

# Health Consultation

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Exposure Investigation Report

DUPONT DELISLE PLANT  
(a/k/a DUPONT E I DE NEMOURS AND COMPANY, INCORPORATED)

PASS CHRISTIAN, HARRISON COUNTY, MISSISSIPPI

EPA FACILITY ID: MSD096046792

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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**

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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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## **Executive Summary**

To assess potential community exposure to dioxin-like compounds generated at the DeLisle, MS DuPont DeLisle plant, ATSDR tested blue crab and sediments in St. Louis Bay and, as a reference, in Heron Bay. In 2004, DuPont DeLisle's titanium dioxide plant reported the third highest amount of dioxin-like compounds in EPA's Toxic Release Inventory (TRI). In 2005, the Hurricane Katrina storm surge flooded significant portions of the plant. Unlike other aquatic organisms, blue crabs do not have the ability to metabolize quickly certain dioxin-like compounds (polychlorinated dibenzofurans) that predominate in the coke and ore solids waste stream of the plant. Results of the testing show that consumption of crabmeat at typical levels poses no apparent public health hazard. Frequent consumption of crab hepatopancreas may, however, be a health concern for some community members. Specifically, to reduce exposing infants to dioxin during pregnancy later in life, adolescent girls and young women should currently avoid consumption of crab hepatopancreas.

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## Toxicity Equivalence Factors

Throughout this document ATSDR describes concentrations in terms of toxic equivalents (TEQs). TEQs are based on the theory that dioxins, furans, and co-planar PCBs are believed to have similar health effects. But the different congeners of these chemicals are thought to have varying strengths or potencies and thus contribute to health effects in varying degrees. For example, to derive the toxic equivalent for dioxin, all forms of dioxin are added together. The most toxic forms contribute greatly to the sum while less toxic forms contribute very little. The resultant TEQ, then, provides relative perspective to the potency of any given dioxin mixture. Other approaches for calculating TEQs are also available. For details and discussion of TEQs see ATSDR's *Toxicological Profile for Chlorinated Dibenzo-p-dioxins*, pages 256–61 [1].

WHO Toxic Equivalence (TEQ) using World Health Organization (WHO) toxicity equivalence factors (WHO-TEF) and EPA TEF values (I-TEF) shown in Table 1, below [2,3].

**Table 1. Toxicity Equivalence Factors used in WHO-TEQ**

Abbreviation	Chemical name	1998 WHO-TEF	2005 WHO-TEF	I-TEF
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin	1	1	1
2,3,7,8-TCDF	2,3,7,8-tetrachlorodibenzofuran	0.1	0.1	0.1
1,2,3,7,8-PCDF	1,2,3,7,8-pentachlorodibenzofuran	0.05	0.03	0.05
2,3,4,7,8-PeCDF	2,3,4,7,8-pentachlorodibenzofuran	0.5	0.3	0.5
1,2,3,7,8-PeCDD	1,2,3,4,7,8-pentachlorodibenzo-p-dioxin	1	1	0.5
1,2,3,4,7,8-HxCDF	1,2,3,4,7,8-hexachlorodibenzofuran	0.1	0.1	0.1
1,2,3,6,7,8-HxCDF	1,2,3,6,7,8-hexachlorodibenzofuran	0.1	0.1	0.1
2,3,4,6,7,8-HxCDF	2,3,4,6,7,8-hexachlorodibenzofuran	0.1	0.1	0.1
1,2,3,7,8,9-HxCDF	1,2,3,7,8,9-hexachlorodibenzofuran	0.1	0.1	0.1
1,2,3,4,7,8-HxCDD	1,2,3,4,7,8-hexachlorodibenzo-p-dioxin	0.1	0.1	0.1
1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	0.1	0.1	0.1
1,2,3,7,8,9-HxCDD	1,2,3,7,8,9-hexachlorodibenzo-p-dioxin	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDF	1,2,3,4,6,7,8-heptachlorodibenzofuran	0.01	0.01	0.01
1,2,3,4,7,8,9-HpCDF	1,2,3,4,7,8,9-heptachlorodibenzofuran	0.01	0.01	0.01
1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	0.01	0.01	0.01
OCDF	Octachlorodibenzofuran	0.0001	0.0003	0.001
OCDD	Octachlorodibenzo-p-dioxin	0.0001	0.0003	0.001

## Objectives and Rationale

In an effort to protect the health of area recreational crabbers, ATSDR tested St. Louis Bay blue crabs (*Callinectes sapidus*) for dioxin-like compounds (DLC). Dioxin-like compounds are a community concern — DuPont operates its DuPont DeLisle titanium dioxide manufacturing plant near the bay. In 2004 this plant reported the third highest amount of dioxin-like compounds in EPA’s Toxic Release Inventory (TRI) [4]. Previous tests of St. Louis Bay fish and oysters were inadequate to determine the health risk to consumers; a key sentinel species—crabs—were not collected. Crabs are an important indicator species. The majority of the dioxins reported in analytical tests of DuPont DeLisle’s waste streams are polychlorinated dibenzofurans (CDF). Unlike other aquatic organisms such as fish, crabs lack the ability to metabolize most CDF isomers [5]. In 2005, Hurricane Katrina’s storm surge flooded many portions of the DuPont DeLisle plant. Although reports from Mississippi Department of Environmental Quality (MSDEQ) did not identify a significant release of waste from the plant, some community members nonetheless remain concerned that the hurricane’s flooding or winds may have resulted in releases of dioxin-like compounds from DuPont DeLisle [6].

## Background

When titanium dioxide is manufactured using the chloride-ilmenite process, dioxin-like compounds are a byproduct [7]. Dioxins and dioxin-like compounds represent 17 specific polychlorinated dibenzo dioxins (CDDs) and chlorodibenzofurans (CDFs). Most of dioxin-like compounds generated at DuPont DeLisle are chlorodibenzofurans, which are chemically similar to dioxins [8]. The majority of the dioxin-like compounds are bound to solid waste that is disposed of in an on-site landfill. The landfill is known as Solid Waste Management Unit (SWMU) 8, located in the “Borrow Pit Area” of the plant. The dioxin-like “Coke and Ore Solids” — the compound concentration in the material disposed of in SWMU 8 — has been decreasing. In 2001, the coke and ore solids contained approximately 1,200 ppt WHO98-TEQ. In 2004, dioxin TEQs in the coke and ore solids at the plant have ranged from 317 through 399.5 ppt WHO98- TEQ. Community members have expressed concern that the DuPont DeLisle coke and ore solids might reach the bay either through runoff or through fugitive air emissions from the reprocessing of coke and ore solids. Stack air emissions of dioxin-like compounds result from this process, and DuPont operates a coal boiler, which also generates dioxin-like compounds.

The plant’s effluent outfalls (Table 1) are permitted under the National Pollution Elimination System (NPDES) [9]. St. Louis Bay is a shallow, lagoon-type bay with a relatively narrow inlet connecting it to the waters of Mississippi sound [10]. The approximate wet surface area of the bay at mean low water is 15.74 square miles [10]. The Jourdan and Wolf rivers discharge into St. Louis Bay. Approximately 27 tidal bayous also drain into St. Louis Bay [10]. Larger bayous are Portage, DeLisle, Mallini, Joes, Watts, Catfish, and Cutoff [10]. The discharge from the Wolf and Jourdan Rivers and predominantly north-south wind patterns influence cyclonic (counter-clockwise) circulation in St. Louis Bay [10].



## **Methods**

### **Exposure Investigation Design**

This EI assesses whether dioxin-like compounds in St. Louis Bay crabs could present a health hazard to persons who consume them. Possible routes for dioxin-like compounds from the DuPont DeLisle plant to reach St. Louis Bay include discharges and runoff from the plant, as well as fugitive and stack emissions from plant operations.

During September, 2006, blue crabs and sediment were collected from St. Louis Bay, and, to serve as a reference, from Heron Bay as well. With assistance from Mississippi Department of Marine Resources (MDMR), ATSDR deployed crab pots at seven sampling stations in four general areas of St. Louis Bay, and one trap in Heron Bay. Initially, ATSDR had planned to collect samples at eight sampling stations, but MDMR did not have enough crab pots to support eight stations, so the number was reduced to seven. From each of these traps, ATSDR collected 10 male blue crabs. The crabs were shipped to SRS Paradigm Analytic Laboratory (Wilmington, NC), where homogenates of finmeat and hepatopancreas were analyzed for dioxin-like compounds.

### **Target Population**

Because commercial crabbing north of the CSX railroad bridge is prohibited in St. Louis Bay, the target population for this EI includes only persons who consume St. Louis Bay crabs caught recreationally [11]. During multiple site visits, ATSDR staff observed recreational crabbing in the St. Louis Bay.

### **Environmental Sampling**

Crabs were caught in crab-pot traps located in the bay. As a reference sample, one trap was placed in Heron Bay, approximately 10 miles west of the mouth of St. Louis Bay. Placement within these areas was determined by a combination of

- the proximity to the plant outfalls, and
- observation of local crabbers.

Once placed, the location of the traps was referenced using a global positioning system (GPS) device. The trap buoys were unmarked to prevent sample tampering with or removal of the traps. Figures 1 and 2 show sample locations.

### ***Data Collection/Sampling Procedures***

#### ***Crab Collection and Processing***

With the assistance of MDMR personnel, ATSDR staff checked each trap daily. Staff members removed male blue crabs from the traps, and euthanized and shipped them to the laboratory until 10 crabs were collected from each sampling location. Sample locations were logged using a GPS. Female and undersized crabs were returned to the bay. Sampling equipment was precleaned and kept near the front of the boat, away from the motor and any exhaust gases. Crabs were handled using new, commercially purchased crab tongs or disposable nitrile gloves. Between sampling stations crab tongs were rinsed with site water and scrubbed clean. Crabs with any damage to their exoskeletons were not used [12]. Crabs were generally within the legal size

range. Still, at three stations, A-1, B-1, and C-2, blue crab that initially appeared within legal limits were, when euthanized, discovered to be slightly below legal size. Average size for each composite sample was however within legal bounds.

