Mercury in Marijuana

Some of the problems arising from marijuana use might result from the intake of bioaccumulated mercury

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Plants are known to accumulate metals and metalloids from the environment. Often the metal content of vegetation is used to indicate local ore deposits or to detect pollutants (Cannon 1960, 1971, Vinogradov 1959, Warren et al. 1968). Mercury and its inorganic derivatives in plants have become increasingly recognized as coming from a variety of natural sources including thermal springs and volcanoes (Siegel and Siegel 1982, 1987a, Siegel et al. 1985, 1987). Without minimizing the significance of anthropogenic release of mercury into the biosphere by fossil fuel burning (Andren and Nriagu 1979) or the microbial formation of organic mercury compounds (Jensen and Jernelov 1969), abundant evidence now exists for natural volcanic and geothermal sites as major sources of environmental mercury available for uptake by vegetation (Phelan-Kotra et al. 1983, Siegel and Siegel 1984, 1987b, United States Geological Survey 1970, Varekamp and Buseck 1986).

Plants take up elemental mercury vapor (Hg^0) through their leaves from the atmosphere, and the ionic forms of mercury enter via the roots from the soil solution. Subsequently the plants return part of this mercury as Hg^0 to the environment (Anelli et al. 1973, Siegel and Siegel 1985, 1987 a, b, c). Mercury uptake occurs in primary producers at the base of the food chain, and it is a major human dietary concern. But the efficiency of mercury absorption by the gut is only approximately ten percent as efficient as that of the lungs (WHO Task Group 1976). Therefore, mercury in vegetation that is inhaled through smoking can have a far more significant impact than that that is ingested. Generally, tobacco (*Nicotiana* sp.) is grown in clay solids low in mercury. However, the best-quality marijuana

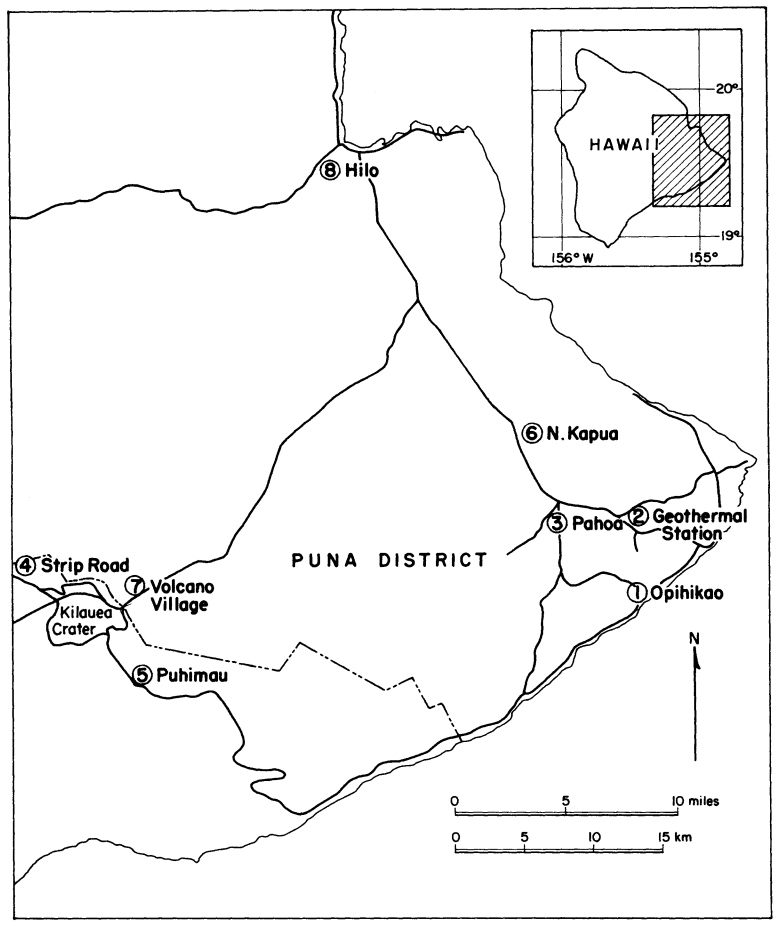

Figure 1. A map showing the Island of Hawaii (inset) and the location of the numbered plant collection sites (see Tables 2–4) in the Puna District.

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(*Cannabis sativa* L.) appears to come from areas known to have rich mercuriferous soils, such as Hawaii, California, and parts of Mexico. Chronic human exposure to mercury vapor results in a variety of symptoms, largely neurological, including forgetfulness, irritability, restricted visual fields, tremors, and paranoia.

Volcanism and plant mercury

Plants growing in regions of current or recent volcanism are likely to contain substantial amounts of mercury. Soils in these areas originate from igneous rock, which is rich in this element. Such locations are by no means rare given the wide geographic distribution of volcanic eruptions during just the past century (Table 1). Among the 51 global sites identified by Simkin et al. (1981), nearly half have been tested for the mercury content of their volcanic and geothermal emissions. In every case, the element was in volcanic extrusives, whether gaseous, aqueous, or magmatic.

