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Development of a centralized inland marine hazardous materials response database

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Abstract

The state of the practice for obtaining chemical reference at a typical hazardous materials transportation accident scene is to consult multiple printed references. This often leads to confusion. This paper describes the design and development of a centralized response database. This is accomplished by identifying the most commonly used emergency response databases for all modes of transportation, developing relationships between the data, and building intuitive interfaces that allow for rapid information retrieval. The tool is subsequently applied to a previous accident to demonstrate the value-added from its availability in a response scenario. By combining all datasets in one application, data redundancy, errors and lags between updates of the data sets can be reduced. The linkages between the database and supporting files enables the data to be easily updated.

While the database is designed to aid response to marine transportation accidents, the tool could also be applied to other modes of transportation. Moreover, facility and vessel operators could benefit from having a comprehensive chemical source accessible in case of release or human contact with the material. Finally, the inclusion of commodity flow information enables decision makers to prepare for high risk commodities.

Keywords: Database management systems; Marine transportation; Chemical reference data; Emergency response information; Spill response information system

1. Introduction

Each year, between 5000 and 7000 spills of hazardous materials occur in US waters [1], a portion of which are from inland marine towboats and barges. Chemical spills on

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inland waterways constitute a unique response situation since there are both airborne and waterborne chemical dispersion to consider, affecting land-based receptors and those in the waterway (drinking water intakes), respectively. Some of the data available for chemical spill response are tailored to the propagation medium through which the target responder is most likely to act. For example, the United States Coast Guard (USCG) maintains the chemical hazard response information system (CHRIS), which contains considerable information on how chemicals will react in water, while North American Emergency Response Guidebook (NAERG) is focused more on protecting the population from chemical vapor airborne dispersion.

Land-based responders, such as fire and police, are typically called in to assist with inland marine transportation accidents involving hazardous materials. Response to these incidents is often inhibited by the difficulties in identifying the hazardous materials involved and, consequently, how to assess the accident scene. This can result in significant delays associated with spill response.

With the advent of carrier-maintained information systems, geographic information systems (GIS), database management systems (DBMS) and the Internet, the potential exists for responders to access important information that is timely, accurate, comprehensive and visually appealing. To support this functionality, a database is necessary to process carrier-provided data in the event of an accident, convert tabular data to geographic layers and attach a hazard profile to the particular tow in question.

This paper describes the development of a centralized chemical reference database and associated tables towards achieving this goal. It is designed to provide responders with as much relevant information as possible without requiring an inordinate amount of database knowledge or time spent at a computer during the response. Real-life examples of confusion at inland marine transportation accident scenes that could have been alleviated with the availability of an inter-agency database are also presented and discussed.

2. Prior inland marine accidents

Historically, shipping documents, vessel crew and response manuals have not always been reliable sources for identifying the actual chemicals of the tow. This has seemed to undermine the confidence of responders in using such information to formulate response strategies and make decisions. The discussion below describes a couple of cases involving prior waterborne accidents where this has occurred.

Just after midnight on 18 October 1997, a barge carrying what was thought to be ammonium nitrate fertilizer (an explosive) had to be grounded along the Intracoastal Waterway (ICWW) after taking on water [2]. The fertilizer was being transported at an unknown concentration, and the approximate amount of product spilled into the water was unknown. The product was not correctly identified as urea fertilizer (a much less hazardous chemical) until 29 October 1997, more than a week and a half into the cleanup. During this time, responders treated the product spilled as an explosive and fire hazard, unnecessarily delaying spill remediation and re-opening of the waterway.

On 17 March 1997 at 5:25 p.m., a barge carrying raw pyrolysis gasoline capsized near Baton Rouge, Louisiana, spilling over 60,000 gal into the Mississippi River [3]. The tank barge was part of a 25-barge tow that struck the US Highway 190 bridge, forced the evacuation of nearly 3000 people, shut down a 2.5 miles stretch of the lower Mississippi River and caused several water intake closures. A bluish haze lingered over the city for days and hundreds of citizens were treated at local hospitals for nausea, burning throats and other symptoms of chemical exposure. Raw pyrolysis gasoline, a blend of toluene and benzene, is not explicitly included in the NAERG or the CHRIS Manual. Responders consulted material safety data sheets (MSDS) to determine that benzene was the chemical that posed the greatest risk (representing 70% of pyrolysis gasoline by volume).

