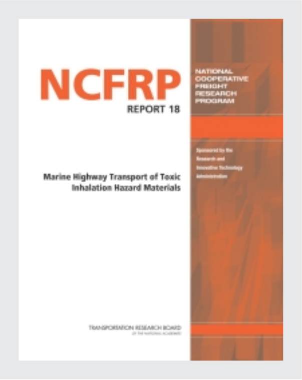

Marine Highway Transport of Toxic Inhalation Hazard Materials

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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

NCFRP REPORT 18

Marine Highway Transport of Toxic Inhalation Hazard Materials

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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

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The research reported herein was performed under NCFRP Project 17(01) by the Center for Ports and Waterways at the Texas Transportation Institute (TTI), The Texas A&M University System. C. James Kruse was the Project Director and Principal Investigator. The other authors of the report are Annie Protopapas, Associate Research Scientist at TTI; Les Olson, Associate Research Scientist at TTI; Nathan Hutson, Freight Analyst at Cambridge Systematics, Inc.; and Michael Donelan, retired barge industry executive.

FOREWORD

By William C. Rogers
Staff Officer
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NCFRP Report 18: Marine Highway Transport of Toxic Inhalation Hazard Materials examines the possibility of transporting greater volumes of chlorine and anhydrous ammonia shipments via the marine highway system than is currently shipped via water. At present, there is no coastwise and limited inland waterway activity related to either commodity. By developing a business case, the research considers such issues as market definition, return on investment, obstacles, impacts on other modes and their likely reactions, labor issues, environmental concerns, risks, and lessons learned from international experience.

Ammonia and chlorine are pervasive in daily life. Ammonia is the nation's dominant commercial fertilizer and is used either directly in anhydrous form or indirectly in manufactured fertilizer. Chlorine is an essential component appearing in 45 percent of all commercial products. Both substances are extremely toxic upon release and have unique properties that must be accounted for in the design and operation of transportation and storage equipment. Ammonia and chlorine account for about 90 percent of all toxic inhalation hazard (TIH) materials shipped across all modes. A serious TIH release is considered a low-probability/high-consequence event: high-consequence because the release is not readily, if at all, containable, no matter how rapidly the response team reacts; low-probability because in the last 23 years only four major releases have occurred in the United States, two for each substance. All four releases occurred during rail shipment.

Under NCFRP Project 17(01), the Texas Transportation Institute was asked to answer the following question: If the market favors marine transportation, why isn't marine transportation of TIH materials already expanding? To answer this question the researchers (1) determined current volume of shipments by mode; (2) interviewed shippers and carriers; (3) reviewed international experiences; (4) defined the regulatory and security environment; (5) defined vessel requirements; (6) defined the economic environment; (7) identified obstacles; (8) defined and analyzed externalities; and (9) described various alternative courses of action.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SUMMARY

Marine Highway Transport of Toxic Inhalation Hazard Materials

In the first phase of this research effort, NCFRP Project 17, "North American Marine Highway Operations," the authors noted the need to further research the possibility of diverting heavy and hazardous shipments to water. From a strictly environmental and public safety viewpoint, it would appear that diverting heavy and hazardous shipments to water would be desirable.

After reviewing the research recommendations, the project panel appointed by the Transportation Research Board determined that this additional research should be undertaken as Phase 2 of the initial study. Specifically, the objective of this second phase of research was to develop a business case for transporting a larger share of chlorine and anhydrous ammonia shipments via the marine highway system than is currently shipped via water. ("Anhydrous" means "without water.") Both of these products are classified as toxic inhalation hazard (TIH) materials.

The business case, at a minimum, would need to consider the following issues: market definition; return on investment; obstacles; impacts on other modes and their likely reactions; labor issues; environmental concerns and benefits directly related to the transport of the two commodities; risks; regulatory, security, infrastructure, and vessel requirements; transportation congestion impacts; and lessons learned from international experience (e.g., Marco Polo/Smart Rivers).

The underlying question driving this research effort was the following: If the market favors marine transportation, why isn't marine transportation already expanding? In attempting to answer this question and identify the factors that inhibit the growth of the system, the authors researched the following topics:

- Nature of the cargo (anhydrous ammonia and chlorine).
- Current delivery systems and practices.
- Motivation for encouraging more waterborne shipments.
- Experience of Europe and Canada in this area.
- Vessel requirements and associated capital expenditures.
- Currently available fleets for rail, truck, and marine.
- Economic issues.
- Major obstacles to further development and expansion.
- Potential courses of action.

Ammonia and chlorine are pervasive in everyday life. Agricultural industries are the major users of ammonia, accounting for over 85 percent of all ammonia produced in the United States. Ammonia (nitrogen) is the nation's dominant commercial fertilizer and is used either directly in anhydrous form or indirectly in manufactured fertilizers. Chlorine is an essential component in 45 percent of all commercial products. The major uses of chlorine (in descending order of quantities used) are for the manufacturing of organic compounds, manufacturing of vinyl chloride to make polyvinyl chloride (PVC) plastics, manufacturing of inorganic chemicals, water treatment, and bleaching of pulp and paper.

Ammonia is widely used throughout U.S. agricultural areas and thus, like chlorine, must be transported from a limited number of production and import locations to geographically dispersed U.S. agricultural production areas. Most chlorine is shipped from production locations directly to consumption sites. Users do not typically consume large amounts of chlorine at any given site. Roughly two-thirds of chlorine is never shipped, but rather is used on site in chemical manufacturing or is moved by pipeline to nearby facilities.

The researchers arrived at the conclusion that further expansion or development of TIH marine transportation services is not likely—and may not even be possible—given current obstacles and market conditions. Geographical dispersion is the most formidable obstacle to a significant increase in the volume of TIH marine shipments. The capital cost of equipment and infrastructure and the difficulty of acquiring permits were cited several times by interviewees as the most important limiting factors for marine shipments. The risk of a catastrophic accident also limits the interest of potential new market participants because such incidents have no liability limit. Because of these risks, users of ammonia and chlorine may begin relocating to sites closer to producers, thereby eliminating transportation altogether.

Steps will most likely have to be taken to actively discourage transportation by rail and encourage transportation by water. (Trucking is not economically viable and is rarely considered by shippers for high-volume and/or long-distance shipments.) This report describes various alternative courses of action. Almost all of them include some type of government action—not necessarily a direct financial incentive—in order to change the environment within which these transportation services are offered. They include the following:

- Limit risk to carriers and shippers.
- Require safer equipment and technology.
- Require ammonia to be diluted for transport.
- Establish grants to support the acquisition of equipment or infrastructure modifications.
- Establish tax incentives to promote facility and supply chain modifications.
- Restrict movements through high-population areas (high threat urban areas).
- Maintain and upgrade the infrastructure and guarantee its condition.
- Encourage the location of new plants and facilities near marine terminals.
- Integrate the value of marine transportation into national planning.

However, there are no measures that can overcome the geographical dispersion of producers and users, the lack of density in any given corridor, and the fact that the markets are mature. Therefore, significant expansion of TIH material transportation via marine highways is not anticipated.

A bibliography of documents consulted but not cited is included in this report as Appendix C in order to allow the reader to further explore issues that are tangential to the objective of this study.

CHAPTER 1

Background

After reviewing the research recommendations set forth in NCFRP Project 17 (published as *NCFRP Report 5: North American Marine Highways*), the project panel determined that a follow-up study should be completed on identifying promising long-term markets for the domestic maritime sector. The results of this follow-up study, defined as Phase 2 of the initial study, is described herein and expands upon relevant findings introduced in the first phase of the research.

Specifically, the objective of the second phase of research was to develop a business case for transporting a larger share of chlorine (Cl) and anhydrous ammonia (NH_3) shipments via the marine highway system than is currently shipped via water. ("Anhydrous" means "without water.") Both of these products are classified as toxic inhalation hazard (TIH) materials.

To make the business case, the following issues need to be considered: market definition; return on investment; obstacles; impacts on other modes and their likely reactions; labor issues; environmental concerns and benefits directly related to the transport of the two commodities; risks; regulatory, security, infrastructure, and vessel requirements; vessel availability; transportation congestion impacts; and lessons learned from international experience.

It is important to define how the term "business case" will be used in this report. A business case typically captures the reasoning for initiating a project or task. It provides the information necessary to assess the benefits of a project against costs and resources. The logic of the business case is that whenever resources or efforts are consumed, they should be in support of a specific business need. There may be legitimate justifications for advancing domestic marine transportation that will not be included in a traditional business case analysis. A compelling business case adequately captures both the quantitative and qualitative characteristics of a proposed project or a series of proposed projects. Consideration should also be given to the option of doing nothing, including the costs and risks of inactivity. From this information, the justification for the project is derived.

For purposes of this study, the marine highway marketplace under consideration was limited to U.S. domestic movements and shipments between the United States and Canada. In the case of export or import shipments, the researchers treated the port of entry or exit as the source or destination of the movement. This included inland waterway movements and coastwise movements.

The researchers encountered a scarcity of literature that specifically dealt with the issues related to developing a business case for the transport of TIH materials. In order to obtain the latest and most accurate information, the researchers interviewed several executives involved in the production and/or distribution of anhydrous ammonia or chlorine. Some of these individuals were recently retired but very knowledgeable about the marketplace. Several interviewees requested that neither they nor their company be identified; therefore, names are not provided in this report. The following list includes the types of individuals the researchers interviewed:

- Chlorine manufacturers (two).
- Fertilizer industry executive (active).
- Fertilizer industry executive (retired).
- Marine highway consultant.
- Potential marine highway service start-up.
- Railroad executive.
- Shipyard executives (two).
- Towing company executives (three active).
- Towing company executive (retired).

Nature of the Cargo

Classification of Chlorine and Anhydrous Ammonia

Chlorine and anhydrous ammonia belong to a larger set of substances classified as hazardous materials. The U.S. Department of Transportation (U.S. DOT) defines a hazardous material as "a substance or material that the Secretary of

Transportation has determined is capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and has designated as hazardous under Section 5103 of federal hazardous materials transportation law (49 U.S.C. 5103: implemented in 49 CFR, Part 105.5) (*1*). More than 3,000 materials subject to regulation are identified by name, along with thousands of unnamed materials categorized as explosive, flammable, corrosive, infectious, or otherwise hazardous (*2*). While a large number of materials are classified as hazardous to transport, the potential implications of a release vary substantially.

The U.S. DOT categorizes hazardous materials into nine hazard classes based on the type of danger posed in transportation. It further subcategorizes the classes into divisions. Below are the nine hazard classes and the division numbers under each class:

- Class 1: Explosives (Divisions 1.1, 1.2, 1.3, 1.4, 1.5, 1.6).
- Class 2: Gases (Divisions 2.1, 2.2, 2.3).
- Class 3: Flammable liquids and combustible liquids.
- Class 4: Flammable solids, spontaneously combustible materials, and water-reactive substances (Divisions 4.1, 4.2, 4.3).
- Class 5: Oxidizing substances and organic peroxides (Divisions 5.1, 5.2).
- Class 6: Toxic substances and infectious substances (Divisions 6.1, 6.2).
- Class 7: Radioactive.
- Class 8: Corrosive.
- Class 9: Miscellaneous hazardous materials.

Domestically, chlorine is shipped as Class 2.2, "Non-Flammable Gas"; for international shipments, it falls under Class 2.3, "Toxic Gases." Anhydrous ammonia falls within Class 2.3. The Coast Guard defines these cargoes as "toxic cargoes" (46 CFR 154.7) (*3*).

Within the broader category of hazardous materials, there is a class of substances known as TIH materials. The federal government defines them as "gases or liquids that are known or presumed on the basis of tests to be so toxic to humans as to pose a health hazard in the event of a release during transportation" (*4*). Examples of widely transported TIH materials include chlorine, ammonia, sulfur dioxide, hydrogen fluoride, fuming nitric acid, fuming sulfuric acid, hydrogen chloride, and ethylene oxide. The first six of these receive the most attention in the discussion of risk and safety in the literature, primarily because of the volumes shipped.

Three of the materials listed above account for 90 percent of TIH shipments across all modes (*5*). Anhydrous ammonia and chlorine alone account for 80 percent.

- Anhydrous ammonia (45 percent).
- Chlorine (35 percent).
- Ethylene oxide (10 percent).

Physical Properties and Health Effects

Chlorine and anhydrous ammonia are extremely toxic upon release and have unique properties that must be accounted for in the design and operation of transportation and storage equipment.

Ammonia (UN1005)

It is important to distinguish between nitrogen fertilizer solutions and anhydrous ammonia. Aqueous solutions containing ammonia are not nearly as toxic as anhydrous ammonia; thus, nitrogen fertilizer solutions are considered non-hazardous, and barges that transport these solutions are not legally required to carry a United States Coast Guard (USCG) Certificate of Inspection (COI).

Ammonia is a colorless, toxic, and corrosive gas with an extremely pungent odor. Under pressure, it changes its state into a water-white liquid (liquefied ammonia gas), and it is soluble in water (ammonium hydroxide solution). Ammonia is a compound of nitrogen and hydrogen and is lighter than air (specific gravity of 0.59).

Ammonia acts as a choking agent on the lungs, causing breathing difficulty and potentially permanent lung damage. It is severely irritating to the eyes and can cause permanent damage and blindness. Other eye-related symptoms include pain, tears, swelling, redness, and blurred vision. Ammonia gas is also very irritating to skin. It can cause permanent skin injury (including scarring). Extensive and prolonged contact can cause significant injury to underlying tissue and possibly death. Symptoms include feelings of pain or heat, discoloration, swelling, and blistering. Ingestion may cause severe irritation/ulceration of the digestive tract, which may in turn result in nausea, vomiting, diarrhea, and in severe cases, collapse, shock, and death. Even though this substance is a flammability hazard, it only exhibits such hazard under extreme fire conditions in a confined area. Although it is flammable in concentrations between 15 and 28 percent, the ignition temperature is relatively high (1100°K, 1520°F) (*6*).

Anhydrous ammonia exists naturally in a gaseous state under atmospheric pressure and temperature. Under moderate pressure, it readily changes to a liquid, becoming a gas again when the pressure is reduced. Industries take advantage of this characteristic by shipping and storing liquefied ammonia in pressurized railway cars, tank trucks, cylinders of various sizes, and either fully pressurized or semi-pressurized ships and barges (*7*). At 60°F and atmospheric pressure, 1 lb of liquefied ammonia will expand into 850 cu ft of ammonia gas. It is typically carried as a liquid at reduced temperature and at atmospheric pressure. It can also be kept liquid at normal temperature but at increased pressure (as is done with rail cars). Anhydrous ammonia is 82-percent nitrogen and weighs 5 lb/gal when carried at 114 psi; anhydrous ammonia transported in barges typically weighs 6.83 lb/gal when maintained at –33.3°C (–27.4°F). Aqueous ammonia, which is highly diluted, is 32-percent nitrogen and weighs 11.04 lb/gal. Therefore, transporting ammonia in liquefied form allows the shipper to transport, handle, and store significantly less volume of product for the same amount of nitrogen.

Dissolution of liquefied ammonia in water is accompanied by an exothermic process and a concomitant increase in pH. The ammonium hydroxide solutions are destructive to flora and fauna, and the water is also unsafe for human consumption (*6*).

Chlorine (UN1017)

Chlorine is a non-flammable, greenish-yellow gas, with a pungent odor. The gas is much heavier than air (specific gravity of 2.486) and is miscible in water. ("Miscibility" refers to the ability of a liquid or gas to dissolve uniformly in another liquid or gas.) It is corrosive to glass and most metals because it forms hypochlorous acid and/or hydrochloric acid when combined with water. Chlorine is a powerful oxidant that may cause fire.

Chlorine is highly irritating to skin, eyes, and mucous membranes. It acts as a choking agent on the lungs, causing breathing difficulty and potentially permanent lung damage. It creates a burning sensation, cough, headache, labored breathing, nausea, and sore throat. More seriously, it can be very painful; it can cause skin burns, eye pain, blurred vision, and severe deep burns.

When evaluating the potential effects of spills from marine transportation, it is important to note that chlorine is highly toxic to all forms of aquatic life; there is no potential for bioaccumulation or bioconcentration (*8*).

Chlorine gas injected into the water during water chlorination quickly dissolves and forms chloride and hypochlorous acid within seconds (*8*). Liquefied chlorine in a ruptured tank or spilled onto the ground or into water during an accident is expected to volatilize rapidly, forming a greenish-yellow cloud of chlorine gas. This gas cloud, which is heavier than air and moves at ground level, can be carried several miles away from the source of release while maintaining dangerous levels of chlorine gas concentrations. Since chlorine gas is so reactive, it disperses quickly and does not remain in the environment very long after it is released. Chlorine immediately reacts with both organic and inorganic materials with which it comes into contact and is converted within seconds once it dissolves in water. Chlorine undergoes direct photolysis in the air, and its half-life in the troposphere is on the order of several minutes (*9*). ("Half-life" is the time when the expected value of the number of entities that have decayed is equal to half the original number. "Troposphere" is the lowest atmospheric layer—the layer "resting" on the earth's surface.)

Chlorine has a liquid volume to gas volume expansion factor of 521 at a temperature of 59°F and one atmosphere. This indicates that liquid chlorine volume to weight is at least 500 times more efficient than its gaseous state for purposes of transportation (*10*).

Uses

Ammonia and chlorine are pervasive in everyday life. They are found in many ordinary household products, despite their toxicity in their elemental form.

Ammonia

Agricultural industries are the major users of ammonia, accounting for over 85 percent of all ammonia produced in the United States. Within this category of usage, the production of fertilizers consumes a high percentage (particularly for corn and wheat). The largest use of commercial nitrogen fertilizer is on corn, which makes up 43 percent of nitrogen fertilizer consumption (*11*). Ammonia (nitrogen) is the nation's dominant commercial fertilizer and is used either directly in anhydrous form or indirectly in manufactured fertilizers. It is applied extensively throughout the country's main agricultural regions, particularly the Midwest farm states. As The Fertilizer Institute (TFI) testified to the Surface Transportation Board (STB) in the spring of 2009, there is no viable alternative for ammonia: "We always hear talk about how ammonia is on its way out, but we continue to use as much as we did 30 years ago" (*12*).

Average anhydrous ammonia prices have long been closely correlated with the price of natural gas because natural gas is the major variable cost item in the production of anhydrous ammonia. In recent years, however, the price of anhydrous ammonia has been increasing even as the price of natural gas has held steady. Significant global demand for anhydrous ammonia has continuously pushed prices higher, exceeding $850/ton in October 2011. Figure 1 shows the correlation of anhydrous ammonia prices with the price of natural gas. As can be seen, the relative price ratio increased from a stable average of 49:1 until December 2006 to an average of over 130:1 for the first half of 2011 (*13*).

Urea, ammonium nitrate, ammonium phosphates, nitric acid, and ammonium sulfate are the major derivatives of ammonia in the United States, in descending order of production volume. In 2010, approximately 87 percent of apparent domestic ammonia consumption went toward fertilizer use, including anhydrous ammonia for direct application, and production of urea, ammonium nitrates, ammonium phosphates, and other nitrogen compounds.

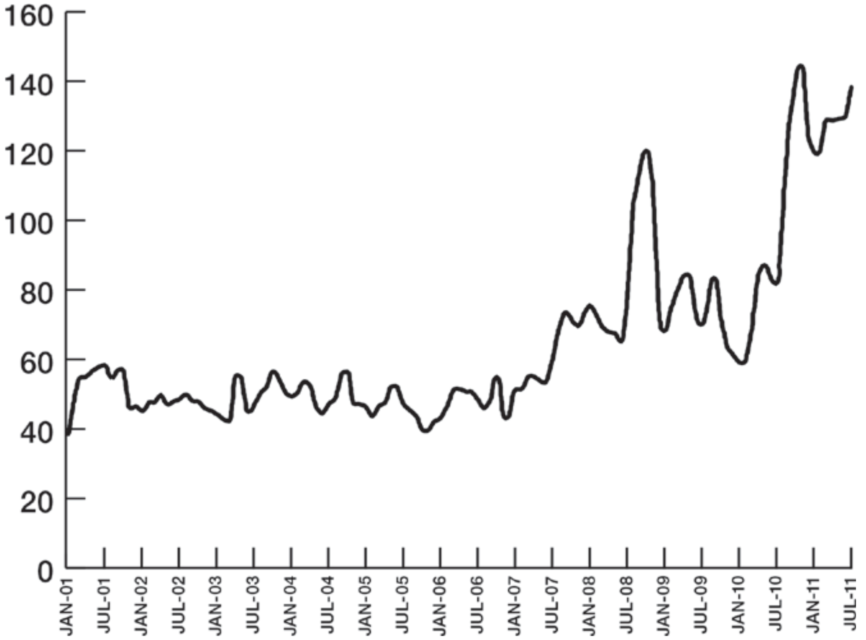


Figure 1. Wholesale anhydrous ammonia price divided by industrial natural gas price, 2001 to 2011.

There has been some discussion in the marketplace and regulatory arena about replacing anhydrous ammonia with another product to reduce the handling risk; however, there are numerous economic and logistical challenges to replacing anhydrous ammonia. Anhydrous ammonia is the least costly and most effective source of nitrogen fertilizer for American farmers. Ammonia is also an input for other nitrogen-based fertilizers, such as nitrogen solutions or urea, as well as phosphate fertilizers. In many Corn Belt states, anhydrous ammonia is typically the only nitrogen source recommended by universities for fall application to spring-planted crops (*14*). Thus, it is argued, any fertilizer substitutes for anhydrous ammonia would be required in greater volumes, at greater cost, and with a high impact to farmers. Substitution of ammonia in industrial processes would likely be even more complicated.

While a high percentage of ammonia is sent directly to the fields for fertilizer application, a significant amount of ammonia is used to produce granular fertilizers known as diammonium phosphate (DAP) and monoammonium phosphate (MAP). DAP is typically 46-percent phosphate and 18-percent nitrogen and can be applied by itself or easily mixed with nitrogen and/or potash fertilizers, often as part of a total nitrogen, phosphate, and potash (N-P-K) plant food mix. Since it is a granular product, DAP can be applied directly to the soil using conventional spreading equipment. MAP is 52-percent phosphate and 11-percent nitrogen and—as with DAP—can be applied by itself or easily mixed with nitrogen and/or potash fertilizers, often as part of a total N-P-K plant food mix. MAP is often used on crops such as soybeans. As is the case with DAP, MAP can be applied directly to the soil using conventional spreading equipment.

