2011

Top Consequence Hazardous Materials by Commodities & Failure Modes 2005-2009

Pipeline and
Hazardous Materials
Safety Administration

Issue 3
9/1/2011

This page left blank intentionally.

Report Summary

The Pipeline and Hazardous Materials Safety Administration (PHMSA) evaluates safety risk and historical consequences in hazardous materials transportation when setting priorities, making policy, budgeting and allocating resources, drafting rules, targeting inspections, measuring performance, and communicating with stakeholders. In carrying out our mission to protect people and the environment from the risks inherent in transportation of hazardous materials, PHMSA uses data reflecting outcomes signaling areas of concern to the Administration and the nation, particularly those of high consequence to people and the environment.

This paper outlines the hazardous materials (hazmat) in transport that have been responsible for the most serious consequences in terms of deaths and major injuries during the years 2005 to 2009. It also identifies failure modes and the corresponding transportation phases that have resulted in the most high-impact casualties during this same period.

In response to initial feedback from stakeholders, this document has been revised to correct misreported figures due to duplicate and erroneous incident records. In particular, we adjusted the overall number of casualties involving gasoline and diesel fuel—as well as all casualties occurring in the highway and air modes—and validated the breakdown of incidents by failure cause, most notably derailment, rollover, and incidents with unreported causes. We have further expanded the section on selected emerging risks, highlighting some which have yet to produce serious consequences in transportation.

As PHMSA analyzes alternatives to increase the safety of hazmat transportation, the agency will consider several findings from this report:

- Some hazardous materials have high consequences due to their high levels of transport (i.e. high exposure) while in other cases it is the sheer volatility or danger of the substance that leads to significant consequences despite modest exposure;
- Most of the deaths and injuries due to hazmat can be linked to a small sub-section of all hazardous materials;
- Nearly all of the hazmat fatalities between 2005 and 2009 occurred during either rail or highway transport. (The exception was a single multiple-fatality waterborne incident.) The vast majority of major injuries (98%) were also associated with these two modes; and
- Rollover and Derailment while in transit are the principal failure causes recorded (and are specific to road and rail transportation, respectively).

A note of caution: while the five-year period analyzed here presents a valuable snapshot of the leading causes of hazmat-related losses in the U.S. recently, it does not supplant consideration of long-term trends and the need for a robust hazmat safety, incident prevention, and emergency response regime equipped to deal with both predictable and unpredictable events and avert catastrophe whenever possible. This is only the first step in a concerted series of efforts to identify areas of concern, target risks, and project future initiatives.

Preface: Uses and Limitations of the Data and Analysis

Probability and Risk

The commodity rankings in the report reflect documented incident[1] consequences. Outcomes such as those under consideration here highlight some areas of needed improvement but do not represent all aspects of underlying risk. Many hazardous materials present a special kind of risk – low-probability, high-consequence (LPHC) risk – that might not appear in the historical data, especially when the reference period is short. This analysis used a five-year reference period, in part, to help illustrate recent/current kinds of risk since these can change over time, and to align with recent data from the Commodity Flow Survey. This five-year period includes at least one LPHC incident: the train derailment at Graniteville that resulted in multiple deaths and injuries associated with chlorine. Without context, this incident might overstate the risks of chlorine. The same might be true for other commodities that are presented in the tables with very few deaths or injuries, particularly those with only one over a five year period. At the same time, there are other kinds of incidents, with other commodities, that have occurred outside the most recent five years but that still present some risk. Further analysis, and a longer reference period (with more data), is needed to help present a better picture of these LPHC risks.

Injury Weighting

Most of the rankings in this analysis use weighted numbers of incidents, where injuries are weighted less heavily than fatalities. This reflects a difference in the degree of consequence, and follows the same convention used in most benefit-cost analyses for rulemaking. However, the difference between a serious injury and death is sometimes a matter of "chance" or some other extraneous factor like physical condition of the victim, proximity to the release, etc. An unweighted sum of the incidents that cause any harm to people reflects the role of uncertainty in the safety risks we are trying to address in accordance with PHMSA's primary performance measure for hazardous materials safety being the number of incidents involving death or major injury. Weighting of injuries also introduces an assumption about the

[1] 49 CFR 171.15 and 171.16 contain the threshold for reporting, and define a reportable incident as:
(b) *Reportable incident.* A telephone report is required whenever any of the following occurs during the course of transportation in commerce (including loading, unloading, and temporary storage):

(1) As a direct result of a hazardous material—

(i) A person is killed;

(ii) A person receives an injury requiring admittance to a hospital severity of injuries to compensate for the fact that the incident data do not provide any injury severity information. Further research is needed on this to help refine the weighting in this analysis as well as for regulatory analyses.

