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PROTOCOL FOR INTERPRETATION AND USE OF SENSORY TESTING AND ANALYTICAL CHEMISTRY RESULTS FOR RE-OPENING OIL-IMPACTED AREAS CLOSED TO SEAFOOD HARVESTING

INTRODUCTION

The U.S. Food and Drug Administration (FDA) operates a mandatory safety program for all fish and fishery products under the provisions of the Federal Food, Drug and Cosmetic Act, the Public Health Service Act and related regulations. Actions and criteria discussed in this protocol should be followed in addition to the provisions already in place. The National Oceanic and Atmospheric Administration (NOAA) has the authority to close and open Federal waters for seafood harvest and operates the Seafood Inspection Program providing the agency seafood safety and quality expertise. After an oil spill has occurred, Federal and State agencies are faced with the issue of determining when the seafood from the previously contaminated area may once again be safe for harvest and human consumption. NOAA Office of Response and Restoration (OR&R) publication entitled *Managing Seafood Safety after an Oil Spill*[1] provides agencies guidance in such situations. This guidance and other input from both NOAA and the FDA have been used in consultation with the Environmental Protection Agency (EPA) and the Gulf Coast States to establish this protocol. This protocol is applicable to the re-openings of commercial and recreation fisheries in both federal and state waters.

In establishing this protocol it is important to understand the following principles:

- NOAA and the FDA are working with other federal and state agencies to protect consumers from adulterated and unsafe seafood, while minimizing undue economic burden on any impacted seafood industries.

- Once oil or chemical contaminants are visually observed on the surface, it is recommended that the fishery be closed until free of sheen, and subsequent testing has been completed to confirm that seafood from affected areas are wholesome and safe for human consumption and use in animal feed.

- After the initial fishery closure, the best approach for determining the safety and acceptability of seafood from oil-contaminated areas is one that involves organoleptic analysis of products (i.e. sensory testing) followed by chemical analysis.

- Fishery closure areas also include areas that NOAA projects will have surface oil and a precautionary buffer zone around known contaminated waters to account for uncertainty. After confirming through subsequent evaluation that oil did not enter an area, the area may be re-opened without subjecting seafood samples to evaluation under this protocol. This protocol is an added layer of protection being applied to seafood only in areas known to have been contaminated.

Oil contamination presents two kinds of risks: the presence of petroleum taint that renders seafood unfit for human consumption, and the presence of polycyclic aromatic hydrocarbons (PAHs) that are chemical hazards. Federal government and state agencies therefore close oil-contaminated harvest areas for health reasons.

Oil-contaminated seafood is adulterated if the contamination is perceivable by olfaction (taint), or in the absence of taint, chemical analysis determines that the level of PAHs in it exceeds FDA levels of concern. Consequently, after an oil spill, seafood suspected of oil contamination can only be brought into interstate commerce when it passes both sensory testing for petroleum taint, and chemical analysis for PAHs.

To date, available information indicates that the dispersants being used to combat the oil spill do not appear to accumulate in seafood and therefore, there is likely little public health concern from them due to seafood consumption. However, as per this protocol, sensory testing and further work to identify component compounds in known exposed fish will be conducted for dispersants.

The purpose of this protocol is to specify how the results of sensory testing and chemical analyses will be used in re-opening seafood closure areas. The principles of the protocol are as follows:

Generally:

1. The closure of a fishery assumes a worst case scenario, and is intended to protect seafood consumers until the safety of the seafood can be established.
2. Area re-opening will be based on an acceptable reduction of the threat of seafood exposure to oil contamination, and analyses that assure the safety and wholesomeness of the seafood.
3. Once seafood samples from an area pass sensory testing, area samples must also pass chemical analysis for PAHs before that fishery may be re-opened.
4. Re-openings may be fisheries specific.
5. Opening boundaries will be based on results of analyses (sensory and chemical) that demonstrate the product is untainted and safe for human consumption.

