Human Health

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1. Executive Summary

The Deepwater Horizon spill released over 200 million gallons of oil into the Gulf of Mexico raising concerns for human health as well as ecological damage. As oil entered the Gulf of Mexico and inland waters, officials closed fishing areas to protect public health. Health assessment methodology provides a framework for the systematic analysis of the routes by which populations may be exposed to contaminants and the characterization of public health implications. This assessment provides a basis for decision making to protect public health and inform the public of the risks associated with the event. The two major pathways for exposure are the inhalation of volatile compounds and the consumption of oil-contaminated seafood. From a human health perspective, seafood is a possible route of human exposure if the fish or shellfish take up and accumulates contaminants in oil.

Crude oil is composed of thousands of hydrocarbons and the composition begins to change, or "weather", as soon as it enters the environment. Contaminants of concern in crude oil are the volatile organic compounds (VOCs), especially the aromatic hydrocarbons, BTEX (benzene, toluene, ethylbenzene and xylene). Inhalation is the primary route of exposure for the VOCs. The other major compounds of concern are the polycyclic aromatic hydrocarbons (PAHs) which have the potential to be taken up by seafood that is consumed by people. PAHs are widespread in the environment and do not accumulate to any extent. Finfish and crustaceans metabolize PAHs and will breakdown and excrete any that are taken up; mollusks breakdown PAHs more slowly and can accumulate these compounds when the amount in the environment is high.

Extensive testing must be conducted to reopen closed fishing areas. Federal and state agencies developed a seafood monitoring protocol for reopening of waters closed to fishing. The overall plan utilizes a three tiered screening approach: 1) No visible oil observed in the designated areas; 2) Organoleptic testing of the seafood; and 3) Chemical testing of the seafood. Sampling for organoleptic or chemical analysis occurs only in areas with no visible oil and under consideration for reopening. The seafood monitoring program is designed to test areas free of oil and under consideration for reopening. The tiered approach to sampling screens out areas with observable oil and uses the chemical analysis to confirm the seafood is free of contamination.

The chemical testing has not detected PAHs in any sample above the level of concern; PAHs were not detected in the majority of the samples. Overwhelmingly, the seafood monitoring data demonstrates that Gulf Coast seafood harvested in the reopened areas is free of contamination by the crude oil. In spite of the seafood monitoring results, producers along the Gulf Coast report a limited market for seafood after the oil spill, and the general public remain apprehensive about the safety of consuming Gulf seafood. Seafood along the Gulf Coast is undergoing more extensive testing and scrutiny than most other seafood products from around the world. Seafood from other areas of the country and foreign seafood is not tested for PAHs and other hydrocarbons. The seafood monitoring will continue for an extended period of time and will ensure that Gulf seafood that reaches the market is not contaminated from the oil spill.

2. Looking Back

Assessing the Impact of the Oil Spill on Human Health: Gulf Seafood

Federal and state public health agencies launched efforts to assess and minimize the human health impact of the oil from the Deepwater Horizon spill. Fishing area in the Gulf of Mexico and inland waterways were closed to fishing and harvesting of other seafood when the crude oil threatened these areas. Louisiana and the Gulf Coast is a major producer of seafood for the United States. The Gulf States produce over 40% of the seafood for the United States; Louisiana alone produces 30% of the total US seafood which is 70% of the total seafood harvested from the Gulf of Mexico. Only Alaska produces more fin fish, and Louisiana is the leading producer shrimp (69%), oysters (70%) and crabs in the US.[11] The closure of fishing, shrimping, crabbing and oystering on the Gulf Coast has an impact on the availability of fresh seafood nationwide.

Oil spills produce devastating ecological effects on the marine environments, especially sensitive estuaries. Much of the damage in estuaries and marine environments occurs from the physical properties of oil rather than its chemical toxicity. Oil coats the surface reducing oxygen availability to small organism, plants and other marine life. Heavily oiled birds cannot fly, lose the insulating properties of the feathers and cannot eat or drink, leading to hyperthermia, dehydration and starvation. If an oil-covered bird is found in time, it can be fed, hydrated, cleaned and restored to health[34].

The Deepwater Horizon oil spill released an estimated 200 million gallons of oil into the Gulf, raising concerns for human health effects. Since oil is a mixture of thousands of hydrocarbons, the assessment of health effects must identify the more toxic components and determine how these compounds come into contact with populations. The two major pathways for exposure are the inhalation of volatile compounds and the consumption of oil-contaminated seafood. From a human health perspective, seafood is a possible route of human exposure if the fish or shellfish take up and accumulates contaminants in oil.