Figure 2 illustrates the industrial uses of ammonia.

Other uses of ammonia include the following:

- Protein in livestock feeds.
- Pre-harvest cotton defoliant.
- Anti-fungal agent for certain fruits.
- Preservative for storage of high-moisture corn.
- Manufacture of
  - Nitric acid.
  - Alkalis (e.g., soda ash).
  - Dyes.
  - Pharmaceuticals.
  - Synthetic textile fibers.
  - Certain plastics.
  - Explosives.
- Metal treating operations.
- Neutralization of acid constituents of crude oil.
- Protection of petroleum equipment from corrosion.
- Extraction of metals such as copper, nickel, and molybdenum from their ores in mining industry.
- Water and wastewater treatment.
- Stack emission control systems.
- Developing agent in photochemical processes.
- Industrial refrigeration systems (R717).
- Stabilization of natural and synthetic latex to prevent premature coagulation (rubber industry).

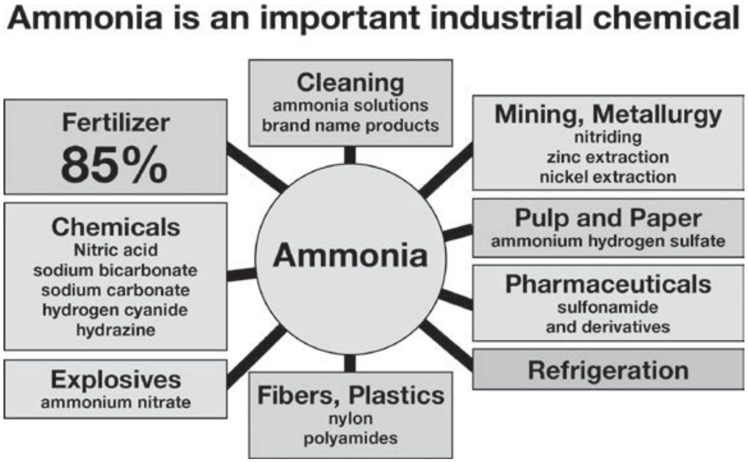


Figure 2. Industrial uses of ammonia (15).

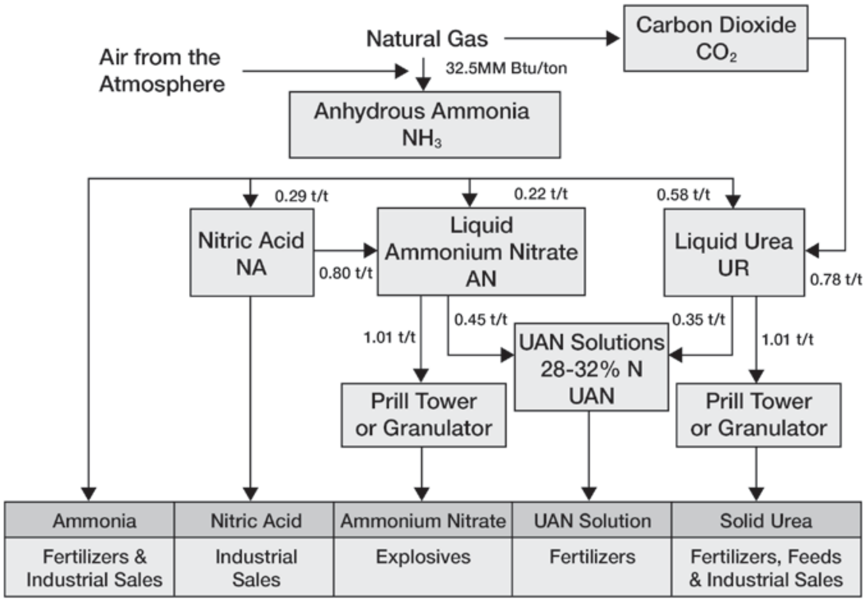
- Pulping wood and as a casein dispersant in the coating of paper.
- Nitrogen needed for yeast and microorganisms for the food and beverage industry.
- Hydrogen for some fuel cells.
- Curing agent, as a slime and mold preventative in tanning liquors, and as a protective agent for leathers and furs in storage.
- Commercial household cleaners and detergents (typically 5 to 10 percent ammonia by weight (*16*).

Figure 3 illustrates the downstream products of ammonia.

Chlorine

Chlorine gas is used for purifying potable water and wastewater at treatment plants. It is used in swimming pools throughout the country and as a chemical intermediary in various manufacturing processes for products ranging from PVC pipes to shampoo. In fact, chlorine is an essential component in 45 percent of all commercial products (*17*).

The major uses of chlorine (in descending order of quantities used) are for the manufacturing of other organic compounds, the manufacturing of vinyl chloride to make PVC plastics, the manufacturing of inorganic chemicals, water treatment, and pulp and paper bleaching. Nearly one-third



Source: Overview of Potash Corp and its Industry 09

Figure 3. Downstream products of ammonia.

of all chlorine is used to produce vinyl for products such as wire and cable, pipe, flooring, siding, windows, and doors.

Chlorine plays a role in the production stream of some important end products including refrigerants, aerosols, silicones, silicone rubber, plastics, solvents, polyethers, varnishes, foams, chlorinated rubber, polyurethane, detergents, dyes, insecticides, pesticides, disinfectants, bleaches, and white pigment enamel. The food industry has used chlorine as a bleaching agent for flour. Chlorine is also used to manufacture phosgene.

Caustic soda (NaOH) is a co-product of the chlorine production process. It is also a fundamental chemical product with myriad uses, and its availability is directly dependent on chlorine production.

Volumes Produced and Shipped

Over 2.2 billion tons of hazardous materials valued at $1.4 trillion were transported in the United States in 2007, the latest year for which comprehensive data are available, with each shipment moving an average of 96 mi (*18*). The average shipment distance decreased from 136 mi in 2002. The literature indicates that the distance hauled has decreased due to greater co-location of suppliers and consumers (*19*). In 2007, 26.9 million tons of TIH (1.2 percent of the total) was moved by all modes (*20*).

Table 1 summarizes the volume of domestic ammonia and chlorine shipments in 2007 (latest data available) by mode. The statistics reported for inland barge include both anhydrous ammonia and aqueous solution. It is not possible to determine the tonnage for anhydrous ammonia alone.

Ammonia

In 2010, the U.S. Census Bureau reported ammonia production of 11.1 million short tons and imports of 7.4 million short tons. In 2010, U.S. producers operated at about 85 percent of their rated capacity (*22*). The figures for 2009 were 10.3 million short tons and 6.1 million short tons, respectively. Exports were negligible in both years (*23*). Table 2 summarizes the Census statistics.

An average scale ammonia plant in the United States produces 500 to 1,000 tons of ammonia per day. The United States has cut back on its domestic ammonia production over the past decade and has recently imported as much as 40 percent of the 15–20 million tons of ammonia that it consumes annually. This is primarily due to the historically more abundant supplies of natural gas (hence, lower production costs) in other countries. However, this trend may reverse itself with greater domestic shale gas production. Greater reliance on imports might open the potential for new supply chains and routes that have not historically handled significant supplies of anhydrous ammonia in transit, but this does not appear likely.

Table 1. Volume of ammonia and chlorine shipments in 2007 (*20, 21*).

Mode	Ammonia (000 tons)	Chlorine (000 tons)
Truck	9257	N/A*
Rail	1141	3241
Inland Barge	1536	109
Pipeline	2896	N/A*
* Data Not Available		

Table 2. Ammonia production and imports.

Ammonia Source (million short tons)	2009	2010
Domestic Production	10.3	11.1
Imports	6.1	7.4
Total	16.4	18.5

Chlorine

According to statistics from the Chlorine Institute, in 2008, the U.S. chlor-alkali industry produced 11.5 million short tons of chlorine and 12.1 million short tons of caustic soda (sodium hydroxide) (*24*). Table 3 lists the production capacity of the major chlorine-producing companies in 2009.

Olin Chlor Alkali Products, a division of Olin Corporation (Olin), is the largest merchant producer (one who sells to another party outside the corporate umbrella) of chlorine in North America. Industry estimates pegged Olin's total North American chlor-alkali capacity at 1.96 million tons/year as of 2009, following Dow Chemical's 3.9 million and Occidental Chemical's (OxyChem's) 3.4 million tons/year of capacities. PPG Industries follows Olin with 1.85 million tons/year of capacity (*25*). Dow's production is directed to captive use (primarily the vinyl chloride supply chain); very little is sold to other entities.

Geography of Commodity Flows

The producers of both anhydrous ammonia and chlorine tend to locate near their principal feedstock and low-cost energy supply; hence, they tend to cluster within a region. Choice of transportation mode depends primarily on locations of supply and consumption. It is also influenced by the

Table 3. Chlorine production capacity—2009.

Company	Capacity (million tons/year)
Dow Chemical	3.9
Occidental Chemical (OxyChem)	3.4
Olin Chlor Alkali	1.96
PPG Industries	1.85

Figure 4. Worldwide ammonia flows in million metric tons for 2007 and 2006 (15).

parcel size of individual shipments. Where possible, economics generally favor bulk transportation of basic materials such as ammonia and chlorine, which inherently favors high-volume modes such as marine or rail.

Ammonia

Ammonia is widely used throughout U.S. agricultural areas and thus, like chlorine, must be transported from a limited number of production and import locations to the broad geography of U.S. agricultural production areas. Twelve companies produced ammonia at 24 plants in 16 states in the United States during 2010. Sixty percent of total U.S. ammonia production capacity was located in Louisiana, Oklahoma, and Texas because of their large reserves of natural gas, the dominant domestic feedstock (*26*).

Peak anhydrous ammonia production in the United States occurred in 1998 at 16.8 million tons sold, excluding quantities used to make nitrogen-based fertilizers at production facilities. The total, including nitrogen-based fertilizers, was roughly 23 to 24 million tons. Since 1998, the United States has been importing greater amounts of anhydrous ammonia (including nitrogen-based fertilizers) and producing less domestically because the price of natural gas has been lower in other producing countries (*16*). However, this situation may change with the projected increase in domestic shale gas production. Figure 4 shows recent major ammonia flows on a global basis.

Ammonia production and industrial usage are concentrated in just a few companies. One of these companies, CF Industries, owns a DAP/MAP production facility in Plant City, Florida. This is one of the largest integrated ammonium phosphate fertilizer production complexes in the United States. CF Industries imports 450,000 tons per year of ammonia through the Port of Tampa to feed this complex.

Interestingly, ammonia from the Port of Tampa also feeds a PCS fertilizer complex in Raleigh, North Carolina, by truck. PCS attempted to arrange an alternative route but has not been able to secure an ocean import facility on the East Coast. The PCS Raleigh DAP/MAP plant consumes approximately 100,000 short tons per year of ammonia, all supplied by truck.

Other Gulf Coast import facilities exist at Pascagoula, Mississippi; Beaumont, Texas; Houston, Texas; Pasadena, Texas; Freeport, Texas; and Point Comfort, Texas. Final delivery is typically made by pipe or truck to local industrial customers or by rail to landlocked destinations, such as from Houston to North Texas.

Figure 5 shows the locations of these major import facilities.

PCS operates additional ammonia plants in Augusta, Georgia (0.71 million tons) and Lima, Ohio (0.59 million tons). These two plants do not have water access. PCS will produce an additional 0.54 million tons with the scheduled restart of its Geismar, Louisiana, ammonia facility in 2012. Ammonia production at Geismar was idled in 2003 due to high natural

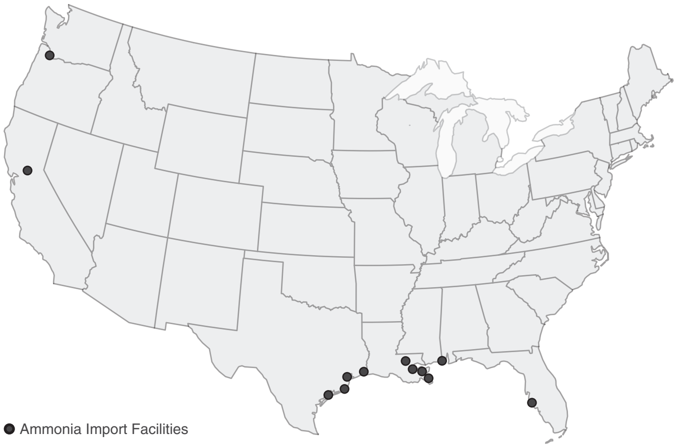


Figure 5. Major ammonia import facilities.

gas feedstock prices, but large-scale production of downstream nitrogen products (UAN, urea, nitric acid) continued at Geismar using ammonia feedstock imported from Trinidad. With the projected increases in domestic shale gas production, the Geismar ammonia production facility is once again feasible. Geismar is one of three major import locations for offshore ammonia located on the Mississippi River system.

Mississippi Phosphates is a major U.S. producer and marketer of DAP (the most widely used phosphate fertilizer). The production facilities are strategically located on a deep-water channel in Pascagoula, Mississippi, with direct access to the Gulf of Mexico. This site, as opposed to the sites previously mentioned, is one where the required ammonia is produced on site rather than imported. The manufacturing facilities consist of two sulfuric acid plants, a phosphoric acid plant, and a DAP granulation plant. The DAP granulation plant has a maximum annual DAP production capacity of approximately 870,000 tons. The existing sulfuric acid plants currently produce sulfuric acid sufficient for annual DAP production of approximately 750,000 tons (*27*).

There is not enough farmland along the East or West Coasts to justify major import facilities, with the exception of the areas around Stockton, California, and Portland, Oregon. J.R. Simplot Company produces various fertilizer products that use ammonia as input at its Lathrop and Helm, California, facilities. It imports through the Port of Stockton for its California facilities and the Port of Portland for distribution by truck and rail.

There is no domestic coastwise movement of anhydrous ammonia at present. (“Coastwise” includes the Great Lakes.) Previously, there was a cross-Gulf movement from Taft, Louisiana, to Tampa, Florida. Just a few water ammonia shippers exist. They are CF Industries, which acquired Terra Nitrogen in 2010, Koch Fertilizer, PCS Nitrogen Fertilizer, and trading companies such as Transammonia.

Most ammonia barge activity originates at three terminals on the Lower Mississippi River. Cargo is predominantly imported material. Imports are always routed through a shore terminal—never lightered (transferred) directly from ship to barge. The three major barge terminals are the following:

- Geismar, Louisiana—PCS Nitrogen Fertilizer (river mile 186 above head of passes [AHP]).
- Donaldsonville, Louisiana—CF Industries (river mile 174 AHP).
- Taft, Louisiana—Koch Fertilizer (river mile 129 AHP).

Wood River, Illinois, might also be considered an ammonia barge origin. It connects to the Kaneb (NuStar) pipeline from the Gulf, and from there, it distributes ammonia throughout the region via the waterways. Illinois is one of the larger ammonia user states because most of its soils are heavy and organic, which helps the injected nitrogen cling to them (*12*).

Figure 6 shows the location of major ammonia production facilities, industrial users, and distribution facilities.

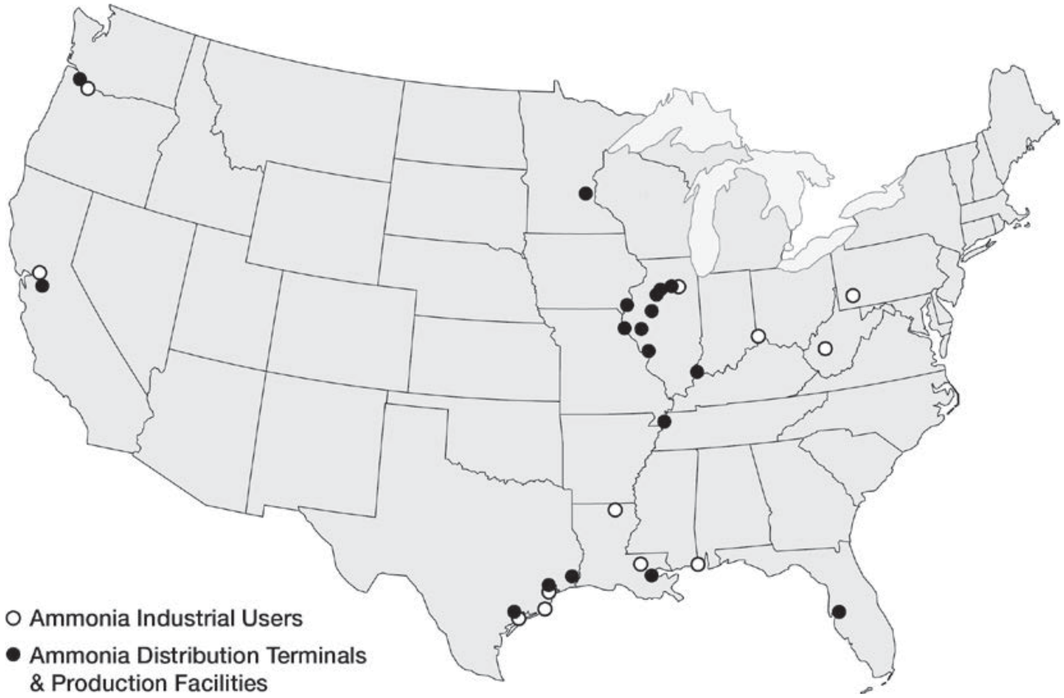


Figure 6. Major ammonia production facilities, distribution terminals, and industrial users.

Source: Energy Information Administration based on data from various published studies
Updated: May 9, 2011

Figure 7. Shale plays in the lower 48 states.

New shale gas plays have been discovered in recent years, and oil and gas production activities are underway. Since the cost of ammonia is primarily determined by the cost of natural gas, this could potentially affect the location of production facilities. Currently identified shale oil and gas plays are shown in Figure 7.

No plans have been announced by any ammonia producers to build new facilities near existing natural gas sources. The newer shale gas plays might induce producers to build new facilities near these new sources. These plays include the following:

- **Eagle Ford (South Texas).** This was discovered in 2008. The play's southernmost window contains mostly gas, but depressed natural gas prices have ensured that much of the drilling activity to date has occurred in the oil and wet-gas windows, a bias that is expected to persist for the foreseeable future. Production facilities already exist along the Texas Gulf Coast with marine transportation access that could economically tap into this new source.
- **Niobrara Shale (eastern Colorado as well as parts of southern Wyoming and western Kansas and Nebraska).** This play was announced in 2010. Given its location, it will not have any effect on waterborne transportation opportunities.
- **Brown Dense (north Louisiana, south Arkansas).** This play is still being evaluated. If developed, it could potentially result in a new production site with access to the Red River for shipments.

Because the ammonia market is a mature market with little growth potential, it is doubtful that these plays will result in the construction of new ammonia production facilities. However, should any new construction occur, it might induce a small shift from rail or pipeline to waterborne transportation.

Chlorine

Most TIH chemicals are shipped from production locations directly to consumption sites (although some are produced, stored, and used at a single site). Chlorine, for example, is produced at chemical plants mostly concentrated in the southern part of the country (see Figure 8), from which it is shipped to customer sites, such as water purification plants and other chemical plants. The only major chlorine-receiving terminal using inland waterway transportation is a DuPont titanium dioxide plant located in New Johnsonville, Tennessee.

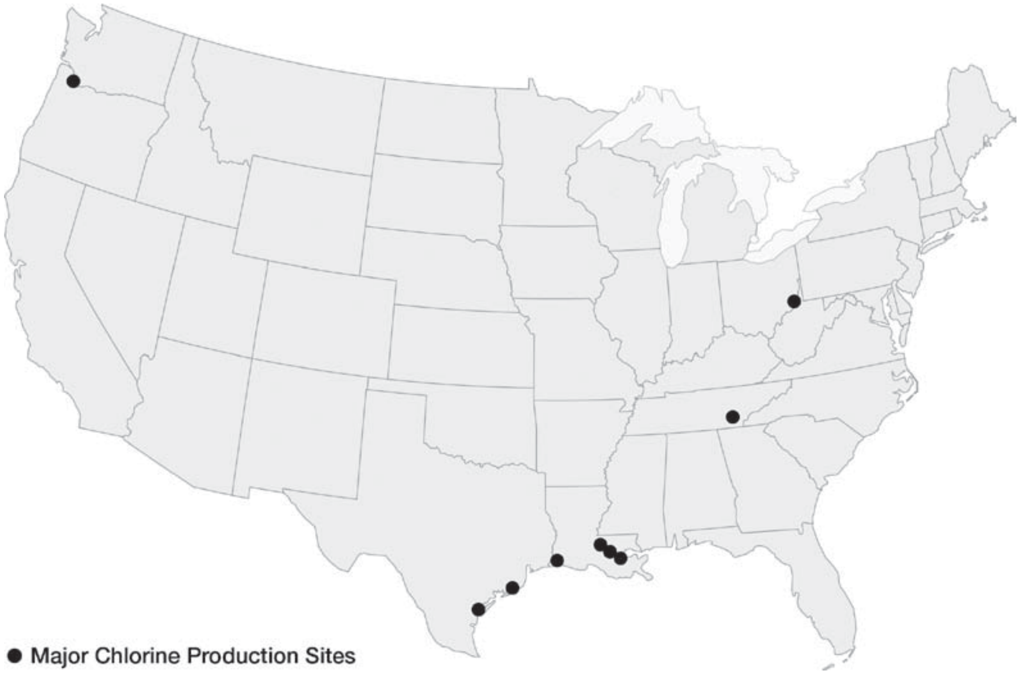


Figure 8. Major chlorine production sites.

Economic factors favor rail transportation of chlorine, and indeed the vast majority of chlorine shipments in the United States are shipped by rail. The other safe and practical mode for long-distance transportation of chlorine is barge, which is considered safer than rail but is less available and more restricted in its ability to reach many origins and destinations. Trucking companies are reluctant to offer long-haul chlorine transportation services (*18*).

Chlorine producers also ship to chlorine packaging locations and sodium hypochlorite bleach production facilities. Additional destinations include PVC plastics producers, some paper mills, and chemical manufacturers. Roughly two-thirds of chlorine is never shipped but rather is used on site in chemical manufacturing or is moved by pipeline to nearby facilities.