Specific Re-opening Criteria:

1. Low threat of exposure – Threat of exposure will be based on past observations and the status of the spill and conditions.
2. Evaluation of oil movement – Confirmation that the closure area is free of sheen on the surface by visual observation and/or aerial reconnaissance, or the presence of oil in the water column through visual observation or water testing.
3. Assessment of seafood contamination by sensory testing – Determine if the seafood is contaminated by tissue collection and sensory testing. The acceptable condition is that all specimens must pass sensory testing conducted by a NOAA-FDA expert sensory panel or a NOAA-FDA trained panel of state assessors.
4. Assessment of seafood contamination by chemical analyses – Chemical analyses are performed on samples that pass sensory assessment to confirm that PAH concentrations are below the applicable FDA levels of concern for human health. Final determinations may take into consideration what is known regarding relevant background information for specific harvest areas.

ANALYSIS

1. NOAA sensory testing protocol reviewed by FDA[2, 3].
2. When sensory tested samples are acceptable, verify sensory testing outcomes with chemical analyses performed using the NOAA PAH method[4].

ADDITIONAL INFORMATIVE DATA

Additional investigation protocols may be designed and used to assess water and sediment contamination, toxicity testing, ecological injury and other environmental parameters. These investigations are not directly related to or considered a part of this protocol, but can be extremely informative in the overall determination process. Data from these investigations will be reviewed prior to making any decisions to re-open an area or a fishery and may be the basis for requiring additional sampling/analysis as per this protocol. For example, sediment chemical data from fishery areas may be used to identify contaminant "hot spots." Water column data, toxicity test results and other data, required of BP or generated by federal (e.g. EPA) or state agencies, are among the various data that may be considered for any re-opening determination.

Water analysis for PAHs may be used to gain an understanding of the effectiveness of the containment and cleanup of the spill. Toxicity testing of water column or sediment samples for oil and dispersant related contaminants can also provide important insights on impacts to other biota. Such water analysis should be performed on representative samples of the affected water column. In addition water and tissue analysis may be used to determine any residual concentration of the dispersants used. The necessary sampling criteria will be based on many factors including the area of the closure, depth of the water within the closure, and sites and species considered for re-opening of harvest areas or fishery. With regard to inshore fisheries such as molluscan shellfish, sediment samples may also be analyzed.

Surveillance of fisheries should be conducted in response to identified "hot spots" or other relevant changes in environmental conditions (e.g., increases in PAH levels in water or seafood) if warranted, based on the protocol defined.

RE-OPENING PROCESS

NOAA, in consultation with FDA, will review the data generated as a result of the implementation of this protocol in federal waters, evaluate the accuracy and quality of the data and assess compliance with the agreed criteria. Based on this assessment NOAA may re-open federal waters subject to the closure. NOAA and FDA will coordinate with State agencies for the re-opening of State commercial waters to ensure orderly and appropriately enforced re-openings. No partial re-openings will be allowed which are unenforceable, i.e., requiring harvesters to segregate their catch and discard catch from fisheries that remain closed.

Sensory testing based on NOAA Technical Memorandum NOS OR&R 9: *Guidance on Sensory Testing and Monitoring of Seafood for Presence of Petroleum Taint Following an Oil Spill*[2] will be utilized. A panel of ten expert assessors from NOAA and/or the FDA, and state agencies if available, will conduct sensory testing. Samples will be examined by organoleptic methods both in the raw and cooked states. If samples from a particular fishery pass sensory testing within a defined sampling area, chemical analyses will be performed on representative samples from that same fishery and area[4]. If chemical analyses pass the risk based assessment criteria for the species in question, that zone will be considered for re-opening. If samples from an area fail sensory testing a determination will be made as to when retesting will occur taking into consideration the conditions of the fishery and the failure results.

SELECTION OF TARGET PAHs and LEVELS OF CONCERN

Most petrochemical products such as diesel oil and crude oil contain aromatic components: mono-, bi-, and polycyclic aromatic hydrocarbons. Well-established liquid chromatography (LC)/fluorescence detection (FD) and gas chromatography (GC)/mass spectrometry (MS) methods are used to separate and quantify these contaminants in seafood.

