

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

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Problem Statement

The former Diamond Alkali site at 80 Lister Avenue in Newark was determined to be contaminated with dioxin from the production of various herbicides and pesticides including defoliants used in the Vietnam War. The site, designated a Superfund site by U.S.EPA, is a source of contaminated sediment in the Passaic River. Over the last several years, the responsible party has been working with EPA Region 2 and the NJDEP to determine the extent of contamination in the Passaic River Study Area (PRSA). Part of this analysis is the evaluation of contaminants in fish and crabs in the PRSA. This area has been determined to have a large recreational fishery including crabs. While studies over many years have shown the concentration of dioxin in fish and crabs for this region to be elevated, until now, data have not been available to determine consumption patterns of recreational anglers in the Newark Bay Complex. The Newark Bay Complex includes tidal portions of the Hackensack and Passaic Rivers, the Arthur Kill, the Kill Van Kull, and the Newark Bay and all waters that run into it. The PRSA is part of the Newark Bay Complex. The risk analysis that follows estimates the risk to crabbers from the Newark Bay Complex from consumption of recreationally caught crabs.

Crab Consumption Data

It is important to note that taking or attempting to take blue crabs or selling blue crabs from the Newark Bay Complex is prohibited. This information is provided in DEP fish consumption publications and advisories. This information is also periodically posted at known fishing areas around the complex, but the postings are often removed by the public. The data on crab consumption that follows are taken from an angler survey conducted in 1995 of anglers in the Newark Bay Complex as part of the Urban Angler Survey (NJDEP, 1995; Pflugh, et al., 1999). They reflect consumption which occurs despite the prohibitions and advisories.

Method

Interviews were conducted with 300 urban anglers at 26 fishing and crabbing sites around the Newark Bay Complex. In-person interviews at fishing locations were selected because it would greatly increase the likelihood of reaching anglers who were fishing in the Complex and possibly consuming contaminated species. A pretest of the survey was conducted in early July 1995, and interviews with anglers were conducted from July through October 1995 for 39 field days. A team of two interviewers was responsible for approximately six sites each field day. Not all sites were visited every field day, but all sites were visited on Sunday through Saturday to get a sample of anglers at each site on different days of the week and to determine if some days were more popular than other days. This helped to ensure the

inclusion of the widest possible cross section of the angler population in the survey. Because access to most sites required cars, interviewers drove from site to site or visited sites by boat at least twice each field day in order to interview anglers who might arrive at different times during the course of the day. Interviews took approximately 15 to 20 minutes to complete. As near as possible, interview teams tried to enter the field during high tide, the time when anglers would most likely be fishing and crabbing. Field personnel conducted interviews each day of the week throughout this period to assure as representative a cross section of urban anglers from this region as possible.

Data were collected on the six species under state fish consumption advisory for recreational fishing: blue claw crab, striped bass, American eel, white catfish, white perch and bluefish. Of these species, 124 anglers reported consuming blue claw crab. This species was the most popular of the species under advisory for consumption. Of the 124 anglers who ate crabs, 13% were female and 87% are male; 46% Caucasian, 31% Hispanic, 16% African American and 6% other. The greatest number of crabbers (26%) fall into the age category of 30-39 year old followed by 20% in the 60-69 year old category. The language crabbers were most comfortable reading is English 95% followed by Spanish 16%. The greatest number of crabbers (42) reported completing high school followed by 35% who reported having some high school education. Thirty-six percent of the anglers reported a household income of between \$15,000 and \$34,999.

The highest levels of dioxins in crab tissue are found in the hepatopancreas (Skinner et al., 1997). When crabbers were asked if they eat the hepatopancreas, 19 of the 124 (15%) indicated that they eat this part of the crab (NJDEP, 1995). Furthermore, since the crabs are cooked whole, even those consumers who do not deliberately eat the hepatopancreas, are likely exposed to all or part of its contents due to its fluid nature and its dispersion in the cooking liquid. The concentration of 2,3,7,8-TCDD and/or 2,3,7,8-TCDD equivalent concentration (TEQ) in the whole crab, including the hepatopancreas, is therefore used as the basis for the risk estimates.

Table 1 reports the frequency of consumption of crabs in the Newark Bay Complex. Table 2 reports the number of years that crabs have been consumed, and Table 3 reports the number of crabs eaten at each meal.