Crabs were euthanized by asphyxiation using dry ice-generated carbon dioxide. Crabs were wrapped individually in aluminum foil (shiny side out), placed in double plastic freezer bags, and then in dry ice-lined coolers. Crabs were stored shell side down so that body cavity fluids would drain away from muscle tissue. Tissue was shipped to the lab frozen over dry ice. Dissection and removal of the hepatopancreas was performed at the laboratory.

### *Ponar Grab Sampling*

On the first day of sampling, ATSDR staff collected three point composite samples of sediment in the immediate area of the traps. Sediment samples were collected with a mini-Ponar grab sampler, following EPA-ERT SOP#2016 [13]. Samples were homogenized and placed in certified, precleaned 4-oz amber glass sampling jars provided by the laboratory. Between sampling events the Ponar sampler was decontaminated with site water.

Samples were stored on ice and shipped to the laboratory overnight with a water temperature indicator sample to verify the laboratory received the samples at proper temperature.

### *Laboratory Analytic Procedures*

Laboratory procedures are specified in U.S. EPA's "The Statement of Work for Multi-Media, Multi-Concentration Dioxins and Furans Analysis" (DLM02.0) [14]. Until the tissue from 10 crabs could be homogenized and the analysis for dioxin-like compounds performed, tissue removed from the crabs was stored per DLM02.0. Laboratory reporting is specified in DLM02.0, Exhibit B.

### **Data Analysis Procedures**

For dioxins, ATSDR used the Toxicity Equivalence Factors (TEFs) to calculate Total Equivalents (TEQ). ATSDR then utilized the guidance in Chapters 7 and 8 of the ATSDR Public Health Assessment Guidance Manual to evaluate the public health implications of the data [15]. ATSDR has published a Minimum Risk Level (MRL) for dioxins of 1 pg/kg/day WHO-TEQ for a 70-kg adult [1]. To compare the data to ATSDR's Minimal Risk Level for dioxins of 1 pg/kg/day WHO-TEQ, consumption rates were estimated using previously published crab-consumption studies (Appendix C).

Additionally, the results will be compared to the MSDEQ dioxin limit consumption criterion of 5.0 ppt I-TEQ [16]. As previously discussed, I-TEQs utilize different TEFs than do WHO-TEQs. The MSDEQ value was based on

- 1.2 pg/kg/day dose ( based on a  $1 \times 10^{-5}$  lifetime cancer risk using FDA's risk-specific dose),
- 15.7 grams of fish eaten per day, and
- 70-kg adult body weight [16].

## Results

Higher dioxin-like compounds were detected in St. Louis Bay than in Heron Bay (Figures 1 and 2). The highest concentration of dioxin-like compounds was detected near the outfall of the plant located in St. Louis Bay (0.541 ppt 2005 WHO TEQ in crab meat composite and 6.47 2005 WHO TEQ in the hepatopancreas composite). Congener-specific results are shown in Tables 2, 3, and 4.

## Discussion

Because a persistent release of dioxins from the DeLisle plant could result in higher levels of dioxins nearer the plant, ATSDR staff examined the data statistically to look for spatial clustering. To test for spatial clustering, Local Moran's I was utilized as a cluster analysis technique on the TEQ values of the sediment and on biota samples from the DuPont DeLisle exposure investigation. Local Moran's I is a translation of a nonspatial correlation measure to a spatial context [17]. It examines for clusters of points by identifying samples surrounded by similar samples. The cluster analysis output is an Index value and a z-score for each sample. A significant positive z-score indicates the clustering of similar points near a sample. In this analysis, no samples with a significant positive z-score were found, indicating no clustering of high (or low) WHO 2005 TEQ values. Nevertheless, the most striking aspect of the WHO 2005 TEQ data was that the highest value in all media (sediment, hepatopancreas, and meat) came from the same A-1 location.

The sediment sample results are not consistent with a major release of any dioxin-like compound (DLC) from the DuPont DeLisle plant. On a congener level, sediment concentrations of DLC in St. Louis Bay appear to be lower, but still within the range of previously reported levels from 2004 [18]. For 16 of the 17 dioxin-like congeners analyzed, the six sediment samples in St. Louis Bay were within the range of previous sampling by Elston *et al.* [18]. The single congener found in this EI at lower levels than Elston *et al.* was 2,3,7,8-TCDD. In our samples, the dibenzofuran congeners associated with DuPont DeLisle were not elevated.

For most crabmeat consumption patterns, the dioxin-like compound levels people ingest are not expected to be harmful doses. At the highest concentration of meat, a person would have to consume an average of 127.5 grams of crab per day to result in a dose of dioxin-like compounds equal to ATSDR's MRL of 1 pg/kg/day. But the consumption of hepatopancreas would result in much higher dosages. For instance, a person would have to consume only 10.8 grams of hepatopancreas per day to result in a dose equal to ATSDR's MRL. Doses (Table 5, Table 6, Table 7) are based on consumption levels calculated as shown in Appendix C. Consumption of 11–15 crab per week containing the highest concentration of dioxin detected in this EI, with consumption of hepatopancreas, would not result in a dose higher than ATSDR's MRL. Without consumption of hepatopancreas, a 70-kg person could eat 11–15 crabs, 2–3 times per week without exceeding the ATSDR MRL.

To compare the sampling against the MSDEQ 5-ppt I-TEQ, ATSDR recalculated the crab values into I-TEQ (Table 8). Crabmeat did not exceed the MSDEQ limit consumption criterion. Hepatopancreas from sample location A-1 did however marginally exceed the MSDEQ criterion. For comparison with other published data for Blue Crab and other species, we have also

converted the data using WHO 1998 TEQs (Table 8). Table 8 also shows the average size for each composite sample of crab, as well as range of values.

## **Toxicological Implications**

### ***Noncancer Health Effects***

Chloracne is the best-documented health effect in people exposed to relatively large amounts of dioxins [1]. Chloracne is a severe skin disease characterized by acne-like lesions. It generally occurs on the face and upper body, but can occur elsewhere on the body as well. Unlike common acne, severe chloracne is harder to cure and can be more disfiguring. Although in mild cases the lesions heal several months after exposure ends, in more severe cases the lesions can last for many years after exposure. Most chloracne cases have been attributed to accidental or occupational exposure to high doses of dioxins, which have resulted in body burdens of dioxins ranging from 91 to 2,727 times background levels [19]. Other effects to the skin, such as erythema or red skin rashes, discoloration, and excessive body hair have been reported following exposure to high concentrations of dioxins [1]. Alterations in the ability of the liver to metabolize (i.e., break down) hemoglobin, lipids, sugar, and protein have been reported in people who have been exposed to relatively high concentrations of dioxins. Most of the effects are considered mild and reversible [1]. Still, in some people these effects may last for many years [1]. Some studies of people exposed to dioxins have found slight increases in the risk of diabetes and abnormal glucose tolerance [1]. A more recent analysis of the National Health Examination Survey data found a strong a dose-response relationship between serum concentrations of persistent organic pollutants — including some dioxins — and the prevalence of diabetes [20]. That said, further research examining this possible relationship is needed [20]. Animal studies suggest that the most sensitive health effects of dioxin exposure are developmental, neurobehavioral, and reproductive [1,21], and ATSDR's chronic MRL is based on developmental effects in an animal study [1]. We recognize also that several studies have associated different developmental effects in humans [21,22]. In Dutch preschool children, perinatal exposure to PCBs and dioxins has been associated with changes in T-cell lymphocyte population. [23] In the same study, a higher prevalence of recurrent middle-ear infections and of chicken pox was also attributed to perinatal PCBs and dioxins [23]. Yet this study also found a lower prevalence of allergic reactions and less shortness of breath [23].

ATSDR's MRL is about one to two orders of magnitude below any effect levels demonstrated either experimentally or in epidemiologic studies for both cancer and noncancer health endpoints [21]. To evaluate the potential for noncancerous effects of dioxin-like compounds in blue crab samples, we calculated the amount of crab that would have to be consumed to reach a dose equivalent to ATSDR's chronic MRL.<sup>a</sup> These substance-specific estimates, which are intended to serve as screening levels, are used by ATSDR health assessors and other responders to identify contaminants and potential health effects that may be of concern at hazardous waste sites. It is important to note that MRLs are not intended to define cleanup or action levels for ATSDR or other agencies. To derive MRLs for hazardous substances, ATSDR uses the no-observed-adverse-effect-level/uncertainty factor (NOAEL/UF) approach. These values are set below levels

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<sup>a</sup> An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure.

that, based on current information, might cause adverse health effects in the people most sensitive to such substance-induced effects. For the oral and inhalation routes of exposure, MRLs are derived for acute (1–14 days), intermediate (>14–364 days), and chronic (365 days and longer) exposure durations. MRLs are generally based on the most sensitive substance-induced endpoint considered to be of relevance to humans. As an additional precaution and to avoid the risk of choosing endpoints associated with frank toxicity, ATSDR does not use serious health effects — such as irreparable damage to the liver or kidneys — or birth defects as a basis for establishing MRLs. Also, exposure to a contaminant at a level above the MRL does not in itself mean that adverse health effects will occur.

