Health Consultation

Consumption Advisory Guidelines for
Oysters Contaminated with Polycyclic Aromatic Hydrocarbons

LAFAYETTE RIVER
NORFOLK, VIRGINIA

Prepared by the Virginia Department of Health

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Health Consultation: A Note of Explanation

A Health Consultation is a verbal or written response from the Virginia Department of Health (VDH) 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 letter health consultation process for the Lafayette River, unless additional information is obtained by VDH which, in the Department's opinion, indicates a need to revise or append the conclusions previously issued.

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SUMMARY

Introduction	The taking of molluscan shellfish, including oysters, from the Lafayette River in Norfolk, Virginia has been prohibited for over 20 years. This is due in part to microbial and chemical contamination in the river. Recent efforts to restore the river to its original condition have been successful in decreasing the concentrations of chemical contaminants in oysters including polycyclic aromatic hydrocarbons (PAH). The surrounding community consists of oyster gardeners who wish to raise oysters for consumption. To assess the risk of consuming oysters raised in the Lafayette River, the Division of Shellfish Sanitation (DSS) asked the Division of Environmental Epidemiology (DEE) to provide an oyster collection sampling plan and a risk-based oyster consumption guideline for PAHs.
Conclusion 1	Currently, oysters contaminated with PAHs in the Lafayette River are not harming people’s health.
Basis for Conclusion	It is prohibited to take oysters from the Lafayette River.
Conclusion 2	The B[a]P equivalent concentrations in oyster tissue were different between oysters collected in the fall and summer, with the results from the summer warranting a consumption advisory.
Basis for Conclusion	The B[a]P equivalent concentration in oysters collected in November 2010 and June 2011 was 18.1 and 32.4 ppb, respectively. The risk-based trigger level for issuing an oyster consumption is 25 parts per billion (ppb).
Conclusion 3	Based on the B[a]P equivalent concentration in oyster collected in June 2011, consuming no more than two oyster meals a month with each meal consisting of 12 oysters is safe for most individuals.
Basis for Conclusion	The B[a]P equivalent concentration in oysters collected in June 2011 was 32.4 ppb. This is within DEE’s risk-based oyster consumption advisory, which recommends two oyster meals per month when B[a]P equivalent concentrations are between 25 and 50 ppb.
Next Steps	DEE recommends that the DSS use a multi-tier oyster consumption advisory for the Lafayette River. DEE recommends that DSS continue to sample Lafayette River oysters year round (with a focus on typical harvesting months) to better delineate seasonal variability of PAH levels. DEE also recommends that pregnant women, women of child-bearing age, nursing mothers, infants, and young children should avoid eating oysters from the Lafayette River, since PAHs may have a greater effect on developing organs in young children or during fetal development. Also, this language should be included in any consumption advisory or posting.

BACKGROUND

Site History

The Virginia Department of Health's Division of Shellfish Sanitation (DSS) requested that the Division of Environmental Epidemiology (DEE) provide oyster collection guidance and evaluate the public health risk associated with the consumption of oysters from the Lafayette River. The Lafayette River empties into the Elizabeth River, both of which are sub basins of the lower James River in southeastern Virginia. The taking of bivalve molluscan shellfish, which includes oysters, from the Lafayette and Elizabeth Rivers has been *restricted* since the 1920's due to microbiological contamination. In 1982, the classification on both rivers changed to *prohibited* because the lead concentrations in the bivalve molluscan shellfish exceeded allowable Food and Drug Safety Administration (FDA) standards.

> *prohibited status* - bivalve molluscan shellfish cannot be taken from the area for human consumption
> *restricted status* - bivalve molluscan shellfish cannot be harvested for direct sale to market, but can be moved to approved waters during warm weather for 15 days to self-depurate

In 1983, high concentrations of polycyclic aromatic hydrocarbons (PAH) were found in the Elizabeth River. This was due primarily to past industrial use of creosote along the Elizabeth River. By the early 1990's, lead concentrations in shellfish had greatly reduced, and PAH concentrations in much of the Elizabeth River (except the Southern Branch) were reduced due to dredging activities. In 1994, after PAH concentrations in the main stem of the Elizabeth River had improved, clams were collected from the Lafayette and Elizabeth Rivers and analyzed for toxins in an effort to change the status of the Lafayette and part of the Elizabeth Rivers from prohibited to restricted. Clams were analyzed for heavy metals, tributyltin (TBT), chlorinated hydrocarbon, pesticides, and PAHs. In 1996, the Division of Toxic Substances Information reviewed the data and found that "…there are no human health hazards associated with the levels of PAH and TBT reported in the mollusks analyzed…" The concentrations of heavy metals were all within FDA guidance at the time except one clam sample from the Eastern Branch of the Elizabeth River, which was taken 1.8 miles from the mouth of the Eastern Branch (B. Croonenberghs, Personal Communication 11/03/2010). Due to heightened media coverage, the two rivers' classification remained prohibited.

Multiple resources from federal, state, and community organizations, have been put into cleaning the Elizabeth River and its many tributaries including the Lafayette River. DSS and the Elizabeth River Project decided that the recent environmental activities to restore the Lafayette River to its original condition may warrant a change in the classification of the river from prohibited to restricted. In early November 2010, DSS met with DEE personnel to discuss oyster sampling in the Lafayette River.