Users tend to be widely dispersed and large amounts of chlorine are not typically consumed at any given site. One leading railroad indicated that origin-destination pairs with annual volumes of 100 rail cars were notable exceptions to the widespread dispersion of chemical shipments.

The three largest producers of chlorine are Dow Chemical, OxyChem, and PPG, in that order. The largest producer (Dow) produces chlorine for captive use (primarily the vinyl chloride supply chain) and is not considered a merchant producer (one who sells to another party outside the corporate umbrella). There are three merchant producers of chlorine: Olin, OxyChem, and PPG. Only two of them (Olin and PPG) deliver liquefied chlorine by tank barge. In both cases, the producers themselves own the barges—no commercial transportation company currently offers chlorine barges for hire.

PPG operates water-served chlorine plants in Lake Charles, Louisiana (Gulf Intracoastal Waterway), and Natrium, West Virginia (Ohio River). Currently, PPG ships 70 to 75 percent of its chlorine by pipeline, 20 to 25 percent by rail, and approximately 1 percent by barge. PPG does not ship chlorine by truck or by either ocean or coastwise vessel.

Olin produces chlorine at three water-served facilities (Charleston, Tennessee; McIntosh, Alabama; and St. Gabriel, Louisiana). However, chlorine is loaded in barges at only one facility: Charleston, Tennessee. The 402-mile, Charleston-to-New-Johnsonville chlorine barge movement lies entirely within the Tennessee River system. A single towing company tows Olin's barges under an evergreen contract.

There is presently no identifiable coastwise shipment of bulk liquefied chlorine by water. (Pennwalt, subsequently acquired by Elf Aquitaine, formerly operated an ocean chlor-alkali barge with bulk chlorine tanks installed on deck, but that service is defunct.)

On July 21, 2011, OxyChem, a competitor of Olin, announced plans to construct a chlor-alkali plant at New Johnsonville, adjacent to DuPont's titanium dioxide facility, at a cost of $250 to $290 million. If completed, this new chlorine production plant located next to the customer's site is expected to permanently end barge deliveries of chlorine to New Johnsonville. With the addition of this chlor-alkali plant, shipments of chlorine by barge will be significantly reduced, if not eliminated.

CHAPTER 2

Motivation for Increasing Waterborne Shipments

Public Safety

Statistically, the United States has achieved an excellent safety record for the transport of hazardous materials by all modes. Because releases are so rare, it is often difficult to demonstrate statistically that one mode is inherently less prone to accidents than another. However, the probability of an accident is only part of the risk equation. Equally important, and in some cases more important, is the population that would be potentially impacted by a severe accident were it to occur. Because of the potential severity of an accident involving a release, anything less than an accident-free record leaves the potential for a catastrophic event to occur. As noted in the previous chapter, both chlorine and ammonia are highly toxic. While the probability of a significant release is small, the potential consequences could be catastrophic.

Although TIH materials constitute only 0.3 percent of all hazardous material shipments by rail, this still equates to more than 21.6 million ton-miles of TIH material movement each year. The rail HAZMAT safety record is excellent. In 2008 (the most recent available data), 99.998 percent of rail HAZMAT shipments reached their destination without a release caused by a train accident (*28*). The railroads and trucking industries carry roughly the same amount of ton-mileage of hazardous materials, but the trucking industry has 16 times the amount of hazardous material release than railroads do (*19*). Most cases of interest have focused on combustibles or toxic compounds with boiling points below ambient temperature, such as chlorine, ammonia, and liquefied petroleum gas (*29*).

From 1965 (the earliest data available) through 2005, there were at least 2.2 million tank car shipments of chlorine—only 788 of which were involved in accidents (0.036 percent of all the shipments). Of those accidents, there were 11 instances of a catastrophic loss (i.e., a loss of all, or nearly all) of the chlorine lading (0.0005 percent of all the shipments). Of the 11 catastrophic losses, four resulted in fatalities (0.00018 percent of all the shipments)—the most recent two of which (in Macdona, Texas, and Graniteville, South Carolina) are discussed below (*30*).

Risk could be evaluated according to parameters that include least population exposed to TIH risk, shortest route by distance, shortest route by time, or safest track quality. Complicating the issue is that these criteria may conflict with each other. The Rail Safety Improvement Act of 2008 established federal regulatory requirements known as HM-232E: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shipments, whereby rail operators are required to perform route risk analysis (including assessment of route alternatives) and consider 27 required criteria, including network infrastructure characteristics, railroad operating characteristics, human factors, and environmental and terrorist-related parameters (*31*). These factors are discussed in more detail in the section on the U.S. regulatory and security environment later in this report.

In its simplest form, risk is a function of the number of times a cargo is handled, the condition of the rail line, and the number of high threat urban areas (HTUAs) through which the cargo must pass. The federal standards provide for safety enhancement, public participation, consultation with other parties, through-highway routing, reasonable routes to facilities such as terminals, timely agreement between jurisdictions, and timely local compliance.

Potential Severity of Effects of Releases

A serious TIH release is a low-probability/high-consequence event; hence, while the probability of such an event is low, the risk factor is extremely high due to the magnitude of the effects. The most important element in a TIH release response is the fact that such a release is not readily—if at all—containable, no matter how rapidly the response team reacts. The severity of the effects is determined by wind, weather, time, geography, and population density in the vicinity of the release. Once TIH material is vented, responders can remove the population from the exposure but can do little to speed the natural dissipation through atmospheric pressure and wind (*32*).

A recent study conducted by Risk Management Solutions (the "RMS Study" [*33*]) concluded that a rush-hour rail accident in Chicago involving a chlorine release from a single car could result in 10,000 fatalities, 32,600 other casualties, and more than $7 billion in claims. If such an incident involved the release of TIH from multiple cars, the losses would be considerably higher (*34*). For instance, the Department of Homeland Security estimates that a major chlorine rail car spill could kill 17,500 people. A naval research lab likewise found that such a spill from a 90-ton car in the center of Washington, DC, could quickly cause 100,000 serious injuries or deaths under a scenario involving large holiday crowds (*35*). While none of these events has a high probability of occurrence, they are possible scenarios that must be evaluated.

The most catastrophic releases would involve liquefied gases. Dispersion is very rapid during daytime with no cloud cover (i.e., maximum surface heating) and very poor during nighttime with clear skies and light winds (*35*).

When a chlorine spill takes place, it can affect a large area in a very short time. For example, a large chlorine release requires an initial isolation and protective action distance of 2,000 ft. If the accident were to occur at night, the critical distance would increase to 5 mi for persons located downwind of the spill (*36*).

In the last 23 years, four major accidental TIH releases have occurred in the United States and one in Canada that resulted in fatalities caused by the transported substance. Two involved chlorine, and two involved anhydrous ammonia. The following case descriptions illustrate how severe the consequences can be.

Minot, North Dakota

This incident was a January 18, 2002, derailment of a Canadian Pacific freight train in Minot, North Dakota. The derailment and subsequent loss of tank car integrity resulted in the release of anhydrous ammonia that killed one person, injured 333 others, and required the evacuation of 11,600 inhabitants for more than 1 week. Industry sources estimated the total losses from the accident as approximately $125 million.

The accident caused one death, due to anhydrous ammonia inhalation; the victim had become disoriented while trying to flee the area immediately following the accident. Equipment damage reported to the National Transportation Safety Board (NTSB) totaled $2.5 million, and environmental cleanup costs were $8 million. Valuation for property damage and casualties is not available (*37*).

Macdona, Texas

During an accident that occurred on June 28, 2004, chlorine escaping from a punctured tank car immediately vaporized into a cloud of chlorine gas that engulfed the accident area to a radius of at least 700 ft before drifting away from the site. Three persons, including the conductor of the Union Pacific (UP) train and two occupants of a residence about 200 ft south of the grade crossing where the accident occurred, died because of chlorine gas inhalation. The UP train engineer, 23 civilians, and 6 emergency responders were treated for respiratory distress or other injuries related to the collision and derailment. Damages to rolling stock, track, and signal equipment were estimated at $5.7 million, with environmental cleanup costs estimated at $150,000. Property damage values and compensation for victims is not publicly available (*37*).

Graniteville, South Carolina

With 9 deaths and over 500 injuries, the January 6, 2005, accident at Graniteville, South Carolina, was the most serious of the fatal railway releases of TIH. The chlorine spill occurred centrally in a populated area, and the gas harmed everything it touched. It damaged wiring in buildings, ruined almost everything electronic, and killed trees, plants, shrubbery, birds, and insects (*38*). Avondale Mills (a textile mill) reported that it was unable to recover financially from the accident and closed its 10 mills in South Carolina and Georgia. (This company alone asserted claims against Norfolk Southern [NS] for $420 million.) Among the fatalities were the NS train engineer, six Avondale Mills employees, a truck driver, and a local resident. Approximately 554 people were taken to local hospitals, and 75 were admitted for treatment. All casualties were due to chlorine exposure.

Publicly available information indicates that claims of all parties affected by the Graniteville accident will exceed $500 million, not including extensive environmental remediation costs. The gas release rendered the town of Graniteville uninhabitable for 2 weeks, necessitating the evacuation of 5,400 people.

In addition, property damages reported to the NTSB totaled $6.9 million; a later Federal Railroad Administration (FRA) analysis estimated that the total cost of the accident was $126 million, including fatalities, injuries, evacuation costs, property damage, environmental cleanup, and track out of service.

It was established the day after the accident that chlorine was leaking from only one rail car tank and that possibly 40 percent of the chlorine still remained in the tank. The chlorine gas continued to escape from a fist-sized hole in the tank. On January 9, when a temporary patch was used to plug the hole in the tank, it was estimated that 30 tons of chlorine remained in the tank and 60 tons had escaped (*39*).

Red Deer, Alberta

At approximately 8:23 p.m. on February 2, 2001, Canadian Pacific Railway train CP 966-02 was being prepared for departure in the Red Deer Yard. As part of this process, it was traveling south at about 3.9 mph when an emergency brake application occurred and the train movement stopped. Five loaded tank cars containing anhydrous ammonia had derailed at mile 95.4 of the Red Deer Subdivision. Two of the derailed tank cars were overturned, and 71.74 metric tons (the entire load) of anhydrous ammonia leaked from one of the overturned cars. This leak resulted in the evacuation of approximately 1,300 local residents and businesses. Thirty-four people checked into the Red Deer hospital for exposure concerns, where they were treated and released.

There was one fatality, a person who had been overcome by the anhydrous ammonia vapors while crossing the railway right-of-way. While assessing the site on February 3, 2001, at approximately 1:40 a.m., the dangerous goods teams from Canadian Pacific Railway and Agrium discovered an unconscious man beside the rail cars in the midst of the ammonia vapor cloud. He was taken by ambulance to the hospital in Red Deer and diagnosed with first-degree chemical burns to the face, second-degree burns to other areas of the body, and damage to the interior of the mouth and the upper airway system due to the inhalation of anhydrous ammonia. Three days later, the patient experienced respiratory failure due to these injuries and was successfully revived. On February 8, 2001, the patient was diagnosed with marked inflammation of the airway, trachea, primary carina, and right and left bronchi of the lung. This medical condition continued until May when he succumbed to pneumonia, attributed to irreparable chemical damage to the respiratory tract from anhydrous ammonia exposure (*40*).

Environmental Concerns

Ammonia

The greatest immediate concern regarding an accidental ammonia release would be human exposure; however, there would also be the potential for harmful impacts to the natural marine environment. When ammonia is spilled in the marine environment, it floats on the water surface, rapidly dissolving within the water body into ammonium hydroxide (NH_4OH), while at the same time boiling into the atmosphere as gaseous ammonia (NH_3). The partition ratio (the quantity of ammonia that dissolves into the receiving water divided by the total quantity spilled) is normally between 0.5 and 0.8 for surface spills and somewhat higher for underwater spills.

The following discussion was taken from "Case Study of Fate and Effects of Ammonia Spills" and is reproduced here with some edits to accommodate the style of this report (*41*).

Table 4 summarizes expected downwind distances and durations of ammonia concentrations for different spill conditions. The following discussion summarizes the expected impacts on living organisms associated with these spills.

Marine and Aquatic Organisms

In the event of a spill during the loading or offloading of a vessel, ammonia could be leaked directly into the water. Assuming a line is draining directly into the water, 7 tons of liquefied ammonia could be lost. With a partition ratio of 0.6, 4.2 tons of NH_3 would go into solution as ammonium hydroxide, while the remainder would vaporize into the air. The toxicity of an ammonia solution in water is directly proportional to the concentration of nonionized NH_3 present. The amount of nonionized NH_3 is dependent on pH, temperature,

Table 4. Estimated downwind distances of concentrations of NH_3 for various transportation accidents.

Malfunction	Assumed Evaporation Rate (lb/hr)	Maximum Downwind Distance[a] (miles) for: 60 ppm	300 ppm	1,700 ppm	5,000 ppm	Assumed Duration
Vessel venting on loss of refrigeration	500	0.05	0.05	<0.01	<0.01	Until refrigeration is reestablished and the NH_3 is cooled sufficiently
Truck or rail car transfer line accident	8,000	0.33	0.10	0.03	0.02	1 hr[b]
Truck or rail car venting in a fire	9,000	0.36	0.11	0.04	0.02	1 hr[b]
Vessel transfer line accident	14,000	0.48	0.15	0.05	0.02	1 hr[b]
Truck tank rupture	20,000	0.60	0.19	0.06	0.03	2 hr[b]
Rail car tank rupture	80,000	1.40	0.46	0.15	0.12	2 hr[b]

[a] Assumed wind speed, 10 mph; stability class D.

[b] If the durations are shorter (pool depths shallower), the concentrations will be greater; similarly, if the durations are longer, the concentrations will be less.

and salinity. A concentration of nonionized NH_3 greater than 1.25 ppm can be toxic to some freshwater fish.

With a pH range of 8.0 to 9.0, assuming complete mixing within a channel having a 10,000-ft^2 cross-section, a 7-ton spill would produce toxic conditions for fish for a distance of about 1 mi along the channel. There would be a severe fish kill in the immediate vicinity of the spill, where the concentrations of NH_3 would be highest. It could also be assumed that planktonic and benthic organism mortality would occur in the vicinity of the spill.

A spill of lesser magnitude could occur if the refrigeration equipment on a vessel were to develop a leak from a broken pipe or fitting. Such a leak could release from 42 to 125 lb of NH_3 in 5 minutes. The effect of such a release probably would be confined to the local area. However, the possibility of a fish kill within the immediate area would be likely.

In the unlikely event that a catastrophic accident was to occur causing the release of an entire ocean-going vessel's contents, approximately 12,000 tons of NH_3 could be released into the water. Such a spill could ultimately cause toxic concentrations of NH_3 throughout a large area. The size of the affected area would change as the contaminated water moved downstream. There would be massive mortalities of fish, plankton, shellfish, and other benthic organisms. For inland waterway traffic, the maximum spill size would be 5,000 tons (two barges with 2,500 tons each), but this event would be highly unlikely since it assumes complete release of cargo from two independent vessels, each with a double-skin hull in addition to the independent cargo tank itself.

A long-term result of any ammonia spill would be increased eutrophication of the receiving waters, depending on the presence of other needed nutrients. The additional nutrient levels could stimulate noxious blooms of algae, which could cause continuous water quality degradation.

Terrestrial Biology

In sufficiently high concentrations, ammonia is toxic to living organisms. Large amounts of this chemical would be released into the environment in the event of a large leak or spill, such as a total vessel spill. Regardless of where a vessel ruptured along an inland route, high concentrations of ammonium hydroxide would likely reach shore. If this chemical floated into any of the wetlands bordering the shipping route, it would kill much of the vegetation, potentially causing destruction of important habitats for waterfowl, shorebirds, and other shore species.

Waterfowl and shorebirds present in the wetlands at the time the ammonium hydroxide came into shore could be directly affected. A large number of birds could be killed by ingestion of the chemical. The ammonium hydroxide could also strip protective oils from the feathers of waterfowl, causing the loss of the birds' natural water repellency. In this case, birds would die either from drowning or from infections contracted as a result of getting wet.

The ammonia that would escape into the atmosphere would form a plume with a concentration of several thousand ppm at its center. Concentrations of 1,700 ppm or more of ammonia would occur for several minutes at sea level for a distance of several miles downwind of the location of a vessel accident or for longer periods but over a smaller area if the ship leaked slowly. It would be likely that any bird or animal exposed to these high concentrations of ammonia would be injured or rapidly killed. Birds in the vicinity of the accident could possibly become disoriented in their attempts to escape the odor and might fly into the lethal part of the plume. If the vessel broke up near shore, animals and birds could be killed for several miles inland.

Severe damage to vegetation would also be expected to occur. The extent of this damage would depend upon the resistance of individual plant species to ammonia and the time of year the spill occurred. Plant species differ in their sensitivity to ammonia. Some species may be able to withstand high concentrations of the gas for several minutes. In the spring or summer, a concentrated ammonia plume would probably severely damage most vegetation that it contacted. Perennial species in the natural flora would be most affected by ammonia in the summer and early fall when they are under the greatest physiological stress because of low soil moisture. Since seeds are most resistant to ammonia, annual species in the natural flora would not be greatly affected during summer months. These species would be hardest hit in the spring or fall (*41*).

Chlorine

Liquefied chlorine in a ruptured tank or spilled onto the ground or into water during an accident would be expected to volatilize rapidly, forming a greenish-yellow cloud of chlorine gas, which is heavier than air and travels along the ground. This gas cloud can be carried several miles away from the source of release while maintaining dangerous levels of chlorine. When chlorine gas dissolves in water, it rapidly undergoes an oxidation-reduction reaction (disproportionation) to form hypochlorous acid (HOCl) and chloride ion (Cl-)(*1, 2*). This reaction is complete in a matter of seconds.

If a large amount of liquefied chlorine were released in a body of water, such as during a spill or an underwater release from a ruptured tank, some of the chlorine would be expected to escape into the air before it could mix and react with the water. Similarly, if liquefied chlorine were spilled onto the ground or if a tank containing liquefied chlorine ruptured, much of the chlorine would volatilize rapidly into the air, creating a greenish-yellow cloud of chlorine gas. Since chlorine gas is heavier than air, a chlorine gas cloud would remain low to the ground. Movement and dissipation of the gas cloud would be determined by such factors as the release volume, type of release, terrain, topography, temperature, humidity, atmospheric stability, and wind speed and direction.

Since chlorine gas is so reactive, it would not be expected to remain in the environment very long after it was released. Chlorine immediately reacts with both organic and inorganic materials with which it comes into contact. Chlorine is too reactive to be identified in surface water, groundwater, soil, or sediment at any of the 1,704 hazardous waste sites that have been proposed for inclusion on the Environmental Protection Agency (EPA) National Priorities List.

As mentioned above, chlorine is converted within seconds once it dissolves in water. Chlorine undergoes direct photolysis in the air, and its half-life in the troposphere is on the order of several minutes.

The chlorine inside a 90-ton rail car would be shipped as a liquid under its own vapor pressure. Typically, about 85 percent of the volume inside the tank would be liquid and the remaining amount vapor. Assuming an ambient temperature of 50ºF, the pressure inside the tank would be about 60 psi prior to an accident breaching the vessel. If the hole were at the top of the tank, chlorine gas would be released. The drop in pressure inside the tank would cause the chlorine liquid to boil, resulting in more chlorine escaping. As the chlorine boiled, the tank would become chilled, reducing the evaporation rate. Any air moisture would result in chlorine hydrate formation, which could further reduce the evaporation rate. Under these conditions, it would take many days to empty the tank.

On the other hand, if there were a large hole at the bottom of the tank, the pressure would force chlorine liquid out the hole. The tank would empty much sooner. The chlorine liquid on the ground would also evaporate quickly, at least initially, but solid hydrate formation would reduce the evaporation rate. Maximum chlorine concentrations in the air would be much greater.

Movement of chlorine through soil would not be expected to be relevant since chlorine would react and volatilize quickly when spilled onto the ground.

Issues with Shipment of Toxic Inhalation Hazard Materials by Railroad

The railroads' common carrier obligation subjects the railroads to significant risks and even raises the specter of insolvency in the case of a catastrophic release of TIH materials (accidents involving TIH materials have no liability limits). Among transportation companies, railroads are the only entities required to handle TIH materials. Although the absence of catastrophic accidents has made the movement of TIH profitable, this profit does not cover the potential liability to railroads associated with transporting this material in the case of a truly catastrophic event. Moreover, the ability of the railroads to minimize risks is hindered in that they are not in complete control of the process. For example, railroads do not own the tank cars holding TIH materials, do not load the tank cars, are not responsible for maintenance of the tank cars, and cannot ensure against leakage by inspection of the tank cars; yet, they are the party that is ultimately held responsible in the event of an accident, if found negligent (*28*).

The unique costs (for railroads) of handling TIH materials include costs of maintaining insurance that covers the higher risks associated with TIH material transport and costs of compliance with safety and security operating procedures that each railroad has in place due to the enhanced risks associated with the commodities. These operating procedures result not only in capital and operating expenditures directly related to the activity but also in increased capital and operating costs over the rail network (e.g., reducing speed for TIH material trains on an otherwise congested line slows the other trains on the line). Additional costs also result from special carrier operating procedures and risk assessments that are required to meet federal requirements (*34*).

There are not enough trucks or qualified drivers to distribute the ammonia currently moved by rail cars in the time required for it to be used in agriculture. The trucking industry already has strained capacity. The U.S. DOT predicts the national shortage of truck drivers will grow to 200,000 drivers by 2012 (*42*). It is much more difficult to find trucks to haul anhydrous ammonia now than it was 5 years ago. Fewer drivers have the required commercial driver's license with a HAZMAT endorsement. Even if there were enough certified truck drivers to handle the additional freight, the idea of transporting the material by truck rather than rail or water directly contradicts the goal of lowering the externalities caused by transportation activities.

One shipper showed the research team an analysis of rate increases since 2005 that documented rail transportation rate increases of up to 10 times the 2005 rates for their ammonia movements, designed to defray carrier risk and discourage movement of TIH materials.

One example is the cost of anhydrous ammonia rail shipments out of Tampa, Florida, where the imports arrive. In 2000, the cost of rail service was $22.79 per ton from Tampa, Florida, to a facility at Rensselaer, Indiana. Today's rate is $163.55 per ton, thereby eliminating the opportunity to source imported, lower-cost anhydrous ammonia out of Tampa. Every time there is a switch from using a rail car to ship material to using trucking to ship the same volume of material, there are four more semi-tractors pulling 25-ton loads on roadways (*43*).