The aforementioned cases illustrate how the difficulties in material identification and characterization unnecessarily hindered responders' abilities to protect themselves and the general public. Had data from several agencies involved in hazardous materials transportation been integrated into a central repository with an intuitive interface, the quality of information at the scene of an accident could be significantly improved.

3. Agencies involved in inland marine transportation

Several agencies have varying degrees of authority and responsibility relating to marine transportation and hazardous materials response (see Table 1). Their respective roles are discussed below.

3.1. US Department of Transportation

The US Department of Transportation (DOT), the ultimate authority in all commercial freight transportation, delegates responsibility to the Maritime Administration (MARAD) and the US Coast Guard for regulating the marine transportation industry. The DOT's involvement in hazardous materials data collection relates mainly to the classification of hazardous materials in the Code of Federal Regulations (CFR). The DOT also jointly publishes the North American Emergency Response Guidebook [4] with Transport Canada (TC) and the Secretariat of Communications and Transportation (SCT) of Mexico. This guidebook contains basic information that is useful to responders "in quickly identifying the specific or generic hazards of the material(s) involved in the incident, and protecting themselves and the general public during the initial response phase of the incident" [4].

Table 1
Maintainers and users of chemical reference data

Agency	Maintains commodity and chemical data	Uses commodity and chemical data (response purposes only)
DOT	×	
USCG	×	×
NFPA	×	
EPA/NOAA	×	×
NIOSH	×	
USACE	×	

Table 2
Emergency response guidebook table metadata

ID	NAERG identification number
GUIDE_PAGE	NAERG guidebook number/page
MATERIAL	NAERG material name
PRTC_TABLE	Does the material have a corresponding protective and isolation distance? (y/n)
WATR_REACT	Is the material water-reactive? (y/n)
TIH	Is the material toxic by inhalation? (y/n)
LISO_MAX	Large spill maximum isolation distance (miles)
LPRO_MAXD	Large spill maximum protective action distance, daytime (miles)
LPRO_MAXN	Large spill maximum protective action distance, nighttime (miles)
SHAZ	Is the material toxic by inhalation? (y/n)
WATR	Is the material water-reactive? (y/n)

The NAERG is intended for use by fire fighters, police and other emergency services personnel who are often the first to arrive at the scene of a transportation accident involving hazardous materials. This reference familiarizes first responders with general hazards and recommended initial response activities associated with the materials involved. All trucks, trains and vessels transporting dangerous goods are required to document these shipments based on NAERG identification and guide numbers in the dangerous goods manifest (49 CFR 172.200–204). The dangerous goods manifest is usually located on the bridge or pilothouse of a towboat. There is no requirement for placarding of barges as in rail and highway transportation of hazardous materials, further encumbering identification and information gathering tasks associated with inland marine transportation emergency response.

Tables 2 and 3 describe the structure of the NAERG database according to how it can be represented inside a centralized, relational database. Table 2 includes all products contained in the NAERG, including information such as isolation and protective action distances, and whether or not the material is water-reactive and/or toxic by inhalation. Table 3 shows how NAERG textual information can be structured in the centralized database.

3.2. United States Coast Guard (USCG)

The USCG maintains the CHRIS Manual [5]. This manual is primarily intended for USCG personnel during marine transportation accident response. The CHRIS Manual contains each chemical's physical characteristics, incompatible chemical combinations, initial response actions, treatments for exposure, and expected physical and chemical properties. Chemical reference data may be accessed, in paper format, across the Internet or via CD-ROM. The USCG is involved in response and mitigation of hazardous materials acci-

Table 3
Emergency response guidebook text

GUIDE_NO	NAERG guidebook number/page
SEQUENCE	Order of sentences on guidebook page (1, 2, 3, ...)
SENTENCE	Sentence as it appears in the NAERG guidebook page

dents, usually as Federal on-scene coordinators (FOSC) under the 1990 Oil Pollution Act (OPA 90). FOSC's are officers in the Coast Guard or representatives from the Environmental Protection Agency (EPA) who serve in a supervisory role during a response to a spill. The USCG also may take over accident response, if requested by the carrier (immediately responsible party) or if deemed necessary by the FOSC.