Land Use and Demographics

The Lafayette River is a tidal river in Norfolk, Virginia with 1,777 square acres of surface water, 21 square miles of watershed, and 1,134 waterfront homes. It is an upper tributary of the

Elizabeth River. On the Lafayette watershed are private and public schools, Old Dominion University, three cemeteries, parks and recreation areas, the Virginia Zoo, a baseball field, the Hermitage Museum and Gardens, one large marina, and multiple private piers along the shoreline. Hampton Roads Sanitation District has two large municipal wastewater treatment facility (WWTF) outfalls that discharge into the Elizabeth River. One discharge is to the north of the mouth of the Lafayette River and the other is to the south of the mouth (B. Croonenberghs, Personal Communication 6/11/2012).

Community Concerns

In 2009, the Elizabeth River Project, the Chesapeake Bay Foundation, and community partners initiated a plan to restore the Lafayette River to conditions that are safe for swimming and fishing by 2014, and to reopen the river for shellfish harvesting by 2020. The community is interested in oyster gardening and feels that recent efforts have reduced the pollution in the river such that the classification for taking oysters from the river should be changed from prohibited to restricted. *The community would like for DEE to evaluate the levels of PAHs in Lafayette River oysters and determine if they are safe for human consumption.*

Method

Sampling

DEE and DSS staff met in November 2010 to discuss the best approach for collecting and analyzing oysters in the Lafayette River for PAHs. Multiple sampling elements need to be considered before collecting and analyzing oysters for a consumption advisory. The major elements include: selecting shellfish species that are consumed by the local population, identifying sampling sites where oysters can be harvested by the community, collecting enough oysters of the size normally consumed, and taking any state or federal harvesting regulations into consideration. These and other sampling elements are presented in Table 1.

Table 1. Recommended sampling protocol for oysters in the Lafayette River contaminated with polycyclic aromatic hydrocarbons

Sampling element	**DEE Recommendation**	**Notes**
Sampling sites	Four to six	Collect from four to six sites evenly spaced out along the river.
Oyster size	Two to four inches	This size represents the size that most oyster harvesters would collect for consumption.
Number of samples collected	12 to 20 oysters	More than a dozen oysters collected from each site would provide sufficient statistical power.
Sampling time	Fall and summer	Oysters are consumed year round. PAH concentrations may change during spawning periods and when surface water temperature decreases.
Sample type	Composite sample	Each composite sample contained at least a dozen oysters from the same sampling site. Cost effective.
Number of times collected	Two	Local oyster harvesters may consume oysters year round.
Tissue analyzed	Whole oyster	The oyster is eaten whole excluding the shell.
State and federal harvesting regulations	None	It is prohibited to take shellfish from the Lafayette River.

Oyster Sampling Discussion

There are homes along the entire Lafayette River where oyster gardeners could potentially harvest oysters; therefore, oysters were collected from multiple sites along the entire river. The community reports that oysters are consumed year round, particularly during the fall and summer. Oysters spawn during the summer, and during this time, their lipid content changes as well as their ability to uptake and eliminate toxins. PAHs are lipophilic and stored in the fat content; therefore, DEE recommended a sampling procedure that would capture any difference in levels of PAHs that this phase of the oyster lifecycle might have on levels of PAHs. Also, oysters do not open their shells when the surface water temperature decreases in colder months. It is not known how this activity influences the uptake of PAHs in oysters. Comparing PAH levels in oysters collected during colder water temperatures to oysters collected in the summer would provide additional information for year-round oyster consumption (1).

Composite samples were analyzed to reduce cost. Composite samples contain approximately a dozen or more oysters collected from the same site on the river, and are analyzed as one homogenous mixture. Ten or more oysters analyzed per composite sample increase the statistical power of the analysis. The result is the average of all the oysters in the mixture. DEE recognizes that there are limitations to composite samples, such as not knowing the highest or lowest concentration of PAHs in oysters sampled. Because it is prohibited for anyone to take oysters from the Lafayette River, there were plenty of oysters of edible size available to collect for analysis.

Collection Results and Laboratory Analysis

Oysters were collected from four sites along the Lafayette River in November 2010 and from four sites in June 2011. Maps of the sampling locations are included in Appendix A. Composite samples contained the edible portion of more than a dozen oysters from each collection site. One composite sample contained 11 oysters. The oysters measured between two to four inches in length. A difference in the percent lipids was identified between the oysters collected in the summer and the oysters collected in the fall. On average, the oysters collected in the fall were composed of 19% percent extractable lipids, and the oysters collected in the summer were composed of 12%. The water temperature in the summer was approximately 25 °C and the water temperature in the fall was between 13 and 14 °C (B. Croonenberghs, Personal Communication, 7/2/2012).

Laboratory analysis was performed by the Virginia Institute of Marine Science. Composite samples were lyophilized, spiked with deuterated surrogate standards and extracted with dichloromethane. Extracts were reduced under dry nitrogen and separated by size exclusion chromatography and open column chromatography. The internal standard was p-terphenyl and the extracts were analyzed on a Varian Saturn GC/MS/MS ion trap mass spectrometer operated in electron ionization mode. Blanks and calibrators were extracted with each batch of samples and analytical replicates were included (B. Croonenberghs, Personal Communication, 10/5/2011)

Analytical Results

The concentrations of 43 different PAHs in oysters were reported by the laboratory. The complete list can be found in the Appendix B. Out of the 43 PAHs, 15 of them were selected for developing an oyster consumption guideline because their toxicity had been fully evaluated by the Agency for Toxic Substances and Disease Registry (ATSDR) (2). The concentrations of 15 selected PAHs from the list, which are used to develop oyster consumption guidelines, are in Table 2. All 15 PAHs were detected in each sample except acenaphthene and dibenz[a,h]anthracene, which were not detected in two samples collected in November 2010. The two highest PAH concentrations reported during both sampling periods were for fluoranthene and pyrene, and the two lowest PAH concentrations reported during both sampling periods were for acenaphthene and dibenz[a,h]anthracene.