Table 1. Frequency of Crab Consumption N=124

	# Of sampled individuals	Percent of total
Everyday	4	3%
4-6 times a week	3	2%
2-3 times a week	28	23%
Once a week	24	20%
2 times a month	24	20%
One a month	15	12%
Less than once a month	16	13%
Not enough information	9	7%

Table 2 - Number of Years Eating Crabs N= 124

	# of sampled individuals	percent of total
Less than 5 years	24	19%
11-15 years	24	19%
16-20	15	12%
21-50+ years	45	36%
>50 years	8	7%
Not enough information	8	7%

Table 3-Number of Crabs Eaten at each meal N=124

	# Of sampled individuals	percent of total
1-3 crabs	34	27%
4-6 crabs	36	29%
7-10 crabs	10	8%
11-15 crabs	23	19%
Over 15 crabs	10	8%
Not enough information	11	9%

The portion sizes selected for assessment were: 2 crabs per meal and 15 crabs per meal, and 5 crabs per meal. These represent consumption by those with relatively low, relatively high, and median consumption.

Edible Mass of Crabs

The average mass of blue claw crab from the Newark Bay Complex is 75 grams (Weidow, 1981). This includes the mass of the hepatopancreas (14 g) and the total mass of the muscle (61g) (Weidow, 1981). This is assumed to represent the total consumed mass of tissue per crab.

Dioxin Concentration in Crabs

For this analysis, three studies of the Newark Bay Complex crabs were chosen. The first study, (Hague, et al., 1994) is a study of finfish and crabs taken throughout the state to determine 2,3,7,8-TCDD concentration. The concentrations used in this analysis represent samples taken from the Newark Bay Complex on the Passaic River in the area of Diamond Alkali site. We report the mean concentration of crabs (418 ppt) and the maximum reported concentration (480 ppt). The values represent composite samples of the total edible portions of the crab including the hepatopancreas. The 480 pg/g of 2,3,7,8-TCDD total edible crab represents a composite sample of an organism taken at the N.J. Turnpike near Diamond Alkali site. (Hague, et al., 1994) This number represents the maximum concentration of dioxin in crabs taken from this region. The mean concentration 418 ppt represents a composite sample of the total edible portion of three crabs.

Table 4 - Hague et al. – Maximum and Mean Concentration of 2,3,7,8-TCDD in Crabs-1994

Maximum total edible muscle and hepatopancreas crab	480 ppt (10^{-9} mg/g)
Mean total edible muscle and hepatopancreas crab (N=3)	418 ppt (10^{-9} mg/g)

We have also provided 2,3,7,8-TCDD TEQ concentrations from a study conducted in 1995 (Skinner et al., 1997), conducted by the NY State Department of Environmental Conservation. This study of Newark Bay reports dioxin concentration in the muscle and the hepatopancreas of six blue claw crabs separately. The 290 pg/g is the maximum value for the concentration of dioxins in the hepatopancreas and 17 pg/g is the maximum concentration of dioxin in the muscle. The values 190 pg/g and 8 pg/g are the mean concentrations of the hepatopancreas and muscle respectively.

Table 5 - Skinner et al.-1997 High and Mean 2,3,7,8-TCDD TEQ Concentration in Muscle and Hepatopancreas of Crab

Maximum hepatopancreas	290 ppt (10^{-9} mg/g)
Minimum hepatopancreas	98 ppt (10^{-9} mg/g)
Mean hepatopancreas n = 6	190 ppt (10^{-9} mg/g)
Maximum muscle	17 ppt (10^{-9} mg/g)
Minimum muscle	4 ppt (10^{-9} mg/g)
Mean muscle n = 6	8 ppt (10^{-9} mg/g)

A third more recent study was conducted by Chemical Land Holdings, Inc. (CLH, 2001) under an EPA-approved sampling plan for the Passaic River Study Area. Approximately 15 blue claw crab samples were collected in 1999/2000 in the Passaic River. Samples were collected for hepatopancreas, muscle, and soft tissue (combined hepatopancreas and muscle tissue). The data is depicted in Table 6.

Table 6 – Chemical Land Holdings, Inc.-2001 High and Mean 2,3,7,8-TCDD Concentration in Muscle, Hepatopancreas, and soft tissue (combined muscle/hepatopancreas) of Crab

Maximum hepatopancreas	371 ppt (10^{-9} mg/g)
Minimum hepatopancreas	195 ppt (10^{-9} mg/g)
Mean hepatopancreas (n = 15)	262 ppt (10^{-9} mg/g)
Maximum muscle	22.7 ppt (10^{-9} mg/g)
Minimum muscle	10.7 ppt (10^{-9} mg/g)
Mean muscle (n = 18)	17.7 ppt (10^{-9} mg/g)
Maximum soft tissue	141 ppt (10^{-9} mg/g)
Minimum soft tissue	28.1 ppt (10^{-9} mg/g)
Mean soft tissue (n=18)	75 ppt (10^{-9} mg/g)

The CLH data, like the Hague et al. data, is for 2,3,7,8-TCDD and does not include TCDD toxic equivalent (TEQ) values. Therefore, the use of TCDD alone underestimates the dioxin toxic equivalents within these samples. The CLH study crabs were collected within the area of concern (i.e., PRSA). The soft tissue data, which represents the combined muscle and hepatopancreas, were used in this risk assessment.