Table 4 shows the metadata of the USCG CHRIS Manual. The original format of this data is in Adobe Acrobat documents, however, the raw data is also included on the CD-ROM as a Microsoft Access database. This data was imported into the centralized database with little manipulation required to relate the 'CHRIS Code' fields to the previously imported chemical reference tables. As the CHRIS Manual is more comprehensive than the NAERG, there is a considerable amount of additional data available by combining the datasets inside a single database.

The CHRIS Manual also classifies each chemical into a commodity grouping. There are 37 such groupings, and these are primarily used to determine when cargos are incompatible. The matrix that exists on the CHRIS Manual CD-ROM in Adobe portable document file (pdf) format was manually converted into a relational database table named, 'CHRISINCOMPAT.' CHRISGROUP1 and CHRISGROUP2 are the field names and each record constitutes an incompatible cargo grouping. Maintaining this information in a relational database rather than inside a matrix constitutes an improvement since a matrix only describes which generic cargo groupings ("caustics", "aldehydes" are two such groupings) are incompatible. The relational database quickly determines not just the incompatible broad grouping numbers, but allows "drill down" to identify specific cargoes (in the previous example, furfural is a member of the caustic grouping). In addition to time savings gained from storing the matrix information inside a table, the likelihood of errors is reduced.

3.3. National Fire Protection Association

The National Fire Protection Association (NFPA) maintains chemical ratings for commodities in the "Recommended System for the Identification of the Fire Hazards of Materials" (NFPA No. 704M) [6]. Each chemical has a rating from 0 to 4 in regards to health, flammability, and reactivity, respectively. Some special hazards are also included, such as whether the material is water-reactive or an oxidizing agent. The NFPA also publishes several resources related to hazardous materials transportation incident response.

Table 5 illustrates the structure of the NFPA table inside the centralized database. NAERG references are included, if available. These fields were populated for several records by joining the compound name to the NAERG tables. The descriptions for each rating category field (e.g. an H rating of three translates to, "corrosive or toxic, avoid skin contact or inhalation") are stored in a separate table.

3.4. Environmental Protection Agency and National Oceanic and Atmospheric Agency

The Environmental Protection Agency and National Oceanic and Atmospheric Agency (NOAA) jointly developed the emergency response software CAMEO (Computer Aided

Table 4
CHRIS Manual metadata

CHRIS Code	Neutralizing agents for acids and caustics
Hotlink	Polymerization
IMO, UN numbers	Inhibitor of polymerization
CG compatability group ID	Aquatic toxicity
Formula	Waterfowl toxicity
DOT ID number	BOD
NAERG guide number	Food chain concentration potential
CAS registry number	GESAMP bioaccumulation
Physical state shipped	GESAMP damage to living resources
Color, odor	GESAMP human oral hazard
Characteristics in water	GESAMP human contact hazard
Cautionary response actions	GESAMP reduction amenities
Fire info	GESAMP comments
Exposure info	Grades of purity
Water pollution info	Storage temperature
Corrective response actions	Inert atmosphere
Standard industrial trade classification	Venting
Personal protective equipment	IMO pollution category
Exposure symptoms	Ship type
Exposure treatments	Barge hull type
TLV-TWA, STEL, ceiling	49 CFR category, class, package group
Toxicity by ingestion grade, data	Marine pollutant
Toxicity by inhalation grade, data	EPA reportable quantity
Chronic toxicity	EPA pollution category
Vapor (gas) irritant characteristics	RCRA waste number
Liquid or solid irritant characteristics	EPA FWPCA list
Odor threshold	Physical state at 15 °C and 1 atm
IDLH value	Molecular weight
OSHA PEL-TWA, STEL, ceiling	Boiling point at 1 atm
Flash point	Freezing point
Flammable limits in air	Critical temperature, pressure
Fire extinguishing agents	Specific gravity
Fire ext. agents not to be used	Liquid surface tension
Spec. hazards of combustion products	Liquid water interfacial tension
Behavior in fire	Vapor (gas) specific gravity
Ignition temperature	Ratio of specific heats of vapor (gas)
Electrical hazards	Latent heat of vaporization
Burning rate	Heat of combustion
Adiabatic flame temperature	Heat of decomposition
Stoichometric air to fuel ratio	Heat of solution
Flame temperature	Heat of polymerization
Combustion molar ratio	Heat of fusion
MOCC	Limiting value
Reactivity in water, with common materials	Reid vapor pressure
Stability during transport	CIW_Raw, CRA_Raw
H	FI_Raw
F	EI_Raw
R	WP_Raw

Table 5
NFPA ratings table metadata

Field name	Field description
NAERG_ID	NAERG ID number (if available)
NAERG_GUIDE	NAERG guidebook number (if available)
Compound	Compound name
H	NFPA health rating (0–4)
F	NFPA flammability rating (0–4)
R	NFPA reactivity rating (0–4)
W	Water-reactive?
OX	Oxidizing agent?