For most cases, exposure doses are anticipated to be below the MRL from consumption of local crabmeat and even hepatopancreas. A worldwide consensus holds that 1 to 4 pg/kg/day is a tolerable daily intake [21]. The ATSDR MRL for dioxin is consistent with

- World Health Organizations (WHO) Tolerable Daily Intake (TDI), of 1-4 pg/kg/day, [24]
- The Joint Food and Agriculture Organization of the United Nations/WHO Expert Committee on Food Additives tolerable monthly intake of 70 pg/kg/month, [25]
- The European Commission TDI of 2 pg/kg/day, [25]
- The Netherlands' TDI of 1 pg/kg/day, [25]
- Japan's TDI of 4 pg/kg/day, [25] and
- Australia's proposed tolerable monthly intake of 70 pg/kg/month [25].

This EI demonstrated that for most patterns of consumption, the ATSDR MRL is unlikely to be exceeded. Thus noncancer effects of dioxins are not anticipated in populations consuming recreationally caught crabs from St. Louis Bay. Nevertheless, fetuses and breastfeeding infants may be at particular risk from exposure to DLCs due to potential adverse neurodevelopmental, neurobehavioral, and immune system effects. Therefore, the National Academies of Sciences have recommended that girls and young women in the years before pregnancy limit their consumption of foods that contain higher levels of DLCs, such as limiting consumption of foods high in animal fat [24].

### ***Cancer***

Several studies of workers exposed to high levels (i.e., more than 50 times higher than background levels) of 2,3,7,8-tetrachlorodibenzodioxin (2,3,7,8-TCDD) suggest that exposure to 2,3,7,8-TCDD could increase the risk of cancer [1]. The data on specific types of cancers are inconclusive. Many studies reported only small relative risks — the possible impact of confounding factors was not sufficiently evaluated [21]. Although the genotoxicity data are inconclusive, the available data on cancer provide sufficient evidence that 2,3,7,8-TCDD is a carcinogen in animals, and its action is not solely dependent on initiation by other substances [21]. It has been proposed that 2,3,7,8-TCDD is a hormonal carcinogen causing effects in targeted organs and secondary targets through hormonal imbalance. Furthermore, 2,3,7,8-TCDD could promote metabolism of procarcinogens to active intermediates [21].

EPA is in the process of updating its risk assessment for dioxin and dioxin-like compounds [26]. This reassessment was recently reviewed by the National Academies of Science [27].

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Some of the key conclusions and recommendations made by the NAS review include

1. The committee agreed that “although the weight of epidemiological evidence that dioxin is a human carcinogen is not strong, the human data available from occupational cohort studies are consistent with a modest positive association between relatively high body burdens of dioxin and increased mortality from all cancers” [27].
2. Positive animal studies and mechanistic data support classification of dioxin as a human carcinogen. The committee was however split on whether the weight of evidence met all of the criteria necessary to classify dioxin as “carcinogenic to humans.” The committee noted that the evidence for classification of dioxin lies on a continuum with no bright line for easy distinction between a “carcinogenic to humans” versus a “likely carcinogenic to humans” category [27].
3. The committee also concluded adequate evidence is available to support a hypothesis that the relationship between the dioxin dose and cancer risk is likely sublinear at low doses, perhaps reflecting responses indistinguishable from background risk [27].
4. EPA should characterize more completely the uncertainty associated with its cancer risk estimate, and EPA should also consider alternative dose-response functional forms consistent with the available data [27].

The current EPA-recommended cancer slope factor for assessing dioxin in fish and shellfish is  $1.56 \times 10^5$  per mg/kg/day [28]. Using this slope factor, cancer risks are calculated for consumption of crab meat (Table 9) and hepatopancreas (Table 10). Typically, acceptable lifetime risk range for cancer ranges from less than 1 in 1,000,000 to 1 in 10,000 [15,29]. For most consumption patterns, risks fall below the risk level of 1 in 10,000 for meat. Moderate consumption of hepatopancreas will likely result in risk levels higher than 1 in 10,000. Accordingly, ATSDR discourages residents from frequently consuming the crab hepatopancreas.

## **Child Health Considerations**

In communities faced with air, water, or food contamination, the many physical differences between children and adults demand special emphasis. Children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children are shorter than are adults; this means they breathe dust, soil, and vapors close to the ground. A child’s lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus adults need as much information as possible to make informed decisions regarding their children’s health.

Because of DLCs’ potential to cause adverse neurodevelopmental, neurobehavioral, and immune system effects in developing systems, fetuses and breastfeeding infants may be at particular risk from exposure [25]. Potential is also present for exposure to breastfeeding infants to comparatively high levels of DLCs in breast milk [25]. The American Academy of Pediatrics currently recommends that women do not stop breast feeding on the basis of exposure to low-level environmental chemical agents [30]. Long-term breastfeeding has been found to be

beneficial to neurodevelopment, potentially counterbalancing the impact of exposure to chemicals through breast milk [31].

## **Conclusions**

1. ATSDR concludes that consuming crabmeat from 4 to 6 St. Louis Bay blue crabs per day poses no apparent public health hazard.
2. Crab hepatopancreas contains higher concentrations of dioxin than does crabmeat. Therefore, consumption of crabmeat plus hepatopancreas should be limited to no more than two crabs per day.

## **Recommendations**

ATSDR recommends that persons limit their routine consumption of St. Louis Bay blue crab hepatopancreas. Sensitive populations, such as girls and young women in the crucial years before pregnancy, should especially avoid routine consumption of blue crab hepatopancreas. This advice supplements previously published recommendations that this population substitute low-fat or skim milk for whole milk, and make other substitutions of foods lower in animal fat [25].

## **Public Health Action Plan**

ATSDR Health Promotion and Community Involvement Branch will work to develop appropriate materials to inform the community of

- The known health effects of dioxin,
- Those populations sensitive to dioxin exposure, and
- The steps everyone can take to reduce exposure to DLCs.

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## References

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1. Agency for Toxic Substances and Disease Registry. Toxicological profile for chlorinated dibenzo-p-dioxins. Atlanta: US Department of Health and Human Services; 1998 May.
2. Van den Berg M, Birnbaum L, Bosveld ATC, et al. 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, and PCDFs for humans and wildlife. *Environ Health Perspect* 1998; 106(12):775-792.
3. Van den Berg *et al.* The 2005 The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds. *Toxicological Sciences* 93(2): 223-241 (2006).
4. US Environmental Protection Agency. Toxics release inventory facility report for dioxin and dioxin-like compounds. Available at <http://www.epa.gov/triexplorer/facility.htm>. Last accessed 2006 April 18.
5. Oehme M, Bartonova A, Knutzen J. Estimation of polychlorinated dibenzofuran and dibenzop-dioxin contamination of coastal region using isomer profiles in crabs. *Environ Sci Technol* 1990;24:1836–41.
6. Mississippi Department of Environmental Quality. Press Release: MDEQ DuPont Inspection Information. Jackson, MS: Mississippi Department of Environmental Quality; 2005 September.
7. US Environmental Protection Agency. Final titanium dioxide listing background document for the inorganic chemical listing determination. Washington, DC: US Environmental Protection Agency; 2001 October.
8. Agency for Toxic Substances and Disease Registry. Toxicological profile for chlorodibenzofurans. Atlanta: US Department of Health and Human Services; May 1994.
9. Fact Sheet: Application for national pollutant discharge elimination system permit to discharge wastewater to waters of the State of Mississippi. Application No: MS0027294. Jackson, MS: Mississippi Department of Environmental Quality; 2003 May.
10. Eleuterius, CK. St. Louis Bay study, Section I, Hydrography. Ocean Springs, MS: Gulf Coast Research Laboratory; 1973 December.
11. Mississippi Department of Marine Resources. A guide to Mississippi saltwater rules and regulations, 2005–2006. Biloxi, MS; 2005 June.
12. Washington State Department of Health, Under cooperative agreement with the Agency for Toxic Substances and Disease Registry. Lower Elwha Klallam Tribe shellfish beds near Port Angeles Harbor, Port Angeles, Clallam County, Washington. Exposure Investigation workplan for health consultation. Atlanta: US Department of Health and Human Services; 2002 December.
13. US Environmental Protection Agency. Emergency response team standard operating procedure #2016, sediment sampling. Edison, NJ; November 1994. Available at: <http://www.ert.org/products/2016.PDF>. Last accessed 2007 March 8.
14. US Environmental Protection Agency. The Statement of Work (SOW) for multi-media, multi-concentration dioxins and furans analysis (DLM02.0). Washington DC; 2005 May.

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Available at: <http://www.epa.gov/superfund/programs/clp/dlm2.htm>. Last accessed 2006 May.

