Health Consultation

LAND CRAB EVALUATION

(National Oceanographic Atmospheric Administration Data)

ISLA DE VIEQUES
VIEQUES, PUERTO RICO

EPA FACILITY ID: PRN000204694

FEBRUARY 22, 2006

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Vieques, Puerto Rico

February 22, 2006

Prepared by the

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation

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Land Crab Evaluation on the Isla de Vieques, Puerto Rico

Purpose

The Agency for Toxic Substances and Disease Registry (ATSDR) prepared this health consultation in response to a request made by the National Oceanic and Atmospheric Administration (NOAA), Office of Response and Restoration (ORR), to evaluate the health impact of eating land crab from various locations on the Isla de Vieques, Puerto Rico. In June 2005, NOAA sampled land crabs (*Cardisoma guanhumi*) and fiddler crabs (*Uca* spp.) from 14 locations (13 on Vieques and one on the mainland of Puerto Rico). Crabs were analyzed for explosive compounds, polychlorinated biphenyls (PCBs), organochlorine pesticides, and trace elements. Some of these chemical compounds are thought to be present in the environment from Navy operations. Results from these evaluations will assist the U.S. Fish and Wildlife Service (FWS) in determining whether selected refuge areas can be opened to crab harvesting. ATSDR focused this consultation on the consumption of land crabs, because people do not eat fiddler crabs.

Findings

1. The levels of PCBs, organochlorine pesticides, and trace elements found in land crabs are much lower than levels reported in the scientific literature as causing harmful health effects. Therefore, ATSDR does not expect that adults or children will experience harmful health effects from eating land crabs from Vieques.

2. The crab samples collected from 12 different areas and two reference locations all show levels of contaminants below the U.S. Food and Drug Administration (FDA) regulatory contaminant limit for shellfish consumption. Explosive compounds were not detected in any crab sample.

3. ATSDR found no association between sampling location and contaminant levels in land crabs. PCBs and pesticides were detected in only a few land crab samples, indicating that the presence of PCBs and pesticides in land crabs is not widespread.

History and Land Use

Vieques is the largest offshore island in the Commonwealth of Puerto Rico. Vieques is 20 miles long, 4.5 miles wide at its widest point, and about 33,000 acres (or 51 square miles) in area. The nearest island to Vieques is the main island of Puerto Rico, approximately 7 miles to the west. St. Thomas, St. John, St. Croix, and other U.S. Virgin Islands are all 20 miles or more northeast and southeast of Vieques.

From 1941 until 2001, the U.S. Navy owned much of the eastern and western most portions of Vieques. The Navy owned roughly the eastern half of Vieques, which included the Eastern Maneuver Area (EMA) and the Atlantic Fleet Weapons Training Facility (AFWTF). In 1960, the Navy established targets on Vieques and began bombing practice (Navy 1990). The use of the Live Impact Area (LIA) for air-to-ground and ship-to-shore training increased after the closing of the Culebra Island range in the mid-1970s. The Navy used these areas for combat training—

for example, for shore landing exercises, for small arms training, as an impact area for artillery, and as a bombing range for aerial and naval bombardment (CH2MHILL and Baker 1999; IT Corporation 2000). The western portion of Vieques is the former Naval Ammunition Support Detachment (NASD). Prior to May 2001, the Navy used this 8,200-acre area for ammunition storage, rock quarry, communication facilities, and Navy support buildings (IT Corporation 2000).

In 2001, the Navy transferred ownership of approximately 7,500 acres of land on the west end of the island to the municipality of Vieques, the Puerto Rico Conservation Trust, and the FWS, but retained about 100 acres of the former NASD lands for radar and communication facilities (Navy 2001). Some NASD areas were leased to local farmers for cattle grazing and other agricultural purposes (EPA 2004). On May 1, 2003, the Navy ceased all military operations on and around the island and transferred its property on the east end of the island (approximately 14,575 acres) to the FWS (EPA 2004). The land on the east end of the island and the land controlled by the FWS on the west end of the island were then designated a national wildlife refuge. Site investigations and cleanup actions have been initiated by the Navy and are ongoing under the guidelines of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

The central 7,000 acres of Vieques house the entire residential population of the island, mostly in the towns of Isabel Segunda and Esperanza. Approximately 9,300 civilian Puerto Ricans live in the central residential section of the island. Vieques land is used for residential, agricultural, commercial, and industrial purposes. In the past, sugarcane was the principal crop. Other crops have included coconuts, grains, sweet potatoes, avocados, bananas, and papayas. In the 1960s and 1970s, manufacturing was important for the economy, beginning in 1969 with the construction of the General Electric plant (Bermudez 1998). Currently, only minimal manufacturing takes place on the island. Isabel Segunda and Esperanza are home to commercial fishing fleets, and recently tourism has been increasing in economic importance.

Prior ATSDR Involvement

ATSDR conducted four public health assessments to address Vieques residents' concerns that military training activities at the LIA were adversely affecting their health. ATSDR evaluated the ways Vieques residents could contact contaminants, including drinking groundwater, incidentally ingesting or touching soil, eating fish and shellfish, and breathing air. These evaluations are presented in separate public health assessment documents, which are available at ATSDR's Web site: http://www.atsdr.cdc.gov/HAC/PHA/region_2.html#puertorico.

ATSDR concluded that, overall, residents of Vieques might have been exposed to very low levels of environmental contamination. However, the contaminant levels that people were most likely exposed to are too low to cause harmful health effects.