The Hawaiian Islands, volcanic in origin, have relatively high natural baselines of environmental mercury and ubiquitous mercury-gathering plants. On the Island of Hawaii itself, where Kilauea and Mauna Loa volcanoes have erupted repeatedly and massively over the past century, a variety of plant species have been shown to accumulate this element. This vegetation includes the endemic forest dominant 'ohi'a (*Metrosideros polymorpha* Gaud. Rock) and the exotics— guava (*Psidium guajava* L.) and pluchea (*Pluchea odorata* L. Cass) (Table 2, Figure 1).

Among these species, the plant-to-soil concentration ratios range from 1.5 to 4.2, except at the thermally active Puhimau area. Here the ratio falls below 1.0, probably because the material in which the plants are growing is exceptionally rich in mercury, often reaching levels in excess of 7000 ng mercury per gram of substratum. Although the concentration ratios may vary according to species and local conditions, any plant growing in a mercury-rich environment might be expected to contain moderate to substantial amounts of the element. This generalization extends to cultivated plants (Siegel and Siegel 1987b) including tobacco, which ranges from 40 to 550 ng/g of tissue when exposed to experimentally high mercury levels (Anelli et al. 1973, Pelosi et al. 1976). It is no surprise, therefore, that *Cannabis sativa* L. growing in Hawaiian soils also contains mercury (Table 3), and that concentration ratios are similar to those found for other species analyzed—about 1.5 to 4.6 ng of mercury per g of plant material.

The bioaccumulation of mercury by *Cannabis* is not restricted to locations with recent volcanic activity but also includes places spatially and temporally distinct from historic eruptions (Table 4). For example, near the city of Hilo on the island of Hawaii, some 20 km east of the center of volcanic activity, air and soil mercury levels are much less than near the village of Volcano on the flank of Kilauea. Even lower mercury levels were measured at Pupukea on the north shore of Oahu (Honolulu County). Yet near Hilo and at Pupu-

Table 1. Global locations of volcanic eruptions 1886–1986 (Simkin et al. 1981).

Region/Continent	Country/Island	Region/Continent	Country/Island
Africa	Cameroon	South America	Argentina
	Canary Islands		Chile
	Ethiopia		Columbia
	Morocco		Ecuador
	Nigeria		Galapagos
	Red Sea		
	Tanzania		
	Uganda	Central and	Bonin Island
		Western Pacific	Indonesia
Central America/	Costa Rica		Japan
Caribbean	Guatemala		Java
	El Salvador		Kamchatka
	Martinique		Kurile Island
	St. Vincent		Marianas Island
			New Hebrides
Europe (including	Azores		New Zealand
Mid-Atlantic	Greece		Papua, New Guinea
Ridge)	Iceland		Philippines
	Italy		Samoa
	Jan Mayen Island		Solomon Island
	Tristan de Cunha		Sumatra
	Turkey		Sunda Island
North America		Antarctica	Erebus
Canada	Alberta		
	British Columbia	USA	Alaska/Aleutians
Mexico	Michoacan State		California
	Guerrero State		Hawaii
	Mexico State		Oregon
			Washington

Table 2. Mercury content of indicator plant species growing in the Puna District or adjacent to Hawaii Volcanoes National Park (HVNP), Hawaii County (see Figure 1).

Collection date	Site*	Sample	Mercury Content† (ng/g dry weight)	Plant Soil
July 1980	1. Opihikao (100 m)	'Ohi'a leaves	181 ± 9	1.97
		Pluchea shoot	176 ± 5	1.91
		Guava leaves	181 ± 17	1.97
		Soil	92 ± 10	
January 1981	2. Pohoiki Road near geothermal field (300 m)	'Ohi'a leaves	439 ± 56	4.26
		Pluchea shoot	161 ± 9	1.56
		Guava leaves	206 ± 124	2.00
		Soil	103 ± 20	
May 1982	3. South side of Pahoa Village (150 m)	'Ohi'a leaves	180 ± 6	2.14
		Pluchea shoot	182 ± 10	2.17
		Guava leaves	223 ± 15	2.66
		Soil	84 ± 8	
December 1985	4. HVNP—Mauna Loa Strip Road (200 m)	'Ohi'a leaves	38 ± 7	1.90
		Soil	20 ± 3	
	5. HVNP—Puhimau Thermal area (1300 m)	'Ohi'a leaves	539 ± 210	0.64
		Soil	846 ± 190	

*(Elevation above mean sea level)
†Mercury analysis by acid digestion and cold vapor atomic absorption spectrophotometry, as described in Siegel and Siegel 1984 and Siegel et al. 1985.

kea the flowers and even the leaves of marijuana remain surprisingly high in mercury, even though the last volcanic eruption took place in Honolulu County about 10,000 years ago and on the south side of Oahu (MacDonald and Abbott 1970). However, the soil and/or air concentrations of mercury apparently suffice to provide an effective reservoir for the vegetation, since no anthropogenic sources are known to exist in Hawaii.