Normalization

Normalizing hazmat incident data to account for differences in risk exposure helps to identify "hidden" risks—those commodities that might present a higher inherent risk, but that do not present high numbers of incidents simply because the exposure is small. Normalization might be especially helpful in targeting interventions since a high inherent risk might suggest a gap in defenses. That said, we also recognize that the exposure data from the Commodity Flow Survey is limited for this purpose. It covers only a quarter of the individual commodities with any associated incidents in the past five years, and provides only hazard class for all other hazmat. There might be ways of estimating the exposure for commodities that present death or injury incidents, but this will require further analysis beyond the scope of this report. This could provide more insight on the risks associated with the commodities not included in the tables.

Two exposure measures were used to normalize the data in this analysis: tons and ton-miles. Tons are probably a better denominator for loading, unloading, and temporary storage incidents, where the amount of material handled is an important risk factor. Ton-miles are probably better for incidents occurring in transit, where the length of haul is an important risk factor. Further analysis might break out the incidents by transportation phase, and associate different incidents with different denominators, depending on the phase of transportation in which they occurred.

Failure Modes

The analysis of failure causes draws on data as reported by carriers, without further judgment. In some cases, there might be incidents that have been misclassified with respect to cause, as hundreds of different people might have interpreted reporting guidance differently. Further examination of individual cases might reveal better coding for some cases, but this was beyond the scope of the current analysis.

One of the broader limitations from this analysis is the uncertainty surrounding the numbers, especially the smaller numbers, as a representation of risk. While we believe there is some underreporting of hazardous materials incidents, reporting of deaths and injuries is probably the most reliable since these incidents are not easy to ignore or hide. However, we are still dealing with some very small numbers, sometimes only one or two incidents involving a particular commodity over a five-year period. Any other five-year period is likely to show a different mix of commodities for these small-number cases. A longer reference period might help. Another possibility is to identify important risk factors using conditional probabilities, then use incidents with these risk factors to help extend the data to a broader set of incidents. Some preliminary analysis with conditional probabilities suggests this could be a promising approach, but it will require further work.

Section 1:

Commodity Data

The top 10 commodities based on high-impact casualties are displayed below in multiple rankings to reflect the varying policy uses and conclusions resulting from different emphases in the ranking methodologies. **Appendix A** provides general information for all commodities examined in the analysis, including industry uses and hazard class/division.

Table 1.1 is based on aggregate weighted consequences in terms of high-impact casualties (Ca); the data do not consider casualties *per unit* of commodity carried. High-impact casualties in this table are the weighed sum of deaths and major injuries or hospitalizations, in accordance with MAIS coefficients for DOT's established value of a statistical life (VSL).[2] Major injuries are assumed at an average level of MAIS 4 ("severe," 18.75% of VSL), compared to fatalities (MAIS 6).[3] While not so consequential as fatalities, major injuries are considered important in this context for their likelihood of causing permanent, disabling alterations to quality of life and as preventable experiences. Overall, this list has applications for resource allocation and program prioritization in light of reducing high-profile fatalities.

Among the commodities that top the list of high consequences are several whose high rate of exposure (i.e. high presence in transport) are largely responsible for the magnitude of their consequences. Gasoline and diesel fuel are two examples of commodities that fall into this category. Conversely, the sheer volatility or danger of other substances has led to significant consequences despite only modest exposure. Sulfuric acid and chlorine are examples of commodities that fall into this category.

[2] Available at http://ostpxweb.dot.gov/policy/reports/VSL%20Guidance%20031809%20a.pdf

[3] The range of MAIS values applicable to hospitalized injuries may reach from 2 (moderate, 1.55% VSL) to 5 (critical, 76.24% VSL); due to the lack of detailed information on injury severities, MAIS 4 was selected as a plausible intermediate.

