Response to Liquid Asphalt Releases in Aquatic Environments

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Coastal Response Research Center
University of New Hampshire

Coastal Response
Research Center

FORWARD

The Coastal Response Research Center, a partnership between the National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration (ORR) and the University of New Hampshire (UNH), develops new approaches to marine spill response and restoration through research and synthesis of information. The Center's mission requires it to serve as a hub for research, development, and technology transfer to the spill community. The Center, in cooperation with NOAA and Sprague Energy (Portsmouth, NH), hosted a one day workshop to investigate response to releases of liquid asphalt to aquatic environments. The October, 2009 workshop was held at the University of New Hampshire in Durham, NH. This report provides a qualitative analysis of characteristics, effects, fate and behavior, mitigation techniques and recovery of liquid asphalt spills.

We hope you find the report interesting and the discussion insightful. If you have any comments, please contact us. We look forward to hearing from you.

Sincerely,

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I. INTRODUCTION

Each year, approximately 29 million tons of liquid asphalt are used in the United States as a binder in pavement construction. Liquid asphalt is generated as a byproduct of refining crude oil, and is typically shipped from areas with large refineries to major ports in specially designed heated tankers. The liquid asphalt is offloaded to barges, rail or tractor trailers for delivery to end users across the country.

Asphalt is a solid at room temperature, and must be heated to 250 - 300°F in order to liquefy and allow it to be shipped and pumped. Asphalt is typically rated by paving grade (PG), and identified by the lower and upper temperature ranges that the asphalt can withstand. A typical asphalt for New England would be PG 64-28, which would indicate that the asphalt can withstand temperatures from +64 to -28°C. The specific gravity of asphalt varies from 0.98 to 1.03, and varies with temperature and source. With the exception of temperature tolerance, the physical and chemical properties of asphalt can vary significantly from batch to batch, primarily due to differences of the crude oil source.

While liquid asphalt spills into waterways are relatively rare, little is known about the potential effects of such a spill, detection and behavior of the spilled product, or efficient methods of recovery. In 2006, the M/V Kelly Lee and three barges were involved in a collision which resulted in the release of an estimated 243,000 gallons of liquid asphalt into the Kentucky section of the Ohio River. Despite extensive cleanup efforts, only 13,000 gallons of product were recovered. Despite the quick response and availability of clean-up equipment, the majority of the liquid asphalt that was spilled was never found, demonstrating the unique nature of these spills and the need to tailor response techniques and equipment specifically to liquid asphalt.

Because the specific gravity of liquid asphalt is very close to that of water, slight chemical or physical differences from batch to batch may make the difference between the asphalt sinking or floating. In addition, the behavior may differ as a function of the salinity of the receiving water. In order to improve response to liquid asphalt spills in waterways, the Coastal Response Research Center hosted a workshop which brought together experts from the liquid asphalt industry, academia and government agencies to discuss the physical and chemical properties of asphalt, and develop recommendations for response.

II. WORKSHOP ORGANIZATION AND STRUCTURE

The workshop, held at the University of New Hampshire on October 21, 2009 consisted of seven plenary sessions where invited speakers presented their experiences with liquid asphalt and workshop participants discussed the characteristics, effects, fate, behavior, modeling and mitigation, detection, and recovery techniques. In the final session, the workshop participants developed a list of research priorities and steps forward. The workshop agenda (Appendix A), participants (Appendix B), and discussion topics were identified and developed by an organizing committee comprised of members of government, academia and industry.

III. BREAKOUT GROUP REPORTS

I. CHARACTERISTICS OF ASPHALT

The characteristics of asphalt can vary with each batch. Current commercial production of asphalt results in a specific gravity of 0.98 – 1.04. The temperature of the asphalt dictates many of its physical attributes. The specific gravity changes with varying temperatures; asphalt at room temperature typically has a specific gravity of 1.0 and will decrease as the temperature increases. Understanding this relationship is important in order to define when spilled asphalt will be suspended in the water column, sink, or float. Past experience has shown that spilled asphalt tends to form "pancakes" varying in diameter. As the exterior of the asphalt cools, it hardens into a crust which encases the warmer asphalt, resulting in a chunk of asphalt that becomes denser over time as it cools. Numerous questions remain, including: (1) What are the impacts of removing the hardened asphalt (or "crust") from the sea bottom? (2) Will removing the crust cause it to float? (3) Will the crusts release liquid if they crack? (4) What are the interactions between asphalt and suspended solids and how do they affect th buoyancy?