Management of Emergency Operations). CAMEO is widely used for determining spill response strategies, particularly in identifying hazardous locations based on airborne chemical dispersion. The database that supports this functionality is included with the CD-ROM, and is in a format that can be easily read and imported by desktop database application software. The CAMEO database contains over 6000 chemicals with associated synonyms and trade names commonly used to identify a product.

Table 6 describes the fields of the CAMEO table as it exists within the centralized database design. The CAMEO database is oriented toward providing the emergency responder with information on each chemical related to fire and explosive hazards, health hazards, fire-fighting techniques, cleanup procedures, and protective clothing [7].

Table 6
CAMEO database table metadata

Chemical name	Regulatory names
CAS number	Physical state
UN number	LOC
STCC Code	LFAD
CHRIS Code	LFBD
General description	LFM
Properties	SEC 112R
Fire hazard	CAA RQ
Health hazards	MATERIAL
Fire fighting	MATRIX B
Non-fire response	FABRIC
Protective clothing	GLOVES
First Aid	BOOTS
Formula	FACESHIELD
Label	Reactive group numbers
Synonyms	Air and water reactions
Regulated chemical	Chemical profile
CERCLA	Hazard category
EHS	General description
SEC 313	RQ
RCRA	EHSTPQ

Table 7
NIOSH Pocket Guide to chemical hazards metadata

Field name	Field description
NPGGUIDENO	NIOSH guide number
CHEMNAME	Chemical name
CAS	Chemical abstracts services number
RTECS	US registry of toxic effects of chemical substances number
NPG_PAGE	NIOSH Pocket Guide page hyperlink (local)

3.5. National Institute for Occupational Safety and Health

The National Institute for Occupational Safety and Health (NIOSH) publishes the *Pocket Guide to Chemical Hazards* [8]. This manual contains previously described data (e.g. NFPA ratings, USDOT ID numbers) and is available in digital and hard copy format. Table 7 describes the metadata of the imported pocket guide as catalogued in the centralized database. The NIOSH Pocket Guide (NPG) presents key information intended for use by chemical industry health professionals. The NPG is an abbreviated reference with information on chemicals and groupings (similar to the CHRIS Manual, cyanides, fluorides, etc.) including exposure limits, immediately dangerous to life and health concentrations, measurement methods and protective clothing recommendations.

3.6. United States Army Corps of Engineers

Whereas previous agencies are involved with information sources to aid responders when managing a hazardous materials accident the US Army Corps of Engineers (USACE) is tasked with navigable waterway maintenance, commodity flow data, statistics compilation and generating reports related to US waterborne commerce. This data is publicly available and updated on an annual basis.

When chemical response data is combined with information codes routinely used to document shipments for commodity flow analyses, a powerful real-time system capability emerges. However, the Corps uses its own commodity nomenclature for waterborne commerce, which does not completely correspond to the codes and identification protocols of the emergency response community. A significant amount of effort has been expended in correlating Corps commodity codes with those used by other Federal agencies and internationally [9]. Further correlation and integration of this commodity flow information with other response data (mentioned earlier in this section) would be of great value to parties involved in responding to and preparing for hazardous materials accidents.

The USACE commodity flow information also enables decision makers to develop spill response preparation scenarios by use of the National Waterway Network (NWN). The NWN is a geographic layer of all navigable waterways in the United States, which describes US shallow and deepwater draft channels and is accurate to a scale of 1:100,000. Commodity flow information may be attached to this network and displayed in a geospatial environment.