Table 2. Concentrations of 15 selected polycyclic aromatic hydrocarbons in oysters collected from the Lafayette River in November 2010 and June 2011*

	November 2010			June 2011		
Polycyclic aromatic hydrocarbon	Average	High	Lowest	Average	High	Low
acenaphthylene	13.9	20.9	8.4	28.3	36.8	19.4
acenaphthene	1.3	3.5	0.0	2.6	3.1	2.0
fluorene	5.6	7.3	4.4	5.6	6.6	4.7
phenanthrene	26.5	31.8	22.7	29.9	45.9	16.1
anthracene	22.5	29.6	15.8	32.4	38.7	24.7
fluoranthene	110.0	193.3	58.5	143.5	189.8	120.8
pyrene	69.8	140.1	31.2	105.9	135.9	77.7
benz(a)anthracene	20.2	22.9	18.6	35.4	43.3	21.9
chrysene	60.8	88.3	42.1	78.7	99.3	66.4
benzo(b)fluoranthene	45.0	50.0	41.0	56.8	70.6	29.9
benzo(k)fluoranthene	13.4	19.1	9.3	21.3	29.3	12.4
benzo(a)pyrene	5.2	9.8	2.7	8.7	13.2	3.5
indeno(1,2,3,cd)pyrene	4.0	6.9	1.9	6.0	9.5	2.2
dibenz(a,h)anthracene	0.7	1.9	0.0	2.0	3.3	1.2
benzo(g,h,i)perylene	5.4	8.3	2.3	7.4	11.0	3.2

(*Source*: DSS) *All units are in µg/kg. Results are the average, high, and low of four composite samples collected during November 2010 and June 2011.

Polycyclic Aromatic Hydrocarbons Toxicity Equivalency Factor

Because there are so many PAHs and their concentrations differ from one chemical mixture to the next, several methods to quantify the carcinogenic potential of PAH mixtures exist (3). DEE currently uses toxicity equivalency factors (TEF) to evaluate the carcinogenic potential of PAHs in mixtures. This method is used by the ATSDR and was most recently used by the FDA to evaluate the safety of consuming shellfish from the Gulf of Mexico after the BP oil spill (2,5). The carcinogenic activity of benzo[a]pyrene (B[a]P) is assigned a value of one (2) and then the carcinogenic potency of the other PAHs relative to B[a]P are expressed as a TEF. The tissue concentration of individual PAHs are multiplied by their respective TEF and summed to determine the equivalent B[a]P concentration of the mixture. The sum of the B[a]P equivalents can then be used to evaluate if an oyster consumption advisory is warranted. Cancer classification, TEF for individual PAHs, and calculated B[a]P equivalents are presented in Table 3.

Table 3. Individual polycyclic aromatic hydrocarbons cancer classification, toxicity equivalent factors, and benzo[a]pyrene equivalent concentrations from oysters collected November 2010 and June 2011*

Polycyclic aromatic hydrocarbon	Cancer Classification†				November 2010	June 2011	Highest Composite
	DHHS	EPA	IARC	TEF	B[a]P equivalent	B[a]P equivalent	B[a]P equivalent
acenaphthylene				0.001	0	0	0.0
acenaphthene			3	0.001	0	0	0.0
fluorene		D	3	0.001	0	0	0.0
phenanthrene		D	3	0.001	0	0	0.0
anthracene		D	3	0.01	0.2	0.3	0.4
fluoranthene		D	3	0.001	0.1	0.1	0.2
pyrene		D	3	0.001	0.1	0.1	0.1
benz(a)anthracene	2	B2	2B	0.1	2	3.5	4.3
chrysene		B2	2B	0.01	0.6	0.8	1.0
benzo(b)fluoranthene	2	B2	2B	0.1	4.5	5.7	7.1
benzo(k)fluoranthene	2	B2	2B	0.1	1.3	2.1	2.9
benzo(a)pyrene	2	B2	1	1	5.2	8.7	13.2
indeno(1,2,3,cd)pyrene	2	B2	2B	0.1	0.4	0.6	0.9
dibenz(a,h)anthracene	2	B2	2A	5	3.5	10.2	16.4
benzo(g,h,i)perylene		D	3	0.01	0.1	0.1	0.1
Sum B[a]P equivalent	15 PAHs				18.1	32.4	46.0
	43 PAHs††				18.2	32.6	46.1

(*Source*: DSS) *All units are in µg/kg. DHHS=Department of Health and Human Services. EPA=Environmental Protection Agency. IARC=International Agency for Research on Cancer. Values are reported as one decimal place for clarity and may not necessarily be zero. †2=Reasonably anticipated to be a carcinogen. D=Not classified as to human carcinogenicity. B2=Probable human carcinogen (inadequate human, sufficient animal studies). 3=Not Classifiable. 2B=Possibly carcinogenic to humans (limited human evidence; less than sufficient evidence in animals). 2A=Probably carcinogenic to humans (limited human evidence; sufficient evidence in animals). B[a]P=benzo[a]pyrene. PAH=polycyclic aromatic hydrocarbons. ††Provided for comparison. For a list of all 43 PAHs and their TEF see Appendix B.