Discussion

NOAA Land Crab Sampling

In June 2005, NOAA sampled land crabs from mudflats, mangrove wetlands, coastal forested areas, and sandy areas on the east and west ends of Vieques Island. Land crabs were collected because of their importance in the diet of the island's residents. Five or six land crab specimens were collected from each of 14 sampling locations, which represented 12 potential harvest areas (six locations on the west end of the island and six locations on the east end), and two reference sites of similar habitat (one on Vieques and one on the main island of Puerto Rico). Seventy-four samples were analyzed. NOAA selected the sampling locations with input from the FWS, the U.S. Environmental Protection Agency (EPA), and the Puerto Rico Department of Natural Resources, based on results from the limited prior studies and consideration of areas where hazardous substances may have been released on the island.

Western Vieques	Eastern Vieques	Reference Locations
Area 1: Downgradient from SWMU 7	Area 7: Mosquito Bay	Area 13: Blue Horizon (Vieques)
Area 2: Downgradient from AOCs J & R	Area 8: Puerto Ferro	Area 14: Humacao Wildlife Reserve
Area 3: Laguna Kiani	Area 9: Red Beach	(mainland of Puerto Rico)
Area 4: Laguna Kiani South	Area 10: Blue Beach	
Area 5: Boca Quebrada	Area 11: Bahia Tapon	
Area 6: Laguna Playa Grande	Area 12: Live Impact Area (LIA)	

Individual whole-body land crab samples were analyzed for organic compounds (explosive compounds, PCBs, and organochlorine pesticides) and trace elements. Exoskeletons were included in the analysis because many local recipes use them to add flavor to soups and stews. All analytical data were independently reviewed and validated to ensure usability prior to evaluation (Ridolfi and NOAA 2005).

In addition, separate exoskeleton (carapace and shell) and tissue (muscle and internal organs) samples from 14 land crabs were analyzed for trace elements. Even though some of the average tissue samples were higher than the average whole body samples, ATSDR's evaluation of the tissue samples yielded similar results to the whole body land crab evaluation detailed in this report—no harmful health effects would be expected to occur from eating one meal of the land crab tissue every day.

Analysis Results

All samples showed levels of contaminants below the FDA regulatory contaminant limit for shellfish consumption. Explosive compounds were not detected in any of the 74 land crab samples. The PCB mixture Aroclor 1260 was found in a single land crab sample from Laguna Kiani, at a level considered to be near the detection limit for the laboratory method. Most pesticides were either not detected or detected infrequently (i.e., in less than 5 percent of the samples). As in previous investigations, DDT and its metabolites were detected in multiple land crab samples. The second most observed pesticide was gamma-chlordane. Chlordane compounds were detected—always just at the detection limit—in land crabs at half the sites, including the on-island Blue Horizon reference site (Area 13).

Because trace elements have both natural and manmade sources, their detections in land crab varied by location and individual element. Almost all the trace elements were regularly detected at all locations, including the reference locations.

Human Health Effects

To be protective and to ensure that our evaluation includes people who would have been exposed, ATSDR overestimates likely exposures. ATSDR performed screening-level mathematical calculations, including exposure dose estimates and risk calculations that use a set of assumptions about exposure to determine if the level of contaminants present in land crabs could result in adverse health effects. Appendix A contains our assumptions and methodology. In addition to calculations, we referred to the most current available scientific literature to determine if health effects would be expected.

The information we used relates the environmental concentration (the amount of contaminant) to a dose—an amount taken into a person's body over a period of time. We assumed that people would eat land crabs every day of the year; and that children would eat 4 ounces every day for 6 years and adults would eat 8 ounces of land crab for 70 years.

To determine if the doses we calculated were likely to cause health effects, we compared them to health-based screening guidelines. Estimated exposure doses that are less than screening guideline values are quickly ruled out as having a health impact. Estimated doses above screening guidelines were evaluated further for their potential to cause health effects using the most current scientific studies.

An exposure dose is the amount of chemical a person is exposed to over time.

Because no one study or source of information can guarantee certainty, we used many sources of information to increase the confidence of our conclusion. Based on the substantial evidence from various studies, ATSDR concludes that contaminant levels detected in land crabs are much lower than levels of those chemicals shown to cause adverse health effects. Note that we evaluated combined exposures, as well as exposures to single chemicals. Many trace elements tend to compete against each other in the body. This antagonist effect, as it is called, reduces the body's ability to absorb the chemicals and thus the effects (both desired and undesired) of the competing trace element. This is seen with lead and calcium, copper and selenium, calcium and iron, and many others. Levels of contaminants detected in Vieques land crabs were much lower than levels reported to produce additive or multiplicative effects.

While no chemicals were detected in land crabs at levels likely to cause adverse health effects, several chemicals were above screening levels, which indicated that a toxicological review was needed. These chemicals are listed in Table 1 and discussed in the following sections.

Table 1. Chemicals Detected in Vieques Land Crabs That Required Additional Evaluation

Chemical	*Average Concentration (mg/kg)*	*FDA Regulatory Level (mg/kg)*	*Exposure Doses (mg/kg/day)*		*Noncancer Health Effect Level (mg/kg/day)*	*Cancer Effect Level (mg/kg/day)*	*Levels in Vieques Land Crabs Compared to Levels Shown to Cause Adverse Health Effects*
			Child	*Adult*			
4,4-DDE	0.021	5	1.5×10^{-4}	6.9×10^{-5}	5.0×10^{-1}	0.33–116	Below
Arsenic*	0.33	76	2.3×10^{-4}	1.1×10^{-4}	8.0×10^{-4}	0.0011–3.67	Below
Cadmium	0.04	3	2.8×10^{-4}	1.3×10^{-4}	2.1×10^{-3}	NA†	Below
Chromium	1.4	12	9.9×10^{-3}	4.5×10^{-3}	2.5	NA†	Below
Copper§	32.2	NA	3.7 mg/day	7.3 mg/day	10–12 mg/day	NA†	Below
Iron§	76.9	NA	8.7 mg/day	17.5 mg/day	200 mg/event	NA†	Below
Nickel	4.6	70	3.3×10^{-2}	1.5×10^{-2}	5.0	NA†	Below
Vanadium	0.33	NA	2.3×10^{-3}	1.1×10^{-3}	1.3	NA†	Below

Average concentrations were calculated using detected values only.