The USACE uses different commodity code classifications for different purposes. The lock performance monitoring system (PMS) code (LPMS: 2 digits, 41 unique commodities)

Table 8
Performance monitoring system table metadata

Field name	Field description
PMS_CODE	Performance monitoring system code (2-digit code)
PMS_NAME	Performance monitoring system name

Table 9
Public domain commodity table metadata

Field name	Field description
PDDB_GROUP	Public domain database code
PDDB_NAME	Public domain database name

is used to represent shipments transiting key locks. Commodity flow information is made available to the public at the LPMS code level of detail. The WCSC code (5 digits, 662 unique commodities) is used by carriers for reporting purposes. However, commodity flow information at the WCSC level of detail is not available to the public, but is available to authorized parties, such as response agencies, on a case-by-case basis [10]. The final commodity code classification adopted by the Corps is the publications group code, which is used in annual report and performance indicators of US navigable waterways.

Tables 8–11 show centralized data structures extracted from the performance monitoring system, public domain, WCSC, and publication group commodity codes, respectively. The USACE maintains a cross-walk table that defines how these four codes relate to each other. However, caution must be exercised when translating commodity codes of varying levels of aggregation. For example, it is not correct to translate a WCSC code to a NAERG identification and guide number, and assign those same hazardous classifications to a PMS code since the WCSC codes are much more specific (e.g. the WCSC code is "sodium nitrate," and the corresponding PMS code is "fertilizers"). There are 662 WCSC codes, but only 41 PMS, 16 public domain, and 158 publication group commodity codes.

Table 10
Waterborne Commerce Statistics Center commodity table metadata

Field name	Field description
WCSC_CODE	Waterborne Commerce Statistics Center commodity code
WCSC_DESC	Waterborne Commerce Statistics Center commodity code description

Table 11
Publication group commodity table metadata

Field name	Field description
PUB_CODE	Publication group commodity code
PUB_NAME	Publication group commodity code name

While there are other agencies and information that could be used in certain circumstances to aid responders at a marine transportation accident scene, generally the aforementioned databases collectively contain the pertinent information. These other agencies and documents are listed below for reference purposes only.

- Chemical Transportation Emergency Center (CHEMTREC) is operated by the American Chemistry Council 24 h per day [11]. This center is able to field calls through a 1–800 telephone number and deliver expert advice on spills and response techniques. This number is routinely dialed in the absence of first responder information, such as what is contained in the NAERG. The data that the operators use at CHEMTREC is not freely available to the public, however.
- The Oil and Hazardous Materials Technical Assistance Data System (OHM-TADS) is a system developed by the EPA [12]. This data was created to serve as a reference for over 1200 hazardous materials, and may be accessed from computers at Coast Guard Marine Safety Offices and EPA regional offices.
- Poison Control Centers are located throughout the US at hospitals. Personnel at these centers are able to provide information on the chemical composition, appearance and toxicity of common chemical materials as well as recommended treatment in the event of exposure.
- The American Association of Railroads (AAR) has developed emergency action guides for 134 commonly transported (by rail) commodities [13]. This is the railroad equivalent of the CHRIS Manual, and is contained in a single binder along with initial response guidance.
- The US Fire Administration (USFA), an entity of the Federal Emergency Management Agency (FEMA), has created a handbook for first responders to fixed facility and transportation hazardous materials accidents, *USFA Hazardous Materials Guide for First Responders* [14]. This handbook has general information on first responder actions when dealing with hazardous material releases and fires. The information is organized into first aid, hazards, general description, training and awareness for incidents involving the chemical.

4. Database construction

The import and correlation of relevant response and database forms began with the hazardous commodity table generated by the Dr. Joe Svirbeley of the USACE [9]. Note that this table is the result of appending these two tables into one for display purposes (see Table 12).

To eliminate data redundancy inside these tables, all records were appended into a single table, and the table was normalized for a more efficient data structure. Normalization involves the progressive decomposition of database attributes to result in a minimum of storage required. Once normalized, a database can make greater use of indices and relationships to retrieve information. For instance, there is no need to store guidebook numbers and descriptions in this cross-reference table. By keeping only the guidebook number in the table, another table may be created that stores the guidebook number and other corresponding

