

A COMPARATIVE ANALYSIS OF THE GENOTOXICITY ALONG THE SHORELINES POST THE BP AND SANTA BARBARA OIL SPILLS

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ABSTRACT

- ▶ This is a comparative study between the 2010 British Petroleum (BP) Deep Water Oil Spill releasing millions of gallons of crude oil in the Gulf of Mexico near the Louisiana shoreline and the 2015 when thousands of gallons of crude oil spilling on land then into the Pacific Ocean from a Santa Barbara corroded ruptured pipeline near the Refugio, CA Shoreline. Then the Shell Oil Spill Occurred in the Gulf in 2016. In the Gulf toxic dispersants were applied. Toxic chemical additives in the pipeline were mixed in with Pacific Oil leak. In both cases the oil caused serious harm to the ecosystems, human, animal, and other lifeforms. The purpose of this study is to compare the aerosol genotoxic levels along the Gulf of Mexico and the Pacific Ocean shorelines following the BP and Refugio Oil Spills. Air samples were collected from contaminated sites using Impingers, Mini-vol's, and the URG-3000 (multi-filter sampler)- Grand Isle, Elmer's Island, Port Fourchon, in-water (by boat) LA and the control site Sea Rim Park, Tx. Air samples were also collected at the contaminated Refugio Spill site and the control site Gaviota Beach. Tarballs and sediments were collected as well. The air samples were processed in the laboratory according to the manufacturer recommendations- Umu Chromo Test assay EBPL. The results were expressed as induction ratios. The induction ratio of 1.5 and above is considered to be genotoxic. All the contaminated sites had induction ratios in the genotoxic range; on the LA shoreline the induction ratios range between 3.7 and 4.7 and on the shoreline of CA the range was between 6.2 and 6.7. As can be seen the genotoxicity levels are higher on the California shoreline compared to the Louisiana shoreline. X-ray Diffractions were used to analyze the tarballs to determine the components present that may be contributing to the genotoxicity. The components included from the tarballs are Quartz, SiO₂, Tridymite, Cristobalite low, Sodalite, Goethite, α -Polypropylene. There are a number of factors that can be considered to take in account for the higher level of genotoxicity in CA compared to LA. The oil types, natural crude oil seeps (Santa Barbara has the largest oil seeps in the Country) , the cleanup methods, and response efforts. Future next steps include processing the new samples collected. Continue to monitor the effects of the Spills on the environment and study the recovery process.

INTRODUCTION

- ▶ On May 19, 2015, the Refugio Oil Spill happened in Santa Barbara, California from a corroded pipeline rupture inland which released 101,000 gallons of crude oil of that 21,000 gallons went into the Pacific Ocean (Oceana et al 2015).
- ▶ On April 20, 2010, the BP oil spill, the largest in US history, led to approximately 134 million gallons of crude oil into the Gulf of Mexico (U.S. v. BP et al. 2015).

INTRODUCTION

- ▶ The Refugio Oil Spill cleanup process consisted of on water and on shore recoveries.
- ▶ On-shore recovery consisted of assignments on specific areas, and recovery operations were handled by trained staff with equipment to contain, collect, and recover spilled material (Office of Spill Prevention and Response et al 2016).
- ▶ The on-water recovery was conducted by brush type skimmers that are permanently mounted on Clean Sea vessels that are staged in the Santa Barbara area (Office of Spill Prevention and Response et al 2016).

INTRODUCTION

- ▶ Skimming vessels were used to concentrate, confine and store oil (Office of Spill Prevention and Response et al 2016).
- ▶ Booms were used to collect light oil closer to the shore.
- ▶ Fingerprint analysis identified oil that came from pipeline 901, which traveled along south of the California coastline.

INTRODUCTION

- ▶ The cleanup efforts in the Refugio spill helped but the environmental consequences still transpired.
- ▶ It was documented in November 2015, that 202 birds and 99 mammals died along with numerous aquatic species covered in oil and extremely sickened (NOAA et al 2015).

INTRODUCTION

- ▶ The BP oil spill in 2010, was caused by an oil rig explosion that released crude oil directly into the Gulf of Mexico.
- ▶ In the impact zone, coral colonies were found coated in a sludge type material.
- ▶ This oil flowed with the current east passing Mississippi, Alabama, and even Florida's coastline.

INTRODUCTION

- ▶ Due to the depth of the BP spill, oil columnized in the water.
- ▶ A cleanup crew dumped 7 million liters of a toxic chemical dispersant called, Corexit aimed to allow bacteria access to the oil. (Kleindienst et al 2015).
- ▶ The cleanup process involved skimmers and burning of the oil.
- ▶ The volunteers, residents, scientists and paid workers were complaining about bleeding from the nose, chest pains and mild cognitive impairment. (Visser et al 2013).