Seafood may become contaminated with components in crude oil, especially along the coastline and in shallower waters. While finfish, crabs and shrimp often swim away from contaminated areas, oysters and mussels cannot. Oil floating on the surface may not be available or affect species in lower water levels.[34] Oysters are filter feeders and may take up contaminants in an oiled area. The concentration of crude oil determines how the oil impacts the marine organisms. If the concentrations of crude oil are very high, the oil will kill marine organism. While this is a serious ecological problem, it reduces the risk of human exposure through seafood consumption. For contaminants to be taken up into seafood, the amount of oil must be low enough not to kill or seriously injure the organism, but sufficiently high (so that the rate of uptake exceeds the rate of metabolism and elimination.[17]

<u>Human Health: Assessment of the Health Impact of Crude Oil</u>

Health assessment methodology provides a framework for the systematic analysis of the routes by which populations may be exposed to contaminants and the characterization of public health implications.[1, 27] This assessment provides a basis for decision making to protect public health and inform the public of the risks associated with the event. Steps for assessing the impact of the crude oil on public health include: 1) Identify the compounds of concern in crude oil and characterize the changing composition of weathered crude oil; 2) Determine the environmental media (air, water, food) and pathways (inhalation, dermal, ingestion) by which the compounds of concern interact with specific populations; 3) Based on environmental monitoring data, estimate the level (dose) and duration of exposure to specific populations; 4) Characterize possible health outcomes from the exposure scenarios.[1]

Throughout the oil spill, the US EPA conducted environmental monitoring of air, water, and sediments along the coast. The environmental monitoring provided large source of quantitative data with which to characterize contaminants in air and water and analysis of crude oil collected near the coast.[1] The environmental monitoring methods have limitations, but the large volume of sampling and analysis provides data for exposure assessments.

Identifying Components of Crude Oil and Human Toxicity

Petroleum is composed of thousands of hydrocarbons that range in size and complexity from the simplest one carbon hydrocarbon (methane, CH_4) to very long chain and multi-ringed structures. As a natural resource, the mix of compounds in crude oil from different locations varies in the proportion of types of hydrocarbons and the amounts of sulfur, nitrogen, oxygen and metals as nickel, vanadium and chromium.[17] Since crude oil is a mixture, human toxicity relates to the specific compounds present in the oil and their properties. While the total petroleum hydrocarbons (TPH) can be analytically measured as a group, this provides very little information for human toxicology assessments because of the wide range of toxicity within the array of hydrocarbons. Many hydrocarbons have a low degree of human toxicity, while others exert adverse effects on people. The toxic constituents that come into contact with people must be identified to provide an estimate of health effects.[2]

The Deepwater Horizon well site is located 50 miles off the Louisiana coastline and one mile below the surface of the Gulf. Oil from the Deepwater Horizon is classified as Louisiana light sweet crude oil. Light crude contains a greater proportion of smaller molecular weight components that are gasses and volatile organic compounds (VOCs). Sweet crude oil indicates very low levels of sulfur containing compounds. The crude oil from the Deepwater Horizon is estimated to contain over 40% natural gas and volatile compounds.[7, 14]

The composition of crude oil begins to change as soon as it enters the environment. Crude oil 'weathers,' as components volatilize out or break down through photolysis or biodegradation.[14, 17] The hot temperature in the Gulf of Mexico and the distance of the well site from the coast are conducive to the weathering of the crude oil. The oil that eventually reaches the coastline has different physical, chemical and toxicological properties than the petroleum leaking from the wellhead.

As the oil rises through a mile of water to the surface, it becomes emulsified and loses gases and VOCs. The gasses and VOCs that reach the surface quickly volatilize in the hot summer temperatures.[5] The weathered oil has a greater proportion the heavier compounds with thicker consistency (FSU, NOAA, 2010). In the US EPA analysis, VOCs were not detected in samples of weathered oil, mousse or tarballs collected near the coast, confirming the volatilization of these compounds.[29]