ATSDR compared average concentrations with FDA regulatory levels. ATSDR also compared estimated exposure doses with noncancer health effect levels and cancer effect levels. These comparisons indicated that none of the chemicals were detected at levels shown in the scientific literature to cause or be associated with adverse health effects.

Doses were calculated using the following formulas:

child dose = (average concentration × 0.1135 kg/day × 365 days/year × 6 years)/(16 kg × (365 days/year × 6 years))

adult dose = (average concentration × 0.227 kg/day × 365 days/year × 70 years)/(70 kg × (365 days/year × 70 years))

*10% of the total arsenic was assumed to be inorganic arsenic.

†From ingestion, this chemical is NOT considered to be a carcinogen.

§Very few toxicological and epidemiological studies are available for copper and iron. Therefore, ATSDR calculated daily consumption rates using the following formulas:

child dose = average concentration × 0.1135 kg/day

adult dose = average concentration × 0.227 kg/day

FDA = U.S. Food & Drug Administration
mg/day = milligram per day
mg/kg = milligrams of contaminant per kilogram of medium
mg/kg/day = milligrams of contaminant per kilogram of body weight per day
NA = not applicable

Chemical	**Source of Noncancer Health Effect Level/ Cancer Effect Level**
4,4-DDE	Hayes et al. 1956 / ATSDR 2002
Arsenic	Tseng et al. 1968 / ATSDR 2005b
Cadmium	Nogawa et al. 1989
Chromium	MacKenzie et al. 1958
Copper	NAS 2000
Iron	FDA 1997
Nickel	Ambrose et al. 1976
Vanadium	Dimond et al. 1963

4,4-DDE

DDE is a primary metabolite of DDT, a pesticide that was once widely used to control insects on agricultural crops and insects that carry diseases, but is now used in only a few countries to control malaria. DDE has no commercial use, and is only found in the environment as a result of contamination or breakdown of DDT (ATSDR 2002). ATSDR reviewed the literature and found that DDE and DDT at the levels detected in Vieques land crabs have not been shown to cause adverse health effects. Both adult and child exposure doses were below the noncancer screening guideline, as well as the noncancer health effect levels for DDE and DDT.

In a human study of people chronically exposed to 0.5 milligrams per kilogram per day (mg/kg/day) DDT, no adverse health effects were observed (Hayes et al. 1956). Studies of DDE show health effects at higher levels (19–59 mg/kg/day; ATSDR 2002). All of these effect levels are more than 3,000 times higher than the estimated exposure doses (1.5×10^{-4} mg/kg/day for children and 6.9×10^{-5} mg/kg/day for adults; see Table 1). Therefore, **ATSDR does not expect that people will experience harmful noncancer health effects from eating Vieques land crabs containing DDE.**

FDA regulates the level of DDE in food. To limit the intake to a level considered to be safe, FDA set an action level of 5 mg/kg for the edible portions of fish (FDA 2001). The land crab samples collected from Vieques contain average DDE concentrations (0.021 mg/kg) well below this level.

The theoretical cancer risk prompted ATSDR to review the toxicological literature to evaluate potential cancer effects. Studies in animals have shown that oral exposure to DDT can cause liver cancer. However, the cancer effect levels (CELs) reported in the literature (0.33–116 mg/kg/day in animals; ATSDR 2002) are much higher than the estimated lifetime exposure dose from ingesting Vieques land crabs (6.9×10^{-5} mg/kg/day). Further, numerous studies have examined the possible association between exposure to DDT and related compounds and cancer in humans. These studies have examined exposure to the general population as well as those exposed occupationally by measuring DDT residues (most often DDE because of its persistence in the body and in the environment) in blood or in adipose tissue. However, taking all factors into consideration, the existing information does not support the hypothesis that exposure to DDT/DDE/DDD increases the risk of cancer in humans (ATSDR 2002). Therefore, **no excess cancers from DDE exposures are expected from eating land crabs caught on Vieques.**

Arsenic

Although elemental arsenic sometimes occurs naturally, arsenic is usually found in the environment in two forms—inorganic (arsenic combined with oxygen, chlorine, and sulfur) and organic (arsenic combined with carbon and hydrogen). The organic forms of arsenic are usually less toxic than the inorganic forms (ATSDR 2005b). Arsenic can be found in most foods, with seafood, particularly shellfish, containing the highest concentrations (FDA 1993). However, most of the arsenic in seafood is in the less harmful organic form (ATSDR 2005b; FDA 1993).

The human body has the ability to change inorganic arsenic to less toxic organic forms (i.e., by methylation) that are more readily excreted in urine. In addition, inorganic arsenic is also directly excreted in the urine. It is estimated that, through these two processes, more than 75 percent of the absorbed arsenic dose is excreted in the urine (Marcus and Rispin 1988).