PAHs are abundant in our environment; in addition to sources from petrochemical products they are generated by nearly all pyrolytic processes including forest fires, char-grilled and smoked meat, and fuel combustion in automobiles. Crude petroleum is composed of a complex mixture of many hundreds of compounds. Most of the compounds are volatile, and evaporate to produce the pungent odor of petroleum. Others are less volatile and persist in the environment (e.g. formation of tar balls or sink to the bottom). The PAHs in petroleum mixtures are of greatest concern for human health because of their persistence (i.e. lower evaporation rates), and their potential for toxic or carcinogenic effects. The subset of 12 PAHs and their alkylated homologues selected for critical analysis in the Deepwater Horizon Spill (Table I) are among the most studied PAHs in petroleum mixtures. These compounds have been found to reflect the potential for toxic or carcinogenic effects of the mixture of compounds present in crude petroleum[5] based on experience with previous oil spills (e.g. North Cape Oil Spill, 1996, Rhode Island).

Most seafood risk assessments conducted after oil spills in the U.S. have followed an approach used by the FDA in 1990 after the *Exxon Valdez* oil spill in Prince William Sound, Alaska[6, 7]. This approach uses a set of calculations to determine seafood (harvested for human consumption) PAH tissue concentrations, expressed in benzo[a]pyrene (BaP) equivalents (µg/kg), above which an appropriate, conservatively estimated upper-bound risk level for cancer is exceeded. Levels of concern for non-cancer risks are also evaluated. The values for several variables in these calculations can be adjusted on a case-by-case basis, depending on seafood consumption rates of the exposed population, average body weight of the exposed population, estimates of exposure time for a particular spill, and the cancer risk level deemed appropriate. This approach to calculating seafood advisory levels has been used after several other oil spills, including the *North Cape* spill in Rhode Island, the *Julie N* spill in Maine, the *Kure* spill in California, and the *New Carissa* spill in Oregon.

The level of appropriate risk is the maximum level of individual lifetime carcinogenic risk that is considered appropriate by risk managers. The relative risk level to be used for low dose cancer risk calculations is 1×10^{-5}. This implies that exposure to PAH in seafood below a specified tissue concentration, at a defined consumption rate, and over a defined exposure period would yield a lifetime cancer risk of no greater than 1 in 100,000. A risk level of 1×10^{-5} was used in the risk assessment conducted by the State of Maine for the Julie N oil spill and the State of Alaska for the *Kuroshima* oil spill[1].

Depending upon levels of petrogenic PAHs accumulated by aquatic species, consumption of petroleum contaminated fishery products may pose a health risk to seafood consumers. The risk is considered higher for high-level consumers of fishery products. These concerns necessitate consideration of consumption rates for high-level consumers of fish, shrimp, crab and oysters. FDA uses the 90th percentile of national consumption data from the National Health and Nutrition Examination Survey (NHANES) for fish, shrimp, crab and oysters for calculating risk of PAH exposure in high-level consumers of seafood products. To determine an appropriate fish consumption rate for high-level consumers, FDA adjusted the 90% meal size to account for the number of meals eaten by a 90th percentile consumer.

Table I shows the criteria for re-opening based upon non-cancer risks and a 1×10^{-5} cancer risk for different PAHs. For the non-cancer evaluation (naphthalene, fluorene, anthracene, phenanthrene, pyrene, and fluoranthene) the EPA Integrated Risk Information System (IRIS) reference dose (RfD) values were used[8-13]. For the cancer evaluation (chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benz(a)anthracene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, and benzo(a)pyrene), the EPA IRIS BaP equivalence (BaPE) values were used[14]. The EPA IRIS cancer slope factor for BaP was also used. As discussed above, 90th percentile consumption values were used for generating calculations for average daily consumption rates of shrimp and crabs, oysters and finfish for consumers only. For generating cancer risk values, exposures are assumed to last for 5 years.

Recent results from PAH chemical analysis of finfish (grouper, red snapper and red drum) collected by NOAA from the unaffected Dauphin Island area in early May 2010 show PAH concentrations to be below the levels of concern shown in Table I. An evaluation of PAH chemical analysis data collected by the NOAA mussel watch program showed that in 2007-2008 average concentrations were below FDA levels of concern in oysters in commercially harvestable areas.