The TEF for 15 PAHs expressed as the sum of B[a]P equivalent concentrations was 18.1 micrograms/kilogram (µg/kg) in edible tissue of oysters collected during the fall and 32.4 µg/kg during the summer (Table 3). To evaluate the carcinogenic potential of all 43 PAHs, an equivalent TEF was assigned to each methyl or alkyl homologue of the parent compound. For example, phenanthrene has a TEF=0.001; therefore, each of its methyl analogues (i.e. 2-methyl phenanthrene, 4-methyl phenanthrene) was assigned a TEF=0.001. PAHs for which ATSDR does not derive a TEF were assigned a value = 0.001. This conservative approach assumes that the analogues have the same carcinogenic potential as the parent compounds. It also assigns carcinogenic TEF to chemicals that may not be a carcinogen. The B[a]P equivalent concentrations of all 43 PAHs collected during the fall and the summer were 18.2 and 32.6 µg/kg, respectively. The B[a]P equivalent concentration difference between all 43 PAHs and the selected 15 PAHs is less than one percent and is not considered significant. See Appendix B for a list of the individual and total B[a]P equivalent concentration for all 43 PAHs collected in the summer.

DISCUSSION

To determine public health implications associated with chemical contaminants in the environment, DEE first evaluates specific ways (exposure pathways) in which people might come into contact with environmental contaminants. Then, based on identified exposure pathways (e.g., consuming oysters from the Lafayette River) and the levels of contaminants (PAHs), DEE determines whether or not there is a risk to the public. Currently, it is prohibited to take oysters from the Lafayette River; therefore, the community is not being exposed to PAHs in Lafayette oysters.

In this section, guidelines for issuance of oyster-eating advisory due to contamination of oysters with PAHs are discussed. These guidelines can be used by DSS when considering changing the "taking-of-oyster" status for the Lafayette River.

Public Health Implications

Polycyclic Aromatic Hydrocarbons

PAHs are a group of chemicals that are ubiquitous in the environment. They are organic compounds that have a fused ring structure of two or more benzene rings and can be either man-made or formed during the incomplete combustion of organic material such as tobacco, charbroiled meat, coal, oil, gas, and wood. PAHs are found in creosote, asphalt, coal tars, and petroleum products. There are over 100 different PAHs and they are often present in the environment as a mixture. Fifty-four PAHs have been identified at multiple National Priority Listing (NPL) sites. Of these 54 PAHs, 17 have been evaluated further by ATSDR because of their toxicity, potential for human exposure, frequency of occurrence at NPL sites, and extent of reliable health-based and environmental information. Of these 17 PAHs, ATSDR has developed TEFs (based on carcinogenicity) for 15 PAHs (Tables 2 and 3) (2).

Little is known about the non-cancer health effects of PAHs in humans. In mice studies, those that were fed high levels of PAHs during pregnancy had difficulty reproducing, and yielded a higher rate of birth defects in their offspring. Other animal studies have shown that PAHs can cause harmful effects to the skin, and the immune system. PAHs have been shown in animal and human studies to cause cancer in multiple organs via different routes of exposure. The Department of Health and Human Services has determined that some PAHs may reasonably be expected to cause cancer in humans. Because cancer is the most toxic endpoint of concern for PAH exposure, oyster consumption guidelines will be based on this toxic endpoint (3,5).

Industrial and maritime shipping activities along with urbanization of the watershed along the Elizabeth and Lafayette River are largely responsible for the elevated levels of PAHs in the Lafayette River ecosystem. Because PAHs are not soluble in water, they accumulate in the sediment and on particles in aqueous environments. Oysters are sedentary and feed by pumping water through their gills to capture food particles in the water. Therefore, they are subject to exposure to contaminants in the environment such as PAHs (1,4). People may be exposed to PAHs if they consume oysters from the Lafayette River.

Derivation of Acceptable Concentration of PAHs in Oysters for Human Consumption

The potential to cause cancer in humans is considered to be the most important toxic endpoint for PAHs. The formula for calculating an acceptable concentration, corresponding to a two meals per month of PAHs in oysters, for protecting consumers from potential carcinogenic effects is as follows:

$$C = \frac{RLxBWxEDFxT}{CSFxMSxNM}$$

Where:

Abbreviation	**Parameter**	**Value & Units**
C	Concentration	(mg/kg)
RL	Risk level	(1×10^{-5})
BW	Body weight	80 kg
EDF	Exposure duration factor	2.4 Unitless
T	Time	30 days/month
CSF	Cancer slope factor	7.3 $(mg/kg/day)^{-1}$
MS	Meal size	0.168 kg/meal
NM	Number of meals	2 meals/month

Substituting for assumptions and factors in the above equation, an acceptable concentration of equal to or less than 0.023 mg/kg or 23 parts per billion (ppb) of B[a]P equivalents in oysters was derived corresponding to the consumption of two meals per month. This value was rounded to 25 ppb.

$$0.023\, mg/kg = \frac{1x10^{-5}\ x\ 80\ kg\ x\ 2.4\ x\ 30\ days/month}{7.3\ (mg/kg/day)^{-1}\ \ x\ 0.168\ kg/meal\ x\ 2\ meals/month}$$

Various assumptions used in deriving the acceptable concentration are described as follows:

Risk Level (RL)

Typically for carcinogens, acceptable risk levels for incremental increase in cancer over the background incidence ranging between 10^{-4} (one additional cancer in a population of ten thousand people) to 10^{-6} (one additional cancer in a population of one million people) have been used in making risk management decisions by several regulatory agencies. Derivation of an acceptable concentration in oyster tissue using a risk level within this range is considered conservative and protective of human health. DEE used the risk level of 10^{-5}, or one additional cancer over the background incidence expected to be found in a population of 100,000 people, when deriving a trigger level for issuing an oyster consumption advisory.