Shippers of chlorine and other highly toxic gases have said they think railroads will target them with sharply higher freight rates to offset positive train control (PTC) costs required by recent regulations. In enacting this legislation, Congress cited risks from rail cargoes and ordered freight railroads to install the systems before 2016 (see the section on the regulatory and security environment in the United States later in this report). The law also orders PTC to be deployed on rail lines used by passenger trains (*44*).

Utah-based chlorine producer U.S. Magnesium sought to use UP to move tanker cars by rail to four sites in Louisiana and Texas, but the railroad asked the STB to be relieved from its "common carrier" requirement because the transfer would pose "remote, but deadly, risks" as the material passed through high-population cities such as Chicago, Houston, and Kansas City (*45*). Pending the STB's response, UP would not quote a freight rate. Customers on the receiving end, the railroad said, could get the chemical by pipeline or shorter rail deliveries (*46*).

Historically, truck rates have been competitive with rail rates up to about 200 mi. Because trucks are less fuel efficient and typically must return empty on an anhydrous ammonia backhaul, greater distances simply have not been profitable. At current rail rate levels, however, that range has expanded to nearly 500 mi, despite record-high fuel costs and a longer empty backhaul. In order to accomplish the delivery of ammonia rail cars immediately upon arrival, the rail industry is requiring receivers to have sufficient yard capacity to receive all loads promptly. Typically, this is being done through punitively high storage charges and penalties for being unable to receive loaded cars upon delivery (*34*).

In fact, several railroads have made requests for, and at times demanded, complete indemnification from the railroads' own acts or omissions, including rail accidents with TIH products, regardless of their own gross negligence. As a result of the railroads' position on handling TIH products and the lack of competition involved with a substantial portion of PPG's rail shipments, PPG has seen the cost per ton to ship chlorine throughout its system increase over 100 percent (excluding mileage income) since 2004. In comparison, the cost per ton for all other chlor-alkali chemicals (excluding TIH) shipped by PPG has risen only slightly more than 20 percent (excluding mileage income) since 2004, and the all-inclusive index less fuel, a rail index that tracks costs, has risen only 31 percent during this same period (*17*).

In June 2011, the STB held a 2-day public hearing to explore the current state of competition in the railroad industry and possible policy alternatives to facilitate more competition, where appropriate. Interestingly, during the hearing, publicly available evidence was presented that shows that freight costs are a tiny fraction of the total delivered cost of many of the chemicals shipped by witnesses at the hearing (*47*).

CHAPTER 3

Current Operating Environment

Current Logistics Systems

Each year, there are approximately 34 million freight rail shipments. Of these, approximately 1.6 to 1.7 million shipments are for hazardous materials (5 percent), and of these, 100,000 to 105,000 are for TIH materials (0.3 percent). Almost two-thirds (64 percent) of all TIH shipments are moved by rail (*18*). This is the equivalent of approximately 75,000 carloads. Most rail HAZMAT shipments, including virtually all TIH shipments, are transported in tank cars.

Trucks carry the largest number of shipments, but rail moves more ton-miles. Annual liquid chlorine transport by truck totals approximately 500,000 tons, but these shipments tend to travel shorter distances than chlorine transported by rail and are always shipped in smaller quantities. Due to these factors, an estimated 85 percent of long-distance chlorine movements occur by rail (*18*).

Ammonia

Anhydrous ammonia, the richest, most common, and most cost-effective nitrogen source used by farmers, is transported via truck, barge, and rail, but rail is dominant for long-haul shipments. In 2007, 1.1 million tons of anhydrous ammonia was shipped by rail (848 million ton-miles with an average distance of 733 mi) as opposed to 1.5 million tons of anhydrous ammonia and aqueous ammonia solution shipped by inland barge (1.221 billion ton-miles with an estimated average distance of 795 mi; see Table 1). It is not possible to break out anhydrous ammonia for inland barge shipments separately in the published data.

Pipeline transport is an option, but existing pipelines are at or near capacity with 2 to 3 million tons being transported each year. There is also the complicating factor of seasonal demand and decreases in anhydrous ammonia storage along the pipeline (*3*).

Bulk anhydrous ammonia is typically shipped as a liquefied compressed gas. This state is maintained by applying pressure, reducing temperature, or a combination of both. For long-distance marine shipping, ammonia is usually carried in mid-size liquefied petroleum gas (LPG) ships. LPG ships or barges carrying ammonia are either fully refrigerated (FR) or semi-refrigerated (SR). The FR LPG ships have a large cooling capacity and keep the ammonia fully refrigerated at −27°F (some sources say −32.5°C) and at a vapor pressure below the atmospheric pressure. SR LPG ships have a less powerful cooling capacity and can keep the ammonia at the liquefied condition with a temperature of −15°F to 5°F (some sources say −25°C to −15°C) and at a vapor pressure of 4 to 5 atmospheres. These vessels engage exclusively in international trade; none of the vessels used in this trade are Jones Act vessels.

Most ammonia destined for direct application to the soil and stored at terminals is transported by truck to the final destination. Long-distance trucking operations tend to be price competitive only when they have some type of backhaul. As an example, if a truck is backhauling corn, it can go 80 to 90 mi from the river without transport costs becoming prohibitive. If a truck is backhauling soybeans, the economical shipping radius can be 130 to 140 mi. Of course, backhaul traffic, whether by truck, rail, or barge, can be seasonal and may or may not concur with fertilizer movement needs.

When shipping by inland barge, typical shipment sizes for ammonia tend to be close to 5,000 short tons (*7*).

Table 5 summarizes the salient characteristics of the current modal logistics systems for ammonia.

Chlorine

In terms of volume, pipeline is the preferred mode of transport for chlorine. However, most chlorine pipelines exist within a single plant complex, and all run 10 or fewer miles. Unlike the case with ammonia, there are no commercial long-distance pipelines for chlorine. Overall, pipelines carry about 75 percent of chlorine production (*7*). Unlike

Table 5. Summary of modal characteristics of ammonia transport (*20*).

Rail Tank Car	Truck Cargo Tank	Pipeline	Barge
Each rail tank car can carry 80 tons of ammonia.	Each truck cargo tank carries 20 tons of ammonia.	In 2007, approximately 2.9 million tons of anhydrous ammonia was transported by pipeline.	In 2007, approximately 1.5 million tons of ammonia (anhydrous and aqueous) were transported by inland barge.
In 2007, there were just over 14,000 rail shipments* of anhydrous ammonia, delivering approximately 1.14 million tons of anhydrous ammonia.	In 2007, truck cargo tanks (for hire and private) carried approximately 9.3 million tons of product on the nation's highways.	There are only two ammonia pipelines—one runs from Texas to Minnesota and the other from Louisiana to Nebraska and Indiana.	Only a few retail and manufacturing locations are currently served by the river system.
TFI members own or lease approximately 6,000 tank cars.	Each additional truck cargo tank increases congestion on our nation's roads and the risk of accidents.		
*1.14 million tons divided by 80 tons per car			

ammonia, bulk chlorine rarely moves by truck. Railroads carry 20 to 25 percent of chlorine production, and barges only about 1 percent.

Only two companies operate inland chlorine barges, and the producers own the barges, not commercial transportation companies. According to industry sources, the level of activity is about 20 barge loads per month for the inland waterway system.

Chlorine barges carry liquefied gas under pressure, without need for complex equipment or instrumentation. Chlorine barges are designed and engineered with margins of safety such that releases almost never occur. They are typically incorporated into linehaul operations, which means the barges are handled by multiple vessels—including shift boats at each end of the voyage—whose crews may or may not be sufficiently familiar with the cargoes they are carrying. While the safety record for chlorine barges is excellent, this operational characteristic makes major carriers reluctant to risk carrying such cargoes in linehaul tows.

In 2007, rail moved approximately 3,241,000 tons of chlorine (*22*). Eighty-five percent of long-distance chlorine movements occur by rail (*18*). Marine deliveries of elemental chlorine currently total 40,000 to 50,000 short tons per year.

The determining factor in chlorine logistics is that producers cannot economically store chlorine. This means chlorine moves from the manufacturing site to the consuming location where it enters the production process immediately, with only nominal inventory on site.

Chlorine is typically shipped and stored as a liquid in a container under pressure. The maximum size container (at least in the United States) shipped by rail is capable of holding 90 tons of liquid chlorine. The maximum size chlorine tank shipped on a barge may have a capacity of up to 1,100 tons. The usual size of a chlorine shipment on an inland barge is about 1,100 short tons, in either four or six integral tanks (not removable). Tank cars shipped by motor vehicle may have a capacity of up to 22 tons (*39*).

The chlorine inside a 90-ton rail car would be shipped as a liquid under its own vapor pressure. Approximately 85 percent of the volume inside the tank would be liquid and the remaining amount vapor and some nitrogen (*39*). Railroad tank cars have a spring-loaded safety release device set to discharge at a gauge pressure of 225 psig (on cars marked 105A300W) or 375 psig (on cars marked 105A500W). Barge tanks will also have several release devices for each tank; the ones designated 4 QJ are designed to release at 300 psig. These design features protect against a rupture of the tank and a large release of material. Additional details on safety devices are published in "The Chlorine Manual," published by the Chlorine Institute (*39*).

Railroad companies have attempted to implement several safety-related operational measures that have met with resistance from shippers. A special-interest group consisting of the American Chemistry Council, the Chlorine Institute, The Fertilizer Institute, and PPG Industries Inc., filed a complaint before the STB seeking to halt implementation of enhanced safety measures applying to transportation of chlorine and other toxic and poisonous commodities on the Alabama Gulf Coast Railway (AGR) and other railroads operated by RailAmerica Inc., including the Florida East Coast Railway, which operates from Jacksonville to Miami.

The safety protocols that are being challenged begin with advance notification of a car's delivery and continue with a special inspection of the car once it comes into the railroad's possession. The toxic/poison cars are then placed into short, dedicated trains with no more than three toxic/poison cars per train, after which the dedicated train is operated at a deliberate pace.

Trucking companies are reluctant to offer long-haul chlorine transportation services. One major chlorine producer interviewed for this study indicated that the company does not ship chlorine by truck or by ocean or coastwise vessel. In general, producers involved in this study do not ship by truck, primarily due to safety concerns.

Interviewees indicated that barge transportation is possible if (1) consumption supports deliveries of 1,000 to 1,200 tons of chlorine per shipment and (2) marine facilities exist. Marine shipments of chlorine are severely limited by the number of facilities capable of receiving chlorine by barge. As a result of industry interviews, the researchers were able to determine that there are only two such facilities on U.S. inland waterways. The two sites are a DuPont titanium dioxide plant in New Johnsonville, Tennessee, and a Westlake Monomers vinyl chloride plant in Calvert City, Kentucky, both located on the Tennessee River.

Interviewees did not see any readily viable alternatives to rail movement, whether by water or other mode. The reasons include geographic location of the customer base, the maturity of the chlorine industry, and the practical limitation that producers cannot easily relocate plants to waterfront sites.

Domestic chlorine shipments are typically sent to repackagers for further distribution in 1-ton and 150-pound containers, primarily for water treatment. International shipments are handled by converting the chlorine molecule into a different product, such as ethylene dichloride (EDC), vinyl chloride monomer (VCM), or PVC.

In current STB proceedings regarding rail rates for hazardous materials shipments, much of the shippers' efforts before the STB have aimed at increasing direct competition between rail carriers. Little or no attention is given to the possibility of promoting alternative transportation modes, such as marine transportation. Evidently, shippers expect continuing prominence of railroads in shipping of TIH materials in the long term.

Regulatory and Security Environment

General

The three federal regulatory agencies responsible for creating and enforcing security rules for TIH material shipments are the FRA, Pipeline and Hazardous Materials Safety Administration (PHMSA), and Transportation Security Administration (TSA). The primary U.S. DOT hazardous material regulations are issued by PHMSA in Title 49, Parts 172–174 and 179. The two relevant federal statutes are the Hazardous Materials Transportation Authorization Act of 1994 (HMTA) and the Federal Railroad Safety Improvement Act of 2008 (*48*). Under current U.S. DOT rules, railroads must adopt security plans for TIH materials, including analyses of safety and security risks (see 49 CFR 172.800, 172.802, 172.820.12). Where it is impossible to comply with both a federal and a non-federal (i.e., state or local) requirement, the non-federal requirements are preempted. When a non-federal requirement, as applied or enforced, frustrates the purpose or serves as an obstacle to carrying out the full effect of the federal law, it is preempted (*48*).

Insurance to help guard against TIH-related liability risks is difficult and extremely costly for railroads to obtain. It is impossible for railroads to fully insure against the potential catastrophic losses associated with TIH shipments.

Although there are certain specific regulatory requirements, marine carriers sometimes elect to exceed regulatory requirements in their carriage of hazardous materials, especially TIH materials. For example, carriers sometimes insist that contracts provide for dedicated towboats even though dedicated towboats may not be required by regulation. Otherwise, the carrier may refuse to carry those cargoes altogether. Inland water carriers are not "common carriers," so there is no legislative or regulatory mandate that they must accept certain cargoes. The cargo has to be attractive from a risk/reward standpoint or they will not accept it.

Regulations Specific to Ammonia

Ships carrying liquefied compressed ammonia are regulated by the U.S. Coast Guard in 46 CFR Part 154—Safety Standards for Self-Propelled Vessels Carrying Bulk Liquefied Gases. Barges carrying liquefied compressed ammonia are regulated by 46 CFR Part 151—Barges Carrying Bulk Liquid Hazardous Material Cargoes. These regulations contain requirements for vessel inspection, testing, and certification; vessel and cargo tank design and construction; equipment and materials; operations; and special requirements for specific cargoes.

Additional limitations include the requirement that ammonia shipments have specialized crews and the requirement that a licensed ammonia tankerman be on towing vessels at all times. Crews transporting ammonia are required to take specific training courses. Tankerman barge safety training is designed to ensure workers are fully qualified to not only work safely but also protect the safety of the waterways. Kirby Inland Marine, a leading tank barge operator, requires training on the topics of refrigeration theory, anhydrous ammonia safety, transfer procedures, transfer system components, transfer system problem troubleshooting, and first aid and CPR. Southern Towing has similar training requirements. Federal regulations prohibit any training facility from issuing certifications and endorsements until students have fully and successfully completed each training course. The U.S. Coast Guard is responsible for evaluating training courses provided by training facilities for compliance with federal regulations on the operation of tank barges in U.S. waters. Only fully qualified barge tankermen are allowed to work on barges transporting hazardous liquids and materials (*49*). Captains must ensure that proper handling techniques and equipment are used during each cargo transfer.

Ammonia tows generally consist of two (sometimes three) barges in the continuous custody of a single towboat with a specially trained crew that stays with the barges at all times, including load and discharge operations. While not mandated, these measures are typically implemented because refrigerated ammonia barges are complex systems that have to be constantly monitored and under the care of crews that know what to do in routine and non-routine situations. Unit tows are not a Coast Guard mandate.

Regulations Specific to Chlorine

The Chlorine Institute is the policy maker and keeper of the rules for the chlorine industry, particularly with regard to safety. Regulations specific to chlorine are contained in 46 CFR Subpart 151.50.31. Chlorine barges can be tramped (as opposed to requiring a dedicated tow); however, there are limitations on their position in tow. Barges cannot be on the head or in an exposed location.

Issues Specific to Railroads

Railroads and their TIH cargoes are subject to regulations of PHMSA and STB, both of which are part of the U.S. DOT, as well as the regulations of TSA, which is part of the Department of Homeland Security (DHS). Local officials can do little to restrict rail operations.

The Rail Safety Improvement Act of 2008 established federal regulatory requirements known as HM-232E: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shipments, whereby rail operators are required to perform route risk analysis (including assessment of route alternatives) and consider 27 required criteria, including network infrastructure characteristics, railroad operating characteristics, human factors, and environmental and terrorist-related parameters. The following are the 27 factors to be considered:

1. Volume of hazardous material transported.
2. Rail traffic density.
3. Trip length for route.
4. Presence and characteristics of railroad facilities.
5. Track type, class, and maintenance schedule.
6. Track grade and curvature.
7. Presence or absence of signals and train control systems along the route ("dark" versus signaled territory).
8. Presence or absence of wayside hazard detectors.
9. Number and types of grade crossings.
10. Single versus double track territory.
11. Frequency and location of track turnouts.
12. Proximity to iconic targets.
13. Environmentally sensitive or significant areas.
14. Population density along the route.
15. Venues along the route (stations, events, places of congregation).
16. Emergency response capability along the route.
17. Areas of high consequence along the route, including high-consequence targets as defined in § 172.820(c).
18. Presence of passenger traffic along route (shared track).
19. Speed of train operations.
20. Proximity to en route storage or repair facilities.
21. Known threats, including any non-public threat scenarios provided by DHS or U.S. DOT for carrier use in the development of the route assessment.
22. Measures in place to address apparent safety and security risks.
23. Availability of practicable alternative routes.
24. Past incidents.
25. Overall times in transit.
26. Training and skill level of crews.
27. Impact on rail network traffic and congestion.

According to pronouncements made by the Association of American Railroads, the federal government does not allow railroads to set rates at a level high enough to recover from TIH shippers the billions of dollars of added costs associated with TIH shipments. In addition to liability costs, these added costs include the costs of TIH-related insurance, the multibillion dollar costs of installing PTC technology on tracks over which TIH materials are transported, and the costs of complying with the extensive government-mandated safety and security operating procedures that railroads must have in place due to the higher risks associated with TIH commodities.

Since 2010, railroads have been required to conduct risk analyses annually to assess the safety and security risks along the current route utilized to transport the specified shipments, and they must also assess the risks on practicable alternative routes over which they have authority to operate.

Railroad security plans must include the following: (1) a procedure for consulting with offerors and consignees to minimize the time that a HAZMAT shipment is stored incidental to its movement from origin to destination; (2) measures to limit access to such shipments during temporary storage and delays in transit; (3) measures to mitigate risk to population centers during temporary storage incidental to transportation; and (4) pre-trip inspections for signs of tampering with the rail car, including its seals and closures, and an inspection for any item that does not belong, is suspicious, or may be an improvised explosive device (IED) (*50*).

In addition to a structured evaluation of routes utilized to transport HAZMAT, federal regulations will require railroads to implement a PTC signal system on routes where TIH materials are transported by 2015. Railroads will have to install PTC on approximately 73,000 mi and around 17,000 locomotives. Roughly 75 percent of these miles are subject to the PTC mandate because they are used to transport TIH materials. In other words, if not for TIH materials, railroads' PTC-related costs would be many billions of dollars lower (*28*). New regulations also require rail tank cars transporting the most toxic HAZMAT to be designed to comply with higher safety standards than the existing tank cars.

Under proposed TSA regulations, a railroad must have a security coordinator, procedures to determine the location and shipping information for each TIH rail car under its physical custody, and the ability to provide TSA with such information within 1 hour of request. There are also stringent requirements on transfers of cars containing TIH materials between interchanging railroads and between railroads and shippers or receivers. These include the requirement that cars being transferred within an HTUA, or which may subsequently enter an HTUA, may not be left unattended at any time during the transfer of custody.

CHAPTER 4

Movement of Toxic Inhalation Hazard Materials in Europe and Canada

Background

The danger associated with moving toxic inhalation hazard materials is a problem faced all over the world. Interestingly, if asked to name a major chemical producing area in the world, places that come to mind might be Houston, Singapore, or one of the large complexes in Germany. An area less likely to be named is the Flanders region of Belgium at the mouth of the Scheldt River system, yet it contains the highest concentration of chemical facilities in Europe and boasts the second-largest chemical cluster in the world at Antwerp.

A surge of new vessel construction combined with delay in the retirement of older single-hulled vessels has led to a degree of overcapacity in the tanker shipping sector in Europe. There have also been some high-profile accidents involving dangerous goods on the Rhine that have driven home the importance of using double-hulled vessels. There was a major accident on the Rhine involving a chemical tanker on January 13, 2011, near the Lorelei at St. Goarshausen that resulted in the death of two crew members and the halting of shipping activity for nearly a month in one direction. Fortunately, the vessel was double-hulled, and this was credited with preventing an environmental disaster. The disruption was significant enough to hold down 2011 inland shipping totals in Germany and Switzerland. The Lorelei is seen as a chokepoint, as it is one of the narrowest points of the Rhine. The vessel was carrying sulfuric acid from the BASF plant in Ludwigshafen to Antwerp, Belgium (*51*). There is an ongoing investigation into the party responsible for the accident. Clearly, with such a substantial impact on the economy of the Rhine, the accident has increased discussion of safe transport of dangerous goods in Europe.

Regulatory and Security Environment

In both Europe and Canada, the term "dangerous goods" is used in lieu of "hazardous materials"; yet the meaning is essentially identical. Both chlorine and anhydrous ammonia are essential building blocks of the chemical and agricultural product industries, respectively. The Canadians and Europeans have taken substantial steps to standardize and centralize control of the movement of dangerous goods. For Canada, this has meant imposing an unusual amount of federal control on the provinces, which otherwise enjoy substantial autonomy. For the European Union (EU), it has meant working within a very old and arcane preexisting structure of bodies and regulations in order to develop a core of standards and practices that would be consistent throughout the EU, despite the sharply different infrastructure endowments of Eastern and Western states.

The foundational document for the regulation of dangerous goods by water in Canada is the Transportation of Dangerous Goods Act of 1992 and its subsequent amendments. The equivalent document in the EU is the European Agreement Concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN). These documents were extensively reviewed to examine potential applicability to the United States. Both entities have utilized the United Nations (UN) Recommendations on the Transport of Dangerous Goods—Model Regulations in the development of their policies. The UN standards, currently in their 15th iteration, have been evolving since 1956. The UN recommendations do not apply to the bulk transport of dangerous goods in seagoing or inland navigation bulk carriers or tank vessels, which is subject to special international or national regulations (*53*).

