Response Strategies for Scenarios with Persistent Volatile Organic Compounds

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Abstract

711532. The objective of this paper is to discuss the adaptations to response strategies that must be considered in spill scenarios with persistent Volatile Organic Compounds (VOCs). By comparing two scenarios, one where VOCs evaporated before presenting prolonged risk to responder safety and one where they did not, this paper will show how Marine Spill Response Corporation had to adjust traditional approaches to Personal Protective Equipment, shift length, and response resources to account for prolonged presence of VOCs. Further, this paper also seeks to describe additional techniques not used in these responses that could further increase responder safety in a persistent VOC condition. Each of these strategies has a set of unique challenges that must be addressed so they can become a viable tool in the response toolbox.

Introduction

Marine Spill Response Corporation (MSRC)'s large and varied membership basis has provided opportunities to support spill response under a wide range of conditions. This provides a unique perspective to identify the impact various types of spill scenarios and conditions can have on response strategies. In 2019, MSRC supported two events occurring in similar environments that can serve as a useful comparison to identify the effect of the evaporation rates of Volatile Organic Compounds (VOCs) on response tactics. In one scenario, VOC evaporation occurred within expected timelines, given the conditions present at the spill (e.g. temperature, wind, etc.). Therefore, the traditional response strategies were effective as it relates to responder safety and other considerations. In the comparative event, the use of fire-fighting foam in the early stages of the incident prevented the evaporation of VOCs from the foam/product mixture released. Inhibited VOC evaporation required response strategies to be evaluated, and alternative approaches and strategies were deployed to account for responder safety under this persistent VOC condition. Though MSRC was ultimately successful in mitigating risks to responder safety both in the evaporative and non-evaporative conditions, there are additional techniques for reducing the risk of non-evaporative VOCs that should be considered for use in future spills.

I. VOLATILE ORGANIC COMPOUNDS AND THEIR RISK TO RESPONDER SAFETY

The presence of Volatile Organic Compounds (VOCs) and their potential impact to responder health and safety must be a primary consideration in every spill response. Though to varied degrees, VOCs are present in all forms of petroleum products. Their ability to cause health effects varies greatly: from VOCs that are highly carcinogenic, to those with little known health effects. The extent and nature of the health effect will depend on many factors, including levels of concentration and duration of exposure. The description of health effects below is provided by the National Institutes of Health (NIH, 2017):

Short-term exposure:

Health effects from VOCs may cause:

- Irritation of the eyes and respiratory tract
- Headaches
- Dizziness
- Visual disorders
- Memory problems

Long-term exposure:

Health effects from VOCs may cause:

- Irritation of the eyes, nose, and throat
- Nausea
- Fatigue
- Loss of coordination
- Dizziness
- Damage to the liver, kidneys, and central nervous system
- Cancer

VOCs pose a threat to responder health, particularly in the time frame immediately following the release of product when the concentration of VOCs at the air-water interface is the highest. Representing a wide range of organic compounds, of primary concern to responder safety are xylene, toluene, hexane and especially, benzene - a known carcinogen. Symptoms from mild exposure include dizziness, weakness, euphoria, headache, nausea, vomiting, tightness in chest, and staggering. If exposure is more severe, symptoms progress to blurred vision, tremors, shallow and rapid respiratory breathing, ventricular irregularities, paralysis, and unconsciousness. At high concentrations, benzene is also classified as an extremely flammable liquid with a flashpoint of 12 degrees F.

Typically, the presence of VOCs is only a concern in the time period immediately following the release. Though heavily influenced by environmental conditions such as temperature, humidity, wind presence, etc., VOCs are known to evaporate quickly. As time progresses and this evaporation occurs, the risks associated with VOCs at the site of the product source are greatly diminished. Common strategies for oil spill response are generally predicated on the idea that, within a relatively small window of time, VOCs will no longer present a high risk. Generally, before response operations have commenced and equipment has been deployed, VOCs have dispersed to acceptable levels.

However, in some scenarios the conditions inherent to the spill prohibit the evaporation of VOCs. Scenarios include, but are not limited to: continuous release; a release in a confined space; or the presence of an additive, in this case fire-fighting foam. In such scenarios, additional precautions must be taken and traditional response strategies should be reconsidered or revised to account for responder safety during recovery operations.