Table 1.1 – Top 10 Commodities 2005-09 Ranked by Weighted High-Impact Casualties
(High Impact Casualties = Fatalities + Major Injuries or Hospitalizations)

Rank	Commodity Name	High-Impact Casualties (Weighted)	Fatalities	Major Injuries	Incidents
1.	Gasoline	33.56	30	19	1,306
2.	Chlorine	24.56	9	83	48
3.	Diesel fuel	13.31	12	7	573
4.	Propylene	4.94	1	21	15
5.	Fireworks	4.19	4	1	60
6.	Liquefied petroleum gas (LPG)	4.00	1	16	473
7.	Carbon dioxide, refrigerated liquid	3.56	3	3	1,269
8.	Sulfuric acid	3.31	2	7	1,270
9.	Argon, refrigerated liquid	3.00	3	0	42
10.	Propane	3.00	3	0	31

Source: Hazardous Materials Intelligence Portal, June 2011

All of the casualties calculated in Table 1.1 were associated with either rail or highway transport, except for those attributable to a multiple-casualty argon incident, which occurred aboard vessel transport. Additionally, the principal incident mode is the same as the principal carrier mode for all of the commodities in Table 1.1 (Extending the period of analysis back 10 years to 2000-2009, the only differences in the list are that anhydrous ammonia and alcohols replace argon and propane.)

When we simply sum the number of high-impact casualties for each commodity (reflecting the agency's overall goal of accounting for and reducing *all* casualty incidents), the list appears as follows in **Table 1.2**:

Table 1.2 – 10 Commodities Ranked by Unweighted High-Impact Casualties
(High Impact Casualties = Fatalities + Major Injuries or Hospitalizations)

Rank	Commodity Name	High-Impact Casualties (Unweighted)	Fatalities	Major Injuries	Incidents
1.	Chlorine	92	9	83	48
2.	Gasoline	49	30	19	1,306
3.	Propylene	22	1	21	15
4.	Diesel fuel	19	12	7	573
5.	Liquefied petroleum gas (LPG)	17	1	16	473
6.	Sodium hydroxide solution	10	0	10	2,239
7.	Sulfuric acid	9	2	7	1,269
8.	Ammonia, anhydrous	8	1	7	317
9.	Corrosive liquids, toxic, n.o.s.	8	0	8	511
10.	Carbon dioxide, refrigerated liquid	6	3	3	51

Source: Hazardous Materials Intelligence Portal, June 2011

Over 10 years, hydrochloric acid and fireworks would replace toxic corrosive liquids and carbon dioxide on the list.

To add another dimension to the rankings, **Tables 1.3(a) and (b)** not only calculate the high-impact casualty cost of an incident when it occurs, but also the *frequency* of past events relative to the amount of the commodity carried (known as exposure). The first normalization variable selected utilizes millions of ton-miles (MTM), taken from the US DOT 2007 Commodity Flow Survey (CFS), as a benchmark measure of exposure, incorporating the dimensions of both volume and distance. By contrast, the second methodology utilizes thousands of tons (kT), also from the CFS. The differing uses of the two, as explained in the preface, emphasizes the likelihood of consequences occurring in different phases of transport. As a result, these *per-unit* measures serve as a further factor for consideration when ranking the top 10 commodities.

Table 1.3(a) – Top 10 Commodities by *Normalization by Exposure*
(Weighted Casualties per Million Ton-Miles)

Overall Ranking			Consequences			Exposure
Rank	Commodity Name	Normalization Factor x 1,000 (N = Ca / MTM)	High- Impact Weighted Casualties (Ca)	Fatalities	Major Injuries	Million Ton-Miles (MTM, CFS 2007)
1.	Amines, liquid, corrosive, flammable, n.o.s.	26.79	0.38	0	2	14
2.	Toxic liquids, flammable, organic, n.o.s.	11.72	0.19	0	1	16
3.	Corrosive liquids, toxic, n.o.s.	10.56	1.50	0	8	142
4.	Chlorine	7.69	24.56	9	83	3,195
5.	Propane	4.65	3.00	3	0	645
6.	Calcium hypochlorite, hydrated	3.02	0.19	0	1	62
7.	Corrosive solid, basic, inorganic, n.o.s.	2.70	0.38	0	2	139
8.	Corrosive liquid, basic, organic, n.o.s.	1.64	0.19	0	1	114
9.	Ammonia solutions	1.05	0.19	0	1	179
10.	Corrosive liquid, acidic, inorganic, n.o.s.	1.05	0.94	0	5	897

Source: Hazardous Materials Intelligence Portal, June 2011

Table 1.3(b) – Top 10 Commodities by *Normalization by Exposure*
(Weighted Casualties by Thousands of Tons)