Smoking mercury

Pelosi et al. (1976) and Andren and Harriss (1971) have shown that less than one percent of the mercury present in tobacco leaf remains in the ash after combustion ("smoking"), and the entire smoke content exists as Hg^0. Pyrolysis during the smoking process, as in tobacco, provides chemical reducing conditions and is probably no different than in any other dried plant biomass.

Smoking any form of *Cannabis* (e.g., marijuana, hashish, and bhang), therefore, can also introduce virtually the entire mercury burden into the lungs, where 75–85% of inhaled mercury is absorbed and retained. The deposited mercury undergoes almost complete absorption in the alveoli and is completely absorbed into the system within 40 hours. As a comparison, less than seven percent of the mercury is retained by the body after ingestion (WHO Task Group 1976).

In the course of smoking 1 kg of *Cannabis*, a person will retain 320 μg of Hg (80% of 400 μg). This mercury will enter the pulmonary circulation and be subject to redistribution into various organs, including the brain, as the element readily crosses the blood/brain barrier. In a human 1600-gram (fresh weight) brain, a total mercury content of 140 μg is considered normal (International Commission on Radiological Protec-

Table 3. Mercury content of *Cannabis* plants and associated soils collected in the Puna District, Island of Hawaii (Hawaii County) 1980–1986 (see Figure 1).

Collection date	Site	Sample	Mercury content (ng/g dry weight)	Plant soil
July 1980	1. Opihikao	Leafy 30-cm shoot	397 ± 31	4.36
		Soil	91	
January 1981	2. Pohoiki Road near geothermal field	Leafy 50-cm shoot	392 ± 26	4.56
		Soil	86	
May 1982	3. South side of Pahoa Village	Leafy 20-cm shoot	387 ± 38	3.99
		Soil	97	
October 1986	4. N. Kapua, near Belt Hwy., Puna	20-cm shoot	385	2.55
		Dried leaves	309 ± 24	2.05
		Soil	151	

Table 4. Mercury content in *Cannabis* plants of 1986–1987 collected from contrasting exposure conditions (See Figure 1).

Site	Ambient ranges		Mercury content (ng/g dry weight)			
	Air (ng/m^3)	Soil (ng/g)	Root	Stem	Leaves	Flowers
Hawaii County (Hawaii)						
7. Volcano (1000 m)	1500–10,000	100–400	70 ± 5	420 ± 12	430 ± 30	440 ± 40
8. Hilo (100 m)	100–600	20–50	–	<10	85 ± 5	280 ± 30
Honolulu County (Oahu)						
9. Pupukea (120 m)	75–100	10–50	55 ± 10	<10	90 ± 10	240 ± 32

tion 1974). This corresponds to about 0.09 μg/g. The threshold concentration for histopathological and/or behavioral disturbances in man and experimental mammals appears to be between 1 and 10 μg/g of brain tissue (Suzuki 1979) for long-term exposures to moderate mercury levels, with the critical organ being the brain. Unfortunately correlations between histological and/or behavioral changes and analyzed brain concentrations remain quite limited and incomplete, as do the consequences of low-level long-term (chronic) mercury intoxications.

The Joint FAO/WHO Expert Committee on food additives (1972) recommended, for the average adult, a "provisional tolerable weekly intake" of 300 μg of total mercury. In view of the recognized higher efficiency of the pulmonary route relative to alimentary uptake, the smoking of any vegetable matter containing the levels of mercury discussed here (280–550 μg/kg) seems to invite a significant additional risk to neurological/behavioral well-being. Smoking as little as 100 gms of marijuana per week may lead to more mercury being taken into the body than the prescribed "provisional tolerable weekly intake."

The symptoms of elemental mercury exposure are classic (and include the Mad Hatter of *Alice in Wonderland* and probably Sir Isaac Newton [Broad 1981]). Although there is great individual variation, the most commonly reported syndrome includes loss of memory, insomnia, lack of self-control, irritability and excitability, anxiety, loss of self-confidence, drowsiness, and depression. In the more severe cases, delirium with hallucinations, suicidal melancholia, or even manic-depressive psychoses have been detailed (WHO 1976). Acute *Cannabis* intoxication is also associated with a variety of learning and memory problems (Hooker and Jones 1987). We, therefore, propose that in certain instances the problems arising from marijuana use may result only partially from the cannabinoids within the plant, and that psycho/physiological disturbances might result from the intake of bioaccumulated mercury found in plants growing in both old and new volcanic regions including Hawaii, California, Mexico, and Central America.

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