IMAGE 1: SANTA BARBARA, CALIFORNIA PIPELINE RUPTURE
NEAR REFUGIO. 2015 WWW.AOL.COM/ENVIORNMENTALIST

IMAGE 2. THE
2010 BP RIG
EXPLOSION.
[HTTPS://
EN.WIKIPEDIA.ORG/
WIKI/
DEEPWATER_HO
RIZON_EXPLOSION](https://en.wikipedia.org/wiki/Deepwater_Horizon_explosion)



PURPOSE

- ▶ The purpose of this study is to compare the aerosol genotoxic levels along the Gulf of Mexico and the Pacific Ocean shorelines following the BP and Refugio Oil Spills.

METHODS AND MATERIALS (FIELD SAMPLING)

- ▶ Following the BP and the Refugio Beach oil spill air samples were collected with the SKC Biosampler Impinger, Mini-Vol Filter Sampler, and a URG-3000ABC Filter sampler.
- ▶ Air samples were collected from the following highly contaminated costal areas: Grand Isle, Elmer's Island and Port Fourchon in Louisiana along with Refugio Beach in California.
- ▶ Tarball samples were collected from each sampling site and processed by way of X-Ray Diffraction.

METHODS AND MATERIALS (FIELD SAMPLING)

- ▶ The control sites' samples were collected at Sea Rim State Park, Texas for the BP oil spill and Gaviota State Beach, California for the Refugio Beach oil spill.
- ▶ In-water samples were collected in the Gulf of Mexico from the surface level using a reagent bottle, and using a Niskin Bottle at 100 ft, and 150 ft below the surface.

METHODS AND MATERIALS (LABORATORY TESTING)

- ▶ Overall genotoxicity of the collected air samples was evaluated using a genetically engineered bacterial reporter, umu-Chromo test assay from EBPL.
- ▶ In this assay, DNA damage activates the reporter gene, umuC, as part of genotoxic response. In this system, the umuC gene is fused to lacZ, thus its activation results in the production of Beta-galactosidase.
- ▶ The samples were processed according to the manufacturer recommendation (umu-ChromoTest, EBPL) and Beta-galactosidase activity was evaluated using UV-vis plate reader, OD600.

METHODS AND MATERIALS (LABORATORY TESTING)

- ▶ The results are expressed as Induction Ratios and were calculated using the formula recommended by the manufacturer in which the positive control is the response to the known genotoxic compound [4-nitroquinoline 1-oxide (4NQ1O)], and negative control is the response to the elution buffer.
- ▶ Accordingly, the Induction Ratio of 1.5 and above is considered genotoxic, Data represent average values from three experiments with standard deviation (n=3).

FIGURE 1: HERE WE TAKE A CLOSER LOOK AT GRAND ISLE AND ELMER'S ISLAND IN LOUISIANA WHERE THE WATER, AIR, AND SEDIMENT/TAR BALL SAMPLES WERE COLLECTED FOR MICROBIAL AND GENOTOXIC ASSESSMENTS THE PAST SEVEN YEARS ELMER'S ISLAND (LEFT) GRANDE ISLE (RIGHT)