Liquid asphalt may interact with suspended solids in the water column, which can affect buoyancy of the mixture. If the specific gravity of the asphalt and the density of sediment are known, it may be possible to determine buoyancy. However, there are other factors, including particle shape, stickiness and particle size that may affect buoyancy. One potential research area is the size of pieces of spilled asphalt and specifically conditions that would result in formation of small pieces. Recently spilled asphalt may be more elastic until it is thoroughly cooled; thus, currents and larger waves are more likely to break a "pancake" into smaller pieces. Hardened asphalt is very difficult to break up.

The type of shoreline determines the break up time scale. Ultraviolet (UV) light exposure can cause oxidation of the hardened asphalt, which creates a more brittle surface and increases the likelihood of breakup.

II. EFFECTS OF ASPHALT

Spilled asphalt can injure biota via: direct toxicity resulting from exposure to the chemicals in asphalt, ingestion, smothering, and physical fouling. The impacts of ingestion by organisms (e.g., clams, mussels) are not well known. While the spilled asphalt is cooling, it is extremely sticky, and most anything that it comes into contact with will adhere, including biota. After the spilled asphalt hardens, it begins to weather and break into smaller pieces that can be ingested. Benthic invertebrates, fish and turtles are some of the species at risk of ingesting asphalt. There could potentially be chronic effects and little is known about bioaccumulation of asphalt constituents in the food web. The size of the pieces of spilled asphalt is a key aspect of understanding the potential effects. Toxicity varies with each batch because of differing compounds and their concentrations, and it is difficult to predict toxicity without detailed knowledge of the chemical makeup of the asphalt in question. It is believed that asphalt has minimum leachability once hardened. The fate and transport of asphalt is key in describing and understanding its effects on the biota.

III. FATE, BEHAVIOR, & MODELING OF SPILLED ASPHALT

In order to model the fate and behavior of spilled asphalt, there must be some initial knowledge or information assumed about the product. The physical and chemical properties of asphalt are crucial in predicting how it will move and react in the environment. However, because the properties of asphalt are variable, it is not always possible to make accurate predictions with models. Developing a model for predicting the fate and behavior of spilled asphalt will require additional research and information. At a minimum, the size, shape and volume of the spilled asphalt, as well as temperature, buoyancy and viscosity should all be input into a model, if possible. The temperature, density, and turbulence of the receiving water also affect the behavior of spilled asphalt. Heat transfer properties (e.g., thermal conductivity) will help predict where the asphalt will migrate soon after the spill. Modifying certain aspects of fate and transport models used to predict oil spills may help in developing a useful model for asphalt. Asphalt is similar to #6 oil and contains limited soluble components. Most asphalt spills in the past have not resulted in observed sheens, however, there have been some. Sheen production depends on the properties of the asphalt.

Once the asphalt sinks and hardens, a different model may be useful in predicting its fate. In some aquatic systems, the sunken asphalt may not move or degrade for a long time. The hardened asphalt is relatively non-biodegradable and resistant to chemical reaction. Hence, abrasion may be the main mechanism to affect the fate of the large pieces of sunken asphalt. In turbulent systems (e.g., high currents, large wave action, high flows in rivers) more movement of the sunken asphalt may lead to a faster break-up of the mass into smaller pieces.

IV. MITIGATION TECHNIQUES FOR SPILLED ASPHALT

Mitigation of liquid asphalt releases can occur in the brief window after the spill has occurred, but before recovery begins, and is meant to reduce the impact of the release. The majority of mitigation should occur before the asphalt sinks and hardens, and primarily is accomplished through recovery of floating or neutrally buoyant liquid or hardening asphalt. One important aspect to consider for mitigation planning is the physical characteristics of the receiving waters. The temperature and salinity of the water will affect the rate of hardening, entrainment of air, and buoyancy of the spilled asphalt. Two basic strategies were identified for mitigation: (1) corralling or redirecting floating asphalt with booms, barges, and/or boats; and (2) entanglement of solidifying liquid asphalt with a mesh material (e.g., chain link fence, snow fence). Both strategies would prevent the asphalt from sinking and smothering the benthic zone, or being lost to the current. In some situations with low current and relatively high temperatures, it may be possible to inject air at the spill site to encourage bubble entrainment in the asphalt mass and increase positive buoyancy. This method would likely only be effective within the first few minutes of the spill while the asphalt is highly malleable, and would need to be coupled with corralling or capturing.