Final determinations for opening oil spill affected fisheries and areas may take into consideration available PAH background level data and assumptions on duration of exposure.

Criteria for Sensory Testing

A minimum of 6 sub-samples per species (3 sub-samples for oysters) from each sample location in the area under consideration for re-opening must be tested. A sub-sample will consist of an individual organism for legal size finfish and multiple organisms for shrimp and shellfish, depending on the intact animal type (e.g. 3 to 6 blue crabs, 6 oysters, 0.4 – 0.5 lb shrimp). The samples will be evaluated by a panel of a minimum of 10 expert assessors in the raw and cooked state. Samples will be evaluated first for raw odor, then cooked odor, then cooked flavor in that order. If at any time the analyst finds detectable petroleum or dispersant, the analyst will not further evaluate the sample.

For a closed fisheries area to be considered for re-opening, the following criteria must be met (these criteria are based on past oil spill information and ensure a high confidence level that the seafood is not tainted by oil):

- A minimum of seventy percent (70%) of the expert assessors must find NO detectable petroleum or dispersant odor or flavor from each sub-sample. If any sub-sample fails, the sample location fails.
- All contiguous stations or sample locations must pass for an area to open.

If the area passes the sensory test then samples will undergo chemical analyses. Samples must then pass chemical analyses for PAHs before the area may re-open.

Criteria for Chemical Analyses

For crabs specifically, a sample of edible muscle from a minimum of ten (10) individuals, of legal size if available, should be collected from each sampling location. Tissue samples from individual crabs will be combined to make separate composite samples of the muscle tissue. For all other seafood, a sample of edible tissue from a composite (of at least 200 grams) from a minimum of 10 or more individuals collected at or near the locations specified is required. All samples should be collected from sites selected as commonly used fishing grounds or normally harvestable molluscan shellfish bed.

Contaminant Levels in Fish and Shellfish Tissue that Pose No Significant Risk

The safety of commercial seafood is generally determined by comparison of tissue contaminant concentrations to FDA levels of concern. Risk-based criteria to establish the safety of commercial or recreational fish and shellfish following an oil spill were developed using standard FDA and EPA risk assessment methods, as described below.

Cancer Risk

In order to interpret the cancer risk for individual PAH compounds likely to be found in the Gulf of Mexico light crude petroleum, the carcinogenic activity relative to benzo(a)pyrene (BaP) is estimated as a toxicity equivalency factor (TEF)[8]. TEFs for chrysene, benzo[k]fluoranthene, benz[a]anthracene, indeno[1,2,3-cd]pyrene, benzo[b]fluoranthene, and dibenz[a,h]anthracene are 0.001, 0.01, 0.1, 0.1, 0.1, and 1 respectively. Tissue concentrations of PAHs other than BaP are multiplied by their respective TEF and added to the tissue concentration of BaP to determine the BaP equivalent (BaPE) concentration. The BaPE concentration is considered the most valid measure of the carcinogenic potency of a complex mixture of PAH compounds. For the purpose of this risk assessment, substituted alkylated homologues of the above PAHs will be summed with the parent compound and multiplied as a single value by the appropriate TEF.

The following equation was used to determine the public health levels of concern (LOC: in μg/g or mg/kg = ppm wet weight) for carcinogenic PAH compounds (BaPE) potentially found in seafood:

$$LOC\ (BaPE) = (RL \times BW \times AT \times CF)/(CSF \times CR \times ED)$$

Where *LOC* is the level of concern; BaPE is the benzo(a)pyrene equivalency; *RL* is the risk level; *BW* is the average consumer body weight; *AT* is the averaging time (i.e. life expectancy); *CF* is the unit conversion factor; *CSF* is the cancer slope factor of BaP; *CR* is the consumption rate (the daily amount of seafood consumed); and *ED* is the assumed exposure duration.