Overall Ranking			Consequences			Exposure
Rank	Commodity Name	Normalization Factor x 1,000 (N = Ca / kT)	High- Impact Weighted Casualties (Ca)	Fatalities	Major Injuries	Thousands of Tons (kT, CFS 2007)
1.	Sodium hydroxide solution	42.61	1.88	0	10	44
2.	Amines, liquid, corrosive, flammable, n.o.s.	10.42	0.38	0	2	36
3.	Chlorite solution	9.87	0.56	0	3	57
4.	Propylene see also Petroleum gases, liquefied	6.25	4.94	1	21	790
5.	Corrosive liquids, toxic, n.o.s.	6.25	1.50	0	8	240
6.	Butyl acetates	3.02	0.19	0	1	62
7.	Chlorine	2.88	24.56	9	83	8,533
8.	Sulfur dioxide	1.93	0.19	0	1	97
9.	Calcium hypochlorite, hydrated	1.48	0.19	0	1	127
10.	Corrosive solid, basic, inorganic, n.o.s.	1.47	0.38	0	2	255

Source: Hazardous Materials Intelligence Portal, June 2011

What these lists show is that the consequence attributable to a commodity group such as liquid amines, sodium hydroxide, or flammable organic toxic liquids have recently been disproportionate to their exposure. The corrosive liquids subgroups, for example, exert a noticeable dominance over the list normalized by ton-miles; not surprisingly, incidents involving these materials generally occurred while in transit.

A downside of the analysis presented in Tables 1.3(a) and (b), however, is that the CFS is not encyclopedic; it does not have exposure figures for all commodities with recorded hazmat incidents, including some with multiple fatalities such as propylene or argon.[4]

PHMSA has elected not to estimate exposure figures for other commodities due to concerns about impartiality and the complexity of reproducing CFS methods. Were the data available, a pure normalization by exposure would possibly bring still other commodities and concerns to the foreground; nonetheless those that dominate here are worth further evaluation.

[4] There were over 900 UN hazmat codes referenced in incident reports between 2005 and 2009; fewer than 200 of them had corresponding values recorded in the Commodity Flow Survey.

Section 2:

Failure Mode in each Transportation Phase

Failure mode, or the specific cause of an incident, is an important factor to consider when mitigating hazardous materials incidents. As a result, PHMSA analyzed failure modes across all phases of transportation (i.e. Loading, In Transit, In Transit Storage, and Unloading) for all commodities from 2005-2009. **Table 2.1** below ranks the top 10 failure modes by high impact casualties and indicates the primary transportation phase(s) in which each failure mode occurs. This table also takes into consideration if multiple failure modes were listed on the incident report form, and separates them into another category.

Again, high-impact casualties (Ca) in this paper are the weighed sum of deaths and major injuries or hospitalizations, in accordance with MAIS coefficients for DOT's established value of a statistical life (VSL). [5] Major injuries are assumed at an average level of MAIS 4 severe," 18.75% of VSL), compared to fatalities (MAIS 6).

Findings of particular importance in the failure mode table:

- Rollover Accidents and Derailments, which solely occurred during the In Transit phase, resulted in the highest casualties;[6]
- Human Error is the only failure mode of the top 10 failure modes that occurs in each of the four transportation phases.

Note that PHMSA does not collect the failure mode for a significant number of incidents that result in high impact casualties and 17 incidents had at least two failure modes recorded.

Prior to 2005, failure modes were coded differently and a comparison with prior data would not be apt.

[5] Available at http://ostpxweb.dot.gov/policy/reports/VSL%20Guidance%20031809%20a.pdf.

[6] Rollover and Crash are sometimes treated the same by reporting individuals; PHMSA believes that Rollovers may be underestimated.

Table 2.1 – Top 10 Failure Modes (across all Transportation Phases) Ranked by Weighted High Impact Casualties
(High Impact Casualties = Fatalities + Major Injuries or Hospitalizations)

Rank	Failure Mode	High Impact Casualtied (Weighted)	High Impact Casualties (Unweighted)	Fatalities	Major Injuries	Incidents with Fatalities or Major Injuries	Primary Transportation Phase(s) (with corresponding weighted casualties)
1.	Rollover	31.94	49	28	21	39	In Transit - 31.94
2.	Derailment	25.19	91	10	81	3	In Transit - 25.19
3.	Human Error	12.44	36	7	29	28	Loading - 0.94 In Transit - 2.38 Unloading - 4.75 In Transit Storage - 4.38
4.	Component or Device*	12.00	51	3	48	25	Loading - .38 Unloading - 3.81 In Transit - 7.82
+	Multiple Causes	11.44	22	9	13	17	Loading - 0.19 Unloading - 0.38 In Transit - 10.88
5.	Vehicular Crash or Accident	9.50	16	8	8	12	In Transit - 9.50
6.	Fire, Temperature, or Heat	2.69	10	1	9	6	Unloading - 0.38 In Transit - 2.31
7.	Impact with Sharp or Protruding Object (e.g. nails)	1.94	6	1	5	3	In Transit Storage - 0.38 In Transit - 1.56
8.	Overpressurized	1.69	9	0	9	4	Unloading - 0.38 In Transit - 1.31
9.	Conveyer or Material Handling Equipment Mishap	1.56	4	1	3	4	Loading - 0.19 Unloading - 1.38
10.	Inadequate/Improper Preparation for Transportation**	1.50	8	0	8	6	Loading - 0.38 In Transit - 1.12