Average Body Weight (BW)

The average adult body weight (80 kg) is widely accepted by many regulatory agencies for risk assessment and establishing guidelines and standards for chemical exposure (6).

Exposure Duration Factor (EDF)

The exposure duration factor is the ratio of a lifetime exposure to a chemical and the actual exposure. The life expectancy of the U.S. population is 80 years. The 90^{th} percentile estimate of residence time is 32 years (length of time an individual lives in an area before moving). This assumes that a person will consume oysters from the Lafayette River for 32 years and live to be 80 years old ($80 \div 32 = 2.4$) (6).

Time Period (T)

Time period of 30 days per month was used to calculate the allowable concentration of PAHs in oysters.

Cancer Slope Factor (CSF)

The cancer slope factor (CSF) represents an assumption about cancer risk associated with low levels of exposure. It is an upper-bound estimate of the probability that an individual will develop cancer over a lifetime as a consequence of exposure to a given dose and is expressed as $(\text{milligram/kilogram/day})^{-1}$. EPA has derived the cancer slope factor of 7.3 $(\text{mg/kg/day})^{-1}$ as the central risk estimate for B[a]P (2,7).

Meal Size (MS)

An average meal size of 0.168 kg was assumed in calculating the acceptable concentration of PAHs in oysters. DEE recognizes that an average oyster meal would consist of a dozen oysters each weighing 14 grams (12 x 14 grams = 168 grams or 0.168 kg) (8). This is consistent with other governmental agencies that use an oyster consumption rate of 12 g/day or 180 grams/meal (12 g/day x 30 days/month = 360 grams/month; 360 grams/month ÷ 2 meals/month = 180 gram/meal) for risk assessment (6).

Number of Meals (NM)

An acceptable concentration of PAHs in oysters was derived assuming two oyster meals during a period of 30 days (24 meals per year). It is expected that oyster harvesters may consume more oysters than the general public. A baseline survey of raw oyster consumers by the Interstate Shellfish Sanitation Conference reported that the average number of oyster meals per year for four costal states was six (9).

Table 4. Lafayette River oyster consumption guidelines for polycyclic aromatic hydrocarbons contaminated oysters*

B[a]P equivalent concentration in oysters	Advisory
Less than 25 ppb	No advisory
25 to 50 ppb	Two meals per month
Between 50 to 100 ppb	One meal per month
100 ppb and above	Do not eat oyster from the advisory area

*One meal consists of 12 oysters. **B[a]P**=benzo[a]pyrene. **ppb**=parts per billion or µg/kg.

DEE uses a multi-tier approach when providing guidelines for fish consumption advisories. A multi-tier approach can be used for consuming oysters taken from the Lafayette River (see Table 4). The risk level from consuming two oyster meals per month when B[a]P equivalent concentrations are between 25 and 50 ppb is two additional cancers in background levels for 100,000 people. The risk level does not change when advising individuals to limit oyster meals to one per month when B[a]p equivalent concentrations are between 50 and 100 ppb.

DEE applied the multi-tier oyster consumption guidelines to the average composite samples collected during November 2010 and June 2011 (Table 5). The B[a]P equivalent concentration of PAHs in oysters collected in November 2010 would not have resulted in a consumption advisory. The B[a]P equivalent concentration of PAHs from the June 2011 sampling would have resulted in an oyster consumption advisory limiting the number of oyster meals per month from the Lafayette River to two.

Table 5. Lafayette River oyster consumption advisory for samples collected November 2010 and June 2011*

Collection Period	Average B[a]P equivalent Concentration	Oyster Consumption Advisory
November 2010	18.1 ppb	No advisory
June 2011	32.4 ppb	Two meals per month

*One meal consists of 12 oysters. **ppb**=parts per billion or µg/kg.

The B[a]P equivalent concentration in oysters collected in November were lower than the oysters collected in June. This may be due to the life cycle of the oysters which spawn during warmer months. During this time, the oyster's ability to eliminate and metabolize chemicals differs. The percent lipid was notably different in oysters collected during November and June and may account for the difference in PAH concentration.

Oysters do not necessarily hibernate like warm blooded animals, but they do not open in colder temperatures. This activity may limit their exposure to contaminants in the aqueous environment. Also, because oysters are sedentary they are susceptible to changes in their environment. River activities that may have stirred up contaminants in the environment, river dredging, or chemical spills may also account for the difference in PAH concentrations in oysters collected in November and June.

Child Health and Special Populations

DEE recognizes that children, because of their behavior, size and growing bodies, may be particularly vulnerable to site-related exposures. Developing fetuses also may be more vulnerable to such exposures. Thus, the impact to children is considered first when evaluating the health threat to a community. The health impacts to other potentially high-risk groups within the community (such as the elderly, the chronically ill, and people who may have higher exposure potential) were also taken into account during this evaluation.

