final report by the same amount of time.

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If the terms, conditions and mutual understandings specified above meet with your approval, please indicate acceptance thereof by affixing your signature in the space below, and return the original of this Agreement to DOH, care of Dr. Bruce Anderson. A duplicate copy is enclosed for your records.

Very truly yours,

John C. Lewin, M.D.

ACCEPTED:

____

Date: ______________________

JCL/DRA:wg63091.ctr

GODDARD & GODDARD ENGINEERING

Environmental Studies

Dean Nakano
State of Hawaii
Department of Land and Natural Resources
FAX 808-548-6052

June 30, 1991

RE: Element III Air and Noise Review Data Request

Dear Dean:

I have been in contact with Robert Reynolds, Chairman, Element III Committee and reviewed the Suggested Tasks that you have outlined. The Tasks appear achievable within the three week review period provided that we have your group's assistance in promptly obtaining the necessary data.

Since we will be in frequent contact with Mr. Reynolds during his site visit, it will aid progress and communications if you will provide him with the following requests as well as supplying copies by over-night mail to us at G&GE. This will allow us to proceed with our analysis as well as provide Bob and I with data to discuss during his on-site review with your group.

The following data will be necessary for our review to begin:

1. A 7.5 minute USGS topographic quad map of the area extending for 10 km (6 mi) surrounding the site of the venting.

2. A 15 minute USGS topographic quad map of the area extending for 6 mi surrounding the site of the venting.

3. Photocopy portions of the 15 minute quad and mark the locations of the following items:
   a. Power plant site and the location of the venting accident.
   b. Locate and identify each air monitoring and noise monitoring site.
   c. Location of each residence within the 3,500 ft perimeter.
   d. Location of residences within 2 mi of the site.
   e. Location of each community, town or subdivision within 6 mi of the site.
   f. Location of any other sensitive receptors such as meeting halls, churches, nursing homes or similar sites located within 6 mi of the site.

4. Prepare an hour by hour sequence of events which identifies the location and symptoms of affected residents or other affected individuals. Use a copy of the item 3. maps to show the location of affected persons. During development of this data, try to distinguish symptoms as slight, moderate, strong, over-powering smell of hydrogen sulfide. Symptoms should include smarting eyes, coughing, congestion and headaches. Attempt to quantify the noise level as perceptible, loud, very loud and painfully loud.

   On any photocopied maps, provide a scale at the same resolution.

6870 Frontage Rd., Lucerne, CA 95458-8504 (707) 274-2171

5. Quantify for the duration hour by hour or at a shorter interval as needed the venting source as to rate and concentration including the following estimates:
   a. the steam rate in lb/hr including all noted changes;
   b. the temperature of exiting steam;
   c. the concentration of hydrogen sulfide;
   d. the concentration of other toxic constituents;
   e. the rate of particulate emissions in lb/hr;
   f. the size and chemical composition of the particulates;
   g. the size of the exit orifice;
   h. the height of the exiting steam; and
   i. the cardinal orientation in degrees from north of the exiting orifice

6. Provide the air quality, meteorological and noise monitoring data reduced to hourly averages as well as copies of the raw data in digital or strip chart form.

7. Provide a description of the instruments used, their calibration coefficients, and the mode of data acquisition for each recording instrument used in the monitoring program. Describe the Quality Assurance program for the monitoring program as well as when the latest calibrations were conducted.

8. Provide any other field data which augmented the stationary monitoring network during the event such as OSHA hydrogen sulfide and sound level meter measurements made with hand held instruments.

9. Provide the general synoptic meteorological conditions during the event. Synoptic maps and general weather descriptions from local newspapers will be adequate. Include a general description of the weather conditions from those on-site during the event including the degree of cloudiness, etc.

10. Provide any pictures or videos of the exiting steam or plume. Scale the pictures by relating to local objects such as the height of the drilling rig or other objects shown in the pictures or videos.

11. Provide copies of State and County regulations applicable to the permittee. Include pertinent sections applicable to the event from the Federal, State and County Health and Safety Regulations including OSHA standards.

12. Provide copies of State and County permit conditions.

This information will allow us to proceed with the necessary analysis. If you have any questions on the above information request, please give me a call at 619-764-2551 during the week of July 1, 1991.

We look forward to receiving the above information and proceeding with the Element III review.