Table 12
Hazardous commodity—WCSC correlation metadata

Field name	Description
WCSC_NUM	WCSC number
WCSC_DESC	WCSC commodity description
NAERG_DESC	Name of material (NAERG description)
NAERG_ID	ID number (NAERG)
NAERG_GUIDE	Guidebook number (NAERG)
GUIDE_DESC	Guidebook description (NAERG)
HAZ_CLASS	Hazard class (NAERG)
CLASS_DESC	Hazard class description (NAERG)
HAZ_DIV	Hazard division (NAERG)
DIV_DESC	Hazard division description (NAERG)
SUB_DIV	Subsidiary hazard division (NAERG)
SUB_DESC	Subsidiary hazard division description (NAERG)
REGULATED	Regulated 1 = FIFRA, 2 = OPA, 3 = CWA, 4 = indirect CWA
COMMENTS	Regulated comments
CHRIS_CODE	CHRIS Manual three-letter chemical code
CHRIS_NAME	CHRIS Manual name
CAS_NUMBER	Chemical abstract service number

data and descriptions. A relationship is created between the two tables' guidebook number fields so that the text information (guidebook description) remains available. This eliminates a significant amount of storage space since the descriptions for chemicals are stored only once in one table inside the database.

Using a similar process, other tables were created from this hazardous commodity table. For example, a NAERG table was constructed which contained NAERG identification number, NAERG guidebook number and NAERG description fields. The NAERG identification and guidebook numbers uniquely identify each chemical, and remain in the cross-reference table (renamed 'CROSS_REF'). A relation between the CROSS_REF and NAERG tables enables the NAERG descriptive information and chemical name to be viewed. A similar procedure was performed for the CHRIS Manual, hazard classes and the CAS identification numbers. Once these tables were created, each source was imported into the database. For example, the CHRIS Manual was imported into the database and all of the information associated with CHRIS is available via a relationship between the CROSS_REF table (field name "CHRIS_CODE" relates to "CHRIS_CODE" in the CHRIS Manual table).

The other tables that were not in the original USACE hazardous commodity table include the NFPA ratings, CAMEO datafields, CAS registry information and NIOSH chemical data. These data sets had to be imported into the database and related to the original cross-reference table. Along the way, chemicals that were not in the original hazardous commodity table were added to the cross-reference table. These other data sets existed in several formats, including html, pdf, and excel spreadsheets. A significant amount of manipulation was required to import these non-standard data formats.

By combining airborne and surface water dispersion datasets into a single database, update and retrieval of pertinent attributes describing hazardous chemicals can be made easier and less time-consuming. Furthermore, by making the data available to responders by download across the Internet or on CD-ROM, the response community can become better prepared for hazardous materials emergencies, no matter where they occur (on highway, rail, or on a waterway). For CD-ROM distribution, mechanisms for routine data update and the addition of new chemicals (such as downloadable data sets, or patches, that could be appended to the database on a responder's hard drive) is recommended.

5. Database user interface design

Following development of the centralized database structure, attention turned to user interface design. This effort focused on making the database as useful as possible to the emergency responder. This was accomplished using a series of forms. A central form greets the user upon opening the database. From this form, others may be opened depending on the input information available to the user.

The database may be queried by NAERG identification and guide numbers, any Corps commodity code, chemical name, CHRIS code, and/or type of hazard. Once data for a commodity is retrieved by the database, the user can view specific information, such as the NAERG page or the CHRIS Manual page, by hyperlink. The database also contains a form that allows a user to select a waterway and view the chemicals transported during the last reporting year. This is included to demonstrate that including commodity flow and manuscript cargo files increases the value of the database to responders for planning and emergency response exercises.

Fig. 1 displays a screenshot of the first form to greet a user. This switchboard form enables a user to perform any of the prescribed chemical reference searches and queries. Every time the database is opened, this form will appear. A user may proceed directly to a specific data source (e.g. NAERG, CAMEO, etc.).

However, the more likely type of search is to find a specific chemical and retrieve data from all sources. Fig. 2 displays the form that opens when this option is chosen. Note that the chemical selected in Fig. 2 is chlorine and the active tab is the NAERG, with isolation and protective action distances displayed. By using forms and subforms, a user may select a tab to view information maintained on a specific chemical by a certain agency or data source (CAMEO, NPG, etc.). As the user switches from one tab to the next, a common reference ensures that there is no need to find the chemical again in the drop down box, as there would be if the forms were maintained separately.

Two of the tabs contain hotlinks to the electronic pages for the CHRIS Manual and the NIOSH Pocket Guide. On these tabs, a hotlink opens a pdf file in Adobe Acrobat and an html document for the CHRIS Manual and NPG, respectively. These pages exist in the same file directory as the database so as new data becomes available from these agencies, the html and pdf files can be overwritten, making data update easier. Storing these pages locally eliminates the need for Internet access, which is seldom available at the scene of a hazardous materials transportation accident. The file size of the database and associated files is just over 90 megabytes.

