

**Consumption Advisory Guidelines for
Oysters Contaminated with Polycyclic Aromatic
Hydrocarbons**

Lynnhaven River
Virginia Beach, Virginia

Health Consultation

January 14, 2014

Virginia Department of Health
Division of Environmental Epidemiology
109 Governor Street
Richmond, Virginia 23219



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Dear Dr. Croonenberghs,

Thank you for the opportunity to review the concentrations of polycyclic aromatic hydrocarbons (PAHs) in oyster composite samples taken from the Lynnhaven River in Virginia Beach, Virginia in December 2011-January 2012. In addition, oyster composite samples taken from the Lynnhaven River Inlet in June 2011 and November 2010 were also included in this review and used to determine if an oyster consumption advisory for the Lynnhaven River is warranted.

A detailed discussion of the toxicity of PAHs, oyster collection, laboratory analysis, and development of oyster consumption guidelines for oysters containing PAHs can be found in the Health Consultation titled "Consumption Advisory Guidelines for Oysters Contaminated with Polycyclic Aromatic Hydrocarbons" submitted to your office in October 2012.

I trust that this information will be of help to you. Should you have any questions please contact me at (804) 864-8127 or via email at dwight.flammia@vdh.virginia.gov.

BACKGROUND

Several decades ago the Lynnhaven River was made famous for its oysters. Today, oyster harvesting continues to be challenged by the presence of fecal coliform bacteria in the river that mostly comes from rainfall-induced urban runoff. The first partial shellfish closure due to elevated bacteria in the river was made in 1930 followed by a full closure in 1971. By 2011, 42% of the river was made available for shellfish harvesting because of the river's restoration activities.¹ There is no reason to believe that oysters in the Lynnhaven River are unfit for human consumption due to chemical contamination including PAHs. Rather, oysters in the Lynnhaven

¹ Lynnhaven River Watershed. [Application for Federal no Discharge Zone Designation](#). Prepared by the City of Virginia Beach, Virginia and the Virginia Department of Environmental Quality.

River were collected and analyzed for PAHs to determine a background baseline concentration of PAHs in oysters taken from a river with a watershed similar to the Lafayette River. While the two rivers have a similar watershed and use, the oysters in the Lafayette River are at greater risk for PAH contamination because it is a tributary of the Elizabeth River which is heavily traveled, industrial, and subjected to past creosote dumping.

Land Use and Demographics

The Lynnhaven River is located in the northern part of the coastal plain of Virginia Beach, VA. The river consists of the Eastern Branch, the Western Branch and Broad Bay/Linkhorn Bay. The drainage area of the Western Branch is about 8.21 square miles and about 6.53 for the Eastern Branch². The river encompasses an area of land and water that spans about 64 square miles with approximately 150 miles of shoreline.

The river is home to approximately 230,000 residents, which is close to 3,600 people per square mile or 18 people per acre.³ The shoreline surrounding the Lynnhaven River includes residential buildings, schools, public access areas, marinas, boat launch facilities, waterside restaurants, parks and more. See Attachment for a more detailed list of findings on the watershed including demographics.

Oyster Collection and Laboratory Analysis

Oysters were collected from four sites along the Lynnhaven River: Western Branch, Eastern Branch, Long Creek, and Linkhorn Bay Rainey Gut in December 2011-January 2012 (Winter); from the Western Branch of the Lynnhaven River in the vicinity of station 70-7 in June 2011 (Summer); and from Lynnhaven Inlet in November 2010 (Fall). A map of the sampling locations is included in the attachment. Oysters were analyzed as composite samples containing the edible portion of more than a dozen oysters from each collection site, and the laboratory analysis was performed by the Virginia Institute of Marine Science.

Analytical Results

The oysters were analyzed for 43 different PAHs. 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).⁴ The concentrations of the 15 selected PAHs in oysters, which are used to develop oyster consumption guidelines, are in Table 1. Of the 15 PAHs, benzo(a,h,)anthracene and benzo(g,h,i)perylene were not detected in composite oysters collected in the winter or fall. Benzo(a)pyrene was not detected in samples collected during the summer and indeno (1,2,3,cd)pyrene was not detected in oysters collected in the winter.

² [Lynnhaven River Shoreline Management Plan](#). Prepared by Virginia Institute of Marine Science, College of William and Mary. Gloucester Point, Virginia. April 2013.