The following specific factors and assumptions were used in the above equation:

- *Risk Level (RL):* Risk-based criteria were selected to prevent consumers from being exposed to the carcinogenic components of crude petroleum in doses that exceed a RL of 1×10^{-5} (1 in 100,000). This RL is within the acceptable range of risks (1×10^{-4} to 1×10^{-6}) used by the FDA and EPA in regulatory criteria for food and drinking water[15] and is provided as an example of an acceptable risk level in the *U.S. EPA Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories*[16].

- *Body Weight (BW):* The average adult body weight for these calculations, 80 kg, was adopted from the most recent CDC National health Statistics Report[17].

- *Averaging Time (AT):* The averaging time for these calculations, 78 yr, was adopted from the most recent CDC National Health Statistics Report[18].

- *Conversion Factor (CF):* Unit conversion factor (1000 μg/mg).

- *Cancer Slope Factor (CSF): Also known as a Cancer Potency Factor):* The upper-bound estimate of the probability that an individual will develop cancer over a lifetime as a consequence of exposure to a given dose of a specific carcinogen. For the purpose of this risk assessment, U.S. EPA current CSF for benzo[a]pyrene of 7.3 $(mg/kg\text{-}day)^{-1}$ was adopted (U.S. EPA, 1994)[14].

- *Consumption Rate (CR):* Consumption rates for shrimp & crab (13 g/day), oysters (12 g/day), and finfish (49 g/day) were adopted from 2005-2006 NHANES data for high level (90th percentile) seafood consumers adjusted for consumption frequency. To determine an appropriate fish consumption rate for high-level consumers, FDA adjusted the 90% meal size to account for the number of meals eaten by a 90th percentile consumer[1]:

  [meal frequency /30 days in month] x meal size = grams seafood per day

  Where:
  Meal frequency = 9.1 meals per month for finfish; 2.9 for oysters; and 4.4 for shrimp/crab
  Days per month = 30
  Meal size = 160 g for finfish; 120 g for oysters ; 90 g for shrimp/ crab
  Grams seafood/day = 49 g for finfish; 12 g for oysters; and 13 for shrimp/crab

- *Exposure Duration (ED):* The exposure duration was assumed to be 5 yr. This is a conservative estimate of the potential retention period of Deepwater Horizon oil contaminants in Gulf seafood.

Calculation of the Public Health Levels of Concern for Carcinogenic PAHs (BaPE) in Seafood:

Applying the specific factors and assumptions to the equation above results in the following LOC for BaPE in finfish:

$$[(1\times10^{-5})(80\ kg)(78\ yr)(1000\ \mu g/mg)] / [7.3\ (mg/kg\text{-}day)^{-1}(49 g/day)(5\ yr)] = 0.035\ \mu g/g \text{ or ppm BaPE}$$

Applying the specific factors and assumptions to the equation above results in the following LOC for BaPE in shrimp/crabs:

[1] For 90th percentile consumption values, data from the 2005-2006 NHANES two day recall survey were used. To determine the average daily rate for these consumers, the 2005-2006 30 day recall survey was used to determine frequency of seafood meals by 90th percentile consumers.

$$[(1x10^{-5})(80\ kg)(78\ yr)(1000\ \mu g/mg)] / [7.3\ (mg/kg\text{-}day)^{-1}(13\ g/day)(5\ yr)] = 0.132\ \mu g/g \text{ or ppm BaPE}$$

Applying the specific factors and assumptions to the equation above results in the following LOC for BaPE for oysters:

$$[(1x10^{-5})(80\ kg)(78\ yr)(1000\ \mu g/mg)] / [7.3\ (mg/kg\text{-}day)^{-1}(12\ g/day)(5\ yr)] = 0.143\ \mu g/g \text{ or ppm BaPE}$$

Non-Cancer Risks

Non-cancer risks were determined for anthracene, phenanthrene, fluoranthene, fluorene, naphthalene, and pyrene. For the purpose of this risk assessment, substituted homologues of the above PAHs will be summed with the parent compound and compared to the appropriate toxicity criterion. The following general equation was used to set the public health protective level of concern (µg/g or mg/kg = ppm wet weight) for these compounds potentially found in seafood:

$$LOC = (RfD)(BW)(CF)/CR$$

Where *RfD* is reference dose; *BW* is the body weight (kilograms); *CF* is the conversion factor (1000 µg/mg); and *CR* is the consumption rate (the daily amount of fish or shellfish consumed).

The following specific factors and assumptions were used in the above equation:

- *Reference Dose (RfD):* An estimate of daily human exposure to a chemical that is likely to be without significant risk of adverse effects during a lifetime, in mg/kg/day. RfDs for selected PAH compounds were obtained from the U.S. EPA's Integrated Risk Information Service (IRIS) database (accessed June, 2010; see references for specific chemicals).

- *Body Weight (BW):* The average adult body weight for these calculations, 80 kg, was adopted from the most recent CDC National Health Statistics Report[15].

- *Conversion Factor (CF):* Unit conversion factor (1000 µg/mg).

- *Consumption Rate (CR):* Consumption rates for shrimp & crab (13 g/day), oysters (12 g/day), and finfish (49 g/day) were adopted from 2005-2006 NHANES data for high level (90th percentile) seafood consumers adjusted for consumption frequency as described above.

Using the above equation and assumptions, the non-cancer public health levels of concern for individual PAHs were calculated and are presented in Table 1.

The PAH levels of concern in Table I are based upon seafood consumption rates derived from 90^{th} percentile, seafood consumers only, data from the 2005-2006 NHANES survey adjusted for consumption frequency. FDA and NOAA are taking this approach to ensure protection for the diverse US population as fisheries are re-opened. This approach may not necessarily affect a particular state's local and state-wide fish advisories or a state's determination regarding the opening or closing of state waters. As appropriate, states should use the best-available, relevant, state-specific data to make local and state-wide determinations. The PAH levels of concern, and factors for their derivation, were developed specifically for the unprecedented Deepwater Horizon Oil Spill event, and will not necessarily be applicable after all fisheries closed due to oil contamination are re-opened for safe harvest. Levels of concern and other factors for any subsequent oil spill event would be independently evaluated based on case-specific information.

Table I
Levels of Concern

Chemical[1]	Levels of Concern (ppm) 13 g/day (Shrimp and Crabs)	12 g/day (Oysters)	49 g/day (Finfish)	Basis
Naphthalene	123	133	32.7	Non-cancer EPA RfD[2]; 80kg bw
Fluorene	246	267	65.3	Non-cancer EPA RfD[2]; 80kg bw
Anthracene/Phenanthrene	1846	2000	490	Non-cancer EPA RfD[2]; 80kg bw
Pyrene	185	200	49.0	Non-cancer EPA RfD[2]; 80kg bw
Fluoranthene	246	267	65.3	Non-cancer EPA RfD[2]; 80kg bw
Chrysene	132	143	35.0	Cancer 0.001 BaP equivalent[3]
Benzo(k)fluoranthene	13.2	14.3	3.5	Cancer 0.01 BaP equivalent[3]
Benzo(b)fluoranthene	1.32	1.43	0.35	Cancer 0.10 BaP equivalent[3]
Benz(a)anthracene	1.32	1.43	0.35	Cancer 0.10 BaP equivalent[3]
Indeno(1,2,3-cd)pyrene	1.32	1.43	0.35	Cancer 0.10 BaP equivalent[3]
Dibenz(a,h)anthracene	0.132	0.143	0.035	Cancer 1.0 BaP equivalent[3]
Benzo(a)pyrene	0.132	0.143	0.035	10^{-5} Cancer risk = (0.110 µg/person/day)(78/5 yr)[3]

[1] Includes alkylated homologues, for example C-1, C-2, C-3, C-4 napthalenes, fluorenes, anthracenes, fluoranthenes, pyrenes and chrysenes. Alkylated homologues are assumed to have similar toxicities to the parent compounds.

[2]With respect to the Basis:

Chemical	RfD x Body Wt. x CF/ Intake
Naphthalene:	(0.02 mg/kg/day x 80 kg x 1000 µg/mg) / Intake (g/day)
Fluorene:	(0.04 mg/kg/day x 80 kg x 1000 µg/mg) / Intake (g/day)
Anthracene:	(0.30 mg/kg/day x 80 kg x 1000 µg/mg) / Intake (g/day)
Pyrene	(0.03 mg/kg/day x 80 kg x 1000 µg/mg) / Intake (g/day)
Fluoranthene	(0.04 mg/kg/day x 80 kg x 1000 µg/mg) / Intake (g/day)

[3]Criteria are based on a one-in-a-one hundred thousand increase in the lifetime (78 yr) upper bound cancer risk adjusted to account for exposures which are expected to last 5 years (78/5 yr). For any sample containing, chrysene, benzo(k)fluoranthene, benzo(b)fluoranthene, benz(a)anthracene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene or benzo(a)pyrene, the sum of the individual ratios of the detected levels to the levels of concern cannot exceed 1.

Cancer risk-based criteria:

Chemical	[(RL x BW)/CSF x (AT/ED)]/[Intake x TEF]
Chrysene	[0.110 µg/p/day x (78/5 yr)] / [Intake (g/day) x 0.001]
Benzo(k)fluoranthene	[0.110 µg/p/day x (78/5 yr)] / [Intake (g/day) x 0.01]
Benzo(b)fluoranthene	[0.110 µg/p/day x (78/5yr)] / [Intake (g/day) x 0.1]
Benz(a)anthracene	[0.110 µg/p/day x (78/5yr)] / [Intake (g/day) x 0.1]
Indeno(1,2,3-cd)pyrene	[0.110 µg/p/day x (78/5 yr] / [Intake (g/day) x 0.1]
Dibenz(a,h)anthracene	[0.110 µg/p/day x (78/5 yr)] / Intake (g/day)
Benzo(a)pyrene	[0.110 µg/p/day x (78/5 yr)] / Intake (g/day)

References:

1. Yender, R., Michel, J., and Lord, C. (2002). Managing Seafood Safety after an Oil Spill. Seattle: Hazardous Materials Response Division, Office of Response and Restoration, National Oceanic and Atmospheric Administration. 72 pp. Available: http://response.restoration.noaa.gov/book_shelf/963_seafood2.pdf

2. Reilly, T.I., and York, R.K. (2001) Guidance on Sensory Testing and Monitoring of Seafood for Presence of Petroleum Taint following an Oil Spill. NOAA Technical Memorandum NOS OR&R 9. Seattle: Office of Response and Restoration, National Oceanic and Atmospheric Administration. 109 pp.

3. Yender, R. (2003). Improving Seafood Safety Management after an Oil Spill. In: *Proceedings of the 2003 International Oil Spill Conference*. 8 pp. Available: http://www.iosc.org/papers/IOSC%202003%20a416.pdf

4. Sloan, C.A., Brown, D.W., Pearce, R.W., Boyer, R.H., Bolton, J.L., Burrows, D.G., Herman, D.P., and Krahn, M.M. (2004). Extraction, Cleanup, and Gas Chromatography/Mass Spectrometry Analysis of Sediments and Tissues for Organic Contaminants. U.S. Dept. Commer. NOAA Tech. Memo. NMFS-NWFSC-59, 47 pp.

5. Bolger, M. and Carrington, C. (1999). Hazard and Risk Assessment of Crude Oil in Subsistence Seafood Samples from Prince William Sound: Lessons learned from the Exxon Valdez. In L. Jay Field et al. (eds.). *Evaluating and Communicating Subsistence Seafood Safety in a Cross-Cultural Context: Lessons Learned from the Exxon Valdez Oil Spill.* Pensacola: Society of Environmental Toxicology and Chemistry. Pp. 195-204.

6. Bolger, M., Henry, S.H., and Carrington, C.D. (1996). Hazard and Risk Assessment of Crude Oil Contaminants in Subsistence Seafood Samples from Prince William Sound. Proc. *EXXON VALDEZ Oil Spill Symposium*, S.D. Rice, R.B. Spies, D.A. Wolfe, and B.A. Wright (eds.). American Fisheries Symposium Vol. 18, pp. 837-843.