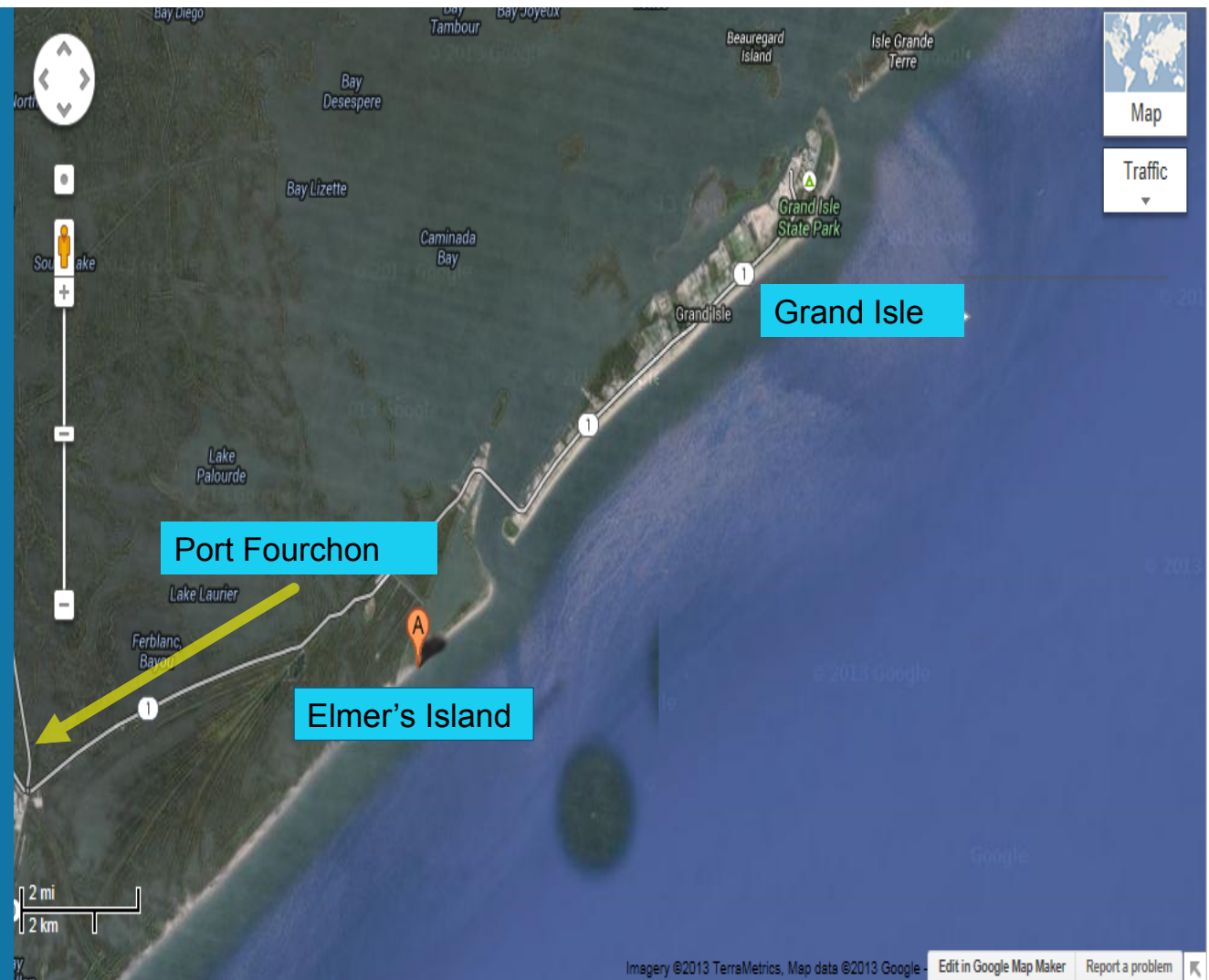


FIGURE 1: MAP OF THE LOCATIONS/ SITES OF THE BP DEEP WATER(2010) AND SHELL (2016) OIL SPILLS OCCURRED. THESE ARE THE AREAS WHERE THE DILLARD RESEARCH TEAM COLLECTED SAMPLES ON SHORELINES AND IN THE WATER AT THE SPILLS OF THE GULF OF MEXICO-GRAND ISLE, ELMER'S ISLAND, LOUISIANA (TOXIC AREAS) AND THE CONTROL SITE SEA RIM STATE PARK, TEXAS. THE SAMPLES WERE ASSESSED FOR MICROBIAL POPULATION AND THE GENOTOXICITY.

