AN INTEGRATED DECISION-SUPPORT SYSTEM FOR INDUSTRIAL ACCIDENTS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

SERKAN GİRGİN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
ENVIRONMENTAL ENGINEERING

MARCH 2008

Approval of the thesis:

AN INTEGRATED DECISION-SUPPORT SYSTEM FOR INDUSTRIAL ACCIDENTS

submitted by **SERKAN GİRGİN** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Environmental Engineering Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen ______________
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Göksel Demirer ______________
Head of Department, **Environmental Engineering**

Prof. Dr. Ülkü Yetiş ______________
Supervisor, **Environmental Engineering Dept., METU**

Examining Committee Members:

Prof. Dr. Kahraman Ünlü ______________
Environmental Engineering Dept., METU

Prof. Dr. Ülkü Yetiş ______________
Environmental Engineering Dept., METU

Prof. Dr. Cemal Saydam ______________
Environmental Engineering Dept., Hacettepe University

Assoc. Prof. Dr. Ayşegül Aksoy ______________
Environmental Engineering Dept., METU

Assoc. Prof. Dr. İpek İmamoğlu ______________
Environmental Engineering Dept., METU

Date: ______________

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name	:	Serkan Girgin
Signature	:	

ABSTRACT

AN INTEGRATED DECISION-SUPPORT SYSTEM FOR INDUSTRIAL ACCIDENTS

Girgin, Serkan
Ph.D., Department of Environmental Engineering
Supervisor: Prof. Dr. Ülkü Yetiş

March 2008, 274 pages

Availability of data on accidents and chemical inventories, together with assessment and analysis tools is a prerequisite for integrated control of industrial accidents. Although Turkey has a developing industry, legislative measures for control of industrial accidents are lacking, past accidents are not systematically enlisted and industrial facilities and hazardous substances thereof are not properly registered. While some accident data is available in international databases, they are incomplete and erroneous.

In the present study, a decision support system has been developed for collection and analysis of past accident information, assessment of current accident potentials of industrial establishments and modeling of probable accidents to reveal risks possessed thereby. The system supports web based multilingual and multi-user environment, and aims contribution of all interested parties in a collaborative manner. Information on technological accidents can be systematically archived together with reference data and visual materials. Initial data covering a time period of 30 years has been provided. The system is capable of storing hazard classifications and physico-chemical properties of substances, and providing standardized data for calculations. It can determine major-accident potential of industrial facilities as dictated by the 96/82/EC Directive of the EU and update relevant information automatically as required. An easy to use accident model for rapid assessment of off-site consequences of industrial accidents is also featured.

Developed system allows integrated management of data on industrial accidents and provides decision support tools for assessing current and future accident potential, which can be used for national as well as the EU needs.

Keywords: Industrial Accident, Decision Support System, 96/82/EC Directive, Chemical Database, Accident Model

ÖZ

ENDÜSTRİYEL KAZALAR İÇİN ENTEGRE BİR KARAR DESTEK SİSTEMİ

Girgin, Serkan
Doktora, Çevre Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Ülkü Yetiş

Mart 2008, 274 sayfa

Kaza bilgileri ve kimyasal envanterleri ile birlikte değerlendirme ve analiz araçlarının mevcudiyeti, endüstriyel kazaların entegre kontrolü için bir erekliliktir. Endüstrisi gelişmekte olan Türkiye'de endüstriyel kazaların kontrolüne yönelik yasal düzenlemeler eksik olup, yaşanmış kazalar sistematik olarak derlenmemekte, endüstriyel tesisler ile tesislerdeki tehlikeli maddeler de uygun şekilde kayıt altına alınmamaktadır. Uluslararası veritabanlarında bazı kazalara ilişkin bulunan bilgiler eksik ve hatalıdır.

Bu çalışmada, geçmiş kaza bilgilerinin derlenmesi ve analizi, endüstriyel tesislerin mevcut kaza potansiyellerinin değerlendirilmesi ve olası kazaların modellenerek risklerin belirlenmesi için bir karar destek sistemi geliştirilmiştir. Web tabanlı, çok dilli ve çok kullanıcılı olan sistem, ilgili bütün tarafların katılımcı bir şekilde katkıda bulunabilmesini amaçlamaktadır. Teknolojik kazalar ile ilgili bilgiler, referans veriler ve görsel materyaller ile birlikte sistematik olarak arşivlenebilmektedir. 30 yıllı kapsayan başlangıç verisi sistem ile birlikte sunulmuştur. Sistem, kimyasal maddelere ait tehlike sınıflandırmaları ile fiziko-kimyasal özellikleri barındırabilmekte ve hesaplamalar için standardize veri sağlayabilmektedir. AB'nin 96/82/EC direktifi doğrultusunda endüstriyel tesislerin kaza potansiyeli belirlenebilmekte ve gerek görüldüğü durumlarda otomatik olarak güncellenebilmektedir. Ayrıca, endüstriyel kazaların saha dışı

etkilerinin hızlı bir biçimde değerlendirilmesi için kullanımı kolay bir kaza modeli de sunulmuştur.

