

Collaborative USA-Vietnamese Agent Orange Research From 1968 to 2002:

Also Including German, Canadian, Dutch, Japanese
and Finnish Scientific Collaboration

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Introduction

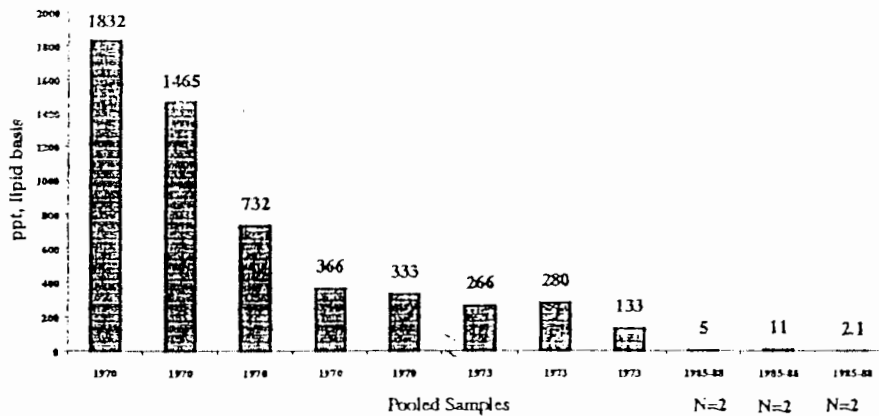
This paper selectively summarizes Vietnamese and United States collaborative research on Agent Orange and its dioxin contaminant, 2,3,7,8-TCDD. This work which began in 1968 includes TCDD measurements in approximately 3000 Vietnamese human and environmental samples; similar work in Cambodia and in Laos; and parallel work in the United States with American Vietnam veterans. Many of the published results are referenced in this paper (references 1-64). Major findings include the first measured 2,3,7,8-TCDD levels in humans and in food, with findings as high as 1,850 ppt TCDD, lipid, in human milk from fish-eating Vietnamese women living in a sprayed area in 1970, and up to 800 ppt TCDD in fish, whole weight.¹⁻⁵ Later studies from the 1980s and 1990s reported declining human tissue levels of TCDD; elevated TCDD in some southern food and wildlife; elevated TCDD in some sediment (and elevated higher chlorinated dioxins in sediment, this latter not from Agent Orange).⁶⁻¹¹ The newest findings, from Bien Hoa City as compared to Hanoi, show elevated blood TCDD (up to 413 ppt; comparison 2 ppt) in most residents sampled, some elevated TCDD in the presence of other dioxins in nearby river sediment, and one area of soil with over 1,000,000 ppt TCDD, apparently from a spill at an airbase which stored Agent Orange.¹²⁻¹³ The contamination of people is ongoing: some children born after Agent Orange spraying ended in 1971 and some new residents to Bien Hoa had elevated TCDD. This research documents exposure of humans to TCDD and environmental contamination with TCDD, primarily from Agent Orange, in selected areas in the south of Vietnam which were sampled because of known Agent Orange spraying.

Results

Figure 1 presents TCDD levels in milk samples from the south of Vietnam during three collection periods (1970, 1973, and 1985-88).³ Specimens from 1970 and 1973 were collected by John D. Constable and those from 1984 on were collected by A. J. Schechter, Le Cao Dai, and other Vietnamese colleagues. Fish eaters, especially from Can Gio and Tan Uyen villages, volunteered milk in 1970 and 1973 for TCDD analysis by R. Baughman in the laboratory of Mathew Meselson at Harvard University. The very high levels measured in the 1970s seemed to decline markedly over time (Figure 1). TCDD levels in northern Vietnam were much lower with TCDD concentration of 2.1 ppt when first measured in the 1980s.³

The plausibility of dioxin exposure through fish consumption was highlighted by levels measured by Baughman in fish and shrimp samples collected in 1970-73 as shown in Table 1. TCDD levels were found to be as high as 810 ppt in catfish and 540 ppt in carp (wet weight).⁵

Figure 1: 2,3,7,8-TCDD in Human Milk From the South of Vietnam, 1970-1988 (ppt, lipid basis)



The 1970 and 1973 analyses were from individual samples and were calculated assuming 3% milk lipid. Collection sites (1970 & 1973): the villages of Tan Uyen, Can Gio, Quang Xuen, Dau Tieng, and Huu Cuong.