CONCLUSIONS

Currently, oysters contaminated with PAHs in the Lafayette River are not harming people's health because the taking of oysters from the river is prohibited.

The B[a]P equivalent concentrations in oyster tissue were different between oysters collected in the fall and summer, with the results from the summer warranting a consumption advisory.

Based on the B[a]P equivalent concentration in oyster collected in June 2011, consuming no more than two oyster meals a month with each meal consisting of 12 oysters is safe for most individuals.

RECOMMENDATIONS

DEE recommends limiting the number of oyster meals to two per month when the B[a]P equivalent concentration in oysters is between 25 and 50 ppb.

DEE recommends limiting the number of oyster meals to one per month when the B[a]P equivalent concentration in oysters is between 50 and 100 ppb.

DEE recommends not eating oysters when the B[a]P equivalent concentration in oysters is above 100 ppb.

DEE recommends that pregnant women, women of child-bearing age, nursing mothers, infants, and young children should avoid eating oysters when the B[a]P equivalent concentration in oysters is 25 ppb or greater.

DEE recommends that DSS continue to sample the Lafayette River oysters year round (with a focus on typical harvesting months) to better delineate the seasonal variability of PAH levels.

PUBLIC HEALTH ACTION PLAN

Actions Undertaken

DEE met with DSS in November 2010 to discuss oyster sampling guidelines.

DEE collected oysters with DSS staff in June 2011 from the Lafayette River. DSS also provided a tour of the Lafayette River watershed by boat.

Actions Planned

DEE will evaluate any additional oyster data that becomes available.

At the request of DSS or the community, DEE will participate in any public meeting or forum to discuss the findings of this health consultation.

DEE may adjust the current consumption advisory should additional risk-based assumptions or updated TEFs become available.

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REPORT PREPARATION

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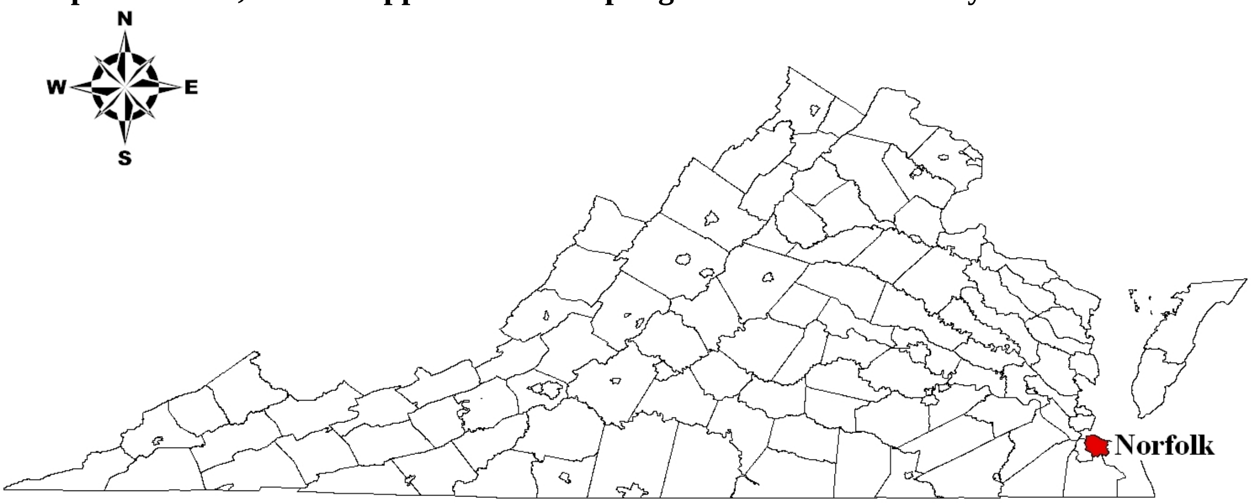
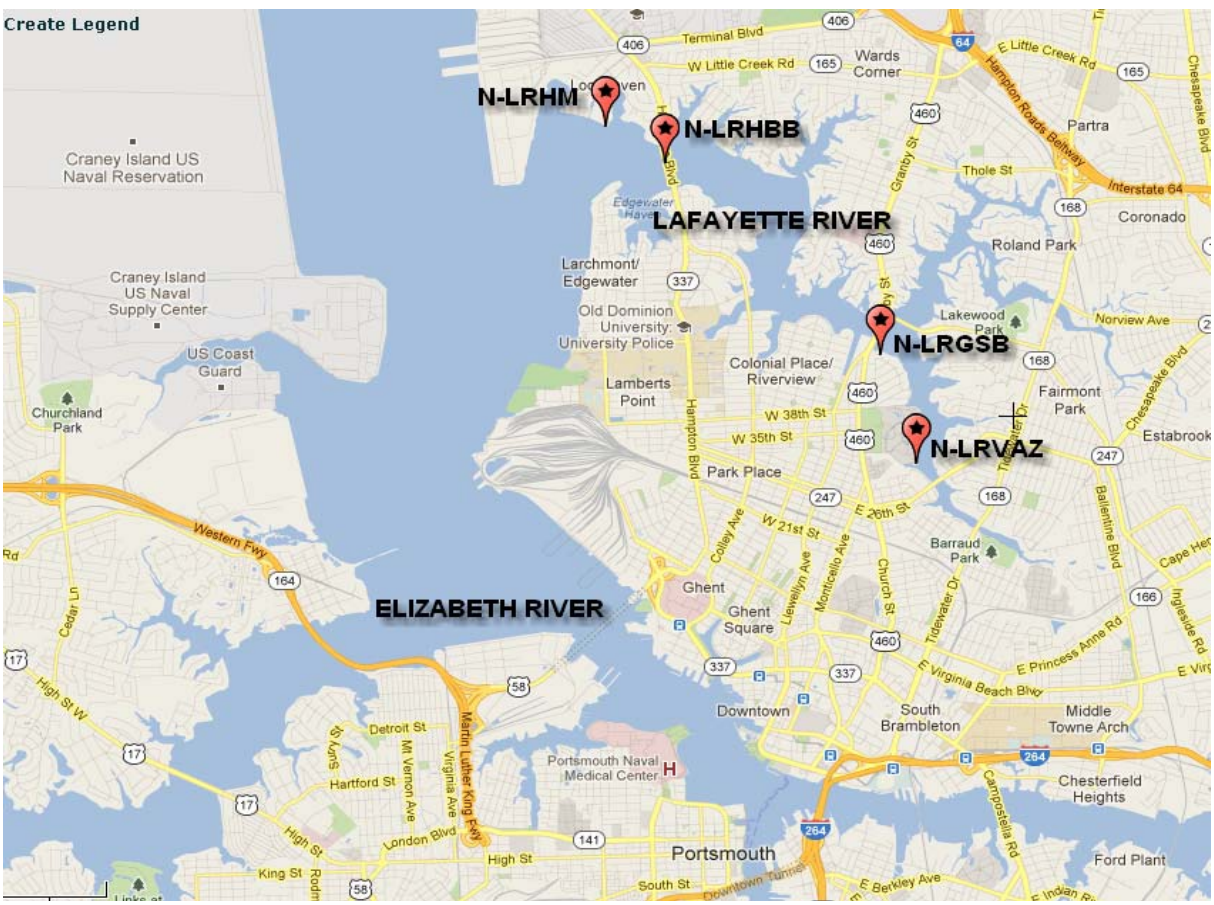
Appendix A