II. RESPONSE COMPARISONS

a. TRADITIONAL RESPONSE STRATEGIES WITH TYPICAL VOC EVAPORATION PATTERNS

MSRC was successful employing traditional response strategies to support the release of product in a major shipping port. An LNG tanker collided with two barges in a tow carrying a cargo with high potential for VOCs. As a result of the collision, the barge remained afloat but with a breached cargo tank, resulting in product leaking into a major ports shipping channel. The potential safety concerns inherent to the cargo, combined with the economic impact of the ship channel’s closure heightened the urgency for expedient success in this response. MSRC was activated shortly after the incident occurred and supported a full-scale response.

The reformate cargo’s composition typically includes a high percentage of VOCs and, as a result, air monitoring equipment was immediately deployed and readings were taken at each proposed worksite. Initial readings revealed that, common to most traditional oil spills, VOCs were not in a high enough concentration to be a significant concern for responder safety in most worksite locations.

MSRC’s initial response strategy focused primarily on the mechanical recovery of product leaked as a result of the collision. MSRC’s Oil Spill Response Vessel (OSRV), the S.T.

Benz Responder, was initially assigned to monitor for recoverable product in the ship channel. Four of MSRC's MARCO Skimmers were activated to collect in the area near the damaged barge. It was recognized that the potential for additional release of product was imminent as offloading operations began for the damaged barge. The area surrounding the barge was boomed, and the S.T. Benz Responder was repositioned close to the pocket of contained product (see figure 1). Recovery operations began using the high-volume skimmer outfitted on the S.T. Benz. Use of this high-volume skimmer resulted in collection of 90% of the content of this pocket overnight. Throughout this process, VOC presence was continually monitored. Responders working on MARCO skimmers nearest to the breach in the barge were required to wear respirators as the concentration of product, and associated VOCs, was highest there. However, for the majority of the worksite and recovery operations, VOCs had evaporated as they are expected to do, and conditions were safe to work.

Figure 1

Mechanical recovery activities were able to begin promptly in this scenario because VOCs evaporated quickly. As a result, the response saw an expedited timeline to resolution. Recovery operations were complete within 4 days of MSRC's activation. The full response was concluded in just one week. There were no recordable safety incidents and the shipping channel was opened quickly, minimizing additional economic impact. An independent media source cited the response as having limited impact to air and water quality, credited largely to the efficient and "rapid response" (Trevizo, 2019).

b. RESPONSE STRATEGIES WITH NON-EVAPORATIVE VOCS

There are some scenarios where VOC evaporation is inhibited by the conditions surrounding the spill. Another response supported by MSRC involved a scenario where the presence of fire fighting foam was mixed with released hydrocarbon product, preventing VOC evaporation. In this scenario, response strategies must be carefully evaluated and often altered to ensure responders are not exposed to hazards associated with these compounds.

The scenario began with a fire in a tank farm at a terminal, also located on a high-volume ship channel. This farm contained multiple tanks now compromised, totaling nearly 500,000 barrels of stored product, some with high VOC potential. Response efforts were initially focused on controlling the fire, and large amounts of water and fire fighting foam were applied in the tank farm area. The local Oil Spill Removal Organization (OSRO) initially activated for the response developed strategies for managing the water-foam-product mix in containment dike surrounding the tanks. Preventative boom was deployed and attempts were made at pumping the mixture out of the containment dike. Despite these efforts, however, the dike eventually breached and this mixture of stored product, water, and fire fighting foam was released into a nearby bayou and eventually into the ship channel.