Sincerely,

WB Goddard

Wilson B. Goddard, Ph.D. /CBG
Principal

RUSH **DRAFT**

June 28, 1991

MEMORANDUM

TO: The Honorable John Waihee
Governor, State of Hawaii

FROM: Susumu Ono
Dr. Bruce Anderson, DOH
Dean Nakano, DLNR
Dean Anderson, DBED

~~THROUGH~~: Murray E. Towill, Director, DBED
William W. Paty, Director, DLNR
Dr. John C. Lewin, Director, DOH

SUBJECT: Plan for Element III, an Independent Evaluation of the Geothermal Air and Noise Monitoring Programs

Element III is the third of three elements of the proposed Geothermal Action Plan outlined in the attached Memorandum. It will be a joint State/County effort to review the adequacy of the existing noise and air quality monitoring programs. This review is being conducted pursuant to the unplanned venting incident on June 12 and 13, and [which] caused residents to be affected by noise and hydrogen sulfide emissions.

1. Team of Investigators

It is important that this review be conducted by qualified experts outside the State and County regulatory agencies with experience in regulatory affairs and noise and air quality monitoring.

The investigation team will consist of the following two individuals: (1) Wilson B. Goddard, Goddard and Goddard Engineering; and (2) Robert L. Reynolds, Lake County Air Quality Management District.

In selecting the team, we sought a public sector consultant with considerable experience in geothermal regulation and an expert who was experienced in monitoring air quality. These individuals have excellent reputations for integrity and competence.

2. Contractual Arrangements

To be arranged.

3. Scope of the Review

The review will focus on the adequacy of the air and noise monitoring program in view of the unplanned release incident. The scope-of-work set forth in letters of agreement will call for the consultant to serve as a member of a team which will: (1) review the existing noise and air quality monitoring programs; and (2) make recommendations for any appropriate changes in monitoring equipment, procedures and sites. The State Department of Health (DOH) and the County Planning Department will serve as lead agencies in this review since they issue air permits and regulate noise, respectively. Existing data on air quality and noise impacts resulting from the incident will be provided by the DOH. We hope that this review can be accomplished within approximately three weeks.

4. Requirement for a Written Investigation Report

The agreements will require that a written report be submitted to the State by July ___, 1991. The report will consist of: (1) comments on air and noise monitoring data (available data will be compiled by DOH); (2) a presentation of conclusions drawn from a site inspections and interviews with staff; (3) recommendations for changes in the air and noise monitoring programs.

5. Use of the Report

The written report will be made public after the State and County determines that it is complete. The report will be used by DOH and the County as a basis for making decisions on appropriate changes in the air and noise monitoring programs.

ELEMENT III

REVIEW OF THE AIR AND NOISE MONITORING PROGRAMS AND PERMITS

SUGGESTED TASKS

1. Interview DOH staff involved in air and noise monitoring activities.

2. Review data on air quality and noise impacts resulting from the incident (compiled by DOH).

3. Evaluate equipment and sites for air quality and noise monitoring.

4. Determine if the permittee has been adhering to all State and County regulations and permit conditions.

5. Develop recommendations for changes in sites, procedures and, if necessary, equipment for air quality and noise monitoring.

FACSIMILE TRANSMISSION REQUEST

DEPARTMENT OF HEALTH FAX NO. (808) 548-3263

ADDRESSEE: (NAME ORGANIZATION & PHONE NO.)	FROM: (NAME, ORGANIZATION & PHONE NO.)
Dean Nakano DLNR x86461	DEPARTMENT OF HEALTH Dale

TOTAL PAGES (INCLUDING COVER PAGE)	DATE
4	6/28/91

REMARKS:

Dean,

Please review the memorandum to Governor to see if it is okay.

IF RETRANSMISSION IS NECESSARY, PLEASE CALL GERRY AT (808) 548-6210. THANK YOU.

EXECUTIVE CHAMBERS
HONOLULU

JOHN WAIHEE
GOVERNOR

FACSIMILE TRANSMITTAL

DATE: 6/28/91

TO: Dean Wakana
DCNR

FACSIMILE NO. 548-6052

FROM: Tom Yoneyama

COMMENTS OR SPECIAL INSTRUCTIONS: ATTACHED IS DRAFT OF Joint Release announcing review of monitoring program. Take a close look at first paragraph – wording? Look also at Reynolds title – is this correct? I couldn't determine from resume. Call me w/ corrections & questions.

Total number of pages, including this cover sheet 5

If you do not receive all pages, or if there are any questions, please call (808) 548-6422.

Transmitted from Facsimile No. (808) 548-1559

DRAFT

FRIDAY, JUNE 21, 1991 91-061

HILO--Governor John Waihee and County of Hawaii Mayor Lorraine Inouye today jointly announced the appointment of the evaluation team that will conduct a review of the State's Air and Noise Monitoring programs at Puna Geothermal Venture's geothermal site on the Big Island.