There is a substantial difference between a general agreement to follow UN recommendations and an actual binding legal structure. European policy in this area has been slow and deliberate in its evolution; however, as of 2011, many formerly non-aligned states, such as Switzerland and former Eastern bloc countries including Serbia, Poland, and Ukraine, have acceded to the agreement. In the past, there has been collaboration between Canada and the EU regarding strategies for the movement of dangerous goods. The North Atlantic Treaty Organization (NATO), in which Canada is a very active participant, served as an early forum for collaboration between European and Canadian partners in assessing the need to enhance the safety of dangerous goods movements. Improper handling of anhydrous ammonia within the former Soviet Union was a major point of contention for Europe during the early 1990s (*54*). NATO conducted a pilot study in the 1990s to evaluate different options for moving dangerous goods across international borders, taking into account the need to integrate the newly independent states into a cohesive structure. One issue identified early in the process is that there are multiple distinct strategies for moving dangerous goods. A frequent holdup to agreements in moving these products is that different states champion different strategies that might all be equally valid but lead to delays when crossing from one jurisdiction to another (*54*).

The "Pilot Study on the Transport of Dangerous Goods" soon grew into a general Canadian-European forum on dangerous goods policies that constituted a series of international meetings held in Canada and Europe between 1994 and 2000. Given the international security elements tied to certain classes of dangerous goods, NATO may again play a coordinating role in refining international procedures for member states.

These early studies examined the recommendations of the UN Committee of Experts on the Transportation of Dangerous Goods, the International Maritime Dangerous Goods Code, and the International Civil Aviation Organization's Technical Instructions, as well as the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) and the ADN. Thus, these meetings occurred after the passage of the Canadian Transportation of Dangerous Goods Act but significantly in advance of the ratification of the ADN. (The ADR has no overall enforcing authority; in practice, contracting parties carry out checks, and national authorities deal with non-compliance in accordance with their domestic legislation.) (*55*). The United States currently does not have an analogous overarching structure for the regulation of hazardous material shipments by water, yet this does not suggest that the U.S. system is less strictly enforced. The current structure of the European system emerged from earlier regulation of Rhine commerce. Conversely, in the United States, the Coast Guard has played a unique role in enforcing maritime safety. This, in addition to the concentration of U.S. chemical shipments on the coast (as opposed to inland rivers) may explain why the two systems have developed differently.

The likelihood that the European model of regulation will find favor in the United States in the future will depend in part on whether U.S. conditions will grow closer to those of Europe. For example, when compared to the United States, the European inland market is characterized by smaller firm size and a comparatively larger set of actors. In these conditions, a standardized protocol is very useful for setting minimal thresholds that can be universally conveyed. If the U.S. inland waterway system were to expand to include more small, owner-operator companies, a standardized protocol would be useful in ensuring that the complexity of regulation does not serve as a barrier to market entry.

The following are some of the provisions of the ADN that are most relevant to this analysis:

- The ADN requires all shipments of dangerous goods to be accompanied by an expert, designated as an individual who has passed an examination on ADN procedures.
- Experts are required to renew their training through refresher courses at 5-year intervals.
- A separate training is required for experts who escort dangerous materials in gaseous form (or those that enter a gaseous state on contact with air or water).
- In order to be recertified, experts in the carriage of gases must certify that they worked on a Type G tank vessel for at least 1 of the last 2 years.

It is interesting to note that there is less explicit mention of handling procedures for chlorine in the ADN than there is for anhydrous ammonia. This may, in part, be due to the diminished role chlorine shipments play in total dangerous good movements in comparison with anhydrous ammonia. Chlorine is a Class 2 material with a UN classification code of 1017 and is listed as a commodity with no excepted quantity; yet, there are no commodity-specific handling instructions. Regulations applicable to transport of chlorine can be found under general provisions for liquid cargo tanks.

Market Description

Rhine Chemical Shipments

At present, the Rhine carries 65 percent of the tonnage of all commodities transported by inland waterways in Europe. Eleven EU member states primarily utilize inland waterways that are tributaries of the Rhine, Elbe, Danube, and Oder river basins (*56*).

The Port of Antwerp is of critical importance in facilitating chemical transport to the Rhine system. After pipelines, barge movements are the largest mode for transport of chemicals from the port, accounting for 34 percent of transport. This compares to a European average of 4 percent for the distribution of chemicals by inland navigation (*57*).

The Central Commission for Navigation on the Rhine (CCNR) has specific authority to specify technical requirements for vessels operating on the Rhine (*56*). As confirmed through an interview with CCNR officials at CCNR's headquarters in Strasbourg, France, the legal structure that was only recently enacted for the EU has existed on the Rhine through the CCNR since 1971 (*56*). Chemicals as a general category are increasing; however, the transport of fertilizers is declining on the Rhine due to an overall falloff in European demand.

Chemical transport on the European inland waterway network is attractive due to a very high specialization of the tanker shipping industry. Passenger rail in Europe has priority over freight rail, in contrast with the United States, where Class I railroads own and operate the corridors used for passenger service. Consequently, the freight rail system in the United States is regarded as the most efficient in the world. In Europe, by contrast, the railway is not viewed as a promising transport mode for the modal shift of dangerous (hazardous) cargoes that currently move by truck (*58*). Furthermore, the railroad does not have the experience and reputation for expertise in the movement of hazardous cargoes, as is the case in the United States. The cost to ship dangerous goods by truck can be very high, so in most cases where a modal shift to water is possible, it has already been realized.

The fixed infrastructure of the chemical industry is very important in Europe. Particularly notable are the enormous facilities in Ludwigshafen, Germany—principally BASF, which is one of the largest chemical companies in the world. These chemical industries have located along the Rhine in order to take advantage of it to move not only end products but also raw materials. It is a very well-established market, which allows shippers to realize economies of scale. The broader chemical industry concentrated along the Rhine is supported by a high concentration of refineries in Rotterdam. One major shift that is occurring within Europe is a decline in refining capability with a shift in sourcing to the Middle East. This is tied in large part to the higher shipping cost of European products. There have been two major refinery closures in Germany and another two in France in 2010 alone. The same economic factors that are affecting refined petroleum production in Europe are also affecting fertilizer production and distribution.

The CCNR used to track fertilizers, including anhydrous ammonia, within the general category of chemicals; yet, in recent years it has broken these into two separate categories in order to clearly demonstrate that while overall chemical transport on the Rhine is consistently increasing, fertilizer transport has been consistently falling. The total volume of chemical products transported on the Rhine increased 29 percent between 2004 and 2010, as shown in Figure 9.

Danube Shipments

An interview conducted by one of the project researchers with researchers at the University of Belgrade confirmed that the ratification of the ADN is also proving to be a positive development for the Danube-dependent nations (*60*). For the newly independent states, one of the key difficulties in transporting dangerous goods was the need to integrate procedures with the West. Inland shipping on the Rhine had been largely standardized even prior to the establishment of the ADN; however, the situation was more difficult for shippers on the Danube, who sometimes face contradictory safety requirements for different nations when engaging in international shipments. For example, it was noted that the ADN removed the maximum limits on shipment size, which previously made the transport of some commodities nonviable. The signatories to the agreement, including Serbia, subsequently passed national laws echoing the main provisions. In general, inland shipping on the Danube has declined in recent years, particularly since the economic crisis; it is hindered by a cargo imbalance as well as deficiencies in infrastructure. It is hoped that with the ADN now in force, additional legal barriers will be minimized.

In addition to the provisions of the ADN, there has been a concerted effort for some years now to minimize the movement of chlorine and other highly dangerous cargoes. In fact, this has been a principal argument for retaining a core of

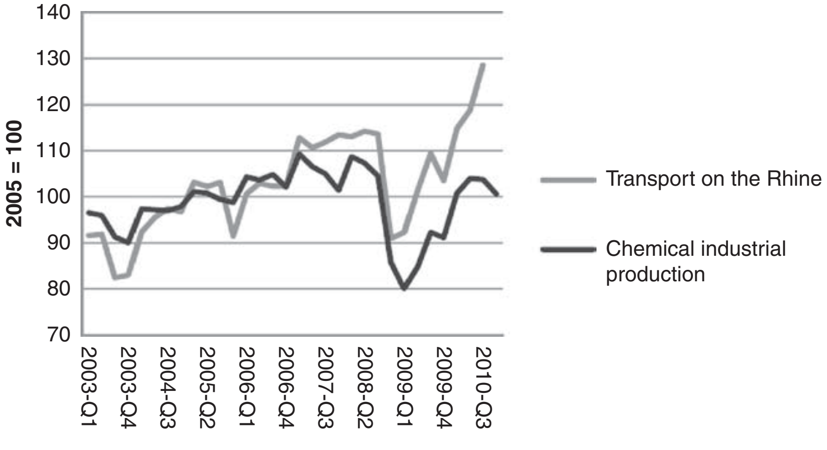


Figure 9. Transport of chemical products on the Rhine (59).

domestic production within Europe despite high manufacturing costs. Over-reliance on imports would mean, in many cases, longer supply chains and greater exposure to transport the commodities to the point of consumption.

Chlorine and Anhydrous Ammonia Production Strategies in Europe and Canada

Changes in the production process of chlorine have begun to have a significant impact on how and where chlorine is produced, particularly in Europe. Anhydrous ammonia production in Canada is particularly important due to the large role played by commercial agriculture. At the same time, large-scale production of agricultural commodities for domestic consumption and export is possible in large part due to the substantial ammonia production within Canada.

The following section reviews the chlorine and anhydrous ammonia industries in both Europe and Canada and examines the legal and administrative structure used for safely handling them.

The Canadian Ammonia Industry

Canada produces approximately 12 percent of global fertilizers. The industry generates between 4 and 5 million tons of ammonia per year. The vast majority of Canadian ammonia production is concentrated inland, primarily in the province of Alberta. There are only two Canadian ammonia production units in proximity to water—the Courtright, Ontario, facility that is located near Lake Huron and the Kitimat facility located in British Columbia near the new Port of Prince Rupert. The opening of the Port of Prince Rupert has given Canada an important new avenue for exporting anhydrous ammonia without moving the material through large population centers. At present, however, there has been almost no anhydrous ammonia shipped through this gateway. Figure 10 shows the location of the main ammonia production facilities in Canada.

Given that natural gas constitutes 70 to 90 percent of the total cost of ammonia production, the locations of ammonia production units are closely correlated with major natural gas production areas.

In 2010, the United States imported 1,115,857 tons ($441 million) of anhydrous ammonia from Canada, compared with only 95,874 tons ($11 million) of ammonia in aqueous solution, or 3 percent of the total (*61*). Table 6 shows Canadian exports of anhydrous ammonia to all countries from 2006 through 2010 in U.S. dollars. For all practical purposes, the United States is Canada's only export partner for anhydrous ammonia. To this point, Canada has not made substantial use of its maritime ports for anhydrous ammonia exports.

Table 7 provides a breakdown of provinces of origin for Canadian anhydrous ammonia production. The dominance of shipments from Alberta is obvious.

Figure 11 provides a summary of the level of Canadian ammonia production for the last 10 years.

In tracking trade statistics, Statistics Canada examines ammonia within the broader category of fertilizers. There are currently 55 manufacturers located within Canada that produce fertilizers such as ammonia (*63*). North Dakota has

Figure 10. Location of ammonia production units in Canada.

Table 6. Canadian exports of anhydrous ammonia (U.S. Dollars) (*62*).

	2006	2007	2008	2009	2010
United States	389,454,194	401,087,831	740,998,313	358,981,035	450,235,486
St. Pierre-Miquelon	5,060	13,565	19,373	0	3,169
Greenland	0	326	0	0	0
TOTAL (ALL COUNTRIES)	389,459,254	401,101,722	741,017,686	358,981,035	450,238,655

been the largest single recipient of Canadian fertilizer exports (*64*). Washington State is the U.S. destination state with the most potential to receive a modal shift to water for fertilizer exports, as it is the third-largest recipient of fertilizer exports and the largest with a significant port and marine highway system. A logical supply chain would be to move ammonia by rail to the Port of Prince Rupert from Albertan factories and then move the shipment by ship or ocean-going barge to the Columbia or Snake River system. Eventually, maritime shipments could also be made as far south as California.

Chlorine Manufacturing in Canada and Europe

Alkali and chlorine manufacturing within Canada has been declining in recent years. As of December 2010, there were only seven manufacturers of chlorine and alkali within Canada—three in Quebec, two in Ontario, one in New Brunswick, and one in British Colombia.

Within Europe, the production of chlorine is an important industry, yet one that is seen as either stagnant or declining. With a stable population, long-term projected demand growth for PVC—heavily used in the housing industry—is modest outside of Eastern Europe. In other cases, higher production costs have led to greater importation, particularly from regions with lower energy costs. The principal strategy employed by European countries to avoid risk exposure from the transportation of chlorine is to minimize the instances when chlorine needs to be moved. Less than 10 percent of chlorine produced within Europe is moved off site. Europe has a large number of chlorine-producing factories, but most are modest in size—tailored to the needs of a specific industrial use.

Today, installed capacity for chlorine in Europe exceeds demand. Players say restructuring and closures, particularly of old, small units, are inevitable. The United States has also seen a slowing of chlorine demand yet has retained more long-haul shipments due in large part to the efficacy of the freight rail network.

Figure 12 lists the international instruments administered within the UN Economic Commission for Europe (UNECE).

The sharply different roles played by anhydrous ammonia in the Canadian and European economies are characterized by a key distinction. In Europe, neither chlorine nor anhydrous ammonia is manufactured for export abroad, whereas for Canada ammonia is a key export. High manufacturing costs and the difficulty in moving dangerous goods through heavily populated regions have limited the roles that chlorine and ammonia production have played in the European economic picture. Like the United States, where chlorine production peaked in 2004 and has been in decline ever since, European chlorine production has been falling in large part

Table 7. Provinces of origin for Canadian anhydrous ammonia production (*62*).

	2006	2007	2008	2009	2010
Alberta	313,784,177	315,356,000	621,674,661	268,273,403	346,702,573
Ontario	60,079,685	75,805,006	108,165,079	85,013,348	89,391,346
Manitoba	13,245,013	9,062,759	10,655,268	4,310,901	7,275,441
Saskatchewan	2,265,520	833,552	437,527	1,383,383	6,710,188
Quebec	56,157	0	0	0	155,939
British Columbia	0	30,513	65,778	0	0
New Brunswick	23,641	0	0	0	0
Prince Edward Island	0	0	0	0	0
Nova Scotia	0	0	0	0	0
Nunavut	0	0	0	0	0
Newfoundland and Labrador	0	0	0	0	0
Northwest Territories	0	0	0	0	0
Yukon Territory	0	0	0	0	0
Sub-total (to United States)	389,454,193	401,087,830	740,998,313	358,981,035	450,235,487
Others	5,060	13,892	19,372	0	3,168
Total (all countries)	389,459,253	401,101,722	741,017,685	358,981,035	450,238,655

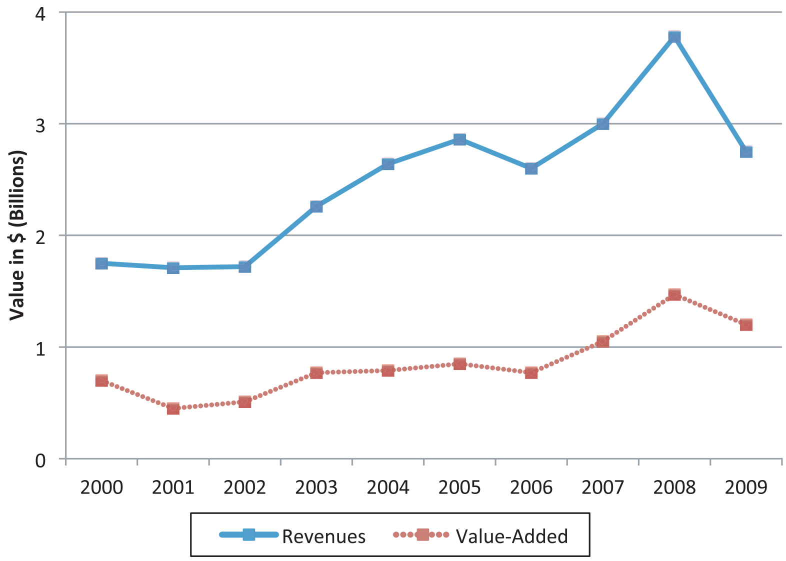


Figure 11. Canadian fertilizer production (values in Canadian Dollars) (63).

due to safety and environmental concerns (*65*). Nevertheless, the general market for chemical shipments on the Rhine has been positive in recent years.

The impact of the ADN treaty has been strongly felt within the chemical shipping market, and its impact, according to the CCNR, has been largely positive. The ADN mandated a transition from single-hulled to double-hulled vessels, which has helped create a boom in vessel construction (*58*). From 2006 to 2010, 280 new tanker vessels were deployed in the European market. In order to take advantage of economies of scale, when shipbuilders construct new double-hulled vessels to replace single-hulled ones, they build vessels with much greater capacity than the vessels that are being replaced. To this day, there is an environment of strong investment in new ship construction for inland navigation in Europe, and, due to the double-hulled new builds that have already entered service, the average capacity of the tanker fleet is also increasing. The provisions of the ADN allow single-hulled vessels to continue to operate for some commodities until 2018.

Energy usage is a key area of concern for the European chlorine industry. Chlorine production is energy intensive, and with the comparatively higher cost of energy in Europe, there is concern that production could be outsourced to countries that have less efficient processes, thereby increasing the total carbon footprint of European chlorine production. In Europe, electricity accounts for approximately 50 percent of the cost of chlorine and caustic soda production.

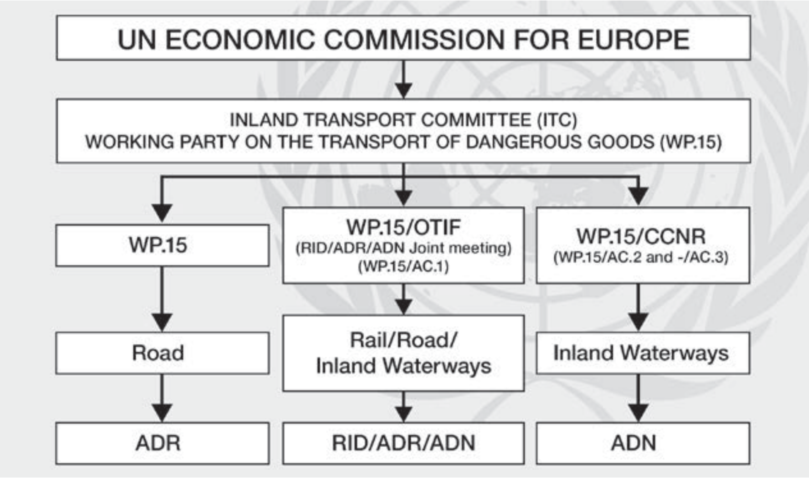


Figure 12. International instruments administered within the UNECE.

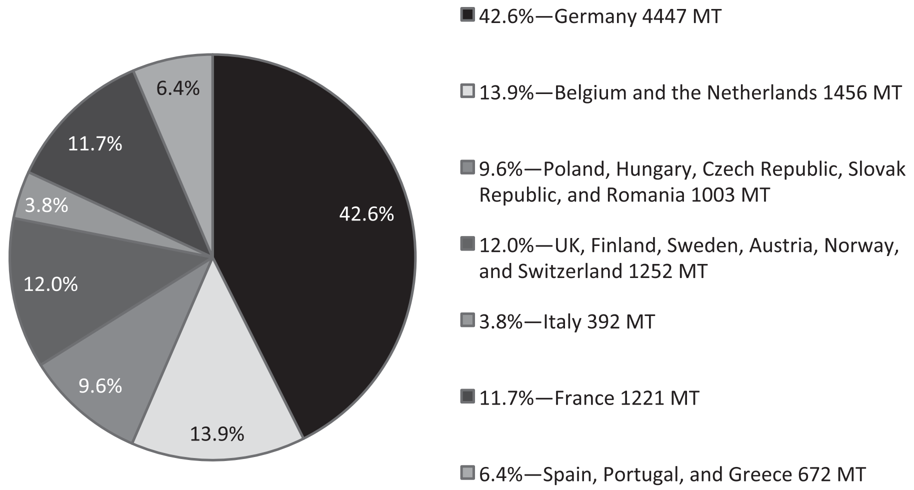


Figure 13. European chlorine production, 2008 (000 Metric Tons) (66).

Figure 13 shows the breakdown of chlorine production within Europe in 2008. Table 8 shows the location and capacity of chlorine production sites within Europe.

Differences from the U.S. System

In Europe, the railway is not viewed as a promising transport mode for the modal shift of dangerous cargoes that currently move by truck. Furthermore, the railroad does not have the experience and reputation for expertise in the movement of hazardous cargoes that the railroad has in the United States. The cost to ship dangerous goods by truck can be very high, so in most cases where modal shift to water is possible, it has already been realized. The location of the fixed infrastructure of the chemical industry is very important in Europe for determining the modal options available.

Conclusions

For ammonia production, it is important to understand that 80 percent of global ammonia production is used for fertilizers, and this accounts for the location of major consumption points and corridors. The production process for anhydrous ammonia has changed little over the past several decades. Thus, while there is variation in the technology used in the production of ammonia, the most significant determinant of where ammonia is produced is the availability of feedstock, principally natural gas. In countries with high gas prices, ammonia production has generally not been expanding in recent years. Many countries with copious natural gas reserves have moved into the ammonia market. The Middle East is a notable example where the specialization in ammonia production is driven not by agricultural demand but by the ready accessibility to natural gas. For countries that wish to export ammonia, proximity of the production site to water

Table 8. Major European chlorine production capacity (*66*).