The total number of crabs represented by the Hague, et al. (1994), and Skinner et al. (1997) studies is small. However, several factors need to be pointed out. Due to the site-specific nature of this risk assessment, crabs taken from the PRSA or sites as near to the PRSA as possible were used. The Hague, et al. (1994) study also examined crabs taken from other locations in the Newark Bay Complex and other coastal locations in New Jersey. Dioxin concentration in crab tissue and hepatopancreas is elevated in crabs taken from these other locations in the Complex (Hague, et al., 1994), although this data was not used. The Skinner et al. study looked at a number of aquatic species taken from a variety of locations in the Newark Bay Complex and the greater NY/NJ Harbor region. The crabs included in this analysis are those taken from within the Newark Bay Complex. We believe the decision to use crabs taken from the Newark Bay Complex and not just the PRSA is valid because the Passaic River is part of the network of rivers in the Newark Bay Complex and because crabs are a migratory species and move throughout the estuary system. The CLH data are specific to the PRSA.

Finally, it should be noted, that while the sample size reported here is small, the dioxin concentrations from these, and other samples taken as part of the Hague, et al. (1994) study, determined the implementation of New Jersey's Fish Consumption Advisories and a ban on the consumption, sale and harvesting of blue claw crabs from these waters. These advisories and bans remain in place, unchanged, today.

Cancer Potency for 2,3,7,8-TCDD and 2,3,7,8-TCDD Equivalents

The value for the cancer potency slope for 2,3,7,8-TCDD was taken to be $1.5 \times 10^5 \text{ (mg/kg/day)}^{-1}$ (U.S.EPA, 1997). This value was applied to the concentration of 2,3,7,8-TCDD in crabs as reported in the Hague et al. (1994) data, and 2,3,7,8-TCDD equivalents in crabs as reported in the Skinner et al. (1997) data.

Risk Assessment Model

The excess lifetime cancer risk resulting from consumption of crabs was calculated based on the following model:

$$R = ((C \times F \times N \times M \times L) / W) \times P$$

where:

R = The excess lifetime cancer risk resulting from consumption of crabs.

C = The 2,3,7,8-TCDD or 2,3,7,8-TCDD TEQ concentration in the edible crab tissue
(ppt = pg/g = mg/g $\times 10^{-9}$)

F = The frequency of consumption of crab meals (meals/day)

N = The number of crabs consumed per meal (crab/meal)

M = The mass of crab tissue consumed/meal (g/crab)

L = The fraction of a lifetime over which crab consumption occurs (unitless ratio)

W = Body weight (kg)

P = The 2,3,7,8-TCDD cancer potency slope ((mg/kg/day)^{-1})

Assumed Values:

C

480 ppt = concentration of 2,3,7,8-TCDD in total crab represents a composite sample of a single organism (including hepatopancreas) taken at N.J. Turnpike near Diamond Alkali site. (Hague, et al., 1994)

418 ppt = mean concentration of 2,3,7,8-TCDD in 3 crab specimens (including hepatopancreas) (Hague et al., 1994)

68 ppt = maximum concentration of 2,3,7,8-TCDD TEQ per crab for combined maximum muscle and maximum hepatopancreas concentrations (different crabs) for blue claw crab taken from Newark Bay during September 1995. (Skinner et al., 1997).

Max. hepatopancreas conc. 2,3,7,8- TCDD TEQ = 290 ppt

Max. crab muscle concentration 2,3,7,8- TCDD TEQ = 17 ppt

Mass of hepatopancreas = 14 g

Mass of edible crab muscle = 61 g

Mass of edible crab tissue = 14g + 61 g = 75 g

Concentration = 290 ppt (14 g/75 g) + 17 ppt (61 g/75 g) = 68 ppt = 68 mg/g $\times 10^{-9}$

42 ppt = mean concentration of 2,3,7,8-TCDD TEQ per crab for combined muscle and hepatopancreas for blue claw crab taken from Newark Bay during September 1995. (Skinner et al., 1997)