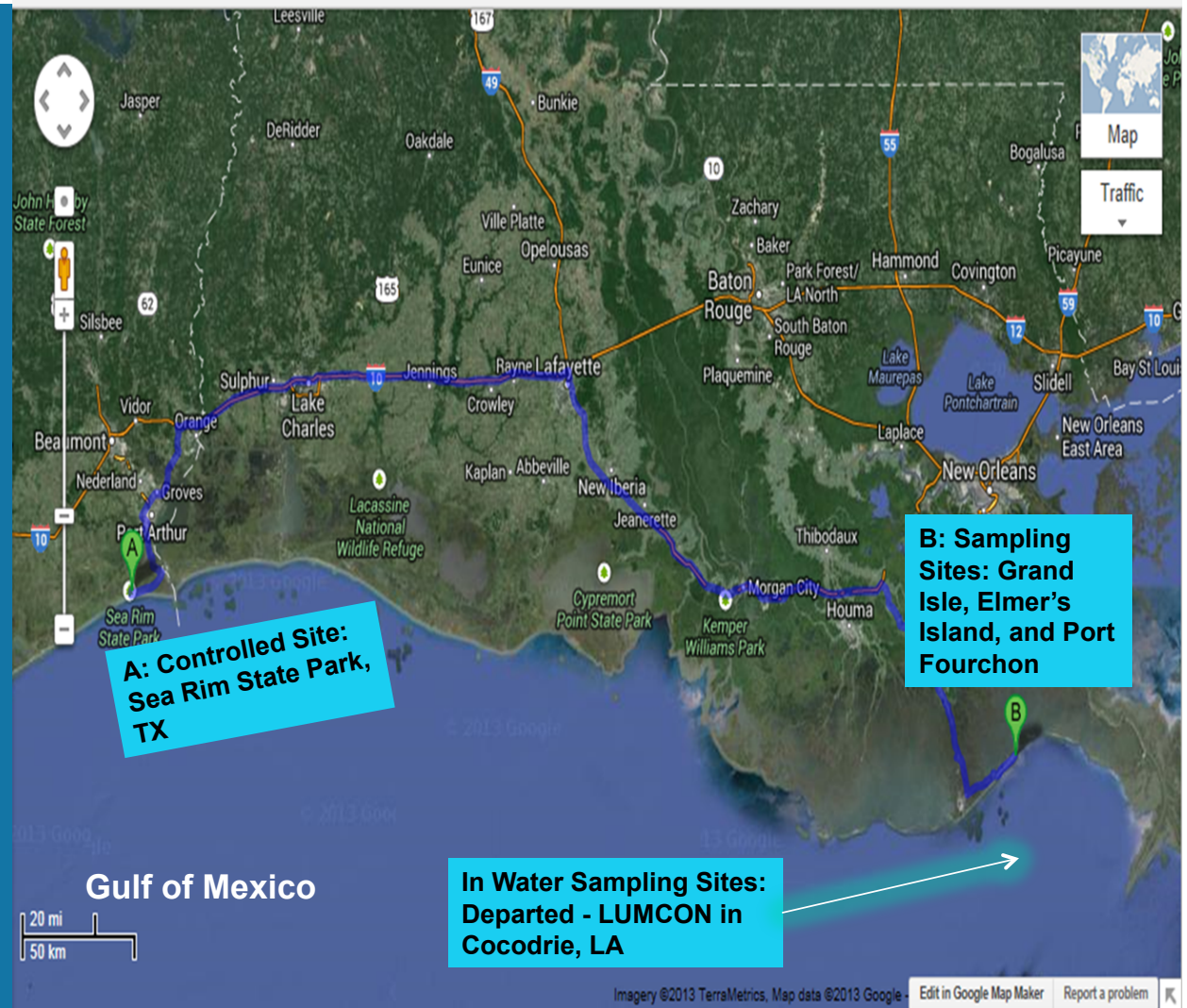


FIGURE 2: SAMPLING SITES ON THE SHORELINE OF THE CONTROL SITE (GAVIOTA STATE BEACH, SANTA BARBARA, CA) TO THE LEFT AND NEAR THE RUPTURED PIPELINE OIL SPILL SITE TO THE RIGHT (REFUGIO STATE BEACH, SANTA BARBARA, CA). THE SAMPLES WERE ASSESSED FOR MICROBIAL POPULATION AND GENOTOXICITY.