7. Bolger, M. and Carrington, C. (1999). Estimation of Risk Associated with consumption of Oil-Contaminated Fish and Shellfish by Alaskan Subsistence Fishermen using a Benzo[a]pyrene Equivalency Approach. In L. Jay Field et al. (eds.). *Evaluating and Communicating Subsistence Seafood Safety in a Cross-Cultural Context: Lessons Learned from the Exxon Valdez Oil Spill. Pensacola: Society of Environmental Toxicology and Chemistry. Appendix 3: Report of the Quantitative Risk Assessment Committee, Center for Food Safety and Applied Nutrition, U.S. food and Drug Administration*, 9 August 1990, pp. 295-304

8. U.S. EPA. 1993. Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons. United States Environmental Protection Agency, Office of Research and Development. July, 1993. Washington DC.

9. U.S. EPA. 1998. Integrated Risk Information System. Online at: http://www.epa.gov/iris/subst/0436.htm. Naphthalene (CASRN 91-20-3). Database maintained by the Office of Health and Environmental Assessment. U.S. Environmental Protection Agency Environmental Criteria and Assessment Office, Cincinnati, Ohio. Accessed June 10, 2010.

10. U.S. EPA. 1990. Integrated Risk Information System. Online at: http://www.epa.gov/ncea/iris/subst/0435.htm. Fluorene (CASRN 86-73-7)/ Database maintained by the Office of Health and Environmental Assessment. U.S. Environmental Protection Agency Environmental Criteria and Assessment Office, Cincinnati, Ohio. Accessed June 10, 2010.

11. U.S. EPA. 1993. Integrated Risk Information System. Online at: http://www.epa.gov/ncea/iris/subst/0445.htm. Pyrene (CASRN 129-00-0). Database maintained by the Office of Health and Environmental Assessment. U.S. Environmental Protection Agency Environmental Criteria and Assessment Office, Cincinnati, Ohio. Accessed June 10, 2010.

12. U.S. EPA. 1993. Integrated Risk Information System. Online at: http://www.epa.gov/ncea/iris/subst/0434.htm. Anthracene (CASRN 120-12-7). Database maintained by the Office of Health and Environmental Assessment. U.S. Environmental Protection Agency Environmental Criteria and Assessment Office, Cincinnati, Ohio. Accessed June 10, 2010.

13. U.S. EPA. 1993. Integrated Risk Information System. Online at: http://www.epa.gov/ncea/iris/subst/0444.htm. Fluoranthene (CASRN 206-44-0). Database maintained by the Office of Health and Environmental Assessment. U.S. Environmental Protection Agency Environmental Criteria and Assessment Office, Cincinnati, Ohio. Accessed June 10, 2010.

14. U.S. EPA. 1994. Integrated Risk Information System. Online at: http://www.epa.gov/iris/subst/0136.htm. Benzo[a]pyrene (BaP) (CASRN 50-32-8). Database maintained by the Office of Health and Environmental Assessment. U.S. Environmental Protection Agency Environmental Criteria and Assessment Office, Cincinnati, Ohio. Accessed June 10, 2010.

15. U.S. EPA. 1998. Draft Water Quality Criteria Methodology Revisions: Human Health, Notice. Fed. Reg. 63(157):43755-43828. Available: http://www.epa.gov/fedrgstr/EPA-WATER/1998/August/Day-14/w21517.htm

16. U.S. EPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 2. Risk Assessment and Fish Consumption Limits. 3rd Ed. EPA 823-B-00-007. Washington, DC: U.S. Environmental Protection Agency. Available: http://www.epa.gov/fishadvisories/advice/volume2/v2cover.pdf

17. McDowell MA, Fryar CD, Ogden CL, Flegal KM. Anthropometric Reference Data for Children and Adults: United States, 2003–2006. National Health Statistics Reports; no 10. Hyattsville, MD: National Center for Health Statistics. 2008.

18. Heron MP, Hoyert DL, Murphy SL, Xu JQ, Kochanek KD, Tejada-Vera B. Deaths: Final data for 2006. National vital statistics reports; vol 57 no 14. Hyattsville, MD: National Center for Health Statistics. 2009.