³ [2011 State of the River Report](#). Presented by Lynnhaven River NOW.

⁴ Agency for Toxic Substances and Disease Registry. Toxicological profile for polycyclic aromatic hydrocarbons; U.S. Public Health Service; U.S. Department of Health and Human Services. Atlanta, Georgia. 1995.

Table 1. Average concentrations of 15 selected PAHs in oyster composite samples collected from the Lynnhaven River 2010-2012

Polycyclic aromatic hydrocarbon	Winter (Dec. 2011-Jan. 2012)	Summer (June 2011)	Fall (November 2010)
acenaphylene	10.0	10.1	11.7
acenaphthene	6.9	0.9	5.0
fluorene	3.7	2.4	6.9
phenanthrene	18.3	13.9	45.1
anthracene	15.2	13.6	13.8
flouranthene	56.4	59.2	87.7
pyrene	63.9	46.0	150.8
benz(a)anthracene	4.4	8.4	5.9
chrysene	16.2	28.4	19.6
benzo(b)flouranthene	3.2	12.1	7.6
benzo(k)flouranthene	0.8	7.0	1.9
benzo(a)pyrene	1.3	ND	0.6
indeno(1,2,3,cd)pyrene	ND	1.1	0.4
benzo(a,h)anthracene	ND	0.6	ND
benzo(g,h,i)perylene	ND	1.5	ND

(Source: DSS) All units are in µg/kg. ND=not detected.

DISCUSSION

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 toxicity equivalency factors (TEFs) (based on carcinogenicity) for 15 PAHs.

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.⁵ The Division of Environmental Epidemiology (DEE) recently used TEFs to evaluate PAHs in oysters taken from the Lafayette River. This method is used by the ATSDR and was used by the Food and Drug Administration to evaluate the safety of consuming shellfish from the Gulf of Mexico

⁵ Office of Research and Development. PA Peer Consultation Workshop on Approaches to Polycyclic Aromatic Hydrocarbon (PAH) Health Assessment. National Center for Environment Assessment. U.S. Environmental Protection Agency. Washington, DC. January 2002

after the BP oil spill.⁶ The carcinogenic activity of benzo[a]pyrene (B[a]P) is assigned a value of one and then the carcinogenic potency of the other PAHs relative to B[a]P are expressed as TEFs. 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 whether an oyster consumption advisory is warranted. For the Lynnhaven River, the TEF for 15 PAHs expressed as the sum of B[a]P equivalent concentrations was 2.8 micrograms/kilogram ($\mu\text{g}/\text{kg}$) in edible tissue of oysters collected during the fall, 6.5 $\mu\text{g}/\text{kg}$ during the summer, and 2.6 $\mu\text{g}/\text{kg}$ for oysters collected during the winter. Cancer classification, TEF for individual PAHs, and calculated B[a]P equivalents are presented in Table 2.

Table 2. Individual polycyclic aromatic hydrocarbons cancer classification, toxicity equivalent factors, and benzo[a]pyrene equivalent concentrations from oysters collected in 2010 through 2012

Polycyclic aromatic hydrocarbon	Cancer Classification [†]			Toxicity equivalent factor	Winter	Summer	Fall
	DHHS	EPA	IARC		B[a]P equivalent	B[a]P equivalent	B[a]P equivalent
acenaphthylene				0.001	0.0	0.0	0.0
acenaphthene			3	0.001	0.0	0.0	0.0
fluorene		D	3	0.001	0.0	0.0	0.0
phenanthrene		D	3	0.001	0.0	0.0	0.0
anthracene		D	3	0.01	0.2	0.1	0.1
fluoranthene		D	3	0.001	0.1	0.1	0.1
pyrene		D	3	0.001	0.1	0.0	0.2
benz(a)anthracene	2	B2	2B	0.1	0.4	0.8	0.6
chrysene		B2	2B	0.01	0.2	0.3	0.2
benzo(b)fluoranthene	2	B2	2B	0.1	0.3	1.2	0.8
benzo(k)fluoranthene	2	B2	2B	0.1	0.1	0.7	0.2
benzo(a)pyrene	2	B2	1	1	1.3	0.0	0.6
indeno(1,2,3,cd)pyrene	2	B2	2B	0.1	0.0	0.1	0.0
dibenz(a,h)anthracene	2	B2	2A	5	0.0	3.0	0.0
benzo(g,h,i)perylene		D	3	0.01	0.0	0.0	0.0
Sum B[a]P equivalent	15 PAHs				2.6	6.5	2.8
	43 PAHs ^{††}				2.8	6.5	3.0