Table 1: TCDD levels in fish and shrimp from southern Vietnam, 1970-73

Sample	Location	TCDD level (ppt wet weight)
Interior		
Carp (Cyprininae)	Dông Nai River	540
Catfish (Siluridae)	Dong Nai River	810
Catfish (Tachysuridae)	Dong Nai River	520
Catfish (Schilbeidae)	Sai Gon River	70
River Prawn (Palemonidae)	Sai Gon River	42
Seaside		
Croaker (Sciaenidae)	Can Gio Village	79
Prawn (Peneidae)	Can Gio Village	18

Table 2 shows TCDD levels in blood samples from population studies conducted in the early 1990s (in collaboration with Vietnamese researchers from medical schools and hospitals in northern, central and southern Vietnam). In this collection of over 2,500 human samples, we observed TCDD levels ranging from 1.2 to 6.1 ppt in the north, from 2.9 to 19.0 ppt in the center, and from 1.0 to 33.0 ppt in the south of Vietnam in individual as well as pooled samples that were analyzed.³ Total dioxin toxicity or toxic equivalents (TEQ) were as high as 104 ppt, due to contributions from other dioxins not characteristic of Agent Orange.

In some American Vietnam veterans, including sprayers of Agent Orange, elevated TCDD was reported.^{49, 51-52} Various dioxins were measured, although not elevated TCDD, in semen of American Vietnam veterans, potentially exposed to Agent Orange spraying.⁵³

Table 2: 2,3,7,8-TCDD and Dioxin Toxic Equivalents in Pooled Blood from Vietnam (1991-92)

Collection Date	Number	Mean Age	TCDD	TEQ	TCDD/TEQ	
Northern Vietnam (n = 166)						
Hanoi, Hospital 103	3/91	33	45	1.2	12.0	TCDD 1.2-29 (6.1)*
Tay Nguyen (veterans)	11/91	35	48	6.1	40.3	TEQ 12-18 (40.3)*
Quang Binh, Dong Hoa	1/91	50	47	2.9	17.2	
Thanh Hoa	11/91	50	55	2.9	18.0	
Central Vietnam (n = 490)						
Thua Thien, Hue	1/91	30	57	11.0	57.0	TCDD 2.9-19.0
Quang Tri, Quang Tri	1/91	50	51	9.5	34.0	TEQ 23-118.2
Da Nang, Da Nang	2/91	49	59	18.0	77.0	
Thua Thien, A Luc	1/91	35	52	15.0	23.0	
Kh. Hoa, Nha Trang	1/92	50	49	4.1	29.5	
Phu Yen, Phu Yen	1/92	43	51	6.2	26.4	
Ninh Thuan, Phan Rang	1/92	33	56	2.9	31.7	
Da Nang, Da Nang (18-40 y)	8/92	100	30	14.0	96.3	
Da Nang, Da Nang (>40 y)	8/92	100	56	19.0	118.2	
Southern Vietnam (n = 2062)						
Dong Nai, Tri An (Ma Da Forest)	3/91	50	47	12.0	19.0	TCDD 1.0-33.0
Cuu Long, Vinh Long	8/91	51	59	4.3	16.9	TEQ 8.7-104.6
Dong Nai, Bien Hoa	3/91	50	51	28.0	47.0	
Ben Tre, Gioong Trom	8/91	34	55	10.2	29.0	
Kien Giang, Go Quao	8/91	37	58	10.9	27.5	
Kien Giang, Rach Gia	8/91	48	58	4.9	17.3	
Minh Hai, Ca Mau	8/91	52	59	7.2	19.9	
Song Be, Song Be	3/91	47	47	9.0	48.0	
Song Be, Tan Uyen	3/91	48	54	32.0	55.0	
Tay Ninh, Tan Bien	2/91	50	60	5.3	25.0	
Tay Ninh, Tay Ninh	3/91	50	53	6.8	16	
Cuu Long, Tra Vinh	8/91	48	57	7.2	27.7	
Hau Giang, Can Tho	8/91	52	61	4.8	16.4	
An Giang, Long Xuyen	8/91	49	62	2.2	10.5	
An Giang, Chau Doc	8/91	46	56	3.5	16.8	
Ho Chi Minh, Cho Ray Hospital	2/91	48	54	10.8	30.0	
Minh Hai, Bac Lieu	8/91	50	60	10.3	34.8	
Gia Lai, Pleyku	1/91	50	57	4.2	34.2	
Tay Ninh, Chan Thanh	8/92	100	54	4.6	19.4	
Tra Noc, Can Tho	8/92	102	51	33.0	104.6	
Song Be, Tan Uyen (18-40 y)	8/92	100	32	9.4	25.4	
Song Be, Tan Uyen (>40 y)	8/92	100	51	5.7	18.9	
Song Be, Ben Cat	8/92	100	32	12.0	49.8	
Dong Nai (18-40 y)	8/92	100	51	14.0	61.0	
Dong Nai (>40 y)	8/92	100	53	19.0	53.7	
Tay Ninh, Hoa Thanh	8/92	100	50	1.0	38.8	
Song Be, Dong Xoi	8/92	100	50	3.1	8.7	
Tay Ninh, DM Chan	5/92	100	50	7.0	35.3	
Dong Nai, Bien Hoa (18-40 y)	5/92	100	47	7.3	22.8	
Dong Nai, Bien Hoa (>40 y)	5/92	100	N/A	12.0	49.0	

