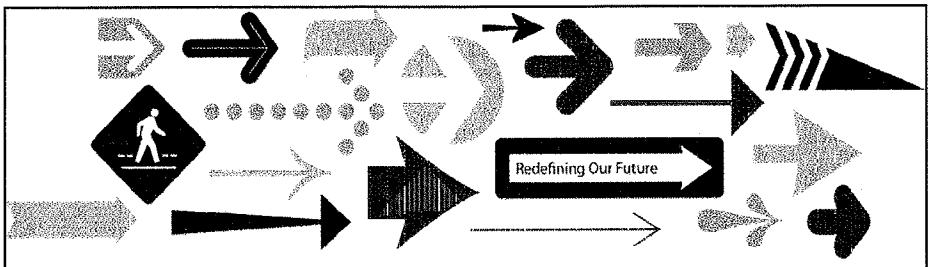

BP's response to the Gulf Oil Spill

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2012 AIHCE, Indianapolis, IN
June 21, 2012

AIHce 2012 INDIANAPOLIS

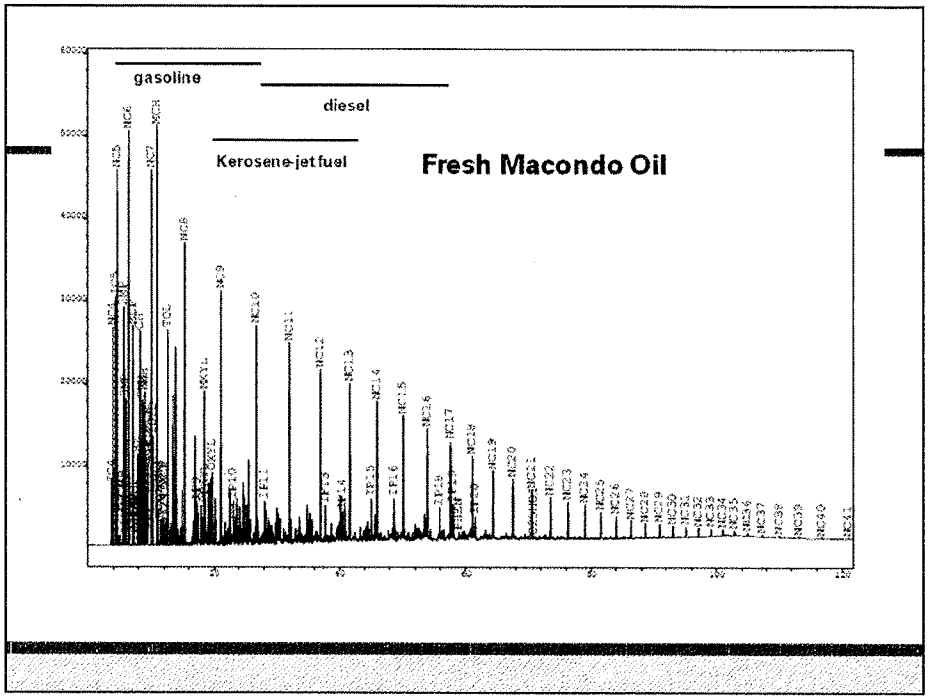
Good afternoon everyone, and welcome.

The focus of my presentation is a fact-based, transparent account of the industrial hygiene issues BP faced in the aftermath of the Deepwater Horizon accident and our response to them.

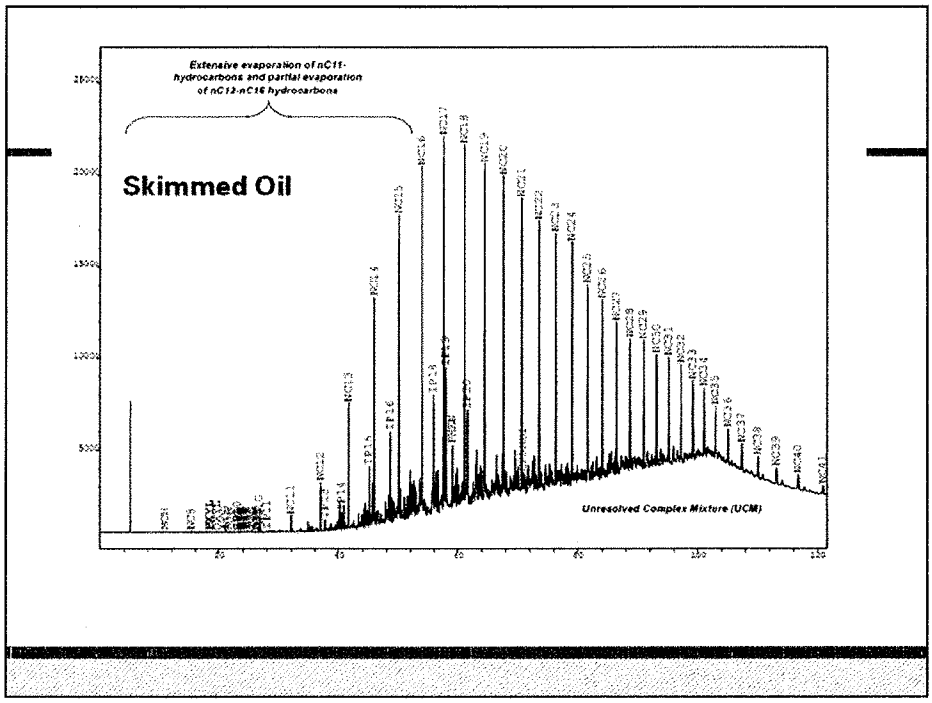
I want to share with you some of the valuable insights we learned through addressing an accident of this magnitude, and the implications they have for how we will be addressing potential industrial hygiene risks in the future.

4,300 miles of shoreline were surveyed, approximately 6,500 vessels responded (23 times the active US Navy) and approximately 48,000 workers worked 66.5 million manhours.

The industrial hygiene offshore response included mustering industrial hygiene technicians and Certified Industrial Hygienists with sampling equipment onboard the offshore vessels. The sampling equipment included passive monitoring badges for personal sampling and portable screening instruments for area samples. The first offshore personal industrial hygiene samples were taken on April 27, 2010.



•Here is a chromatogram of MC 252 oil from a sample taken before the incident.
•Note how the chromatogram is defined by the normal alkanes (the lines labeled "NC" with a number). The normal alkanes are the "book marks" for the chromatogram, defining the most abundant compounds and "fractions".
•The gasoline fraction is defined between the NC5 and NC10 peaks.
•The diesel fraction is defined approximately between the NC10 and NC20 peaks.
•Note how most of this fresh oil consists of the gasoline and diesel fractions.
•Look at how the chromatogram forms a kind of "ski slope" from left to right. This indicates that most of this oil is in the lighter range, as a result of which it evaporates readily.

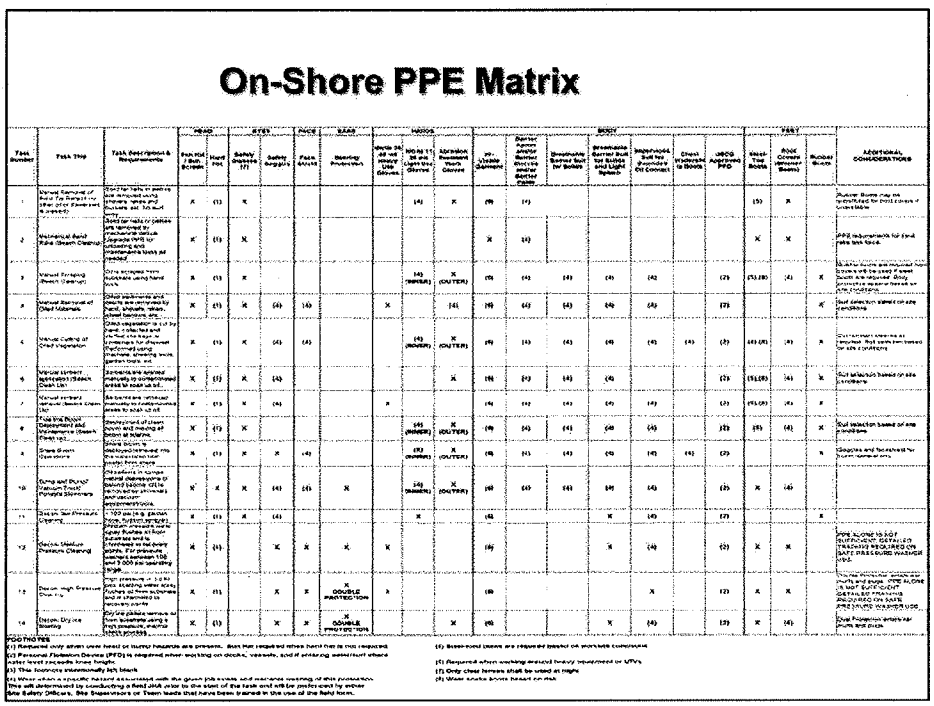


•This chromatogram is from skimmed oil off of the sea surface not far from the subsea well location. Note how much of the light fractions (gasoline range and some diesel range) have evaporated. The strong peaks of the remaining normal alkanes tend to indicate that although some biodegradation has occurred it is not yet the dominant process.
•Note how the Unresolved Complex Mixture "hump" is developing as the oil weathers. This hump becomes more prominent as other compounds weather out of the oil.
•As the crude weathers generally, other compounds such as PAHs (polynuclear aromatic hydrocarbons) also weather out of the oil.