Source: Hazardous Materials Intelligence Portal, June 2011

+This category contains incidents for which there were two or more failure modes reported.
**This failure mode is an aggregate of five failure modes: 1) Broken Component or Device; 2) Loose Closure, Component or Device; 3) Defective Component or Device; 4) Missing Component or Device; 5) Misaligned Material, Component or Device. The values provided have been adjusted to ensure that there is no double counting as a result of this aggregation.*
***This failure mode is an aggregate of two failure modes: 1) Improper Preparation for Transportation; 2) Inadequate Preparation for Transportation. The values provided have been adjusted to ensure that there is no double counting as a result of this aggregation.*

In addition to the incidents outlined above, there was one incident with two fatalities for which the cause could not be identified.[7] The primary transportation phase for this incident was Unloading.

Of the 17 incidents that had two failure modes, only 11 had a combination of failure modes solely from the top 10.

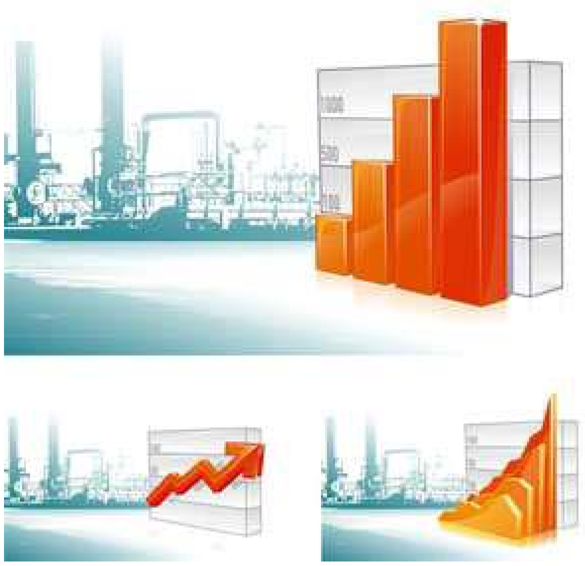
These combinations (without respect to order) include:

- Fire, Temperature, or Heat and Rollover Accident (3 incidents)
- Rollover Accident and Vehicular Crash or Accident Damage (2 incidents)
- Inadequate Preparation for Transportation and Loose Closure, Component, or Device (2 incidents)
- Human Error and Rollover Accident (1 incident)
- Human Error and Impact with Sharp or Protruding Object (1 incident)
- Human Error and Missing Component or Device (1 incident)
- Human Error and Deterioration or Aging (1 incident)

In addition to the four incidents that have human error as one failure cause listed above, there is a fifth where the second failure mode is Dropped. These five incidents that include human error as one failure mode resulted in three fatalities and three hospitalizations. Human Error is still the most often cited failure mode across all transportation phases, indicating a need for additional analysis.

One method, root cause analysis, attempts to trace the chain of failures from the *proximate cause*—the last failure in the chain—to the *root cause*—the reason why the chain of failures occurred in the first place. For example, the immediate cause of a hazmat release might be a failure to tighten a fitting while the more fundamental problem might be the design of the fitting or the qualifications of the person with the responsibility to tighten the fitting. The aim is to identify and solve the underlying problem, or the key interaction of problems in the chain of events, rather than only the surface manifestation of that problem.

[7] For all other incidents where a cause could not be identified, cause is assigned based on narrative and other information in the Incident Report Form.

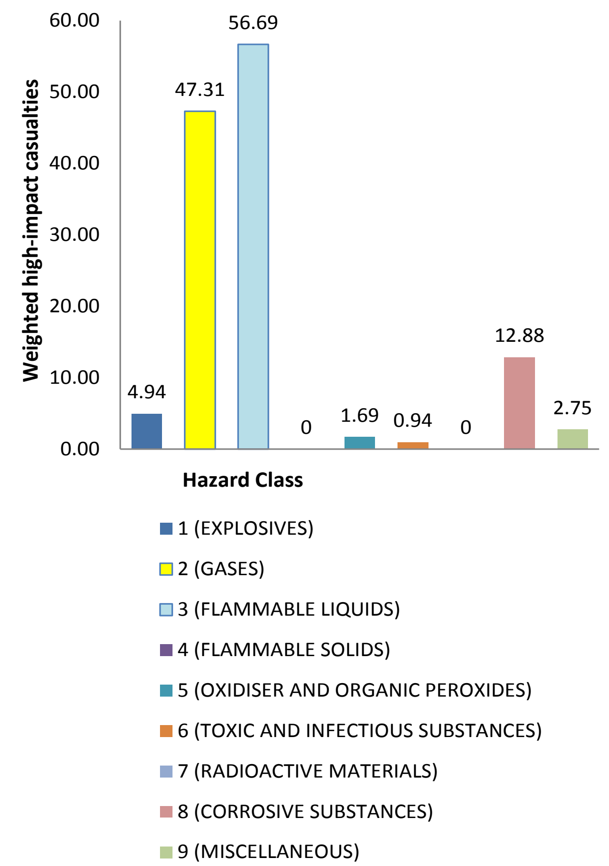


Section 3:

General Conclusions and Further Considerations

Examining commodities resulting in the greatest consequences and casualties in transport is more than just an exercise in deriving ranking statistics. At a macro level, the data presented in this paper shows that the great majority of casualties attributable to incidents associated with the transport of hazardous materials result from a small core number of hazmat commodities being transported. The top 10 commodities in Table 1.2 accounted for 97.44 weighted casualties out of 118.06 overall (from 71 fatalities and 251 major injuries) over the last five years for which data are available, or nearly 83 percent.

Hazmat from Classes 3 (flammable liquids, including gasoline and diesel fuel), 2 (gases, including chlorine), and 8 (corrosives, including sodium hydroxide and sulfuric acid) accounted for the vast majority of the total casualties, as summarized in **Chart 3.1**. No incidents involved flammable solids or radioactive materials. Note that as one incident may involve multiple commodities, these figures may include minor duplications.



Source: Hazardous Materials Intelligence Portal, June 2011

While hazard class serves as a functional summary shorthand for commodities, failure mode is related more closely to mode of transportation: for example, Derailments are naturally only a risk for railways. **Table 3.1** further illustrates the impact of the mode of transportation when considering fatalities and injuries caused by hazardous materials.

Table 3.1 – Incident Consequences by Transportation Mode, 2005-2009

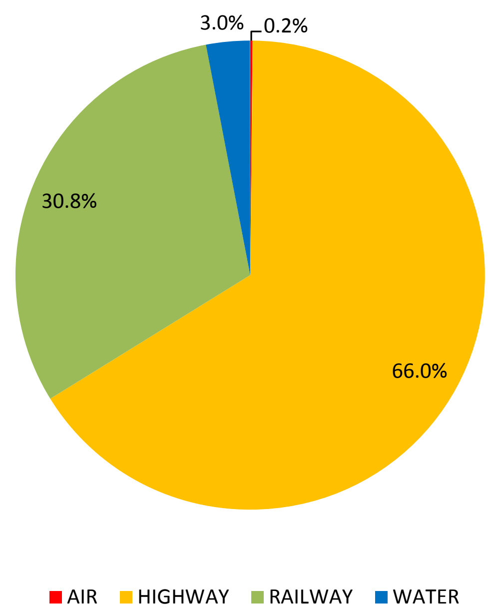
Mode of Transportation	Total Number of Fatalities	Total Number Hospitalized	Incident Count	Incidents with Fatalities or Major Injuries
AIR	0	1	8,254	1
HIGHWAY	56	117	75,094	135
RAILWAY	12	130	3,593	28
WATER	3	3	387	2
TOTAL	**71**	**251**	**87,328**	**166**

Source: Hazardous Materials Intelligence Portal, June 2011

Two thirds of all weighted consequences are attributable to highway incidents (see **Chart 3.2**, below), but casualties *per rail incident* were consistently higher than for all other modes except water:[8]

- For example, there were 1.3 weighted casualties (fatalities or major injuries) per *casualty-causing* rail incident as opposed to 0.6 for road incidents;
- Over *all* incidents, the difference was even more pronounced: note in particular that there are roughly the same number of major injuries (and a factor of five in fatalities) between the two modes despite there being 20 times as many incidents recorded on roadways as on railways.