Robert Reynolds, the Air Pollution Control Officer for Lake County, California, has been hired as a third-party consultant and will begin on Monday, July 1, the process of gathering data and inspecting geothermal sites in evaluating the State's air and monitoring programs.

As the Air Pollution Control Officer for the Lake County Air Quality Management District, Reynolds is responsible for developing and enforcing various county, state and federal regulations and laws relating to air quality management--which, in Lake County, includes an emphasis on geothermal regulations.

Under his direction, Lake County has developed rules and regulations, implemented plans of performance for geothermal drilling operations, acquired and perfected the ability to perform geothermal steam and power plant source tests, initiated programs to automate and audit such procedures, developed new monitoring programs, and, in general, caused the implementation of the best available control technology in geothermal exploratory and production operations.

Upon completion of his on-site inspections, Reynolds will assess and evaluate his finding in consultation with Wilson Goddard, principal and chief research engineer with Goddard & Goddard Engineering, a private California company specializing in environmental research and impact assessment. From their evaluations, a written report will be prepared that should be completed by -------.

The review of the State's air and noise pollution monitoring programs is the third "element" of the Action Plan announced earlier by the State and County to evaluate recent uncontrolled steam release at the Puna geothermal site.

The first element was the creation of an independent, third-part, technical investigation into the cause or causes of the unplanned venting. The second element was an inter-departmental review of emergency response procedures to determine the adequacy of those procedures.

The elements, as distinguished from "phases", are discrete activities not necessarily sequential or inter-dependent.

#30#

June 28, 1991

To: Dr. Jack Lewin
Department of Health
State of Hawai
and
Dean Nakano
Department of Land and Native Resources
State of Hawai

From: Bob Reynolds, LCAQMD *Bob Reynolds*

I have had a chance now to talk with Bruce Anderson, Dean Nakano and Jack Lewin. The below is addressed to Jack Lewin with the assumption that this is the Department I am assisting, and references are made to conversations with all three of you. The intent is to ensure we have a chance to exchange our thoughts efficiently, understand mutual expectations, and what is desired to be accomplished. It is important for me to feel that my input is productive, otherwise my giving up vacation time to assist you in this matter makes little sense for me.

Scope of work issues.- The draft faxed by Bruce emphasizes the review of the air and noise monitoring program, and a review of permits. Hopefully (from a noise and air quality regulation standpoint) this can be refined to also assist the DOH in isolating and defining causes and indicators of such upsets in a manner that will assist in environmental management and improved public health and welfare protection. I understand that the incident evaluation will be ongoing but available from Ormat and the independent geologists presently on site and evaluating the drilling aspects of the incident. The refined goals would also include: 1) to learn from the experience in order to lessen and better manage the impact if such similar uncontrolled events reoccur; 2) remove to the greatest extent possible the likelihood that events will occur without appropriate mitigation in place; and 3) comment upon or assist in establishing an awareness of steps to be taken to manage and mitigate the possibility of such events. This aspect can be incorporated into your Task 4, and or serve as a basis for review of the existing permit(s). You should however understand that Task 4 itself, as presently worded, could take extensive time and is most appropriately accomplished after a good understanding of the overall picture and objectives of the permits. Any more than a precursory review by myself would be unlikely. This is especially true as regards regulations that I am probably not even aware of at this point.

Team Approach - I remain concerned, if I am to be the only reviewer, as to your expectations given the time frame, and I think Bruce, Dean and I have agreed upon a method to work which will still not delay the desired review. It was my suggestion that after the site visit, your Department, in a separate consultant contract, utilize other other parties to assist myself (perhaps one of those contacted or my staff) in preparing the review.

As I stated to Dean it is impractical to charge costs off against our AQMD budget and then be reimbursed by your Department(s). I therefore have charged the airline ticket against my personal credit card and desire to be reimbursed promptly. I assume your office is arranging for the remainder of the inter island flights, hotel and car. Should there be any problem please let me know promptly, and fax me a correspondence on this item.

Additional Information - I would like to have the following information provided upon arrival or as soon as possible thereafter.