15. Agency for Toxic Substances and Disease Registry. Public health assessment guidance manual (Update). Atlanta: US Department of Health and Human Services; 2005.
16. Mississippi Department of Environmental Quality. Fish tissue criteria for dioxins. Jackson, MS: Mississippi Department of Environmental Quality; 1990 November.
17. Moran PAP. Notes on continuous stochastic phenomena, *Biometrika* 1950; 37:17–23.
18. Elston R, Cake EW, Humphrey K, Isphording WC, and Rensell JE. Dioxin and heavy metal contamination of shellfish and sediments in St. Louis Bay Mississippi and adjacent waters. *J Shellfish Res* 2005;24(1):227–41.
19. DeVito MJ, Brinbaum LS, Farland WH, Gasiewicz TA. Comparisons of estimated human body burdens of dioxinlike chemicals and TCDD body burdens in experimentally exposed animals. *Environ Health Perspect* 1995;103:820–30.
20. Lee D, Lee I, Song K, Steffes M, Toscana W, Baker BA, et al. A strong dose-response relation between serum concentrations of persistent organic pollutants and diabetes, results from the national health and examination survey 1999–2002. *Diabetes Care* 2006;29(7):1638–1644.
21. Pohl HR, Hicks HE, Jones DE, Hansen H, DeRosa C. Public health perspectives on dioxin risks: two decades of evaluations. *Human Ecol Risk Assess* 2002;2:233–50.
22. Yonemoto J. The effects of dioxin on reproduction and development. *Indus Health* 2000; 38(3):259–68.
23. Weisglas-Kuperus N, et al. Immunologic effects of background exposure to polychlorinated biphenyls and dioxins in Dutch preschool children. *Environ Health Perspect* 2000;108(12): 1203–7.
24. van Leeuwen RFX, Feeley M, Schrenk D, Jarsen JC, Farland W, Younes M. Dioxins: WHO’s tolerable daily intake (TDI) revisited. *Chemosphere* 2000;40:1095–1101.
25. Institute of Medicine, Committee. Dioxins and dioxin-like compounds in the food supply: strategies to decrease exposure. Washington DC: National Academies Press; 2003.
26. US Environmental Protection Agency. Exposure and human health reassessment of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and related compounds. National Academy of Sciences (NAS) Review Draft. Washington DC; 2003.
27. National Research Council. Health risks from dioxin and related compounds evaluation of the EPA reassessment. Washington DC: National Academies Press; 2006.
28. US Environmental Protection Agency. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 2: Risk assessment and fish consumption limits. Third Ed. Washington DC; 2000.
29. Remedial investigation/feasibility study and selection of remedy. US Code of Federal Regulations. 40 CFR 300.430
30. American Academy of Pediatrics. Policy statement: breastfeeding and the use of human milk. *Pediatr* 2005; 115(2):496-506.

31. Ribas-Fitó N, Cardo E, Sala M, Eulàlia de Muga M, Mazón C, Verdú A, et al. Breastfeeding, exposure to organochlorine compounds, and neurodevelopment in infants. *Pediatr* 2003; 111:580–85.

## Appendix A. Tables

**Table 1. DuPont DeLisle NPDES Permitted Outfalls**

<i>Outfall</i>	<i>Description of Pollution Abatement Technology</i>	<i>Receiving Waters</i>	<i>Description of Discharge</i>
Outfall 001: Multiport diffuser located in St. Louis Bay.	Equalization, sedimentation, two-stage neutralization, two-stage mixing, flocculation, sedimentation, and cooling.	St. Louis Bay	Treated process wastewater, non-contact cooling water, and stormwater runoff from process area.
Outfall 002: Site ditch leading to St. Louis Bay (under "extreme conditions").	Equalization and sedimentation.	Either underground injection wells or under extreme conditions, an on-site ditch thence St. Louis Bay.	Stormwater runoff from emergency overflow of process trench areas.
Outfall 003: An internal outfall to retention/sedimentation basin.	Activated sludge followed by chlorine disinfection.	Either underground injection wells or through Outfall 002 to St. Louis Bay.	Treated sanitary wastewater.

**Table 2. Dioxin-like Compounds Sampling Results – Crabmeat (ppt)**

ID		2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	OCDF	WHO 2005 TEQ Totals
WHO 2005 TEF		1	1	0.1	0.1	0.1	0.01	0.0003	0.1	0.03	0.3	0.1	0.1	0.1	0.1	0.01	0.0003	
DL-BC-A-1	Lab Result	[0.149]	[0.221]	[0.111]	0.213 J	0.178 J	1.02 J	6.72 J	0.483 J	[0.0723]	[0.129]	0.0489 J	0.0469 J	ND (0.0627)	ND (0.0976)	0.0743 J	ND (0.145)	0.166 J
	adjusted	0.149	0.221	0.111	0.213	0.178	1.02	6.72	0.483	0.0723	0.129	0.0489	0.0469	0.03135	0.0488	0.0743	0.0725	0.166
	TEQ	0.149	0.221	0.0111	0.0213	0.0178	0.0102	0.00202	0.0483	0.00217	0.0387	0.00489	0.00469	0.00314	0.00488	0.000743	0.000725	0.0000498
DL-BC-A-2	Lab Result	[0.0933]	0.134 J	[0.108]	0.235 J	0.17 J	0.804 J	5.99 J	0.3 J	0.0616 J	0.097 J	0.0392 J	ND (0.042)	ND (0.0414)	ND (0.0616)	[0.0914]	ND (0.0819)	0.203 J
	adjusted	0.0933	0.134	0.108	0.235	0.17	0.804	5.99	0.3	0.0616	0.097	0.0392	0.021	0.0207	0.0308	0.0914	0.04095	0.203
	TEQ	0.0933	0.134	0.0108	0.0235	0.017	0.00804	0.0018	0.03	0.00185	0.0291	0.00392	0.0021	0.00207	0.00308	0.000914	0.000410	0.0000609
DL-BC-B-1	Lab Result	ND (0.101)	[0.156]	0.0906 J	0.198 J	0.171 J	1.5 J	14.2	[0.325]	[0.0564]	[0.0957]	0.0547 J	ND (0.0548)	ND (0.0538)	ND (0.0781)	0.236 J	ND (0.118)	0.515 J
	adjusted	0.0505	0.156	0.0906	0.198	0.171	1.5	14.2	0.325	0.0564	0.0957	0.0547	0.0274	0.0269	0.03905	0.236	0.059	0.515
	TEQ	0.0505	0.156	0.00906	0.0198	0.0171	0.015	0.00426	0.0325	0.00169	0.0287	0.00547	0.00274	0.00269	0.00391	0.002360	0.000590	0.0001550
DL-BC-B-2	Lab Result	ND (0.0645)	[0.098]	0.0524 J	0.127 J	0.0811 J	0.764 J	7.6 J	0.24 J	0.0524 J	0.0676 J	0.027 J	0.0372 J	ND (0.0353)	ND (0.0518)	0.0845 J	ND (0.0666)	ND (0.173)
	adjusted	0.03225	0.098	0.0524	0.127	0.0811	0.764	7.6	0.24	0.0524	0.0676	0.027	0.0372	0.01765	0.0259	0.0845	0.0333	0.086
	TEQ	0.0323	0.098	0.00524	0.0127	0.00811	0.00764	0.0023	0.024	0.00157	0.0203	0.0027	0.00372	0.00177	0.00259	0.000845	0.000333	0.0000258
DL-BC-C-1	Lab Result	ND (0.0678)	0.155 J	ND (0.0581)	0.202 J	0.119 J	0.915 J	7.33 J	0.289 J	[0.0517]	0.0969 J	0.0549 J	0.0323 J	ND (0.0469)	ND (0.0694)	0.128 J	ND (0.099)	0.194 J
	adjusted	0.0339	0.155	0.02905	0.202	0.119	0.915	7.33	0.289	0.0517	0.0969	0.0549	0.0323	0.02345	0.0347	0.128	0.0495	0.194
	TEQ	0.0339	0.155	0.00291	0.0202	0.0119	0.00915	0.00220	0.0289	0.00155	0.0291	0.00549	0.00323	0.00235	0.00347	0.001280	0.000495	0.0000582
DL-BC-C-2	Lab Result	ND (0.0731)	0.149 J	[0.0784]	0.174 J	[0.11]	0.651 J	6.22 J	0.27 J	ND (0.0616)	0.162 J	0.126 J	0.0576 J	ND (0.084)	ND (0.124)	0.12 J	ND (0.124)	0.328 J
	adjusted	0.03655	0.149	0.0784	0.174	0.11	0.651	6.22	0.27	0.0308	0.162	0.126	0.0576	0.042	0.062	0.12	0.062	0.328
	TEQ	0.0366	0.149	0.00784	0.0174	0.011	0.00651	0.00187	0.027	0.000924	0.0486	0.0126	0.00576	0.0042	0.0062	0.001200	0.000620	0.0000984
DL-BC-D-1	Lab Result	ND (0.0971)	0.0833 J	0.0678 J	0.112 J	ND (0.0895)	0.703 J	7.58 J	0.292 J	0.0329 J	0.0736 J	0.0271 J	[0.031]	ND (0.0581)	ND (0.0824)	0.114 J	ND (0.113)	[0.236]
	adjusted	0.04855	0.0833	0.0678	0.112	0.04475	0.703	7.58	0.292	0.0329	0.0736	0.0271	0.031	0.02905	0.0412	0.114	0.0565	0.236
	TEQ	0.0486	0.0833	0.00678	0.0112	0.00448	0.00703	0.00227	0.0292	0.000987	0.0221	0.00271	0.0031	0.00291	0.00412	0.001140	0.000565	0.0000708
DL-BC-E-1	Lab Result	ND (0.0882)	[0.0654]	0.0561 J	0.0879 J	ND (0.0886)	0.91 J	12.2	0.256 J	0.0449 J	ND (0.0327)	ND (0.0531)	ND (0.055)	ND (0.0497)	ND (0.0755)	0.105 J	ND (0.0978)	[0.254]
	adjusted	0.0441	0.0654	0.0561	0.0879	0.0443	0.91	12.2	0.256	0.0449	0.01635	0.02655	0.0275	0.02485	0.03775	0.105	0.0489	0.254
	TEQ	0.0441	0.0654	0.00561	0.00879	0.00443	0.0091	0.00366	0.0256	0.00135	0.00491	0.00266	0.00275	0.00249	0.00378	0.00105	0.000489	0.0000762

J = Amount detected is between the Method Detection Limit and the Lower Calibration Limit

ND = Nondetect (detection limit in parenthesis)