Note: N/A = not available; TCDD = 2,3,7,8-TCDD; TEQ = total dioxin toxic equivalent, (Lipid Basis, Parts per Trillion)

Elevated TCDD was also found in sediments collected by Schechter and Dai in southern Vietnam in 1984-86 and analyzed by Gross, Hites and colleagues as shown in Table 3. We found elevated TCDD levels from Agent Orange and also elevated higher chlorinated dioxins (not from Agent Orange) compared to northern sediment and sediment from certain other parts of the world.^{9,11}

Table 3: Vietnam Sediments Concentrations in Comparison to Average Total Concentrations in Lake Sediments of Industrialized Countries (pg/g)

Site	Total Concentration of PCDD/F	Site	Total Concentration	TCDD only *
		South of Vietnam		
Lake Huron	1240	Saigon River	6782	210 (6)
Lake Michigan	1600	Dong Nai River 1	1365	ND (21) ^b
Lake Erie	2150	Dong Nai River 2	838	
Lake Ontario	11000	Dong Nai River 3	1437	
Siskiwit Lake	730	Dong Nai River 4	1052	
Lake Zurich	1500	Dong Nai River 5	1433	
Lake Baldeg	1500	North of Vietnam		
Lake Lugano	2000	Red River 1	255	ND (47) ^b
		Red River 2	219	

* For TCDD only limit of detection in parenthesis; ^b Pooled sediments results for Dong Nai and Red River

Food collected in the 1980s in Agent Orange sprayed areas showed elevated TCDD in some southern samples as compared to both northern samples and to selected European samples. For instance, a pork fat sample from the south had 6.2 ppt, from Hanoi, 0.58 ppt, and from the Netherlands, 0.42 ppt TCDD. A chicken fat sample from the south measured 31.5 ppt, from Hanoi, 3.30 ppt, and from Holland, 1.61 ppt TCDD.⁷⁻⁸

Because 10 % of the south of Vietnam was sprayed with Agent Orange and none of the north was sprayed, most Vietnamese people probably were not contaminated and most food in or from Vietnam is probably low in dioxin content. We will present new data on dioxin levels in Vietnamese food exported to USA at this meeting.

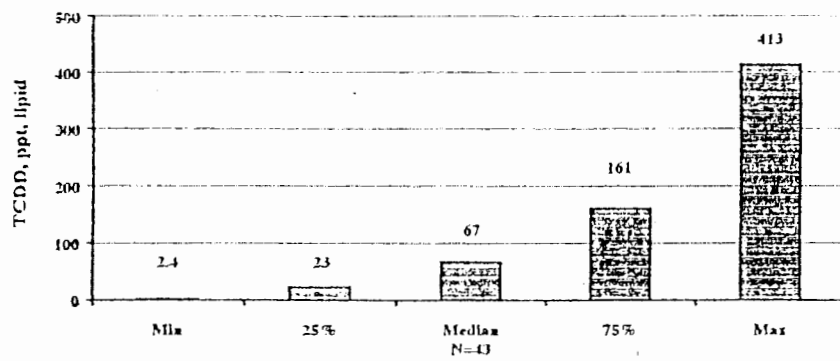
In the 1980s, we also reported elevated TCDD levels from limited samples of wildlife living in Agent Orange sprayed areas. The values of TCDD in turtle ovaries was 250 ppt, turtle liver 88 ppt, turtle gall bladder 39 ppt, and snake muscle 11.6 ppt.⁷⁻⁸

Bien Hoa City was the location of an airfield used for Agent Orange storage and spray missions. Spills of Agent Orange occurred there, especially in 1970. During 1999-2001, elevated TCDD was detected in the blood of most sampled residents of Bien Hoa City (Table 4 and Figure 2), with levels up to 413 ppt; whereas non-exposed persons averaged 2 ppt. Forty-one out of 43 blood samples (95 %) from Bien Hoa City have elevated TCDD (>5 ppt) and 15 subjects (36%) had TCDD levels above 100 ppt.¹³ This nearly 200-fold increase in human TCDD blood level exposure in Bien Hoa is almost certainly from current contamination of fish and other animal food.¹³

Table 4: Vietnamese blood TCDD levels, Bien Hoa City, 1999-2001

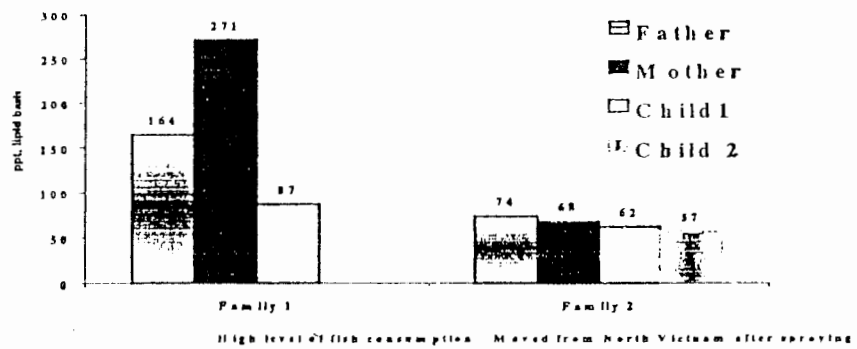
		TCDD level		TCDD level	
Sample	Year of Birth	(ppt lipid basis)	Sample	Year of Birth	(ppt lipid basis)
South Vietnam (Individual samples)					
1	1962	2.4	23	1942	68.3
2	1950	3.4	24	1962	70.2
3	1952	5.1	25	1935	73.9
4	1962	5.6	26	1960	76
5	1980	5.7	27	1980	87
6	1942	7.1	28	1985	91
7	1950	7.8	29	1962	101
8	1930	20	30	1966	102
9	1947	21	31	1963	103
10	1939	22	32	1963	154
11	1955	23	33	1959	161
12	1955	24	34	1954	162
13	1942	29	35	1955	164
14	1955	30	36	1958	168
15	1982	35	37	1982	174
16	1955	38	38	1985	177
17	1952	39	39	1967	236
18	1979	50	40	1950	238
19	1981	57	41	1954	271
20	1981	62	42	1963	326
21	1983	63	43	1973	413
22	1958	67			
North Vietnam (Individual samples)					
1	1930	1.6	4	1930	1.2
2	1924	1.9	5	1932	2.3
3	1939	1.4			
North Vietnam (pooled sample, n=100)					
Hanoi	1959-79	2.2			

Figure 2: Summary of Bien Hoa City Blood TCDD Levels, 1999-2001



As shown in Figure 3, some newcomers to the south of Vietnam (arriving after Agent Orange spraying ended) had elevated TCDD blood levels consistent with TCDD contamination subsequent to the end of Agent Orange spraying. Figure 3 also shows elevation in a sustenance fish eating family including a child born after spraying ended. These blood levels are of the same order of magnitude as found in 1970 and 1973 milk samples when Agent Orange spraying occurred or had recently ended.^{3, 12, 13}

