The Hawaii Geothermal Project: An Aerometric Study of Mercury and Sulfur Emissions

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Abstract

Predrilling environmental baseline studies and extensive ongoing comparative aerometry in volcanic and rift areas have made it possible to characterize the University Experimental Geothermal Well (HGP-A) as a low-Hg, low-HgS emitter and to account for high levels of Hg in the environs of HGP-A in terms of natural events and processes in Kilauea and the East Rift.

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The environmental program of the Hawaii Geothermal Project (HGP) was inaugurated in May 1975, coincident with final drill-site selection, and 7 months in advance of the December start of drilling operations.

(Kamins, et al., 1976). Aerometric data collected from May to August, 1975, gave no indication of abnormal levels of HgS or oxides of sulfur, nitrogen or carbon. These findings were not surprising, as the Kilauea East Rift was quiescent, and the closest readings carried only light and sporadic vehicular traffic in a rural setting. It was therefore somewhat surprising to find air Hg levels totalling 0.9 ± 0.4 μg·m⁻³ (by flameless atomic absorption spectrophotometry). This Hg consisted of HgO vapor, trapped on gold foil and ionic species, presumably as halide salts (Siegel and Siegel, 1978).

Similar total air values prevailed through June 1976, but when the well was first flashed, during July 1976, the ambient air Hg levels rose to 9.9 μg·m⁻³. Unfortunately there had been no opportunity to establish air levels during warmup or pre-warmup phases or flow tests after drilling was completed in April 1976. Unknown to the HGP environmental staff, a long quiescent cone, Heiheafahu, located on the East Rift some 15 km SW of wellhead (HGP-A) had begun fuming in late spring of 1976. (Eaton, 1977). This site was shown to be an active source of Hg and HgS. During the same period prior to flashing, air Hg levels at the Sulfur Banks fumerole area, 40 km NSW of HGP-A, reached nearly 50 μg·m⁻³.

It is virtually impossible to be familiar with the Island of Hawaii yet unaware of the proximity to HGP-A of a host of natural thermal sites. Nevertheless, a realistic assessment of the situation that yielded the high air Hg level when the well was flashed in July was only possible when the well was again scheduled for flashing after a nearly 2 month shutdown. On 31 October, prior to warmup, HGP-A ambient air yielded 16 μg·m⁻³ of Hg. During the warmup phase, 1-2 November, levels of 15-18 μg·m⁻³ were found, but on 3 November, after 4 hours flashing, the level had fallen to 7 μg·m⁻³, yet during the two weeks after the well was shutdown, values of 13-29 μg·m⁻³ were recorded.

The HGP-A baseline Hg level, varying around a mean of approximately 1 μg·m⁻³, is itself high, when compared with more representative air values of 0.003-0.030 μg·m⁻³ (McCarthy, 1970, Siegel and Siegel, 1979). This, taken together with other data that had accumulated by November 1976 suggested strongly that Hg measurements at HGP-A could not be interpreted without additional information about the activity status of the Kilauea system. This surmise was fully confirmed by (a) repeated direct measurement of Hg emission in steam condensate and (b) Hg aerometry before, during and after the Kalalua eruption of September 1977.

Expressed as emission, the steam plume releases as much as 10 g·24 hr⁻¹ at well startup but under stabilized flow conditions, approaches an asymptotic value of about 1 g·24 hr⁻¹ (fig. 1). This may be compared with Environmental Protection Agency Emission Standards of 2300 g or 1600 g in 24 hr for coal-fired electric and incinerator facilities, respectively (EPA, 1976). A low Hg content of about 1 μg·L⁻¹ is also characteristic of discharge waters (Kroopnick, et al, 1977).