[ ] = Estimated Maximum Possible Concentration

**Table 3: Dioxin-like Compound Sampling Results – Crab Hepatopancreas (ppt)**

ID		2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	WHO 2005 TEQ Totals
WHO 2005 TEF		1	1	0.1	0.1	0.1	0.01	0.0003	0.1	0.03	0.3	0.1	0.1	0.1	0.1	0.01	0.01	0.0003	
DL-BC-A-1	Lab Result	0.779 J	3.45 J	2.25 J	5.31	3.92 J	15	31.6	2.64	0.82 J	1.54 J	0.763 J	0.478 J	0.324 J	ND (0.33)	0.875 J	ND 0.131	0.24 J	
	adjusted	0.779	3.45	2.25	5.31	3.92	15	31.6	2.64	0.82	1.54	0.763	0.478	0.324	0.165	0.875	0.0655	0.24	
	TEQ	0.779	3.45	0.225	0.531	0.392	0.15	0.00948	0.264	0.0246	0.462	0.0763	0.0478	0.0324	0.0165	0.00875	0.000655	0.000072	6.47
DL-BC-A-2	Lab Result	[0.339]	[1.91]	1 J	2.41 J	[1.74]	7.05	14.4	0.984	0.458 J	0.793 JQ	0.418 J	0.228 J	0.222 J	ND (0.145)	0.457 J	ND (0.0764)	[0.175]	
	adjusted	0.339	1.91	1	2.41	1.74	7.05	14.4	0.984	0.458	0.793	0.418	0.228	0.222	0.0725	0.457	0.0382	0.175	
	TEQ	0.339	1.91	0.1	0.241	0.174	0.071	0.0043	0.098	0.0137	0.238	0.0418	0.0228	0.0222	0.00725	0.00457	0.000382	0.0000525	3.29
DL-BC-B-1	Lab Result	0.789 J	3.16 J	1.62 J	3.63 J	2.98 J	11.6	58.9	1.95	0.546 J	1.24 J	0.444 J	0.346 J	0.239 J	ND (0.145)	0.556 J	ND (0.109)	0.224 J	
	adjusted	0.789	3.16	1.62	3.63	2.98	11.6	58.9	1.95	0.546	1.24	0.444	0.346	0.239	0.0725	0.556	0.0545	0.224	
	TEQ	0.789	3.16	0.162	0.363	0.298	0.116	0.0177	0.195	0.0164	0.372	0.0444	0.0346	0.0239	0.00725	0.00556	0.000545	0.0000672	5.61
DL-BC-B-2	Lab Result	0.538 J	2.01 JQ	1.13 J	2.95 J	2.07 J	8.24	34.7	1.52	0.338 J	0.7 J	0.275 J	0.303 J	0.185 J	ND (0.148)	0.465 J	ND (0.0781)	0.239 J	
	adjusted	0.538	2.01	1.13	2.95	2.07	8.24	34.7	1.52	0.338	0.7	0.275	0.303	0.185	0.0740	0.465	0.03905	0.239	
	TEQ	0.538	2.01	0.113	0.295	0.207	0.0824	0.0104	0.152	0.0101	0.2	0.0275	0.0303	0.0185	0.00740	0.00465	0.000391	0.0000717	3.7
DL-BC-C-1	Lab Result	0.734 J	2.8 J	1.25 J	2.66 J	1.9 J	7.53	19.6	1.96	0.485 J	0.98 J	0.422 J	0.338 J	0.175 J	ND (0.134)	0.6 J	ND (0.0724)	0.189 J	
	adjusted	0.734	2.8	1.25	2.66	1.9	7.53	19.6	1.96	0.485	0.98	0.422	0.338	0.175	0.0675	0.6	0.0362	0.189	
	TEQ	0.734	2.8	0.125	0.266	0.19	0.0753	0.00588	0.196	0.0146	0.29	0.0422	0.0338	0.0175	0.00675	0.006	0.000362	0.0000567	4.80
DL-BC-C-2	Lab Result	0.389 J	[1.83] Q	0.963 J	2.3 J	1.6 J	5.91	18.5	1.15	0.367 J	0.915 J	0.487 J	0.276 J	0.161 J	ND (0.125)	0.528 J	ND (0.0986)	0.322 J	
	adjusted	0.389	1.83	0.963	2.3	1.6	5.91	18.5	1.15	0.367	0.915	0.487	0.276	0.161	0.0625	0.528	0.0493	0.322	
	TEQ	0.389	1.83	0.0963	0.23	0.16	0.0591	0.00555	0.115	0.011	0.275	0.0487	0.0276	0.0161	0.00625	0.00528	0.000493	0.0000966	3.28
DL-BC-D-1	Lab Result	0.581 J	2.15 J	1.22 J	2.85 J	2.29 J	9.73	50.7	1.73	0.411 J	0.743 J	0.282 J	0.309 J	0.179 J	ND (0.125)	0.509 J	ND (0.105)	0.261 J	
	adjusted	0.581	2.15	1.22	2.85	2.29	9.73	50.7	1.73	0.411	0.743	0.282	0.309	0.179	0.0625	0.509	0.0525	0.261	
	TEQ	0.581	2.15	0.122	0.285	0.229	0.0973	0.0152	0.173	0.0123	0.223	0.0282	0.0309	0.0179	0.0063	0.00509	0.000525	0.0000783	3.98
DL-BC-E-1	raw	[0.368]	1.04 J	0.633 J	1.32 J	0.961 J	4.78	27.7	0.941	0.164 J	0.435 J	[0.124]	0.133 J	0.083 J	ND (0.081)	0.299 J	ND (0.128)	0.323 J	
	adjusted	0.368	1.04	0.633	1.32	0.961	4.78	27.7	0.941	0.164	0.435	0.124	0.133	0.083	0.0405	0.299	0.064	0.323	
	TEQ	0.368	1.04	0.0633	0.132	0.0961	0.0478	0.00831	0.0941	0.00492	0.131	0.0124	0.0133	0.0083	0.0041	0.00299	0.000640	0.0000969	2.03

J = Amount detected is between the Method Detection Limit and the Lower Calibration Limit

Q=Indicates the presence of a qualitative interference that could cause a false positive or overestimation of the affected analytes

ND = Nondetect (detection limit in parenthesis)

[ ] = Estimated Maximum Possible Concentration

**Table 4. Dioxin-like Compound Results – Sediment (ppt)**

ID		2,3,7,8-TCDD	1,2,3,7,8-PeCDD	1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDD	1,2,3,7,8,9-HxCDD	1,2,3,4,6,7,8-HpCDD	OCDD	2,3,7,8-TCDF	1,2,3,7,8-PeCDF	2,3,4,7,8-PeCDF	1,2,3,4,7,8-HxCDF	1,2,3,6,7,8-HxCDF	2,3,4,6,7,8-HxCDF	1,2,3,7,8,9-HxCDF	1,2,3,4,6,7,8-HpCDF	1,2,3,4,7,8,9-HpCDF	OCDF	WHO 2005 TEQ Totals
WHO 2005 TEF		1	1	0.1	0.1	0.1	0.01	0.0003	0.1	0.03	0.3	0.1	0.1	0.1	0.1	0.01	0.01	0.0003	
DL-SD-A-1	Lab Result	[0.19]	0.56 J	1.67 J	3.81 J	6.29	159	2960	[0.503]	0.315 J	0.345 J	0.791 J	0.615 J	0.671 J	[0.224]	5.69	0.848 J	18.4	
	adjusted	0.19	0.56	1.67	3.81	6.29	159	2960	0.503	0.315	0.345	0.791	0.615	0.671	0.224	5.69	0.848	18.4	
	TEQ	0.19	0.56	0.167	0.381	0.629	1.59	0.888	0.0503	0.00945	0.104	0.0791	0.0615	0.0671	0.0224	0.0569	0.008480	0.005500	4.87
DL-SD-A-2	Lab Result	[0.117]	0.398 J	0.899 J	2.02 J	3.33 J	71	1110	0.416 J	0.207 J	0.207 J	0.641 J	0.283 J	0.32 J	[0.227]	2.62 J	0.565 J	14.6	
	adjusted	0.117	0.398	0.899	2.02	3.33	71	1110	0.416	0.207	0.207	0.641	0.283	0.32	0.227	2.62	0.565	14.6	
	TEQ	0.117	0.398	0.0899	0.202	0.333	0.71	0.333	0.0416	0.00621	0.0621	0.0641	0.0283	0.032	0.0227	0.0262	0.00565	0.00440	2.48
DL-SD-B-1	Lab Result	ND (0.0678)	[0.106]	0.354 J	0.704 J	1.07 J	30.7	733	0.264 J	[0.0623]	0.0977 J	0.104 J	0.0893 J	[0.104]	ND (0.0796)	0.835 J	0.0926 J	1.91 J	
	adjusted	0.0339	0.106	0.354	0.704	1.07	30.7	733	0.264	0.0623	0.0977	0.104	0.0893	0.104	0.0398	0.835	0.0926	1.91	
	TEQ	0.0339	0.106	0.0354	0.0704	0.107	0.307	0.220	0.0264	0.00187	0.0293	0.0104	0.00893	0.0104	0.00398	0.00835	0.000926	0.000570	0.981
DL-SD-B-2	Lab Result	[0.163]	0.452 J	1.22 J	3.03 J	4.72 J	142	2560	0.327 J	0.159 J	0.265 J	0.352 J	0.331 J	0.408 J	0.168 J	4 J	0.393 J	8.59 J	
	adjusted	0.163	0.452	1.22	3.03	4.72	142	2560	0.327	0.159	0.265	0.352	0.331	0.408	0.168	4	0.393	8.59	
	TEQ	0.163	0.452	0.122	0.303	0.472	1.42	0.768	0.0327	0.00477	0.0795	0.0352	0.0331	0.0408	0.0168	0.04	0.00393	0.00260	3.99
DL-SD-C-1	Lab Result	[0.17]	0.485 J	1.13 J	2.99 J	5.12	128	2600	0.351 J	[0.168]	0.297 J	0.403 J	0.48 J	0.595 J	0.147 J	6.29	0.401 J	10.4	
	adjusted	0.17	0.485	1.13	2.99	5.12	128	2600	0.351	0.168	0.297	0.403	0.48	0.595	0.147	6.29	0.401	10.4	
	TEQ	0.17	0.485	0.113	0.299	0.512	1.28	0.7800	0.0351	0.00504	0.0891	0.0403	0.048	0.0595	0.0147	0.0629	0.00401	0.00310	4.00
DL-SD-C-2	Lab Result	ND (0.0896)	0.352 J	0.993 J	1.92 J	2.88 J	87.2	1420	0.414 J	[0.114]	0.177 J	0.188 J	0.227 J	0.319 J	ND (0.16)	2.91 J	0.285 J	5.37 J	
	adjusted	0.0448	0.352	0.993	1.92	2.88	87.2	1420	0.414	0.114	0.177	0.188	0.227	0.319	0.080	2.91	0.285	5.37	
	TEQ	0.0448	0.352	0.0993	0.192	0.288	0.872	0.4260	0.0414	0.00342	0.0531	0.0188	0.0227	0.0319	0.0080	0.0291	0.00285	0.00160	2.49
DL-SD-D-1	Lab Result	[0.125]	0.569 J	1.2 J	3.18 J	5.39 J	142	2210	0.351 J	0.103 J	0.186 J	0.28 J	0.275 J	0.339 J	ND (0.154)	2.89 J	0.267 J	4.77 J	
	adjusted	0.125	0.569	1.2	3.18	5.39	142	2210	0.351	0.103	0.186	0.28	0.275	0.339	0.0770	2.89	0.267	4.77	
	TEQ	0.125	0.569	0.12	0.318	0.539	1.42	0.6630	0.0351	0.00309	0.0558	0.028	0.0275	0.0339	0.00770	0.0289	0.00267	0.00140	3.98
DI-SD-E-1	Lab Result	[0.182]	0.227 J	0.403 J	1.01 J	1.28 J	36	504	0.399 J	ND (0.0836)	0.114 J	ND (0.153)	0.146 J	0.117 J	ND (0.189)	1.71 J	0.237 J	13 J	
	adjusted	0.182	0.227	0.403	1.01	1.28	36	504	0.399	0.0418	0.114	0.0765	0.146	0.117	0.0945	1.71	0.237	13	
	TEQ	0.182	0.227	0.0403	0.101	0.128	0.36	0.151	0.0399	0.00125	0.0342	0.00765	0.0146	0.0117	0.00945	0.0171	0.00237	0.00039	1.33