Because inorganic arsenic is much more harmful than organic arsenic, ATSDR based its health assessment on the levels of inorganic arsenic that are present. In seafood, generally about 1 to 20 percent of the total arsenic is in the more harmful inorganic form (ATSDR 2005b; Francesconi and Edmonds 1997; NAS 2000; FDA 1993). The FDA proposes that 10 percent of the total arsenic be estimated as inorganic arsenic (FDA 1993). Therefore, ATSDR used a conversion factor of 10 percent to calculate the estimated dose to reflect inorganic arsenic levels in land crabs from Vieques (i.e., ATSDR assumed that 10 percent of the total arsenic detected was inorganic arsenic).

The metabolism of inorganic arsenic (i.e., how it is broken down in the body) has been extensively studied in humans and animals. ATSDR's estimated doses (2.3×10^{-4} mg/kg/day for children and 1.1×10^{-4} mg/kg/day for adults; see Table 1) are well below those that inhibit the body's ability to detoxify or change arsenic to nonharmful forms (doses greater than 5.0×10^{-2} mg/kg/day inhibit detoxification). Therefore, the amount of arsenic that a person consumes in land crabs from Vieques would be reduced by normal metabolic processes in the body.

Further, both adult and child exposure doses were below the noncancer screening guideline, as well as the noncancer health effect levels. Hyperkeratosis (thickening of the skin) and hyperpigmentation (darkening of the skin) were reported in humans exposed to 1.4×10^{-2} mg/kg/day of arsenic in their drinking water for more than 45 years (Tseng et al. 1968). The same study also reported a no-observed-adverse-effect level (NOAEL) of 8.0×10^{-4} mg/kg/day. Therefore, **ATSDR does not expect that people will experience harmful noncancer health effects from eating land crabs containing arsenic from Vieques.**

FDA regulates the level of arsenic in food. To limit the intake to a level considered to be safe, FDA set an action level of 76 mg/kg for crustaceans (FDA 1993). The land crab samples collected from Vieques contain average arsenic concentrations (0.33 mg/kg) well below this level.

The theoretical cancer risk prompted ATSDR to review the toxicological literature to evaluate potential cancer effects. The U.S. Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC), and the EPA have all independently determined that inorganic arsenic is carcinogenic to humans (ATSDR 2005b). Skin cancer was reported for people exposed to 1.4×10^{-2} mg/kg/day of arsenic in their water for more than 45 years (Tseng et al. 1968). However, there is much uncertainty surrounding the reported dose. Because estimates of water intake and dietary arsenic are highly uncertain in this and similar studies, some scientists argue that reported effects may actually be associated with doses higher than 1.4×10^{-2} mg/kg/day. Additional CELs in the literature ranged from 0.0011 to 3.67 mg/kg/day (ATSDR 2005b). The estimated lifetime dose (1.1×10^{-4} mg/kg/day) is at least an order of magnitude below these levels. As such, **no excess cancers from arsenic exposures are expected from consumption of land crabs caught on Vieques.**

Cadmium

Cadmium is an element that occurs naturally in the earth's crust. It is not usually present in the environment as a pure metal, but as a mineral combined with other elements such as oxygen, chlorine, or sulfur (ATSDR 1999). People are mainly exposed to cadmium by smoking cigarettes and, to a lesser extent, eating foods contaminated with cadmium. However, only about 5 to 10

percent of ingested cadmium is actually absorbed by the body; the majority is passed out of the body in feces (McLellan et al. 1978; Rahola et al. 1973). The body changes most of the cadmium into a form that is not harmful, but if too much cadmium is absorbed, the liver and kidneys cannot convert all of it into the harmless form (Kotsonis and Klaassen 1978; Sendelbach and Klaassen 1988).

FDA regulates the level of cadmium in food. To limit the intake to a level considered to be safe, FDA set an action level of 3 mg/kg for crustaceans (FDA 2001). The land crabs collected from Vieques contained average cadmium concentrations (0.04 mg/kg) well below this level.

ATSDR reviewed the literature and found that cadmium at the levels detected in Vieques land crabs has not been shown to cause adverse health effects. In a study of people who ate contaminated rice for up to 70 years, no adverse health effects were observed at doses of 2.1×10^{-3} mg/kg/day (Nogawa et al. 1989). EPA's RfD is based on a toxicokinetic model (using data from several studies), which predicts that people chronically exposed to 1.0×10^{-2} mg/kg/day of cadmium in their food would experience no adverse health effects (EPA 1985). Both these health effect levels are at least one order of magnitude higher than the estimated exposure doses (2.8×10^{-4} mg/kg/day for children and 1.3×10^{-4} mg/kg/day for adults; see Table 1); therefore, **ATSDR does not expect that people will experience harmful health effects from eating land crabs containing cadmium from Vieques.**

Chromium

Chromium, a naturally occurring element, can be found in three main forms—chromium 0, chromium III (also known as trivalent chromium), and chromium VI (also known as hexavalent chromium). Chromium III is an essential nutrient required by the body. Chromium VI is more harmful, and more easily absorbed. However, once inside the body, some of it is converted into chromium III. In addition, most of the chromium ingested will exit the body in feces within a few days and never enter the bloodstream. Only a very small amount (0.4 to 2.1 percent) of chromium can pass through the walls of the intestine and enter the bloodstream (Anderson et al. 1983; Anderson 1986; Donaldson and Barreras 1966).