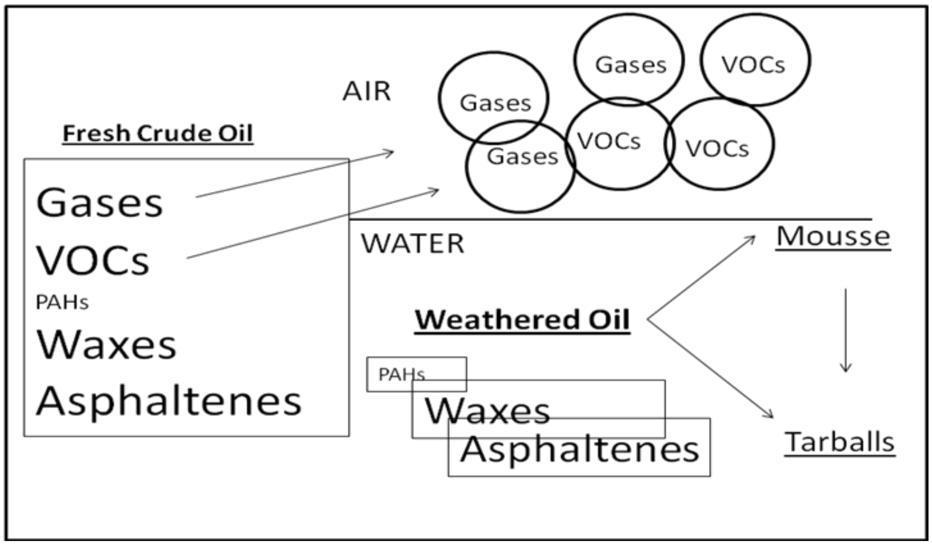

Figure 2.1 – Changing composition of weathered crude oil.

The environmental distribution and characteristics of crude oil influence the routes of human exposure. The lightest fraction is the natural gasses (C1 to C4) that disperse into the air immediately. The adverse effects are related to their flammability and explosive nature. The volatile organic compounds (VOCs) are in the liquids fraction from which gasoline, diesel, other fuels and solvents are obtained[22]; these compounds readily evaporate from the crude oil during spills. The alkanes and cycloalkanes (C_5-C_{12}) have a relatively low degree of human toxicity. VOCs also contains aromatic hydrocarbons, specifically benzene, toluene, ethylbenzene and xylene (BTEX) which have a higher toxicity to humans. The inhalation of a sufficient level of VOCs may cause acute neurodepressant effects (dizziness, headache, loss of coordination) and respiratory effects.[2] In addition, benzene is a carcinogen and a primary compound of concern for chronic exposures.[2, 17] Off-shore workers above and near the site are at risk of inhalation of VOCs, including the BTEX group.

The weathering process continues as the oil moves in the Gulf and further breakdown through photolysis, oxidation and biodegradation in the environment.[17, 33] The emulsified weathered oil has a thick "gooey" consistency described as mousse. While aliphatic hydrocarbons may taint the odor or taste of seafood, they have a low degree of toxicity and their noxious properties preclude consumption of significant amounts. Tar balls or tar patties form from the higher molecular weight waxes, paraffins and alphenes which are more solid in nature.[17] The heavier hydrocarbons have a lower toxicity and less potential for causing acute health effects than volatile components. In some sensitive individuals, dermal irritation may result from direct contact to the mousse or tarballs.

The polycyclic aromatic hydrocarbons (PAH) are may found with the heavier hydrocarbons that make up the mousse and tar balls. PAHs are a large chemical family of fused benzene rings, some of which have carcinogenic properties which make them compounds of concern. The amount and composition of PAHs in crude oil varies widely in different types of crude oil and contributes to the finger prints in oil.[3, 17] While all crude oil contains PAHs, light crude oil has been shown to contain fewer PAHs than heavy crude oil (NOAA) and fewer of the carcinogenic PAHs are found in light crude.[17] PAHs also continue to breakdown during the weathering process.[9] In EPA's analyses of the weathered oil, mousse and tarballs sampled near the coastline, PAHs were detected in <1% of the samples with acenaphthene and phenanthrene the most commonly PAHs detected.[31]

The PAHs are widespread in the environment and originate from multiple sources. The complement of PAH found is determined by the original source or means of generation. Petroleum contains petrogenic PAHs which differ from pyrolytic PAHs that are formed during combustion of organic materials, by combustion engines and found in industrial and municipal wastes and runoff. PAHs formed during pyrolysis are more likely to have carcinogenic properties than those found in light crude oil.[17, 34]

PAHs are contaminant of concern because of the carcinogenic properties of some in this family. The PAHs do not manifest acute effects and do not affect the taste or odor if taken up by seafood. The uptake and elimination of PAHs into finfish and shell fish varies widely among species and ecological factors as feeding behaviors, habitat.[10, 19] PAHs are readily metabolized by the CYP-450 enzyme system present in organisms and, therefore, do not bioaccumulate.[3, 19, 33, 34] The mechanism for the carcinogenic activity for PAHs depends on this metabolic activity.