1. Copy of current permits that are relevent, summaries of the incident that are available and likely to be helpful.
2. Topographic map showing sources, residents or other sensitive receptors and monitoring locations, two copies please. If possible, identify forested areas or other possible significant obstructions. Diagram(s) of the sampling stations and if appropriate a local more detailed map showing each station location.
3. A schematic or diagram of the layout of each station. Include the sampling manifold, probe setup, and shelter description. Identify any quality assurance program as well as audit program. State how often identified actions or steps are taken. This should, as necessary, be delineated for each station and operator (i.e., Ormat or DOH/DLNR).
4. Identify each instrument make and model, the type of instrument and the mode(s) in which it is operated. To the extent practical provide summary information on historical QA checks or audits, especially that performed by DOH on privately operated stations. Provide sample strip chart readouts, or other hard record methods of data reporting.
5. Diagram and layout of drilling operations indicating points of emission, flowrate, temperature, composition, and any on site monitoring.
6. If there is an onsite emergency plan, any monitoring that assists in this, including evacuating the drill site, please also provide that information.
7. Any available VCR tape or pictures relevent to the work anticipated including of the monitoring sites and equipment.
8. Names, titles and phone #'s of developer site and DOH/DLNR contacts and relevent staff.

Addition information, questions or points of discussion

1. Timing of DOH/DLNR Meeting - Will these occur before or after site interviews and visits? It might be best to delay spending significant time until I have a chance to review more of the current data and situation if that is also

consistent with your staff's desire. I appreciate the commitment expressed by Bruce Anderson and the desire to allow good information exchange between staff at the project site, your staff and myself. Presently, I am planning to fly from Santa Rosa and the times are as indicated at the end of this correspondence. If necessary, I could delay returning until Saturday or Friday evening (if a reservation can be arranged) and plan to meet with your staff on Friday.

2. Bruce and Dean mentioned the itinerary was open and left it to me. I assume that interactions with the DOH staff would be significant, and Dean also mentioned meeting with the Mayor of Hilo on Monday and a possible public hearing on July 3, 1991. Are there other meetings? Would you please make certain that any available written information describing the purpose or a tentative agenda is made available to me. I am proceeding under the assumption that I will be provided an opportunity to talk with industry staff on site, review drill logs, incident reports, and talk or meet with persons complaining of the incident.

3. Were any mitigation steps or technology to minimize air and noise impacts applied during the incident? Were they available at the site?

4. Will the report have other than time constraints?

5. It is my understanding that you are prepared to compensate myself for all travel and perdiem costs, and Dean, or your staff, have already made considerable arrangements. In addition work necessary in evaluating the information, value in using District equipment and staff time in preparing the written report will be directly compensated for by Hawai DOH/DLNR as a reimbursable cost to the Air quality Management District.

General Interest Questions

Is there any historical review of incidents and monitoring other than the present incident? Do you keep complaint forms? Apparently a similar incident did happen in the same area, can or was anything relevant learned from that incident about the monitoring or cause(s). How extensive is the mentioned assimilated monitoring data? Is ther actual source test data, or estimates of the range of emissions to compare to the ambient monitoring recorded. This is essential to estimate if retrospective studies are to be attempted and it is not available from records that presently exist.

United Airlines Santa Rosa to Honolulu

June 30,	Flight 3254	dep. SR 12:15 pm	arr. SFO 1 pm Need seat arrangement
	Flight 185	dep. SFO 1:40 pm	arr. Hon 3:54 pm, Seat 36F

United Airlines Honolulu to Santa Rosa

July 5	Flight 818	dep. Hon 9:15	arr. SFO 5:07 Seat 18H
	Flight 3257	dep. SFO 7:50	arr. SR 8:30 pm Seat 5B

Need to notify United Airlines at least 2 days in advance to change departure date without incurring penalty

FAX COVER SHEET

Date: 6-28-91   Log No.

Time: 11:10   Number of Pages: 4 (including cover sheet)

TO:

(Mr)/Ms. Jack Lewin

Of: Dept. of Health - Hawaii

FAX #: (808) 548-3263

FROM:

(Mr)/Ms. Robert L Reynolds

Of: Lake Co. Air Quality

Address:

FAX #: (707) 263-1052

SPECIAL INSTRUCTIONS: **COPY TO:**

- ☐ Confidential
- ☐ Urgent
- ☐ Please reply
- ☐ For your information

MESSAGE:

If not received correctly, please call:

Faxed June 28, 1991

To: Dr. Jack Lewin
Department of Health
State of Hawai
and
Dean Nakano
Department of Land and Native Resources
State of Hawai

From: Bob Reynolds, LCAQMD

I have had a chance now to talk with Bruce Anderson, Dean Nakano and Jack Lewin. The below is addressed to Jack Lewin with the assumption that this is the Department I am assisting, and references are made to conversations with all three of you. The intent is to ensure we have a chance to exchange our thoughts efficiently, understand mutual expectations, and what is desired to be accomplished. It is important for me to feel that my input is productive, otherwise my giving up vacation time to assist you in this matter makes little sense for me.