Both the child and adult exposure doses were above the screening guideline for chromium VI, but both were below the screening guideline for chromium III. The oral screening guideline for chromium VI is based on a study in which no adverse health effects were reported in animals exposed to 2.5 mg/kg/day of chromium VI in their drinking water (MacKenzie et al. 1958). In comparison, rats were fed 1,468 mg/kg/day of chromium III and experienced no adverse health effects (Ivankovic and Preussmann 1975). Both these health effect levels are over a hundred times higher than the estimated exposure doses (9.9×10^{-3} mg/kg/day for children and 4.5×10^{-3} mg/kg/day for adults; see Table 1); therefore, **ATSDR does not expect that people will experience harmful noncancer health effects from eating land crabs containing chromium from Vieques.**

FDA regulates the level of chromium in food. To limit the intake to a level considered to be safe, FDA set an action level of 12 mg/kg for crustaceans (FDA 2001). The land crabs collected from Vieques contained average chromium concentrations (1.4 mg/kg) well below this level.

DHHS has determined that certain chromium VI compounds are known human carcinogens when inhaled, not when eaten. IARC has determined that chromium VI is carcinogenic to

humans and chromium 0 and chromium III are not classifiable as to their carcinogenicity. EPA has determined that chromium VI in air is a human carcinogen, but insufficient evidence exists to determine whether chromium VI and chromium III in food and water are human carcinogens (ATSDR 2000a). Once chromium VI gets into the body of a living organism, it is converted to chromium III. Therefore, consuming land crabs with chromium is not expected to result in an increase in cancer because the available scientific evidence suggests that oral exposure to chromium would not cause cancer. Animal studies involving chromium ingestion have found no evidence of carcinogenicity (Ivankovic and Preussmann 1975). Therefore, **no excess cancers from chromium exposures are expected from eating land crabs caught on Vieques.**

Copper

Copper is a naturally occurring metal. Once ingested, it is absorbed by the stomach and small intestines, enters the bloodstream, and is distributed throughout the body. About two-thirds of the body's copper content is found in the skeleton and muscle, and the liver is a key site for maintaining copper concentrations (NAS 2000). The body has homeostatic mechanisms that effectively block high levels from entering the bloodstream (ATSDR 2004). Several factors affect the absorption of copper, including competition with other metals, such as cadmium, iron, and zinc; the amount of copper in a person's diet; and age (ATSDR 2004). Both copper absorption and bioavailability vary with dietary copper intake—the higher the copper intake, the lower the absorption and bioavailability (NAS 2000).

Copper is essential for good health. It is required for the normal functioning of at least 30 enzymes (ATSDR 2004). It aids in the absorption and utilization of iron and in the production of hemoglobin, which transports oxygen in the body. However, even though the body is very good at regulating how much copper enters the bloodstream, excessive intakes can cause harmful health effects.

Very few toxicological and epidemiological studies are available for copper because it is a necessary nutrient. The National Academy of Sciences reports that no long-term adverse effects (i.e., liver damage) were observed at doses of 10–12 milligrams per day (mg/day) (NAS 2000). To support their assessment, the National Academy of Sciences reviewed a large international database for humans according to which there are no adverse effects from daily consumption of 10–12 mg/day of copper in foods. Further, observed liver damage from copper exposure in people with normal copper homeostasis is rare. Therefore, for comparison, ATSDR calculated a daily consumption from exposure to the average concentration of copper in land crabs using a modification of the dose equation (dose = concentration × ingestion rate); and compared this daily dose to the level determined by the National Academy of Sciences to be safe (10 mg/day).

Eating land crabs from Vieques would increase a child's daily consumption of copper by about 3.7 mg/day and an adult's daily consumption by about 7.3 mg/day. The median copper intake in the United States from food is approximately 1.0–1.6 mg/day (NAS 2000). The daily increases in consumption (from eating land crabs from Vieques) are not likely to increase a child's daily dose above the National Academy of Sciences' Tolerable Upper Intake Level of 10 mg/day. An adult's daily intake might approach this level; however, given the body's ability to regulate the

absorption of copper, **ATSDR does not expect that eating land crabs containing copper would cause harmful health effects in healthy individuals.**[1]

That said, there is a relatively recent study that evaluated gastrointestinal symptoms in groups of 327–340 men and women who were exposed to copper in their drinking water for 2 months (Araya et al. 2003). The estimated exposure dose for children was slightly above the level that showed a significantly increased incidence of gastrointestinal symptoms. Therefore, there is some indication that children may experience short-term, reversible gastrointestinal disturbances. However, for the following reasons, ATSDR does not expect that eating the level of copper detected in Vieques land crabs would cause gastrointestinal symptoms in children.

- In biological systems such as humans and animals, copper tends to bind to proteins instead of other elements to form salts. The chemical form of copper found in land crabs is not as easily absorbed by the body as the form of copper found in water. The National Academy of Sciences reported that liver damage is a more relevant critical endpoint for exposure through food than gastrointestinal effects (NAS 2000). As noted previously, the estimated child daily intake is below levels reported as causing no adverse liver effects.

- The exposure doses were calculated from whole land crab samples (including exoskeleton and internal organs). The average copper concentration of the muscle sampled by ATSDR in 2001 (14.2 mg/kg) was about half the average concentration of the whole land crab sampled by NOAA (32.2 mg/kg). The exoskeleton data suggest that copper concentrations in the exoskeleton (average concentration = 6.0 mg/kg) are much lower than in the whole crab samples. Crabs use a copper-containing blood protein called hemocyanin to transport oxygen in their bodies. From the analysis data of land crabs, it appears that the copper is found mostly in the internal organs (where most of the blood is). If people do not eat the internal organs, their exposure would be lower than estimated.

  Children who eat the muscle portion of the land crab every day are not expected to experience short- or long-term health effects.

- Based on the levels and widespread prevalence detected in all Vieques land crabs including the reference locations, copper does not seem to be coming from an environmental release. The average concentrations detected in the areas ranged from 19.65 mg/kg at Area 9 to 55.42 at Area 7.[2] The average copper concentrations in land crabs from the reference locations were 24.72 mg/kg at Area 14 and 29.2 mg/kg at Area 13.