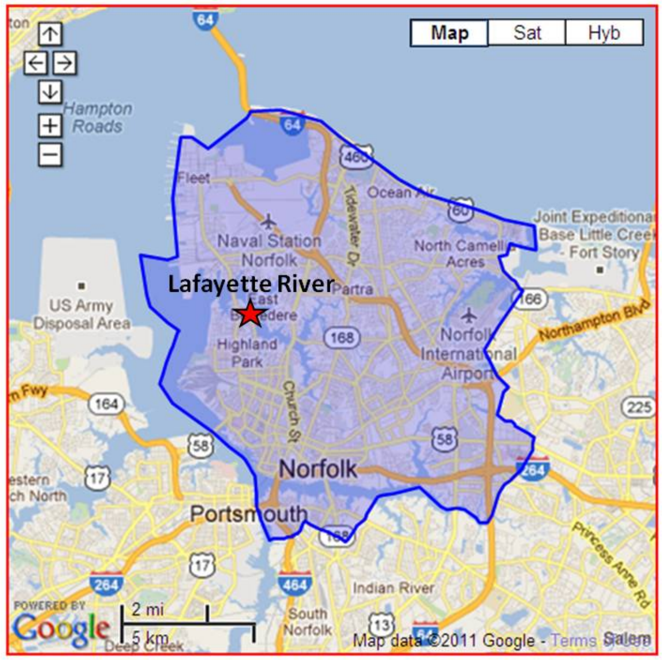
Map of Norfolk, VA and approximate sampling locations on the Lafayette River.





(*Source*: Google Map)

Map of Norfolk City and location of Lafayette River. Demographics are from shaded area.
The demographics between the state of Virginia and Norfolk City, where the Lafayette River is located have many similarities[1]. The ratio of males to females is relatively equal. The community consists of mostly Caucasians (47%) and African Americans (43%). The percentage of people under 5 years old and those 65 years and over in Norfolk are about the same as the state. Educational attainment is about the same, where roughly the same amount of people have obtained a high school diploma or equivalent, but those who have attained college degrees are slightly lower on the city level compared to the state. According to the Bureau of Labor and Statistics, the unemployment rate in 2010 was higher in the city of Norfolk compared to the state wide percentage. Likewise, the number of families living below the poverty level was higher in the city compared to the state [2].



Demographics for Norfolk City and Virginia

	Norfolk City	**Virginia**
Total Population	242,803	8,001,024
Male	51%	49%
Female	49%	51%
Race or Ethnicity		
White/Caucasian	47%	68.6%
Black/African American	43%	19.4%
Age Distribution		
Under 5 years old	6.8%	6.4%
Over 65 years old	9.4%	12.2%
Educational Attainment		
High school diploma or equivalent	85.1%	85.8%
Bachelor's degree or higher	24.8%	33.4%
Economics		
Unemployment Rate 2010	8.9%	6.5%
Families below poverty level 2010	11.8%	7.2%

(*Source:* U.S. Bureau of Labor and Statistics and U.S. Census)

[1] U.S. Census Bureau http://quickfacts.census.gov/qfd/states/51/5135000.html Last accessed April 2012.