Following an oil spill, PAHs may build up in marine organisms on a short term basis when the amount of oil in the water is high. Accumulation will occur when the rate of uptake exceeds the rate of metabolism and excretion.[33, 34] Once the oil dissipates, PAHs will be eliminated from the seafood species. Various species metabolize PAHs at different rates; finfish readily metabolize and eliminate PAHs, crustaceans metabolize PAH more slowly and mollusks had slower metabolic activity.[34] The half-life of PAHs in fish is in the order of days[33] and in oysters is days to weeks.[19] During oil spills, mollusks have the potential to build up PAHs in the short term when crude oil is present.[8, 34] For this reason, the monitoring of PAHs in seafood is needed to protect public health.

<u>Dispersants:</u>

Dispersants are important tools in managing oil spills, however, the use of dispersants became a highly controversial issue during the Deepwater Horizon spill.[34] Dispersants decrease the amount of surface oil and facilitate the breakdown of oil in the environment. Dispersants are composed of two types of compounds: surfactants and solvents. Surfactant molecules form an interface between the oil in water that reduces the surface tension; this breaks oil into small oil droplets that descend into the water column.[18, 34] The small droplets have a greater surface area which facilitates the biodegradation of oil by micro-organisms. When used properly, dispersants decreases the impact on coastal areas by decreasing the amount of oil on the surface of the water and accelerating the degradation of oil in the environment.[18, 34]

Corexit 9500 and Corexit 9527(briefly) were the dispersants used during the Deepwater Horizon Oil Spill. Several factors contributed to the controversy and underlying distrust of dispersants. First, the magnitude of the oil spill evoked serious concern and fear of the impact of the oil on the estuaries and Gulf Coast. Adding more chemicals to this already serious situation was met with skepticism. Second, when agencies and the press requested the composition of the Corexit, the manufacturer would not provide the chemical make-up, citing the propriety nature of its formulation. This immediately spurred immense distrust and, with the lack of information, the news media and others assumed it contained very toxic components. Next, the aquatic toxicology of dispersants, including Corexit, was misinterpreted; rumors purporting high human toxicity of dispersants alone and mixed with oil were rampantly propagated by the news media and others.

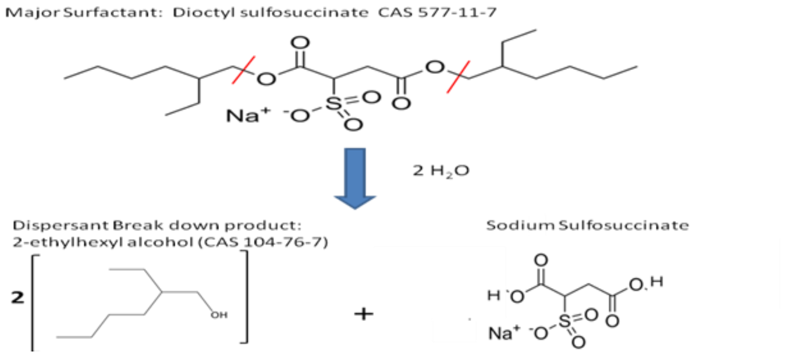

Figure 2.2 - Breakdown of surfactant in Corexit 9500.

The Deepwater Horizon spill is the first time dispersants were applied underwater in deep sea at cold temperatures and high pressures. While the surface use of dispersants is fairly well characterized, no data were available on deep sea behavior of the dispersant or combination of dispersant and oil. Further, the impact of the dispersant/oil mixture on marine life in deep waters was unknown and contributed to the concern. Responders at the surface documented the decrease in surface oil when the dispersants were administered at the well head, however, many feared giant deep water oil/dispersant plumes.

The public and news media questioned information provided by academic and government scientists on the relative toxicity of dispersants. The US EPA conducted two series of aquatic toxicity tests on eight dispersants, including Corexit, during the summer of 2010 using the Gulf mysid, *Americamysis bahia*, and the inland silverside, *Menidia beryllina*. They issued two reports on the toxicity of the dispersants on aquatic organisms and the combination of dispersants and crude oil.[25, 26] Toxicity testing is based on the LD$_{50}$, and EPA found that 7 of 8 dispersants tested had LD50 ranging from 20 to 130 ppm and classified as slightly toxic to practically nontoxic to the species tested. One dispersant (not Corexit) was classified as moderately toxic to *Menidia*. Corexit 9500 was classified as slightly toxic for mysids and practically non-toxic to *Menidia*.[25, 26] These results were consistent with previous aquatic toxicity tests. In spite of these results, the general public and news media remain extremely concerned about the toxic effects of dispersants.