Company	Location	Capacity*
Akzo Nobel	Botlek, the Netherlands	633
	Delfzijl, the Netherlands	109
	Frankfurt, Germany	167
	Ibbenbüren, Germany	125
Anwil	Wloclawek, Poland	214
Arkema	Fos, France	310
	Jarrie, France	170
	Lavera, France	350
BASF	Ludwigshafen, Germany	385
Bayer	Brunsbüttel, Germany	210
	Dormagen, Germany	480
	Leverkusen, Germany	360
	Uerdingen, Germany	240
Borsodchem	Kazincbarcika, Hungary	299
Chimcomplex	Borzesti, Romania	107
Dow Chemical	Schkopau, Germany	250
	Stade, Germany	1,585
Ercros	Flix, Spain	150
	Huelva, Spain	100
	Vilaseca, Spain	190
Evonik Degussa	Lülsdorf, Germany	136
INEOSChlorVinyls	Rafnes, Norway	260
	Runcorn, UK	746
	Stenungsund, Sweden	120
	Wilhelmshaven, Germany	149
Oltchim	Râmnicu Vâlcea, Romania	260
Perstorp	Pont-de-Claix, France	170
Polimeri	Devnya, Bulgaria	124
Rokita	Brzeg Dolny, Poland	125
Solvay	Rheinberg, Germany	200
	Rosignano, Italy	150
	Tavaux, France	375
SolVin	Antwerp, Belgium	474
	Jemeppe, Belgium	174
	Martorell, Spain	218
Spolana	Neratovice, Czech Republic	135
Syndial	Assemini, Italy	153
Tessenderlo Chemie	Tessenderlo, Belgium	400
Vestolit	Marl, Germany	260
Vinnolit	Gendorf, Germany	172
	Knapsack, Germany	250

*Thousand Metric Tons/Year

Note: Only plants over 100,000 metric tons/year are shown.

is also strategic. Thus, while Canada is a substantial ammonia producer due to its robust agricultural sector, its ability to become a major ammonia exporter is limited by the fact that most of its ammonia production is concentrated inland, away from deep-water ports or a navigable waterway system capable of transporting ammonia to export terminals. Nevertheless, the west coast of Canada is likely to be the most important marine highway for Canadian exports of anhydrous ammonia to the United States.

The growth in ammonia demand has implications for the growth in biofuels (corn ethanol). The intense carbon dioxide (CO_2) release in the course of manufacturing ammonia for fertilizer used in U.S. corn production is one of the key reasons that corn ethanol is not considered to be very promising in substantial net lifecycle reductions in CO_2 emissions (well-to-wheels). Nevertheless, while ammonia production is inherently carbon intensive, there are a number of factors that can lower the overall carbon footprint per unit of ammonia. Transportation has not often been discussed in this context; yet it is clear that a country with a carbon minimizing strategy should consider incorporating marine transportation.

For the EU, the principal goals regarding transport of anhydrous ammonia and chlorine have been to lessen human exposure while still ensuring that major agricultural and industrial users can secure a sufficient amount of product so as not to undermine the economy. Although it only governs the Rhine Basin, the CCNR is the most established organization within Europe for ensuring safe navigation on inland waterways. One of the key objectives of the CCNR is to ensure the safety of navigation, which makes the regulation of dangerous goods shipments a natural priority area. The CCNR's founding documents were drafted in the 19th century and thus predate many of the nation states that currently constitute Europe. For this reason, newer regulations such as the ADN must incorporate the basic framework established by the CCNR.

The ADN entered into force in 2008 after having first been agreed to in 2000. It set out to standardize minimum requirements for dangerous goods shipments such as packaging requirements, placarding, vessel crewing requirements, and vessel inspection requirements.

The level of complexity involved in integrating existing practices has meant that standardization efforts have been slow. Nevertheless, full implementation of the ADN promises to significantly affect inland marine shipping of dangerous goods for the whole of Europe.

CHAPTER 5

Vessel Requirements

Existing Fleet—Inland

Ammonia

All existing anhydrous ammonia barges are of semi-pressurized design, carrying liquefied anhydrous ammonia under pressure at −28°F in tanks built to about 40 psi test pressure. This design is analogous to semi-refrigerated LPG carriers, in which the pressure rating of cargo tanks can be less since cargo pressure is much reduced due to low temperature, in contrast to cargoes kept in a liquid state by pressure alone. The inland distribution system is limited, therefore, by the availability of terminals that can handle refrigerated cargo. Additional limitations are the requirements for specialized crews and a licensed ammonia tankerman on towing vessels at all times.

Carrying capacity of a typical ammonia barge is about 2,500 short tons. Usually, two or three ammonia barges are operated together in a single string as a unit tow with a dedicated towboat.

Kirby Inland Marine operates 12 barges out of an industry-wide fleet of 33 anhydrous ammonia barges. Other market participants include Southern Towing (Memphis, Tennessee) and Duvall Towing (Lake Charles, Louisiana). Table 9 shows the breakdown of the current fleet.

The ammonia barge fleet is rather aged, but there appear to be no plans to add to or replace any units in the fleet. Market forces determine vessel demand, and the economics do not support new construction. Figure 14 shows an ammonia barge tow in operation.

Chlorine

The researchers were only able to identify two chlorine shippers. They are both manufacturers using their own equipment. The tug companies involved are TVT and American Commercial Lines. There are currently no commercial movements of chlorine by water in for-hire vessels.

Liquid chlorine barges are of fully pressurized design—cargo is kept in a liquid state by pressure alone, at ambient temperature. Typical pressure in cargo vapor space while underway is 90 to 100 psi. Chlorine barges are standard size (195 ft × 35 ft), double skinned, with independent pressure tanks mounted on saddles within a hopper. Either four or six tanks are mounted on each barge, with a total carrying capacity of 1,100 tons per barge. Pressure tanks are tested to 450 psi and are constructed of $1\frac{3}{8}$-inch mild steel. Tanks are unlined. Cargo is loaded and discharged by pressure—there are no self-contained barge pumps. Valves and shutdown devices are air actuated and shut when air pressure is removed. Chlorine barges are typically operated in linehaul service, that is, they are placed in mixed tows with other barges carrying other cargoes. Dedicated towboats are generally not utilized.

Barges are drydocked every 3 years and comply with both U.S. Coast Guard rules and Chlorine Institute guidelines.

Table 10 shows the composition of the current chlorine barge fleet. Shipyards report that there has been some recent exploratory interest in replacing older chlorine equipment, with no serious inquiries at present.

Existing Fleet—Coastwise

There are no Jones Act vessels engaged in the coastwise shipment of either chlorine or ammonia. The U.S. Maritime Administration (MARAD) provided the researchers with a list of Jones Act vessels that included 56 tankers (see Appendix A). Of these 56 tankers, 10 have already been broken up, 6 are scheduled to be broken up, and 1 is laid up. Thirty-eight are engaged in shipments for refinery operations, and one is in the molten sulfur trade. Of the 38 tankers, the researchers were only able to identify 2 that might be suitable for use in TIH shipments, but they would most likely require significant modifications—additional research is required. Even without the research, it is apparent that there is a lack of Jones Act equipment to conduct any significant shipping of TIH materials in a coastwise trade.

Table 9. Composition of ammonia barge fleet.

Company	Barge No.	Capacity (Short Ton)	Year Built
Kirby	Kirby 20850	2098	1966
Kirby	Kirby 20851	2098	1965
Kirby	Kirby 21850	2208	1965
Kirby	Kirby 21851	2203	1965
Kirby	Kirby 21852	2212	1967
Kirby	Kirby 21853	2213	1967
Kirby	Kirby 21854	2202	1969
Kirby	Kirby 21857	2642	1967
Kirby	Kirby 23850	2902	1967
Kirby	Kirby 23851	3033	1967
Southern Towing	A-1	2500	1966
Southern Towing	A-2	2500	1966
Southern Towing	A F 12	2500	1965
Southern Towing	A F 13	2500	1965
Southern Towing	A F 14	2500	1967
Southern Towing	A F 15	2500	1967
Southern Towing	STC 2502	2500	1964
Southern Towing	STC 2503	2500	1964
Southern Towing	STC 2505	2500	1966
Southern Towing	STC 2507	2500	1966
Southern Towing	STC 2508	2500	1967
Southern Towing	STC 2509	2500	1968
Southern Towing	STC 2510	2400	1967
Southern Towing	STC 2602	2500	1966
Southern Towing	CF 101L	2600	1966
Southern Towing	CF 102T	2800	1966
Southern Towing	CF 103L	2800	1966
Southern Towing	CF 104T	2800	1966
Southern Towing	CF 105B	2874	1967
Southern Towing	CF 106B	2874	1968
Devall Towing	EIDC 53	2500	1967
Devall Towing	EIDC 57 (DCBL 57)	2350	1967
Port Arthur Towing	PATCO 50	1800	1967
AVERAGE		2488	1966

The researchers investigated the existing fleet of articulated tug/barges (ATBs) and did not find any that would be capable of carrying anhydrous ammonia or chlorine. Appendix B provides a list of the ATBs that are included in Lloyd's Register.

Photo by William Alden III

Figure 14. Ammonia barge tow.

Rail and Truck Fleets

As of September 30, 2011, the North American tank car fleet is made up of 314,956 privately owned tank cars. These tank cars make up 16 percent of the entire 1,951,593-car fleet (*68*). Only about one-fourth of the tank car fleet is approved for use with TIH chemicals. One source estimated the number of ammonia tank cars at 6,000 in 2006 (*69*). Given the relative stability of this market, it is reasonable to assume that this number was roughly the same in 2011. There are no publicly available statistics on the number of tank trucks available for hazardous materials shipments.

Functional Requirements

Marine ammonia terminals must be capable of receiving and holding anhydrous ammonia in a refrigerated state, loading out to refrigerated barges, and reheating ammonia to feed non-refrigerated pipelines, rail cars, and trucks. The cost of establishing a new terminal facility would be $18 to 20 million, assuming a site with a dock but without a control room, piping, or required diking around tanks. The site would also have to have a scale, road access, permits, and so forth.

Table 10. Composition of chlorine barge fleet (*67*).

Company	Barge No.	Capacity (Short Ton)	Year Built
Olin Corporation	OL 654	1100	1978
	OL 655	1100	1979
	OMCC 651	1110	1964
	OMCC 652	1108	1964
	SBI 601	1110	1958
	SBI 602	1110	1958
	SBI 603	1110	1958
PPG Industries	PPG 400	1100	1964
	PPG 401	1100	1964
	PPG 402	1100	1964
	PPG 403	1100	1966
	PPG 404	1100	1966
	PPG 405	1100	1966
	PPG 406	1100	1966
	PPG 407	1100	1967
	PPG 409	1200	1996
	PPG 410	1100	1966
	PPG 411	1116	1966
	RD OSUCHA	1200	1996

Table 11. Types of anhydrous ammonia storage (*69*).

Location	Type of Storage and Regulation
Locations with > 10,000 lb	Risk Management Program (RMP) Rule 40 CFR 68 Process Safety Management (PSM) Rule 29 CFR 1910.119
Producing Plants & Large Distribution Terminals	Refrigerated Storage ~ 30,000 tons @ < −28 ºF, 15 psi
Local Distribution, "Dealers"	Pressure Tank ~ 30,000 gal 265 psi minimum design & local municipal codes
Farms	Nurse Tank ~ 1,000 gal 265 psi minimum design

Depending on the location and the type of handling desired, the requirements for an ammonia terminal can vary significantly. Table 11 shows the range of typical ammonia distribution facility characteristics. The third type, "Local Distribution, Dealers," is the type that would typically be constructed at a barge terminal.

Figure 15 shows an ammonia distribution facility using 30,000-ton storage tanks (a common size for ammonia storage).

Chlorine shipments at the present time are being delivered directly to the user and are being moved into the industrial process immediately upon arrival; therefore, a storage terminal is not necessary. Because of the difficulties and hazards of storing large amounts of chlorine, the development of a storage terminal is highly unlikely.

Conclusions on Vessel Requirements

The construction of ammonia and chlorine barges for inland waterways is highly standardized. Any advances in design will likely be incremental—for example, improved designs for valves and fittings or larger vessels offering economies of scale, if traffic volume supports it. Towboat propulsion systems continue to evolve. Revolutionary change in transportation technology for TIH is unlikely, however.

Ammonia barges are semi-pressurized, carrying cargo at zero pressure and −28°F. There is currently not enough demand to build new ammonia barges. If such barges were

Figure 15. Example of an ammonia terminal (70).

to be ordered, they would cost approximately $14 million per barge (with a capacity of 2500 tons) and take approximately 10 to 11 months to build.

Chlorine barges are of semi-pressurized design, carrying liquefied chlorine under pressure at –28°F in tanks built to about 40 psi test pressure. The barges are a standard size (195 ft × 35 ft), double skinned, with independent pressure tanks mounted on saddles within a hopper. Either four or six tanks are mounted on each barge, with a total carrying capacity of 1,100 tons per barge. Only two chlorine barges in use today were constructed after 1996. Due to the highly uncertain nature of market conditions, there is very little demand for new construction. If new barges were to be constructed, they would cost approximately $6 million and take approximately 7 to 8 months to build.

There are no Jones Act vessels available for coastwise carriage of ammonia or chlorine. There is no reason to expect any ammonia or chlorine vessels to be constructed in the United States due to the regulatory, safety, and economic aspects of production and distribution, which would make coastwise movements highly unlikely, as explained elsewhere in this report.

CHAPTER 6

Economics of Expanded Operations

Market Conditions

It is important to note that both ammonia and chlorine are characterized by mature, low-growth markets. Interviewees indicated that the ammonia volumes for 2010 and 2011 are probably close to the ceiling for the United States. In other words, this market is a mature market with few, if any, existing service gaps. The hazardous properties of elemental chlorine and consequent potential liabilities work against expansion of transportation and storage of chlorine gas itself. These factors indicate that for marine transportation to increase its shipment volumes of either ammonia or chlorine, it will be necessary to attract shipments currently moving by rail; there is not enough expansion in the market for marine transportation services to target new shipments.

Ammonia

Since September 2008, anhydrous ammonia prices have been correlated with both corn and natural gas prices. The correlation between ammonia and corn likely indicates a demand relationship; higher corn prices indicate larger future planting of nitrogen-using crops, leading to more use of and higher prices for ammonia. Moreover, higher corn prices indicate a greater ability of farmers to pay for nitrogen. The correlation between ammonia and natural gas likely indicates a supply relationship; natural gas is a key input in anhydrous ammonia production, with higher natural gas prices leading to higher costs of producing ammonia (*71*).

It is generally agreed that fertilizer demand is inelastic with respect to price. This means that fertilizer use is insensitive to its own price (*72*). Data compiled by the U.S. Geological Survey show that there is a weak relationship between the price of ammonia and the consumption of nitrogen fertilizer. Figure 16 and Figure 17 illustrate this (*22, 73*).

According to the U.S. Army Corps of Engineers (USACE), 1,334,000 tons of ammonia were shipped on the inland waterway system in 2009. Approximately 10.3 million short tons were produced in the United States in 2009, and 6.1 million short tons were imported. Therefore, waterborne shipments accounted for 7.9 percent of the total ammonia shipped throughout the United States.

Chlorine

In contrast to ammonia, chlorine imports are not a viable alternative because of the difficulty in transporting chlorine in bulk. According to statistics from the Chlorine Institute, in 2008, the U.S. chlor-alkali industry produced 11.5 million short tons of chlorine and 12.1 million short tons of caustic soda (sodium hydroxide). The USACE does not report chlorine as a separate commodity in its public statistics, but as stated earlier in this report, waterborne chlorine shipments are reported to make up approximately 1 percent of the total.

Transportation Rate Pressure

Ammonia

For ammonia shipments, the weighted average revenue per rail car was $2,825 in the fourth quarter of 2010. (Fertilizer was defined as STCC 2871: “fertilizers exc. milled, mined or otherwise prepared natural boron, sodium or potassium”) (*74*). At 80 net tons per car, this equates to a rate of $35.31 per net ton. The Barge Costing Model, a model used for a number of years by the USACE in its feasibility and rate studies, estimates the linehaul cost of shipments from New Orleans to St. Louis at $39.79 per ton. While both the rail and barge rates are only estimates, they indicate that the two are close to parity.

The cost of ammonia is directly proportional to the cost of natural gas, which comprises more than 80 percent of the production cost of ammonia. The sharp rises and declines in natural gas prices have caused a similar fluctuation in the cost of ammonia. This causes the relative importance of transportation costs to rise and fall as well. For example, CF Industries estimated that it cost $34/ton to ship ammonia from the

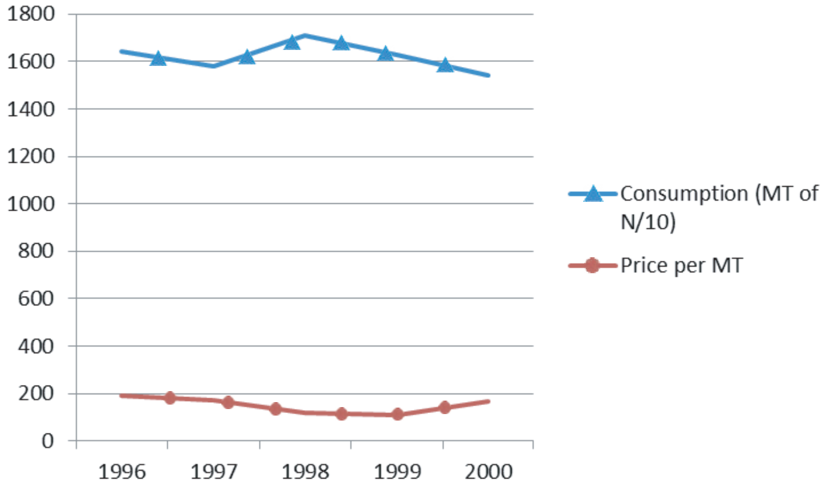


Figure 16. Consumption of nitrogen fertilizer versus cost—1996 to 2000.

Gulf to Corn Belt locations in 2010 (this would be $3,060 per rail car) (*75*). A shipment cost of $34/ton would represent 8.7 percent of U.S. Gulf prices in 2010 ($390/ton) but would have been 5.8 percent of 2008 prices ($590/ton). To put this in perspective, a 10-percent reduction ($3.40) in transportation costs would represent only 0.87 percent of the Gulf price of ammonia in 2010 and 0.58 percent of the 2008 price. It is important to note that U.S. consumers have shown a strong tendency to substitute domestic product with imports when the cost of imports is competitive. This will affect the routing of shipments and the ton-miles of shipments.

These figures all point to the conclusion that while in absolute dollars the transportation costs might be significant, in relative terms they would have little effect on the production or distribution of ammonia. Therefore, it does not appear that competing on the basis of cost alone would be an effective strategy for increasing waterborne ammonia shipments. The basis of competition would have to be the ability to handle large volumes reliably and safely at an acceptable price.

Chlorine

Since imports are not a viable alternative to domestic production of chlorine, there is possibly some price elasticity in the cost of chlorine; however, since chlorine is only being shipped by the producers in company-owned barges, an evaluation of the effect of barge rates would be speculative at best. The USACE Barge Costing Model estimates the linehaul cost of chlorine shipments from New Orleans to St. Louis to be $52.39/ton in the fourth quarter of 2010.

In recent testimony before the STB, counsel for Consumers United for Rail Equity (CURE) stated that rail rates have

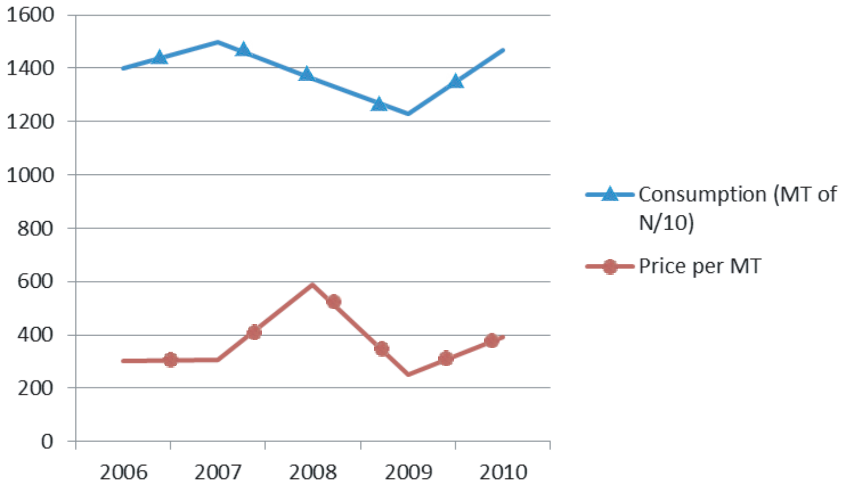


Figure 17. Consumption of nitrogen fertilizer versus cost—2006 to 2010.

caused transportation costs to rise to more than 50 percent of the total cost of producing chlorine in many markets. He indicated that rail rates either are or could have been determinative as to whether specific plants stayed in operation. Rail rates are now often the single most important factor in whether chemical companies can compete (*76*). The average rate per carload increased 133 percent between 2000 and 2009. In the same hearing, a representative of the Chlorine Institute echoed this statistic. The vice president of sourcing and logistics for DuPont stated that the company reviewed price and transit times for several of its highest-volume lanes and determined that since 2003, the average rate has gone up 100 percent and the average transit time has gone up 17 percent. The vice president of supply chain for Occidental Chemical (OxyChem) stated that in the 5 years between 2005 and 2010, which included a sustained period of general economic recession, OxyChem rail rates increased from 30 percent to 160 percent on average.

A recent analysis of OxyChem's freight rates shows that rail freight transportation expense accounts for 10 to 15 percent of the delivered price of its products and up to 25 percent of its manufacturing costs. An increase in rail rates has a direct effect on the prices customers pay for not only the primary chemical products but also the downstream goods that are made with these products (*77, pp. 138, 144*).

Specific rail rates are very difficult to obtain. However, in the above-cited STB hearing, a representative of Olin discussed a specific rail rate example. Less than 15 years ago, the initial rate for movement of chlorine from Olin's Sunbelt plant in Alabama to a customer location in LaPorte, Texas, was less than $1,440 per car. Today, the tariff rate for that same movement is almost $11,763 per car, an increase of over 817 percent from the original rate. The rate is predicated on Sunbelt's commitment to deliver up to 250,000 tons of chlorine (approximately 2,777 rail tank cars) per year. Assuming 80 tons per rail car, this is equivalent to $147.04/ton.

Although the statistics include chemicals other than chlorine, OxyChem stated before the STB that in 2010 it shipped 63,000 loaded rail cars and incurred more than $220 million in rail freight charges—an average of approximately $3,500 per rail car movement. This equates to $43.75 per ton for an 80-ton load.

As explained elsewhere in this report, truck transportation is not considered a viable option for chlorine producers because of shipment volumes and safety considerations. Dow Chemical has explained in public hearings that the use of trucks is not a viable alternative for Dow or many of its customers. Dow and its customers have built their production facilities around rail transportation. Rail cars reduce the need for permanent storage facilities, which are very costly. In addition, the volume of commodities that Dow ships presents unique challenges for trucks (*77, p. 113*).