Mean. hepatopancreas conc. 2,3,7,8- TCDD TEQ = 190 ppt

Mean. crab muscle concentration 2,3,7,8- TCDD TEQ = 8 ppt

Mass of hepatopancreas = 14 g

Mass of edible crab muscle = 61 g

Mass of edible crab tissue = 14g + 61 g = 75 g

Concentration = 190 ppt (14 g/75 g) + 8 ppt (61 g/75 g) = 42 ppt = 42 mg/g x 10⁻⁹

141 ppt = maximum concentration of 2,3,7,8,-TCDD in soft tissue (combined hepatopancreas and muscle tissue) from 18 samples collected in 1999 and 2000 from the PRSA (CLH, 2001)

71 ppt = mean concentration of 2,3,7,8-TCDD in soft tissue (combined hepatopancreas and muscle tissue) from 18 samples collected in 1999 and 2000 from the PRSA (CLH, 2001)

F

1 crab meal/day - Upper percentile of crab consumption frequency (Pflugh et al., 1995)

0.14 crab meal/day = 1 crab meal/week - Approximate median crab consumption frequency (Pflugh et al., 1995).

N

2 crabs/meal - Lower percentiles of portion size (Pflugh et al., 1995)

5 crabs/meal - Approximate median portion size (Pflugh et al., 1995).

15 crabs/meal - Upper percentile of portion size (Pflugh et al., 1995).

M

75 g/crab - includes hepatopancreas (14 g) and edible muscle tissue (61 g) (Weidou, 1981)

L

1.0 - Exposure over an entire 70 year lifetime - The data presented in Table 2 indicate that 36% of crabbers consumed crabs for 21-50 years, and 7% of the crabbers consumed crabs for more than 50 years. Since these data represent an ongoing rather than retrospective exposure, it is not clear how these percentages may change in the future, but it is possible that an even larger percentage of those who had been consuming crabs for (e.g.) 21-50 years would eventually consume crabs for more than 50 years.

W

70 kg - Adult body weight (U.S.EPA, 1991)

P

$1.5 \times 10^5 \text{ (mg/kg/day)}^{-1}$ - Cancer potency slope for 2,3,7,8-TCDD (U.S.EPA, 1997).

Example Calculation:

The following calculation yields the upper risk estimate in the last cell of the first row in Table 6:

$$\text{Risk} = (480 \text{ mg/g} \times 10^{-9} \text{ mg/g} \times 1 \text{ meal/day} \times 15 \text{ crab/meal} \times 75 \text{ g/crab} \times 1.0/70 \text{ kg}) \times 1.5 \times 10^5 \text{ (mg/kg day)}^{-1} = 1.15.$$

Results

Table 7 presents nine different estimates of risk representing a range of possible risks to the crab consuming population consuming crabs from the Newark Bay Complex in the area of Diamond Alkali on the Passaic River. This range of risk represents the range of consumption frequencies, portion sizes, and 2,3,7,8-TCDD concentrations represented in the data discussed above.

These estimates are based on consumption of the whole crab (i.e., muscle plus hepatopancreas). This reflects the risk to the 15% of consumers who said they consumed the entire crab. In theory, the risk based on the dioxin contained in the muscle tissue only would be about an order of magnitude lower. However, since the crab is cooked whole, consumption of only the muscle tissue would still reflect consumption of some of the dioxins initially contained in the hepatopancreas. Thus, the risk from consumption of muscle tissue only would be less than that from consumption of the whole crab, but the actual reduction in risk cannot be calculated on the basis of the available data.

Conclusion

The estimated lifetime excess risk from consumption of crabs from the Newark Bay Complex ranges from a low of 5,000 per million to a high of more than 1.0 million per million (i.e., greater than a 100% risk). The values calculated here are extremely high, and they are consistently high based on data from three different studies, including those specific to the PRSA.

TABLE 7 - MEAN AND HIGH ESTIMATED RISK TO CRABBERS IN THE NEWARK BAY COMPLEX

2,3,7,8-TCDD (ppt) total edible tissue	Consumption of 5 crabs/week (54 g/day)	Consumption of 2 crabs per day (150 g/day)	Consumption of 15 crabs per day (1125 g/day)
	Cancer Risk x 10 ⁰		
<i>Study One- Hague et al., 1994</i>			
Maximum (480)	0.06	0.154	1.15
Mean (418)	0.05	0.134	1.007
<i>Study Two- Skinner et al., 1997</i>			
Maximum (69)	0.008	0.02	0.166
Mean (43)	0.005	0.014	0.104
<i>Study Three- Chemical Land Holdings, 2001</i>			
Maximum (141)	0.016	0.045	0.340
Mean (71)	0.008	0.023	0.171

References

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