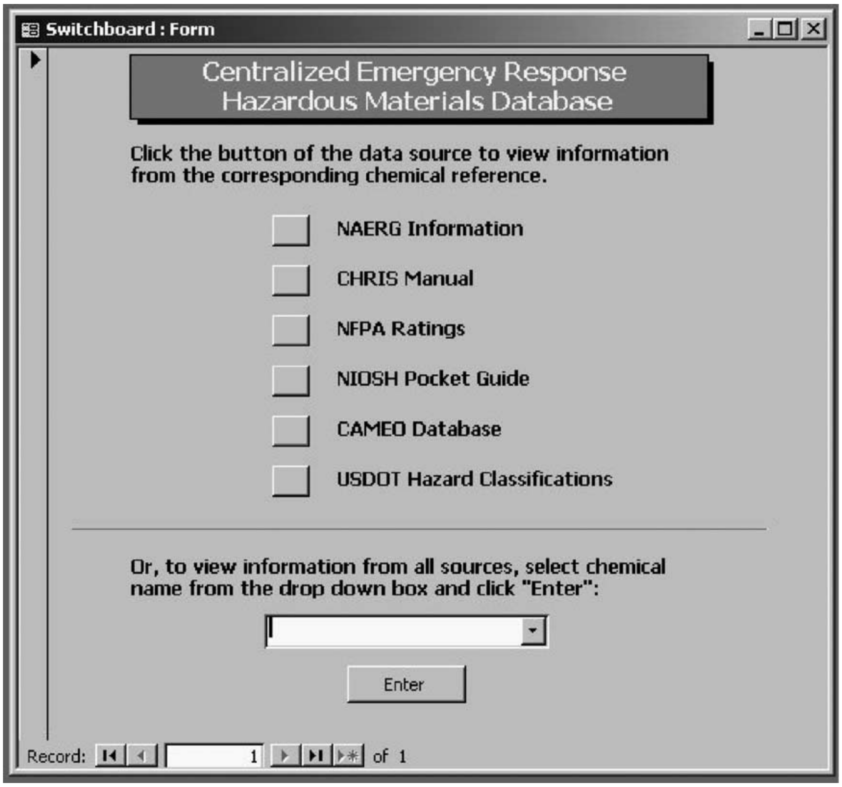

Fig. 1. Database switchboard form.

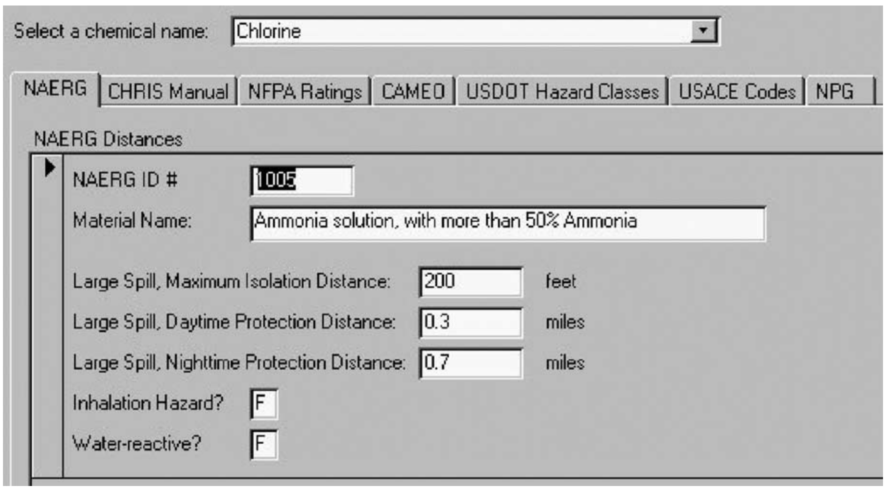

Fig. 2. Chemical reference data form containing all sources.

6. Case study application

To demonstrate how such a database tool may improve hazardous material spill response, a prior inland marine hazardous materials accident is reconstructed and areas where the centralized response database tool may have made a difference in the quality of response are highlighted.