Opportunities for barge companies to compete for chlorine shipments are severely limited by current distribution patterns and practices. Many water carriers do not accept transportation of chlorine as a matter of policy. Water carriers are not common carriers under the law, so they do not have to accept chlorine shipments. Most of the major carriers have chosen not to do so.

Relative Importance

Given the estimates mentioned above, rail rates are competitive with water rates in most cases. There is not an inherent advantage for waterborne transportation in terms of rates. Furthermore, as this report explains in other sections, the origin-destination pairs for these products preclude the use of waterborne transportation for a high percentage of the production volume. As an example, many of OxyChem's plants can only be served by rail, and Olin has stated that there is no reasonable alternative to shipping Olin's products by rail (*77, pp. 142–143*). In its filings with the STB, CF Industries stated that its inland plants, despite the presence of a local truck market, are highly dependent on rail to service their facilities. In 2010, 85 percent of shipments from the Yazoo City, Mississippi, plant and over 75 percent of shipments from the Verdigris, Oklahoma, plant were shipped by rail (*78*).

It will be difficult for marine transportation service providers to increase their volumes except for a very limited number of origin-destination pairs. Chlorine producers have made it clear that they prefer rail, and current waterborne shipments are performed only with company-owned barges towed by barge companies with exclusive contracts. In the case of ammonia, there appears to be strong rate competition for routes where barge companies can compete.

Finally, it is important to keep in mind that while in some instances high rail rates may indicate the ability to compete on price, numerous studies and reports have shown that rail companies will often lower their prices in order to maintain market share or exclude new entrants. For example, compare the case of Olin's shipments, where there is no modal competition, with OxyChem's stated average transportation cost by rail. While this would seem to run counter to the railroads' desire to eliminate TIH movements, they may still compete with barges in order to solidify their relationship with customers who also ship other products in high volume. Today's high prices may become tomorrow's competitive prices with the emergence of competition.

Capital Requirements

Since trucks are not a viable option for large quantities and long distances, the analysis of capital requirements focuses on marine and rail equipment and facilities. For marine carriers (i.e., barge companies), the capital cost of equipment does not

Table 12. Ammonia infrastructure capital costs (*69*).

Capital Item	Cost (2006 dollars)
Conventional Production Facility 1,500 tons/day with storage	$300 million
Pipeline 12″ Diameter—1,000 mi	$240 million
Large Refrigerated Storage Terminal 30,000-ton capacity	$20 million
Pressure Storage Tanks—30,000 gallons $5/gallon installed	$150,000
Ammonia Rail Tank Car	
Current design: 340 psi	$118,000
Proposed design: 500 psi	$135,000–$150,000

appear to be a deterrent to participation in TIH transportation; capital costs are recaptured in the freight rate and are manageable in terms of financing. However, for terminal operators, shippers, and buyers, capital costs are a significant barrier.

Ammonia

The landside capital costs required to establish an ammonia terminal are well defined. Table 12 shows the estimated cost of the various infrastructure components in 2006 dollars. Figure 18 shows a 30,000-ton ammonia storage tank.

Ammonia storage tanks typically have the following characteristics:

- 126 to 170 ft in diameter.
- 60 to 105 ft high.
- 6 to 12 million gal capacity (15,000 to 30,000 tons).
- Usually 1 psig maximum internal pressure (~ –28°F).

Marine ammonia terminals must be capable of receiving and holding anhydrous ammonia in a refrigerated state, loading out to refrigerated barges, and reheating ammonia to feed non-refrigerated pipelines, rail cars, and trucks. It takes about 3 years to start up a new terminal (*11*).

Figure 18. Ammonia storage tank (7).

The cost of a new ammonia barge is approximately $14 million (with a capacity of 2,500 tons) (*7*). Ammonia barges with a capacity around 3,000 tons are currently quoted at around $15 million apiece. Invariably, these barges operate in two-piece and sometimes three-piece unit tows, requiring capital of $30 to $45 million per tow, not counting dedicated towboats required for propulsion. New barges do not necessarily require a new towboat, but a new towboat could cost an additional $5 to $6 million.

Ammonia barges require unit tows because they are refrigerated and require specially trained crews to operate the refrigeration equipment en route and conduct transfer operations at each end. In this regard, they are similar to hot oil barges that are equipped with self-contained heating equipment and are used to transport cargoes such as asphalt and coker feedstock. However, the Coast Guard does not mandate unit tows.

A barge can only be expected to make seven to eight round trips a year (because of weather, transit time, demand, etc.). To date, ammonia freight rates do not support the capital cost, so new equipment has not been built for some time.

The average cost of a rail tank car in 2008 was around $120,000 (*18*). TFI reports that its member ammonia shippers do not own tank cars; rather they lease the cars on a contract basis. TFI estimates the cost to TFI members of replacing current leased cars over the next 8 years (meeting the requirements of the latest FRA proposal) to be somewhere between $800 and $1,500 more per car per month and possibly exceeding $100 million per year (*34*). The typical life span for these rail cars is 30 years (*79*).

Chlorine

Marine shipments of chlorine are severely limited by the number of facilities capable of receiving it by barge. There are only two such facilities on U.S. inland waterways (the DuPont titanium dioxide plant in New Johnsonville, Tennessee, and the Westlake Monomers vinyl chloride plant in Calvert City, Kentucky, both located on the Tennessee River). There are no coastwise shipments of chlorine in the United States.

In the interviews conducted for this study, the capital cost of equipment and infrastructure was cited several times as the most important limiting factor for marine shipments. A switch to transportation by water requires suppliers and end users to invest large amounts of capital for infrastructure. This could range from $5 million to $100+ million depending on the size and scope of the project, whereas rail and truck already have infrastructure in place with government and private funding to maintain it.

The cost of a new chlorine barge is approximately $6 million (with a capacity of 1,100 tons) (*7*). Unlike ammonia, chlorine barges do not operate in dedicated unit tows. They operate in linehaul mode, meaning the barges go into tow with other barges carrying other commodities for other customers. They would, therefore, not require the acquisition of new towboats. However, even though they have this advantage over ammonia barges, many towing companies do not handle chlorine barges due to risk.

When moving chlorine by rail, the shipper must consider the cost of new rail tank cars, which is between $140,000 and $150,000 each (*80*).

Risk

Railroads clearly consider the risk of TIH shipments to be the most important cost factor (potentially). The total risk associated with many of these materials is greatly influenced by low-probability/high-consequence events. The extent of potential carrier liability far exceeds the levels of commercial insurance that carriers can practicably obtain.

While the risk of catastrophic property and environmental damage and loss of life is lower for marine shipments, the possibility of involvement in a large-sum lawsuit exists and must be accounted for in the carrier's economic analysis.

CHAPTER 7

Obstacles

Geographical Dispersion

Geographical dispersion is the most formidable obstacle to a significant increase in the volume of TIH marine shipments. As noted in Chapter 1, in the section labeled “Geography of Commodity Flows,” producers tend to cluster, but consumers tend to be widely dispersed throughout the country.

Since natural gas is by far the most important cost component in the production of ammonia, new shale gas plays might result in the construction of ammonia production facilities in new locations, which would in turn affect commodity flows. To date, no ammonia producer has announced its intention to build a facility near one of these plays. Even if it were to do so, it is unlikely that waterborne transportation would be part of the logistics chain, given the location of these new plays.

There is very little concentration of chlorine shipments between any origin-destination pair. With the announced intention of the chlorine industry to co-locate more production facilities adjacent to consumer facilities and with a widespread initiative underway to substitute safer products for chlorine, the likelihood of additional concentration or new high-volume corridors developing is minimal.

Financial Risk of Catastrophes

The railroads purchase insurance to mitigate the financial risk of carrying hazardous materials, but this coverage is both expensive and limited in availability. According to the Association of American Railroads (AAR), highly hazardous commodities constitute only 0.3 percent of the total carload but account for 50 percent of the insurance costs of railroad companies (*81*). Any marine carrier wishing to enter the chlorine transportation marketplace will have to determine whether the cost of insurance against catastrophic accidents will outweigh the economic benefits of the transportation operation. According to the AAR, the revenue that highly hazardous materials generate for the railroads does not come close to covering the potential liability to railroads associated with transporting this traffic (*34*).

Operational

Ammonia

The STB noted in recent proceedings that barge companies lack sufficient barge capacity and there is insufficient storage capacity (the shipper’s responsibility) to handle a significant shift of anhydrous ammonia traffic from pipeline to barge. Barge transport involves higher costs than pipeline transport, which could make a shift prohibitively expensive. Barges, unlike pipelines, are hindered by floods, low water, and icing, and barge trips take from days to weeks, while pipeline injection and withdrawal is essentially instantaneous. Some of the qualitative considerations that the STB found to limit the effectiveness of barge competition were capacity, reliability, speed, and safety. Because of insufficient storage capacity at barge destination points, someone would have to make prohibitively large expenditures or investments to shift from pipeline to barge (*82*).

Chlorine

Producers cannot store chlorine. This means chlorine moves from the manufacturing site to the consuming location and into the production process immediately with only nominal inventory on site. The ideal solution in this environment is to build consuming plants or locations at the production site.

One of the chlorine producers interviewed for this study indicated that marine possibilities are limited by customer locations, lack of marine routes, absence of marine docks and storage facilities, and insufficient demand for the bulk quantities that can be economically delivered (typically 1,100 short tons per barge).

A further complication for both chlorine and ammonia shipments is the fact that in the northern reaches of the river system (especially the Upper Mississippi River), ice is a problem in the winter. The Upper Mississippi River above Quincy, Illinois, closes annually from December to March/April, and navigation is often restricted on the Illinois River in January and February. The fact that chlorine cannot be stored in sufficient quantities to last the winter becomes a severe operational and financial constraint for logistics managers.

Regulatory

The current regulatory environment tends to discourage new market entrants. For example, accidents involving TIH materials have no liability limits. A single hazardous materials accident can bankrupt a small carrier.

Several of the interviewees for this study indicated that one of the biggest obstacles to building new transportation and storage facilities is the permitting process. Uncertainty about the time it will take to acquire the permit and then construct the project makes a rapid response to market shifts very difficult.

Jones Act requirements that restrict domestic service to vessels that are constructed in the United States, with a U.S. flag and a U.S. crew, make coastal movements an impossibility in the short run. There are no Jones Act vessels involved in coastal trade, and the cost to convert existing vessels would be prohibitive. Interviewees made the case that there is no need to move anything along the coast anyway. If port facilities were available, imports would be made directly by foreign-flag vessels and then shipped by barge, rail, or pipeline to the ultimate destination.

Market

A start-up enterprise or an expanding operation will need to consider two major market risks. The first is that manufacturers may begin substituting for TIH materials to avoid the risks and transportation expenses and difficulties. This is already happening with chlorine-based producers, the most notable being Clorox. The other major risk is that producers may actively seek to cluster their facilities to avoid having to transport TIH materials over significant distances. The proposed new chlorine plant in New Johnsonville, Tennessee, is an example of such a strategy. In other words, users of ammonia and chlorine may begin relocating to sites closer to producers, thereby cutting out transportation altogether.

Ammonia-Specific Factors

The ammonia marketplace has shown itself to be sensitive to external factors, such as natural gas prices, that can vary dramatically over relatively short periods of time. Investment in such infrastructure is therefore uncertain and appears unlikely in the current regulatory environment with lengthy permitting processes and easy substitution via imports.

U.S. fertilizer demand is not expected to grow much at all—it is a mature market. There is only so much available land, and only so much fertilizer can be put on that land. Interviewees indicated that the volumes for 2010 and 2011 are probably close to the ceiling for the United States. In other words, this market is a mature market with few, if any, existing service gaps.

Chlorine-Specific Factors

Chlorine demand is not expected to decrease significantly, despite the industry's status as a "mature business." Given the importance of chlorine-derived products in a modern economy (ranging from basic construction materials such as PVC to refrigerants, bleaches, agricultural chemicals, water purification, and many other applications), it is unlikely that overall chlorine use will significantly decline, despite a perception that chlorine is environmentally unfriendly. Nonetheless, the hazardous properties of elemental chlorine and consequent potential liabilities work against expansion of transportation and storage of chlorine gas itself.

Infrastructure Conditions

Businesses and associations that have an interest in marine transportation via the inland waterway system are almost unanimous in their concern over the condition of the locks and dams that make much of the system navigable. Such groups include the Waterways Council, the National Waterways Conference, regional port associations, agricultural associations, and private businesses. Lack of trust in the long-term viability of the physical infrastructure is a significant roadblock to investment in businesses that use the system. In fact, one interviewee for this study stated very clearly that all considerations are secondary to the concern over the ability to use the system over the long term. Concerns include the state of major navigation projects such as locks and dams (many of which are in need of significant rehabilitation) and the availability of funds to support maintenance dredging of navigable channels throughout the inland waterways system.

Externalities to Consider

Reaction of Organized Labor

International Longshore and Warehouse Union (ILWU)

The Coast Committee of the ILWU, supported by the Coast Longshore Division Caucus, opposes the United States government's usage of scarce tax dollars to promote and subsidize short sea shipping in the north/south movement of containers on the West Coast of the Americas. In the committee's opinion, such water trade movement, by its very nature, cannot compete economically with truck and rail (even if subsidized) and will only serve to further drive down the sector's wages and working conditions. It will establish the framework for non-union and non-ILWU predatory union challenges to the Coast Longshore Division's jurisdiction.

In Seattle, no ILWU longshoremen handle the cargo associated with short sea shipping. It is all handled on the Duwamish River, either by non-union workers or longshoremen represented by the Inland Boatmen's Union (IBU) under a Pacific Coast Longshore Contract Document (PCLCD) "substandard agreement." In the upriver ports of the Columbia River, the containers are handled exclusively by non-union dockworkers. Operators in non-union upriver Columbia River ports are requesting government subsidies to build barges designed to bypass ILWU longshoremen in Portland and transport commodities directly to the non-union Duwamish, where the barge can be unloaded for the short truck transport to Seattle's International Port. Already, the Coast Committee is being approached with requests for manning and wage reductions that would be unique to short sea shipping. Potential operators are seeking advantages from non-Pacific Maritime Association (PMA) member public port authorities to lease blocks of property for the purpose of establishing container yards (CYs) with no ILWU Coast Longshore Division presence. The AFL-CIO's Transportation Trade Department (TTD) wants to support short sea shipping, but the Coast Longshore Division is blocking any formal endorsement (*83*).

ILWU Coast Committeeman Leal Sundet claims that short sea shipping proposals promising lower costs and environmental benefits by using ships to transport goods between West Coast ports (instead of trucks) are largely based on models employing non-union or low-wage labor in order to compete with the largely non-union trucking industry. He, therefore, opposes any government support for short sea shipping (*84*).

AFL-CIO Maritime Trades Department

The AFL-CIO strongly supports legislation introduced by Sen. Frank Lautenberg (D-NJ) that would amend the Internal Revenue Code to exempt the waterborne transportation of cargo between domestic U.S. ports from the Harbor Maintenance Tax (HMT) (*85*).

Maritime labor is hoping to use provisions of the Energy Independence and Security Act of 2007 to promote important national concerns, including more jobs for U.S. civilian mariners, enhanced U.S. productivity, less gridlock, and a safer environment. Among other things, the bill establishes a formal "marine highway" program within the federal government and provides for seed money for selected programs (*86*).

International Longshoremen's Association (ILA)

According to its website (http://www.ilaunion.org), the ILA represents more than 65,000 longshoremen on the Atlantic and Gulf Coasts, Great Lakes, major U.S. rivers, Puerto Rico, and Eastern Canada. The ILA supports short sea shipping. Recently, the ILA publicly welcomed American Feeder Lines' announcement to begin a coastwise service in the Northeast. ILA members in that region are largely idle during the winter. According to ILA representatives, the new service will put up to 20 people to work every week, unloading cargo and operating the terminal (*87*).

Reaction of Rail and Trucking Interests

The desire by railroads to exit the business of transporting chlorine and anhydrous ammonia is documented elsewhere in this report. Given their desire to exit, railroads will not pose a competitive threat to any barge operations in most cases. This premise was verified in an interview with a Class I railroad executive, but this same individual also pointed out that the off-water location of origins and destinations for these shipments makes a diversion to marine traffic almost impossible.

Shippers do not consider trucking to be a viable alternative for long-haul transportation. Cost and safety elements make the use of truck transportation non-competitive, except in rare, well-defined cases. Therefore, a new or expanded marine service for long-haul transportation would not expect to face significant opposition by trucking interests.

Public Safety and Environmental Issues

The dramatic railroad incidents described earlier in this report illustrate the significant public safety risk inherent in the long-haul transportation of TIH materials. Given that marine transportation generally does not pass through or adjacent to residential areas, it would appear that there is less risk to public safety when transporting by water. Such assumptions would clearly depend upon specific routes and origin/destination locations.

The basis for the assumption that a marine accident would have less severe consequences than a tank rail car accident is that an accident below the water line or at water level has reduced consequences. The researchers reviewed all large spills (>=1,000 gal) from inland waterway traffic from 2001 through 2009. There have been no chlorine or ammonia spills. Unfortunately, Coast Guard records are spotty, but the researchers identified and reviewed 55 instances where at least 1,000 gal of hazardous material was spilled. There were seven instances where an accident caused a loss of product from a barge. Three of these spills definitely occurred below the waterline. Three others are inconclusive, but they occurred in bays or heavy industrial areas. Another one that was inconclusive occurred in a populated area (McAlpine Lock). None of the incidents involved a spill from loading or unloading operations. The data appear to support the hypothesis that marine-related incidents are less risky to human health and safety than rail accidents.

Potential Roadway Congestion Mitigation

The volumes associated with ammonia and chlorine are substantial in terms of the truckloads and rail carloads they represent. In 2010, approximately 11.1 million short tons of ammonia were produced domestically. Assuming that an ammonia tank truck carries 20 tons of ammonia, the total production volume equates to approximately 555,000 full truckloads. Similarly, assuming that an ammonia tank rail car carries 80 tons of ammonia, the total production volume equates to 138,750 rail car loads.

In 2009, Olin, OxyChem, and PPG had a combined chlorine production capacity of 7.21 million tons. The literature does not state the level of utilization at these facilities; however, assuming it were 90 percent, the actual production would be 6.5 million tons. Chlorine cargo tank trucks meeting U.S. DOT Specification MC331 or MC330 have an approximate capacity of 15 to 20 tons (*88*). Assuming a tank truck carries 20 tons, the total production volume equates to 325,000 truckloads. Assuming that a chlorine tank rail car carries 90 tons (*89*), the total production volume equates to 72,000 rail carloads.

However, even though the annual transported volume of these commodities is significant, the potential for roadway congestion mitigation is severely limited. Trucking is already the mode of last resort for ammonia and chlorine shippers. There are currently virtually no chlorine movements by truck and only a small number of long-haul truck movements of ammonia. To put this in perspective, there were 4.9 million tons of ammonia transported by truck in 2007 with an average shipment distance of 194 mi per shipment. This indicates that trucking is used primarily for local delivery and would not make a good target for congestion relief by barges. There is so little chlorine shipped by truck, it does not appear in the federal government statistics.

CHAPTER 8

Potential Courses of Action

Background

There are several measures or courses of action that could be implemented to encourage the shipment of greater volumes of TIH materials via water. Some would require substantial sums of money, some would require regulatory changes, and others would require operational changes. This chapter will summarize the incentives, funding, and mandates that could be put in place to address the challenge of moving TIH materials by water.

Various regulatory instruments seek to internalize external costs and protect the public. These include taxes such as the gasoline tax, emissions standards, market-based controls including cap-and-trade regimes, and limitations on liability and insurance schemes employed for nuclear reactors, oil spills, or bank deposits. Perhaps the most straightforward way of addressing a situation in which private actors do not take into account the public consequence of their actions is to tax an offending activity or subsidize a beneficial activity.

There are at least four obstacles to regulatory reform. The first is the inherently uncertain nature of research to support these reforms. A second and related obstacle is that long-time horizons may be necessary to research new technical options and put them into practice. Third, systems integration challenges confront industry supply chains. Modification of such large, complex technical systems can result in unintended consequences. Fourth, absent regulatory restrictions or taxes on the existing technology, the incentive to adopt a new technology may be insufficient to induce its creation and adoption.

There are many proposed measures for dealing with TIH materials that have little or nothing to do with the choice of mode or supply chains. Examples of these measures include the following:

- Product substitution (elimination of the product altogether).
- Government action to limit use of TIH (force reduction in usage volumes).
- Placement of a limit on the distance of domestic shipments.

While these measures are important to the overall discussion of TIH materials, they are not directly related to the objective of this study and are therefore not included here.

Limit Risk to Carriers and Shippers—Institute Insurance Program

Ultimately, to move more hazardous cargoes safely via marine highway services, federal action would be required to clearly define the common carriage and financial obligations of the carriers and to accurately reflect the monetary risk and operating costs of moving such cargoes. As noted earlier, significant policy determinations would be required to augment the economic viability of marine highway services, potentially including policies related to cost-based pricing of HAZMAT transportation services.

The railroads have suggested alternatives for policymakers to consider that might be relevant and adaptable to the marine transportation system:

- Allow carriers to require TIH shippers to indemnify them for liability above a certain reasonable amount.
- Create a fund, to which producers and end users of TIH materials would contribute to pay for damages above a certain amount (similar to "Price-Anderson" protections in the transportation of nuclear energy waste, where a federal pool of funds was created to compensate victims of a nuclear accident that might take place at any point in the supply chain).
- Create a statutory liability cap for carriers.
- Allow carriers to require shippers to provide evidence of insurance to cover their indemnification requirements (financial responsibility).

This would not absolve carriers of responsibility or remove the incentive to be safety conscious, since carriers would continue to assume liability for the risk of transporting TIH materials at the primary level and accept the normal risks of operations and accidents associated with the transport of any commodity. Carriers would, however, be provided assurance that shippers would share the extraordinary risks presented by a potential release of the extra-hazardous TIH materials they chose to ship.

The Oil Pollution Act of 1990 (OPA 90) might be a good example of an emergency fund that the marine industry already pays into to cover the costs of catastrophic accidents. OPA 90 authorized the creation of the Oil Spill Liability Trust Fund (OSLTF), managed by the National Pollution Funds Center. The OSLTF is financed by industry via a tax of $0.05 per barrel of imported oil, interest on the fund principal, assessed penalties, and cost recovery from responsible parties. The fund totaled a maximum of $2.7 billion as of 2005. The OSLTF can be used for federal cleanup costs and to meet damage claims by government entities, corporations, or individuals. If an accident occurs, the responsible party must cover cleanup and claims up to its liability limit (except that liability for a spill due to gross negligence is not capped).