Figure 3: TCDD Blood Levels in Bien Hoa City, 1999 - 2001



River and lake sediments collected in 2000 showed moderately elevated TCDD (Table 5) in 2000. TCDD was not detected in most Vietnam soil, but one sample from Bien Hoa airbase contained 1,100,000 ppt, presumably from an Agent Orange spill in 1970 (Table 6). A Canadian study conducted in central Vietnam also showed elevated TCDD in some humans and food samples.¹⁴ To date, no elevations of TCDD in humans or in environmental samples have been found in Cambodia or Laos.⁴⁵⁻⁴⁹

Table 5: Dioxin Levels in Sediment of Lake Bien Hung and the Dong Nai River, 1999-2001

	Hanoi	Bien Hung Lake-1			Bien Hung Lake-2			Dong Nai River		Bien Hung Lake-3	
		A	B	C	A	B	C	A	B	Down-Stream	Up-Stream
2,3,7,8-TCDD	ND	10	14	1.6	177	114	98	0.8	1.5	1.7	1.1
Total PCDD Measured	403	199	291	532	1,970	1,413	1,455	543	715	697	497
Total PCDF Measured	703	9.2	11	9.9	134	98.8	89.4	2.1	6.8	18.9	28
Total TEQ	7	12	17	4	193	126	108	2	3	4	4

TEQ = Total Dioxin Toxicity. "Down" and "Up" stream reference relative to airbase.

Table 6: TCDD Levels in Soil at Bien Hoa Airbase

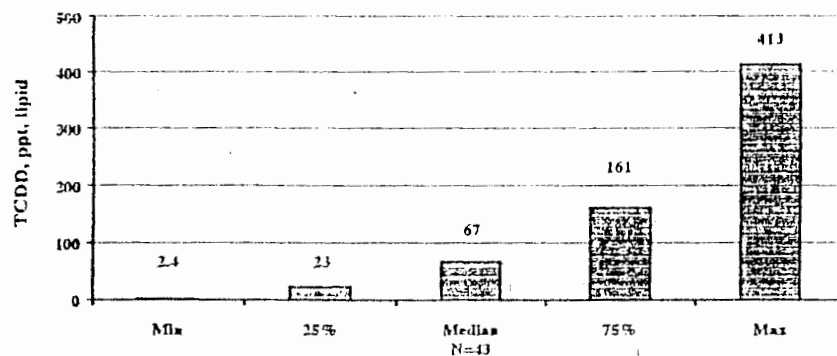
	Sample 1	Sample 2	Sample 3	Sample 4
2,3,7,8-TCDD	1,164,699	603,968	ND	1,058

ND = Not Detected, Pp/g (ppt). "Up" stream and "Down" stream in reference to Airbase.

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Sample	Year of Birth	TCDD level		Sample	Year of Birth	TCDD level	
		(ppt lipid basis)				(ppt lipid basis)	
South Vietnam (individual samples)							
1	1962	2.4		23	1942	68.3	
2	1950	3.4		24	1962	70.2	
3	1952	5.1		25	1935	73.9	
4	1962	5.6		26	1960	76	
5	1980	5.7		27	1980	87	
6	1942	7.1		28	1985	91	
7	1950	7.8		29	1962	101	
8	1930	20		30	1966	102	
9	1947	21		31	1963	103	
10	1939	22		32	1963	154	
11	1955	23		33	1959	161	
12	1955	24		34	1954	162	
13	1942	29		35	1955	164	
14	1955	30		36	1958	168	
15	1982	35		37	1982	174	
16	1955	38		38	1985	177	
17	1952	39		39	1967	236	
18	1979	50		40	1950	238	
19	1981	57		41	1954	271	
20	1981	62		42	1963	326	
21	1983	63		43	1973	413	
22	1958	67					
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1	1930	1.6		4	1930	1.2	
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North Vietnam (pooled sample, n=100)							
Hanoi	1959-79	2.2					