Iron

Iron is an important mineral, assisting in the maintenance of basic life functions. It combines with protein and copper to make hemoglobin, which transports oxygen in the blood from the lungs to other parts of the body, including the heart. It also aids in the formation of myoglobin, which supplies oxygen to muscle tissues. Without sufficient iron, the body cannot produce enough hemoglobin or myoglobin to sustain life. Iron deficiency anemia is a condition that occurs when the body does not receive enough iron.

[1] Persons with Wilson's disease have a genetic defect that impairs copper homeostatic mechanisms (ATSDR 2004).
[2] Area 7 contained the highest land crab concentration (107 mg/kg). The next highest concentration was 68.1 mg/kg, from Area 10.

Only the child exposure dose was above the noncancer health guideline. The oral health guideline for iron is based on dietary intake data collected as part of EPA's Second National Health and Nutrition Examination Survey, in which no adverse health effects were associated with average iron intakes of 0.15–0.27 mg/kg/day. These levels were determined to be sufficient for protection against iron deficiency, but also low enough not to cause harmful health effects. Eating Vieques land crabs would result in exposure doses higher than these NOAELs. However, estimated doses that exceed the NOAELs do not automatically indicate that an adverse health effect will occur, because NOAELs indicate a level in which no adverse health effects were observed. Further, the body uses a homeostatic mechanism to keep iron burdens at a constant level despite variations in the diet (Eisenstein and Blemings 1998).

Generally, iron is not considered to cause harmful health effects except when swallowed in extremely large doses, as in the case of accidental drug ingestion. Acute iron poisoning has been reported in children less than 6 years of age who have accidentally overdosed on iron-containing supplements for adults. According to the FDA, doses greater than 200 mg per event could poison or kill a child (FDA 1997). For comparison, ATSDR calculated a daily consumption from exposure to the average concentration of iron in land crabs using a modification of the dose equation (dose = concentration × ingestion rate).

Eating land crabs from Vieques would increase a child's daily consumption of iron by about 8.7 mg/day (see Table 1). The median daily intake of dietary iron is roughly 11–13 mg/day for children 1 to 8 years old and 13–20 mg/day for adolescents 9 to 18 years old (NAS 2000). Therefore, the daily increases in consumption (from eating land crabs) are not likely to cause a child's daily dose to exceed levels known to induce poisoning (e.g., more than 200 mg/event). Therefore, **ATSDR does not expect that eating land crabs containing iron would cause harmful health effects.**

Nickel

Nickel is the 24th most abundant element and, combined with other elements (primarily oxygen or sulfur), occurs naturally in the earth's crust. Pure nickel is a hard, silvery-white metal that has properties that make it very desirable for combining with other metals (e.g., iron, copper, chromium, and zinc) to form alloys (ATSDR 2005a). Data show only 4 to 7 percent of the nickel taken into the body with food is absorbed by the body; the rest passes through into the urine (Solomons et al. 1982).

Only the child exposure dose was above the noncancer screening guideline. The oral screening guideline for nickel is based on a study in which no adverse health effects were observed in rats exposed to 5.0 mg/kg/day of nickel in their diet for 2 years (Ambrose et al. 1976). In human studies, no adverse effects were seen from ingestion of 0.014 to 0.043 mg/kg/day of nickel (ATSDR 2005a). Allergic dermatitis is the most common adverse effect seen in people exposed by all routes. The exposure doses ATSDR estimated for nickel (3.3×10^{-2} mg/kg/day for children and 1.5×10^{-2} mg/kg/day for adults; see Table 1) are within the range shown to cause no adverse health effects in humans. Therefore, **ATSDR does not expect that people will experience harmful health effects from eating land crabs containing nickel from Vieques.**

DHHS has determined that metallic nickel can reasonably be anticipated to be a human carcinogen and that nickel compounds are known to be human carcinogens when inhaled. Similarly, IARC (1990) classified metallic nickel as possibly carcinogenic to humans and nickel compounds as carcinogenic to humans. While inhaled nickel dust is considered to be carcinogenic, there is no indication that the form of nickel found in foods causes cancer. Additionally, the form of nickel found in foods is not readily absorbed by the body. Therefore, **no excess cancers from nickel exposures are expected from eating land crabs caught on Vieques.**

FDA regulates the level of nickel in food. To limit the intake to a level considered to be safe, FDA set an action level of 70 mg/kg for crustaceans (FDA 2001). The land crabs collected from Vieques contained average nickel concentrations (4.6 mg/kg) below this level.

Vanadium

Vanadium is a natural element in the earth, often found as crystals. In the environment it is usually combined with other elements such as oxygen, sodium, sulfur, or chloride. Most of the vanadium that is ingested is not absorbed into the bloodstream. Studies on volunteers and animals suggest that vanadium is poorly absorbed (less than 3 percent; ATSDR 1992).

Both adult and child exposure doses were above the noncancer screening guideline. The lowest human health effect level reported in the scientific literature is from a study in which no adverse health effects were observed in people exposed to 1.3 mg/kg/day of vanadium for 3 months (Dimond et al. 1963). The exposure doses ATSDR estimated for vanadium (2.3×10^{-3} mg/kg/day for children and 1.1×10^{-3} mg/kg/day for adults; see Table 1) are three orders of magnitude below this NOAEL. As such, **ATSDR does not expect that people will experience harmful health effects from eating land crabs containing vanadium from Vieques.**

Area-Specific Evaluation

Some of the areas sampled contained higher average concentrations for certain chemicals than the other areas. For example, Area 3 and Area 9 contained higher average 4,4-DDE concentrations than the other areas sampled, including the reference locations. Another notable example is that Area 12 contained higher cadmium concentrations than the other areas sampled. However, the concentrations in one or two individual crabs varied as much as 10 times higher than the other samples from that area pushing up the average concentration for the area. Such variation suggests that location is not sole determining factor in contaminant concentration. For other chemicals ATSDR evaluated further, there were no remarkable differences between the average concentrations calculated for each location.