Chart 3.2: Weighted High-Impact Casualties by Transportation Mode as Percent of Total, 2005-2009



Source: Hazardous Materials Intelligence Portal, June 2011

Emerging Risks

While the incident data PHMSA collects can provide an overview of past consequences and bolster efforts to remediate extant needs for regulation, this information is a lagging indicator. As an agency with a complex mission, PHMSA strives to address emerging threats and prevent catastrophic events for commodities that have not yet amassed a robust record of incident consequences. In these cases, PHMSA reviews data and research information on production, consumption and new technologies associated with hazardous materials.

[8] Water incidents tend to be low-frequency high-consequence events from which it is difficult to draw general conclusions.

Emerging risks in hazardous materials commodities include materials ranging from biofuels and compressed hydrogen to fireworks, perchlorate and ammonium nitrate – commodities with an anticipated increase in production and consumption volumes in the United States. Some of these commodities are outlined below.

Biofuels

Biofuels including ethanol and methanol are gaining popularity throughout the world, as they have the potential to offer a more cost-effective and local alternative to importers of gasoline and other fuels. Production of biofuels in 2010 was 1869.937 trillion Btu, over a 700% increase from 2000, when the production was 233.146 trillion Btu.[9] The International Energy Agency has predicted that biofuels will have the potential to meet 27% of the world demand for transportation fuels by 2050.[10] New forms of biofuels like biogas pose less safety risks than their more toxic alternatives, making them more suitable for distribution through existing pipelines as well as through existing surface transportation methods for other fuels. However, the seemingly unavoidable increase in transportation of biofuels over the next several years— such as bioethanol and biodiesel—make it still imperative that measures are taken to ensure these fuels are being handled and transported appropriately.

Perchlorate

Perchlorate has been recognized for years as a potential danger in drinking water across the United States. It is now increasingly being used in a variety of additional applications, including pyrotechnics and fireworks, blasting agents, matches, lubricating oils, textile dye fixing, nuclear reactors, electronic tubes, tanning and finishing leather, rubber manufacturing, electroplating, aluminum refinishing, automobile air bag inflators, paint and enamel production, and pharmaceuticals.[11] When exposed to the human body, perchlorate has the potential for devastating health effects, including damage to the thyroid gland and therefore the metabolism and normal growth development. These health risks, combined with the chemical's combination of solubility, persistence, and mobility creates the potential for both localized and widespread impacts of toxicological interest,[12] and is therefore a chemical that should be transported with the utmost care.

Ammonium Nitrate

The global market for ammonia is forecast to reach 174 million metric tons by 2015[13]—a 60% increase from 109 million in 2004[14] and a 34% increase from 130 million in 2009[15]. This is a result of increased end-use markets, such as fertilizers, explosives, and industrial applications, in addition to the

[9] http://www.eia.gov/totalenergy/data/monthly/#renewable
[10] http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Oil/6017103
[11] http://www.clu-in.org/contaminantfocus/default.focus/sec/perchlorate/cat/Overview/
[12] http://www.mass.gov/dep/cleanup/sites/percsour.pdf
[13] http://www.prweb.com/releases/ammonia/urea_fertilizers/prweb4634144.htm
[14] http://minerals.usgs.gov/minerals/pubs/commodity/nitrogen/nitromcs05.pdf
[15] http://www.indexmundi.com/en/commodities/minerals/nitrogen/nitrogen_t12.html

emergence of new markets, including biofuels, and a sudden increase in capacity expansions across developing countries.[16] Though ingestion risk of ammonium nitrate is minimal, the chemical's supporting oxidation makes it prone to fire risk when stored in large quantities, and should therefore be transported in an appropriate manner.

Increasing rail and trucking transport for these commodities is expected. There remains a need for further analysis of the challenges these commodities may present in transportation.

The Office of Hazardous Materials Safety envisions a further series of reports to pick up where this leaves off, exploring both (1) the dimensions of risk probability attributable to individual commodities or transportation processes and (2) an overview of the distribution of consequences and potential frequency of their occurrence.

The source data for the commodity analysis were obtained from PHMSA's Hazmat Intelligence Portal (HIP) in September 2010 with modifications in February and June 2011 to account for incidents reported late and the acquisition of more refined data. The data were cleaned to combine instances of commodities listed under multiple identification numbers (e.g., diesel fuel, which is reportable as both UN1202 and NA1993) and to remove records of casualties not attributable to hazmat. The source data for the analysis of transportation phase and failure mode were obtained from HIP in June 2011.

