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Gasoline risk management: A compendium of regulations, standards, and industry practices

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ABSTRACT

This paper is part of a special series of publications regarding gasoline toxicology testing and gasoline risk management; this article covers regulations, standards, and industry practices concerning gasoline risk management. Gasoline is one of the highest volume liquid fuel products produced globally. In the U.S., gasoline production in 2013 was the highest on record (API, 2013). Regulations such as those pursuant to the Clean Air Act (CAA) (Clean Air Act, 2012: § 7401, et seq.) and many others provide the U.S. federal government with extensive authority to regulate gasoline composition, manufacture, storage, transportation and distribution practices, worker and consumer exposure, product labeling, and emissions from engines and other sources designed to operate on this fuel. The entire gasoline lifecycle—from manufacture, through distribution, to end-use—is subject to detailed, complex, and overlapping regulatory schemes intended to protect human health, welfare, and the environment. In addition to these legal requirements, industry has implemented a broad array of voluntary standards and best management practices to ensure that risks from gasoline manufacturing, distribution, and use are minimized.

1. Introduction

Gasoline is a liquid fuel intended for use in spark-ignition, internal combustion engines and the U.S., gasoline production in 2013 was the highest on record (API, 2013). It is typically composed of hundreds of paraffinic, olefinic, naphthenic and aromatic hydrocarbons (generally referred to as PONA) refined from petroleum (crude oil) in the C4–C12 carbon-chain length range (API, 2008). In addition to the hydrocarbon base, gasoline also can contain a variety of blending components, such as oxygenates (e.g., alcohols, ethers). During gasoline manufacture, crude oil is fractionated, the fractions are chemically modified, and resulting refinery process "streams" are blended to meet specific physical and chemical property requirements (e.g., octane rating, sulfur limits, oxygen content, etc.), which comply with government regulations and industry performance and quality specifications. The property requirements, in turn, influence the chemical composition of gasoline.

This article summarizes current U.S. risk management measures for gasoline at selected stages in its lifecycle (see Fig. 1)—from the point where the gasoline is produced at a refinery, through its delivery at the retail station pump, and concluding with its use as a motor fuel. It highlights both regulatory controls and current industry standards and practices during the lifecycle. The start and end points chosen for this analysis are appropriate for evaluating gasoline risk management from the viewpoint of a chemical regulatory framework. Accordingly, this analysis focuses on the management of gasoline, including:

- Registration requirements, including testing and formulation requirements, for gasoline, its components and additives;
- Controlling potential safety and environmental risks from gasoline during refining and distribution operations;
- Hazard communication and protecting occupational safety and health during manufacturing and handling operations; and
- Controlling potential risks of gasoline to end-users/consumers.

2. Regulation of gasoline and gasoline additives

Federal regulations administered by the U.S. Environmental Protection Agency (EPA) control the constituents in gasoline and the gasoline additives in order to minimize the environmental and public health consequences, and ensure proper performance when used as a motor fuel. Gasoline regulations may require the reduction of certain constituents (e.g., benzene) during refining,

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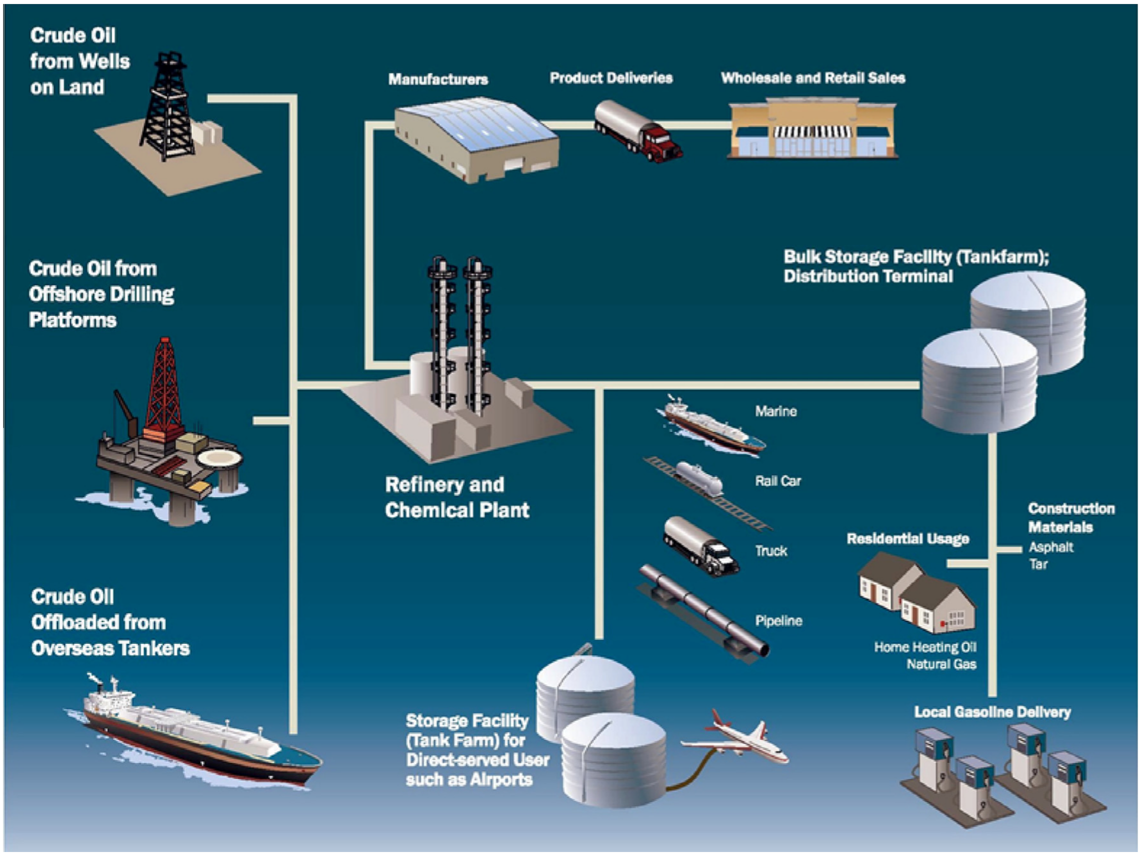

Fig. 1. The gasoline lifecycle.

or the inclusion of oxygenates and additives, such as detergents, prior to retail sale. Individual states may impose further, more stringent controls to address local air quality concerns. As a result of these layered requirements, the range of gasoline and additive formulations available for manufacture, distribution, and use is strictly controlled.

In addition to government regulations, industry contracting and purchasing specifications generally require that gasoline meet third-party voluntary performance and quality standards, such as those developed by the American Society for Testing and Materials (ASTM) International. As some standards are incorporated into state fuel quality regulations, these third-party standards effectively are mandatory. As gasoline must be used in, and subjected to, a wide variety of mechanical, physical, and chemical environments, its formulation must provide satisfactory engine performance over a wide range of operating conditions.

The Clean Air Act (CAA) (Clean Air Act, 2012: § 7401, et seq.) is the primary mechanism by which EPA may seek to "control or prohibit the manufacture, introduction into commerce, offering for sale, or sale" of any motor vehicle or non-road engine fuel or fuel additive if, in its judgment and after considering the available scientific and economic data, the Agency determines that a fuel, fuel additive, or their emissions could endanger public health or impair the operation of motor vehicle emission control devices (Clean Air Act, 2012: § 7545(c)). The CAA specifies criteria that gasoline must meet prior to retail sale, and prohibits the presence or use of certain constituents and mandates the addition of others to ensure gasoline presents minimal impact on human health and the environment.

EPA effectuates this mandate through its implementing "Fuels Regulations" found at 40 C.F.R., Parts 79 and 80. Any manufacturer or importer seeking to introduce gasoline or gasoline additives into commerce must first register the product with the Agency. Depending on the type and nature of the gasoline or additive, the Agency may require an extensive battery of environmental fate and human effects testing as part of the registration process. In addition to the fuel registration requirements, over time EPA has regulated the properties of gasoline and gasoline additives in a number of ways such as the following (all of which are discussed in greater detail in Section 2.2):

- Banning the use of lead-containing additives in automotive gasoline;
- Requiring the use of detergent additives to prevent engine deposits;
- Regulating volatility (vapor pressure) to reduce evaporative emissions from gasoline;
- Limiting the average and maximum sulfur content of gasoline;
- Limiting the average and maximum benzene content of gasoline;
- Requiring the use of reformulated gasoline (RFG) in certain geographic areas; and
- Setting anti-dumping requirements that limit emissions of specified pollutants from gasoline.