Geliştirilen sistem, endüstriyel kaza verilerinin entegre yönetimini sağlamakta ve gerek ulusal, gerekse AB ihtiyaçları için mevcut ve gelecekteki kaza potansiyellerinin değerlendirilmesi için karar destek araçları sağlamaktadır.

Anahtar Kelimeler: Endüstriyel Kaza, Karar Destek Sistemi, 96/82/EC Direktifi, Kimyasal Veritabanı, Kaza Modeli

To all who

lost their lifes or suffered deeply

during man-made disasters

ACKNOWLEDGMENTS

I, foremost, would like to express my deepest gratitude to Prof. Dr. Ülkü Yetiş for her guidance, encouragements and confidence during this research.

I also would like to thank to the personnel of the Library of Faculty of Political Sciences, Ankara University for letting me work in the newspaper archive. The assistance and company of Dr. Sertan Girgin and Dr. Burçak Özoğlu Poçan during long, dusty days in the archive are gratefully acknowledged.

Information present in the newspaper articles would never find the way to the information system, without help of Mr. Alkım Özaygen, Ms. Beril Büyüker, Ms. Dinemis Kozok, Mrs. Eylem Elif Maviş, Mr. Ersin Çelik, Mr. Haldun Ülkenli, Ms. İlkay Çorgundağ, Mrs. Meltem Güvener, Mr. Mustafa Cihan, Mrs. Niğmet Uzal, Mrs. Oya Gülsöken, Mr. Şener Polat, Mr. Serdar Gülsöken, Mr. Serhan Poçan, Mr. Soner Büyükatalay, Ms. Suna Yılmaz and Mr. Yalçın Yaldız. I am thankful to all.

Finally, thanks to my family for their patience and continuous support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

TABLES

LIST OF ABBREVIATIONS

APELL	Awareness and Preparedness for Emergencies at a Local Level
ATP	Adaptation to Technical Progress
CAS	Chemical Abstracts Service
CBRT	Central Bank of the Republic of Turkey
CFD	Computational Fluid Dynamics
DBMS	Database Management System
DIPPR	Design Institute for Physical Properties Data
DOI	Digital Object Identifier
EC	European Commission
ECB	European Chemical Bureau
EEC	European Economic Community
EIA	Environmental Impact Assessment
EINECS	European Inventory of Existing Chemical Substances
ELINCS	European List of Notified Chemical Substances
EPA	Environmental Protection Agency
EU	European Union
GIS	Geographic Information System
ILO	International Labour Organization
InChI	International Chemical Identifier
IMO	International Marine Organization
ISIC	UN International Classification of All Economic Activities
IUPAC	International Union of Pure and Applied Chemistry
MEDA	Mediterranean Economic Development Area

MoEF	Ministry of Environment and Forestry
NACE	Statistical Classification of Economic Activities in the European Community
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Co-operation and Development
QSAR	Quantitative Structure-Activity Relationship
SALB	UN Second Administrative Level Boundaries
SI	International System of Units
SMILES	Simplified Molecular Input Line Entry Specification
SMS	State Meteorological Service
SPARC	Sparc Performs Automated Reasoning in Chemistry
TEIA	Convention on the Transboundary Effects of Industrial Accidents
TNO	Netherlands Organisation for Applied Scientific Research
UN/ADR	European Agreement Concerning the International Carriage of Dangerous Goods by Road
UN/ECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
URL	Uniform Resource Locator
UTC	Coordinated Universal Time

CHAPTER 1

INTRODUCTION

Seveso, Italy, 1976
Bhopal, India, 1984
Basel, Switzerland, 1986
Baia Mare, Romenia, 2000
Kocaeli, Turkey, ?

Installations, where hazardous substances are processed, produced, and stored, are essential components of industrial development. Growth of process industries according to the needs of national and international markets results in a proportional increase in kinds and quantities of hazardous substances in process, storage or transport. Although hazardous properties of substances are under control in engineered systems and storage units, there is always an inherent potential of hazard in case something unexpected happens and things go wrong. Indeed, serious accidents had occurred throughout the world in the past and will definitely occur in the future as well, despite all precautionary measures [1].

The major hazards of industrial accidents are fire, explosion and release of toxic substances to the environment, generally to the atmosphere. Besides on-site consequences, the accidents may also affect people, property, and the environment in the vicinity of the installations. Although fire is the most common hazard, explosion and toxic release are more important in terms of their damage potentials [2]. Explosions may result in significant number of fatalities, damage to property, and domino effects, whereas releases may cause large areas to be polluted, even for long time periods, leading to major environmental problems.

Since they are almost random events, it is not possible to predict with absolute confidence either where, when or how the accidents will occur. However, understanding the mechanisms of past incidents may provide useful information to develop accident prevention and control strategies, which may reduce the risk [3]. In order to lessen the adverse consequences of an accident, multi-stakeholder involvement is required at various levels. Operators and employees of the installations, local authorities, competent national authorities, and the public should be prepared to such emergency situations before their occurrence. This can only be achieved by means of an integrated management and control, which should not only include a solid accident prevention policy, but also deal with other aspects such as land-use planning, plant design and operation, accident reporting, inspection, and information to the public.