J = Amount detected is between the Method Detection Limit and the Lower Calibration Limit

ND = Nondetect (detection limit in parenthesis)

[ ] = Estimated Maximum Possible Concentration

**Table 5. Dioxin-like Compounds Dose from consumption of Crab Meat (pg/kg/day, TEQ 2005 WHO)**

Frequency of Consuming Crab							
Number of crabs per meal	Everyday	4-6 times a week	2-3 times a week	Once a week	2 Times a month	One a month	Less than once a month
1-3	0.39	0.28	0.14	0.06	0.03	0.01	0.01
4-6	0.97	0.69	0.35	0.14	0.06	0.03	0.02
7-10	1.66	1.18	0.59	0.24	0.11	0.05	0.03
11-15	2.43	1.73	0.87	0.35	0.16	0.08	0.04
15+	2.92	2.08	1.04	0.42	0.19	0.10	0.05

Assumes DLC concentrations found at station A-1

**Table 6: Dose of Dioxin-like compounds from consumption of Crab Hepatopancreas (pg/kg/day, TEQ 2005 WHO)**

Frequency of Consuming Crab							
Number of crabs per meal	Everyday	4-6 times a week	2-3 times a week	Once a week	2 Times a month	One a month	Less than once a month
1-3	0.70	0.50	0.25	0.10	0.05	0.02	0.01
4-6	1.74	1.24	0.62	0.25	0.11	0.06	0.03
7-10	2.96	2.11	1.05	0.42	0.19	0.10	0.05
11-15	4.35	3.10	1.55	0.62	0.29	0.14	0.07
15+	5.22	3.72	1.86	0.74	0.34	0.17	0.09

Assumes DLC concentrations found at station A-1



**Table 7. Combined Dioxin-like Compounds Dose from Consuming both Meat and Hepatopancreas (pg/kg/day TEQ WHO 2005)**

<b>Frequency of Consuming Crab</b>							
<b>Number of crabs per meal</b>	<b>Everyday</b>	<b>4-6 times a week</b>	<b>2-3 times a week</b>	<b>Once a week</b>	<b>2 Times a month</b>	<b>One a month</b>	<b>Less than once a month</b>
<b>1-3</b>	1.08	0.77	0.38	0.15	0.07	0.04	0.02
<b>4-6</b>	2.70	1.92	0.96	0.38	0.18	0.09	0.04
<b>7-10</b>	4.59	3.27	1.63	0.65	0.30	0.15	0.08
<b>11-15</b>	6.75	4.80	2.40	0.96	0.44	0.22	0.11
<b>15+</b>	8.10	5.76	2.88	1.15	0.53	0.27	0.13

Assumes DLC concentrations at station A-1

**Table 8. Crab Hepatopancreas and Meat Results using I-TEQ and WHO 1998, 2005 TEQ Weighting (ppt, ND=1/2)**

Sample	Average Length of Carapace, inches (Range)	Hepatopancreas			Meat		
		I-TEQ	WHO 1998 TEQ	WHO 2005 TEQ	I-TEQ	WHO 1998 TEQ	WHO 2005 TEQ
DL-BC-A-1	5.6875 (4.75-7.75)	5.1	6.79	6.47	0.463	0.567	0.541
DL-BC-A-2	6.3125 (5.5-6.75)	2.51	3.45	3.29	0.32	0.381	0.362
DL-BC-B-1	5.975 (4.75-6.625)	4.33	5.84	5.61	0.305	0.37	0.353
DL-BC-B-2	6.4375 (5.75-7.75)	2.9	3.9	3.7	0.195	0.237	0.224
DL-BC-C-1	6.725 (6-7.75)	3.63	5.01	4.80	0.259	0.33	0.311
DL-BC-C-2	6.1875 (4.5-6.75)	2.56	3.46	3.28	0.301	0.369	0.337
DL-BC-D-1	6.3125 (5.5-7.5)	3.1	4.12	3.98	0.21	0.244	0.231
DL-BC-E-1	6.125 (5-7.25)	1.62	2.11	2.03	0.166	0.188	0.186

**Table 9. Cancer Risk Values from Consumption of Crab Meat**

<b>Number of crabs per meal</b>	<b>Everyday</b>	<b>4-6 times a week</b>	<b>2-3 times a week</b>	<b>Once a week</b>	<b>2 Times a month</b>	<b>One a month</b>	<b>Less than once a month</b>
<b>1-3</b>	5.98x10 <sup>-05</sup>	4.25x10 <sup>-05</sup>	2.13x10 <sup>-05</sup>	8.51x10 <sup>-06</sup>	3.92x10 <sup>-06</sup>	1.97x10 <sup>-06</sup>	9.84x10 <sup>-07</sup>
<b>4-6</b>	1.49x10 <sup>-04</sup>	1.06x10 <sup>-04</sup>	5.32x10 <sup>-05</sup>	2.13x10 <sup>-05</sup>	9.82E <sup>-06</sup>	4.91x10 <sup>-06</sup>	2.45x10 <sup>-06</sup>
<b>7-10</b>	2.54 x10 <sup>-04</sup>	1.81 x10 <sup>-04</sup>	9.04x10 <sup>-05</sup>	3.62x10 <sup>-05</sup>	1.67x10 <sup>-05</sup>	8.35x10 <sup>-06</sup>	4.17x10 <sup>-06</sup>
<b>11-15</b>	3.73 x10 <sup>-04</sup>	2.66 x10 <sup>-04</sup>	1.33x10 <sup>-04</sup>	5.32x10 <sup>-05</sup>	2.45x10 <sup>-05</sup>	1.23x10 <sup>-05</sup>	6.13x10 <sup>-06</sup>
<b>15+</b>	4.48 x10 <sup>-04</sup>	3.19 x10 <sup>-04</sup>	1.60x10 <sup>-04</sup>	6.38x10 <sup>-05</sup>	2.95x10 <sup>-05</sup>	1.47x10 <sup>-05</sup>	7.36x10 <sup>-06</sup>