The major components in Corexit 9500 include petroleum aliphatics, propylene glycol,, and dioctyl sulfosuccinate (DOSS). Corexit 9527 also contains 2-butoxyethanol which was a concern and a factor that limited use (EPA website). DOSS is also approved by FDA for use in various household products and over-the-counter medication at low levels. The constituents in the dispersants break down relatively quickly in the environment and do not bioaccumulate in organisms.[13, 25, 34] Research conducted at FDA's Dauphin Island, Alabama laboratory and at NOAA's Galveston, Texas laboratory show that dispersants do not buildup in fish, crustaceans and shellfish. Nonetheless, the general public feared that dispersants would contaminant seafood.

3. Looking Forward

Assessing Human Health Effects: Exposure Scenarios

Assessments identified two major pathways for human exposure to compounds of concern in crude oil. The first scenario is the acute inhalation of VOCs by offshore workers where VOCs, including BTEX, could inhaled by workers. Irritant effects on the eye, nose and throat, difficulties breathing or neurological effects as dizziness, disorientation, or headache might be observed. Worker exposure risks to VOCs are covered in another paper.

The second exposure scenario involves the consumption of seafood contaminated by oil. Seafood may be contaminated in two ways: 1) External oil coating fish or shell fish, and 2) PAHs, taken up into edible tissue of seafood consumed by people. External coating of oil will render seafood "tainted" with a petroleum odor and taste. Oil is noxious and readily detected in seafood by smell and taste even at concentrations far below levels that cause acute toxic effects.[16, 20] Of greater concern is the uptake of PAHs into seafood, especially mollusks, because of the carcinogenic potential of some PAHs. PAHs cannot be smelled or tasted in seafood and long term consumption pose a possible route of exposure to the general public.[3, 34]

In addition to the components in the oil, the dispersants posed another concern for many people. Nearly 2 million gallons Corexit 9500 was used to disperse the oil, most through deep sea administration. While dispersants have a low order of toxicity in humans, readily breakdown in the environment and have a low potential to bioaccumulate in seafood, there is substantial public concern about dispersants contaminating seafood.[28]

Assessing PAH Contamination in Seafood

The Gulf of Mexico produces over 40% of the seafood consumed in the United States each year.[11] Consumption of contaminated seafood is a pathway of human exposure. When oil entered a fishing area in the Gulf of Mexico or the inland waters, the FDA and State agencies closed the area to commercial and recreational fishing, shrimping, crabbing and the harvesting of oysters to protect public health.[16]

Federal and state agencies regulate the commercial and recreational harvesting of seafood within their waters. The National Oceanic and Atmospheric Administration (NOAA) has the legislative authority to close and open federal waters while the states have authority to close and open waters to fishing under their jurisdiction. The US Food and Drug Administration (FDA), is responsible for regulating seafood and insuring its safety for human consumption. FDA oversees a mandatory program to insure the safety of seafood under the Federal Food, Drug, and Cosmetic Act, the Public Health Service Act, and related regulations.[32] While legislative authority allows for quickly closing Gulf waters, the reopening of closed areas to commercial and recreational fishing is more difficult. The federal and state agencies developed a protocol with criteria and testing methods for determining when waters may be reopened to fishing and harvesting of seafood for human consumption.[31, 32]

The criterion for closing areas is based on the presence of visual oil on the surface of the water, the projected trajectory for oil movement, and a precautionary buffer zone around the oiled areas. The buffer zone accounts for uncertainty on the movement of the oil. The closing of fishing areas assumed a worse-case scenario to protect the public and insure seafood safety. Figure 3.1 shows areas closed within Louisiana waters.

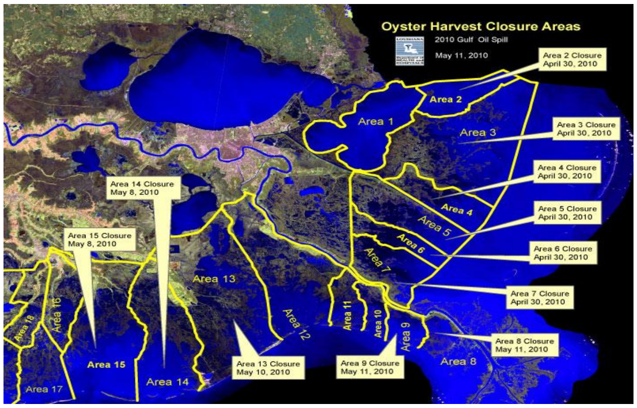

Figure 3.1 – Louisiana fishing areas closed from the Deepwater Horizon oil spill.