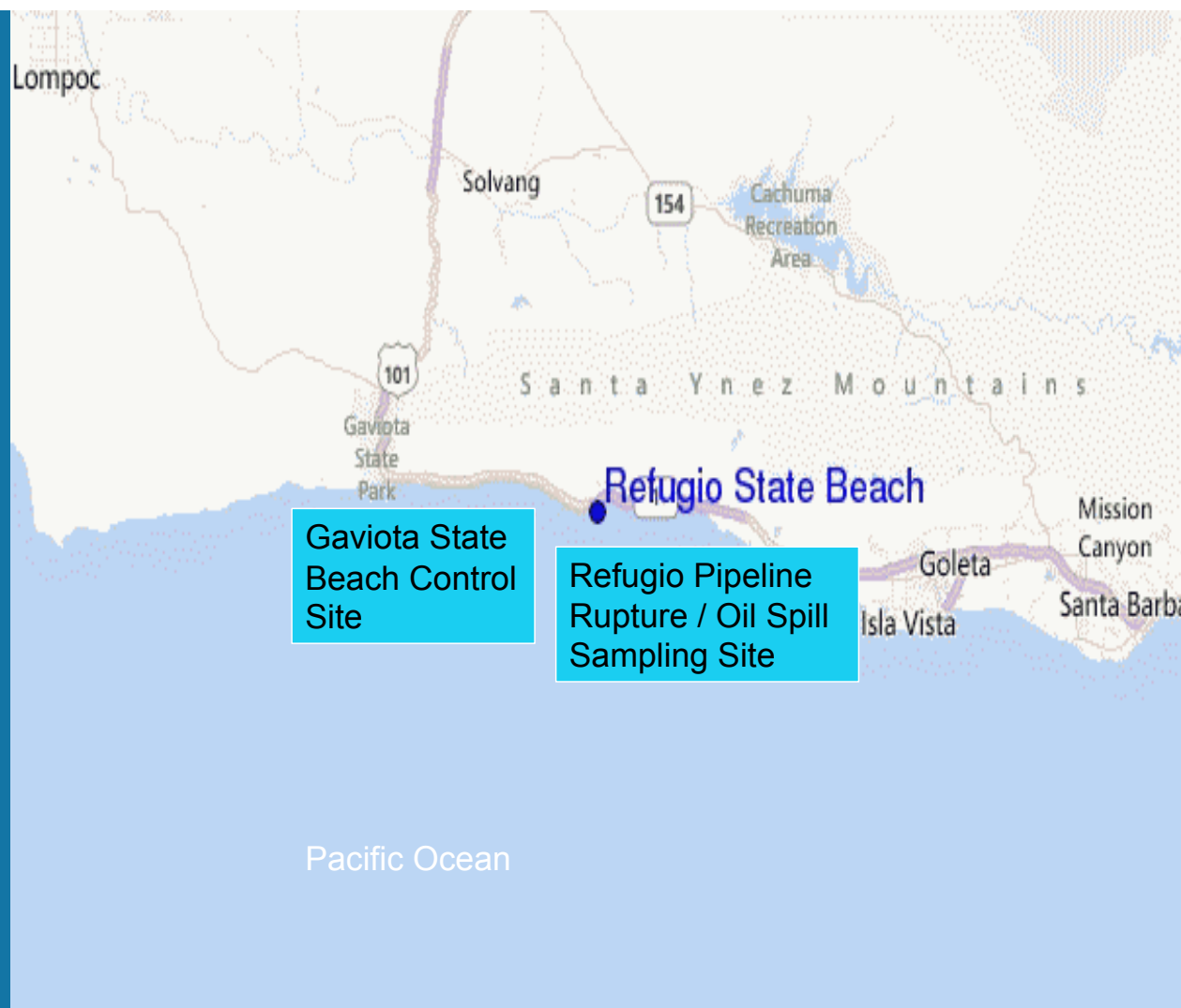


IMAGE 3: GRAND ISLE
REVISITED FOR MORE
SAMPLING ON THE
COAST OF THE GULF OF
MEXICO WHERE THE BP
AND SHELL OIL SPILLS
OCCURRED



IMAGE 4: THE DU-
RESEARCH TEAM ON
ELMER'S ISLAND IN
THE GULF OF
MEXICO AREA TO
COLLECT SAMPLES



IMAGE 5: SAMPLE COLLECTIONS AIR, WATER, AND SEDIMENT AT THE PACIFIC OCEAN SHORELINE AT REFUGIO STATE BEACH, CA WHERE THE RUPTURE OF THE OIL PIPELINE OCCURRED.



IMAGE 6: THE
RESEARCH TEAM AT
GAVIOTA STATE
BEACH, CA, PACIFIC
OCEAN TRIP III TO
COLLECT



IMAGE 7: SAMPLE COLLECTIONS AIR USING SKC LIQUID IMPINGERS AND MINI-VOL SAMPLERS AT THE PACIFIC OCEAN SHORELINE AT REFUGIO STATE BEACH, CA WHERE THE RUPTURE OF THE OIL PIPELINE OCCURRED (SPILL IN THE PACIFIC OCEAN)



FIGURE 3:
PHOTOGRAPH AND
SCHEMATIC OF
PORTABLE HIGH-
VOLUME AEROSOL
SAMPLING
EQUIPMENT HOSTING
ULTRACLEAN
IMPACTOR
CASSETTES, WHICH
WERE FITTED WITH
DIFFERENT FILTERS
FOR PARALLEL
BIOCHEMICAL,
GENETIC AND
TOXICOLOGY ASSAY.