Aware of the differences between locations for some of the chemicals, ATSDR also evaluated whether eating land crabs from any individual area would be expected to cause harmful health effects. Using the same methodologies as previously, ATSDR calculated exposure doses using the average concentration for each area. The levels of PCBs, organochlorine pesticides, and trace elements[3] found in land crabs are lower than levels reported in the scientific literature as causing harmful health effects. Therefore, none of the areas pose a health concern. Based on ATSDR's

[3] Explosive compounds were not detected.

evaluation, **no harmful health effects would be expected to occur from eating one meal of land crab every day from any of the sampled locations.**

Conclusions

1. The levels of PCBs, organochlorine pesticides, and trace elements found in land crabs are much lower than levels reported in the scientific literature as causing harmful health effects. Therefore, ATSDR does not expect that adults or children will experience harmful health effects from eating land crabs from Vieques.

2. The crab samples collected from 12 different areas and two reference locations all show levels of contaminants below the U.S. Food and Drug Administration (FDA) regulatory contaminant limit for shellfish consumption. Explosive compounds were not detected in any crab sample.

3. ATSDR found no association between sampling location and contaminant levels in land crabs. PCBs and pesticides were detected in only a few land crab samples, indicating that the presence of PCBs and pesticides in land crabs is not widespread.

Recommendations

As a prudent public health practice, children can reduce their exposure to copper levels in crab by not eating the land crab's internal organs such as lungs, hepatopancreas, etc.

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Appendix A

Comparing Estimated Doses to Screening Guideline Values

ATSDR evaluates potential exposure to chemicals by calculating exposure doses and comparing the doses to the chemicals' protective screening guideline values (e.g., minimal risk levels [MRLs] and reference doses [RfDs]). Estimated exposure doses that are below screening guideline values are not considered to be of health concern. ATSDR's MRLs and EPA's RfDs are estimates of the daily human exposure to hazardous substances that are likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure.

> An exposure dose, expressed in milligrams per kilogram per day (mg/kg/day), represents the amount of contaminant mass that an individual is assumed to inhale, ingest, or touch (in milligrams), divided by the body weight of the individual (in kilograms) each day.

When estimating exposure doses, health assessors evaluate chemical concentrations to which people could have been exposed, together with the length of time and the frequency of exposure. Collectively, these factors influence an individual's physiological response to chemical exposure and potential outcomes. Where possible, ATSDR used site-specific information regarding the frequency and duration of exposures. When site-specific information was not available, ATSDR employed several protective assumptions to estimate exposures. The following equation was used to calculate exposure doses:

$$\text{Estimated exposure dose} = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

where:

- C — Average concentration (milligrams per kilogram)
- IR — Ingestion rate: adult = 0.227 kilograms/day (8-ounce meal), child = 0.1135 kilograms/day (4-ounce meal)
- EF — Exposure frequency, or number of exposure events per year of exposure: 365 days/year
- ED — Exposure duration, or the duration over which exposure occurs: adult = 70 years (lifetime exposure), child = 6 years (typical ATSDR assumption)
- BW — Body weight: 70 kilograms, child = 16 kilograms (represents an older child/toddler)
- AT — Averaging time, or the period over which cumulative exposures are averaged: noncancer = ED × 365 days/year; cancer/lifetime = 70 years × 365 days/year

MRLs and RfDs are generally based on the most sensitive end point considered to be of relevance to humans. While estimated doses below these values are not considered to be of health concern, exposure to levels above the MRL or RfD does not automatically mean that adverse health effects will occur. To maximize human health protection, MRLs and RfDs have built-in uncertainty or safety factors, making them considerably lower than levels at which health effects have been observed. If a dose is higher than the screening guideline, it is only an indication that ATSDR should further examine the harmful effect levels reported in the scientific literature and more fully review exposure potential.

Estimating Cancer Risk

To screen for cancer effects, estimated chronic-exposure doses were multiplied by EPA's cancer slope factors (CSFs) to measure the relative potency of carcinogens. This calculation estimates a theoretical excess cancer risk expressed as the proportion of a population that may be affected by a carcinogen during a lifetime of exposure. For example, an estimated cancer risk of 1×10^{-6} predicts the probability of one additional cancer over background in a population of 1 million. Because conservative models are used to derive CSFs, the doses associated with these estimated hypothetical risks may be orders of magnitude lower than doses reported in the toxicology literature to cause carcinogenic effects. As such, a low cancer risk estimate indicates that the toxicology literature would support a finding that no excess cancer risk is likely. A higher cancer risk estimate indicates that ATSDR should carefully review the toxicology literature before making conclusions about potential cancer risks.

Comparing Estimated Doses to Health Effects Levels

If the screening guideline values are exceeded, ATSDR examines the health effects levels (e.g., no-observed-adverse-effect levels and lowest-observed-adverse-effect levels) discussed in the scientific literature and more fully reviews exposure potential. ATSDR reviews available human studies and experimental animal studies. This information is used to describe the disease-causing potential of a particular chemical and to compare site-specific dose estimates with doses shown in applicable studies to result in illness (known as the margin of exposure). This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

The no-observed-adverse-effect level (NOAEL) is the highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

The lowest-observed-adverse-effect level (LOAEL) is the lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

When comparing actual health effect levels in the scientific literature, ATSDR tries to estimate more realistic exposure scenarios to use for comparison. In this level of the evaluation, an average concentration was used to calculate exposure doses to estimate a more probable exposure to a range of concentrations over time.