Criteria for Re-opening Areas Closed to Fishing

The FDA, NOAA, the Environmental Protection Agency (EPA), and the Gulf States (Louisiana, Mississippi, Alabama and Florida) developed a coordinated approach for reopening of closed fishing areas.[6, 31] The seafood monitoring plan provides the protocol and data to re-open recreational and commercial fishing. The overall plan utilizes a three tiered screening approach: 1) No visible oil observed in the designated areas; 2) Organoleptic testing of the seafood; and 3) Chemical testing of the seafood. Sampling for organoleptic or chemical analysis occurs only in areas with no visible oil and under consideration for reopening.[31]

Sensory testing and chemical analyses are conducted on samples of each species, i.e., for fin fish, shrimp, crabs, or mollusks (oysters/mussels). Both types of test must show the samples of a given species are free of oil contaminants. The protocol provides for the reopening of areas based on specific fish species; for example, an area may be opened to finfish but not the harvesting of oysters.

Observations for Visible Oil

The first criterion for consideration of reopening is that no visible oil is observed. Oil was tracked throughout the spill through visual observations, aerial surveillance, water quality testing, and satellite imagery. When an area is free of visible oil, seafood samples are collected for sensory testing and chemical analysis for PAHs. Samples are not collected in any area with visible oil.

Sample Collection

Wild fish and shellfish representative of commercial and recreational species are collected using a pre-determined sampling scheme that obtains samples from multiple locations within a designated fishing area. Each of the four Gulf States has seafood monitoring programs that routinely collect samples for testing. Sampling sites were determined randomly within designated area and noted by GIS coordinates for field collection. Baseline samples were collected prior to oil reaching the area and in areas not impacted by the oil spill. The sampling locations are representative of fish and shellfish of coastal fishing areas. In addition, seafood processing facilities are monitored to test commercial seafood. Samples are also collected at boat launches used by recreational fishers. Priority species and the number of individual organisms for each of the four main categories sample were determined as described below.[6, 31] Edible portions of the seafood species are analyzed to reflect the consumption of seafood.

Finfish: Edible portions (muscle) of 3-12 individual fish (within 15% length) are composited into each sample. Whole fish may be tested individually to represent potential exposures of those who eat whole fish or to represent potential contamination of other food sources through processing. Finfish species sampled include: Black drum; Cobia; Croaker; Dolphin ; Greater amberjack; Grouper (species not mixed); Gulf menhaden; King mackerel; Red drum; Red snapper; Sheepshead; Southern flounder; Spotted seatrout; Striped mullet; Tuna (species not mixed); Other species as warranted or requested by state agencies.

S*hrimp:* Shrimp samples consist of a composite of 100 individual shrimp (within 15% length) collected at the same sampling station to obtain a sample weight of 3 pounds. Prior to chemical analysis, the head, shell, appendages and vein are removed to obtain the edible portion of the shrimp.

Blue crabs: Crab samples consist of a composite of 6-12 crabs as available to make two pounds. Meat tissue and the hepatopancreas (crab fat) are analyzed separately.

Oysters: Oyster samples consist of a composite of 20 individual oysters (30 oysters if "seed-size") from a sampling station. Whole oysters with the shell intact are cleaned externally.

Sensory Testing

Louisiana and other states trained agency personnel to conduct first level of sensory testing in the field or at the dock. State conducted field sensory screening for odor. If samples had oil-related odors, the area could not be re-opened. Samples that passed the field sensory test were sent to the FDA expert panel.

Organoleptic testing is conducted by a panel of at least 10 expert sensory assessors who evaluate raw and cooked portions of each sample by odor and taste. Each sample must be considered acceptable and not "tainted" by a minimum of 70% of the expert sensory panel. If a single sample fails to meet this criterion, the entire area remains closed.[31] The states trained health or environmental personnel to conduct sensory levels, but few are of the expert stage at this point. FDA has well-trained sensory assessors who have extensive experience and designated as expert sensory assessors.

Chemical Analyses

Chemical analyses were conducted to monitor for contaminants that might be taken up into tissues. Contaminants of concern in crude oil include aliphatic hydrocarbons and PAHs and their associated methylated or alkylated homologues. FDA approved laboratory methods were used to insure consistency among laboratories and sufficiently sensitive lower limits of detection.[30, 32] Analytical methods were modified to attain detection levels five times below the low risk based levels and to detect the alklyated PAH homologs. The methods selected include: NOAA PAH Method or equivalent; VOC SW846 Method 8260; PAH SW846 Method 8270 or Method 8310 or equivalent; VOC SW846 Method 601; petroleum aliphatics and butanedioic acid, 2-sulfo-,1,4-bis(2-ethylhexyl)ester, sodium salt; 2-butoxyethanol SW846 Method 8015B. Quality control procedures were incorporated into the analyses. FDA and state labs analyzed split samples results compared for quality control and to assure consistency among the laboratories.[12, 15]

Chemical testing of seafood required the enhancement of the infrastructure in state public health labs and FDA labs which upgraded laboratory analytical equipment and implemented FDA approved methodologies for PAHs to their procedures. States also contracted with approved labs to supplement laboratory capacity. Even with these actions, laboratory capacity remains a rate limiting step and constricts the number of test that can be conducted each week. The FDA established labs around the country to help handle the seafood chemical analyses.

