Biofuels: Release Prevention, Environmental Behavior, and Remediation (BIOFUELS-1)

EXECUTIVE SUMMARY

Biofuels are a relatively new category of renewable transportation fuels whose manufacture and consumption are increasing due, in part, to usage mandates and incentives, both in the United States and abroad. In the United States, federal mandates have increased the volume of renewable fuel required to be blended into U.S. transportation fuels from 9 billion gal in 2008 to 36 billion gal in 2022 (Public Law 110-140). Biofuels are expected to account for a large proportion of the renewable fuel increase. A number of U.S. states have passed mandates on the use of biofuels or biofuel blends and/or have producer or retailer incentive programs, labeling requirements, or state fleet fuel purchase/use requirements. Other countries and the European Union have also adopted renewable fuel use targets and offer biofuel tax credits for use of biofuels in the transportation sector.

Definitions of "biofuels" in current use vary. The ITRC Biofuels Team defines the term as liquid fuels and blending components produced from renewable biomass feedstocks used as alternative or supplemental fuels for internal combustion engines. Biofuels are often blended with a conventional petroleum-based fuel to form a biofuel blend, such as E85 (approximately 85% ethanol, 15% gasoline) and B20 (approximately 20% biodiesel, 80% diesel).

The introduction and expanded use of any new transportation fuel poses challenges with respect to understanding its potential impacts to the environment; biofuels are no exception. Except for low-percentage biofuel blends (such as E10, approximately 10% ethanol, 90% gasoline), biofuels differ from conventional fuels with respect to their physical, chemical, and biological properties. Because of the different properties of biofuels and the biofuel component of higher-percentage biofuel blends, these fuels exhibit either known or reasonably projected differences in environmental behavior in comparison to conventional fuels.

The differences in biofuel properties, and therefore environmental behavior, can be evaluated using a multimedia approach. Multimedia evaluations gauge the potential human health and environmental impacts of contaminants in a given fuel or fuel additive. Such an approach was first proposed and recommended by an independent Blue Ribbon Panel convened to advise the U.S. Environmental Protection Agency on the impacts of methyl tertiary-butyl ether–blended gasoline on the environment (USEPA 1999a). To develop regulatory and technical guidance, the ITRC Biofuels Team focused on selected regulatory aspects of biofuel releases using the multimedia evaluation approach as a framework. This framework can be used for both currently commercially available and future biofuels and incorporates a risk-based approach to release characterization and remediation strategies.

An assessment of the potential frequency of biofuel releases depends on the likely release points within the biofuel supply chain infrastructure coupled with consumption (current and future projections). Once the fuels are manufactured, the supply chains for biofuel and petroleum differ primarily with respect to bulk fuel transportation from manufacturing facilities to bulk depots/supply terminals. For example, bulk biofuels (such as denatured fuel ethanol and biodiesel) are transported from manufacturing facilities mostly by tanker truck, railcar, and tank barges, as compared to petroleum, which is transported from refineries to bulk depots/supply

terminals mostly through pipeline networks. Therefore, an increased likelihood of releases from transportation accidents for biofuels exists.

Additional release scenarios arise from the use of incompatible materials in equipment within the supply chain, such as storage tanks, hosing, piping, dispensers, etc. For example, the solvent nature of biofuel can scour the sediment, sludge, rust, and scale built up in an underground storage tank system deposited from previously stored conventional fuels. Furthermore, leak detection equipment may fail if not compatible with the biofuel being stored. Methods to prevent these releases include the use of compatible materials and adjusting management practices.

Once released into the environment, short-term response strategies generally focus on containment and recovery of released biofuel, elimination of any immediate threats, and prevention of transport to sensitive receptors such as waterways and conduits such as sewer lines. If the released biofuel is not contained and recovered, its fate and transport depend highly upon site conditions, the release scenario, and the fraction of biofuel in the release. Nonetheless, some key biofuel properties—including physical-chemical properties, biodegradation, and interactions with other potential contaminants—can provide insight into their fate, transport, and potential impacts to the environment.

The physical and chemical properties of biofuels offer insight into their mobility in different environmental media. Physical properties of fuels, such as the specific gravity and viscosity, can play a role in determining the extent of impact to soil and water. Chemical properties can significantly influence the persistence of volatile fuels in ground and surface waters. For example, fuels with high Henry's law constants (the ratio of vapor pressure to aqueous solubility) tend to easily partition from the aqueous phase into the atmosphere. Hydrophilic fuel components with high aqueous solubility, low Henry's law constant, and low sorptivity (e.g., ethanol) are dissolved in the aqueous phase and transported at rates similar to that of flowing groundwater. Conversely, hydrophobic fuel components (e.g., benzene) preferentially partition to organic materials and are transported at rates much lower than that of water.

Biodegradation rates are affected by several factors, including contaminant concentration, complexity of the chemical structure, the presence of microorganisms, and bioavailability. Biofuels, such as biodiesel, ethanol, and butanol, have simple structures and are readily biodegradable under both aerobic and anaerobic conditions (Corseuil et al. 1998; Lovanh, Hunt, and Alverez 2002; Feris et al. 2008). The relatively rapid and ubiquitous biodegradation of biofuels in soil and groundwater induces changes to the biological and geochemical environments, including stimulation of microorganisms, exertion of oxygen demand, and production of biomass/exudates and methane.

Methane can be produced at petroleum sites, but the volumes are often small, and any methane in soil gas typically degrades rapidly. In contrast, biofuels and biofuel blends have the potential for producing significantly more methane due to their biodegradable nature, but it may not be detected until months after the release. The accumulation of methane in some scenarios can represent a potentially high-risk situation that may require emergency mitigation measures or the use of engineering controls (ITRC 2007b). Methane can become a risk driver for a biofuel release investigation, requiring additional site characterization and longer-term monitoring to assess delayed generation. Biofuel release site conceptual models should therefore consider potential methane accumulation and methane vapor migration pathways (Jewell and Wilson 2011). In addition, an evaluation for potential remobilization of preexisting contamination following a biofuel release should be considered.

Site characterization following a biofuel release may include monitoring for biofuel-related parameters such as methane and methane precursors, specific biofuel contaminants, and the potential dissolved oxygen depletion in surface water. The physical properties of biofuels may require some changes to a site investigation design, such as the use of wire-wrapped or shorter well screens for groundwater monitoring and the use of material-compatible equipment, sampling for additional parameters, and the use of additional field screening equipment (meters).

Once characterized, development of a long-term response strategy for a biofuel release requires consideration of a number of factors, including the type of biofuel, extent and magnitude of the release, regulatory threshold contaminants, and source receptor pathways. A risk-based approach to remediation can be followed to tailor responses to site-specific conditions and risks, as allowed by state policies. These long-term response strategies may include any or all of the following: monitored natural attenuation (MNA), controls (institutional or engineered), and/or contaminant source reduction through implementation of an active remedy.

Because of the biodegradable nature of current widely used biofuels (ethanol and biodiesel), MNA may be an amenable remediation strategy. Under some scenarios, accumulation of methane from biofuel biodegradation may require special attention when MNA is used because of a potential explosive hazard risk. Additionally, because of the potential lag time before methane may be generated, long-term monitoring and/or engineering controls should be evaluated as part of a site management strategy.

In some cases, an active remedy may be desired as part of the response strategy. However, few case studies involving active remediation for biofuels currently exist. Therefore, the ITRC Biofuels Team conducted a detailed analysis of remedial technologies that have been used or are likely to be used when the remediation driver is a biofuel or biofuel degradation product or may be used when petroleum contaminants are the remediation driver but biofuel remediation is also desired. Evaluated technologies include those that have been documented in biofuel release case studies and those identified by states as having been used for biofuel remediation. These technologies were then evaluated with respect to their ability to exploit the physical, chemical, and biological properties of biofuels to achieve remedial goals. For site-specific remediation projects, a technology evaluation and selection process was developed based on considerations for evaluating expected effectiveness, such as the targeted medium; contaminant of concern; and the physical, chemical, or biological property of the contaminant of concern targeted for remediation.

Stakeholder concerns associated with the release prevention, environmental behavior, and remediation of accidental biofuel releases generally depend on the location and timing of the incident, emergency response, and long-term management. In most cases, chronic, small total volume releases impact fewer stakeholders unless the situation is not addressed for an extended period of time. However, the other extreme of sudden catastrophic, large total volume releases can be of immediate and enduring concern to stakeholders.

Response to different biofuel release scenarios, from emergency response to longer-term site management, differ somewhat from well-established petroleum release response procedures. Because of the different biological, chemical, and physical properties of biofuels, the release causes and fate and transport in the environment vary somewhat, with consequences for site characterization considerations and longer-term response strategy development. These property differences provide insight into the differences between biofuels and petroleum fuels, providing a framework for not only currently available biofuel, but also emerging biofuels.