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page 4

FACSIMILE TRANSMISSION REQUEST

DEPARTMENT OF HEALTH FAX NO. (808) 548-3263

ADDRESSEE: (NAME ORGANIZATION & PHONE NO.)	FROM: (NAME, ORGANIZATION & PHONE NO.)
Dean Nakano DLNR	DEPARTMENT OF HEALTH Dan EH

TOTAL PAGES (INCLUDING COVER PAGE)	DATE
5	6/28/91

REMARKS:

IF RETRANSMISSION IS NECESSARY, PLEASE CALL GERRY AT (808) 548-6210. THANK YOU.

SENT BY:DOH ; 6-28-91 ; 9:04AM ; DIRECTOR'S OFFICE→ 8085488052;# 1

GODDARD & GODDARD ENGINEERING

Environmental Studies

Post-it™ Fax Note 7671 | Date 10/14/94 | # of pages ▶ 22
To ART SEKI | From H YOUNG
Co./Dept. HECO | Co.
Phone # | Phone #
Fax # 543-7519 | Fax #

Dean Nakano
State of Hawaii
Department of Land and Nat
808-548-7541

June 27, 1991

Dear Dean:

I will be pleased to assist as a member of the Element III, Independent Evaluation of the Geothermal Air and Noise Monitoring Programs. As we discussed, I will be developing a list of necessary items which will assist my review of the air quality monitoring.

I have enclosed a Statement of Qualifications for your use. I look forward to working with the review team on this important study of the air quality monitoring aspects of the well venting accident and in assisting in developing a useful set of recommendations.

Sincerely,

Wilson B. Goddard, Ph.D.
Principal

6870 Frontage Rd., Lucerne, CA 95458-8504 (707) 274-2171

GODDARD & GODDARD ENGINEERING

Environmental Studies

| | STATEMENT OF QUALIFICATIONS

May 31, 1991

6870 Frontage Rd., Lucerne, CA 95458-8504 (707) 274-2171

HAZARDOUS WASTE REDUCTION TECHNOLOGY

RESEARCH, DEVELOPMENT AND

DEMONSTRATION GRANT PROGRAM

LEGISLATIVE REPORT TO:

The California Legislature, pursuant to Section 25244.11, Chapter 6.5, Division 20, California Health and Safety Code Assembly Bill 685 of 1985, Farr
November, 1990

▾▾▾ CONTENTS

STEP II GRANT

▼▼▼▼▼▼▼▼▼▼▼▼▼▼▼

Project Budget:
Departmental funds Requested
$42,975

Non-Department Match:
Contribution
$4,775

Total Project Budget:
$47,750

Applicant:
Goddard & Goddard Engineering

Address:
6870 Frontage Road
Lucerne, CA
95458-8604

Location:
Coso KGRA
Coso Junction
Inyo County
CA 93542

Project Director:
Dr. Wilson B. Goddard
(707) 274-2171

Department Project Manager:
Mike Vives
Waste Management Engineer
(916) 324-1802

Contract #:
89-T0114

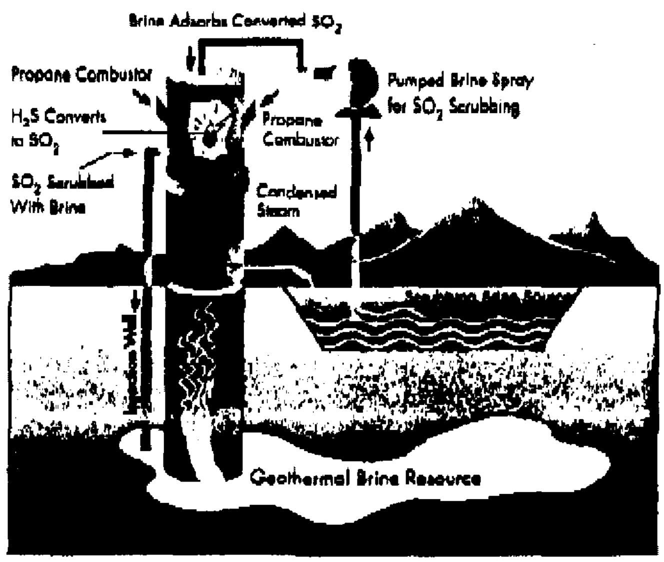
NONCONDENSABLE HYDROGEN SULFIDE EMISSIONS CONTROL SYSTEM

Project Abstract

This Step II design project follows a feasibility study in which this technology was shown to have potential for reducing hazardous wastes from the geothermal electric power-producing industry. The Step II project uses the information developed in the previous Step I grant to design and develop a pilot plant for incineration of geothermal noncondensable hydrogen sulfide gases. Unique design parameters to be studied include methodologies for maintaining stable furnace temperatures at the ignition temperature for hydrogen sulfide, which is below the ignition temperature of other flammable gases contained in the noncondensable gases. This will minimize unwanted products of incomplete combustion by avoiding combustion of other particulates and gases in the steam.