Determination of Comparison Values for Chemical Analysis

The Gulf States Advisory Group composed of representatives of each Gulf state, EPA, FDA. CDC/ASTDR and NOAA developed criteria for evaluating the results of the seafood testing.[6] Risk-based criteria based on FDA and EPA risk assessments methods were developed to determine the safety of commercial and recreational fish and shellfish. The PAH levels of concern were developed to reflect the conditions associated with the Deepwater Horizon spill. To determine the cancer risks, the carcinogenic activity of individual PAH compounds were estimated as a toxicity equivalency factor (TEF) relative to benzo(a)pyrene. TEFs for chrysene, benzo[k]fluoranthene, benz[a]anthracene, indeno[1,2,3-cd]pyrene, benzo[b]fluoranthene, and dibenz[a,h]anthracene were determined. For the risk assessment, substituted alkylated homologs are summed with the parent compound and used as a single value by the appropriate TEF.[6]

Table 3.1 – Analytes and risk-based levels of concern.[31]

Target Analyte/COC	Surface Water Screening Levels (ug/L)	Levels of Concern[3,4] (ug/mg)		
		Shrimp and Crab	Oysters	Finfish
Naphthalene	NA [5]	123	133	32.7
Fluorene	220	246	267	65.3
Anthracene/Phenanthrene	1660	1846	2000	490
Pyrene	166	185	200	49
Fluoranthene	26	246	267	65.3
Chrysene	0.00076	132	143	35
Benzo[k]fluoranthene	0.00076	13.2	14.3	3.5
Benzo[b]fluoranthene	0.00076	1.32	1.43	0.35
Benzo[a]anthracene	0.00076	1.32	1.43	0.35
Indeno[1,2,3-cd]pyrene	0.00076	1.32	1.43	0.35
Dibenzo[ah]anthracene	0.00076	0.132	0.143	0.035
Benzo[a]pyrene	0.00076	0.132	0.143	0.035
Benzene	0.44	17.5	18.9	4.6
Ethylbenzene	106	615	667	163
Toluene	260	492	533	130
Xylene	NA	1230	1333	327
Petroleum Aliphatics C_{10}-C_{36}	NA	615	667	163
2-Butoxyethanol*	NA	615	667	163
Butanedioic acid, 2-sulfo-,1,4-bis(2-ethylhexyl)ester, sodium salt (CAS 577-11-7)*	NA	TBD	TBD	TBD

* Dispersant components

Petroleum aliphatic toxicity values were obtained from *Development of Fraction Specific Reference Doses and Reference Concentrations for Total Petroleum Hydrocarbons*, Total Petroleum Hydrocarbon Criteria Working Group Series, 1997. Water screening levels are one-fifth of the National Recommended Water Quality Criteria for Priority Pollutants, EPA 2009.

Dispersant testing

Dispersants were monitored by testing for: Dioctyl sodium sulfosuccinate, (DOSS) (CAS 577-11-7), its metabolite, 2-ethylhexyl alcohol (CAS 104-76-7), and 2-Butoxyethanol a component in Corexit 9527.[30] One of the issues in testing for components in Corexit 9500 and 9527 is that DOSS and other components in dispersants are used in household products and over-the-counter medication and are occasionally detected in waters that receive municipal discharges.

Results of Seafood Testing

Results of testing

The FDA and state agencies conducted joint testing (split samples) as well as independent testing of finfish, shrimp, crabs and oysters within their waters. FDA reports testing 1,735 samples collected from June through the end of September (FDA news resease). These samples were collected from a wide area of the Gulf of Mexico and included samples in state and federal waters, and from fishermen who brought fish to the docks at the request of federal seafood analysts. Fish samples came from a range of species, including grouper, tuna, wahoo, swordfish, gray snapper, butterfish, red drum, croaker, and shrimp, crabs and oysters. It should be noted that samples sent for sensory analyses and chemical testing were collected from areas that were oil-free; the monitoring program is designed as a process for reopening waters rather than tracking contamination in seafood.[30]

Sensory Testing

Samples passing the field organoleptic test conducted by the states and FDA were sent to the FDA expert panel trained in an advanced sensory analysis methods. The FDA experts conducted 1,735 tests on fish and shell fish collected during June to the end of September.[30]

FDA Chemical analyses

FDA reports conducting 1,735 tissue samples, more than half of the samples were collected to reopen federal waters in Gulf of Mexico and the remainder as split samples with the Gulf states. The chemical analysis did not detect elevated levels of any PAH in the samples. Trace levels of PAHs far below the risk levels were occasionally detected in some tissues. The vast majority of samples had PAHs below the limits of detection of the sensitive analytical methods. Tests for dispersants showed trace amounts of DOSS in 13 of the 1735 samples; these detects were well below the safety threshold of 100 parts per million for finfish and 500 parts per million for shrimp, crabs and oysters.[30]

Chemical Testing in Louisiana

Louisiana oversees the safety of seafood within state waters and conducted extensive chemical testing including baseline samples and those collected for reopening state waters to seafood harvesting.[10] To supplement the samples split with FDA, Louisiana collected additional fish, shrimp, crab and oyster samples to provide wider coverage for state decision making. Louisiana collected baseline samples prior to the oil reaching the coastline and from areas that never received oil. Personnel from the Louisiana Department of Health and Hospital and Louisiana Department of Wildlife and Fisheries collected samples in closed areas as the oil dissipated and was no longer observed. Areas with obvious oil were not sampled as these did not meet the first criterion for reopening, that is, for the whole area to be oil free. From April 22 to October 22, 2010, Louisiana analyzed 705 samples.[10] Each sample was a composite representing a number of individual organisms. The total number of organisms tested was in the tens of thousands.[10]

Trace levels of one or more PAHs were detected at levels below concern in approximately one third of the samples. In samples with PAHs, the results typically showed only one or two PAHs and not the wide array. The methylated and alkylated PAH homologs were added to the total for the parent compound. PAH detected include: Anthracene, benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Chrysene, Fluorene, Fluoranthene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, and Pyrene.[10]

Table 3.2 – Results of PAH analyses in seafood tested in Louisiana.[10]

	Total #	# No PAH Detected	# with trace PAH Detected	# above level of concern	Range (mg/kg)
Oysters	319	166	153	0	ND-0.042
Shrimp	141	107	34	0	ND-0.062
Crab	70	55	15	0	ND-0.014
Finfish	175	144	31	0	ND-0.014
All Seafood	705	472	233	0	ND-0.062

4. Discussion

The chemical testing has not detected PAHs in any sample above the level of concern; PAHs were not detected in the majority of the samples. Overwhelmingly, the seafood monitoring data demonstrates that Gulf Coast seafood harvested in the reopened areas is free of contamination by the crude oil.

In spite of the seafood monitoring results, producers along the Gulf Coast report a limited market for seafood after the oil spill, and the general public remain apprehensive about the safety of consuming Gulf seafood. The seafood monitoring program is designed to test areas free of oil and under consideration for reopening. The tiered approach to sampling screens out areas with observable oil and uses the chemical analysis to confirm the seafood is free of contamination. After months of news media reports of highly toxic oil and dispersants, and general distrust of government and science, most people expect that the seafood should be contaminated and are skeptical of the results. This belief is further supported by conflicting reports from various academic groups, scientists and from legal advocates who have different sampling approaches where they collect samples from highly oiled locations to find and/or characterize the contamination. Seafood marketers face a major challenge in explaining the sampling approach and to convey the fact that seafood harvested from the tested areas is free of contamination.

Other evidence is consistent with the results of the seafood monitoring program. Review of the EPA analysis of water and sediment samples collected near the seafood sampling sites rarely detect trace levels of PAHs. EPA testing of the mousse and tarballs that reach the coastline are found to contain relatively few PAHs. These environmental analyses are consistent with the lack of contamination in the seafood samples.

Finfish and crustaceans are mobile and, given the behavior of fish to leave contaminated areas, and their ability to metabolize PAHs, it is reasonable that PAHs will not be frequently found in edible tissues. Oysters and mussels may act as sentimental species as they are filter feeders that may take up and concentrate any contaminant in the surrounding waters. Oysters are more likely to have elevated levels of PAHs than the other types of commonly consumed seafood species. The testing of oyster beds in oil free areas do not detected elevated PAHs in and many oyster areas have been reopened.

Seafood along the Gulf Coast is undergoing more extensive testing and scrutiny than most other seafood products from around the world. Seafood from other areas of the country and foreign seafood is not tested for PAHs and other hydrocarbons. The seafood monitoring will continue for an extended period of time and will ensure that Gulf seafood that reaches the market is not contaminated from the oil spill.

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