Assumes DLC concentrations at station A-1

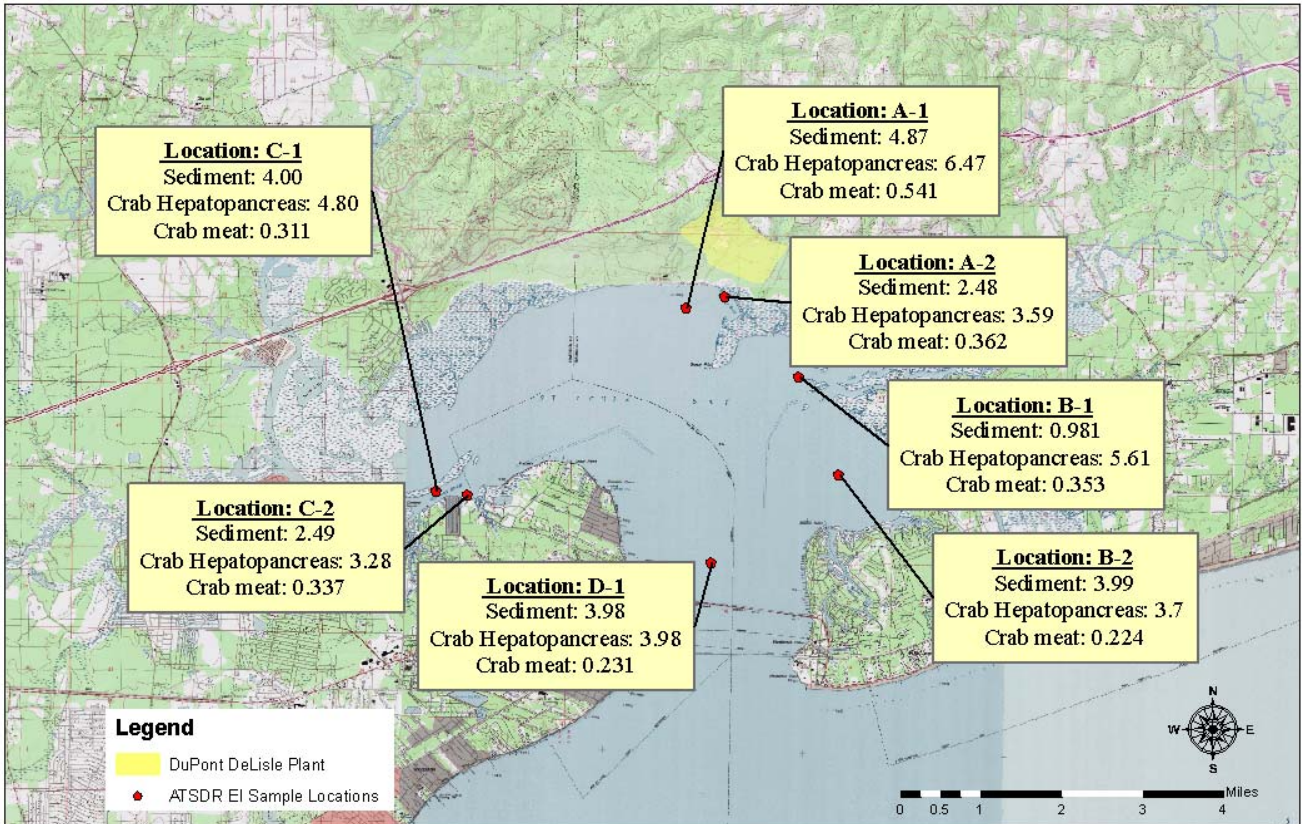
**Table 10. Cancer Risk Values from Consumption of Crab Hepatopancreas**

<b>Number of crabs per meal</b>	<b>Everyday</b>	<b>4-6 times a week</b>	<b>2-3 times a week</b>	<b>Once a week</b>	<b>2 Times a month</b>	<b>One a month</b>	<b>Less than once a month</b>
<b>1-3</b>	1.09 x10 <sup>-04</sup>	7.73 x10 <sup>-05</sup>	3.87 x10 <sup>-05</sup>	1.55 x10 <sup>-05</sup>	7.19 x10 <sup>-06</sup>	3.59 x10 <sup>-06</sup>	1.72 x10 <sup>-06</sup>
<b>4-6</b>	2.72 x10 <sup>-04</sup>	1.93 x10 <sup>-04</sup>	9.67 x10 <sup>-05</sup>	3.87 x10 <sup>-05</sup>	1.78 x10 <sup>-05</sup>	8.91 x10 <sup>-06</sup>	4.46 x10 <sup>-06</sup>
<b>7-10</b>	4.62E x10 <sup>-04</sup>	3.29 x10 <sup>-04</sup>	1.64 x10 <sup>-04</sup>	6.57 x10 <sup>-05</sup>	3.03 x10 <sup>-05</sup>	1.52 x10 <sup>-05</sup>	7.62 x10 <sup>-06</sup>
<b>11-15</b>	6.79 x10 <sup>-04</sup>	4.84 x10 <sup>-04</sup>	2.42 x10 <sup>-04</sup>	9.67 x10 <sup>-05</sup>	4.46 x10 <sup>-05</sup>	2.23 x10 <sup>-05</sup>	1.12 x10 <sup>-05</sup>
<b>15+</b>	8.15 x10 <sup>-04</sup>	5.80 x10 <sup>-04</sup>	2.90 x10 <sup>-04</sup>	1.16 x10 <sup>-04</sup>	5.36 x10 <sup>-05</sup>	2.67 x10 <sup>-05</sup>	1.34 x10 <sup>-05</sup>

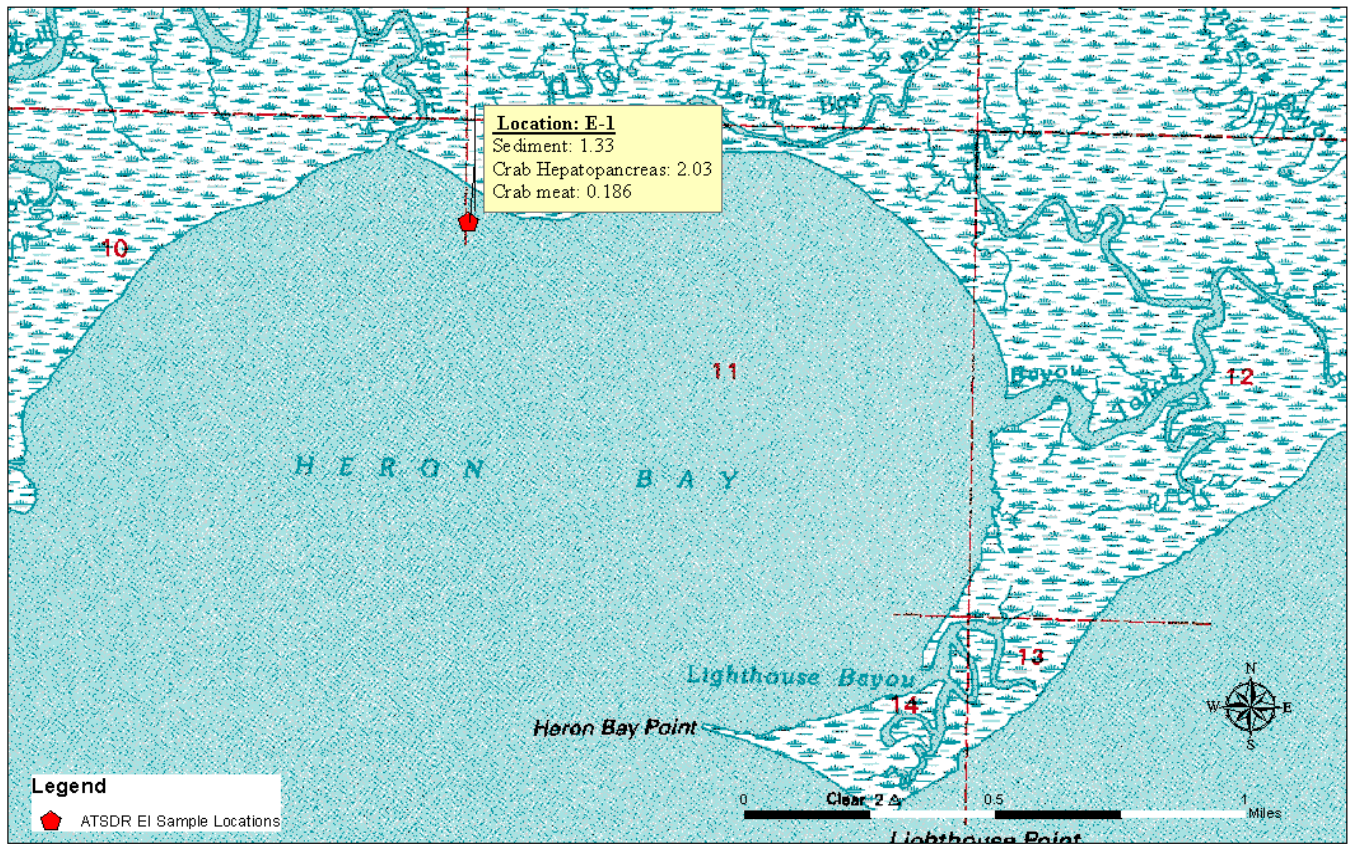
Assumes DLC concentrations at station A-1

## Appendix B. Figures

**Figure 1: St. Louis Bay Crab and Sediment Sampling Locations and Results (ppt TEQ WHO 2005, ND=1/2)**



**Figure 2. Heron Bay Crab and Sediment Sampling Location and Results (ppt TEQ WHO 2005, ND=1/2)**





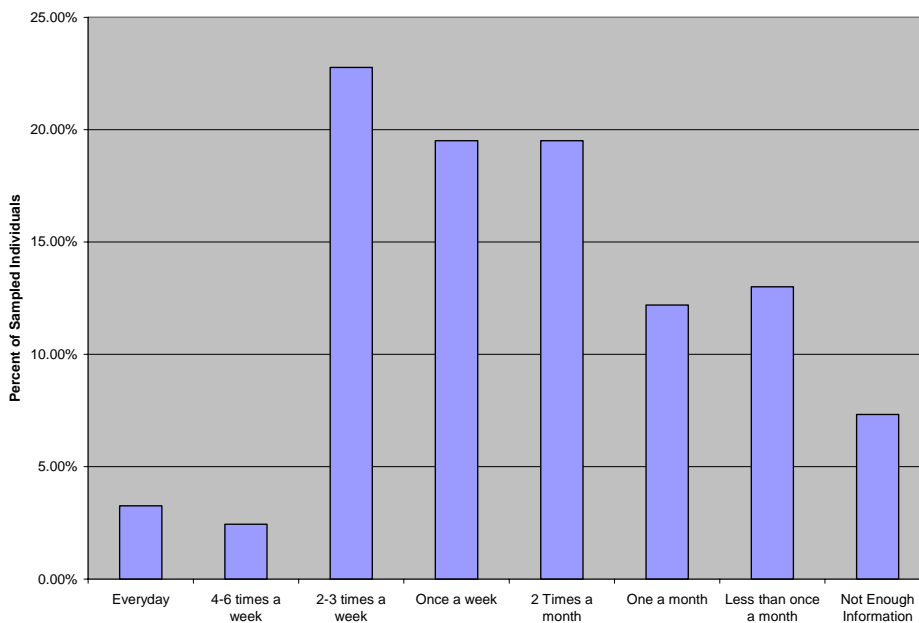
## Appendix C. Crab Consumption Rates Estimation

ATSDR could not locate data on local consumption patterns of crab. Average U.S. consumption of fish and shellfish from fresh water and estuaries is 6.3 grams per day [1]. EPA estimates that the upper 95<sup>th</sup> percentile of long-term fish consumption for the general population is 53 grams per day [2]. For risk assessment purposes, EPA recommends that a consumption rate of 17.5 grams per day for sport fishermen and 142 grams per day for subsistence fishermen [3].