V. DETECTION OF ASPHALT

Accurate and reliable detection of submerged asphalt is an important first step to recovery. Although there are many potential methods to detect sunken asphalt, most involved: remote detection, or direct detection. Remote detection generally uses conductivity, SONAR, or satellite imaging, the latter only being useful when the asphalt is still on the surface. Direct methods use Automated Underwater Vehicles (AUV) or Remotely Operated Vehicles (ROV), anchors or sorbents dragged or towed through the water column or along the bottom to identify areas containing sunken asphalt. Dragging/towing tends to have a low success rate due to the hardness of solidified and cooled asphalt, while AUVs and ROVs are very expensive, and require a general idea of where the asphalt is located because they cover such a small area. Remote sensing using SONAR or conductivity are promising techniques to locate submerged asphalt, however additional work is needed to reduce post processing time and validate the methods. In addition, accurate and detailed pre-spill bathymetry is required when using remote sensing to make the job of identifying submerged asphalt easier.

VI. RECOVERY

Workshop participants identified several potential recovery methods including environmental clamshell dredging or trawl recovery. Due to its viscosity when cooled, pumping asphalt is not an option. During recovery, smaller pieces of asphalt could be created and be driven downstream away from the recovery area. In order to mitigate this risk, two methods were proposed: control of water flow in the dredged or trawled area to prevent the asphalt from moving, or physical barriers to restrict movement of the asphalt. Control of the water flows and associated ice and debris flows could be accomplished with surface barges or boats, as well as submerged logs or booms. Physical barriers could include snare barriers, submerged fencing or other barriers staked along the bottom to capture and prevent loss of asphalt during recovery. Snare barriers are often used in slurry oil and coal tar spills and typically recover up to 75% of the product.

During all recovery methods monitoring must occur to ensure the operation is successful and complete. Validation methods to insure the asphalt is recovered include direct verification using divers, AOVs, ROVs, or a combination of remote sensing with ground truthing. Detection and recovery should be closely linked as, depending on the temperature and salinity of the system, the asphalt may remain somewhat elastic and therefore have significant mobility. Hence, constant tracking may be required. As with other environmental spills, an appropriate recovery endpoint must be chosen by the unified command based upon habitat, ecological/biological services, human use services, productivity, and the impact on system functionality. Less recovery of the asphalt may result in greater compensation to the stakeholders.

VII. RESEARCH NEEDS AND ACTIONS

Workshop members were asked to generate a list of R&D topics and actions needed regarding the behavior of liquid asphalt in aqueous environments:

Physical Properties: R&D
- Heat transfer properties of asphalt (i.e., time to solidify)
- Cooling/density relationships
- Behavior of spilled asphalt in marine environments, especially turbulent ones
- Behavior of asphalt for different types of spills, size distribution, floating/sinking, and changes in these characteristics with time
- Stickiness/tackiness properties
- Physical Properties of discharge, particle size, and bubble entrainment

Physical Properties: Actions
- Use OMHSETT to test characteristics of spilled asphalt
- Develop a model/table of asphalt characteristics in different environments

Detection: R&D
- Effectiveness of detection methods as a function of the size distribution of asphalt particles
- Improved underwater tracking
- Remote detection system
- Detection using electrical conductance
- Remote cleanup confirmation methods

Spill Prevention/Preparation: R&D
- Prevention of spilled product getting into water
- Better methods of containment
- Develop asphalt spill guidance document
- Research into the merits of leaving/recovering asphalt
- Development of effective transfer area containment

Spill Prevention/Preparation: Actions
- Link expected characteristics into model/guidance manual
- Area contingency plans need development in specific annexes re: asphalt
- Drills for Asphalt recovery and detection methods
- Consolidation of worldwide information

Recovery/Response: R&D
- Validating technologies with real world studies
- Research on alternative mitigation and recovery techniques
- Development of user-friendly methods for capturing smaller particles

- Development of booming/fencing system which can readily be available in terminals to minimize migration
- Develop a model to predict fate of spill
- Development of a more efficient method of clamshell recovery

Recovery/Response: Actions
- Prioritizing conditions and locations where more/less aggressive recovery methods can be used
- Develop risk assessment for asphalt spills
- Work Cost/benefit immediately

Toxicity: R&D
- Better understanding of acute and chronic toxicity
- Research on impact of ingested asphalt particles
- Research on conditions that produce ingestible particles

IV. CONCLUSION

Response to spills of liquid asphalt into the aquatic environment will likely need to be specifically tailored to individual site characteristics, as the appropriate response may vary with salinity, temperature, suspended solids, and asphalt composition and volume. Liquid asphalt spills are different than those of crude oil, and require specialized equipment and training. While experts at this workshop developed general response ideas, as the extensive list of basic research needs generated demonstrates, a significant amount of work needs to be done to ensure that response to future liquid asphalt spills is improved. As a step forward, the Coastal Response Research Center convened an asphalt working group, tasked with helping to address the R&D needs outlined in this report.