(Source: DSS) All units are in $\mu\text{g}/\text{kg}$. **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. **1**=Carcinogenic to humans. **2B**=Possibly carcinogenic to humans. **2A**=Probably carcinogenic to humans. **3**=Not classifiable as to its carcinogenicity to humans. **B[a]P**=benzo[a]pyrene. **PAH**=polycyclic aromatic hydrocarbons. ^{††}Provided for comparison.

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

⁶ U. S. Food and Drug Administration. [Protocol for interpretation and use of sensory testing and analytical chemistry results for re-opening oil-impacted areas closed to seafood harvesting due to the deepwater horizon oil spill](#). Updated November 2010.

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.

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.^{7, 8}

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 two meals per month of PAHs in oysters, for protecting consumers from potential carcinogenic effects is as follows:

$$C = \frac{RL \times BW \times EDF \times T}{CSF \times MS \times NM}$$

Where:

Abbreviation	Parameter	Value & Units
C	Concentration	(mg/kg)
RL	Risk level	(1 x 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 is simplified to 25 ppb.

⁷ Virginia Department of Environmental Quality. [Virginia Oyster Gardening Guide](#).

⁸ Pittinger, C. A.; Buikema, A. L.; Hornor, S. G.; Young, R. W. Variation in tissue burdens of polycyclic aromatic hydrocarbons in indigenous and relocated oysters. *Environ. Tox. Chem.* 4, 379-387, 1985.

$$0.023 \text{ mg/kg} = \frac{1 \times 10^{-5} \times 80 \text{ kg} \times 2.4 \times 30 \text{ days/month}}{7.3 (\text{mg/kg/day})^{-1} \times 0.168 \text{ kg/meal} \times 2 \text{ meals/month}}$$

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 Lynnhaven River (see Table 3). 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 per 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.

Table 3. Oyster consumption advisory guideline for oysters containing polycyclic aromatic hydrocarbons

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 applied the multi-tier oyster consumption guidelines to the average composite samples collected from the Lynnhaven River. The B[a]P equivalent concentration of PAHs in oysters collected in winter, summer, and fall would not have resulted in a consumption advisory (see Table 4).

Table 4. Lynnhaven River oyster consumption advisory for samples collected in 2010-2012

Collection Period	Average B[a]P equivalent Concentration	Oyster Consumption Advisory
Fall	2.8 ppb	No advisory
Winter	2.6 ppb	No advisory
Summer	6.5 ppb	No advisory

One meal consists of 12 oysters. **ppb**=parts per billion or µg/kg. **Fall** = November 2010. **Winter** = December 2011-January 2012. **Summer** = June 2011.

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 a 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.

CONCLUSION

The amount of polycyclic aromatic hydrocarbons in oysters taken from the Lynnhaven River in 2010-2012 does not warrant an oyster consumption advisory.

RECOMMENDATIONS

DEE recommends using the multi-tier oyster consumption guidelines to determine if future concentrations of polycyclic aromatic hydrocarbons in oysters taken from the Lynnhaven River warrant a consumption advisory.

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.

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Attachments

Map of Virginia Beach, VA and approximate sampling locations on the Lynnhaven River.



(Source: Google Map)

LYNN=Lynnhaven Inlett.

LRLC=Lynnhaven River Long Creek.

LBRG=Linkhorn Bay Rainey Gut.

LRWB=Lynnhaven River Western Branch.

LREB=Lynnhaven River Eastern Branch.

December 2011-January 2012 sampling sites: LRWB, LREB, LRLC, and LBRG.

Summer 2011 sampling site: LRWB (approximation).

November 2010 sampling site: LYNN.

Demographics & socioeconomic characteristics of Virginia Beach and Virginia

	Virginia Beach		Virginia	
	Total	Percent	Total	Percent
Population Size				
Total Population	437,994	-	8,001,024	-
Males	214,441	49.0	3,794,040	49.1
Females	223,553	51.0	3,927,690	50.9
Race/Ethnicity				
White/Caucasian	296,670	67.7	5,458,832	70.7
Black/African-American	85,935	19.6	1,510,139	19.6
Asian	26,769	6.1	371,788	4.8
American Indian/Alaskan Native	1,685	0.4	22,932	0.3
Hispanic/Latino (Of Any Race)	28,987	6.6	514,959	6.7
Two or More Races	17,656	4.0	159,701	2.1
Age Distribution				
Persons under 5 years old	29,225	6.7	521,279	6.8
Persons 18 years and over	332,745	76.0	5,890,260	76.3
Persons 65 years and over	46,435	10.6	907,858	11.8
Languages				
English Only	361,189	88.6	6,249,294	86.8
Language Other than English	46,607	11.4	951,157	13.2
Spanish	16,343	4.0	424,029	5.9
Other Indo-European Languages	10,686	2.6	225,502	3.1
Asian/Pacific Island Languages	17,840	4.4	227,974	3.2
Socioeconomic Characteristics				
High School Graduate or Higher (≥ 25 yrs)	-	92.9	-	85.8
Bachelor's Degree or Higher (≥ 25 yrs)	-	32.3	-	33.4
In Labor Force (≥ 16 yrs)	247,963	72.1	4,111,333	67.4
Unemployment Rate***	-	5.5	-	5.8
Families below the Poverty Level	-	5.2	-	7.2
Median Household Income	\$65,910	-	\$60,316	-
Per Capita Income	\$31,589	-	\$31,606	-
Median Value, Owner-Occupied Homes	\$276,500	-	\$247,100	-
# Owner-Occupied Housing Units	107,778	65.3	2,030,965	69.2
# Renter-Occupied Housing Units	57,311	34.7	905,669	30.8
Median Monthly Owner Costs (Mortgage)	\$1,831	-	\$1,668	-
Median Monthly Owner Costs (No Mortgage)	\$563	-	\$375	-
Primary Employment in the Community				
Education services and health care	-	20.9%	-	-
Retail trade	-	13.0%	-	-
Professional, scientific, and administrative services	-	12.1%	-	-
Arts, entertainment, and recreation	-	9.9%	-	-
Public administration	-	9.0%	-	-

	Virginia Beach		Virginia	
	Total	Percent	Total	Percent
Crimes Reported** per 100,000 persons				
Violent Crime	188.1	-	213.6	-
Murder and Manslaughter	3.2	-	4.6	-
Robbery	96.8	-	70.7	-
Community Health Indicators**per 100,000 persons				
Heart Disease	118.5	-	-	-
Stroke	48.9	-	-	-
Infant Mortality	7.8	-	-	-
Breast Cancer	23.4	-	-	-
Colon Cancer	19.5	-	-	-
Lung Cancer	57.5	-	-	-

Source: U.S. Census Bureau 2010

** Rate per 100,000 persons

***Source: Bureau of Labor and Statistics 2013 <http://www.bls.gov/ro3/valaus.htm>

Lynnhaven River watershed land use

<p>Schools: Hermitage Elementary School Independence Middle School Bayside High School Princess Anne High School Windsor Woods Elementary School Kings Grant Elementary School Kingston Elementary School Cox High School Great Neck Middle School</p>	<p>Shopping Centers: Haygood Shopping Center Loehmann's Plaza Timberlake Shopping Center Hilltop North Shopping Center Pembroke Mall Shopping Center</p>
<p>Golf courses: Bayville Golf Club Kempsville Greens Municipal Golf Course Broad Bay Country Club</p>	<p>Marinas: Long Bay Pointe Lynnhaven Municipal Marina Lynnhaven Dry Storage Lynnhaven Seafood Marinas Marina Shores Cavalier Golf & Yacht Club</p>
<p>Parks: Bayville District Park First Landing State Park Francis Land History Park Great Neck Park Lynnhaven Park Mount Trashmore Park</p>	<p>Restaurants: Cape Story By The Sea 35th Annual Oyster Roast Lynnhaven Fish House Restaurant Captain George's Seafood Restaurant Bonefish Grill</p>
<p>Hospitals: Sentara Bayside Hospital St Jude Children's Research Sentara Virginia Beach General Hospital</p>	

(Source: Bing, Google maps, 2013) The above were identified through a visual search of the Lynnhaven River watershed using Bing and Google maps between September and October 2013.