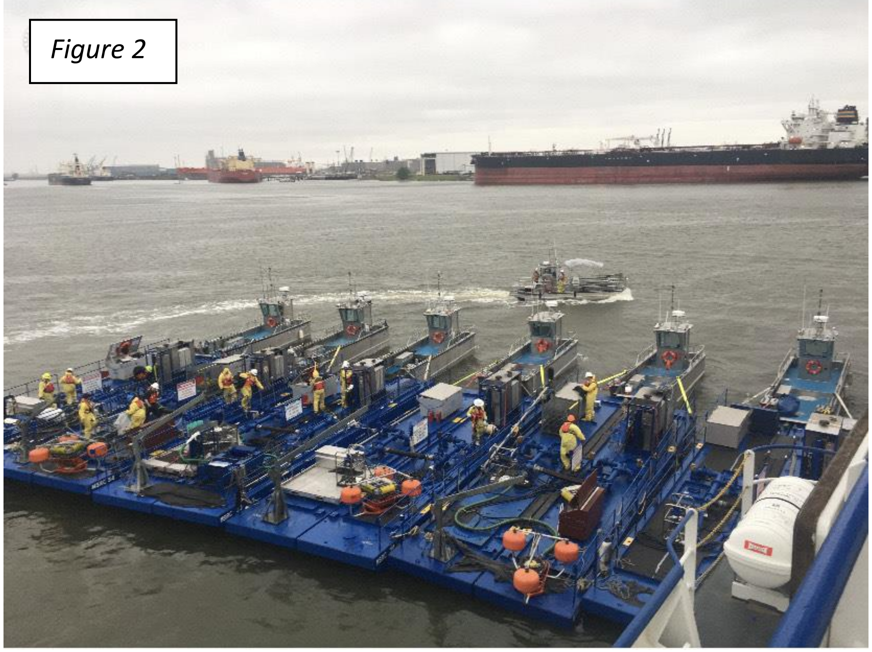
Six days following the initial fire event, MSRC was activated to respond to the release of product. Initially, the Responder Class OSRV, the Texas Responder, was requested for skimming operations in the channel. The presence of the fire-fighting foam continued to inhibit VOC evaporation and the potential presence of VOCs was a persistent concern for responder safety. Air monitoring equipment and personnel were deployed to accompany skimming operations. Initially following the activation of the Texas Responder, conditions remained favorable for responder safety. Operations were positioned to work with wind conditions, and air monitoring recordings revealed low enough concentrations of surface VOCs for responders to safely be in the area to facilitate skimming operations supporting on water recovery. However, as skimming operations progressed, the agitation of the fire-fighting foam in combination with changing wind conditions caused a spike in VOCs, and strategies had to be reassessed.

During this period of skimming operations performed by the Texas Responder, the channel had been reopened for barge traffic only. As a high-volume channel with a high degree of commercial activity, there were strong economic drivers to reopening the channel to deep draft traffic as quickly as safely possible. The potential for increased vessel traffic raised concerns that the 18-inch boom currently deployed would not be sufficient. Rather than the harbor-boom that would typically be used in this scenario, MSRC instead deployed 2,640 feet of its 67-inch Ocean Boom to maintain the contained product while channel traffic was reopened. The boom was deployed off the back deck of the Texas Responder, up river from the response area and was later pulled into place. Once the boom was in place, the resulting concentration of product increased the concerns around VOCs. MSRC’s Responder Class OSRVs are often primary assets for on-water recovery operations, as demonstrated in the ship/barge collision and MSRC’s longstanding history. With four distinct 1,000 barrel storage tanks, integrated oil/water separators, these vessels are specially built for product recovery operations. However, the fire-fighting foam used to control the initial fire, and the resulting atypically lengthy persistence of VOCs in this scenario forced MSRC to reconsider traditional tactics in favor of ones that were better suited for this response.

Since mechanical recovery operations disturbed the foam-water-product mixture, air monitoring readings detected VOC presence in levels unsafe for exposure to worksites unless responders were equipped with necessary PPE. However, the use of PPE in worksites did not resolve concerns around how to manage the safety of any off-duty responders lodging on the vessel, or of any non-respirator trained/fit-tested workforce on the ship (cooks, etc.). VOC concentrations were high enough that anyone on the Texas in any capacity was at risk for exposure. As a result, the Texas Responder was relocated away from the hot-zone area and changes were made to its operational purpose. Rather than serving in its traditional mechanical recovery capacity, it was repurposed as a mobile Staging Center for logistics and recovered product storage. With this change in scope for the Responder, MSRC turned instead to the diversity of its other equipment to be able to continue to successfully support recovery operations during this response.

Six Shallow Water Barge Systems (SBS) were brought on scene and four MARCO Skimming vessels were activated to continue skimming recoverable product, allowing MSRC to develop and enact safety management policies to protect responders in work zones, while removing those off-duty responders stationed on the Texas Responder (see figure 2).

Figure 2



Generally, conditions do not require MSRC Responders to wear Full-Face Respirator Masks in order to perform recovery operations. However, in this persistent VOC scenario, they were required for all personnel operating MSRC equipment performing skimming operations to protect them from the risk associated with exposure to harmful VOCs, namely benzene. The use of these respirators provides its own set of safety and logistical challenges that may have proved prohibitive were it not for MSRC's deep bench strength in qualified responders, as well extensive experience in response strategy and planning. Fatigue and heat stress, though always a consideration in any response, are made a paramount concern when personnel are required to wear this form of PPE. MSRC's national presence mitigated the challenge of maintaining a well-rested workforce, even with the use of respirators. Personnel from other MSRC regions as well as personnel from MSRC's Reservist Program were cascaded in to support the response, thus augmenting MSRC's responder staff to allow for frequent rotation of responders. Additionally, the respirator masks worn in this situation use cartridges that require change-out on a regular schedule, in this case every 4 or 8 hours depending on air monitoring readings. The logistical planning experience of MSRC personnel, combined with use of the Texas Responder as a mobile staging platform, allowed for the maintenance of these challenging change-out schedules.