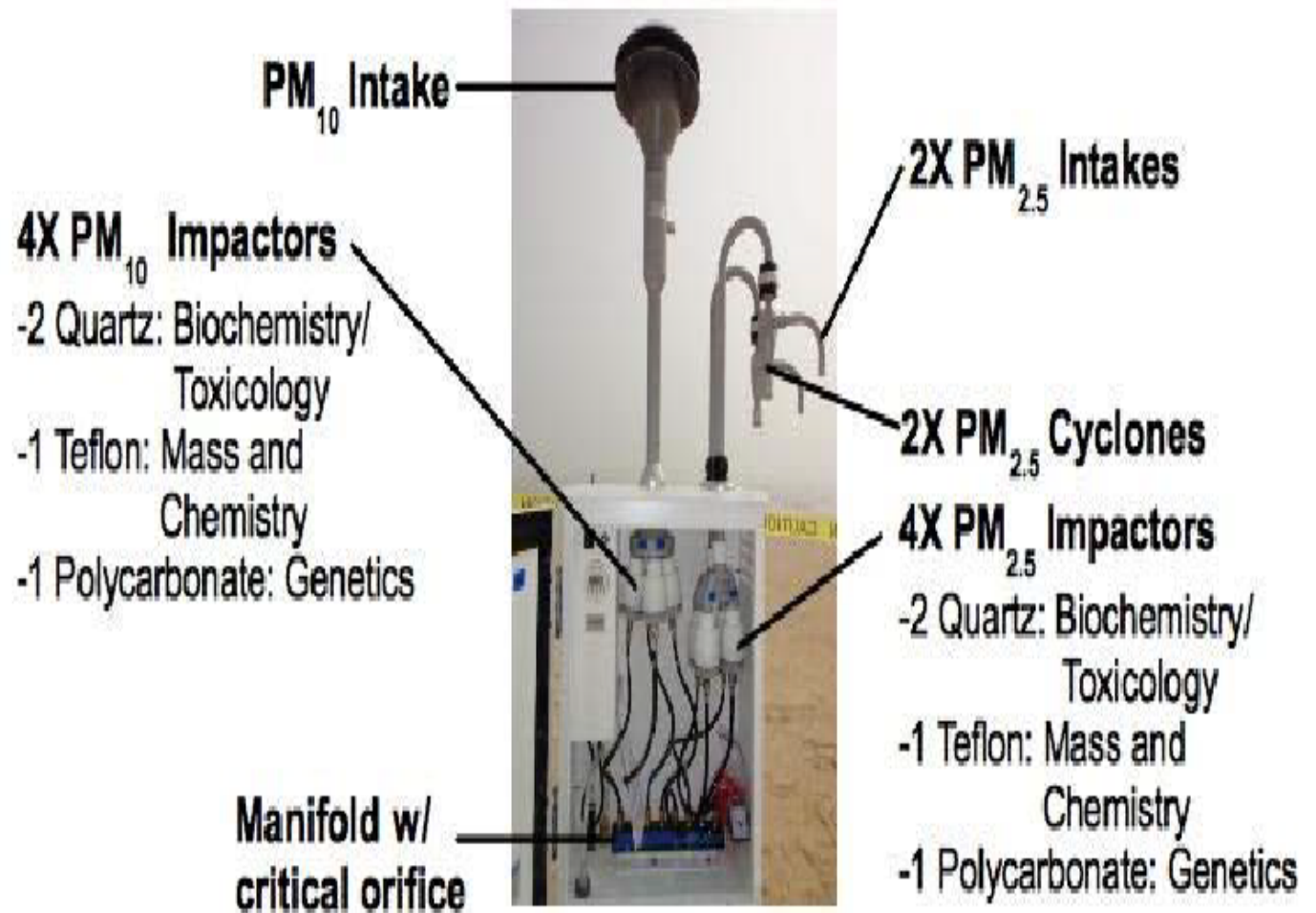




IMAGE 8: TRIP ON THIS VESSEL TO THE SITES OF THE BP AND THE SHELL OIL SPILLS IN THE GULF OF MEXICO TO COLLECT SAMPLES -SINGLETON RESEARCH TEAM USED THIS INSTRUMENT (NISKIN BOTTLE) TO COLLECT WATER SAMPLES AT DIFFERENT DEPTHS OF THE GULF AT THE SITES.

Sampling Team
Image 9: On our
way to collect
samples.
(Left to Right Dr.
Singleton,
Darrell Esnault,
Dr. Ibrahim
Ekaidi, and
Theodore
Johnson)





IMAGE 10: THEODORE JOHNSON AND JUSTIN GRIFFIN
WORKING WITH OUR SAMPLES IN THE LAB

IMAGE 11:
THEODORE
(INTERN)
PREPARING TO
COLLECT
SAMPLES OF
TAR BALLS ON
THE SHORELINE
OF THE GULF
OF MEXICO -
MULTIPLE TAR
BALLS WERE
COLLECTED ON
EACH FIELD
SAMPLING TRIP.





IMAGE 12: PLACING TARBALL SAMPLES IN X-RAY DIFFRACTION MACHINE

METHODS AND MATERIALS (X-RAY DIFFRACTION)

- ▶ X-Ray Diffraction depends on the particle and wave nature of X-Rays to receive information about the structure of the crystalline materials.
- ▶ The method was used to determine the components of the internal structure of tarball samples.
- ▶ The incident beam is generated by a cathode ray tube.
- ▶ The interaction of the incident beam with the sample produces the constructive interference revealing the structure of the sample which allows you to determine the components of the sample.

RESULTS (LOUISIANA)

Louisiana	2011	Texas
Grand Isle/Entree Island State Park Beaches		Sea Rim State Park Beach
Near BP Oil Spill 2010 Site		Control Site
Avg. Induction Ratio		Avg. Induction Ratio
Impingers	4.5	1.4
Mini-Vol	4.2	1.2
URG	4.0	1.3

Table 1: Louisiana 2011 Genotoxicity Results

Louisiana	2012	Texas
Grand Isle/Entree Island State Park Beaches		Sea Rim State Park Beach
Near BP Oil Spill Site		Control Site
Avg. Induction Ratio		Avg. Induction Ratio
Impingers	3.7	1.2
Mini-Vol	4.4	1.4
URG	4.0	1.4

Table 2: Louisiana 2012 Genotoxicity Results

Louisiana	2013	Texas
Grand Isle/Entree Island State Park Beaches		Sea Rim State Park Beach
Near BP Oil Spill Site		Control Site
Avg. Induction Ratio		Avg. Induction Ratio
Impingers	4.7	1.3
Mini-Vol	4.4	1.4
URG	4.2	1.3

Table 3: Louisiana 2013 Genotoxicity Results

RESULTS (CALIFORNIA)

California	2015	California
Refugio State Park Beach		Gaviota State Park Beach
Pipeline Oil Spill Site		Control Site
Avg. Induction Ratio		Avg. Induction Ratio
Impingers	6.7	1.2
Mini-Vol	6.4	1.4
URG	6.2	1.3
Table 4: California 2015 Genotoxicity Results		

California	2016	California
Refugio State Park Beach		Gaviota State Park Beach
Pipeline Oil Spill Site		Control Site
Induction Ratio		Induction Ratio
Impingers	6.4	1.4
Mini-Vol	6.2	1.3
URG	6.5	1.1
Table 5: California 2016 Genotoxicity Results		

California	2017	California
Refugio State Park Beach		Gaviota State Park Beach
Pipeline Oil Spill Site		Control Site
Induction Ratio		Induction Ratio
Impingers	6.4	1.4
Mini-Vol	6.2	1.3
URG	6.5	1.1
Table 6: California 2017 Genotoxicity Results		

RESULTS (Meteorological Data)

Table 7: Results from the Louisiana Gulf of Mexico-Water samples

Averages of Weather Parameters						
Temp F	Humidity	Wind Spd	Heat Indx °F	Wind Dir.	Dew Pt. °F	Wind Chl °F
84°	73%	7mph	97°	S	77°	86°

Table 8: Results from the California Pacific Ocean on the Shoreline Area

Averages of Weather Parameters						
Temp F	Humidity	Wind Spd	Heat Indx °F	Wind Dir.	Dew Pt. °F	Wind Chl °F
75°	74%	7mph	75°	NE	65°	73°

RESULTS (X-RAY DIFFRACTION)

Table 9: X-Ray diffraction results from tarball samples. It is speculated that the crude oil components were consumed by oil eating microbes.

Sample	Sample ID #	XRPD Filename	Phase Identified	Approximate Ratio
Grand Isle (LA)	TCL6884	RX1-15506	Quartz	71.3%
			SiO ₂	15.4%
			Tridymite	7.3%
			Cristobalite low	6.0%
				52.6%
Grand Isle (LA)	TCL6885	RX1-15507	Tridymite	47.4%
			Quartz low	78.4%
Elmer's Island (LA)	TCL6886	RX1-15508	O ₂ Si	21.6%
			Tridymite	96.5%
Elmer's Island (LA)	TCL6887	RX1-15509	O ₂ Si	2.3%
			Cristobalite low	1.1%
			Sodalite	76.5%
Refugio (CA)	TCL6888	RX1-15510	Tridymite	23.5%
			Quartz low	88.7%
Refugio (CA)	TCL6889	RX1-15511	Quartz	11.3%
			Goethite	100%
Refugio (CA)	TCL6890	RX1-15512	α-Polypropylene	

DISCUSSION

- ▶ Every year oil and dangerous substances are discharged into our waterways, contaminating valuable wetlands and shellfish beds, closing fisheries and beaches, and increasing dredging prices.
- ▶ NOAA alone responds to more than 100 oil spills nationwide annually.
- ▶ These activities harm necessary environment for plants and animals and degrade the standard of life for those that live close to, work, and reproduce in surrounding areas.
- ▶ The results show that overall the Pacific is more genotoxic than Gulf of Mexico Shoreline.