2.1. Testing requirements for registration

Companies seeking to register gasoline or gasoline additives into U.S. commerce must submit to EPA a chemical description of their product, as well as technical, marketing, and health-effects information (Registration of Fuels and Fuel Additives, 2013: § 79.51). This information is intended to allow EPA to determine the likely combustion products and other emissions that may be released into the environment during the distribution, sale, and use of the gasoline or additive. Specifically, all registrants must provide basic registration data, including product and manufacturer identification, intended use and concentration, and the specific composition of the product. In addition, the registrant must provide EPA with information on the product's distribution and use profile, including data on total annual production and marketing distribution (Registration of Fuels and Fuel Additives, 2013: § 79.59(b)). Beyond the basic registration data, the Agency's information requirements follow a three-tiered approach. The first two tiers generally apply to most gasoline and gasoline additive manufacturers with limited exceptions for certain specialized additives and small businesses.

As part of the Tier 1 data requirements, gasoline and additive manufacturers must submit to EPA the identity and concentration of certain emission products and any available information on health and welfare effects from exposure to the whole and speciated emissions from the gasoline or additive to be registered (Registration of Fuels and Fuel Additives, 2013: § 79.52). Tier 1 data requirements include both literature and health effects database searches, as well as emissions characterization data. The literature and database searches should provide to EPA all the information available on the product, including the chemical composition and potential adverse effects of the whole combustion and evaporative emissions, relevant combustion emission fractions, as well as the individual emission products. The search must extend back at least 30 years before the registration application, and also must capture data on "welfare" effects such as plant and animal responses to the emissions exposures.

For Tier 1, gasoline and additive manufacturers also must submit to EPA information characterizing emissions from the evaporation and combustion of gasoline or the additive/gasoline mixture in a motor vehicle. Manufacturers are responsible for generating, collecting, and sampling the combustion emissions and, if applicable, the evaporative emissions of their product, and to determine the identity and concentration of individual emission products. This includes characterizing:

- combustion emissions, by determining the concentration of total hydrocarbons, carbon monoxide, nitrogen oxides (NO_x), and particulates;
- total evaporative hydrocarbon emissions;
- individual volatile hydrocarbon compound species, aldehydes, ketones, alcohols, ethers, polycyclic aromatic hydrocarbon (PAH) compounds, and nitrated polycyclic aromatic hydrocarbon (NPAH) compounds, as defined in 40 C.F.R. § 79.52 (b)); and
- semi-volatile and particulate phases of combustion emissions to identify concentrations of PAH detected to 0.001 micrograms, and poly-chlorinated dibenzodioxins and dibenzofurans (PCDD/PCDFs) detected to one part per trillion (ppt) in the air of the combustion emissions.

Manufacturers may rely on existing characterizations in lieu of conducting new tests provided that the data were obtained from tests of either the product in question or a gasoline or gasoline/additive mixture that meets the grouping criteria as defined in 40 C.F.R. § 79.56. The existing characterization information also must have been generated with the use of laboratory practices that are of high quality (per 40 C.F.R. § 79.52 (b)) and properly documented, also per the procedures set out in 40 C.F.R. § 79.52 (b).

Manufacturers must submit Tier 2 data, if they determine that the Tier 1 literature and data searches have failed to yield comparable existing information (as defined in the rule) from previously performed studies. EPA retains final authority to determine whether the Tier 1 data are adequate based on criteria set out in the rule, including the age of the literature search data, as well as the scope and quality of the prior studies. The Tier 2 data must be obtained through testing designed to detect potential adverse health effects from the inhalation of gasoline or gasoline/additive emissions. This generally involves producing emissions from a vehicle or engine in a laboratory setting, exposing laboratory test animals to these whole emissions, and conducting a 90-day subchronic inhalation study to examine general systemic and organ toxicity, including pulmonary effects (Registration of Fuels and Fuel Additives, 2013: § 79.53). Ancillary tests that allow the assessment of several specific health effect endpoints (carcinogenicity, mutagenicity, teratogenicity, reproductive toxicity, and neurotoxicity) also may be conducted within the same exposure schedule. In addition, a fertility assessment also may be coordinated within the same time frame in order to assess reproductive and teratogenic effects.

Following the submission of Tier 1 and Tier 2 data, EPA may at its discretion require gasoline and additive manufacturers to conduct additional health-effects testing if the Agency determines that remaining uncertainties concerning the significance of observed health effects, welfare effects, and/or emissions exposures prevent it from reasonably estimating the potential risks of exposure from the gasoline or additive (Registration of Fuels and Fuel Additives, 2013: § 79.54). These may include additional carcinogenicity, reproductive, and neurotoxicity tests. The Agency may also require the submission of additional technical and marketing information. The purpose of these submissions is to ensure that EPA has a comprehensive suite of information on the likely effects from the evaporation or combustion of gasoline and gasoline additives. In addition to the health-effects data and testing requirements under the Fuel and Fuel Additives Registration Program, EPA also requires manufacturers to submit a quarterly and annual report on gasoline and additive production volumes and the concentration range of each additive used in a designated fuel in order to maintain their registration(s) (Registration of Fuels and Fuel Additives, 2013: § 79.5).

A public website is being created that will permit viewing of the reports submitted to EPA under the CAA 211(b) registration program. That website address will be www.211bResearchGroup.org. These reports can also be accessed at Regulations.gov with Docket ID Number: EPA-HQ-OAR-2003-0065.

2.2. Physical, chemical and emission standards

Section 211 of the CAA directs EPA to implement specific numerical limitations on particular gasoline components and physical and emission properties to further address health and environmental risks. EPA has codified these standards at 40 C.F.R, Part 80. Part 80 establishes protective limitations and conditions for gasoline and gasoline/additive mixtures, as well as recordkeeping and reporting requirements.

Subpart B of Part 80 prohibits the introduction of leaded automotive gasoline into U.S. commerce and establishes controls concerning certain measures of gasoline volatility (Regulation of Fuels and Fuel Additives, 2013: §§ 80.22–80.33).

Volatility is a property of a liquid fuel that influences its evaporative characteristics. EPA limits the Reid Vapor Pressure (RVP) of gasoline introduced into commerce during the Summer months in order to reduce evaporative emissions of volatile organic compounds (VOCs)[1] that contribute to ground-level ozone (Volatility Regulations for Gasoline and Alcohol Blends Sold in Calendar Years 1992 and Beyond, 1990: 23,658).

Section 211(k) requires cities classified as "severe" with respect to non-attainment of the ozone national ambient air quality stan-

[1] 40 CFR § 51.100(s) defines "volatile organic compounds (VOCs)" as any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions. Further to the definition, there is a list of specific chemicals exempt from the VOC definition because they have "negligible photochemical reactivity."

dard to use reformulated gasoline (RFG). Until 2006, RFG needed to contain a minimum of 2.0% oxygen by weight. Refiners typically used ethanol or methyl tertiary-butyl ether (MTBE) as oxygenates. Congress amended Section 211(k) of the Act to eliminate the oxygenate content requirement for RFG (Energy Policy Act, 2012: §§ 1502–1504).

The Antidumping[2] Program under Subpart E sets limits on conventional (i.e., non-reformulated) gasoline emissions of nitrogen oxides (NO_x), benzene, and toxic air pollutants[3] (Regulation of Fuels and Fuel Additives, 2013: §§ 80.90–80.106). NO_x emission reductions abate adverse respiratory effects and the formation of ground-level ozone and particulate matter (PM) (USEPA, 2010). Most of the standards established under the Antidumping Program have been replaced by newer programs.

Subpart F ensures the integrity of reports submitted under the regulations by requiring attestation of these reports by an independent certified public accountant or an internal auditor certified by the Institute of Internal Auditors (Regulation of Fuels and Fuel Additives, 2013: §§ 80.125–80.133). Subpart G sets forth requirements for adding detergent to gasoline. Detergent additives prevent the formation and accumulation of deposits in engines and fuel supply systems, which has been shown to reduce NO_x, hydrocarbon, and carbon monoxide emissions in engine exhaust, while enhancing fuel economy (Regulation of Fuels and Fuel Additives: Certification Standards for Deposit Control Gasoline Additives, 1996: 35,310).

Subpart H phased in increasingly stringent gasoline sulfur content limitations and implements a Sulfur Credit[4] Trading Program (Regulation of Fuels and Fuel Additives, 2013: §§ 80.180–80.415). The regulations currently prohibit refineries from producing reformulated or conventional gasoline containing sulfur in excess of 80 ppm (ppm) for any single gallon of gasoline produced and a 30 ppm limit on sulfur in gasoline on an average annual basis (Regulation of Fuels and Fuel Additives, 2013: § 80.195). EPA estimated that the program resulted in a 90% reduction of average national levels of sulfur in gasoline by 2006 (USEPA, 2014). EPA also estimated that limiting the level of sulfur in gasoline to 30 ppm would result in about 700,000 tons of NO_x reductions per year from light duty vehicles and trucks by 2020 (Control of Air Pollution From New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements, 2000: 6730). In April 2014, EPA promulgated a final rule with additional (Tier 3) regulations on gasoline to limit annual average gasoline sulfur content to 10 ppm (Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards, 2014: 23,414).

The Benzene Control Program of Subpart L establishes benzene concentration limits in gasoline supported by a benzene credit trading program (Regulation of Fuels and Fuel Additives, 2013: §§ 80.1200–1363). Beginning January 1, 2011, refiners had to limit the benzene content in reformulated and conventional gasoline to an annual average of 0.62% by volume in the finished gasoline. Additionally, starting July 1, 2012, a refinery's annual average benzene concentration must not exceed 1.3% by volume, without the use of benzene credits[5] (Regulation of Fuels and Fuel Additives, 2013: § 80.1230). EPA estimates that these limits will reduce total benzene emissions from on-road and off-road mobile sources, portable fuel containers and gasoline distribution approximately 12% by 2015 (Control of Hazardous Air Pollutants From Mobile Sources, 2007: 8454). EPA expects the benzene and sulfur content limits of Subparts H and L to provide greater air toxics reductions than under the RFG and Antidumping Programs (Control of Hazardous Air Pollutants From Mobile Sources, 2007: 8477). As a result, and effective January 1, 2011, these requirements replaced the annual average toxics emission requirements of the RFG and Antidumping Programs and the annual average benzene content limit of the RFG Program (Control of Hazardous Air Pollutants From Mobile Sources, 2007: 8477 and Regulation of Fuels and Fuel Additives, 2013: § 80.815(d)(1)(ii)). The Benzene Control Program requirements also replaced the Mobile Source Air Toxics (MSAT) Program for most gasoline blends, including conventional and reformulated gasoline (Control of Hazardous Air Pollutants From Mobile Sources, 2007: 8477).

3. Regulation of gasoline manufacture at the refinery

Gasoline manufacturing operations are subject to stringent environmental control regulations enacted under the major environmental statutes such as the Clean Air Act (CAA) (Clean Air Act, 2012: § 7401, et seq.) and the Clean Water Act (CWA) (Clean Water Act, 2012: § 1251, et seq.). These regulations govern various emission and discharge sources within the refining operations. The CAA significantly restricts refinery emissions to the atmosphere of harmful air pollutants, and the CWA protects human health and the environment against risks stemming from intentional and inadvertent discharges to water from refineries. Regulations codified by EPA under these statutes impose significant testing, recordkeeping, and reporting requirements to ensure and demonstrate compliance.

3.1. Regulation of refinery emissions to air

Two regulatory schemes under the CAA regulate refinery emissions to the atmosphere. New source performance standards (NSPSs) limit refinery emissions of several "criteria pollutants," including volatile organic compounds (VOCs), sulfur oxides, PM, CO and NO_x. Additionally, national emission standards for hazardous air pollutants (NESHAPs) control refinery emissions of "hazardous air pollutants" (HAPs).

3.1.1. New source performance standards

Section 111 of the CAA requires EPA to establish New Source Performance Standards (NSPSs) for new and modified stationary sources within particular industrial categories to control emissions of criteria air pollutants (e.g., ozone, carbon monoxide, particulate matter, sulfur dioxide, nitrogen dioxide, and lead) (Clean Air Act, 2012: § 7411). EPA has promulgated NSPSs for refinery processing units and other equipment used at petroleum refineries in order to limit and control air emissions of criteria pollutants and also emissions of VOCs (including petroleum), which are precursors to the formation of ozone in the atmosphere. Below the NSPSs for refinery processing units are provided as an example of these standards.

Petroleum refinery processing units must meet the NSPSs codified at 40 C.F.R., Part 60, Subparts J and Ja (Standards of Performance for New Stationary Sources, 2013: §§ 60.100–60.109a). These regulations include emissions limitations and work practice standards for fluid catalytic cracking (FCC) units, fluid coking units, delayed coking units, fuel gas combustion devices, and sulfur recovery plants. Subpart J applies to certain

[2] "Antidumping" in the context of gasoline regulations means not allowing refiners to sell gasoline that is a lower quality (i.e., higher levels of regulated constituents and emission products) than they had previously sold in those areas were only conventional gasoline is required.

[3] Under CAA § 211(k)(10), "toxic air pollutants" means the aggregate emissions of benzene, 1,3-butadiene, polycyclic organic matter, acetaldehyde and formaldehyde.

[4] "Sulfur credit" is a concept where a refiner that does better than the stated average requirements for sulfur content in gasoline generates a credit that could be sold to another refiner that cannot meet the requirements. (See 40 CFR, Part 80, Subpart H-Gasoline Sulfur).

[5] "Benzene Credits" is a concept where a refiner that does better than the stated average requirements for benzene content in gasoline generates a credit that could be sold to another refiner that cannot meet the requirements. (See 40 CFR § 80.1275).

refinery equipment constructed, reconstructed, or modified in various specified timeframes.

Under Subpart J, FCC unit catalyst regenerator emissions of PM, from coke burn-off, cannot exceed 1.0 kilogram/metric ton (kg/MT) (2.0 lb/ton (lb./ton)) (Standards of Performance for New Stationary Sources, 2013: § 60.102). Additionally, gases emitted by these units cannot exhibit greater than 30% opacity or contain CO in excess of 500 ppm (Standards of Performance for New Stationary Sources, 2013: §§ 60.102–60.103).

Subpart J further prohibits the burning, in fuel gas combustion devices, of fuel gas containing hydrogen sulfide in excess of 230 mg/dscm (0.10 gr/dscf) (Standards of Performance for New Stationary Sources, 2013: § 60.104). To facilitate compliance, refiners must install, calibrate, maintain, and operate continuous emissions monitoring systems on the regulated equipment (Standards of Performance for New Stationary Sources, 2013: § 60.105). In 2008, EPA updated the refinery processing unit emission standards. Subpart Ja prescribes new, more stringent limits for those refineries constructed, reconstructed or modified after May 14, 2007. These standards will further reduce PM emissions by approximately 1300 tons/year, sulfur dioxide (SO2) emissions by approximately 17,000 tons/year, NO_x emissions by approximately 11,000 tons/year, and VOC emissions by approximately 200 tons/year (Standards of Performance for Petroleum Refineries, 2008: 35,861).

3.1.2. National emission standards for hazardous air pollutants (NESHAPs)

Section 112 of the CAA directs EPA to develop a list of "major" and "area" stationary sources that emit listed HAPs and establish national emission standards for those sources, known as NESHAPs. NESHAPs for major sources must reflect the maximum achievable control technology (MACT) available, while NESHAPs for area sources can reflect generally available control technology (Clean Air Act, 2012: § 112(d)). Major sources include any stationary source, or group of stationary sources located within a contiguous area and under common control, that emits or has the potential to emit at least 10 tons per year of a single HAP or 25 tons/year of any combination of HAPs (National Emission Standards for Hazardous Air Pollutants for Source Categories, 2013: § 63.2). Area sources include stationary sources of HAPs that do not qualify as major sources.

Petroleum refineries that qualify as major sources must comply with the NESHAPs codified at 40 C.F.R., Part 63, Subparts CC and UUU. The Appendix to Subpart CC lists the HAPs of concern for refining operations, such as benzene, toluene, ethylbenzene, and xylenes (BTEX). Together, these NESHAPs require monitoring and reduction of emissions from process vents, storage vessels, marine tank vessel loading operations, gasoline loading rack operations, equipment leaks, and wastewater treatment systems.

For process vents on FCC units, refiners can control emissions by employing a variety of control devices, including cyclones, electrostatic precipitators, and wet scrubbers (National Emission Standards for Hazardous Air Pollutants for Source Categories, 2013: § 63.1579). For other covered emissions sources, the NESHAPs require more specific control measures. For example, refiners must install vapor collection and processing systems on gasoline loading racks that will reduce emissions to 10 mg of total organic compounds per liter of gasoline loaded into cargo tanks (National Emission Standards for Hazardous Air Pollutants for Source Categories, 2013: § 63.650). Of course, for all covered emission sources refiners must perform testing, conduct monitoring, maintain records, and submit reports to EPA concerning HAPs emission production and control.

3.2. Regulation of refinery discharges to water

The CWA prohibits unpermitted discharges to waters of the U.S. from gasoline manufacturing operations. The primary regulatory regimes applicable to petroleum refineries are the National Pollutant Discharge Elimination System (NPDES) permitting program, the National Pretreatment Program, and the Oil Pollution Prevention Program.

3.2.1. NPDES permitting program for intentional discharges to navigable waters

Under Section 402 of the CWA, petroleum refineries must obtain NPDES permits in order to discharge industrial wastes and other pollutants from a point source into navigable waters of the U.S. (i.e., surface waters–Clean Water Act, 2012: § 1342). Note: Under the CWA, the EPA has the authority to delegate the NPDES program to states for implementation; in those instances, the state program operates the permitting program. NPDES permits contain industry-specific, technology-based and/or water quality-based effluent limits and pollutant monitoring and reporting requirements. EPA has codified its technology-based effluent limitations for the petroleum refining point source category at 40 C.F.R., Part 419 (Petroleum Refining Point Source Category, 2013: §§ 419.10–419.57).

These regulations specify different effluent discharge limitations (based on production rates) according to the specific pollutant or pollutant property controlled and refining operation covered. The controlled pollutants include total suspended solids (TSS), hexavalent chromium, and phenolic compounds, among others. Covered refining operations include topping, cracking, lube oil manufacturing processes, and petrochemical operations.

In general, the effluent limitations represent the best available control technology economically achievable by the petroleum refining industry. Effluent limitations for new sources are also more demanding than those applicable to existing sources. When EPA last amended the effluent limitations for the petroleum refining point source category, it estimated incremental industry-wide reductions in discharges of 286,000 lb per year for total chromium, 18,300 lb per year for hexavalent chromium, and 75,000 lb per year for phenolic compounds (Petroleum Refining Point Source Category, Effluent Limitations Guidelines, 1985: 28,516 and 28,520).

In addition to effluent guidelines, NPDES permits for refinery operations include water-quality-based permit limits for discharges to water bodies not meeting ambient water quality standards. These permit limits for such water bodies are designed to protect ambient water quality and meet the ambient standards.

3.2.2. National pretreatment program for intentional discharges to publicly-owned treatment works

In accordance with CWA § 307(b), numerical pretreatment effluent guidelines apply to discharges from petroleum refineries to publicly-owned treatment works (POTWs) (Clean Water Act, 2012: § 1317(b)(1)). These technology-based standards are also codified at 40 C.F.R., Part 419. Specifically, a refinery's total daily discharge to a POTW cannot contain more than 100 mg/L of oil and grease and 100 mg/L of ammonia. In addition to these limits, new sources must not discharge more than 1 mg/L per day of total chromium to a POTW. In addition to the pretreatment effluent guidelines, indirect discharge permits for refinery discharges to POTWs also include local limits developed by the POTW for prevention of pollutant pass-through or interference with POTW treatment processes, and compliance with POTW sludge disposal limits. Attainment of its NPDES permit effluent limits often also apply to refineries.

3.2.3. Oil spill prevention, notification, and cleanup

Section 311 of the CWA prohibits the discharge of oil or another substance determined to be harmful if the amount meets or exceeds an EPA-designated "reportable quantity" into or upon navigable waters of the U.S. and adjoining shorelines, or the waters of the contiguous zone, or other specified waters (Clean Water Act, 2012: § 1321). The oil pollution prevention regulations, codified at 40 C.F.R., Part 112, require certain non-transportation-related facilities to prepare and implement Oil Spill Prevention, Control and Countermeasure (SPCC) plans. Note that transportation-related facilities, such as pipelines and common carriers, must prepare oil spill prevention and response plans under separate regulatory schemes.

A facility must develop, certify, and implement a SPCC plan if it has an aggregate aboveground oil storage capacity exceeding 1320 U.S. gallons or a completely buried oil storage capacity exceeding 42,000 U.S. gallons not regulated under federal Underground Storage Tank (UST) regulations and, due to its location, could reasonably be expected to discharge oil in quantities that are harmful into covered waters (Oil Pollution Prevention, 2013: § 112.1). The regulations cover oil of any type and in any form and mixture, including petroleum, fuel, sludge, oil refuse, oil mixed with wastes other than dredged soil, and oils from renewable sources. SPCC plans must identify the type and location of stored oil and lay out discharge prevention measures, secondary containment in the event of a release, discharge or drainage controls, and countermeasures for discharge discovery, response, and clean-up.

Additionally, under the Oil Pollution Act (OPA) (Oil Pollution Act, 2012: § 2701, et seq.), facilities covered by the SPCC regulations that pose a threat of substantial harm to covered waters due to their location and volume of oil storage (over 1 million gallons) must prepare and submit to EPA a Facility Response Plan (FRP). FRPs are intended to assist in preparing for and responding to a worst case discharge. Facilities must demonstrate the availability of response resources in a timely manner, thereby reducing a discharge's impact and severity (Oil Pollution Prevention, 2013: Part 112, Subpart D—Response Requirements). FRPs are also intended to aid local and regional response authorities to better understand the potential hazards and response capabilities in their area. The OPA imposes strict liability on owners and operators of facilities responsible for oil spills.

4. Risk management in gasoline storage, transportation and distribution operations

A variety of statutes and industry standards ensure the safe storage, transportation, and distribution of fuel by establishing baseline standards for the design and construction of equipment, imposing strict handling procedures and emissions controls, and requiring the preparation of hazard warnings and accident prevention plans. These standards serve to protect workers, public health, and the environment.

4.1. Pipeline safety standards

The federal pipeline safety regulations prescribe a comprehensive scheme of minimum safety standards and reporting requirements for pipeline facilities used in the transportation of "hazardous liquids," including gasoline and other petroleum products. The U.S. Department of Transportation (DOT) promulgated these regulations, codified at 49 C.F.R., Part 195, under the Pipeline Safety Statute (Pipeline Safety Statute, 2012: § 60101, et seq.). The Pipeline and Hazardous Materials Safety Administration (PHMSA) within the DOT administers these regulations.

Pipeline facilities must meet performance standards applicable to the design, construction, testing, and operation and maintenance of pipeline systems. Design standards, for example, include specifications for internal and external pipeline pressure, new and used pipe materials, valves, fittings, and closures (Transportation of Hazardous Liquids by Pipeline, 2013: §§ 195.100–195.134). Pipeline operators must prepare and follow a procedures manual for conducting normal operations and maintenance activities and handling abnormal operations and emergencies. They must also establish and conduct a continuing emergency response employee training program (Transportation of Hazardous Liquids by Pipeline, 2013: §§ 195.402–195.403). To assure regulatory compliance, pipeline facilities must submit reports on an annual basis and in the event of an accident or discovery of a "safety-related condition," such as general corrosion or leaks (Transportation of Hazardous Liquids by Pipeline, 2013: §§ 195.48–195.64).

4.2. Hazardous materials regulations

The hazardous materials regulations (HMR) govern the transportation of gasoline and other hazardous materials by highway, rail, water, and air. These regulations mitigate the risks to life, property, and the environment inherent in the transportation of hazardous materials by imposing requirements related to shipping papers, packaging materials, hazard communication, safe handling, incident reporting, training, and security. The PHMSA also administers these regulations, codified at 49 C.F.R., Parts 105–180, in accordance with the Hazardous Materials Transportation Act (Hazardous Materials Transportation Act, 2012: § 5101, et seq.). The HMR, coupled with the pipeline safety regulations, control all modes of transportation of fuels.

To ensure appropriate hazard communication, gasoline transporters must affix specific placards indicating that gasoline is a class 3 flammable liquid, to each side of a bulk package, freight container, unit load device, transport vehicle or rail car containing any quantity of gasoline (Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans, 2013: § 172.542). Additional labeling and marking requirements apply to gasoline shipments in order to communicate information such as volume and appropriate handling (Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans, 2013: §§ 172.300–172.450). The HMR also require use of specific packaging materials that depend on whether gasoline is transported in bulk or non-bulk form. Bulk gasoline must be packaged in specialized rail cars or cargo tanks, while non-bulk gasoline may be packaged in steel or aluminum drums, among other types of containers (Shippers—General Requirements for Shipments and Packagings, 2013: §§ 173.202 and 173.242).

In addition, the regulations limit the maximum quantity of gasoline on passenger transport modes. Passenger-carrying aircraft or rail cars cannot transport packages containing more than 5 L of gasoline, whereas cargo-only aircraft can transport packages containing up to 60 L of gasoline (Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans, 2013: § 172.101 (Hazardous Materials Table)). The regulations prohibit motor vehicles carrying passengers for hire from transporting any quantity of gasoline, unless no other practicable means of transportation is available (in which case only a limited quantity may be transported) (Carriage by Public Highway, 2013: § 177.870).

4.3. Marine occupational safety and health standards

All tank ships and barges carrying benzene or benzene-containing liquids in bulk must comply with the marine occupational safety and health standards of 46 C.F.R., Part 197. The regulations require operators of covered vessels to either ensure adherence to permissible exposure limits (PELs) for benzene, or require employees to wear respirators and personal protective clothing and equipment in areas where the airborne benzene concentration can reasonably be expected to exceed PELs (General Provisions: Marine Occupational Safety and Health Standards, 2013: §§ 197.515, 197.520, and 197.535).

The regulations set forth benzene PELs of 1.0 ppm, as averaged over an 8-h period, and 5.0 ppm, as averaged over any 15-min period (General Provisions: Marine Occupational Safety and Health Standards, 2013: § 197.505). These PELs mirror those established by the Occupational Safety and Health Administration (OSHA) for the on-shore work-place. In addition, employers must provide information to workers on covered vessels regarding benzene hazards, including a material safety data sheet (MSDS) and training on benzene risks and protective measures (General Provisions: Marine Occupational Safety and Health Standards, 2013: § 197.565). Employers also must provide, and employees exposed to benzene must submit to, initial and periodic medical examinations. If the examination demonstrates abnormal health conditions, employers must remove employees from areas where the airborne benzene concentration may exceed 0.5 ppm (a concentration lower than both PELs) (General Provisions: Marine Occupational Safety and Health Standards, 2013: § 197.560 and Appendix C to Subpart C of Part 197).

4.4. Chemical accident prevention provisions

Facilities that produce, handle, process, store, or distribute threshold quantities of toxic or flammable substances listed under Section 112(r) of the CAA, including various gasoline constituents, must comply with the chemical accident prevention provisions of 40 C.F.R., Part 68. These provisions aim to prevent accidental releases of substances that can cause serious harm to the public and environment from short-term exposures and to mitigate the severity of releases that do occur.

The regulations require operators of covered facilities to implement a risk management program. This program involves assessing the hazards that may result from accidental releases, implementing accident prevention measures, and developing an emergency response program (Chemical Accident Prevention Provisions, 2013: § 68.12). The centerpiece of the regulations is the preparation and submission to EPA of a risk management plan (RMP). The RMP must describe the facility and regulated substances handled, the general accidental release prevention program and chemical-specific prevention steps, the facility's 5-year accident history, the emergency response program, and planned changes to improve safety (Chemical Accident Prevention Provisions, 2013: §§ 68.150–68.195).

EPA exempted several substances, when used in certain mixtures, from the required threshold quantity determination. Such an exemption exists for gasoline being stored or distributed for use as fuel in internal combustion engines (Chemical Accident Prevention Provisions, 2013: § 68.115(b)(2)(ii)). EPA specifically exempted gasoline because the Agency found it generally does not meet the criteria for a National Fire Protection Association (NFPA) flammability hazard rating of four (severe hazard), and it does not represent a significant threat to the public of vapor cloud explosions (List of Regulated Substances and Thresholds for Accidental Release Prevention, 1998: 640 and 641–642).

4.5. Regulation of air emissions from gasoline distribution and dispensing facilities

Gasoline distribution and dispensing facilities must also comply with NSPS and NESHAP emission limitations for criteria and hazardous air pollutants. These standards, together with the NSPSs and NESHAPs applicable to petroleum refineries (addressed in Section 3), control harmful air emissions from nearly every stage of the gasoline lifecycle.

4.5.1. New source performance standards

Bulk gasoline terminals must meet the NSPS codified at 40 C.F.R., Part 60, Subpart XX (Standards of Performance for New Stationary Sources, 2013: §§ 60.500–60.506). These regulations limit VOC emissions from loading racks used to deliver gasoline into tank trucks. Specifically, operators must equip loading racks with a vapor collection system designed to collect the total organic compounds (TOC) vapors displaced from tank trucks during product loading (Standards of Performance for New Stationary Sources, 2013: § 60.502(a)). Emissions from the vapor collection system must not exceed 35 mg of TOC per liter of gasoline loaded (mg TOC/L gasoline), or 80 mg TOC/L gasoline loaded where loading racks are equipped with existing vapor processing systems (Standards of Performance for New Stationary Sources, 2013: §§ 60.502(b)–(c)). In addition, operators must only load gasoline into vapor-tight gasoline tank trucks (Standards of Performance for New Stationary Sources, 2013: §§ 60.502(e)). To assure adherence to this requirement, they must obtain vapor tightness documentation and follow other specified procedures. The regulations also prescribe testing methods, inspection, and recordkeeping and reporting requirements.

4.5.2. National emission standards for hazardous air pollutants (NESHAP)

Hazardous air pollutant emission limitations apply to major and area source gasoline distribution facilities, as well as area source gasoline dispensing facilities (GDFs).

4.5.2.1. Major source gasoline distribution facilities. Bulk gasoline terminals and pipeline facilities that qualify as major sources under the CAA must comply with emission limits and management practices set forth at 40 C.F.R., Part 63, Subpart R (National Emission Standards for Hazardous Air Pollutants for Gasoline Distribution Facilities, 2013: §§ 63.420–63.429). These requirements apply to all storage tanks, cargo tanks (railcars and tank trucks), loading racks, and equipment leaks within the gasoline distribution facility. Facilities must control VOC emissions from large storage tanks (i.e., those at or above 20,000 gallons capacity) by installing either specified floating roofs and seals or a closed vent system and control device reducing emissions by 95% (National Emission Standards for Hazardous Air Pollutants for Source Categories, 2013: § 63.423 (cross referencing 40 C.F.R. § 60.112(b)–Standards of Performance for New Stationary Source, 2013)). Total organic compound emissions from cargo tanks must also be controlled through use of vapor collection and processing systems and must not exceed 10 mg TOC/L of gasoline loaded (National Emission Standards for Hazardous Air Pollutants for Source Categories, 2013: § 63.422(b)). Control efficiencies for vapor recovery units range from 90% to over 99%, depending on both the nature of the vapors and the type of control equipment used (USEPA, 2008). EPA has assumed a collection efficiency of 99.2% for tank trucks passing the MACT-level annual leak test; 98.7% for trucks passing the NSPS-level annual test; and 70% for trucks not passing one of these required annual leak tests.

4.5.2.2. Area source gasoline terminals, pipeline facilities, and dispensing facilities. All other facilities in the gasoline distribution network that do not qualify as major sources must comply with the NESHAP requirements for area sources at 40 C.F.R., Part 63, Subparts BBBBBB and CCCCCC (National Emission Standards for Hazardous Air Pollutants for Source Categories, 2013: §§ 63.11080–63.11132). The former subpart covers bulk gasoline terminals, bulk gasoline plants, pipeline breakout stations and pipeline pumping stations, and generally imposes emission limits on the same operations covered under Subpart R (discussed above). The latter subpart governs emissions from gasoline dispensing facilities (GDFs), which include stationary facilities used for dispensing gasoline into the fuel tank of an on-road or off-road vehicle or vehicle engine (National Emission Standards for Hazardous Air Pollutants for Source Categories, 2013: § 63.11132). Subpart CCCCCC limits emissions occurring during the off-loading of gasoline from cargo tanks into storage tanks located at a GDF.

State environmental agencies, which normally enforce the NESHAP regulations, can and do impose even more stringent limits on these emission sources. For example, many states require the installation of a vapor balance system between the storage tank at a GDF and the cargo tank (termed Stage I vapor recovery) (Ill. Admin. Code, Tit. 35, §§ 215.583, 218.583, and 219.583 and Mich. Admin. Code, r.336.1606–r.336.1703). Vapor balance systems minimize the release of gasoline vapors during GDF storage tank filling operations through a combination of pipes and hoses that collect displaced gasoline vapors from the storage tank and route them back into the cargo tank. The gasoline terminal then recovers the vapors when the cargo tank returns to reload. The control efficiency of vapor balance systems ranges from 93% to 100% (USEPA, 2008 at 5.2–14). Organic emissions from underground tank filling operations at a GDF employing a vapor balance system and submerged filling are not expected to exceed 40 mg/L (0.3 lb/1000 gallons) of transferred gasoline.

4.6. Regulation of releases to water from gasoline distribution facilities

Facilities involved in the storage, transportation, and distribution of gasoline must also obtain NPDES permits covering discharges to waters of the U.S. and comply with local pretreatment standards applicable to discharges to POTWs. For more information on NPDES permit and POTW pretreatment requirements, see Sections 3.2.1 and 3.2.2.

Storage and distribution facilities also must prepare and implement oil spill prevention and response plans. Under 49 C.F.R., Part 194, onshore pipeline facilities that, due to their location, could reasonably be expected to cause substantial harm to the environment by discharging oil into navigable waters of the U.S. or adjoining shorelines must prepare and submit to the PHMSA an oil spill response plan. The response plan must include procedures and a list of resources for responding to a worst case discharge and to a substantial threat of such a discharge (Response Plans for Onshore Oil Pipelines, 2013: § 194.107). Employee training and response plan review and update procedures must also be included. Off-shore pipeline facilities must also prepare an oil spill response plan and submit the plan to the Bureau of Safety and Environmental Enforcement of the U.S. Department of the Interior for approval under 30 C.F.R., Part 254 (Oil-Spill Response Requirements for Facilities Located Seaward of the Coast Line, 2013: §§ 254.1–254.54).

Similarly, 49 C.F.R., Part 130 prescribes prevention, containment, and response planning requirements applicable to motor vehicles and railcars that transport oil (Oil Spill Prevention and Response Plans, 2013: §§ 130.1–130.33). Marine vessels must also prepare oil spill response plans under 33 C.F.R., Part 155 (Oil or Hazardous Material Pollution Prevention Regulations for Vessels, Tank Vessel Response Plans for Oil, 2013: §§ 155.1010–155.1070). The U.S. Coast Guard must approve the plan prior to the vessel handling, storing, or transporting oil on navigable waters of the U.S. or any other port or place subject to U.S. jurisdiction.

4.7. Industry standards for equipment and handling procedures

Numerous standards have been developed to cover all aspects of gasoline storage, transport, and handling. These standards cover the design, construction, and operation of virtually every piece of equipment from aboveground and underground storage tanks, to piping, terminals and loading racks, to tank trucks, rail cars, and barges.

4.7.1. Operation of gasoline transport, storage, and marketing facilities

The American Petroleum Institute (API) has an array of standards that cover the various types of facilities that transport, store, and ultimately dispense gasoline. For example, API Standard 2610—Design, Construction, Operation, Maintenance & Inspection of Terminal and Tank Facilities—covers the design, construction, operation, inspection, and maintenance of petroleum terminal and tank facilities associated with marketing, refining, pipeline, and other operations. Covered topics range from site selection and spacing, to pollution prevention and waste management, safe operations, fire prevention and protection, tanks, dikes and berms, mechanical systems (pipe, valves, pumps, and piping systems), product transfer, corrosion protection, structures, utilities and yard, and removals and decommissioning.

4.7.2. Storage tanks

API has developed a series of standards and guidelines addressing the design and construction of gasoline storage tanks and their safe operation. Gasoline can be stored in either aboveground storage tanks (ASTs), typically the type of tank used at terminals (i.e., tank farms), or underground storage tanks (USTs), typically used a retail locations (i.e., gas stations). API Standards 620, Design and Construction of Large, Welded, Low-Pressure Storage Tanks, currently in its Eleventh Edition, and 650, Welded Tanks for Oil Storage, are the 2 most commonly used industry standards for ASTs in gasoline service. There are also numerous supporting standards and publications for ASTs that cover tank inspection, repair and reconstruction (API Std 653), leak detection (API Publ 334), venting (API Std 2000), cathodic protection (API Std 651), linings for the bottoms of AST (API Std 652), to name just a few areas. For shop-fabricated and smaller field-erected tanks, the Steel Tank Institute provides its Standard, SP001. There is a similar set of standards for USTs, which have been the subject of extensive federal and state programs to replace all existing USTs and replace them with new tanks designed to prevent leaks. Commonly referenced API standards for USTs include Installation of Underground Petroleum Storage Systems (API RP 1615), Closure of Underground Petroleum Storage Tanks (API RP 1604), and Storing and Handling Ethanol and Gasoline-ethanol Blends at Distribution Terminals and Filling Stations (API RP 1626).

4.7.3. Static electricity during loading and unloading

A static electric charge can be created by the movement and agitation of gasoline during the loading and unloading process, requiring that tanks, transport containers, transfer lines, and so forth be electrically bonded together and grounded. Bonding ensures that connected objects (for example, the loading tube and the tank truck) have the same electrical charge, thereby eliminating the chance for a static spark to be created as the two are disconnected. Grounding allows any built-up static charge to dissipate to ground. There are numerous standards that mandate bonding and grounding in the design and operation of equipment used to store and handle flammable and combustible liquids, including NFPA 1, Fire Code™; NFPA 30, Flammable and Combustible Liquids Code; NFPA 30A, Code for Motor Fuel Dispensing Facilities and Repair Garages; NFPA 70B, Recommended Practice for Electrical Equipment Maintenance; IEEE Standards 81 and 142; and the International Fire Code and others. NFPA 77, Recommended Practice on Static Electricity, and API RP 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents, provide detailed discussions on static electric charge, the evaluation of charge generation, and bonding and grounding. Additionally, electrical devices and installations in specific designated areas where flammable materials are handled should comply with the requirements for Class I Group D hazardous locations (as covered by Chapter 5 of NFPA 70, National Electrical Code).

5. Controlling worker exposure to gasoline

The petrochemical industry has numerous programs to address the safety and health of workers. In the U.S., regulations addressing worker safety and health have been established by the U.S. Occupational Safety and Health Administration (OSHA), state and local agencies. In addition, national standard setting organizations such as the National Institute for Occupational Safety and Health (NIOSH), American Conference of Governmental Industrial Hygienists (ACGIH)®, and the National Fire Protection Association (NFPA), have developed standards, programs, and voluntary exposure limits for workers engaged in all aspects of the petrochemical industry. Epidemiology research has also been conducted to evaluate the effects on workers in refining and gasoline handling occupations. This research is discussed in a separate paper under this series "Gasoline Toxicology: Overview of Regulatory and Product Stewardship Programs" (Swick et al., 2014).

Although there are many occupational safety and health programs in the industry addressing potential fire and physical hazards, this section will focus on the regulations and programs related to worker exposure to hazardous substances. As it relates to gasoline production, handling and distribution, worker exposure programs focus on controlling both exposure to gasoline itself and also exposures to hazardous constituents of gasoline (e.g., benzene). Given the high volatility of gasoline and many of its constituents, inhalation exposure is often the focus of occupational exposure programs; however, there are also procedures and programs in place to limit dermal exposure. Occupational exposure programs include both setting and implementing limits for exposure (i.e., occupational exposure limit (OEL), permissible exposure limit (PEL), Threshold Limit Values (TLV®)) and also hazard communication and training programs to educate workers about potential hazards and properly handling procedures.

There is a considerable difference between the composition of whole gasoline (in its liquid form) and the composition of the gasoline vapor to which an individual could be exposed. Thus, in considering the exposure regulations addressed in this section, it is important to recognize that although a chemical may be a constituent of gasoline in its liquid form, its potential for exposure may not necessarily be proportional to its quantity in the gasoline. For example, light chemical constituents such as pentanes will be much more present in gasoline vapor as compared to aromatic hydrocarbons (BTEX, C9 aromatics that have much lower vapor pressures). More information regarding this can be found in "Inhalation Toxicity of Gasoline and Fuel Oxygenates: Generation and Characterization of Test Articles" (Henley et al., 2014) that is also a publication in this series.

It is also important to consider the additive feature of the occupational exposure regulations and standards discussed in this section. Worker exposure limitations are imposed on top of the already considerable emissions reductions and exposure limitations achieved through the imposition of air emissions controls to reduce HAPs and ozone precursors. As production operations have fugitive and other releases to meet air regulations (see Section 3.1), there has been a side benefit of lowering occupational exposure. Commensurate reductions in consumer and general public exposure also are realized when improvements in emission controls on automobiles, filling stations, and petroleum operations (refineries, tank farms, etc.) are taken into consideration.

5.1. Occupational exposure limits

5.1.1. OSHA permissible exposure limits

OSHA has established a series of inhalation occupational exposure limits—permissible exposure limits (PELs)—for hazardous substances in 29 CFR § 1910.1000 (Z-Tables) or in individual chemical standards (e.g., 29 CFR § 1910.1028 for benzene). While there is not a specific PEL for gasoline, there are PELs for a number of constituents including pentane, n-hexane, heptane, benzene, toluene, xylenes, cumene, and octane. Additionally, several gasoline additives or blending components, such as ethanol, also have PELs.

PELs establish a full-shift (8-h) time-weighted average (TWA) exposure for a substance. This means average exposure concentration for the entire 8-h period needs to be below the PEL. A worker could be exposed to a concentration above the PEL for a short period as long as the 8-h average exposure is below the PEL. However, in some cases OSHA also establishes ceilings of short-term exposure limits (STELs) in order ensure that short-term exposures (typically 15 min or less) do not go above a certain limit.

In addition to PELs, OSHA health standards, such as the one for benzene, establish medical surveillance and monitoring programs and require regular evaluations of workers who are regularly exposed to these chemicals. Such programs ensure that a worker's health is being evaluated and protected beyond simply meeting the OEL requirements. For substances with health standards, OSHA typically establishes an "action level" at 50% of the PEL. This means that if workers have exposures to greater than 50% of the PEL, they would be required to participate in various aspects of the regulation (e.g., medical surveillance, training, etc.). In many instances, the OSHA PELs have become dated and as such industry has often more recently adopted OELs established by ACGIH or internal company standards based on most recent information.

5.1.2. ACGIH threshold limit values

The ACGIH®, has been recommending occupational exposure limits (OELs) for a wide variety of chemical and physical workplace

Table 1
Threshold limit values for typical gasoline constituents.

Substance	TLV® (8 h TWA) (ppm)	STEL (15-min) (ppm)
Gasoline	300	500
Possible constituent chemicals		
Benzene	0.5	2.5
Cumene (isopropylbenzene)	50	
Cyclohexane	100	
Cyclopentane	600	
Ethylbenzene	20	
Heptane (all isomers)	400	500
n-Hexane	50	
Hexane (other isomers)	500	1000
Nonane (all isomers)	200	
Octane (all isomers)	300	
Pentane (all isomers)	600	
Toluene	20	
Xylene (all isomers)	100	150

hazards for decades. The most common OEL for chemical substances, including gasoline and many of its constituents (Table 1), are the Threshold Limit Values (TLV®).

Most constituents of gasoline have TLVs® in a range similar to the TLV® of gasoline. The noteworthy exception is benzene, which has a unique hazard profile and, as discussed above, its own OSHA health standard. The TLV® of benzene is 0.5 ppm (8-h TWA), which is the same as the action level for benzene under the OSHA health standard. Due to its much lower TLV® and PEL, much of the occupational exposure controls related to gasoline and petroleum operations have been focused on meeting the benzene occupational exposure requirements. Generally, the industry has found that the procedures, practices, and equipment (e.g., leak prevention, vapor control, exhaust, etc.) used to meet the benzene exposure limits results in the operations meeting the exposure limits for gasoline and other constituents.

ACGIH® also establishes Biological Exposure Indices (BEI®), including BEIs for benzene, ethylbenzene, n-hexane, toluene and xylenes. Although TLVs® are used to evaluate air samples collected on or near a worker, these BEIs® are used to evaluate biomonitoring samples (e.g., urine) collected from workers. In some cases, the BEIs® are based on an established metabolite of the chemical; for example, the BEI® for benzene is based on S-phenylmercapturic acid or t,t-muconic acid in urine.

5.2. Occupational hazard communication

Hazard communication is a key information exchange between chemical substance manufacturers/importers and their employees who need this information. Hazard communication regulations and programs are intended to provide potentially exposed workers with information about the hazards of a substance so that a worker can take appropriate actions to protect himself or herself. Hazard communications can cover a wide range of potential health (e.g., irritation, sensitization, and carcinogenicity) and physical hazards (e.g., flammability, corrosion, and reactivity). Gasoline and its constituents are covered under various hazard communication regulations in the U.S. and globally so that potentially exposed workers are warned about hazards and appropriate safety measures to avoid excessive exposure, flammability risks, and other hazards.

5.2.1. OSHA hazard communication standard

OSHA's Hazard Communication Standard (HCS) at 29 CFR § 1910.1200 requires that information about a chemical substance's hazards and associated protective measures are disseminated to potentially impacted workers. This regulation requires chemical manufacturers and importers to evaluate the hazards of their chemicals and to provide information about them through container labels and more detailed safety data sheets (SDSs)—formerly referred to as material safety data sheets (MSDSs). All employers with hazardous chemicals in their workplaces must prepare and implement a written hazard communication program, and must ensure that all containers are labeled, employees are provided access to SDSs, and an effective training program is conducted for all potentially exposed employees.

One aspect of hazard communication that has led to considerable confusion and additional paperwork was the situation of differing classification and labeling standards and regulations across the globe. Due to these differences in regulations, it was not uncommon for the same substance to be classified differently (in some cases very differently) from country to country with different labels and SDSs for each country. In order to address this issue, the United Nations undertook an extensive effort to develop a Globally Harmonized System (GHS) for classification and labeling of substances. The GHS hazard communication system was first released in 2003 and is in the process of being implemented around the world (United Nations, 2013). There have been several subsequent updated/revised versions of the GHS system released by UNEP in 2005, 2007, 2009, 2011, and 2013. GHS has now been implemented in a number of countries (e.g., the EU and Japan), and in the U.S., EPA and Consumer Product Safety Commission are now in the process of revising their regulations to implement GHS. OSHA issued a final rule in March 2012 to align its Hazard Communication Standard with the GHS (Hazard Communication, 2012: 17,574).

Providing industry guidance on GHS implementation, the December 2013 issue of Regulatory Toxicology and Pharmacology includes an article entitled "A GHS-consistent approach to health hazard classification of petroleum substances, a class of UVCB substances." The paper discusses petroleum process streams and petroleum products and their treatment as substances of unknown or variable composition, complex reaction products and biological materials (UVCBs) under various regulatory frameworks. The paper presents a systematic approach for the health hazard evaluation of petroleum substances using chemical categories and the GHS (Clark et al., 2013).

6. Controlling commercial and consumer exposure

An array of equipment specifications and chemical reporting requirements protect commercial and consumer end users from fire risks and harmful exposure to gasoline, its constituents, and emissions. These include design and performance specifications applicable to gasoline underground storage tanks (USTs), fuel pumps, and other fuel dispensing equipment. The reporting requirements under the Emergency Planning and Community Right to Know Act (EPCRA) (Emergency Planning and Community Right to Know Act, 2012: § 11001, et seq.) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (Comprehensive Environmental Response, Compensation and Liability Act, 2012: § 9601, et seq.) improve community access to information about chemical hazards and facilitate emergency response actions by federal, state, and local governmental bodies.

6.1. Equipment specifications

6.1.1. Underground storage tank regulations and standards

The regulations at 40 C.F.R., Part 280 require owners and operators of USTs containing petroleum, fuels, or hazardous substances to meet performance standards related to tank and pipe design, construction, installation, and release detection. Covered facilities must use specified spill and overfill prevention equipment (Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks, 2013: §§ 280.20–280.30). Spill prevention equipment, such as spill buckets, must prevent release of product into the environment upon detachment of the transfer hose from the fill pipe. Operators must use one of the following overfill prevention controls: automatic shut-off valves that activate upon the tank reaching 95% capacity; technologies that alert the operator when the tank reaches 90% capacity; or flow restrictions that automatically activate 30-min prior to overflow.

To prevent UST leaks due to corrosion, the regulations prescribe the use and maintenance of corrosion protection systems in accordance with a specified code of practice developed by a nationally recognized association or independent testing laboratory. To avoid releases to surface and ground water, operators must only use USTs made of or lined with materials that are compatible with the substance stored in the UST. Finally, operators must implement release detection methods and report a spill or overfill to the EPA or state environmental authority within 24 h of detection (Technical Standards and Corrective Action Requirements for

Owners and Operators of Underground Storage Tanks, 2013: §§ 280.40–280.67). Of course, operators are responsible for response efforts and any necessary clean up.

As demonstrated by the corrosion prevention requirements, the regulations incorporate numerous industry standards for installation, performance, and operation of USTs. These include American Petroleum Institute (API) Recommended Practice (RP) 1615, "Installation of Underground Petroleum Storage Systems," RP 1621, "Recommended Practice for Bulk Liquid Stock Control at Retail Outlets," and RP 1632, "Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems" (Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks, 2013: § 280.20). The regulations also reference several National Fire Protection Association (NFPA) standards.

6.1.2. Suite of regulations and standards applicable to fuel dispensing equipment

Several legal requirements and industry standards govern the design and use of fuel dispensing equipment to ensure the safety of gasoline station attendants and the general public during refueling.

As discussed in Section 4.5.2., a variety of federal requirements promulgated under the Clean Air Act limit air emissions and prescribe the use of vapor recovery systems at gasoline dispensing facilities. In addition, OSHA regulations require the use of "listed" devices for dispensing flammable liquids such as gasoline (Occupational Safety and Health Standards, 2013: §§ 1910.106(g)(3)(iv)(b)(1) and 1910.106(g)(3)(vi)). Listed devices are those that have been approved by a nationally recognized testing laboratory (Occupational Safety and Health Standards, 2013: § 1910.106(a)(35)–(36)). The OSHA regulations include limitations on the location and pressure of gasoline pumps, and prescribe the installation of circuit breakers to cut off power to all dispensing devices in the event of an emergency (Occupational Safety and Health Standards, 2013: §§ 1910.106(g)(3)(iii) and 1910.106(g)(3)(v)(b)). Facility operators must also install control and impact valves (Occupational Safety and Health Standards, 2013: § 1910.106(g)(3)(v)(d)–(e)). Control valves permit pump operation only upon removal of the dispensing nozzle from its bracket on the dispensing unit and manual activation of the dispensing unit switch. Impact valves incorporate a fusible link that closes automatically upon severe impact to the dispenser or fire exposure.

Many states also regulate fuel-dispensing devices through their fire codes. For example, Colorado has simply adopted by reference the minimum standards for design, construction, location, installation, handling, and operation of liquid fuel systems and equipment prescribed by the National Fire Code, as published by the NFPA and discussed in detail below (Colo. Rev. Stat., 2013: § 8-20-231). California and New York have adopted fire codes largely based on the fire prevention code developed and published by the International Code Council (ICC). Their requirements address the location and protection of dispensing devices, and prescribe the installation of emergency power circuit breakers and use of listed electrical equipment, dispensers, hose, nozzles, and submersible or subsurface pumps (Cal. Code Regs., 2013: Tit. 24, § 2201, et seq.; N.Y. Comp. Codes R. & Regs., 2013: Tit. 29, § 2201, et seq.). California and New York also require periodic inspections by the fire code official to verify that fuel-dispensing and containment equipment is in proper working order and not subject to leakage, and facility testing of emergency shutoff valves and leak detectors at least once per year.

New Jersey and Oregon are the only states in the U.S. that statutorily prohibit operation of gasoline dispensing devices by the general public (N.J. Stat. Ann., 2013: § 34:3A-4, et seq.; N.J. Admin. Code, § 12:196-1.1, et seq.; and Or. Rev. Stat., 2013: § 480.310, et seq.). To limit fire hazards directly associated with the dispensing of fuel and public exposure to fumes, these states require that only trained and certified attendants dispense gasoline. These states have also adopted requirements specific to the dispensing equipment.

NFPA and the ICC both have standards that address safety and fire protection with fuel dispensing equipment and operations at gasoline retail outlets (gas stations) in general. API recently revised its Recommended Practice for Ethanol Storage and Handling (API RP 1626) to include an extensive Fire Protection section to manage the unique risks encountered with ethanol and gasoline ethanol blends. As discussed above, a number of jurisdictions have incorporated these standards into local regulations.