Sources for Health-Based Screening Guideline Values

By Congressional mandate, ATSDR prepares toxicological profiles for hazardous substances found at contaminated sites. These toxicological profiles were used to evaluate potential health effects from eating land crabs (*Cardisoma guanhumi*) caught on Vieques. ATSDR's toxicological profiles are available on the Internet at http://www.atsdr.cdc.gov/toxpro2.html or through the National Technical Information Service (NTIS), which can be contacted at 1-800-553-6847. In some cases, ATSDR also used EPA's health effects guidelines to evaluate potential health effects. These guidelines are found in EPA's Integrated Risk Information System (IRIS)—a database of human health effects that could result from exposure to various substances found in the environment. IRIS is available on the Internet at http://www.epa.gov/iris. For more

information about IRIS, please call EPA's IRIS hotline at 301-345-2870 or e-mail at Hotline.IRIS@epamail.epa.gov.

Chemicals Without Screening Guideline Values

Essential nutrients (e.g., calcium, magnesium, potassium, and sodium) are important minerals that maintain basic life functions; therefore, certain doses are recommended on a daily basis. Because these chemicals are necessary for life, screening guideline values do not exist for them. They are found in many foods, such as milk, bananas, and table salt. Ingestion of these essential nutrients at the concentrations found in the land crabs from Vieques will not result in harmful health effects.

Chemicals Not Detected or Detected Infrequently

Explosive compounds were not detected in land crabs from Vieques. Only one commercial polychlorinated biphenyl (PCB) congener mixture (Aroclor 1260) was detected in a single land crab sample. Many of the pesticides were also not detected or were detected infrequently (i.e., in fewer than 5 percent of the samples). People eating land crabs from Vieques have less than a 1 in 20 chance of eating seafood containing these chemicals.

If no one comes in contact with a chemical (because it is not present in the land crabs they eat), then no exposure occurs, and thus no health effects could occur. The following chemicals were not detected in any land crab sample and were, therefore, not evaluated further:

Explosive Compounds	Pesticides	PCBs
2-Amino-4,6-dinitrotoluene	Chlorpyrifos	Aroclor 1016
4-Amino-2,6-dinitrotoluene	Endosulfan I	Aroclor 1221
1,3-Dinitrobenzene	Endosulfan II	Aroclor 1232
2,4-Dinitrotoluene	Endrin Aldehyde	Aroclor 1242
2,6-Dinitrotoluene	Endrin Ketone	Aroclor 1248
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	alpha-Hexachlorocyclohexane (HCH)	Aroclor 1254
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	beta-HCH	Aroclor 1262
Nitrobenzene	delta-HCH	Aroclor 1268
2-Nitrotoluene	gamma-HCH (Lindane)	
3-Nitrotoluene	Heptachlor	
4-Nitrotoluene	Isodrin	
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	cis-Nonachlor	
1,3,5-Trinitrobenzene	Oxychlordane	
2,4,6-Trinitrotoluene (TNT)	Toxaphene	

The following chemicals were detected in fewer than 5 percent of the samples. ATSDR calculated exposure doses for these chemicals and compared them to screening guideline values and health effect levels. None of the chemicals were detected at levels of health concern.

Pesticides	Pesticides	PCBs
Aldrin	Endosulfan Sulfate	Aroclor 1260
Chlordane	Endrin	
2,4'-DDD	Heptachlor Epoxide	
2,4'-DDE	Methoxychlor	Trace Elements
Dieldrin	trans-Nonachlor	Beryllium

Chemicals with Exposure Doses Below Screening Guideline Values

ATSDR calculated exposure doses for the chemicals that were detected in more than 5 percent of the land crab samples. Exposure doses for the following pesticides and trace elements were below screening guideline values. In other words, the following chemicals were not found at levels of health concern for people eating one meal of Vieques land crab every day.

Pesticides	Trace Elements	Trace Elements
alpha-Chlordane	Aluminum	Selenium
gamma-Chlordane	Barium	Silver
4,4'-DDD	Cobalt	Thallium
2,4'-DDT	Lead	Uranium
4,4'-DDT	Manganese	Zinc
Mirex	Mercury	

Chemicals with Exposure Doses Above Screening Guideline Values

ATSDR determined that the following eight chemicals warranted further evaluation because the exposure doses that were derived using the average concentrations exceeded the screening guideline values.

Pesticides	Trace Elements	Trace Elements
4,4'-DDE (EPA's RfD 5.0E-04)	Arsenic (EPA's RfD 3.0E-04)	Iron (EPA's RfD 3.0E-01
	Cadmium (EPA's RfD 1.0E-03)	Nickel (EPA's RfD 2.0E-02)
	Chromium (EPA's RfD 1.5E+00)	Vanadium (EPA's RfD 1.0 E-03)
	Copper (EPA's RfD 4.0E-02)	

Screening guideline values have built-in safety factors, making these values considerably lower than levels at which health effects have been observed. It does not automatically mean the people who eat land crabs will experience harmful health effects. Rather, this is an indication that ATSDR should further examine the health effect levels reported in the scientific literature and more fully review exposure potential for these chemicals. See the main body of this health consultation and Table 1 for ATSDR's evaluation. EPA's Reference Dose Screening Values are in parentheses