The environmental impact of Kalalua eruption as reflected by Hg aerometry has been detailed elsewhere (Siegel and Siegel, 1978), but aspects of this study underscore the influence of natural process on the apparent quality of ambient air at HGP-A. (fig. 2 A and B).
Atmospheric Hg values about 1 km downwind from Kalalau crater and at the edge of Halemaumau Firepit in Kilauea are seen to rise to peak levels of 50-200 µg·m⁻³. The fumeroles (sulfur banks) followed, with an air maximum of slightly over 10 µg·m⁻³, and at HGP-A, which had been shut down for over 3 months, air Hg rose to about 5 µg·m⁻³ within two weeks following the onset of eruption activity. It is of interest to note in passing that the Heiheiahulu ambient exceeded about 5 µg·m⁻³ on some 6 weeks before the eruption began.

As noted the conspicuously high atmospheric baseline for Hg at HGP-A was not associated with high baseline values for other volcanic gases. This may be explained in part by the stability of Hg whether in elemental or oxidized form, allowing it to be transported long distances from source (Locke et al. 1974, Siegel and Siegel, 1978). An additional factor may be the presence of sulfur-free, Hg-rich natural emissions. A notable example is the Puhimau hot spot along the Chain-of-Craters Road in Hawaii Volcanoes National Park.

Unfortunately, little attention was given to H₂SO₄ during the earlier phases of the environmental program. In July and August, 1977, with HGP-A shut down, barium chloride/perchloric acid traps were deployed both around the wellhead and in natural fume areas of Kilauea, together with MSA and Bendix SO₂ detection tubes. At the wellhead and the nearest human habitation about 1 km to the West, levels of 250 µg·m⁻³ of H₂SO₄ were found without H₂S or SO₂. In contrast natural acid emissions ranged from 500-6,600 µg·m⁻³ and were accompanied by 3.5 to 5 ppm of SO₂, and by H₂S as well.

Although changes in well chemistry could not be ruled out at this early stage in development and reservoir assessment, necessitating continued surveillance for Hg and toxicants, thus far absent such as As compounds, our principle concern became H₂S. At the wellhead during four trials when the well was flashed for at least one hr, the highest H₂S level found directly in the plume averaged somewhat more than 3 ppm (fig 3A). Higher values, 5.5-7 ppm, were highly localized in low-lying steam discharges waters during warmup and startup stages, but these fell off to the 3 ppm level as well. The wellhead and its environs fall below the occupational units for H₂S of 10 ppm for 8 hrs (Threshold Limit Value, State of Hawaii, 1977) and 20 ppm for 5 min. (Short-term Limit Value, State of Hawaii), although natural emission sites in the Hawaii Volcanoes National Park may be frequently in violation. The more general environmental effects of wellhead H₂S are a matter of distance (fig 3B). The air concentration decay of H₂S averaged for three steam flow tests shows a 3-fold reduction from wellhead to 30 m, and an overall reduction of about 10-fold (to <30ppb H₂S) from wellhead to 100 m, both downwind. By comparison, the Sulfur Banks experimental sulfur well shows a higher output at source and stepper fall-off.
Fig. 3 Atmospheric H2S levels. A compares the Sulfur Banks with HGP-A wellhead levels on four dates when well was flashed. B compares data for the fall-off in air H2S with distance at the Sulfur Banks fumerole with data for HGP-A. Circles-HGP-A (left ordinate); Triangles—Sulfur Banks (right ordinate).

No detailed comparisons are needed to establish the fact that HGP-A is a remarkably clean geothermal source (Ellis, 1975, Sabadell and Axtmann, 1975, Siegel and Siegel, 1975), and is, hopefully, representative of the Kapoho Reservoir. The emissions chemistry is a matter of circumstance, but our ability to assess it accurately and realistically in its volcanic setting is a direct consequence of early, i.e. pre-drilling, baseline investigation, and the opportunity to carry out in-depth environmental chemistry on the natural thermal environments of Hawaii. A less comprehensive effort would have left the entire project vulnerable to the responses and reactions of the more sensitive environmentalists, and perhaps justly so.

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REFERENCES