Perhaps the most important NFPA standard related to fuel dispensing is NFPA 30A–Code for Motor Fuel Dispensing Facilities and Repair Garages, 2008 current edition. NFPA 30A sets out baseline details for the design and operation of motor fuel dispensing facilities; marine/motor fuel dispensing facilities; and motor fuel dispensing facilities located inside buildings, at fleet vehicle motor fuel facilities, and at farms and isolated construction sites. This code also covers motor vehicle repair garages. NFPA 1–Fire Code, 2009 current edition, and NFPA 30–Flammable and Combustible Liquids Code, 2008 current edition, also have provisions that relate to retail fuel operations. Similar to NFPA, the ICC also has a comprehensive standard—the International Fire Code—which covers a wide range of operations and facilities including aspects of fuel dispensing operations.

6.1.3. Gasoline pump specifications

To reduce refueling spillage and spitback emissions, the regulations at 40 C.F.R. § 80.22 impose design and performance requirements on gasoline pumps. Specifically, the outside diameter of the terminal end of a nozzle spout must not exceed 0.840 inches (2.134 cm), and the terminal end must have a straight section of at least 2.5 inches (6.34 cm). The retaining spring must also terminate at least 3.0 inches (7.6 cm) from the terminal end. The regulations also prescribe a maximum fuel flow rate for each nozzle not to exceed 10 gallons per minute (37.9 L/min). These specifications prevent fires involving spilled gasoline and the reduce consumer inhalation of gasoline vapors (Evaporative Emission Regulations for Gasoline- and Methanol-Fueled Light-Duty Vehicles, Light-Duty Trucks and Heavy-Duty Vehicle, 1993: 16,002 and 16,005).

6.2. Reporting requirements

Congress enacted EPCRA and CERCLA to provide citizens with information on chemicals and their uses and releases at facilities across the nation. Most importantly, these laws ensure that federal, state, and local emergency responders are equipped with information vital to chemical risk management and emergency planning.

6.2.1. Emergency planning and community right to know act

Under Section § 302(c) of EPCRA, industrial facilities that store or manage certain specified chemicals must report to state emergency response commissions (SERCs) and local emergency planning committees (LEPCs) regarding the nature and quantity of chemicals present at the facility. Specifically, facilities must notify the SERC and LEPC of the on-site presence of any "extremely hazardous substance" (EHS) in excess of the substance's "threshold planning quantity" (TPQ) and appoint an emergency response coordinator. The list of EHSs and their corresponding TPQs is codified at 40 C.F.R., Part 355. Petroleum refineries generally produce a number of EHSs during manufacturing processes. Facilities must also immediately report accidental releases of reportable quantities of EHSs or CERCLA "hazardous substances" in accordance with

EPCRA § 304. CERCLA hazardous substances include gasoline constituents such as benzene, toluene, ethylbenzene, and xylene.

Facilities manufacturing, processing, or storing OSHA ''hazardous chemicals'' must provide MSDSs to SERCs, LEPCs, and local fire departments pursuant to Sections 311 and 312 of EPCRA. The regulations codified at 40 C.F.R., Part 370 also require facilities to submit an annual inventory report to such authorities, if they maintain certain chemicals at or above specified quantities. The annual inventory reporting threshold is 75,000 gallons (all grades combined) for gasoline stored in a UST at a retail outlet; 100,000 gallons (all grades combined) for diesel fuel stored in a UST at retail outlet; either 500 lb or the TPQ for an EHS, whichever is lower; and 10,000 lb for all other hazardous chemicals. This information helps local emergency responders and governments to know the types and amounts, locations and nature of hazardous substances stored at a facility when they respond to chemical spills or releases.

EPCRA § 313 requires facilities manufacturing or otherwise using chemicals listed on the Toxics Release Inventory (TRI), codified at 40 C.F.R. § 372.65, at or above threshold quantities to submit an annual report to EPA. The report covers releases and transfers of toxic chemicals to various facilities and environmental media. EPA publishes the data, which are used by EPA and other public bodies to facilitate oversight. Petroleum refiners generally produce a number of the approximately 600 chemicals listed on the TRI, including but not limited to ammonia, benzene, chlorine, hydrogen sulfide, methyl mercaptan, and sulfuric acid. API has published a compilation of methods for calculating air emission under the TRI provisions (API, 2010). From 1988 to 2006, petroleum facilities reduced their releases, disposals, and transfers to the environment by 75% (API, 2006).

6.2.2. Comprehensive environmental response, compensation and liability act

CERCLA authorizes EPA to respond to releases, or threatened releases, of hazardous substances, and to force responsible parties to undertake cleanup or reimburse the Superfund for response or remediation costs. As noted above, CERCLA hazardous substances include several gasoline constituents, in addition to wastes from the refining process. The regulations at 40 C.F.R., Part 302 require owners or operators of a facility to report any environmental release of a hazardous substance at or above a reportable quantity to the National Response Center (Designation, Reportable Quantities, and Notification, 2013: § 302.4). EPA responds to releases according to procedures outlined in the national oil and hazardous substances pollution contingency plan at 40 C.F.R, Part 300.

Critically, Section 101(14) of CERCLA exempts petroleum and indigenous petroleum constituents from the definition of ''hazardous substance.'' Thus, listed hazardous substances that would otherwise fall within the ambit of CERCLA, such as benzene, are exempt when contained in petroleum, unless the concentration of these substances is increased by contamination or by addition after refining. The EPA Office of the General Counsel has interpreted the petroleum exemption as including gasoline blended during the refining process (USEPA, 2011). On the other hand, specifically listed waste oils, such as F010 and K048 through K052, do not fall within the petroleum exemption. Separated gasoline basestocks may also remain subject to reporting requirements, if spilled in excess of their established reportable quantities.

7. Conclusions

This review of risk management measures currently in effect in the U.S. demonstrates that they comprehensively address and mitigate the environmental and human health risks posed by automotive gasoline. Indeed, the entire gasoline lifecycle—from manufacture, through distribution, to end-use—is subject to detailed, complex, and overlapping regulatory schemes intended to protect both human health and the environment. In addition to these legal requirements, industry has implemented a broad array of standards and best management practices to ensure that risks from gasoline manufacturing, distribution, and use are minimized.

Conflict of interest

Swick reports that he is an employee of the American Petroleum Institute. Jaques reports receiving personal fees from the American Petroleum Institute during the development of the manuscript submitted for publication and also personal fees from the American Petroleum Institute for additional consulting services outside the submitted work. Walker and Estreicher both report receiving personal fees from the American Petroleum Institute.

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Glossary

Acronym: Definition

API: American Petroleum Institute
AST: Aboveground storage tank
ASTM: American Society for Testing and Materials; now called ASTM International.
CAA: Clean Air Act; 1990 reauthorized version
CERCLA: Comprehensive Environmental Response, Compensation and Liability Act
CFR: Code of Federal Regulations
CO: Carbon monoxide
CONCAWE: Conservation of Clean Air and Water Europe
CWA: Clean Water Act
DOT: Department of Transportation
EHS: Extremely hazardous substance
EPA: Environmental Protection Agency; see also USEPA
EPCRA: Emergency Planning and Community Right to Know Act
GDF: Gasoline dispensing facility
HAP: Hazardous air pollutant
HPV: High Production Volume—more than 1 million pounds per year of production
MSAT: Mobile source air toxics
MTBE: Methyl tertiary-butyl ether
NESHAP: National emission standards for hazardous air pollutants
NFPA: National Fire Protection Association
NOx: Nitrogen oxides; includes nitrogen dioxide (NO2), nitrous acid, and nitric acid
NPAH: Nitrated polycyclic aromatic hydrocarbon; NPAHs are defined to include: 7-nitrobenzo[a]anthracene, 6-nitrobenzo[a]pyrene, 6-nitrochrysene, 2-nitrofluorene, and 1-nitropyrene
NPDES: National Pollutant Discharge Elimination System
OPA: Oil Pollution Act
OSHA: Occupational Safety and Health Administration
PAH: Polycyclic aromatic hydrocarbon; PAHs are defined to include: Benzo(a)anthracene, Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo(a)-pyrene, Chrysene, Dibenzo[a,h]anthracene, and, Indeno[1,2,3-c,d]pyrene
PEL: Permissible exposure limit
PM: Particulate matter
PONA: Paraffins, olefins, naphthenes, and aromatics—key chemical constituents in gasoline blending streams
POTW: Publicly-owned treatment works
RFG: Reformulated gasoline
RVP: Reid vapor pressure
SO_2: Sulfur dioxide
TRI: Toxics Release Inventory
TLV: Threshold limit value
USEPA: United States Environmental Protection Agency
UST: Underground storage tank
UVCB: Unknown or Variable compositions, Complex reaction products and Biological; a class of chemical substances that includes most gasoline blending streams
VOC: Volatile Organic Compound, as defined by U.S. EPA at 40 CFR § 51.100