Final design parameters will be obtained for implementing a technology utilizing geothermal brine as a sulfur dioxide scrubber. This will eliminate the use of chemical sulfur dioxide abatement, which is a major source of hazardous waste. The final pilot plant design will include applications for electrically operated stationary incinerators and for portable propane air emission control operations. Bench pilot studies will be performed to obtain final design parameters and to evaluate the pilot plant designs. ▼

▼▼▼ Figure 8: Emission Control System Concept



Source: Contract # 89-T0114, Conceptual Sketch by Mike Vives, DHS Project Manager

FAX COVER SHEET

Date: 6-27-91 Log No.

Time: 9:20 Number of Pages: 7 (Including cover sheet)

TO:

(Mr)/Ms. Dean Nakano

Of: HI Native Land & Resources Agency

FAX #: 808 548-6052

FROM:

(Mr.)/Ms. Robert L. Reynolds

Of: LCAQMD

Address:

FAX #: (707) 263-~~[illegible]~~ 1052

SPECIAL INSTRUCTIONS: **COPY TO:**

- ☐ Confidential
- ☐ Urgent
- ☐ Please reply
- ☐ For your information

MESSAGE:

If not received correctly, please call:

JOHN WAIHEE
GOVERNOR OF HAWAII

JOHN C. LEWIN, M.D.
DIRECTOR OF HEALTH

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HAWAII 96801

In reply, please refer to:
File:

June 26, 1991

MEMORANDUM

TO: The Honorable John Waihee
Governor, State of Hawaii

FROM: John C. Lewin, M.D.
Director of Health

SUBJECT: Authority to Enter Into a Contract for a Review of the Air Quality and Noise Monitoring Program in Response to the Puna Geothermal Venture Unplanned Steam Release of June 12 and 13, 1991

This request is to provide for an independent third-party review of the air quality and noise monitoring program in response to the Puna Geothermal Venture unplanned steam release of June 12 and 13, 1991 to complement the review of the steam release as described in the memorandum from William Paty dated June 18, 1991.

The basic scope-of-work of this contract will call for technical experts to: (1) evaluate the adequacy of the air and noise monitoring program; and (2) make recommendations for any appropriate changes in monitoring equipment and sites. DOH will serve as the lead agency for this activity since it issues air permits and has enforcement powers in this area. We hope that this can be accomplished within approximately one month.

Our intention is to engage on a short term basis the technical assistance of a public sector regulator. The selection and review committee led by Mr. Susumu Ono will contact the appropriate individual.

This air quality impact review will include a review of equipment, procedures, and sites for air quality and noise monitoring. A written report will be made public along with recommendations based on the findings of these experts.

The estimated cost of the required consulting services will not exceed $10,000, including consulting fees, airfare, and travel expenses. If an employee of the state or county government is selected, it may be necessary to enter into agreements with agencies, such as the Lake County Air Quality District, in order to obtain the services of their personnel. Department of Health funds will be used.

We hereby request authorization to enter into these contracts.

APPROVAL/DISAPPROVAL

____
JOHN WAIHEE
Governor of Hawaii

Dated:____________________

FACSIMILE TRANSMISSION REQUEST

DEPARTMENT OF HEALTH FAX NO. (808) 548-3263

ADDRESSEE: (NAME ORGANIZATION & PHONE NO.)	FROM: (NAME, ORGANIZATION & PHONE NO.)
Dean Nakano DLNR	DEPARTMENT OF HEALTH Bruce Anderson DOH

TOTAL PAGES (INCLUDING COVER PAGE)	DATE
43	6/26/91

REMARKS:

IF RETRANSMISSION IS NECESSARY, PLEASE CALL GERRY AT (808) 548-6210. THANK YOU.

June 25, 1991

MEMORANDUM

TO: The Honorable John Waihee
Governor, State of Hawaii

FROM: Susumu Ono
Dr. Bruce Anderson, DOH
Dean Nakano, DLNR
Dean Anderson, DBED

THROUGH: Murray E. Towill, Director, DBED
William W. Paty, Director, DLNR
Dr. John C. Lewin, Director, DOH

SUBJECT: Plan for Element III, an Independent Evaluation of the Geothermal Air and Noise Monitoring Programs

Element III is the third of three elements of the proposed Geothermal Action Plan outlined in the attached Memorandum. It will be a joint State/County effort to review the adequacy of the existing noise and air quality monitoring programs. This review is being conducted pursuant to the unplanned venting incident on June 12 and 13, and caused residents to be affected by noise and hydrogen sulfide emissions.