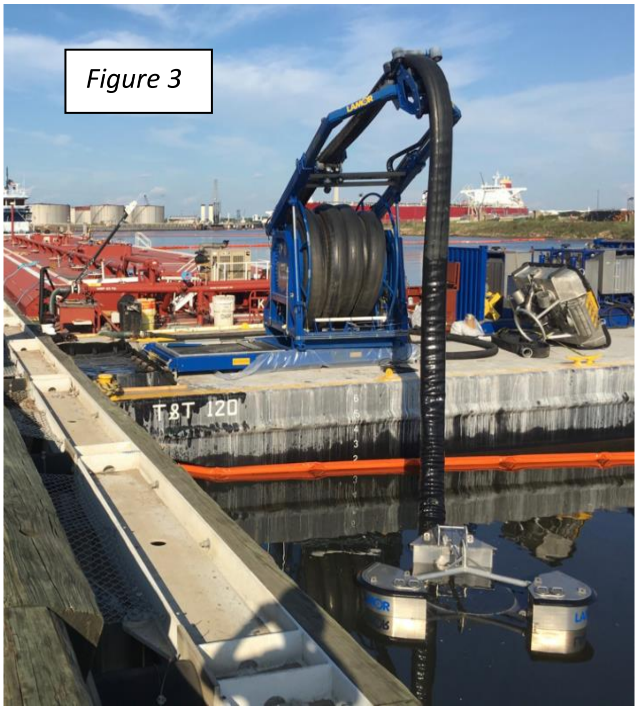


Figure 3

Other strategies were employed to reduce the risk of VOC exposure. Air monitoring, though usually only performed during site assessment and then only periodically as required, was instead done continuously. Further, equipment was relocated and reconfigured to increase distance between recovery operations and response personnel. A high-volume skimmer was put on an unmanned deck barge and the product was pumped to an adjacent recovery barge, also unmanned (see figure 3). The crew was able to operate the skimmer remotely and were able to monitor the skimming operation from a safe distance. Using this strategy allowed MSRC to keep personnel in a non-VOC environment, thus eliminating the risk of exposure.

III. STRATEGIES FOR RISK REDUCTION WITH PERSISTENT VOCS

Though MSRC was ultimately able to manage the risks to responder safety in an incident where VOCs remained persistent, there are improvements that should be evaluated to further reduce the risk profile for future incidents with conditions that similarly prohibit their evaporation. PPE, in this case, served as an effective safety barrier to prevent an occupational health risk to responders. However, there are other techniques and strategies that should be evaluated to reduce the reliance on PPE as the primary barrier such as autonomous techniques and polymerization.

a. AUTONOMOUS TECHNOLOGY

The use of autonomous technology reduces hazards to responder safety by removing proximity requirements between response personnel and incident sites that may contain high

VOC levels or other hazardous conditions. One application to explore is the use of unmanned aerial vehicles (UAVs) to perform air monitoring activities. UAVs would allow trained personnel to remain at a safe distance, while drones or other unmanned vehicles are deployed to collect air samples. This would, however, require accounting for the turbulence generated by the UAV operation to ensure that it does not interfere with the integrity of air sample collection. Further, there is currently limited availability of intrinsically safe UAVs on the market. Because of the potential fire hazard present in these environments, UAVs must be intrinsically safe in order to be deployed to an incident site.