[16] http://www.prweb.com/releases/ammonia/urea_fertilizers/prweb4634144.htm

Appendix

Appendix A – Commodity Industry Uses and Hazard Class/Division

Commodity Name	Industry Uses	Hazard Class, *Division*
Amines, liquid, corrosive, flammable, n.o.s.	Used as a component in natural resins and waxes which are useful in floor finishes, textile finishes, and water-based paints. Other applications include mildew treatment, paint remover, fluorescent brightener, and corrosion prevention.	8, *Corrosive*
Ammonia solutions	Used as a fertilizer and in commercial cleaning products	2.2, *Corrosive*
Ammonia, anhydrous	Used as a fertilizer, as a refrigerant, and in the manufacture of other chemicals.	2.2 (Domestic (U.S.), *Inhalation Hazard (13)* 2.3, 8 (International, Inhalation Hazard Zone D), *Non-Flammable Gas*
Argon, refrigerated liquid	Used as a component in electronics, fabrication, lasers, metals, specrtographic analysis, and window insulation/double-glazing.	2.2, *Non-Flammable Gas*
Butyl acetates	Commonly used as a solvent in the production of lacquers and other products. It is also used as a synthetic fruit flavoring in foods such as candy, ice cream, cheeses, and baked goods.	3, *Flammable Liquid*
Calcium hypochlorite, hydrated	Used for water purification, disinfectant for swimming pools, for bleaching paper and textiles, among other uses.	5.1, *Oxidizer*
Carbon dioxide, refrigerated liquid	Used as a refrigerant and in making carbonated beverages, as well as to freeze food, to control chemical reactions and as a fire extinguishing agent.	2.2, *Non-Flammable Gas*
Chlorine	Disinfectant, component in plastic manufacturing.	2.3, 8 *Poison Gas, Corrosive*
Chlorite solution	Used in drinking water and wastewater treatment, food decontamination, paper and textile bleaching, decontamination of surfaces, and mouthwash.	8, *Corrosive*
Corrosive liquid, acidic, inorganic, n.o.s.	Includes hypophosphorous acid, used in the formulation of pharmaceuticals, discoloration of polymers, water treatment, retrieval of precious or non-ferrous metals.	8, *Corrosive*
Corrosive liquid, basic, organic, n.o.s.	Used as a wetting agent, anti-caking agent, and corrosion inhibitor, as well as in oil production and pigment modification.	8, *Corrosive*
Corrosive liquids, toxic, n.o.s.	Used in the synthesis of some organosulfur compounds (organic compounds containing sulfur).	8, *Corrosive*
Corrosive solid, basic, inorganic, n.o.s.	Used to strip away oil, grease and other deposits from transmissions, radiators, and other metal parts.	8, *Corrosive*
Diesel fuel	Used mostly as a fuel source, also as a palladium extraction agent.	3, *Flammable Liquid*
Fireworks	Class of explosive pyrotechnic devices used for aesthetic and entertainment purposes, most commonly as part of a fireworks display.	1.1G, 1.2G, 1.3G, 1.4G, 1.4S, *Explosives*
Gasoline	Used as a fuel and solvent.	3, *Flammable Liquid*
Liquefied petroleum gas (LPG)	A flammable mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. It is also increasingly used as	2.1, *Flammable Gas*

Appendix A – Commodity Industry Uses and Hazard Class/Division

Commodity Name	Industry Uses	Hazard Class, *Division*
	an aerosol propellant and a refrigerant.	
Propane	Used as a fuel for engines, oxy-gas torches, barbecues, portable stoves and residential central heating. Also mixed with butane to make the vehicle fuel commonly known as liquefied petroleum gas.	2.1, *Flammable Gas*
Propylene	Component used in production of chemicals and plastic products.	2.1, *Flammable Gas*
Propylene see also Petroleum gases, liquefied	Used as a fuel in heating appliances and vehicles, and increasingly used as an aerosol propellant and a refrigerant, replacing chlorofluorocarbons in an effort to reduce damage to the ozone layer.	2.1, *Flammable Gas*
Sodium hydroxide solution	Used as a strong chemical base in the manufacture of pulp and paper, textiles, drinking water, soaps and detergents and as a drain cleaner	8, *Corrosive*
Sulfur dioxide	Used in the production of sulfuric acid, in winemaking, and in biomedical roles. It is also used as a preservative, a reducing agent, a refrigerant, and a laboratory reagent and solvent.	2.3, *Poison Gas, Corrosive*
Sulfuric acid	Used in lead-acid batteries for cars and other vehicles, ore processing, fertilizer manufacturing, oil refining, wastewater processing, and chemical synthesis.	8, *Corrosive*
Toxic liquids, flammable, organic, n.o.s.	Used in many chemical processes, including the production of silicone polymers. A common end product includes coating for silicon and glass surfaces	6.1, *Poisonous Material*