IH Response

- Offshore sampling
  - Industrial hygiene technicians used portable, direct reading screening instruments, and passive monitors for full shift sampling of workers
  - Summa canister samples
  - Offshore monitoring plan with action levels
- Nearshore sampling
- Beach sampling
- Coordination with OSHA, NIOSH, and USCG

The initial IH response was established approximately 50 miles offshore on the drilling and response support vessels. The industrial hygiene technicians were transported to location via helicopters and were supplied with portable, direct reading screening instruments, and passive monitors for full shift sampling of response workers. The passive monitors were shipped back to shore via helicopter, where they were



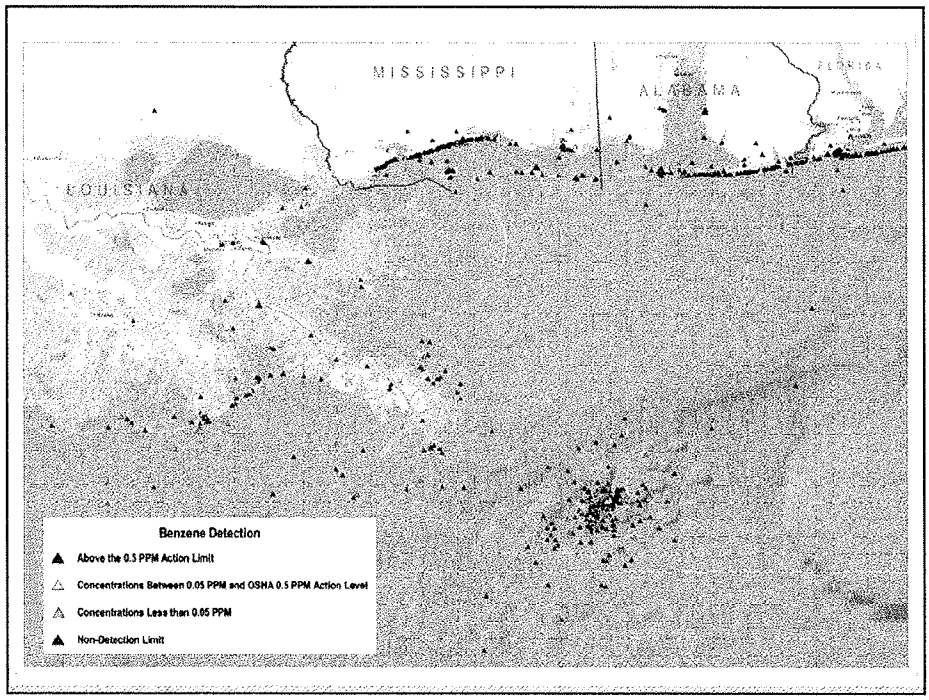
On-Shore PPE Matrix

Task Number	Task Title	Task Description & Requirements	HEAD		EYES		FACE	HAND	HANDS			BODY						FEET			ADDITIONAL CONSIDERATIONS
			Hard Hat (Bump Bonnet)	Hard Hat	Safety Glasses (1)	Safety Goggles	Face Shield	Standard Protection	Nitrile (NO all not always Use Gloves)	NO to 11 (8 mil Light Use) Gloves	Abrasion Resistant Work Gloves	FR Uniform Garment	Barrier Gowns (and/or Barrier Aprons for Chemical Barrier Protection)	Breathable Barrier Suit for Boiler	Breathable Barrier Suit for Boiler and Light Splash	Responder Suit for Extended or Oil Contact	Chest Waders (in Boots)	USCG Approved PFD	Steel-Toe Boots	Rock Climber (Wrestler Boots)	Rubber Boots	
1	Manual Removal of Mud Pit, Pumps or other Shut Equipment Assembly	Shut the hatch or sealing and remove using Hydraulic valve and Hydraulic unit. Tool and Hydraulic unit.	X	(1)	X					(4)	X	(9)	(4)						(5)	X		Rubber Boots may be substituted for Hard Covers if Underfoot
2	Mechanical Bolt Rake (Beam Cleaning)	Bolts or nuts or cables are removed by mechanical bolt rake. Examine nuts for unbolting and unscrewing and unscrewing tools as needed.	X	(1)	X							X	(4)						X	X		PPE requirements for Hard Hats and Hard.
3	Manual Pumping (Bench Cleaning)	Drive accepted from substrate using hand tools.	X	(1)	X					(4) (NITRILE)	X (OUTER)	(9)	(4)	(4)	(4)	(4)		(2)	(5),(6)	(4)	X	Gloves must be worn when hand tools will be used if sweet Teeth are required. Body protective equipment as per Chemical.
4	Manual Removal of Dried Materials	Dried materials and any debris are removed by hand, shovels, rakes, dried benches, etc.	X	(1)	X	(4)	(4)		X		(4)	(9)	(4)	(4)	(4)	(4)		(2)			X	Dust collection system on site if practical
5	Manual Cutting of Dried Materials	Dried materials or cut by hand, collected and shifted into bags or containers for disposal. Performed using machines, shoveling tools, garden tools, etc.	X	(1)	X	(4)	(4)			(4) (INNER)	X (OUTER)	(9)	(4)	(4)	(4)	(4)	(4)	(2)	(4),(5)	(4)	X	Dust emission controls as required. Not work permitted for site conditions
6	Manual Ambient Application (Sweep, Dash Up)	Substances are applied manually to contaminated areas to soak up oil.	X	(1)	X	(4)					X	(9)	(4)	(4)	(4)			(2)	(5),(6)	(4)	X	Dust emissions based on site conditions
7	Manual ambient removal (Sweep Dash Up)	As sand are removed manually to contaminated areas to soak up oil.	X	(1)	X	(4)			X			(4)	(4)	(4)	(4)	(4)		(2)	(4),(5)	(4)	X	
8	Tool the Road Department and Maintenance (Sweep Flush up)	Heavy road surfaces are swept and mopped at Boom at Nights.	X	(1)	X					(4) (INNER)	X (OUTER)	(9)	(4)	(4)	(4)	(4)		(2)	(5)	(4)	X	Dust reduction based on site conditions
9	Grass Boom Operations	Grass booms are removed into Hydraulic unit and transported from shore.	X	(1)	X	X	(4)			(5) (INNER)	X (OUTER)	(9)	(4)	(4)	(4)	(4)	(4)	(2)			X	Gloves are Hazmat for boom operations
10	Dump and Burn of Petroleum Trash/ Pumpkin Skimmers	All debris is burned beyond (debris-zone of Petroleum Trash (PTB) in accordance with Federal and Local environmental.	X	X	X	(4)	(4)	X		(4) (INNER)	X (OUTER)	(9)	(4)	(4)	(4)	(4)		(2)	X	(4)		
11	Steam Jet Pressure Cleaning	1,000 psi (e.g. ground, rock, hydrant, or water)	X	(1)	X	(4)				X		(4)				X	(4)		(7)		X	
12	Electric Medium Pressure Cleaning	Medium pressure (1,000 to 3,000 psi) cleaning of Boom Booms at Boom Intervals and to Environment so that every 200ft. For intervals between between 100 and 3,000 are operating 3,000	X	(1)		X	X	X	X			(4)				X	(4)		(2)	X	X	PPE NOTED IS NOT SUFFICIENT DETAILED TRAINING REQUIRED ON SAFE PRESSURE WASHER USE.
13	Boom High Pressure Cleaning	High pressure (> 3,000 psi) Boom cleaning where extra Pushes at Hose to Environment and is connected to Hydraulic power	X	(1)		X	X	X DOUBLE PROTECTION	X			(4)				X		(2)	X	X	This PPE NOTED IS NOT SUFFICIENT DETAILED TRAINING REQUIRED ON SAFE PRESSURE WASHER USE.
14	Boom, Dry Ice Blasting	Dry ice pellets removed at from substrate using a high pressure, mechanical (non) process	X	(1)		X	X	X DOUBLE PROTECTION			X	(4)				X	(4)		(2)	X	(4)	Dust Protection entails ear muffs and plugs.

FOOTNOTES

(1) Required only when level of noise hazards are present. Box not required when hard hat is not required.
(2) Personal Flotation Device (PFD) is required when working on docks, vessels, and if entering waist/hurt where water level exceeds knee height.
(3) This footnote intentionally left blank.
(4) When when a specific hazard is associated with the given job a risk and mechanical marking of this protection. This will determined by conducting a field JHA prior to the start of the task and will be performed by either Site Safety Officers, Site Supervisors or Team leads that have been trained in the use of the field form.
(5) Based-hood gloves are required based on workable conditions
(6) Required when working around heavy equipment or UTVs
(7) Only chest waders shall be used at night.
(8) Water snake boots based on risk

In conjunction with OSHA, we developed PPE matrices for both onshore and offshore operations, by task. The table here shows tasks by row heading, and PPE choices by column headings. The matrices were continuously revised based on field conditions, operations, and incident investigations.



This next slide shows a map of the Gulf of Mexico and its shoreline from Louisiana to the Florida Panhandle. The colored dots on the map show where the more than 28,000 benzene samples summarized on the previous slide were taken by BP. The concentration of dots toward the bottom of the map represents samples that were taken at or near the well itself.

The blue triangles that you see across most of the map represent the location of worker benzene samples that were taken, but that are below the detection limit of the analytical instruments.

The green triangles represent the locations for worker samples where the benzene concentration is <0.05 ppm.

The yellow triangles are those benzene samples where concentrations are between 0.05 and the OSHA 0.5 ppm action level.

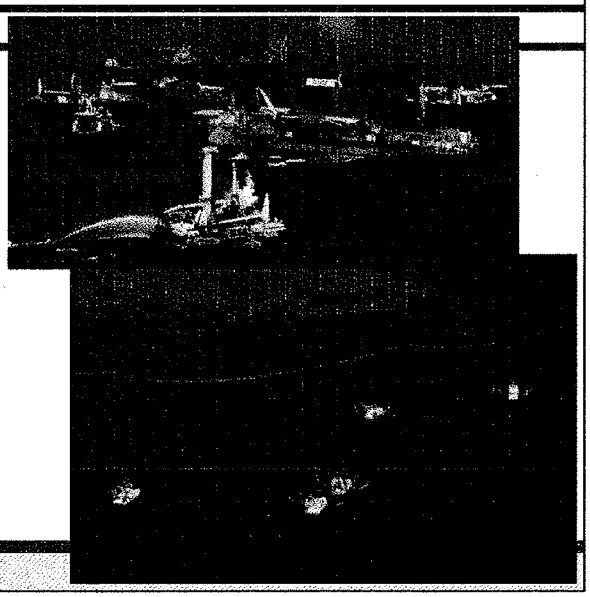
And the red triangles depict benzene samples above the 0.5 ppm action limit.

It is important to note that none of the benzene samples with results above the action limit (0.5 ppm) occurred offshore. Six BP samples out of more than 28,000 resulted in benzene concentrations above the action limit and these occurred in the Nearshore and Beach areas and were generally the result of refueling tasks.

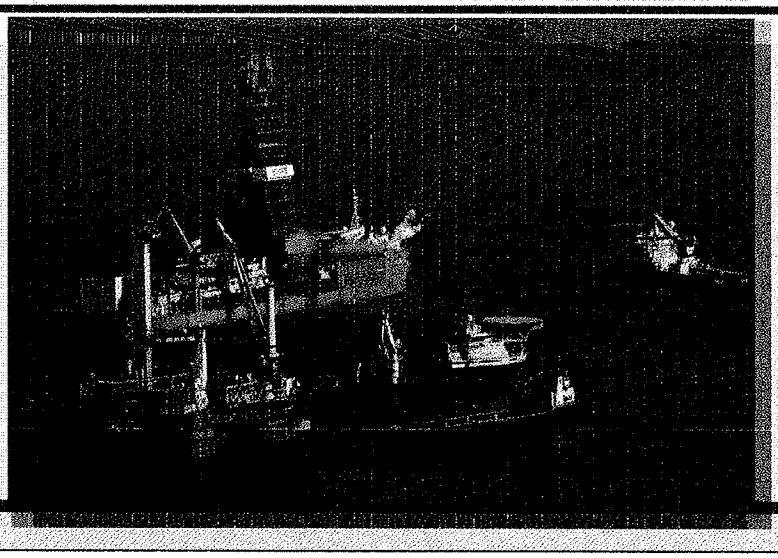
OSHA, NIOSH and the USCG did not have any benzene samples above the action limit.

Exposure Zones

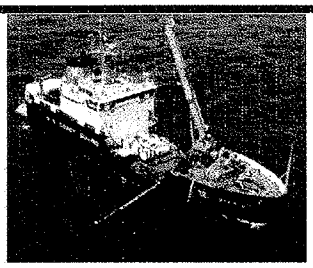
- Offshore
- Nearshore
- Beach

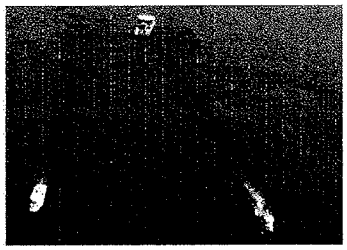


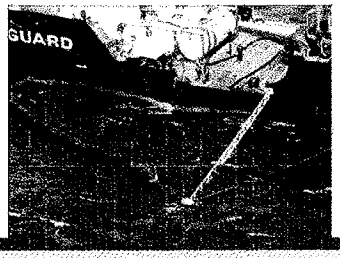
Offshore - MC252 Source Activities



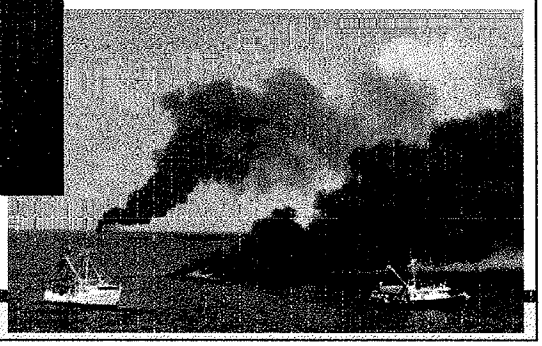
Offshore - Skimming



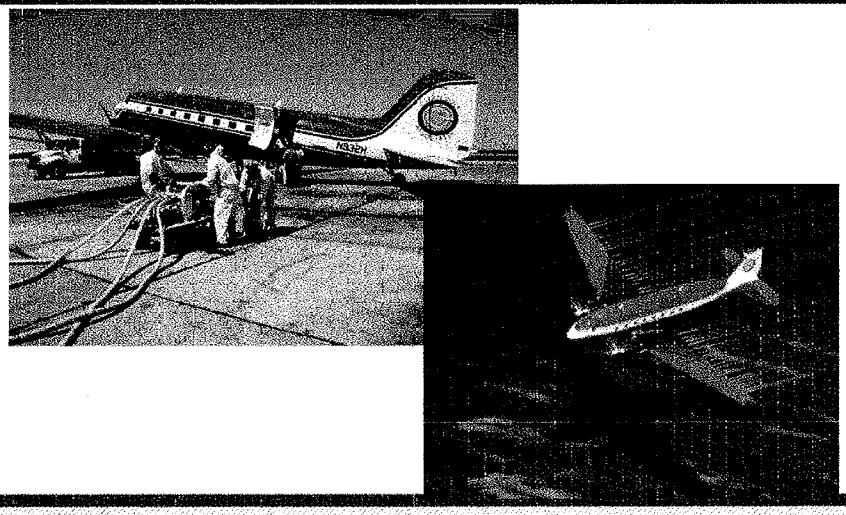




Offshore - Controlled Burning

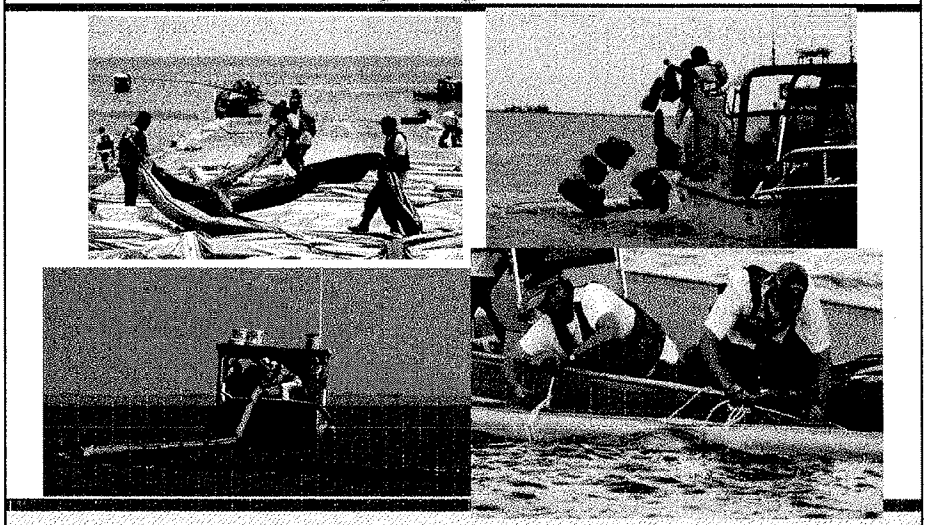


Offshore Aerial – Dispersant Application

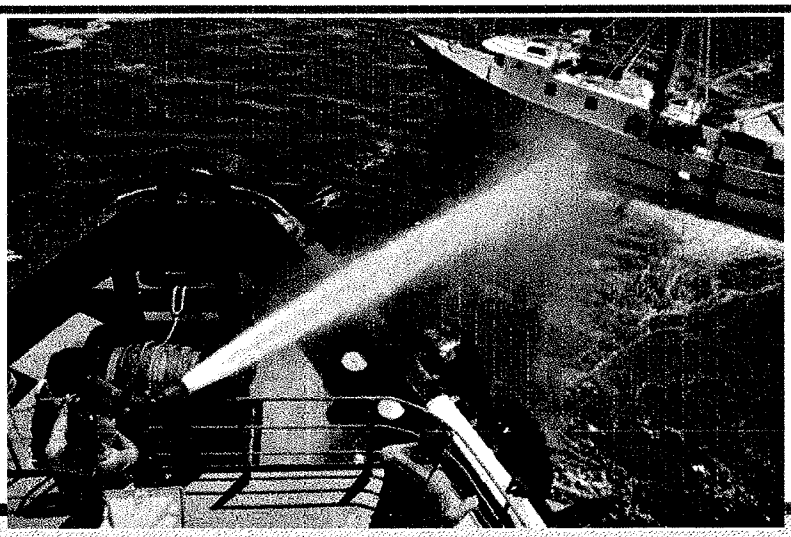


Workers loaded dispersant on the spray planes using a closed pumping system

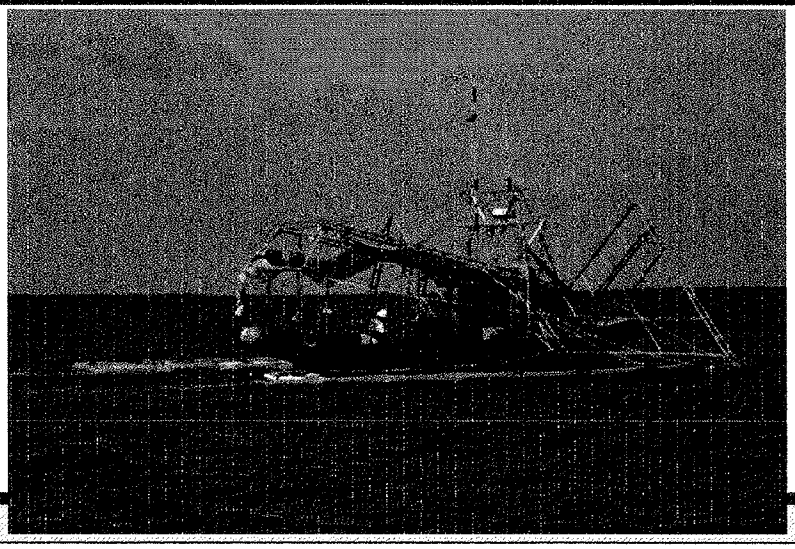
Nearshore – Boom Deployment



Nearshore – Vessel Decon

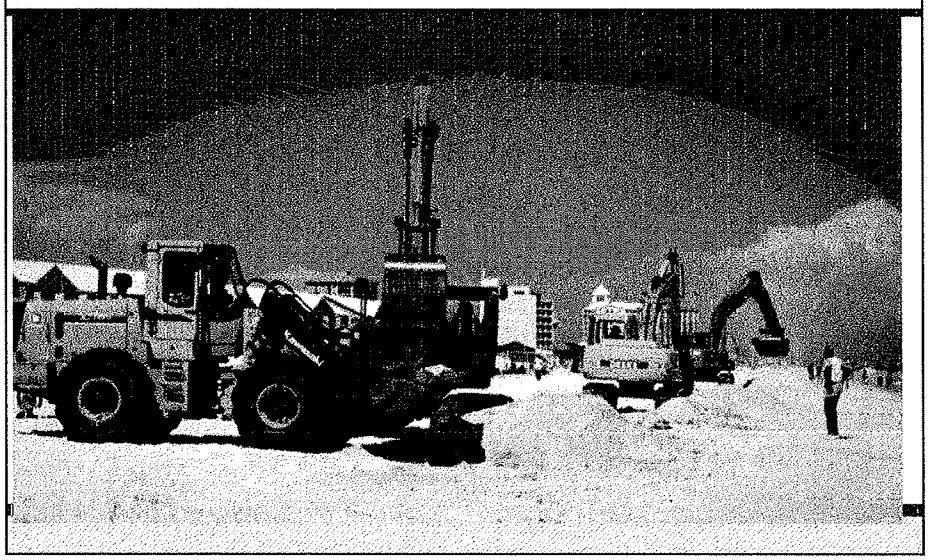


Nearshore – Scouting and Skimming

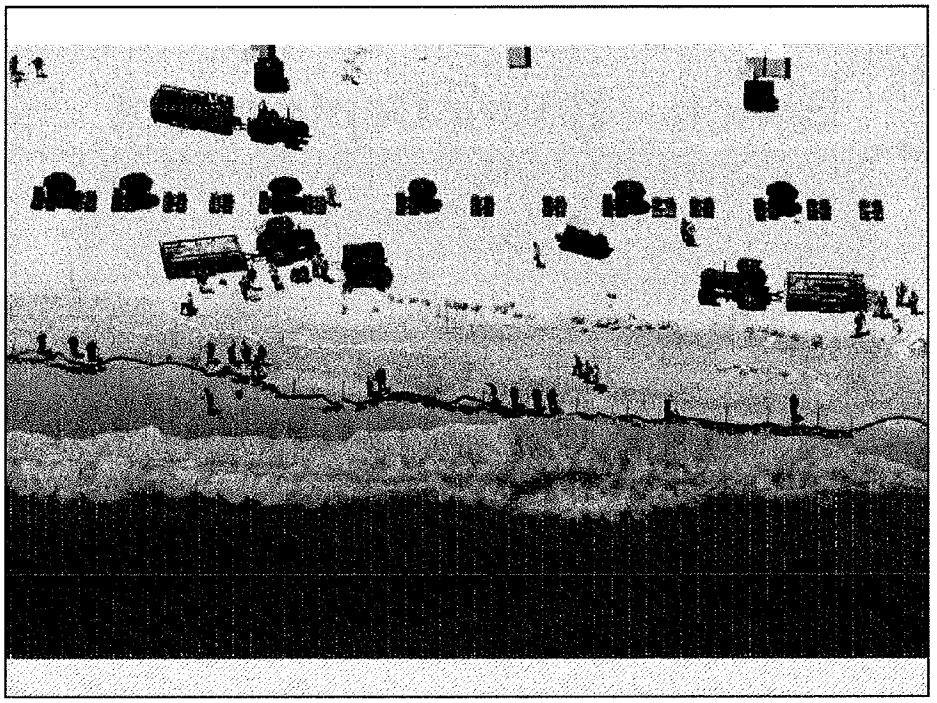


Beach - Cleanup

Beach - Cleanup

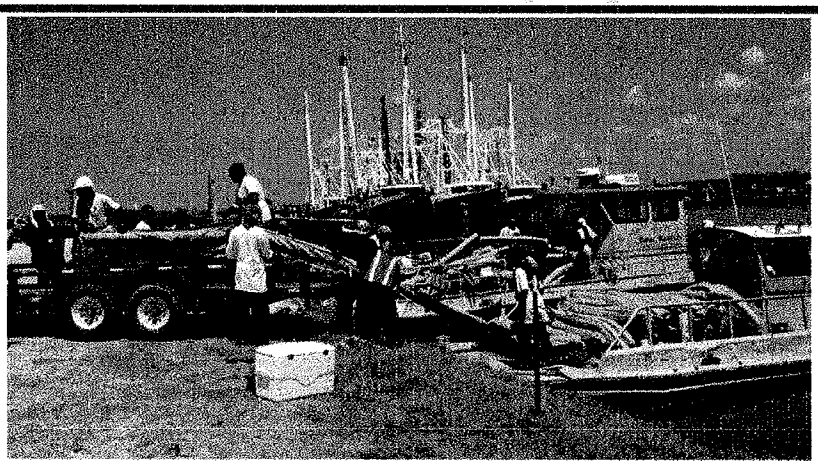


Beach cleanup included the use of heavy equipment with diesel engines.



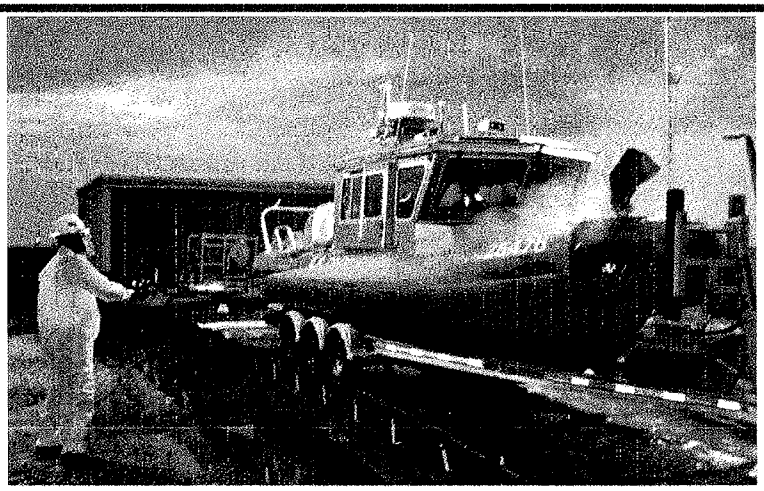
Aerial photograph showing beach cleanup workers with sorbent boom and vehicles carrying personnel and supplies. Heat stress was a real concern for outdoor workers due to the heat and humidity. A hydration station can be seen in the foreground to protect the workers from the effects of the heat.

Beach – Boom Deployment



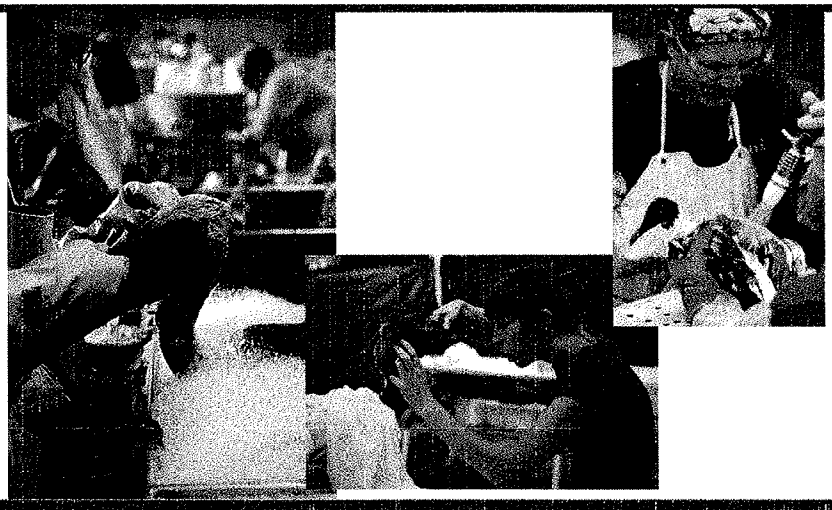
Beach – Boom Decon

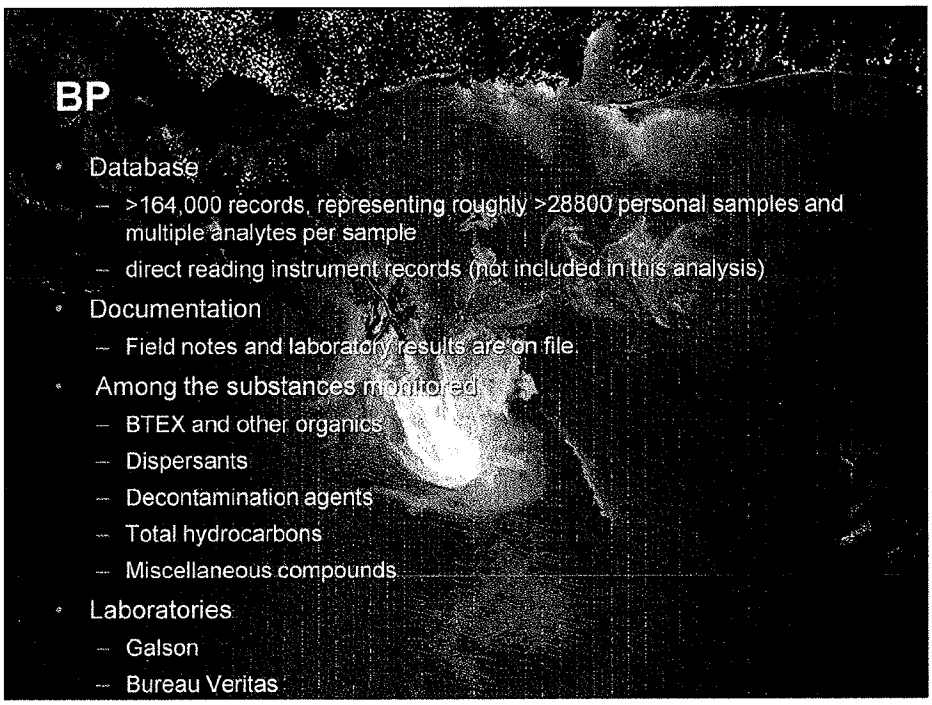
Beach – Vessel Decon



Beach – Personnel Decon

Beach – Animal Rescue





During the Deepwater Horizon Response an extraordinary number of occupational exposure measurements – over 28800 - were collected by BP.

The majority of the samples were analyzed for multiple analytes, which resulted in a database consisting of over 164,000 records.

Governmental agencies – OSHA, USCG, and NIOSH – also collected personal (and area) samples, but we will first focus on the BP samples.

The BP database was created by and is maintained by the CTEH (Center for Toxicology and Environmental Health).

By Substance (as analyzed to date)

Agent	Potential Source	Occupational Exposure Limits		Total	Number of Benzene Measurements per Category (expressed in % of the 0.5ppm Action Limit)				
		OEL	Source		ND	Cat. 1 <=10%	Cat. 2 >10-50%	Cat. 3 >50-100%	Cat. 4 >100%
benzene	Crude Oil and Fuels	0.5 ppm	ACGIH	28,788	28138	489	141	14	6
toluene		20 ppm	ACGIH	28788	27658	1103	25	1	1
ethylbenzene		20 ppm	ACGIH	28788	28279	503	5	1	
xylene		100 ppm	ACGIH	28790	27871	914	5		
cyclohexane		100 ppm	ACGIH	3721	3359	362			
heptane		85 ppm	NIOSH	3721	3209	512			
n-hexane		50 ppm	ACGIH	3721	3029	692			
petroleum distillates		350 mg/m3	NIOSH	38	14	16	8		
tetrahydrofuran		50 ppm	ACGIH	3725	3688	37			
total hydrocarbons		100 ppm	BP	28791	24109	4322	318	28	14
trimethylbenzenes		25 ppm	ACGIH	3721	3424	293	3		1
2-butoxyethanol	Dispersants	5 ppm	NIOSH	1028	821	204	3		
propylene glycol		10 mg/m3	AIHA	8	8				
acetone	Boom Repair	200 ppm	ACGIH	9	5	4			
methyl ethyl ketone		200 ppm	ACGIH	5		5			
limonene	Decontamination	30 ppm	AIHA	244	100	92	40	6	6
Total				163886	153712	9548	546	50	28

BP collected occupational measurements primarily for the volatile organics – benzene, toluene, ethyl benzene, xylenes, total hydrocarbons, and other petroleum related substances – as well as substances associated with the dispersants and decontamination-cleanup activities: 2-butoxyethanol, propylene glycol, and limonene. Several other substances were either detected or monitored and are listed in the database.

This table summarizes the BP data as analyzed to date, showing the number of measurements that fell within each of the AIHA exposure categories, relative to the indicated OEL, or the number of measurements that were non-detects.

The OELs shown are either those used by Incident Command as Action Levels or are conservative limits drawn from the ACGIH, AIHA, and NIOSH guidelines.

By Substance (as analyzed to date)

Agent	Potential Source	Occupational Exposure Limits		Total	Percent of Benzene Measurements per Category (expressed in % of the 0.5ppm Action Limit)				
		OEL	Source		ND	Cat. 1 <=10%	Cat. 2 >10-50%	Cat. 3 >50-100%	Cat. 4 >100%
benzene	Crude Oil and Fuels	0.5 ppm	ACGIH	28788	97.742	1.699	0.490	0.049	0.021
toluene		20 ppm	ACGIH	28788	96.075	3.831	0.087	0.003	0.003
ethylbenzene		20 ppm	ACGIH	28788	98.232	1.747	0.017	0.003	
xylene		100 ppm	ACGIH	28790	96.808	3.175	0.017		
cyclohexane		100 ppm	ACGIH	3721	90.271	9.729			
heptane		85 ppm	NIOSH	3721	86.240	13.760			
n-hexane		50 ppm	ACGIH	3721	81.403	18.597			
petroleum distillates		350 mg/m3	NIOSH	38	36.842	42.105	21.053		
tetrahydrofuran		50 ppm	ACGIH	3725	99.007	0.993			
total hydrocarbons		100 ppm	BP	28791	83.738	15.012	1.105	0.097	0.049
trimethylbenzenes		25 ppm	ACGIH	3721	92.018	7.874	0.081		0.027
2-butoxyethanol	Dispersants	5 ppm	NIOSH	1028	79.864	19.844	0.292		
propylene glycol		10 mg/m3	AIHA	8	100.000				
acetone	Boom Repair	200 ppm	ACGIH	9	55.556	44.444			
methyl ethyl ketone		200 ppm	ACGIH	5		100.000			
limonene	Decontamination	30 ppm	AIHA	244	40.984	37.705	16.393	2.459	2.459
Total				163886	93.792	5.826	0.334	0.031	0.017

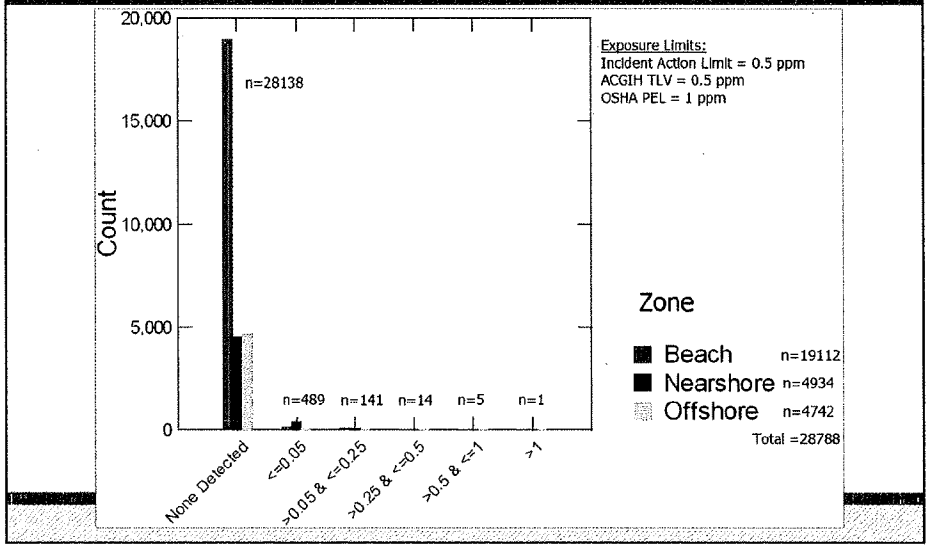
This table is the same as before, but showing the percentage of measurements that were either non-detects or detects that fell within each AIHA exposure control category.

Given the high percentage of non-detects – for example, greater than 95% for BTEX - the calculation of standard descriptive and compliance statistics is problematic. Non-parametric descriptive and compliance statistics can be calculated, but will not be presented here.

If we were to assign AIHA exposure categories to the overall exposures by substance, the exposure ratings for nearly all substances would be Category 1; that is, the 95th percentile exposure was less than 10% of the OEL.

Perhaps the best overall summarization is to say that for all substances in the database 95% or greater of the measurements were either non-detects or less than 10% to 50% of the listed OEL, with only a few measurements approaching or exceeding the OEL.

BP Measurements for Benzene (ppm)



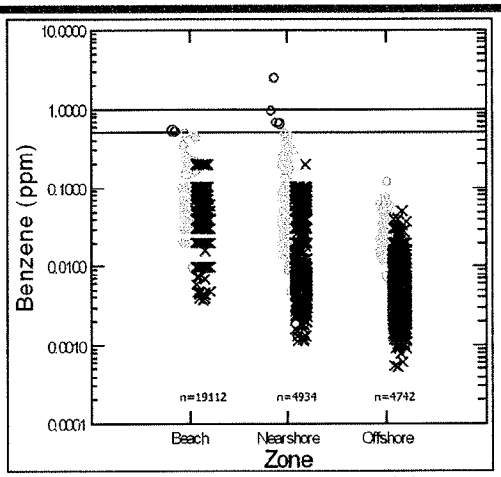
During the response, 28,788 personal samples were analyzed for benzene. The samples were collected in the breathing zone of workers in the three work zones of the response: Beach, Nearshore, and Offshore.

Of these, 28,138 results (97.7%) were below the limit of quantitation (or limit of detection) of the analytical instrumentation.

The average limit of quantitation for Beach and Nearshore samples was <0.012 ppm for 12-hour samples, which is about 1/40 of the OSHA Action Level, and 1/80 of the OSHA permissible exposure limit for benzene (1 ppm).

The limit of detection applicable to Offshore samples was approximately 1/4th of the limit of quantitation for equal sample times.

BP Measurements for Benzene (ppm)



BP personal benzene measurements (n=28788), by Zone.
(blue = non-detect, green = (detect≤0.5 ppm), red = (detect>0.5 ppm))

Exposure Limits:
Incident Action Limit = 0.5 ppm
ACGIH TLV = 0.5 ppm
OSHA PEL = 1 ppm

This figure summarizes the 28,788 industrial hygiene personal samples for benzene collected (as of March 2012). The 'Y' axis represents the concentration of benzene in parts per million. The horizontal line at 1 ppm represents the OSHA Permissible Exposure Limit, while the line at 0.5 ppm indicates the OSHA Action Level as well as the ACGIH TLV. The 'X' axis indicates the exposure zone: Beach, Nearshore, or Offshore.

To visually indicate the number, range, and magnitude of the measurements we used a "jittered-dot density plot". Blue X's represent benzene samples that were non-detects . Green O's represent samples in which benzene was detected. Red O's indicate samples that were detects that also exceeded the Incident Action Level of 0.5 ppm. (Note that we used the non-detect value unchanged, without dividing by 2 or square root of 2, as is common in occupational epidemiology.)

Only one of the more than 28,000 measurements exceeded the OSHA permissible exposure limit of 1 ppm, and only a handful exceeded 0.5 ppm.

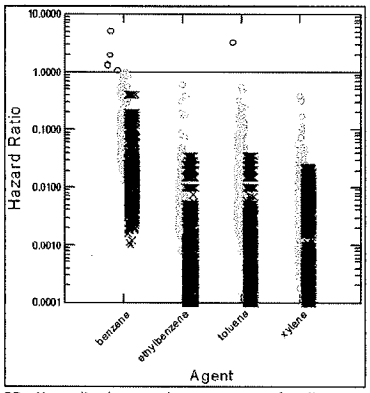
It is worth noting that if the weathered crude oil was truly the source, or a significant source of benzene (and other volatiles) one would expect to see the higher benzene measurements in the offshore dataset. But this was not the case, which reflects the figure shown earlier showing that the more volatile, lower molecular weight organics were not present in the weathered crude oil.

This same effect was noted by NIOSH, in their report on the Exxon Valdez surface spill that occurred in 1989. NIOSH concluded that the "weathered crude oil...was found to be essentially devoid of the lighter, more volatile, petroleum fractions". Benzene was detected in personal breathing zone (PBZ) samples during that incident, but NIOSH further concluded that the nearby gasoline powered engines was the most likely source. The data here support a similar conclusion.

BP Measurements for BTEX and Other Volatiles

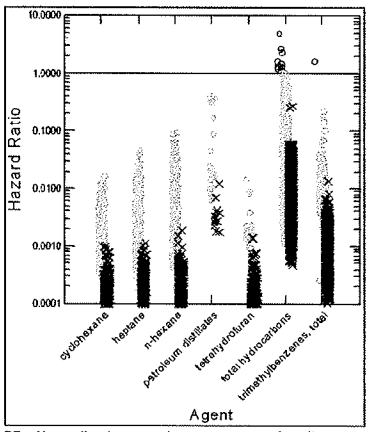
(Hazard Ratio=Concentration/Limit)

BTEX



BP - Normalized personal measurements for all zones. (blue = non-detect, green = (detect≤OEL), red = (detect>OEL))

Other Volatiles



BP - Normalized personal measurements for all zones. (blue = non-detect, green = (detect≤OEL), red = (detect>OEL))

These figures summarize the BP measurements for all of the substances in the BP database, expressing in visual form the information in the previous tables.

The y-axis is in terms of the Hazard Ratio, which is the OEL divided by concentration.

A red marker above a Hazard Ratio of 1 indicates that the measurement was a detect and that it exceeded the OEL for that location, job-task, shift, and worker combination. The blue markers indicate non-detects, while the green markers indicate detects that were less than the OEL.

By Zone, Job-task, and Substance=benzene: Offshore (as analyzed to date)

Offshore	Total	Percent of Benzene Measurements per Category (expressed in % of the 0.5ppm Action Limit)				
		ND	Cat. 1 <=10%	Cat. 2 >10-50%	Cat. 3 >50-100%	Cat. 4 >100%
air/water sampling	174	100.000				
dispersant operations	3	100.000				
drill ship	1564	98.210	1.407	0.384		
firefighter	485	99.588	0.412			
in-situ burning	9	88.889	11.111			
mud vessel	84	100.000				
offshore operations	2242	98.573	1.293	0.134		
oil recovery	2	100.000				
refueling	40	95.000	5.000			
scouting	7	100.000				
skimming	85	100.000				
tanker operations	40	100.000				
vessel decon	7	100.000				
Total	4742	98.629	1.181	0.190		

Overall, the exposure data were low, with the majority being non-detects, but we can look at the data by Zone and Job-task to determine if there are any combinations of Zone and Job-task that were associated with generally higher measurements.

This table summarizes the Offshore benzene data, organized by Job-task.

We created a "refueling" task to reflect any activity that was either directly related to refueling, or during that day involved the maintenance of engine fuel systems, handling and transfer of fuel, etc.

By Zone, Job-task, and Substance=benzene: Nearshore (as analyzed to date)

Nearshore	Total	Percent of Benzene Measurements per Category (expressed in % of the 0.5ppm Action Limit)				
		ND	Cat. 1 <=10%	Cat. 2 >10-50%	Cat. 3 >50-100%	Cat. 4 >100%
SMART	1		100.000			
animal rescue	11	100.000				
boom decon	47	100.000				
boom deploy	2215	88.126	9.707	1.896	0.181	0.090
decon	3	100.000				
dredging	18	100.000				
in-situ burning	1	100.000				
nearshore operations	228	91.228	5.702	1.316	1.754	
offshore operations	1	100.000				
personnel decon	1	100.000				
refueling	56	69.643	14.286	14.286		1.786
scouting	1230	94.553	4.553	0.732	0.081	0.081
skimming	660	92.576	5.455	1.970		
unknown	1		100.000			
vessel decon	387	97.933	1.550	0.517		
vessel operations	2	50.000	50.000			
vessel support	72	90.278	6.944	2.778		
Total	4934	91.204	6.931	1.601	0.182	0.081

This table summarizes the Nearshore benzene data, organized by Job-task.

While the data for the "refueling" task had higher percentages in the exposure categories for detects, there were detects for most of the other tasks.

It is worth noting that most of the vessels involved in Nearshore activities, such as scouting and skimming, were smaller ships, most of them were "vessels of opportunity".

Such vessels were refueled often, perhaps daily. In addition, many of these vessels used gasoline powered equipment.

By Zone, Job-task, and Substance=benzene: Beach (as analyzed to date)

Beach	Total	Percent of Benzene Measurements per Category (expressed in % of the 0.5ppm Action Limit)				
		ND	Cat. 1 <=10%	Cat. 2 >10-50%	Cat. 3 >50-100%	Cat. 4 >100%
animal rescue	162	100.000				
beach cleanup	13474	99.599	0.334	0.052	0.007	0.007
boom decon	1267	99.921		0.079		
boom deploy	50	98.000	2.000			
boom repair	624	95.994	2.244	1.603	0.160	
decon	404	99.752	0.248			
equipment decon	249	100.000				
hazardous waste disposal	51	98.039		1.961		
other	408	98.529	0.980	0.490		
personnel decon	525	100.000				
refueling	189	74.074	9.524	14.286	1.587	0.529
scouting	45	100.000				
vehicle decon	2	100.000				
vessel decon	1608	99.254	0.435	0.311		
vessel operations	5	100.000				
vessel support	49	97.959	2.041			
Total	19112	99.210	0.476	0.277	0.026	0.010

This table summarizes the Beach (i.e., land-based) benzene data, organized by Job-task.

The "refueling" task had higher percentages in the exposure categories for detects, but as with the Nearshore data, there were detects for most of the other tasks..

Beach cleanup activities involved the use of ATVs and gasoline powered electric generators, the refueling of equipment, and fuel storage. In addition, heavy equipment was often used to load, haul, wash, and/or sift beach sand.

By State, Location, and Substance=benzene: Louisiana

Louisiana	Total	Percent of Benzene Measurements per Category (expressed in % of the 0.5ppm Action Limit)				
		ND	Cat. 1 <=10%	Cat. 2 >10-50%	Cat. 3 >50-100%	Cat. 4 >100%
Amelia	228	99.561	0.439			
Barataria Bay	1	100.000				
Battery Worth	23	100.000				
Bay Jimmy	18	100.000				
Buras	16	100.000				
C Port	48	100.000				
Cocodrie	390	95.641	1.282	2.821	0.256	
Delacroix	81	97.531	2.469			
Elmers Island	215	100.000				
Empire	2	100.000				
Fort Jackson	15	100.000				
Fort Pike	8	87.500	12.500			
Grand Isle	1372	99.563	0.364	0.073		
Grand Terre	200	99.500	0.500			
Hammond	13	100.000				
Hopedale	336	97.321	1.488	0.595	0.298	0.298
Houma	1	100.000				

We can also look at the data organized by State and Location, to determine if there are any combinations of State and Location that were associated with generally higher measurements.

Here for Louisiana the percentage of non-detects and detects is similar for all locations.

The results are much the same for each state.

The Louisiana results continue on the next slide.

By State, Location, and Substance=benzene: Louisiana (cont'd)

Louisiana	Total	Percent of Benzene Measurements per Category (expressed in % of the 0.5ppm Action Limit)				
		ND	Cat. 1 <=10%	Cat. 2 >10-50%	Cat. 3 >50-100%	Cat. 4 >100%
Lafitte	63	100.000				
Middle Pearl River	88	100.000				
Morgan City	3	100.000				
North Pass	2	100.000				
Pascagoula	1	100.000				
Pearl River	26	96.154		3.846		
Point Aux Chene Wildlife	5	60.000	20.000	20.000		
Port Fourchon	1628	99.877	0.061		0.061	
Port Sulphur	107	99.065	0.935			
Queen Bess Island	1	100.000				
Shell Beach	116	88.793	3.448	7.759		
Timbalier Island	14	100.000				
Venice	732	98.770	0.956	0.273		
Venice - South Pass	9	100.000				
Total	5762	98.872	0.590	0.469	0.052	0.017

Overall, 98.8% of the measurements were non-detects.

By State, Location, and Substance=benzene: Mississippi

Mississippi	Total	Percent of Benzene Measurements per Category (expressed in % of the 0.5ppm Action Limit)				
		ND	Cat. 1 <=10%	Cat. 2 >10-50%	Cat. 3 >50-100%	Cat. 4 >100%
Bay St Louis	88	100.000				
Bayou Caddy	164	96.951	2.439	0.610		
Bayou Casotte	92	100.000				
Biloxi	670	98.955	0.746	0.149	0.149	
Cat Island	64	100.000				
Gulfport	642	99.688	0.312			
Gulfport Beach	316	99.367	0.633			
Horn Island	49	100.000				
Long Beach	80	100.000				
Ocean Springs	8	100.000				
Pascagoula	1709	99.590	0.117	0.293		
Pass Christian	110	100.000				
Pecan Grove Landfil	2	100.000				
Petit Bois Island	46	100.000				
Ship Island	74	100.000				
Waveland	277	100.000				
Waveland Beach	4	100.000				
Total	4395	99.477	0.341	0.159	0.023	

We see the same pattern for Mississippi, where 99.5% of the measurements were non-detects…

By State, Location, and Substance=benzene: Alabama (as analyzed to date)

Alabama	Total	Percent of Benzene Measurements per Category (expressed in % of the 0.5ppm Action Limit)				
		ND	Cat. 1 <=10%	Cat. 2 >10-50%	Cat. 3 >50-100%	Cat. 4 >100%
Dauphin Island	1725	99.594	0.406			
Fort Morgan	1490	99.597	0.403			
Gulf Islands National Seashore	157	100.000				
Gulf Shores	2583	99.071	0.426	0.465	0.039	
Mobile	186	98.925	1.075			
Orange Beach	52	98.077		1.923		
Perdido Beach	2	100.000				
Perdido Key	306	100.000				
Theodore	598	99.833		0.167		
Weeks Bay	13	100.000				
unknown location	2		100.000			
Total	7114	99.396	0.394	0.197	0.014	

For Alabama 99.4% were non-detects.

By State, Location, and Substance=benzene: Florida (as analyzed to date)

Florida	Total	Percent of Benzene Measurements per Category (expressed in % of the 0.5ppm Action Limit)				
		ND	Cat. 1 <=10%	Cat. 2 >10-50%	Cat. 3 >50-100%	Cat. 4 >100%
Barrancas Beach	1	100.000				
Camp Helen State Park	22	100.000				
Destin	19	89.474	10.526			
Gulf Islands National Sea	242	100.000				
Gulf Shores	27	100.000				
Johnson Beach	140	100.000				
Mirimar Beach	14	100.000				
Naval Air Station	152	100.000				
Navarre	52	100.000				
Panama City	76	98.684		1.316		
Panama City Beach	42	100.000				
Pensacola	747	99.866	0.134			
Perdido Key	255	93.725	4.314	1.569		0.392
Port St Joe	50	100.000				
St George Island	2	100.000				
Total	1841	98.914	0.760	0.272		0.054

...and for Florida 98.9% were non-detects.

Database

- Given the variable Location and Job-Task entries we assigned uniform Location, Job-task, Zone, and State entries to each case (>7000 lines).

B	C	D	E	F	G	H
LOC_original	JobTask_orig	SampleID	LOC_final	JobTask_final	Zone_final	State_final
1.7	vessel decon		FV unknown	vessel decon	Nearshore	
1.7 north of round island	vessel decon		FV unknown	vessel decon	Nearshore	
28th street	beach clean up (tarball)		Gulfport	beach cleanup	Beach	MS
3.7 miles south of northrop grumman	vessel decon		FV North Star	vessel decon	Nearshore	MS
3.7 miles south of pnorthrop grumman	vessel decon		FV North Star	vessel decon	Nearshore	MS
33 miles from the mobile ship channe	offshore skimming		FV Silent Lady	skimming	Nearshore	AL
8th st. decon yard	boom repair		Biloxi	boom repair	Beach	MS
8th street decon yard	boom decon		Biloxi	boom decon	Beach	MS
8th street decon yard	decon		Biloxi	decon	Beach	MS
8th street decon yards	boom decon		Biloxi	boom decon	Beach	MS
8th street decon yards	boom repair		Biloxi	boom repair	Beach	MS
8th street decon yards	decon		Biloxi	decon	Beach	MS
8th street decon yards biloxi ms	boom decon		Biloxi	boom decon	Beach	MS
8th street decon yards pressure was	boom decon		Biloxi	boom decon	Beach	MS
8th street decon yards repair area	boom repair		Biloxi	boom repair	Beach	MS
a-5 staging	beach clean up (tarball)		Destin	beach cleanup	Beach	FL

The database could not be statistically analyzed or summarized without first organizing the data into useful categories.

Given the number of occupational health consultancies and field personnel involved it was not a surprise to find a wide variety in the field reports regarding naming conventions, job task descriptions, and spellings for each combination of Location and Job-task.

We organized the data, making it suitable to analysis, by adding uniform Location and Job-task names. All such "reassignments" are recorded in a master spreadsheet, which at this point has over 7000 rows.

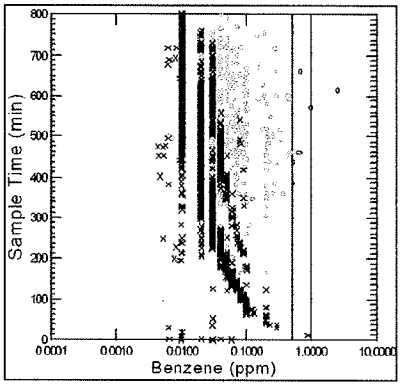
However, we did not change the original entries within the CTEH database. (In fact, we do not have access to the database and can not change any entry.)

Whenever the Location and/or Job-task was ambiguous the final determination usually involved checking the location using the GPS coordinates for the sample, as well as reviewing the comments and remarks that the field personnel may have added to the field survey forms. Occasionally, we had to look at the original forms, particularly if we suspected a transcription error.

Database (cont'd)

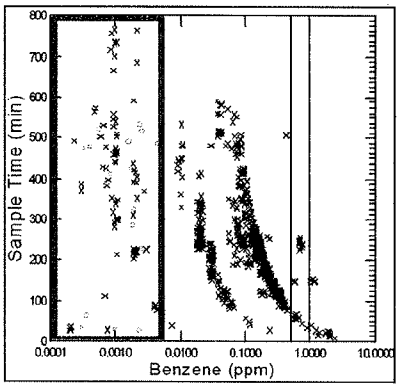
- Non-detects expressed as LOQ vs. LOD

BP



BP - Benzene: Sample time v. Concentration. (blue = non-detect, green = (detect≤0.5 ppm), red = (detect>0.5 ppm))

OSHA, USCG, NIOSH



OSHA, NIOSH, and USCG - Benzene: Sample time v. Concentration. (blue = non-detect, green = (detect≤0.5 ppm), red = (detect>0.5 ppm))

Another database issue involved the Limit of Quantitation. The laboratories used by BP, OSHA, and the USCG reported the non-detects at the "limit of quantitation".

Unless requested otherwise, this is standard practice for analytical laboratories.

NIOSH calculated their non-detects down to the "limit of detection", which can be considerably less than the LOQ.

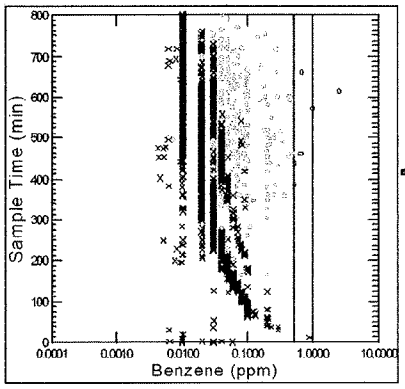
These two figures plot the "sample time" versus the "benzene concentration". Recall that the blue X's indicate non-detects.

The BP, OSHA, and USCG non-detects, based on the limit of quantitation, do not, in general, go below 0.01 ppm. The NIOSH non-detects – shown in the red square – are considerably lower, as they were based on the limit detection.

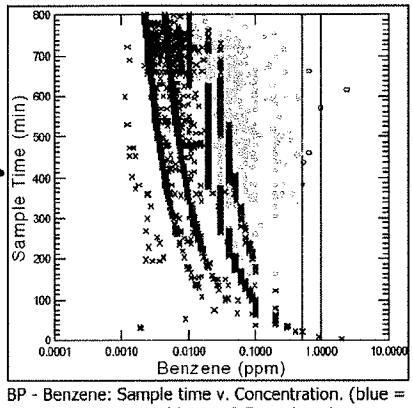
Bureau Veritas analyzed the BP Offshore and many of the BP Nearshore samples. Since Bureau Veritas was also the contract laboratory for NIOSH, we asked Bureau Veritas to determine if was possible to calculate approximate "minimum detection limits" from the available instrument calibration data.

Database (cont'd)

- Bureau Veritas calculated approximate LODs resulting in improved exposure estimates.



BP - Benzene: Sample time v. Concentration. (blue = non-detect, green = (detect≤0.5 ppm), red = (detect>0.5 ppm))



BP - Benzene: Sample time v. Concentration. (blue = non-detect, green = (detect≤0.5 ppm), red = (detect>0.5 ppm))

The answer was "yes", given that similar equipment and calibration curves were used for the analysis of both the BP and NIOSH samples.

Bureau Veritas recalculated the Offshore (and some of the Nearshore) data and provided estimates of the LODs, which were then turned into "minimum detectable concentrations" using the sample volumes.

The end result was that the non-detects in terms of the LOQ could now be expressed as non-detects in terms of the Limit of Detection. In many cases, the mass of benzene detected now exceeded the newly calculated limit of detection, resulting in measurements that can be classified as "detects".

We did not change the original detects or non-detects in the database. We simply added, through CTEH, additional variables reflecting the recalculated concentration values. Also note that these calculations did not affect the original detects, only the non-detects.

The overall effect can be seen in the figure on the right. Many of the original non-detects truncated at the 0.01, 0.02, and 0.03 ppm levels (in the figure on the left) can now be expressed as non-detects (or in some cases as detects) at somewhat lower levels.

For the tables and figures in this presentation we used the original detects and the recalculated non-detects.

Other Occupational Exposure Datasets - OSHA

- Database
  - ~ 4,539 records, representing roughly >900 personal samples
  - ~ 178 direct reading instrument records (not included in this analysis)
- Documentation
  - Dataset and minimal supporting information are available online.
  - Field notes and laboratory results are on file.
- Among the substances monitored
  - BTEX and other organics
  - Dispersants
  - Decontamination agents
  - Petroleum distillates, stoddard solvent, oil mist (mineral)
  - Miscellaneous compounds
- Laboratory
  - OSHA Salt Lake City lab

OSHA, the USCG, and NIOSH also collected occupational exposure data.

The OSHA data, which is available on the OSHA website, consists of both personal and area samples, as well as readings from direct reading instruments,

...and were collected primarily from Nearshore and Beach (land-based) operations, such as beach cleanup, boom deployment, oil scouting and skimming, and vessel decontamination.

The earliest and last measurements were collected on May 27 and September 6, 2010.

Other Occupational Exposure Datasets - USCG

- Database
  - ~ 1,192 records, representing roughly >200 personal samples
- Documentation
  - Dataset and minimal supporting information are available online.
  - Field notes and laboratory results are on file.
- Among the substances monitored
  - BTEX and other organics
  - Dispersants
  - Petroleum distillates, oil mist (mineral)
  - Miscellaneous compounds
- Laboratory
  - OSHA Salt Lake City lab

The USCG data, which is also available on the OSHA website, consists of the personal samples collected from USCG personnel. The USCG samples were sent to the OSHA SLC laboratory for analysis.

The earliest and last measurements were collected on June 14 and July 2, 2010.

Other Occupational Exposure Datasets - NIOSH

- Database
  - No sample or laboratory number
  - ~ 2,577 records, representing roughly >500 samples
    - ~ 840 records from personal samples
    - ~ 1,737 records from general area samples
- Documentation
  - Dataset and a series of reports are available online.
  - Field notes and laboratory results are on file.
- Substances monitored
  - BTEX and other organics
  - Dispersants
  - Decontamination agents
  - Diesel exhaust
  - Total hydrocarbons, total PAHs, H_2S
  - Many miscellaneous compounds
- Laboratories
  - Bureau Veritas

NIOSH was requested by BP to "evaluate potential exposures and health effects among workers involved in Deepwater Horizon Response activities".

NIOSH collected occupational exposure data during the ...
spraying of dispersants,
Controlled oil burns,
oil skimming,
VoO operations,
source control operations (drilling and collection of oil from the well head),
animal cleaning and rehabilitation,
beach cleanup, and
vessel and equipment decontamination.

The earliest and last measurements were collected on June 4 and August 10, 2010.

Database Analytes

BP
2-butoxyethanol
acetone
benzene
cyclohexane
ethyl benzene
heptane
limonene
methyl ethyl ketone
n-hexane
p-cymene
petroleum distillates
propylene glycol
tetrahydrofuran
toluene
total hydrocarbons
trimethylbenzenes, total
xylene

OSHA
2-butoxyethanol
acetone
benzene
coal tar pitch volatiles (benzene soluble fraction)
cyclohexane
cyclohexene
ethyl benzene
formaldehyde
limonene
naphthalene
oil mist, mineral
petroleum distillates (naphtha) (rubber solvent)
propylene glycol
qualitative mass-spec analysis
stoddard solvent
toluene
toluene-2,4-diamine
trimethylbenzene (mixed isomers)
xylene

USCG
benzene
cyclohexane
ethyl benzene
oil mist, mineral
petroleum distillates (naphtha) (rubber solvent)
propylene glycol
qualitative mass spec analysis
toluene
trimethylbenzene (mixed isomers)
xylene

We downloaded the OSHA, USCG, and NIOSH databases. Each database contained exposure data on the analytes of primary concern. The government databases contained a few measurements for other analytes. The substances of primary interest are highlighted in each dataset above.