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Conclusions

Our Agent Orange research indicates elevated TCDD from Agent Orange in some southern Vietnam residents. Sampling was deliberately performed in areas of high Agent Orange spraying, and in the north (Hanoi) for comparison. Although levels of TCDD and of other dioxins varied, breast milk TCDD levels of up to 1,850 ppt were found in fish-eating southern residents living in sprayed villages. These are apparently the highest measured breast milk dioxin levels to date. Levels of TCDD in northern Vietnam residents were found to be much lower, with typical levels at 1-2 ppt. Fish in highly contaminated areas were found to have quite high TCDD levels as were some food, wildlife, soil and sediment samples collected from 1970 to 2001 in sprayed areas of Vietnam. Most recently, elevated TCDD levels were found in blood and environmental samples from Bien Hoa City, a city 35 kilometers north of Ho Chi Minh City, where an airbase used for Agent Orange spraying existed. Most persons sampled had elevated blood TCDD; some sediment had elevated TCDD levels; and several samples of soil were highly contaminated with TCDD. Fish-eaters, children born after Agent Orange spraying ended, and newcomers to the city, had elevated TCDD levels, documenting exposure after cessation of spraying in 1971.

Discussion

The finding of high levels of TCDD in humans and in food during and shortly after Agent Orange spraying is not unexpected. However, the finding of elevated levels from current exposure, 3 decades after spraying ended, is unexpected. This indicates that TCDD can remain in the environment and work its way through the food chain for substantial periods of time following initial contamination. Such findings have implications for Vietnam and other locations contaminated with dioxins, including those American Superfund sites which are contaminated with dioxins. We postulate that TCDD has moved through the soil, into sediment, into the food supply, especially fish, and then into humans in Bien Hoa City and similar Agent Orange sprayed areas. We believe the data suggest that there may be many dioxin contaminated areas or "hot spots" in Vietnam.

Recommendations

Based on our research, we suggest several courses of action. First, further sampling to document other potential "hot spots" (Agent Orange sprayed areas) seems strongly indicated. Second, for persons with elevated dioxin levels, additional medical monitoring and care appear to be warranted. In addition, elimination of contaminated food from the diet constitutes appropriate public health action. Clean up of contaminated areas may be indicated, as may keeping people from contaminated areas. Further human and environmental surveys, followed by health studies, perhaps in concert with health care clinics, also seem reasonable steps to be taken in the very near future.

In addition, there is a need for health studies comparing the large Vietnamese populations exposed to dioxin from Agent Orange (starting in 1962 with the first spraying of Agent Orange), with the large unexposed reference populations, to better characterize the health consequences of dioxins to the exposed populations. With blood dioxin measurements as the established current "gold standard" for exposure, better epidemiological studies can now be performed than in the past. Most Agent Orange was sprayed in Vietnam, but some was also sprayed in Laos,

Cambodia and Thailand. Future studies conducted in these countries would provide additional data on exposure of persons, environment, transport and fate, uptake and elimination of TCDD, as well as health aspects of TCDD exposure.

Further studies might target additional populations. Where TCDD levels in Vietnam are elevated, the potential exists for exposure of foreign Vietnam war veterans. Where levels are low, it is less probable that others, such as American Vietnam veterans, were exposed to Agent Orange. Similarly, former Vietnamese citizens who lived in dioxin contaminated areas who are now living in other countries (such as the USA) may have been exposed and it might be useful to measure their blood dioxin levels.

Finally, TCDD is associated with an increased risk for various diseases. Identification of those at risk, considering spray records and TCDD blood levels, in Southeast Asia and elsewhere, would allow better medical monitoring and hence a decrease in morbidity and mortality in those exposed to dioxins.

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Cambodia and Thailand. Future studies conducted in these countries would provide additional data on exposure of persons, environment, transport and fate, uptake and elimination of TCDD, as well as health aspects of TCDD exposure.

Further studies might target additional populations. Where TCDD levels in Vietnam are elevated, the potential exists for exposure of foreign Vietnam war veterans. Where levels are low, it is less probable that others, such as American Vietnam veterans, were exposed to Agent Orange. Similarly, former Vietnamese citizens who lived in dioxin contaminated areas who are now living in other countries (such as the USA) may have been exposed and it might be useful to measure their blood dioxin levels.

Finally, TCDD is associated with an increased risk for various diseases. Identification of those at risk, considering spray records and TCDD blood levels, in Southeast Asia and elsewhere, would allow better medical monitoring and hence a decrease in morbidity and mortality in those exposed to dioxins.

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