In a situation like the tank-fire scenario where the product mixture to be collected contained an additive prohibiting VOC evaporation, concerns persisted for other response personnel beyond those used to support air monitoring activities. In this and other similar scenarios, advancements in autonomous technology to support recovery operations will provide solutions to eliminate the risk to personnel by removing them from direct contact with the product. MSRC is actively evaluating the potential for additional, more advanced automation in recovery operations. Through a partnership with an autonomous technology company, MSRC has already conducted a successful demonstration of the use of an autonomous command system on board a MSRC-owned skimming vessel in a simulated recovery exercise. This demonstration validated that the following activities could be performed remotely: autonomous vessel control from an remote location, electronic navigational chart-based mission planning, autonomous waypoint tracking, autonomous grid tracking, collaborative autonomy for multi-vessel operations, and wireless, remote payload control to deploy onboard boom, skimmer belt, and other response equipment (Maritime-Executive, 2019)

Though demonstrations of the technology have been successful, use of autonomous technology still has unique challenges that industry must address, many which relate to identifying ways to account for the processes typically supported by human intervention. For example, debris is often present during skimming operations and may result in nearly constant manual intervention to clear skimmers to continue collection. An autonomous skimming solution should consider either more advanced forms debris protection, or a method to remotely clear skimmers of debris should it get entrapped. Further, collection strategies must be frequently evaluated and altered to maintain maximum efficiency for the conditions particular to that spill, or even that window of time within a spill. Autonomous technology will account for the observational capabilities and experience currently provided by an on-site responder to adjust operations in changing conditions. Remote observation and subsequent re-positioning by an offsite responder may serve as one potential solution, but as the technology supporting these autonomous activities grows more sophisticated, the use of artificial intelligence and algorithm-based adjustment will provide even more automation. Industry should also consider the investment in human capital required to support these advancements. Technological skills are seeing an increased importance in this autonomous environment but must also be combined with the skills that have traditionally led to a successful career as a responder. Despite these challenges, advancements across industry continue to progress. Autonomous vessel deployment of herding agents and air monitoring equipment are being considered. Development and incorporation of artificial intelligence will also help make more data-driven response decisions, resulting in an increase in overall spill efficiency.

b. SOLIDIFIERS

Another potential approach to reducing hazards faced by responders in these conditions involves the use of solidifiers to chemically alter the product to making recovery safer.

Solidifiers work by forming a physical bond with the oil, increasing viscosity until the "oil becomes solidified into a rubber-like solid" (National Response Team, 2007). This solidification has the potential to suppress the release of VOCs into the atmosphere, thereby making it safe for responders to be in the work zone.

The use of solidifiers in oil spill response is not a new concept, yet since their introduction in the 1960's, they have seen only limited application (Fingas, 2003). There are many challenges associated with their use, made even more complicated by application to a marine, rather than terrestrial spill. Challenges include:

- Boom deployments in pre and post solidifier application scenarios: Both applying solidifier prior to boom and deployment and after present their own challenges that must be evaluated. Applying the solidifier before boom deployment requires techniques to deploy boom through a now viscous product. If already deployed, the solidified product has the potential to adhere to the boom, making collection challenging
- Collection techniques: Traditional techniques for collection, namely belt/brush/weir skimmers may no longer be effective once solidifiers are applied. Manual recovery techniques, e.g. nets, shovels, rakes, etc. should be considered for effective collection
- Disposal: Can recovered product be considered a recyclable product after solidifiers are applied? Are there facilities that are designed to handle this solidified product
- Education of the response community: The various stakeholders involved with a response (contractors, regulators, public, etc) need to be educated and made comfortable with this non-traditional technique.

Faced with these challenges, MSRC has begun exploring various products cited in the National Contingency Plan Product Schedule as Solidifiers to determine if there may be application for use in a future spill.

Conclusion

Each response remains unique and must be addressed on a case by case basis. MSRC was able to successfully respond in a scenario of persistent VOCs by repurposing response assets, bringing in more maneuverable equipment, cascading personnel from other locations to enable frequent shift rotation (thus facilitating the use of Full-Face Respirators), and contracting continuous air monitoring. Even with the ultimate success of the response, there are clear opportunities to improve the methods for responding to scenarios with persistent VOCs that should be considered by response community. These techniques have their own set of challenges that should be addressed to ensure their functionality during a response.

References

Fingas, Merv. 2013. Review of Solidifers: An Update 2013. Prince William Sound Regional Citizens Advisory Council. Spill Science, Edmonton, Alberta: 1-10.

National Institutes of Health. 2017. Volatile Organic Compounds (VOCs). U.S. National Library of Medicine: Tox Town.

National Response Team Science and Technology Committee. 2007. Application of Sorbents and Solidifiers for Oil Spills. 1-6.

The Maritime Executive. 2019. MARAD to Trial Autonomous Spill Response Vessel. Maritime-executive.com

Trevizo, Paula. 2019. Quick Response Limits Impact of Ship Channel Spill. Houston Chronicle. www.houstonchronical.com