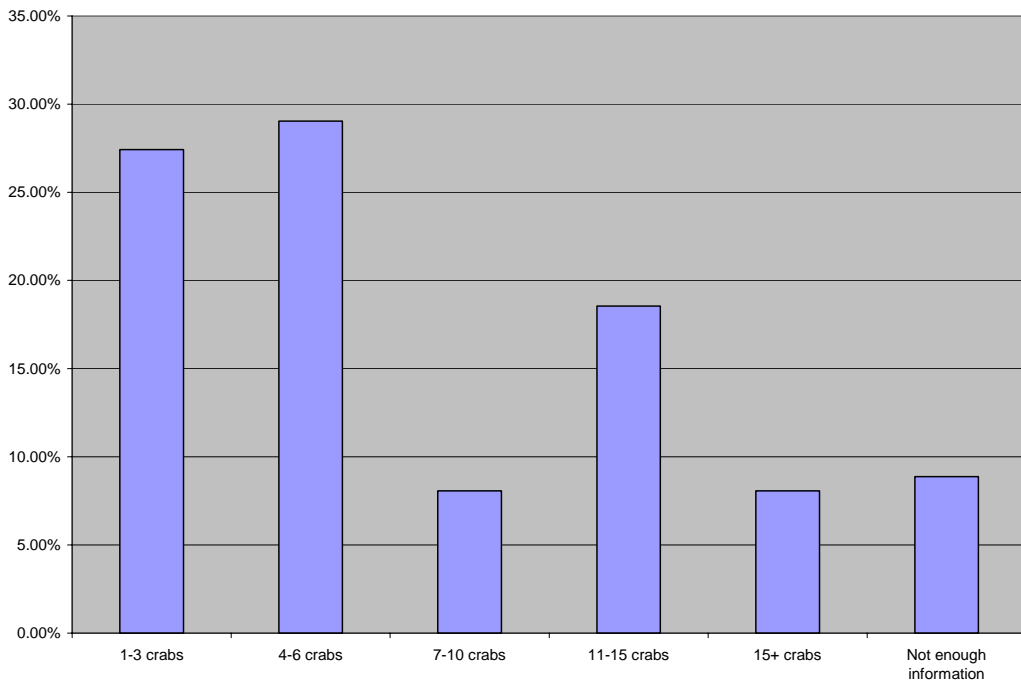
ATSDR was able to locate two assessments of blue crab consumption from local estuaries. The first is the New Jersey Department of Environmental Protection (NJDEP) risk assessment examining risk of consuming blue crabs from the Newark Bay area of New Jersey [4]. The second is a survey of Chesapeake Bay anglers conducted by Virginia Polytechnic Institute and State University [5]. The NJDEP survey yielded slightly higher levels of crab consumption, so it was chosen for calculating consumption rates.

NJDEP’s risk assessment included a survey of 300 anglers using the Newark Bay complex. 124 of the anglers surveyed consumed blue crab. Figure C-1 and C-2 show the frequency of consuming crab and the number of crab consumed in this survey. Most crabbers consumed crab between 2–3 times a week to 2 times a month and 4-6 crabs per meal.

**Figure C-1. Frequency of Crab Consumption, Newark Bay Complex**



**Figure C-2. Number of Crab Consumed per Meal, Newark Bay Complex**



The NJDEP risk assessment used an estimate of 75 grams of meat per crab. Other authorities report that the amount retrievable meat per crab is likely to be less (Table C-1).

**Table C-1. Estimation of Average Meat per Crab**

<i>Meat obtainable (grams per crab)</i>	<i>Basis</i>	<i>Source</i>
21	Avg. crab weight = 1/3 pound. 2.25 ounces of meat per pound of crab	Florida Sea Grant College Program [6]
22.68 -25.20	“About 18 to 20 crabs will produce about 1 pound of meat”	Virginia Sea Grant Advisory Program [7]

Because the NJDEP consumption data was stated as ranges, ATSDR chose central values for each range (Tables C-2 and C-3). Using a per crab weight of 25.2 grams meat/crab, ATSDR calculated yearly consumption rates for each frequency and number of crabs per meal (Table C-4).

**Table C-2. Estimated Annual Number of Days per Year Blue Crab is Consumed (days/year) - NJDEP Risk Assessment - Newark Bay Complex**

<i>Range</i>	<i>Number of days per year</i>	<i>Basis</i>
Everyday	365.242199	1 time a day for year
4-6 times a week	260	5 times a week for 52 weeks
2-3 times a week	130	2.5 times a week for 52 weeks
Once a week	52	1 time a week for 52 weeks
2 Times a month	24	2 times a month for 12 months
One a month	12	1 time a month for 12 months
Less than once a month	6	0.5 times a month for 12 months

**Table C-3. Average Number of Crabs per Meal, NJDEP Risk Assessment – Newark Bay Complex**

<i>Range</i>	<i>Average Number Crabs per Meal</i>
1–3 crabs	2
4–6 crabs	5
7–10 crabs	8.5
11–15 crabs	12.5
15+ crabs	15



**Table C-4. Calculated Average Crab Meat Consumption (g/day) based on NJDEP Risk Assessment – Newark Bay Complex**

Frequency of Consuming Crab							
Number of crabs per meal	Everyday	4-6 times a week	2-3 times a week	Once a week	2 Times a month	One a month	Less than once a month
	Grams/ day						
1-3	50.40	35.88	17.94	7.18	3.31	1.66	0.83
4-6	126.00	89.69	44.85	17.94	8.28	4.14	2.07
7-10	214.20	152.48	76.24	30.50	14.08	7.04	3.52
11-15	315.00	224.23	112.12	44.85	20.70	10.35	5.17
15+	378.00	269.08	134.54	53.82	24.84	12.42	6.21

To assess the average consumption of blue crab hepatopancreas, ATSDR assumed that the hepatopancreas mass was equal to 15% of the amount of edible meat in the blue crab. This assumed value is consistent with other risk assessments examining blue crab hepatopancreas consumption [8]. Calculated average blue crab hepatopancreas consumption values are shown in Table C-5.

**Table C-5. Calculated Average Hepatopancreas Consumption (g/day) based on NJDEP Risk Assessment – Newark Bay Complex**

Frequency of Consuming Crab							
Number of crabs per meal	Everyday	4-6 times a week	2-3 times a week	Once a week	2 Times a month	One a month	Less than once a month
	Grams/ day						
1-3	7.56	5.38	2.69	1.08	0.50	0.25	0.12
4-6	18.90	13.45	6.73	2.69	1.24	0.62	0.31
7-10	32.13	22.87	11.44	4.57	2.11	1.06	0.53
11-15	47.25	33.64	16.82	6.73	3.10	1.55	0.78
15+	56.70	40.36	20.18	8.07	3.73	1.86	0.93

## Appendix C References

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1. US Environmental Protection Agency. Estimated per capita fish consumption in the United States. EPA-821- C- 02-003. Washington DC: August 2002.
2. US Environmental Protection Agency. Exposure factors handbook. Washington DC: US Environmental Protection Agency; 1997.
3. US Environmental Protection Agency. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 2: Risk assessment and fish consumption limits. Third Ed. Washington DC; 2000.
4. New Jersey Department of Environmental Protection. estimate of cancer risk to consumers of crabs caught in the area of the Diamond Alkali Site and other areas of the Newark Bay Complex from 2,3,7,8-TCDD and 2,3,7,8-TCDD Equivalents. Trenton, NJ: New Jersey Department of Environmental Protection, Division of Science, Research and Technology; 2002 April.
5. Gilbson JC, McClafferty JA. Chesapeake Bay Angler Interviews Identifying Populations at Risk for Consuming Contaminated Fish in Three Regions of Concern. Blacksburg, VA: Human Dimensions Division, Conservation Management Institute, College of Natural Resources, Virginia Polytechnic Institute and State University; 2005 March.
6. Sweat DE. Fish facts for Florida consumers, blue crab. Gainesville, FL: Florida Sea Grant College Program, University of Florida. Available at: <http://nsgl.gso.uri.edu/flsgp/flsgpg00006.pdf>. Last accessed 2006 November 22.
7. Virginia Institute of Marine Science, College of William and Mary Marine Advisory Program. Picking blue crab. Available at: <http://www.vims.edu/adv/ed/crab/pick.html>. Last accessed 2006 November 22.
8. Karouna-Renier NK, Snyder RA, Allison JG, Wagner MG, Ranga Rao K. Accumulation of organic and inorganic contaminants in shellfish collected in estuarine waters near Pensacola, Florida: contamination profiles and risks to human consumers. Environ Pollution 2007 January; 145 (2): 474-488.