[2] Bureau of Labor and Statistics http://www.bls.gov/ro3/valaus.htm Last accessed April 2012.

Appendix B

Average concentration of 43 polycyclic aromatic hydrocarbons in composite samples collected in June 2011 including cancer classification, toxicity equivalent factors, and benzo[a]pyrene equivalent concentrations*

Polycyclic aromatic hydrocarbon	Average	TEF	B[a]p equivalent	Cancer Classification†		
				DHHS	EPA	IARC
1,2,3,4-tetramethyl benzene	0.0	0.001	0.000			
naphthalene	5.3	0.001	0.005	2	C	2B
benzo[b]thiophene	0.0	0.001	0.000			
2-methyl napthalene	3.2	0.001	0.003			
1-methyl napthalene	2.3	0.001	0.002			
biphenyl	0.5	0.001	0.000		D	
2-ethylnaphthalene	0.0	0.001	0.000			
1-ethylnaphthalene	0.0	0.001	0.000			
2,6-dimethylnapthalene	0.7	0.001	0.001			
1,3-dimethylnaphthalene	2.3	0.001	0.002			
2,3- &1,4-dimethylnaphthalene	0.0	0.001	0.000			
1,5-dimethylnaphthalene	0.0	0.001	0.000			
acenaphthylene	28.3	0.001	0.028			
acenaphthene	2.6	0.001	0.003			
2-methyl biphenyl	0.0	0.001	0.00			
dibenzofuran	3.1	0.001	0.003		D	
2,3,5,-trimethylnapthalene	0.0	0.001	0.000			
fluorene	5.6	0.001	0.006		D	3
1,4,5-trimethylnaphthalene	0.0	0.001	0.000			
dibenzothiophene	2.5	0.001	0.003			
phenanthrene	29.9	0.001	0.030		D	3
anthracene	32.4	0.010	0.324		D	3
carbazole	0.0	0.001	0.000			3
4-methyl dibenzothiophene	3.3	0.001	0.003			
1-phenyl naphthalene	8.8	0.001	0.009			
2-methyl phenanthrene	10.0	0.001	0.010			
4-methyl phenanthrene	37.6	0.001	0.038			
1-methyl phenanthrene	8.9	0.001	0.009			
4,6-dimethyl dibenzothiophene	2.7	0.001	0.003			
2-phenyl naphthalene	14.2	0.001	0.014			
3,6-dimethyl phenanthrene	4.5	0.001	0.005			
fluoranthene	143.5	0.001	0.144		D	3
pyrene	105.9	0.001	0.106		D	3
benz(a)anthracene	35.4	0.100	3.54	2	B2	2B
chrysene	78.7	0.010	0.787		B3	3
benzo(b)fluoranthene	56.8	0.100	5.68	2	B4	2B
benzo(k)fluoranthene	21.3	0.100	2.131	2	B5	2B
benzo(e)pyrene	41.7	0.001	0.042			3
benzo(a)pyrene	8.7	1.000	8.723	2	B2	1
perylene	6.3	0.001	0.006			3
indeno(1,2,3,cd)pyrene	6.0	0.100	0.600	2	B2	2B

dibenz(a,h)anthracene	2.0	5.000	10.231	2	B2	2A
benzo(g,h,i)perylene	7.4	0.010	0.074		D	3
Sum B[a]P equivalents			32.6			

(*Source:* DSS) *All units are in µg/kg. DHHS=Department of Health and Human Services. EPA=Environmental Protection Agency. IARC=International Agency for Research on Cancer. Values are reported as one decimal place for clarity and may not necessarily be zero. †2=Reasonably anticipated to be a carcinogen. D=Not classified as to human carcinogenicity. B2=Probable human carcinogen (inadequate human, sufficient animal studies). 3=Not Classifiable. 2B=Possibly carcinogenic to humans (limited human evidence; less than sufficient evidence in animals). 2A=Probably carcinogenic to humans (limited human evidence; sufficient evidence in animals). B[a]P=benzo[a]pyrene. PAH=polycyclic aromatic hydrocarbons. November results intentionally not included.

Appendix C

Fish consumption Advisories for the Lafayette River*

Contaminant	Fish Species	Consumption Advisory
PCBs	Gizzard Shad	DO NOT EAT
PCBs	Carp	
PCBs	Blue Catfish ≥ 32 inches	
PCBs	Flathead Catfish ≥ 32 inches	
PCBs	Blue Catfish < 32 inches	No more than two meals/month
PCBs	Flathead Catfish < 32 inches	
PCBs	Channel Catfish	
PCBs	White Catfish	
PCBs	Largemouth Bass	
PCBs	Bluegill Sunfish	
PCBs	American Eel	
PCBs	Quillback Carpsucker	
PCBs	Smallmouth Bass	
PCBs	Creek Chub	
PCBs	Yellow Bullhead Catfish	
PCBs	White Perch	
PCBs	Striped Bass	
PCBs	Bluefish	
PCBs	Croaker	
PCBs	Spot	
PCBs	Blueback Herring	
PCBs	Hickory Shad	
Kepone	All Species	PCBs advisory is more restrictive. Follow the PCBs advisory for the species listed. Any fish species not listed, limit consumption to one meal per day.

(*Source: Virginia Department of Health*) Visit www.vdh.virginia.gov for additional fish consumption advisories in Virginia. Current as of September 2012.