In the accident where urea fertilizer was originally misidentified as ammonium nitrate (as mentioned earlier in this paper), responders originally operated under the assumption (on the recommendation by NOAA chemists) that the material was an explosive and that vapors from the material could be an irritant to response workers. However, 12 days elapsed before the product was correctly identified as urea fertilizer. No explanation for this delay was found in the NOAA and EPA pollution incident reports. The prototype centralized database contains an abundance of data on both chemicals, and it is clear that ammonium nitrate posed a much greater risk to responders than urea would have. Assuming ammonium nitrate was the material in question was undoubtedly the proper course of action. The precautions taken by emergency response workers coincide with those recommended in the chemical reference sources (NAERG, CHRIS Manual and the NPG). The database could possibly have made a difference in the time between the incident and proper identification of the chemical. The CHRIS Manual page for each chemical shows the differences in physical and chemical properties, most importantly the specific gravities (1.72 for ammonium nitrate, 1.34 for urea) and molecular weights (80.05 for ammonium nitrate, 60.06 for urea). These measurable physical characteristics may have helped qualified responders clearly identify or eliminate suspected materials.

Even though the material identification could have been improved through the availability of the centralized database and search tool, the most important observation of this exercise was the lack of complete data for any given chemical from a single reference. For example, specific gravities for each of the chemicals was unknown (a value of "?") in the NIOSH Pocket Guide, but these values did exist in the CHRIS Manual. By incorporating all chemical references inside a single digital source and relating these using a desktop database with easily updateable data structures, the comprehensiveness of chemical reference data is significantly improved. If responders had relied on a single source in this situation, such as the NPG, critical attributes and characteristics of the material in question may not have been known. Additionally, it is intuitive that this visual interface is a much more efficient means of retrieving chemical information than the current approach, which typically consists of consulting several printed sources on the hood of a response vehicle at the accident scene.

7. Summary and conclusions

This research has resulted in the development of a centralized database and search tool to rapidly disseminate critical information to responders in the event of an inland marine hazardous materials accident. These products can also be used in a planning mode to identify chemicals that would have particularly devastating consequences if released in bulk on inland waterways. Database applications can be customized to each responder's particular concern, location, and/or release scenario.

As required by the Oil Pollution Act of 1990, facilities that handle threshold amounts of oil and/or hazardous materials in bulk are required to conduct drill exercises. For this reason, facility operators are also potential users of this database. In addition, there are cases when a barge operator receives bulk hazardous cargo (as in a lightening operation from a larger vessel) without adequate documentation about the chemical in regards to personal exposure dangers and symptoms [15]. This database could assist in enabling vessel operators to better understand the health and environmental risks of their cargo.

The database contains attributes that support dispersion modeling through two important pathways, air and surface water. The value of the dataset is amplified by the inclusion of data from the agencies directly involved in marine transportation, including regulatory authorities, response agencies and the chemical industry. This enables responders to be cognizant of all potential results of a spill, instead of just the most obvious or apparent one.

Maintaining a centralized response database specifically for the response community would eliminate the difficulty in updating data whenever chemical data changes (such as permissible and threshold exposure levels, etc.) or new chemicals are added to the database. For example, suppose new chemicals are added to the Coast Guard's CHRIS Manual. The CHRIS Manual is not an exhaustive list of chemicals transported via barge and new commodities are added occasionally. These new additions, if made to a centralized repository, would be available to the land-based response community in a shorter time frame than the current system provides. Additionally, through a central repository, errors in chemical data could be identified more quickly by cross-referencing and comparing common chemical data (e.g. specific gravity in the CHRIS Manual could be compared with that of the CAMEO database).

The thrust of this research is not to render existing datasets obsolete, but to offer a complementary capability by relating them to databases from other agencies and commodity flow information. The case study application confirmed that no single source of hazardous materials response information is vastly superior to others in terms of completeness and detail. Each reference is tailored to the host agency's mission and charge. The resulting database enables the response community to be better prepared, whether in the planning or real-time mode. Such a centralized database would incorporate the strengths of each agency that currently maintains data while potentially reducing the amount of work spent on recording redundant data and/or correcting data entry errors. The case study also demonstrated that the database could have aided responders in identifying a product and following the proper precautions related to cleanup, first aid and containment.

The custom interfaces created in this database constitute an improvement over the current means of obtaining information at the scene of a hazardous materials accident. Instead of consulting several different printed references and books, users may retrieve the same information electronically from this database. Furthermore, additional forms may be created that enable responders and/or decision makers to search through the database for chemicals that meet certain danger thresholds (by IDLH concentrations, flammable explosive limits, etc.).

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