1. Investigator

It is important that this review be conducted by a qualified expert outside the State and County regulatory agencies with experience in regulatory affairs and noise and air quality monitoring.

We have selected Robert L. Reynolds, Lake County Air Quality Management District. He will be responsible for preparing a report with recommendations.

In selecting Mr. Reynolds, we sought a public sector consultant with considerable experience in geothermal regulation who was also experienced in monitoring air quality and noise. He has an excellent reputation for integrity and competence.

2. Contractual Arrangement

To be arranged.

3. Scope of the Review

The review will focus on the adequacy of the air and noise monitoring program in view of the unplanned release incident. The scope-of-work set forth in a letter of agreement will call for the consultant to: (1) review the existing noise and air quality monitoring programs; and (2) make recommendations for any appropriate changes in monitoring equipment, procedures and sites. The State Department of Health (DOH) and the County Planning Department will serve as lead agencies in this review since they issue air permits and regulate noise, respectively. Existing data on air quality and noise impacts resulting from the incident will be provided by the DOH. We hope that this review can be accomplished within approximately three weeks.

4. Requirement for a Written Investigation Report

The agreements will require that a written report be submitted to the State by July ___, 1991. The report will consist of: (1) comments on air and noise monitoring data (available data will be compiled by DOH); (2) a presentation of conclusions drawn from a site inspections and interviews with staff; (3) recommendations for changes in the air and noise monitoring programs.

5. Use of the Report

The written report will be made public after the State and County determines that it is complete. The report will be used by DOH and the County as a basis for making decisions on appropriate changes in the air and noise monitoring programs.

ELEMENT III

REVIEW OF THE AIR AND NOISE MONITORING PROGRAMS AND PERMITS

SUGGESTED TASKS

1. Interview DOH/County staff involved in air and noise monitoring activities.
2. Review data on air quality and noise impacts resulting from the incident (compiled by DOH).
3. Evaluate equipment and sites for air quality and noise monitoring.
4. Determine if the permittee has been adhering to all State and County regulations and permit conditions.
5. Develop recommendations for changes in sites, procedures and, if necessary, equipment for air quality and noise monitoring.

FACSIMILE TRANSMISSION REQUEST

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Dean Nakano DLNR	DEPARTMENT OF HEALTH Bruce Anderson DOH

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4	6/26/91

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FACSIMILE TRANSMISSION REQUEST

DEPARTMENT OF HEALTH FAX NO. (808) 548-3263 X4139

ADDRESSEE: (NAME ORGANIZATION & PHONE NO.)	FROM: (NAME, ORGANIZATION & PHONE NO.)
Dean Nakano DLNR	DEPARTMENT OF HEALTH Bruce Anderson, Ph.d Deputy Director for Environmental Health

TOTAL PAGES (INCLUDING COVER PAGE)	DATE
4	June 24, 1991

REMARKS:

Correction on page 1. Revised letter attached.

IF RETRANSMISSION IS NECESSARY, PLEASE CALL GERRY AT (808) 548-6210. THANK YOU.

June 24, 1991

MEMORANDUM

TO: The Honorable John Waihee
Governor, State of Hawaii

FROM: Susumu Ono
Dr. Bruce Anderson, DOH
Dean Nakano, DLNR
Dean Anderson, DBED

THROUGH: Murray E. Towill, Director, DBED
William W. Paty, Director, DLNR
Dr. John C. Lewin, Director, DOH

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1. Team of Investigators

It is important that this review be conducted by qualified experts outside the State and County regulatory agencies with experience in regulatory affairs and noise and air quality monitoring.

The investigation team will consist of the following three individuals: ~~(1) James W. Morrow, M.S., Director, Environmental Health, American Lung Association of Hawaii;~~ (2) ~~Wilson D.~~

~~Goddard, Goddard and Goddard Engineering; and (3)~~ Robert L. Reynolds, Lake County Air Quality Management District. James Morrow will serve as the team leader and will be responsible for preparing a report with recommendations.

In selecting the team, we sought a public sector consultant with considerable experience in geothermal regulation and an expert who was experienced in monitoring air quality. These individuals have excellent reputations for integrity and competence.

2. Contractual Arrangements

To be arranged.