The Oil Pollution Act (OPA 90) also set operational mandates relating to vessel construction, crew licensing and manning, and contingency planning in order to reduce the risk of future accidents.

In contrast to the OSLTF, which is not a no-fault model, the desirability of a no-fault insurance model for TIH should be evaluated, since the possibility and extent of damage may be affected by the actions of multiple players.

On an international scale, the International Maritime Organization (IMO) developed the IMO Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (1996). The 1996 Convention establishes strict liability for ships carrying hazardous cargo involved in an accident, sets limits to liability of the ship owner, and makes insurance up to that limit compulsory. In addition, it establishes the International Hazardous and Noxious Substances Fund (HNS Fund) to address excess liability. The HNS Fund is financed by parties that receive specific hazardous cargoes by ship. Perhaps a similar approach could be applied to encourage domestic water transportation of TIH cargoes domestically.

An example of a potentially viable insurance scheme is the Federal Deposit Insurance Corporation (FDIC). Funding for the FDIC derives from fees banks are required to pay based on the volume of deposits they hold. FDIC funds are invested in U.S. Treasury securities.

The most important—and possibly the most difficult—issue is designing a claims fund, deciding how to finance such a fund, and determining for what purposes its assets should be expended.

A continuation of the current liability scheme may actually encourage unnecessary use or shipment of TIH materials because it insulates TIH materials producers and receivers from the risks of their commercial decisions by allowing them to shift those risks to the carriers.

Require Safer Equipment and Technology

The FRA has published rules that require better puncture resistance for TIH tank cars in either the inner shell or outer jacket, installation of full head shields, and enhanced protection for valves and fittings. They also set a 50-mph speed limit for loaded TIH cars and imposed a requirement to prioritize replacement of all tank cars built from non-normalized steel. The rule specified that these standards should be considered interim tank car standards, applying to all cars built after March 16, 2009.

A measure requiring all rail cars to have double shelf couplers is also being discussed. Most TIH releases have been caused by another car in the derailment with a single shelf coupler puncturing the TIH car. This solution, which would dramatically reduce the risk of a puncture, unfortunately would cost the railroad the most money. While obviously not the intent, such requirements may in fact motivate shippers to consider the marine mode where viable in order to avoid the increasing cost of new rail cars. In some cases, the newer, heavier rail cars may not be able to call on previously served customers. To date, there has not been much momentum for change among the railroads because their preferred solution where possible is to simply remove TIH from the system rather than “shore up” the system.

Since many rail shipments could not be diverted to water due to geographical constraints, it will be important to assess the potential of new regulations that would have the effect of encouraging more TIH material shipments on roadways—a much riskier operating environment.

Dilute the Ammonia

Another rail-proposed alternative would be to convert anhydrous ammonia to aqueous ammonia (18 percent solution in water). Although aqueous ammonia is less hazardous, five times as many rail cars would be required to move an equivalent amount of ammonia, and in most cases the water would have to be removed and processed at the receiving end, making that alternative impractical, uneconomic, and environmentally unfriendly. Should this alternative gain traction, there will be a strong incentive for shippers to consider other alternatives.

Establish Incentives

The government has the ability to encourage positive voluntary behavior through incentives it can offer, such as grants to support the acquisition of equipment or infrastructure modifications and tax incentives to promote facility and supply chain modifications.

A tentative first step in this direction has been taken in the form of America's marine highway grants, with a total amount of $7 million issued by MARAD to encourage marine highway service development. Marine highway projects are new waterborne transportation services or expansions of existing services operating between U.S. ports or between U.S. ports and ports in Canada in the Great Lakes Saint Lawrence Seaway. Projects that reduce external cost and provide public benefit by transporting passengers and/or freight (container or wheeled) in support of all or a portion of a marine highway corridor, connector, or crossing (designated by MARAD) may receive support. It is neither the purpose nor the intent of these grants to shift passengers or freight currently moving by water to another water service, but rather to expand the use of marine transportation where landside transportation is currently being utilized and when the water option represents the best overall option. The program gives preference to those projects or components that present the most financially viable transportation services and require the lowest percentage federal share of the costs. Such a program could be modified and augmented to encourage TIH shipments by water.

Restrict Movements through High-Population Areas (High Threat Urban Areas)

One of the more controversial components of a TIH-related policy that UP suggests should be implemented would be a distance threshold for TIH shipments. UP suggests that any request for a TIH rail shipment of more than 1,000 mi would have to be submitted to the STB to justify that the shipment "is in the public interest and cannot be avoided through a less risky or less expensive alternative" (*90*). Such a policy might even require that shipments over a certain threshold be transported via water when the geography allows.

The Chlorine Institute has made the claim that at least one serious potential "unintended consequence" could flow from this type of policy. It is their opinion that forcing customers to acquire their materials from a closer source because of threshold distances would possibly give an unfair pricing power to nearby suppliers, in violation of antitrust laws. However, the literature on the subject of transportation of TIH materials does not address this issue.

Maintain and Improve the Infrastructure and Guarantee Its Condition

For any long-term investment to occur in the marine transportation system, there must be a currently viable infrastructure system in place with some insurance of its continued existence. The Inland Waterways Users Board, in conjunction with the U.S. Army Corps of Engineers, has published a proposed capital investment plan that would prioritize new construction and major rehabilitation projects and provide a path toward making the system more reliable. Their plan also provides a mechanism for increasing the funding available for these projects. However, no action has been taken on the plan.

Encourage the Location of New Plants and Facilities Near Marine Terminals

Economic development (or capital development) grants can be set aside for the use of industries that decide to locate near coastal ports or on inland waterways. These grants can also be used to assist in the construction of pipelines to marine terminals or in the development of the marine terminals themselves. Measures taken to encourage locations with access to marine transportation will result directly in an increase in marine shipments.

Integrate the Value of Marine Transportation into National Planning

Obviously, water transportation cannot serve sections of the country where waterways are not present. Marine vessels typically carry larger quantities of materials and, while in port, must be protected from acts of terrorism (this concern is greatest with regard to large international movements of dangerous cargoes into and out of urban ports). Therefore, adequate security measures will play an important role in developing expanded marine services (*91*).

A transportation system that offers resiliency and affordable systems redundancy can assist in incident recovery and deter those who seek to do harm to the United States. Water transportation is often not impacted by natural or manmade disasters, or if impacted, can frequently resume operations soon after the disabling event. Integrating marine transportation into disaster recovery planning was a premise underlying Title XI shipbuilding assistance and the Maritime Security Program (MSP) administered by MARAD. The Title XI Federal Ship Financing Program provides for a full faith and credit guarantee by the U.S. government to promote the growth and modernization of the U.S. merchant marine and U.S. shipyards. This framework could be used to encourage the construction of more vessels for use in TIH shipments. The MSP provides funding to support the operation of 60 U.S.-flag vessels in the foreign commerce of the United States. Participating operators are required to make their ships and commercial transportation resources available upon request by the Secretary of Defense during times of war or national emergency. This program could also be adapted to a TIH-focused system.

CHAPTER 9

Conclusions

Obstacles and Challenges

The obstacles and challenges facing attempts to increase the quantities of hazardous materials moved by water are daunting. Probably the most severe obstacle is the geographical dispersion of producers and users, followed closely by the fact that the markets for both anhydrous ammonia and chlorine are mature markets and are not inherent growth areas. An increase in marine highway services must necessarily be offset by a decrease in another mode (pipeline, rail, or truck).

Another very important concern is the condition of the current system of locks and dams and the failure to fund its maintenance and improvements. This goes hand-in-hand with concerns over the commitment to maintain navigable channels by dredging in a timely fashion. It is difficult to attract capital to a system where there is concern over its continued viability.

Marine carriers, absent any action to restructure the risk allocation system in place today, will also face the same risk of catastrophic accidents currently faced by rail carriers.

There are significant capital costs and time involved in setting up new terminals, and new terminals will be required if a significant expansion of marine services is to be realized. The permitting process is a significant obstacle because of the time and expense it imposes on developers.

There is a lack of Jones Act vessel capacity available with which to augment existing services.

Fortunately, there do not seem to be any externalities that would impede the expansion of marine highway hazardous material transportation. If anything, they seem to work in favor of such an expansion, especially with regard to public safety and congestion mitigation.

Alternatives

Without a new risk paradigm, there will be little incentive for marine carriers to attract cargo from the other modes (which are already dealing with the risks). Several possible schemes for limiting risk and funding potential liabilities are discussed in the previous chapter.

Provision of seed money and expediting the permit process could allow new marine highway ventures to develop more rapidly. The possibility of establishing a marine pipeline to move ammonia out of the western Canadian provinces to U.S. West Coast destinations is such a project that surfaced during this research. Another possibility would be to identify and assist potential new points of importation of anhydrous ammonia and chlorine into the United States, especially when these locations might tie into transportation networks that are more desirable than current surface transportation corridors. This assistance could target both terminal development and surface transportation issues.

There would also need to be a willingness and commitment to at least maintain the current inland waterway system, even if improvements are postponed. Capital will not flow into a market that depends on a transportation system that could fail at any moment.

A transportation system that offers resiliency and affordable systems redundancy can assist in incident recovery and deter those who seek to do harm. This rationale is the basis of existing programs such as the MSP (*91*).

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APPENDIX A

Jones Act Tankers

Vessel Name	Year Built	Vessel Type	Owner	Vessel Status
ALASKAN EXPLORER	2005	Tanker	AMI Leasing	Broken Up
ALASKAN FRONTIER	2004	Tanker	AMI Leasing	Broken Up
ALASKAN LEGEND	2006	Tanker	BP Oil Shipping	Broken Up
ALASKAN NAVIGATOR	2005	Tanker	AMI Leasing	Broken Up
BLUE RIDGE	1981	Tanker	Crowley Petroleum Transport	Broken Up
OVERSEAS DILIGENCE	1977	Tanker	Overseas Diligence Corp	Broken Up
OVERSEAS NEW ORLEANS	1983	Tanker	OSG Overseas Ship.	Broken Up
OVERSEAS PUGET SOUND	1983	Tanker	OSG Overseas Ship.	Broken Up
PRINCE WILLIAM SOUND	1975	Tanker	Shipco 667	Broken Up
SS WILLIAMS CLARK	1958	Tanker	Keystone Shipping	Broken Up
CALIFORNIA VOYAGER	1999	Chemical Tanker	Lightship Tankers II	In Service
CAPTAIN H. A. DOWNING	1957	Chemical Tanker	American Heavy Lift Shipping	In Service
CHARLESTON	1983	Chemical/Products Tanker	USCS Charleston	In Service
CHEMICAL PIONEER	1968	Chemical/Products Tanker	USCS Chemical Pioneer	In Service
COAST RANGE	1981	Chemical/Products Tanker	Crowley Petroleum Transport	In Service
DELAWARE TRADER	1982	Chemical/Products Tanker	Keystone DT Inc.	In Service
EMPIRE STATE	2010	Chemical/Products Tanker	American Petroleum	In Service
EVERGREEN STATE	2010	Chemical/Products Tanker	American Petroleum	In Service
GOLDEN STATE	2009	Chemical/Products Tanker	JV Tanker Charterer LLC	In Service
KODIAK	1978	Chemical/Products Tanker	Seariver Maritime Inc.	In Service
MISSISSIPPI VOYAGER	1998	Chemical/Products Tanker	Lightship Tankers V	In Service
NEW RIVER	1960	Chemical/Products Tanker	American Heavy Lift Shipping	In Service
OREGON VOYAGER	1999	Chemical/Products Tanker	Chevron Shpg. Co.	In Service
OVERSEAS ANACORTES	2010	Chemical/Products Tanker	ASC Leasing I Inc.	In Service
OVERSEAS BOSTON	2009	Chemical/Products Tanker	ASC Leasing I Inc.	In Service
OVERSEAS CASCADE	2009	Chemical/Products Tanker	Overseas Cascade LLC	In Service
OVERSEAS CHINOOK	2010	Chemical/Products Tanker	ASC Leasing I Inc.	In Service

Vessel Name	Year Built	Vessel Type	Owner	Vessel Status
OVERSEAS HOUSTON	2007	Chemical/Products Tanker	ASC Leasing I Inc.	In Service
OVERSEAS LONG BEACH	2007	Chemical/Products Tanker	ASC Leasing I Inc.	In Service
OVERSEAS LOS ANGELES	2007	Chemical/Products Tanker	ASC Leasing I Inc.	In Service
OVERSEAS MARTINEZ	2010	Chemical/Products Tanker	ASC Leasing I Inc.	In Service
OVERSEAS NEW YORK	2008	Chemical/Products Tanker	ASC Leasing I Inc.	In Service
OVERSEAS NIKISKI	2009	Chemical/Products Tanker	ASC Leasing I Inc.	In Service
OVERSEAS TEXAS CITY	2008	Crude Oil Tanker	ASC Leasing I Inc.	In Service
PELICAN STATE	2009	Crude Oil Tanker	PI 2 Pelican State LLC	In Service
POLAR ADVENTURE	2004	Crude Oil Tanker	Polar Tankers Inc.	In Service
POLAR DISCOVERY	2003	Crude Oil Tanker	Polar Tankers Inc.	In Service
POLAR ENDEAVOUR	2001	Crude Oil Tanker	Polar Tankers Inc.	In Service
POLAR ENTERPRISE	2006	Crude Oil Tanker	Polar Tankers Inc.	In Service
POLAR RESOLUTION	2002	Crude Oil Tanker	Polar Tankers Inc.	In Service
S/R AMERICAN PROGRESS	1997	Crude Oil Tanker	Wells Fargo Northwest	In Service
S/R BAYTOWN	1984	Crude Oil Tanker	Seariver Maritime Inc.	In Service
S/R LONG BEACH	1987	Crude Oil Tanker	Seariver Maritime Inc.	In Service
S/R WILMINGTON	1984	Crude Oil Tanker	Seariver Maritime Inc.	In Service
FLORIDA VOYAGER	1998	Crude/Oil Products Tanker	Seabulk Interntnl	In Service
SEABULK AMERICA	1975	Crude/Oil Products Tanker	Seabulk America	In Service
SEABULK CHALLENGE	1981	Molten Sulfur Tanker	Seabulk Petroleum Transport	In Service
SEABULK TRADER	1981	Products Tanker	Seabulk Energy Transport Inc.	In Service
HOUSTON	1985	Replenishment Tanker	U.S. Shipping Partners LP	In Service
SEABULK ARCTIC	1998	Tanker	Lightship Tankers IV	Laid-Up
COLORADO VOYAGER	1976	Tanker	Chevron USA Inc.	To Be Broken Up
SIERRA	1979	Tanker	Seariver Maritime Inc.	To Be Broken Up
SULPHUR ENTERPRISE	1994	Tanker	ISC-Sulphur Holdings Inc.	To Be Broken Up
SUNSHINE STATE	2009	Tanker	APT Sunshine State	To Be Broken Up
THE MONSEIGNEUR	1959	Tanker	American Heavy Lift Shipping	To Be Broken Up
WASHINGTON VOYAGER	1976	Tanker	Chevron USA Inc.	To Be Broken Up

APPENDIX B

Articulated Tug/Barges (ATBs)

Name of Tug	Use	Trade Regions				
		West	Gulf	East	Great Lakes	All Others
ACHIEVEMENT	Clean Petroleum Products, Heated Cargoes, and EZ Chemicals		x	x		
AMBERJACK	Asphalt/6 Oil			x		x
AUSTIN REINAUER	Oil		x	x		
BARNEY TURECAMO	Petroleum Products		x	x		x
BETTY WOOD	Dry Bulk (Grain)		x	x		x
BEVERLY ANDERSON	Dry Bulk (Coal)		x			
BLUEFIN	Asphalt/6 Oil	x	x	x		
BOUCHARD GIRLS	Petroleum Products		x	x		x
BRADSHAW MCKEE	Industrial Sands					
BRANDYWINE	Petroleum Products		x	x		x
BRENDAN J. BOUCHARD	Clean Oil/Black Oil/Asphalt		x	x	x	x
BROWNSVILLE	Petroleum Products	x	x	x	x	x
BUSTER BOUCHARD	Petroleum Products		x	x		x
CAPT. FRED BOUCHARD	Petroleum Products		x	x		x
CAPT. HAGEN	Petroleum Products		x	x		x
CHRISTIAN REINAUER	Clean Petroleum Products		x	x		
CHRISTIANA	Petroleum Products		x	x		
COASTAL RELIANCE	Petroleum Products	x				
COHO	Asphalt/6 Oil			x		
COMMITMENT	Petroleum Products	x	x	x		x
CORPUS CHRISTI	Petroleum Products	x	x	x	x	x
COURAGE	Petroleum Products		x	x		
CRAIG ERIC REINAUER	Clean Petroleum Products		x	x		
DACE REINAUER	Clean Petroleum Products		x	x		x
DANIELLE M. BOUCHARD	Bulk Petroleum		x	x		
DAVIS SEA	Refined Petroleum Products			x		
DOROTHY ANN	Dry Bulk				x	
DUBLIN SEA	Oil		x	x	x	x
ELIZA	Asphalt		x	x		
ELLEN S. BOUCHARD	Petroleum Products			x		
FREEDOM	Coal	x	x			x
FREEPORT	Petroleum Products		x	x		x
G. L. OSTRANDER	Cement				x	

Name of Tug	Use	Trade Regions				
		West	Gulf	East	Great Lakes	All Others
GALVESTON	Petroleum Products	x	x			x
GULF RELIANCE	Clean Petroleum Products, Heated Cargoes, and EZ Chemicals	x				
HOUMA	Refined Petroleum Products			x		
INNOVATION	Clean Petroleum Products, Heated Cargoes, and EZ Chemicals		x	x		x
INTEGRITY	Clean Petroleum Products, Heated Cargoes, and EZ Chemicals		x	x		
INVINCIBLE	Stone, Aggregates, Coal, and Salt Trades				x	
IRISH SEA	Refined Petroleum Products		x	x		
ITS 100	Undetermined		x			x
J. GEORGE BETZ	Petroleum Products		x	x		x
JANE A. BOUCHARD	Petroleum Products			x		
JAVA SEA	Refined Petroleum Products			x		
JIMMY SMITH	Refined Petroleum Products	x				
JOSEPH H. THOMPSON JR.	Coal and Stone				x	
JOYCE L. VANENKEVORT	Ore and Stone				x	
JULIE	Petroleum Products		x	x	x	x
KELLY	Molten Sulfur		x			
KEN BOOTHE SR.	Dry Bulk	No trading reported in last 12 months				
LAURIE ANN REINAUER	Petroleum Products		x	x		
LEGACY	Petroleum Products	x	x			x
LINCOLN SEA	Refined Petroleum Products		x	x		
LINDA LEE BOUCHARD	Petroleum Products		x	x		x
LINDA MORAN	Petroleum Products		x	x		x
LOIS ANN L. MORAN	Petroleum Products			x		
LUCIA	Asphalt		x	x		
MAKO	Asphalt/6 Oil		x	x		x
MARION C. BOUCHARD	Petroleum Products		x	x		x
MARTIN EXPLORER	Molten Sulfur	No trading reported in last 12 months				
MEREDITH C. REINAUER	Clean Petroleum Products			x		
MICHIGAN	Petroleum Products		x		x	
MORGAN REINAUER	Clean Petroleum Products		x	x	x	
MORTON S. BOUCHARD IV	Petroleum Products		x	x		x
NAIDA RAMIL	Dry Bulk		x	x		x
NICOLE LEIGH REINAUER	Clean Petroleum Products			x		
OCEAN RELIANCE	Petroleum Products	x				
ORION	Molten Sulfur		x			
OSG CONSTITUTION	Crude Oil (Lightering)			x		x
OSG COURAGEOUS	Petroleum Products		x	x		
OSG HORIZON	Crude Oil		x	x		
OSG INTREPID	Petroleum Products		x			
OSG LIBERTY	Petroleum Products		x	x		
OSG NAVIGATOR	Petroleum Products		x			
OSG VISION	Crude Oil		x	x		

Name of Tug	Use	Trade Regions				
		West	Gulf	East	Great Lakes	All Others
OSPREY	Tank Barge		*x*			
PACIFIC RELIANCE	Clean Petroleum Products, Heated Cargoes, and EZ Chemicals	x				
PATI R. MORAN	Petroleum Products			x		
PAUL T MORAN	Petroleum Products		x	x		
PRIDE	Clean Petroleum Products, Heated Cargoes, and EZ Chemicals		x	x		
REBEL	Refined Petroleum Products		x	x		x
RESOLVE	Clean Petroleum Products, Heated Cargoes, and EZ Chemicals	x	x	x		x
RHEA I. BOUCHARD	Petroleum Products		x	x		
ROBERT J. BOUCHARD	Petroleum Products		x	x		x
RUTH M. REINAUER	Clean Petroleum Products			x		
SAMUEL DE CHAMPLAIN	Cement				x	
SCOTT TURECAMO	Petroleum Products		x	x		
SEA EAGLE	Chemical Barge		x			
SEA HAWK	Chemical Barge		x	x		x
SEA RAVEN	Oil		x	x		x
SEA RELIANCE	Petroleum Products	x				
SENECA	Petroleum Products	x				
SHARON DEHART	Grain	x	x	x		x
SKIPJACK	Asphalt/6 Oil	x	x			x
SOUND RELIANCE	Petroleum Products	x				
SPARTAN	Liquid Calcium Chloride			x	x	
TARPON	Asphalt/6 Oil		x	x		
TASMAN SEA	Refined Petroleum Products		x	x		
TERESA	Petroleum Products		x	x		x
TEXAN	Pressurized/Refrigerated Chemical		x	x		
TURECAMO GIRLS	Petroleum Products			x		
UNDAUNTED	Dry Bulk/General Cargo				x	
VALIANT	Asphalt/6 Oil		x	x		x
VICTORY	Limestone				x	
VISION	Clean Petroleum Products, Heated Cargoes, and EZ Chemicals	x				
VOLUNTEER	Refined Petroleum Products (Black Oil)		x	x		x
YANKEE	Refined Petroleum Products		x	x		
YELLOWFIN	Asphalt/6 Oil		x	x		x

APPENDIX C

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Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation