About This Curriculum

Developed by Deep-C Ocean Science Educators Brittany Pace and Amelia Vaughan. Edited by Deep-C Coordinator Tracy Ippolito.

Deep-C Ocean Science Educators Brittany Pace (left) and Amelia Vaughan (right).

Deep Sea to Coast Connectivity: Utilizing scientific research to help students make connections between the theoretical nature of science and real world applications

This Gulf of Mexico multidisciplinary curriculum was developed around the five main research areas of the Deep-C Consortium: geomorphology, geochemistry, ecology, physical oceanography, and modeling. Each module includes five cumulative lessons, background information on the topic, relevant supplementary reading materials, a glossary, and an assessment. The purpose of this curriculum is to:

1. Provide teachers with a user-friendly curriculum that will introduce students to real-world applications of science as well as specific examples of environmental disasters – their impacts on ocean ecosystems as well as nature's ability to and mechanisms for recovering from such events.
2. Synthesize some of the Deep-C Consortium's research efforts, to date.
3. Increase Gulf of Mexico literacy.

It is our hope that this curriculum can serve as a model for future curricula developed based off of scientific research endeavors.

Contributing experts are listed throughout curriculum. Many thanks to these Deep-C researchers and students who edited, authored content, or assisted with development of the lesson plans.

Aligned with Ocean Literacy Principles and the Next Generation Sunshine State Standards

Ocean Literacy: *The Essential Principles of Ocean Sciences for Learners of All Ages, Version 2* was published in March 2013. http://oceanliteracy.wp2.coexploration.org/

Next Generation Sunshine State Standards: CPALMS is the state of Florida's official source for standards information and course descriptions. http://www.cpalms.org/Public/

This curriculum is available online at https://deep-c.org/education-and-outreach/gom-curriculum

For questions or feedback, email contact@coaps.fsu.edu

The Deep-C Consortium conducted an interdisciplinary study of deep sea to coast connectivity in the northeastern Gulf of Mexico.

This research was made possible by a grant from BP/The Gulf of Mexico Research Initiative to the Deep-C Consortium.

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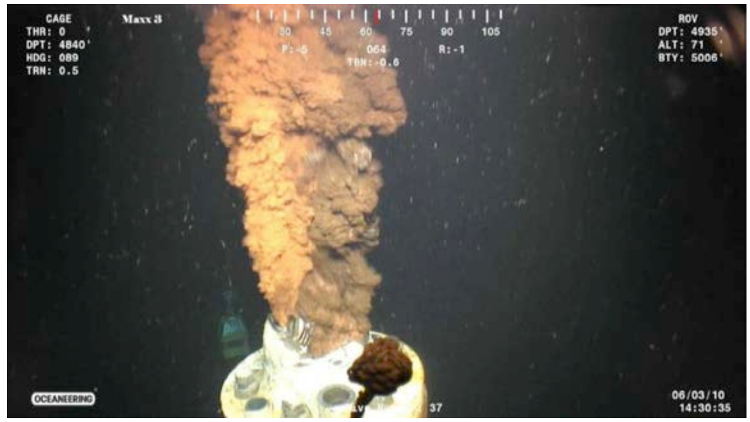


The Macondo well was two days from completion when high-pressure methane gas from the well expanded into the riser, and rose into the drilling rig, where it ignited into an explosion. Experts estimated that oil flowed from the well at a rate of 62,000 barrels per day.

On April 20, 2010, a devastating explosion on the Deepwater Horizon oil rig ~41 miles off the coast of southeastern Louisiana resulted in the deaths of 11 people and triggered a leak at the Macondo well that released close to five million barrels of crude oil into the Gulf of Mexico. Clean-up personnel, scientists, and researchers from all over the country were among the first responders to this environmental disaster. They were tasked with stopping the oil flow, limiting exposure, and cleaning up as quickly as possible using the tools available to them (i.e., dispersants, top kills, in situ burning, oil booms). In the days and months that followed the accident, many of these first responders continued to play an active role in not only helping to mitigate the effects on site but also to offer valuable insight into where the oil and gas would go and the possible effects to the unique and varied Gulf of Mexico ecosystems. When the well was finally capped nearly three months later, many were left wondering what would happen next and what the long-term repercussions might be, both on the Gulf itself as well as the communities that rely on it.

Funding Research in the Gulf of Mexico

In May 2010, BP (the company who owned the rights to the oil from the Macondo well) committed $500 million over a 10-year period to create a broad, independent research program to be conducted at research institutions primarily in the Gulf Coast states. This program, the Gulf of Mexico Research Initiative (GoMRI), has since awarded numerous grants to research consortia, one of which was the Deep-C Consortium. The subsequent research has produced an exhaustive amount of data and provided many new insights into this under-studied ocean environment.

Deep-C Consortium: Deep Sea to Coast Connectivity in the Eastern Gulf of Mexico

Consortium Director: Dr. Eric P. Chassignet

Member and Affiliated Institutions: Florida State University (lead), Dauphin Island Sea Lab, Eckerd College, Georgia Institute of Technology, Leidos, Naval Research Laboratory at Stennis Space Center, Norwegian Meteorological Institute, University of Miami – RSMAS, University of North Florida, University of South Florida, University of West Florida, Valdosta State University, Woods Hole Oceanographic Institution.

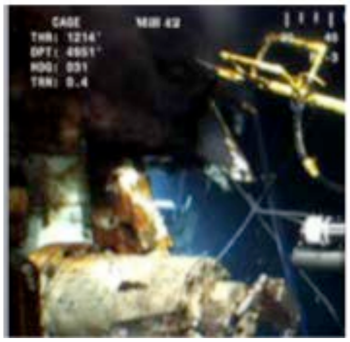
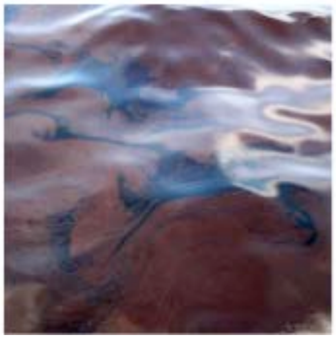
Research Goal: To examine geomorphologic, hydrologic, and biogeochemical settings that influence the distribution and fate of the oil and dispersants while also evaluating and predicting the environmental consequences through integrated earth system and food web models. Research conducted by the Deep-C Consortium, a group of research institutions primarily located in the southeast U.S., provided an opportunity to develop an ocean science curriculum that brings current scientific research into K-12 classrooms.

During and after the Deepwater Horizon oil spill, Deep-C scientists investigated the consequences of petroleum hydrocarbon release in the deep Gulf of Mexico on living marine resources and ecosystem health, as well as nature's response and surprising resiliency. The project sought to answer key questions, including:

1. What are the magnitudes, directions, and spatial and temporal scales of hydrodynamic processes that transport particles and dissolved substances (including oil, gas nutrients, solutes, and organisms) from the deep Gulf to the Florida panhandle shelf waters in the northeastern Gulf of Mexico? How are these influenced by canyon and shelf topography?
2. How does the transport of these particles and dissolved substances influence geochemical, biological, and demographic processes, including food web dynamics, across sea floor, pelagic, and near-shore ecosystems?

The Science of Oil in the Ocean: Origin and Chemical Composition
Exploring Oil Spills on a Molecular Basis

Adapted from National Ocean Science Bowl Professional Development Webinar Series 2015. This webinar, given by Dr. Chris Reddy, a marine geochemist at the Woods Hole Oceanographic Institution, explored how oil is formed, the composition and structure of oil and processes that affect oil. Listen to it at: **http://nosb.org/learn/professional-development/guest-expert-dr-christopher-reddy/**

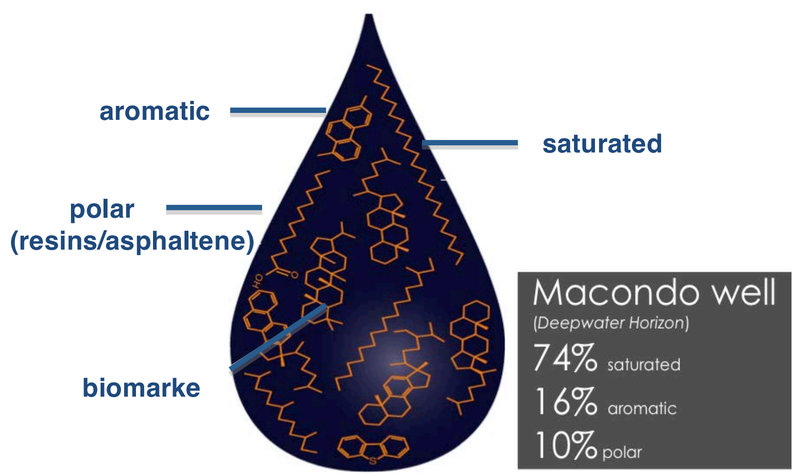
Key Points

- All oils and oil spills are not the same. Oil contains thousands of different compounds with different chemical and biological characteristics.
- What happens to oil released into the environment and the subsequent impacts are dictated by the type of molecules comprised in the spilled oil.
- Released oil's composition changes immediately due to weathering by different processes (e.g. evaporation and microbial degradation that occurs at different speeds and preference for different types of molecules in the oil).
- Where the oil is released is important.
- Investigation of oil spills reveal how nature responds to uninvited guests.

How is Oil Formed?

1. Algae and other organisms fall from the surface to the floor.
2. Debris is reworked by microbes and chemical reactions to form a geopolymer.
3. The geopolymer is "cooked and squeezed" into oil and gas.

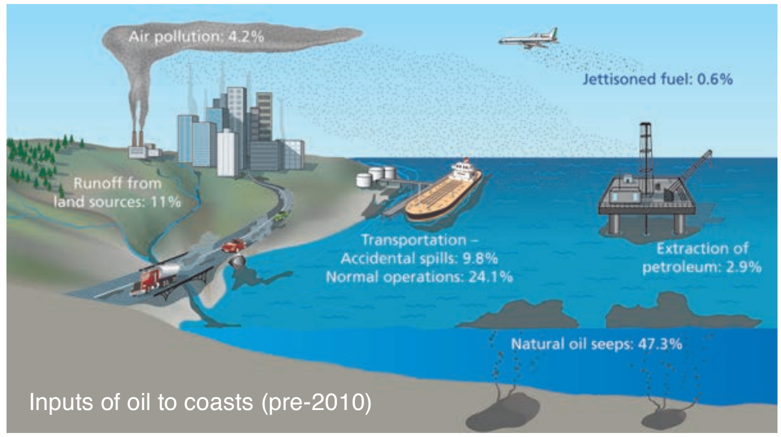
Composition of Oil



Oil is made up of aromatic hydrocarbons, saturated hydrocarbons, and polar compounds. The majority of hydrocarbons in the Macondo well oil were of the saturated variety. Various processes, such as the types of organic matter, depth, temperature, pressure, and time cause differences in the molecular composition of oil. All oil molecules have a different make-up due to the different "personalities" of the many compounds.

Asphaltenes and resins are examples of larger molecules that make up oil and their behavior in the environment is unknown. Petroleum biomarkers, such as hopane, are molecular fossils, invaluable for capturing the "genetic" code of oil. They are the biochemical equivalent of the skeletal remains found at an archeological dig. They do not degrade very fast and can be used for oil fingerprinting to find the source.

Once crude oil is moved from its reservoir, it is then taken to a refinery. The oil is refined through a process where the carbon atoms are broken apart, forming “fractions.” For example: there are 5-10 carbons in gasoline, whereas diesel oils have 14 to 20 carbons. The spectrum of oil that can be released into the environment is vast.

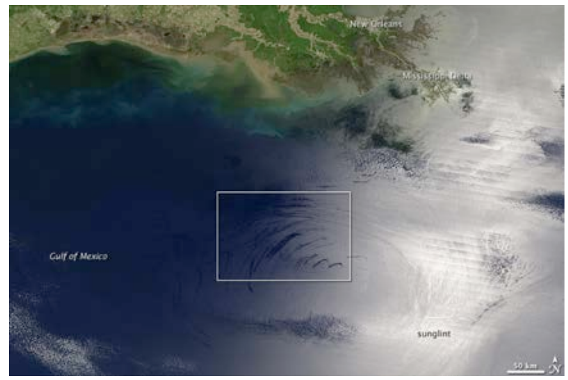


Inputs of oil to coasts (pre-2010)

Natural Oil Seeps versus the Deepwater Horizon Oil Spill

Hydrocarbons are a natural part of the Gulf ecosystem and are released into the ocean environment through a crack in the reservoir, called a natural seep – which creates an oil spill everyday (otherwise known as the “leaky faucet” effect). Specialized bacteria have evolved to eat oil near the seeps. Oil is a calorie rich material for microbes like butter is for us. When oil leaves the reservoir and enters the water column, it changes chemically and its fate is based on both its physical location as well as its molecular makeup.

Characteristic	Natural seeps in the Gulf of Mexico	Deepwater Horizon Disaster
Duration	Occurred everyday for 1000s of years	87 days in 2010
Source	1000s of seeps throughout the Gulf	The Macondo well, 50 miles offshore
Release of oil per/day (Total 2010)	200,000 gallons/day (~800,000,000 gallons in 2010)	55,000 gallons/day (~200,000,000 gallons in 2010)
Type of oil	Weathered crude	Fresh crude
Cause	Nature	Catastrophe
Ecosystem	Evolved to releases	Overwhelmed initially
Damages	Hard to quantify and confirm	Hard to quantify; but they did occur



Satellite imagery of oil slicks in the Gulf of Mexico. Source: NASA Earth Observatory

Processes that Affect Oil

Spreading, drift, evaporation, dissolution, dispersion, emulsification, sedimentation, biodegradation, and photo oxidation are examples of weathering processes that affect a marine oil slick over time. Photochemical degradation is a function of the compound’s capacity to absorb sunlight. The rate of these processes varies. Deepwater Horizon oil traveled 5,000 feet to the surface and its chemical composition at the well when compared to the surface slick was very different. The most volatile compounds evaporated first. And microbes feasted on the released hydrocarbons (first the natural gas, and eventually the oil).

Resources & References

Mixing Oil and Water: Tracking the source and impact of oil pollution in the marine environment - http://www.whoi.edu/oceanus/feature/mixing-oil-and-water

Science in a Time of Crisis - http://www.whoi.edu/deepwaterhorizon

Oil in the Ocean: A Complex Mix - http://www.whoi.edu/oil/main

Contributing Expert

Dr. Christopher Reddy, Marine Chemist at the Woods Hole Oceanographic Institution