All of the OSHA measurements were either non-detects or below the evaluation criteria. OSHA concluded that there was a "low risk of chemical inhalation", and the greater potential risk to health was related to the heat stress experienced by the response workers.

Early on, the USCG concluded that the two primary potential hazards affecting Coast Guard personnel were heat stress and fatigue. USCG analyses revealed that VOCs, such as BTEX, and inorganics, such as hydrogen sulfide and sulfur dioxide, were not detectable in or above the weathered crude oil, having already been dissolved in the water column as the crude oil rises to the surface, or rapidly evaporated once at the surface.

NIOSH				
1,1,1-trichloroethane	4-ethyltoluene	benzyl chloride	ethanol	naphthalene
1,1,2,2-tetrachloroethane	4-methyl-2-pentanone	bromodichloromethane	ethyl acetate	o-xylene
1,1,2-trichloroethane	acenaphthene	bromoform	ethyl benzene	organic carbon (diesel exhaust)
1,1-dichloroethane	acenapthylene	bromomethane	fluoranthene	phenanthrene
1,1-dichloroethene	acetaldehyde	carbon disulfide	fluoranthracene	propene
1,2,4-trichlorobenzene	acetone	carbon monoxide	fluorene	propylene glycol
1,2,4-trimethylbenzene	acetonitrile	carbon tetrachloride	formaldehyde	propylene glycol ethyl ether
1,2-dibromo-3-chloropropane	acrolein	chlorobenzene	hexachlorobutadiene	pyrene
1,2-dibromoethane	acrylonitrile	chloroethane	hydrogen sulfide	styrene
1,2-dichloro-1,1,2,2-tetrafluoroethane (cfc 114)	alpha-pinene	chloroform	indeno(1,2,3-cd)pyrene	tetrachloroethene
1,2-dichlorobenzene	anthracene	chloromethane	isopropyl alcohol	tetrahydrofuran (thf)
1,2-dichloroethane	benzene	chrysene	limonene	toluene
1,2-dichloropropane	benzene soluble fraction	cis-1,2-dichloroethene	m,p-xylenes	total hydrocarbons
1,3,5-trimethylbenzene	benzo(a)anthracene	cis-1,3-dichloropropene	mercury	total pahs
1,3-butadiene	benzo(a)pyrene	cumene	methyl methacrylate	total particulates
1,3-dichlorobenzene	benzene	cyclohexane	methyl tert-butyl ether	trans-1,2-dichloroethene
1,4-dichlorobenzene	benzene soluble fraction	d-limonene	methylene chloride	trans-1,3-dichloropropene
1,4-dioxane	benzo(a)anthracene	dibenzo(a,h)anthracene	n-butyl acetate	trichloroethene
2-butanone (mek)	benzo(a)pyrene	dibromochloromethane	n-heptane	trichlorofluoromethane
2-butoxyethanol	benzo(b)fluoranthene	dichlorodifluoromethane (cfc 12)	n-hexane	trichlorotrifluoroethane
2-hexanone	benzo(e)pyrene	dipropylene glycol butyl ether	n-nonane	vinyl acetate
2-propanol (isopropyl alcohol)	benzo(g,h,i)perylene	dipropylene glycol methyl ether	n-octane	vinyl chloride
3-chloro-1-propene (allyl chloride)	benzo(k)fluoranthene	elemental carbon (diesel exhaust)	n-propylbenzene	xylenes

In additional to area and personal breathing zone samples, NIOSH collected screening samples (Summa canisters and thermal desorption tubes).

The personal and area samples were analyzed for a range of targeted substances, including BTEX, total hydrocarbons and dispersants (2-butoxyethanol and propylene glycol).

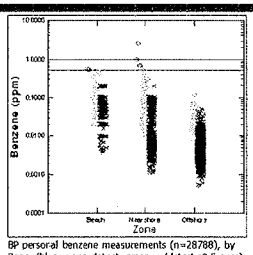
All measurements, with the exception of carbon monoxide, were either non-detects or considerably less than the applicable OELs.

There were several measurements of carbon monoxide, collected using directing reading instruments, that exceeded the NIOSH REL (35 ppm TWA; 200 ppm C). These measurements were associated with the use of gasoline engines.

NIOSH also pointed out in their various reports that employee smoking was common and that smoking cessation programs should be considered.

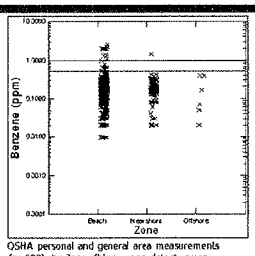
Industrial hygiene sampling summary for benzene (ppm)

BP



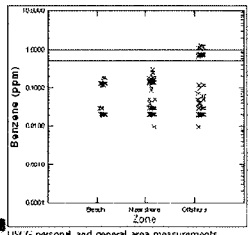
BP personal benzene measurements (n=28788), by Zone. (blue = non-detect, green = (detect≤0.5 ppm), red = (detect>0.5 ppm))

OSHA



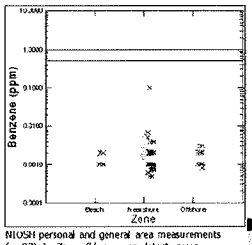
OSHA personal and general area measurements (n=699), by Zone. (blue = non-detect, green = (detect≤0.5 ppm), red = (detect>0.5 ppm))

USCG



USCG personal and general area measurements (n=160), by Zone. (blue = non-detect, green = (detect≤0.5 ppm), red = (detect>0.5 ppm))

NIOSH



NIOSH personal and general area measurements (n=87), by Zone. (blue = non-detect, green = (detect≤0.5 ppm), red = (detect>0.5 ppm))

45

These figures summarize the more than 29,000 industrial hygiene samples for benzene taken by BP, OSHA, the U.S. Coast Guard, and NIOSH.

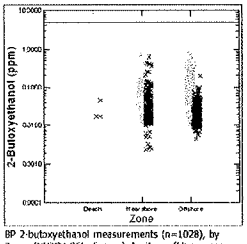
The Deepwater Horizon well was capped on July 15th, 2010. The graphs represent samples primarily collected between May and September, 2010. (BP continues to collected samples from the ongoing beach cleanup activities.)

All but one of the OSHA and USCG measurements for benzene were non-detects, as were most of the BP and NIOSH samples.

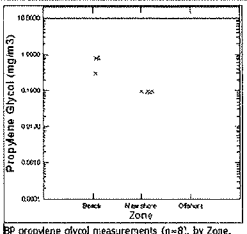
Key points: The job-tasks sampled by OSHA, the Coast Guard, and NIOSH were similar to the job-tasks sampled by BP. The monitoring results of all four organizations were consistent. The overwhelming number of samples were non-detects, with a few detects approaching or exceeding the 0.5 ppm Action Limit.

Industrial hygiene sampling summary for 2-butoxyethanol and propylene glycol

BP



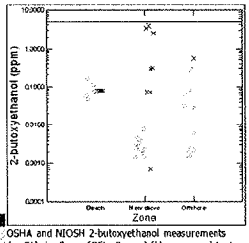
BP 2-butoxyethanol measurements (n=1028), by zone. (NIOSH REL=5 ppm), by Zone. (blue = non-detect, green = (detect≤5 ppm))



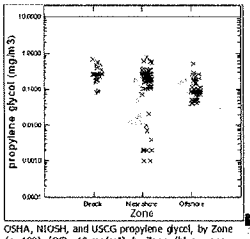
BP propylene glycol measurements (n=8), by Zone. AIHA WEEL=10 mg/m³), by Zone. (blue = non-detect))

BP

USCG
OSHA
NIOSH



OSHA and NIOSH 2-butoxyethanol measurements (n=31), by Zone. (OEL=5 ppm) (blue = non-detect, green = (detect≤5 ppm))



OSHA, NIOSH, and USCG propylene glycol, by Zone (n=194) (OEL=10 mg/m³), by Zone (blue = non-detect, green = (detect≤10 mg/m³))

USCG
OSHA
NIOSH

These figures summarize the nearly 1300 industrial hygiene samples collected by NIOSH, the Coast Guard, OSHA, and BP for 2-butoxyethanol and propylene glycol.

The horizontal line across the top of the two figures on the left shows the 2-butoxyethanol NIOSH Recommended Exposure Limit of 5 ppm (the OSHA Permissible Exposure Limit is 50 ppm).

The horizontal line across the top of the figures on the right shows the propylene glycol AIHA Workplace Environmental Exposure Level of 10 mg/m3 (there is no OSHA PEL for propylene glycol).

The results for the four organizations are consistent, leading to identical conclusions. The detects for both substances were below the exposure limits by about an order of magnitude. The AIHA exposure rating would be Category 1 for these substances; that is, the 95th percentile exposure was less than 10% of the OEL.

Data Analysis Summary

- A dataset of unprecedented size and quality is available for retrospectively assessing occupational exposures related to the Deepwater Horizon Response.
- The majority of the personal exposure measurements were non-detects.
- Detects rarely approached or exceeded the OELs.
- BP, OSHA, USCG, and NIOSH measurements were consistent.
- Risk due to occupational exposures appears to have been low.
- Heat stress and fatigue were identified as being the primary concern.

In summary ... the combined database - consisting of BP, OSHA, USCG, and NIOSH measurements - probably represents the largest occupational exposure dataset ever assembled for a single incident.

For most substances measured, particularly those of primary concern, the overwhelming fraction of the measurements were non-detects.

The small percentages of detects were not excessive, rarely exceeding half of the OEL, and did not appear to be associated with any particular exposure zone, job-task, or location, with the possible exception of the job-task of "refueling" related activities.

The BP, OSHA, USCG, and NIOSH measurements tell the same story and lead to the same conclusion.

That is, potential risk due to occupational, inhalation exposures appears to have been low. The higher exposures were neither excessive nor frequent. Heat stress and fatigue were identified by all participating parties as the primary concern during the response effort.

It should be noted that exposure via the dermal route of exposure was minimized or eliminated by the extensive use of gloves and other personal protective clothing, as well as the non-presence of the lower molecular weight hydrocarbons in the weathered crude oil.