3. Scope of the Review

The review will focus on the adequacy of the air and noise monitoring program in view of the unplanned release incident. The scope-of-work set forth in letters of agreement will call for the consultant to serve as a member of a team which will: (1) review the existing noise and air quality monitoring programs; and (2) make recommendations for any appropriate changes in monitoring equipment, procedures and sites. The State Department of Health (DOH) and the County Planning Department will serve as lead agencies in this review since they issue air permits and regulate noise, respectively. Existing data on air quality and noise impacts resulting from the incident will be provided by the DOH. We hope that this review can be accomplished within approximately three weeks.

4. Requirement for a Written Investigation Report

The agreements will require that a written report be submitted to the State by July ___, 1991. The report will consist of: (1) comments on air and noise monitoring data (available data will be compiled by DOH); (2) a presentation of conclusions drawn from a site inspections and interviews with staff; (3) recommendations for changes in the air and noise monitoring programs.

5. Use of the Report

The written report will be made public after the State and County determines that it is complete. The report will be used by DOH and the County as a basis for making decisions on appropriate changes in the air and noise monitoring programs.

ELEMENT III

REVIEW OF THE AIR AND NOISE MONITORING PROGRAMS AND PERMITS

SUGGESTED TASKS

1. Interview DOH/County staff involved in air and noise monitoring activities.

2. Review data on air quality and noise impacts resulting from the incident (compiled by DOH).

3. Evaluate equipment and sites for air quality and noise monitoring.

4. Determine if the permittee has been adhering to all State and County regulations and permit conditions.

5. Develop recommendations for changes in sites, procedures and, if necessary, equipment for air quality and noise monitoring.

DRAFT

June 21, 1991

MEMORANDUM

TO: The Honorable John Waihee,
Governor, State of Hawaii

FROM: Murray E. Towill

THROUGH: Susumu Ono, Dr. John C. Lewin, William W. Paty

SUBJECT: Geothermal Action Plan Outline

This action plan consists of three "elements" as distinguished from "phases". The elements are discrete activities not necessarily sequential or interdependent. The basic idea is to implement each element as quickly as possible.

Element I: Independent Technical Investigation of the Puna Geothermal Venture Unplanned Steam Release, June 12 and 13, 1991.

Objectives:

Review drilling and blowout equipment and procedures for adequacy.

Involved agencies:

Cooperative effort of State DLNR, ~~DBED,~~ DOH, and County Planning departments.

Coordinators:

Sus Ono (lead); ~~Dean Anderson (DBED);~~ Dean Nakano (DLNR); and Norman Hayashi (County).

Specific Plan:

Attached; involves third-party consultants; contract authorization of Governor will be required; Director of DLNR will execute contract.

Schedule:

Start June 24, 1991; Complete July 7, 1991.

Deliverable:

Written investigation report to be submitted by third party consulting team.

Resulting Action:

Written third-party report to be used by DOH, DLNR, and the County as a basis for making decisions on any appropriate enforcement actions and on the continuation or lifting of the drilling suspension presently in effect.

Budget:

$30,000; DLNR and/or DBED general funds to be used.

Element II: Interdepartmental Review of Emergency Response and Evacuation Procedures

Objectives:

Determine the adequacy of present procedures; recommend improvements.

Involved agencies:

Cooperative effort of State DOH and County Planning, Civil Defense, Police, and Fire departments; also the Red Cross and possibly FEMA as an outside consultant.

Coordinators:

~~[Dr. Bruce Anderson or designate]~~ Mark Ingoglia (DOH);
Harry Kim (County).

Specific Plan:

To be developed cooperatively by State DOH and County.

Schedule:

To be determined by State DOH and County. Estimate approximately one month.

Deliverable:

Written report of findings and recommendations

Resulting Action:

Written interdepartmental report to be used by DOH and the County as a basis for making decisions on any appropriate changes in present procedures.

Budget:

Costs to be absorbed within existing DOH budgets.

Element III: Review of Air Quality Impacts Associated with the Puna Geothermal Venture Unplanned Steam Release of June 12 and 13, 1991.

Objectives:

Determine air quality, health, and noise impacts; evaluate the adequacy of the air and noise monitoring programs; and make recommendations for any appropriate changes in monitoring equipment, procedures and sites, and air permit conditions.

Involved agencies:

Cooperative effort of State DOH and County Planning.

Coordinators:

Dr. Bruce Anderson ~~[or designate]~~ (DOH); Norman Hayashi (County).

Specific Plan:

Attached; involves third-party consultants; contract authorization of Governor will be required; Director of DOH will execute contract.

Schedule:

Approximately three months.

Deliverable:

Written investigation report to be submitted by third party consulting team.

Resulting Action:

Written third-party report to be used by DOH and the County as a basis for making decisions on any appropriate changes in present programs and procedures.

Budget:

$20,000; DOH general funds to be used.

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