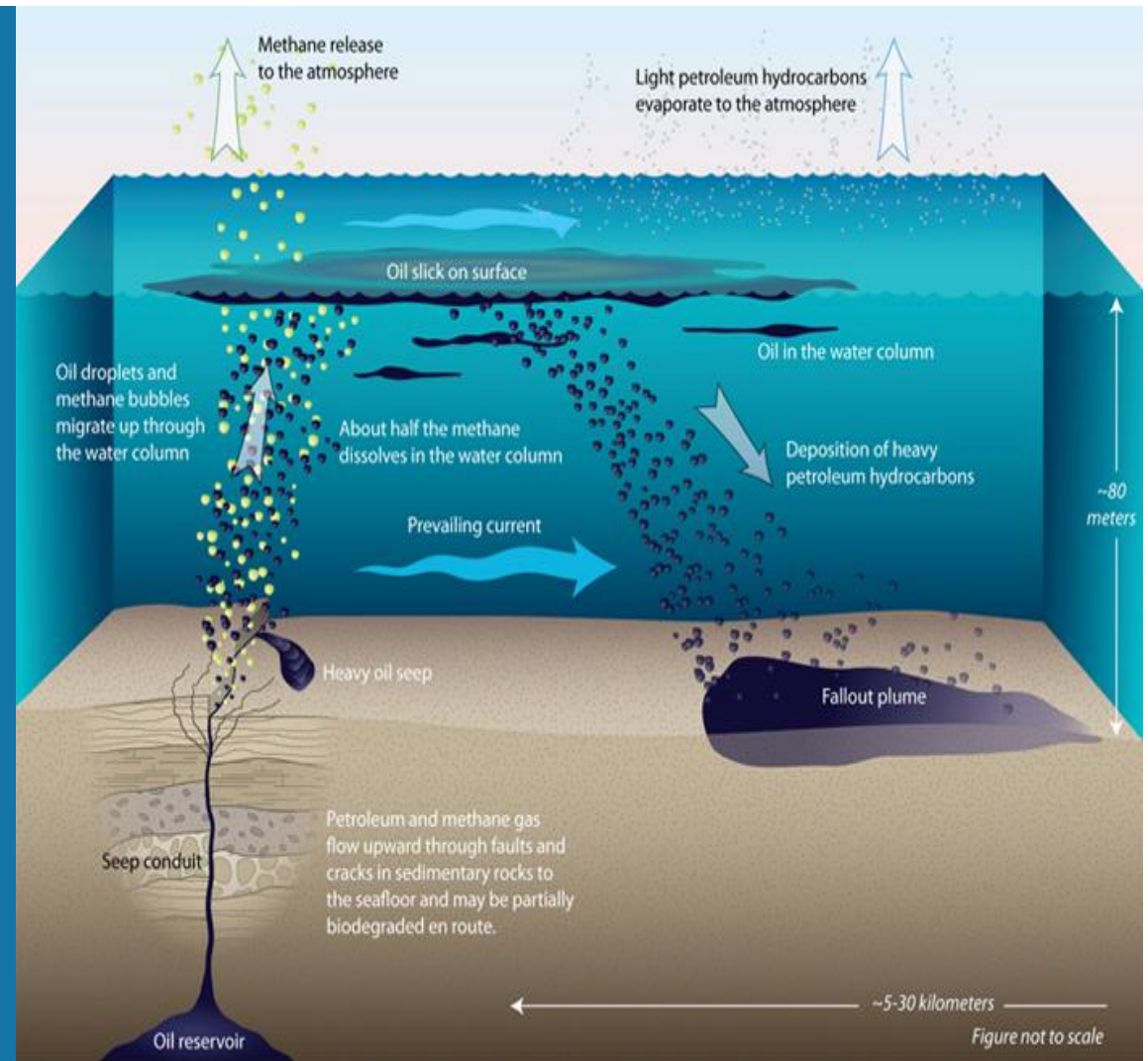
DISCUSSION

- ▶ Santa Barbara County witnesses tons of oil seeps each day.
- ▶ Goleta, a city in Santa Barbara County 15.5 miles from the Refugio Beach Spill, witnesses up to 25 tons of oil from oil seeps daily (American oil & gas historical society et al 2018).
- ▶ The type of oil produced by these formations is shale oil, oil that is produced from shale rock, and contains a higher ratio of asphaltenes.

DISCUSSION

- ▶ Louisiana has Type 1 crude oil “light- sweet oil” which evaporates into the atmosphere. Light oil is also the easiest for natural gas and oil consuming microbes to eat.
- ▶ The Louisiana shoreline’s genotoxic levels may be lower than the California shoreline because of the oil type, differences in geology and the natural seeps in California.

FIGURE 4: THIS ILLUSTRATES THE ROUTE TRAVELED BY NATURAL CRUDE OIL SEEPS LEAVING THE SUB-SEAFLOOR RESERVOIR AS IT TRAVELS THROUGH THE WATER COLUMN TO THE SURFACE AND ULTIMATELY SINKS AND FALLS OUT IN A PLUME SHAPE ONTO THE SEAFLOOR WHERE IT REMAINS IN THE SEDIMENT. (ILLUSTRATION BY JACK COOK, WOODS HOLE OCEANOGRAPHIC INSTITUTION)



CONCLUSION

- ▶ Habitats for plants and animals are damaged under these circumstances, and could affect humans in impacted communities that may rely on these resources.
- ▶ Coral reefs were found to be greatly damaged due to the oil droplets sinking to the ocean floor.
- ▶ In efforts to clean up the oil in the BP spill chemical dispersants, booms, burning of the oil, and skimmers were used while in the Refugio spill toxic additives, skimmers and booms were used.
- ▶ With these efforts for the two oil spills the Gulf of Mexico shoreline is still less genotoxic than the Pacific's.

CONCLUSION

- ▶ Prior to the Refugio spill, Plains All-American Pipeline Company, responsible for the incident failed to properly assess the corrosion after multiple inspections and didn't detect nor respond to the rupture when it occurred. (US Department of Transportation et al 2016)
- ▶ During the Refugio Oil spill, Cultural/Historical Technical Specialists coordinated with Chumash Indians to ensure that cultural and historic properties are protected during the cleanup (Office of Spill Prevention and Response et al 2016).
- ▶ Post the BP oil spill the U.S. Department of the Interior has mandated guidelines for oil well infrastructure maintenance and monitoring (Milman et al 2016).
- ▶ Scientists have been seeking an eco-friendly method to clean up these oil spills.

CONCLUSION

- ▶ Physicist Arden Warner, from Fermilab, invented the Warner Method, by sprinkling magnetic iron shavings onto engine oil.
- ▶ He found that with a magnet it guided the oil blob in any desirable direction.
- ▶ Once the oil is collected, its fillings can be preserved once dried.
- ▶ Importantly, the iron is more environmentally friendly than toxic chemical dispersants used in the BP spill.

CONCLUSION

- ▶ A company in Illinois, Elastec, created a machine that tripled cleanup rates called Elastec's Grooved Disc Skimmer.
- ▶ It has the ability to scoop 4,670 gallons of oil per minute obtaining 90% of the oil.
- ▶ The remediation efforts and cleanup was quicker in the Refugio Pipeline rupture, with newer equipment could enhance cleanups and leave less environmental issues.

FUTURE CONSIDERATIONS

- ▶ Further research includes continuing to monitor the genotoxicity in these areas.
- ▶ Analyze the new samples collected.

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Question?