Health Consultation

Evaluation of Land Crab Contamination

TANAPAG VILLAGE, SAIPAN
COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

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Division of Health Assessment and Consultation

Summary

The Agency for Toxic Substances and Disease Registry (ATSDR) was asked to provide a public health consultation on the public health significance of polychlorinated biphenyl (PCB) contamination in land crab tissues collected in the Tanapag Village area. This health consultation discusses the land crab sampling that occurred in Tanapag Village in May and December 2000, evaluates the public health impact of exposure to polychlorinated biphenyls (PCBs) in land crab and makes recommendations on actions that local agencies and Saipan residents can take to reduce PCB exposure from contaminated crab.

The U.S. Environmental Protection Agency (EPA) and the Commonwealth of the Northern Mariana Islands Division of Environmental Quality (DEQ) collected 92 land crab from four harvest areas near Tanapag and a background (reference) location near Smiling Cove. Sampling indicated PCB in land crab ranging from 0.0007 to 0.9600 milligrams per kilogram (mg/kg) with an average of 0.0242 mg/kg. A few of the crab were tested for metals. Three metals (iron, aluminum, and manganese) were slightly elevated in some areas. The metals concentration in land crab were below levels of health concern.

ATSDR estimated the amount of exposure to PCB from eating large amounts of land crab for many years. From a comparison of estimated exposures to conservative health guidelines and the toxicological and epidemiological literature, it appears that the PCB exposure from eating land crab is too low to result in harmful health effects, even to sensitive groups such as children.

Blood tests are the best measure of long term exposure to PCB from all environmental sources, including crab. The average blood serum PCB level among residents of Tanapag who eat crab are below the U.S. average in people with no known source of exposure, and are below levels where harmful health effects would be expected in people.

A ban on eating land crab does not appear necessary. Although the PCB in Tanapag land crab is not a public health hazard, people can be exposed to small amounts of PCB from eating crab. Because there are still gaps in the scientific knowledge surrounding health effects of exposure to PCB, it is wise to reduce exposure to PCB when possible. As a precaution, ATSDR suggests that people who choose to eat crab, especially pregnant women, women of reproductive age, and families of small children, take steps to prepare and cook crab to remove PCB:

- Remove and throw away the crab's hepatopancreas (liver) before cooking. The liver has most of the PCB.
- Pre-cook the crab by boiling, drain and throw away the cooking water (PCB comes out in the cooking liquid).
- Use pre-cooked crab to prepare dishes in the usual manner.

Statement of Issues

The Agency for Toxic Substances and Disease Registry (ATSDR) was asked by the Commonwealth of the Northern Mariana Department of Public Health (DPH) to provide a public health consultation on the public health significance of polychlorinated biphenyl (PCB) contamination in land crab tissues collected in the Tanapag Village area. The DPH, DEQ and the EPA are interested in this consultation in order to determine what actions are needed to protect public health, and to assist them in their environmental site characterization and clean up of PCB contamination in Tanapag Village.

PCB soil contamination was present in several defined land crab habitats and where land crab are routinely harvested by residents of Saipan. PCB is persistent in the environment and land crab have the potential to accumulate PCB from consuming contaminated soil, sediment and organic material. PCB can pose a health threat to people who are exposed from consuming highly contaminated land crab.

The residents of Saipan depend on land crab as a traditional food source. Tanapag residents have expressed concerns about the potential for harmful health effects from PCB exposure and whether the land crab are safe to eat.

Background

Site Location

Tanapag Village is located on the northwest side of the island of Saipan, in the Commonwealth of the Northern Mariana Islands (CNMI) (see Figure 1). The 46.5 -square mile island of Saipan is about 12.5 miles long and 5.5 miles wide. Tanapag Village is approximately 1.2 square miles in extent. Based on 1999 CNMI Department of Commerce statistics, Tanapag has a population of 2,147. Land uses in Tanapag Village include residential, commercial, recreational, and institutional facilities. Some of the institutional facilities include a public beach park, a church, a cemetery, and a public school.

Three streams are located near Tanapag Village: the Homestead stream (also called Saddok Dogas), the Achugao stream (Saddok Achugao) located just north of Tanapag, and the Agatan stream (Saddok Agatan) located south of Tanapag.

History of PCB contamination

In 1988 and 1989, the CNMI Department of Environmental Quality (DEQ) discovered electrical capacitors containing PCB (Aroclor 1254) in various areas of Tanapag village. DEQ found 53 capacitors, and with EPA assistance, removed the capacitors and stored them at the Lower Base Public Works Yard. Some of the capacitors leaked PCB fluid and a few had been moved by residents and reportedly used for other purposes, including boundary markers, road blocks, cemetery headstones and cooking pit windbreaks. Allegedly some of the capacitors were broken open and the contents removed. After further investigation, it was determined that the capacitors had been originally purchased by the U.S. Department of Defense in the early 1960s, used on Kwajalein Atoll for the Zeus missile system, and ultimately ended up in Tanapag Village.

In 1991 the U.S. Army Corps of Engineers (ACOE) assumed responsibility for remediating the Tanapag site under the Defense Environmental Restoration Program, Formerly Used Defense Sites (DERP/FUDS). ACOE performed subsequent site characterization and soil removal actions. The soil removal has greatly reduced soil PCB concentrations in Tanapag .

Initial land crab sampling, May 2000

In May 2000, EPA, in conjunction with CNMI DEQ, the CNMI Emergency Management Office, the U.S. Coast Guard and the Agency for Toxic Substances and Disease Registry (ATSDR), conducted a multi-media sampling investigation in Tanapag to (1) confirm the effectiveness of ACOE removal actions, (2) identify any additional areas of contamination and (3) to assess the degree of contamination in local foods including fish, shellfish, land crab, taro and yam (USEPA 2000).

What are PCBs?

PCBs are manufactured fire-resistant oils once widely used in electrical equipment. They were banned in the United States in the late 1970's.

PCBs remain in the environment a long time.

For information on possible health effects of exposure, see Appendix C.

With the assistance of CNMI DEQ and Tanapag residents, additional areas of concern were identified and sampled for PCB. Currently, all PCB-contaminated soil at levels greater than 1 milligram per kilogram (mg/kg, also known as parts per million or ppm) in the Cemetery 2 and Tanapag Village areas have been identified, removed, and stockpiled in holding areas at Cemetery 2, awaiting treatment.

The May 2000 multi-matrix sampling effort identified PCBs in five out of eight land crab collected near Lower Base Cemetery 2. The PCB concentrations ranges from non-detectable to a maximum detected concentration of 0.39 mg/kg. The average level was 0.1664 mg/kg. As a precaution, DPH issued an advisory not to eat the crab until further sampling and analysis could be performed.

Phase II land crab sampling, December 2000

ATSDR, EPA, DEQ and the Tanapag community developed a plan to conduct additional sampling of land crab in harvest areas. The objectives for the phase II land crab sampling were to:

- Confirm land crab contamination detected in the initial screening study,
- Define the geographic extent of contaminated land crab,
- Obtain data suitable for determining if a continued land crab consumption advisory is warranted.

In December 2000 EPA and DEQ collected 92 land crab from four areas commonly used for land crab harvesting and a reference area (see Figure 2). Four areas were in Tanapag (Lower Base Cemetery 2, Achugao stream, Southern stream and Tanapag Beach Park) and one area 2 miles southwest of Tanapag was chosen to represent background (Smiling cove). After collection, the land crab were frozen, then the entire organism was homogenized (blended). The land crab were analyzed for total PCB and 22 metals. Total PCBs were determined by gas chromatograph (GC-ECD) according to EPA Method 8082. This analytical method measures all PCB Aroclors. A subset of land crab were tested for twenty-two metals according to EPA analytical methods.

How do PCBs get into land crab?

PCBs are very resistant to degradation (breakdown) and adsorb (stick) to organic material in soil and sediment. Land crab accumulate PCBs from consuming contaminated soil and organic material. PCBs are primarily stored in the fat-rich tissues of the land crab like the liver.

Because land crab tend to accumulate PCB from contaminated soil, we would expect the land crab with the highest PCB levels in areas with the highest soil contamination. This was the case in the Cemetery 2 and the Beach Park (homestead 2) areas.

Analytical results from the phase II sampling are presented in Tables 1 and 2 (USEPA 2000). Data are reported as average, whole body, wet weight concentrations in mg/kg (also known as part per million ppm - see glossary in appendix B). Non-detect samples are reported as being equal to the detection limit of 0.0007 mg/kg. The highest PCB levels were found in Tanapag Beach Park (HMST2) followed by Lower Base Cemetery 2. The two highest PCB levels in land crab came from Beach Park (0.9600 and 0.2500 mg/kg). The average PCB level across all areas was 0.0242 mg/kg, with an upper 95% confidence limit on the mean of 0.0452 mg/kg. Beach Park and Cemetery 2 PCB levels had a statistically significant elevation ($p<0.001$) over the background area in Smiling cove (Table 1). The only metals that were elevated over background were iron, manganese and aluminum (Table 2).

Discussion

How are the land crab tested? How is Aroclor 1254 different from 1260?

In the United States, PCBs were sold under the registered trademark of Aroclor. Aroclors widely used were 1016, 1232, 1242, 1248, 1254, and 1260. Aroclors are not a single chemical, but a mixture of different chemical forms of the PCB molecule called a congener.

There are 209 possible PCB congeners, but approximately 40 to 80 main congeners are detected in commercial Aroclor mixtures. On average, their weight percent chlorine corresponds to the last two numbers in the name. The PCB content of the various Aroclors has been characterized using different analytical techniques which indicate similarities and differences between similar PCB Aroclor mixtures such as 1254 and 1260. There is considerable overlap in the congener pattern in Aroclor 1254 and Aroclor 1260. They are not mutually exclusive.

In analyzing biological samples, the usual approach is to use capillary column gas chromatography. The gas chromatograph separates the PCB into a pattern of peaks or spiked lines on a graph. These peaks correspond to individual PCB congeners. The chemist or analytical instrument picks the pattern of congener peaks in the sample that best matches the pattern of a commercial PCB mixture which is used as a comparison standard (e.g. 1260). The areas of the peaks are then combined to quantify the total PCB content of the sample. Matching the pattern of a sample to a standard is subjective and depends on the skill of the analyst. Because pattern-matching can be error-prone, analysts often report concentrations as 'total PCBs' which gives the sum of the individual congeners that compose the sample without making a tentative identification which Aroclor the sample most closely resembles.

No environmental or biological sample is going to exactly match the original Aroclor composition. PCBs extracted from environmental or biological samples have a different congener composition than that found in the original source PCB mixture (Aroclor). This is because the congeners have different physical and chemical properties that affect how they behave in the environment. This results in different congener patterns as the PCBs move between different environmental media (air, water, soil). Secondly, the congeners vary in their susceptibility to chemical, physical, and biological (metabolic) degradation in the environment. This leads to the reduction of certain PCB congeners in the environment faster than others. This ultimately affects the composition of the PCB mixture that is measured in the environment.

The pattern of PCB congeners in land crabs is also very different from commercial mixtures. The more highly chlorinated PCBs are generally more resistant to metabolism. Therefore, the individual congeners that compose the total amount of PCB in land crab shifts toward the more highly chlorinated PCBs relative to the source.

Table 1. **Average Weight, Size, Lipid and PCB Concentration in land crab (mg/kg).**

Sampling location	Number of samples	Weight (grams)	Carapace size (mm)	% lipid	Total PCBs *
Smiling Cove (background)	10	264.78 (145.87) †	60.20 (11.75)	1.46 (1.35)	0.0026 (0.0015) 0.0007-0.005 ‡
Achugao Stream	21	220.35 (92.78)	55.28 (8.87)	1.46 (0.89)	0.0063 (0.0073) 0.0007-0.035
Southern Stream (HMST 1)	21	254.33 (85.39)	59.62 (8.02)	1.88 (1.43)	0.0029 (0.0025) 0.0007-0.011
Cemetery 2	19	282.98 (101.05)	62.11 (8.81)	1.66 (0.81)	0.0137 § (0.0075) 0.004-0.032
Beach Park (HMST 2)	21	136.95 (61.65)	49.14 (7.43)	2.06 (1.39)	0.0832 § (0.2078) 0.004 - 0.960
Total	92	226.83 (106.39)	56.82 (9.78)	1.73 (1.19)	0.0242 (0.1028) 0.0007 - 0.960

* Reported in mg/kg (ppm) wet weight, whole body. Total PCBs represents the sum of all PCB Aroclors. Detection limit = 0.0007 mg/kg. Non detect samples were reported as equivalent to the detection limit.

† All numbers in parenthesis denote standard deviation.

‡ Range of detected PCB concentration (minimum - maximum).

§. Statistically significant elevation over background (Smiling Cove) $p<0.001$.

Table 2. Average Metals Concentrations in Tanapag land crab (mg/kg).

Site location	Smiling cove	Achugao stream	Southern stream (HMST 1)	Cemetery 2	Beach park (HMST 2)
Number of Samples	4	4	4	4	4
Aluminum	10.7	**89.300***	**126.100***	**104.900***	**81.050***
Antimony	0.117	0.012	0.002	0.063	0.032
Arsenic	0.358	0.325	0.335	0.335	0.448
Barium	18.975	38.825	16.85	26.15	12.14
Beryllium	0	0	0	0	0
Cadmium	0.042	0.048	0.022	0.061	0.026
Calcium	86700	85075	72875	67325	74050
Chromium (total)	0.4	0.225	1.225	0.8	0.925
Cobalt	0.879	1.101	1.039	0.755	0.759
Copper	21.65	13.975	24.725	30.025	30.125
Iron	13.475	91.45	**236.675***	100.675	79.525
Lead	0.438	0.048	0.08	0.205	0.427
Manganese	5.985	**19.750***	**21.175***	12.568	9.568
Mercury	0.004	0.008	0.01	0.007	0.006
Nickel	0	0	0.55	0	0.275
Potassium	1682.5	1350	1680	2035	1727.5
Selenium	0	0	0	0	0
Silver	0.021	0.006	0.009	0.021	0.014
Sodium	3610	3237.5	3960	4002.5	3690
Thallium	0.005	0	0	0.004	0.002
Vanadium	0.225	0.6	1.575	0.425	0.35
Zinc	32.725	21.325	29.125	29.125	33.7

* Statistically significant elevation over background concentration (Smiling cove) $p<0.05$.

Because of this trend toward retaining more highly chlorinated PCBs, the congener patterns in land crabs tends to resemble combinations of both 1254 and 1260 (recall that these commercial mixtures contain the more highly chlorinated PCBs and there is considerable overlap between the two in the pattern of the individual PCB congeners composing the mixture). Because of the similar congener pattern and that the same congeners in both Aroclors tend to comprise the majority of the measurable PCB in land crab, it is nearly impossible to definitively characterize the pattern as predominantly one or the other.

What levels of PCB in land crab and other foods have been found outside of CNMI?

In comparison, the average land crab PCB level of all five areas sampled in Tanapag (0.0242 mg/kg) is lower than land crab samples collected from the U.S. mainland (Table 3). The maximum level reported in one land crab collected from the Tanapag beach park (0.96 mg/kg) is within the range of PCB levels determined from sampling seven urban areas on the Pacific and Atlantic U.S. coasts (Ylitalo 1998).

Table 3. Average measured crab PCB concentrations in the continental U.S.

Location	PCB (mg/kg)	Year
Palos Verdes Peninsula, CA	0.19	1982 *
Santa Monica Bay, CA	0.03-0.38	1986 *
N.E. U.S. Coastal areas	0.043-0.15	1987 *
New Jersey coast	0.33 (muscle) - 5.38 (hepatopancreas) 1.84 (combined)	1990 *
Newark Bay estuary, NJ	0.18 (muscle)-3.71 (hepatopancreas)	1995 †
Seven sites on Atlantic and Pacific coast.	0.100 - 3.0	1998 ‡

* Zabik *et al.* 1992
† Finley *et al.* 1997
‡ Ylitalo *et al.* 1998.

What are the public health implications of land crab contamination in Tanapag?

Although people eating land crab can be exposed to PCB, estimated dose levels were too low to result in harmful health effects, even to sensitive groups such as children. As a precaution, ATSDR is suggesting that pregnant women and children reduce their exposure to PCBs by limiting consumption of land crab. People who choose to eat land crab should prepare and cook the crab to remove PCB before eating.

Residents of Tanapag have asked ATSDR to provide information on possible harmful health effects from exposure to PCBs. *The information is provided for educational purpose and does not mean that people living in Tanapag or eating land crab will experience these health effects.* The general types of health effects from high levels of PCB exposure reported in the scientific literature is in Appendix C.

Exposure assessment methodology

To relate knowledge of chemical toxicity to chemical exposure associated with eating contaminated land crab the nature and extent of that exposure must be determined. Several assumptions are needed to estimate exposure from eating land crab. ATSDR estimated exposure dose levels in milligrams of PCB per kilogram of body weight per day (mg/kg/day) using conservative assumptions designed to overestimate the amount of PCB that would get into people eating Tanapag land crab. From information provided by Tanapag residents, ATSDR estimated that a high-end consumer eats 3 crab per meal, three times per week. Each crab weighs 228 grams on average, which results in a daily intake rate of 290 g/day. For the general U.S. population, the EPA has estimated that on average people consume 20.1 grams/day for all fish and shellfish (EPA 1997b). For Native American subsistence populations, the 95th percentile per capita fish intake rate is estimated at 170 grams/day. Appendix A details the methodology and assumptions used by ATSDR to estimate PCB exposure from eating land crab.

Estimated doses were then compared to the ATSDR minimal risk level (MRL) for PCBs. MRLs are protective by design and represent doses below which non-cancer adverse health effects are not expected to occur, even from daily exposure over a lifetime. The PCB MRL was derived from the lowest adverse effect level (LOAEL) identified in the scientific literature. The LOAEL was then divided by a safety factor of 300 to protect sensitive groups and account for differences between humans and animals in response to exposure.

MRLs are not thresholds for harmful health effects. *A dose that exceeds the MRL indicates only the increasing potential for toxicity and that further toxicological evaluation is needed.* Typically the dose is divided by the MRL to define the margin of exposure (MOE). If the MOE is below 1 then it can be assumed that the dose is well below the protective levels established by the MRL. If the MOE is greater than 1 it does not imply that adverse effects will necessarily occur, but indicates that further evaluation is needed. The higher the estimated dose is above the MRL, the closer it will be to the critical effect level.

For an adult eating contaminated Tanapag land crab the exposure dose estimates are approximately 0.000043 mg/kg/day. For a child, the exposure dose is approximately 0.00001 mg/kg/day (see Table 4).

Table 4. Estimated PCB Exposure Dose Levels from Consuming Tanapag Land crab.

	Dose (mg/kg/day)	MRL (mg/kg/day)	Margin of exposure (dose/MRL)	Average land crab PCB (mg/kg)	FDA Tolerance (mg/kg)
Adult	0.000043	0.00002	2.2	0.0242	2
Child	0.00001	0.00002	0.43	0.0242	2

To provide perspective on these dose levels, the U.S. Food and Drug Administration (FDA) analyzes ready-to-eat foods from markets nationwide to determine the background intake of certain contaminants in the U.S. diet. Since the 1970s, PCB levels are decreasing steadily. Foods from animal origin are the primary source of PCB exposure to the general U.S. population. During 1991-1997, the average daily dietary exposure to PCBs was 0.000002 mg/kg/day (ATSDR 2000).

The FDA has established allowable tolerance levels for PCBs in fish and shellfish at 2.0 mg/kg. The contamination in Tanapag land crab was below this tolerance level. The average PCB level detected was over 82 times lower, while the highest concentration of PCB detected in Tanapag land crab was measured at 0.9600 mg/kg, more than two times below the FDA tolerance level.

The average level of PCB in Tanapag crab is almost identical to or below many common foods eaten daily in the U.S. (see Table 5). Table 5 presents the PCB residues that were recently detected in domestic foods in the U.S. The Total Diet Study, sometimes called the Market Basket Study, is an ongoing FDA program that determines levels of various pesticide residues, contaminants, and nutrients in foods. FDA purchases foods from supermarkets or grocery stores around the U.S., prepares them as they will be eaten, and then analyzes them.

Table 5. PCB residues detected in domestic foods.

Food item	Average level detected (ppm)	Average level in Tanapag land crab (ppm)
Beef steak	0.022	0.024
Canned tuna	0.045	
Pancake mix	0.024	
Meatloaf	0.023	
Chicken breast	0.032	
Salmon steak	0.032	

(U.S. Food and Drug Administration, September 2000)

Eating minute amounts of PCBs in foods over many years contributes to the background levels in human blood serum currently estimated between 4-8 micrograms per liter (µg/L, also known as parts per billion (ppb) - see glossary in appendix B). The average level of PCB in the serum of

Tanapag residents is around 2 µg/L, below the U.S. background (ATSDR 2001a).

PCB effects levels, even in a highly sensitive species such as monkeys, are much higher than normal background levels detected in people. PCB-related adverse health effects in humans will require much higher exposures than the levels found in Tanapag.

PCB in Tanapag land crab - Non-cancer health effects

People who eat Tanapag land crab are not likely to become ill. Exposure to PCB in the land crab, even from eating crab regularly over many years, is too low to cause harmful health effects.

The chronic MRL for PCB is 0.00002 mg/kg/day. The dose to a child was below the conservative MRL while the adult dose was slightly higher. Although the adult dose was higher, it was over 1600 times below the PCB exposure dose range where workers received daily exposures of 0.07-0.14 mg/kg/day for years with no signs of adverse health effects (Kimbrough 1995).

ATSDR's chronic MRL for PCBs (0.00002 mg/kg/day) is based on the lowest observed adverse effect level (LOAEL) identified in the scientific literature, i.e., a LOAEL of 0.005 mg/kg/day for decreased antibody levels in Rhesus monkeys treated daily for 55 months with encapsulated Aroclor 1254 in a glycerol/corn oil mixture (Typhonas et al. 1989; ATSDR 2000). This exposure regimen lead to PCB levels of about 5 mg/kg in fat tissue of these Rhesus monkeys. Similar doses for 37 months induced adverse dermatological (skin) effects in adult monkeys as well as their offspring (Arnold 1993, 1995; ATSDR 2000). However, humans with fat tissue levels up to 100 mg/kg were occupationally exposed daily to 0.07- 0.14 mg/kg/day (14-28 times the Rhesus monkey LOAEL and 3500-7,000 times ATSDR's MRL) for months to years without evidence of impaired health (Kimbrough, 1995; ATSDR 2000). It seems, therefore, that humans are less sensitive than primates are to various adverse effects of PCBs.

Studies of workers exposed to PCBs at levels much higher than in Tanapag demonstrated that the only clear clinical signs of exposure to PCB were dermal (skin) in nature (chloracne) at serum PCB levels around 450 micrograms per liter (µg/L). A slight elevation of liver enzymes was seen around 200 µg/L. No other abnormal findings that could be related to PCB exposure were observed in the workers (Kimbrough 1995). The maximum serum PCB level measured in an exposure investigation of Tanapag residents was 36 µg/L. No detectable levels of PCB were found in children. The mean serum PCB level of 2.0 µg/L was below the range of 4-8 µg/L in U.S. populations with no known exposure source such as the work place. The vast majority of the residents in Tanapag have PCB serum levels below the U.S. average (ATSDR 2001a).

Several studies have been conducted to assess the effect of eating contaminated fish on pregnant women and their newborns. Several of these studies associate subtle neurodevelopmental effects in children born to mothers who ate PCB-contaminated fish during their pregnancies. However the studies are generally inconsistent and inconclusive, and there is still no clear evidence at this time that these subtle effects are causally related to PCB exposure. The effects attributable to PCB exposure in the uterus tend to be within the range of normal variation and unknown clinical significance. Most of the study results could be accounted for by chance or confounding factors such as exposure to other chemicals.

In several studies, effects on brain development and learning in newborns were associated with the highest maternal PCB dose groups (Jacobson et al. 1984, 1985, 1990; Lonkey 1996). The state of Minnesota (Shubat 1990) estimated PCB intake for those women in the Jacobson studies where children showed subtle neurologic effects associated with maternal PCB exposure. For the women who were evaluated, the estimated average daily PCB dose associated with adverse effects (i.e., when fish were assumed to be the only PCB source) was 0.00049 mg/kg/day (ATSDR 2001b). In the Lonky et al. (1996) study, women in the high-exposure group had an estimated average daily intake of 0.00045 mg/kg/day.

For women of reproductive age in Tanapag who consume land crab, assuming an average body weight of 65 kg, the average daily PCB dose level was estimated at 0.000046, ten times below the doses in studies associating consumption of PCB-contaminated Great Lakes fish and subtle effects on the developing brains of unborn babies. It is important to note that ATSDR used conservative assumptions in estimating PCB exposures to Tanapag residents, designed to overestimate actual exposure levels. These high end exposure levels estimated for Tanapag are still well below the highest doses in the Michigan Maternal Infant Cohort study where an association between maternal PCB exposure and neurological effects in newborns was seen.

Infants who were exposed to PCB from mother's milk showed no harmful health effects (ATSDR 2000). Breast feeding has many advantages to both infant and mother and the benefits far outweigh the risk, if any, from low levels of PCB in mother's milk.

To date, evidence suggests that the only clearly adverse health effects attributable to high, occupational PCB exposures are dermal (skin) in nature, e.g., chloracne, abnormal pigmentation, and chronic dermal and eye irritation (James 1993; Kimbrough 1995). In spite of the variety of adverse effects seen in PCB-exposed laboratory animals, adverse effects are generally absent in PCB-exposed humans (ATSDR 2000). Currently, ATSDR's Toxicological Profile for Polychlorinated Biphenyls lists no adverse health effect level of any kind for humans (ATSDR 2000).

PCB in Tanapag land crab - Cancer effects

Because the exposure levels are so low, even from eating a large amount of land crab over many years, eating Tanapag land crab is not likely to result in a significantly increased cancer risk.

Many studies have been performed examining PCB exposure levels and cancer in both animals and humans. Highly chlorinated PCBs (1260) cause liver cancer in rodents fed lifetime dose ranges from 1-5 mg/kg/day (ATSDR 2000). Rats fed mixtures with 54 or 42% chlorination did not develop a statistically significant (i.e. could not have happened by chance) increase in liver tumors (Kimbrough 1995).

Studies in human populations do not present strong evidence that PCBs produce cancer in humans. Although some epidemiological studies provide suggestive evidence, these studies suffer from limitations that weaken the association between PCB exposure and cancer in humans. Most human studies have either been inconclusive or have not shown any association at all between PCBs and human cancer (ATSDR 2000).

ATSDR's Toxicological Profile for Polychlorinated Biphenyls does not list any Cancer Effect Level for humans (ATSDR 2000). Based upon a rat study by Brunner (1996), the human equivalent dose level where a statistically significant increase in tumors was observed corresponded to 1.52 mg/kg/day. The adult dose level to PCB from eating Tanapag land crab was 0.000043 mg/kg/day, which is more than 35,000 times lower than the human dose equivalent to the animal dose where cancer was seen. Some studies had suggested a possible link between PCBs and breast cancer in humans, but recent studies have not confirmed that hypothesis (ATSDR 2000).

Other substances in land crab

Only three metals (aluminum, iron and manganese) were slightly elevated over background, and two of these three metals (iron and manganese) are essential nutrients.

Iron - Adult exposure to the maximum level of iron was estimated at 29.4 mg/day. This is above the recommended dietary allowance (RDA) of 8 mg/day but well below the 45 mg/day tolerable upper limit established by the U.S. Department of Health and Human Services (NAS 2001). Child exposure to the maximum level was below the RDA. A no adverse effect level (NOAEL) in adults was defined as 60 mg/day and based upon gastrointestinal distress. Intake levels greater than 45 mg/day are routinely used to treat iron deficiency anemia (NAS 2001).

Manganese - Adult and child exposure to the maximum detected level was below the RDA of 2-5 mg/day for children and adults, respectively (NAS 2001).

Aluminum - Exposure to the maximum level of aluminum detected in the land crab resulted in an adult dose of 0.22 mg/kg/day and child dose of 0.05 mg/kg/day. These dose levels were 9 and 40 times below the MRL, respectively. No harmful health effects are expected. ATSDR has established an intermediate oral MRL of 2 mg/kg/day based upon a NOAEL of 62 mg/kg/day for neurotoxicity (ATSDR 1999). The MRL is roughly 6-36 times lower than daily intake of aluminum from long term antacid use, and about 20 times higher than average dietary exposure. Aluminum is not known to cause cancer in humans or animals (ATSDR 1999).

Is there a need for a consumption advisory?

ATSDR does not think that a ban on eating land crab is necessary at this time. From a review of the land crab sampling data and toxicological and epidemiological studies in human and animals exposed to PCBs, the PCB levels in land crab appear too low to cause harmful health effects to someone eating crab, even over many years.

However, because the land crab are contaminated, they are a source of PCB exposure to people who eat them. Recreational and subsistence fishers have potentially higher PCB exposures because they eat more fish, shellfish and crustaceans than the general population. Therefore they are at a higher risk for exposure and harmful health effects, especially if the water and sediment they fish in is contaminated.

Land crab are a nutritious and traditional food with cultural importance to the people of Saipan. The PCB and metals should not make anyone sick, however it is wise to reduce exposure to PCB when possible. **ATSDR suggests that people who choose to eat crab prepare and cook the crab to remove PCB before eating them.**

For pregnant women and children, ATSDR estimated the number of land crab that may be consumed per week that would not exceed the ATSDR MRL or EPA reference dose (RfD) for PCB. The MRL and RfD are very conservative estimates of the daily exposure that is NOT likely to cause harm to a person, even over a lifetime. MRLs and RfDs include safety factors intended to protect sensitive groups. For adults such as pregnant women or women of child-bearing age, this amounts to two crab per week. For small children (less than six years), one crab per week would not be expected to exceed the MRL. Details of how these consumption levels were calculated are in Appendix A.

How can I reduce my exposure to PCB in land crab?

- Follow recommended consumption advice from CNMI DPH.
- Don't harvest land crab out of season.
- PCB in the land crab is located mainly in the hepatopancreas (liver). When you steam or boil land crab, the PCB comes out in the cooking water. To reduce PCB exposure, prepare and cook crab by:

A. removing and throwing away the liver before cooking.

B. pre-cooking the crab. If boiling, drain and throwing away the cooking water (PCB comes out in the cooking liquid).

C. use the pre-cooked crab to prepare a dish in the usual manner.

Will I get sick if I've eaten land crab in the past?

No. It requires many years of exposure at much higher levels than those found in Tanapag before adverse health effects are likely to occur. We do not know for certain what past PCB levels were and it is possible that they may have been higher. However, even if land crab PCB levels were higher in the past it is unlikely that they were high enough to result in harmful health effects. If you ate more land crab in the past you might have an exposure level that would have been slightly higher than the MRL or RfD, however the RfD and MRL contain many safety factors and are NOT thresholds for harmful health effects.

The best measure of exposure to PCB from eating crab is blood testing. Since PCB remain in the body for years, blood testing can measure the amount of PCB in the body from past and recent exposure. The results from the blood testing that DPH performed in May 2000 indicated that people had been exposed to PCB, but the PCB levels in blood did not show that anyone had levels high enough to cause harmful health effects.

What about the future?

The source of the PCBs in land crab is the contaminated soil. Soil containing elevated PCB contamination has been removed. Once the PCB contamination source has been removed, the PCB in land crab will gradually decrease. Scientists who measured uptake and elimination of PCB in fiddler land crabs found that after the source was removed, PCB levels initially declined rapidly over a few weeks, then more slowly as the more persistent congeners were metabolized and excreted (Clark 1986). In 2 to 3 years, further sampling should be planned and the need for a consumption advisory reevaluated.

ATSDR's Child Health Initiative

ATSDR is committed to protecting children's health in Tanapag. ATSDR recognizes that infants and children may be more sensitive than adults to environmental exposure in communities faced with water, soil, air or food contamination. This sensitivity is the result of several factors, including: (1) children are smaller than adults, resulting in higher doses of chemical exposure per unit body weight; (2) children's bodies may be more sensitive to the effects of chemical exposures. Children have developing body systems which can sustain permanent damage if toxic exposures occur during critical growth stages. Because of these sensitivities, ATSDR uses health guidelines that are protective for children.

Children appear to be more sensitive to effects on the nervous system from PCB exposure than adults. There are data that indicate the possibility for developmental problems in children who were exposed to PCB while in the womb. However, not all the scientific studies agree on what subtle effects may occur, or if the effects are medically significant.

Babies can be exposed to PCB from mother's milk, however scientific studies show that no harmful health effects were seen in babies who were breast fed. The advantages of breast feeding far outweigh the uncertainty about toxic effects from PCBs in mother's milk. Breast feeding has many important advantages for both babies and mother's including improved nutrition, increases resistance to infection, protection from allergies and improved and emotional development. *Mother's are encouraged to continue to breast feed their infants.*

Children should not experience harmful health effects from PCB in Tanapag land crab. However, it is important to reduce PCB exposure when possible, and ATSDR suggests that those families with small children who choose to eat crab prepare and cook the crab to remove PCB before serving them.

Nutritional benefits of traditional diets containing fish and shellfish

The nutritional benefits of fish, shellfish and crab are well known. Fish and crab are a healthy source of nourishment and include many important vitamins, minerals, protein and essential fats. Fats present in fish, shellfish and crab are generally unsaturated fats that are better for heart health than saturated fats found in many non-subsistence foods. Fish, shellfish and crab provide rich sources of omega-3 fatty acids which are associated with lower rates of heart disease. Some studies show that eating subsistence foods is associated with less glucose intolerance and chance of diabetes (Nobmann 1997).

Before decisions are made to restrict consumption of traditional foods, such as crab harvested from Tanapag, consideration should be given to benefits that the foods provide compared to the potential risks, if any, from low levels of chemical contaminants present in the foods.

Conclusions

1. ATSDR estimated the amount of exposure to PCB from eating land crab for many years. ATSDR used conservative assumptions designed to overestimate actual levels of PCB exposure to be protective of public health and to account for some of the uncertainties surrounding the amount of land crab people eat. From a comparison of estimated exposures to conservative health guidelines and the toxicological and epidemiological literature, it appears that the PCB exposure from eating Tanapag land crab is too low to result in harmful health effects, even to sensitive groups such as children.

2. Blood tests are the best measure of long term exposure to PCB from all environmental sources, including crab. The average blood serum PCB level among residents of Tanapag who eat crab are below U.S. background and are below levels where harmful health effects have been seen in people.

3. A ban on eating land crab is probably not necessary. Although the PCB in Tanapag land crab is not a public health hazard, people can be exposed to small amounts of PCB from eating crab. It is good public health practice to reduce and prevent PCB exposure when possible.

Recommendations

While no adverse health effects are anticipated from exposure to the PCBs in land crab, prudent public health practice calls for actions to reduce or prevent long-term exposure when feasible. As a result, ATSDR makes the following recommendations:

1. The CNMI Department of Public Health should advise the community and appropriate local government agencies on ways that residents can reduce exposure to PCB. This is especially important for pregnant women, women of reproductive age and small children.

- Community members should harvest in accordance with CNMI regulation and seasonal restrictions.
- Provide information to the community on how to reduce the PCB contamination in land crab during preparation and cooking.
- To reduce PCB exposure, ATSDR suggests that people who choose to eat crab, especially pregnant women, women of reproductive age, and families of small children take steps to prepare and cook crab to remove PCB. One way to do this is to:
    1. Remove and throw away the crab's hepatopancreas (liver) before cooking. Most of the PCB is in this organ.
    2. Pre-cook the crab. If boiling, drain and throw away the cooking water (the PCB comes out in the cooking liquid).
    3. Use pre-cooked crab to prepare dishes in the usual manner.

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Additional information about ATSDR services and the public health impacts of exposure to hazardous substances is available on the ATSDR web site at http://www.atsdr.cdc.gov.

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Figures

See figures in **appendix 14.1.2**

Figure 1. Saipan, CNMI
Figure 9 . Land crab sampling areas

Appendix A: Exposure Evaluation Methodology

This appendix details the assumptions and calculations that ATSDR used to estimate potential exposure levels from consumption of PCB-contaminated land crab. To be protective and account for the uncertainty surrounding how representative the exposure factors are for the residents of Tanapag, ATSDR used conservative assumptions to estimate the reasonable maximum exposure level to land crab consumers. This estimate calculates a daily exposure dose in milligrams PCB per kilogram body weight (mg/kg/day). To remain protective of public health, it is intentionally conservative and likely overestimates the amount of PCB exposure from eating land crab to the Tanapag community. This estimate assumes that:

- all the land crab the person eats comes from contaminated areas.
- the person eats a large amount of land crab.
- the person eats land crab all year for many years.
- all the PCB in the land crab gets into the person's body.

Parameter		Value	Unit	Reference	Comment
Exposure dose	D	calculated	mg/kg-day		Represents a hypothetical maximally exposed individual.
Body weight, adult	BWa	71.8	kilograms	EPA 1997	Average weight, men and women 18-75 years of age
Body weight, child	BWc	15.3	kilograms	EPA 1997	Average weight, boys and girls 3 years of age.
Exposure frequency	EF	365	days/year		Assumes land crab is harvested and eaten all year
Exposure duration	ED	30	years	EPA 1997	Upper bound residence duration
Fraction ingested	F	1	unitless		Assumes 100% of all land crab consumed comes from contaminated areas.
Land crab ingestion rate, adult	IRa	0.29	kg/day	site-specific	Equivalent to 3 land crab per meal, 3 meals per week
Land crab ingestion rate, child	IRc	0.05	kg/day	site-specific	Equivalent to 1 land crab per meal, 3 meals per week.
PCB concentration	C	0.0242	mg/kg	site-specific, EPA sampling reports	Average PCB level.
Average land crab weight	Wc	226.83	grams		calculated
Averaging time	AT	25550	days		Assumes 70 year life-span times 365 days/year.

Parameter		Value	Unit	Reference	Comment
PCB minimal risk level (equivalent to EPA RfD)	MRL	0	mg/kg-day	Typhonas *et al.* 1989; ATSDR 2000	Based on the *lowest* effect level identified in the scientific literature, i.e., a LOAEL of 0.005 mg/kg-day.
PCB cooking reduction	CR	1	unitless		Assumes no reduction from cooking
PCB oral bioavailability	OB	1	unitless		Assumes 100% oral bioavailability (all PCB gets into the body).

The land crab ingestion rate for adults is calculated by the following equation:

$$IR(kg/day) = \frac{(crabs/meal \times Wc(g/crab) \times 0.001(kg/g) \times meals/week)}{7day/week}$$

The potential exposure dose is calculated using the following equation:

$$Dose(mg/kg-day) = \frac{(C(mg/kg) \times IR(kg/day) \times F \times CR \times OB \times EF(day) \times ED(year))}{(BW(kg) \times AT(day))}$$

To calculate a daily intake of land crab that would not exceed the MRL:

$$Daily\ \text{int}\,ake(kg/day) = \frac{(MRL(mg/kg-day) \times BW(kg))}{C(mg/kg)}$$

Estimate of the number of land crab per week that if consumed would not exceed the MRL:

$$Crab/week = \frac{(daily\ \text{int}\,ake(kg/day) \times 7days/week \times 1000g/kg)}{(Wc(g/crab))}$$