Especially major accidents like Seveso in 1976 [4] and Bhopal in 1984 [5], had risen serious concerns about hazards of industrial accidents and led to specific regulations and agreements, which are mainly based on lessons learned, to come into force. Currently, many developed countries have comprehensive legislation on control of industrial accidents involving hazardous substances. There are also multinational agreements, which had been put into practice by international organizations, such as ILO and UN/ECE [6, 7].

Although implementation details differ from country to country, basic principles of prevention and control of major industrial accident hazards are quite common throughout the world. The following principles are emphasized in many national and international regulations, agreements, and guidelines [8–12]:

- Proper *land-use planning* to ensure presence of appropriate distance between hazard installations and settlements, public places, environmentally sensitive areas, and other installations, with special emphasis on potential domino effects, process modifications, and illegal settlements such as shanty towns.

- Good *plant design and construction*, proper *operation*, and regular *maintenance* to minimize possibilities of human and technological failures, which may evolve into major hazards.

- Presence of practical and complete *accident prevention policy* to guarantee a high level of protection for man and the environment by appropriate means, such as:

  - Establishment of *safety management systems*, which include not only using appropriate technology and processes but also set up of an effective organizational structure for reduction of hazards and risks.
  - Being prepared to emergencies by adoption and implementation of procedures to *identify probable incidents*, and preparation, testing and review of *internal emergency plans*, which cover emergency provisions that should reduce the effects of such incidents.
  - Considering possible off-site consequences, preparation of *external emergency plans*, which covers arrangements for informing the public, for coordinating resources necessary for emergency response, and for off-site mitigatory actions.

- Systematic *notification and reporting of accidents and near-misses* to learn from past experiences by determining root causes and finding out measures to prevent repetition of incidents.

- Sufficient *information to the public* living in the vicinity of hazard installations about accident risks and what to do in case of an incident to mitigate possible adverse consequences on health, property and the environment.

- Effective *public participation and consultation* in decision making process related to hazardous installations, such as planning of new installations, modifications to existing establishments, and preparation of external emergency plans.

- Regular *inspection* to ensure that safety reports and emergency plans are correctly prepared, the public has been properly informed, and the installations are operated according to the appropriate level of safety for the aim of prevention of major accidents and limitation of their consequences.

As it can be easily realized from the basic principles listed above, prevention and control of industrial accidents is a multidimensional and multidisciplinary process. In order to yield successful results, strong communication and cooperation are required among the interested parties at all stages of the process [9]. Availability of *information* on hazard characteristics of substances, activities and processes of industrial installations, quantities and storage conditions of hazardous substances, probable accident scenarios, mitigation measures and resources available for emergency response, is a key factor for proper communication and cooperation. It is also crucial for good decision-making. Therefore, presence of provisions on and means of systematic data collection and analysis are important.

Noting this importance, notification and reporting systems had been put into practice both in national and international contexts world-wide. The purpose of reporting is mainly twofold. The first aim is to collect information on past accidents and near-misses in order to keep track of causes and consequences of the incidents. Besides allowing lessons learned to be shared and prevention measures to be developed or improved, this kind of data also lets statistics to be calculated, which can be used to follow the trends in accidents and to measure level of success of provisions that had been already put into practice. The second aim is to collect information on hazards possessed by industrial installations in order to know existing risks and to take required precautionary measures to prevent accidents.

In the United States, under the authority of section 112(r) of the Clean Air Act, the Chemical Accident Prevention Provisions require facilities that produce, handle, process, distribute, or store certain chemicals to develop a Risk Management Program, prepare a Risk Management Plan (RMP), and submit the RMP to U.S. EPA, which is the competent authority. There is also Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986, which has major provisions on community-wide emergency planning, emergency release notification, hazardous chemical storage reporting, and toxic chemical release reporting [12]. A wide variety of tools and databases were developed by the U.S. EPA and other related agencies to support regulatory applications [13]. For the development of RMPs, both simple (RMP*Comp) and advanced (ALOHA) modelling tools are available. In order to visualize modeling results mapping application (Marplot) and nation-wide detailed maps (Landview) exist. For preparation of reports to be submitted to the U.S. EPA, electronic reporting tools are offered (Tier2Submit, RMP*Submit). In order to provide information on chemicals and their hazards, detailed chemical libraries are provided (CAMEO). There are even on-line tools that allow individuals from the public quickly find out if they live at a place that could be affected by a chemical accident, just by entering their home addresses (VZIS). Therefore, both legislative measures to control industrial accidents and tools to support their application are available in the United States.

As details will be given in Chapter 2, Council Directive of 9 December 1996 on the control of major-accident hazards involving dangerous substances (96/82/EC) forms the legislative basis concerning major industrial accidents in the European Union (EU). The Directive contains provisions for a wide variety of topics related to control of major industrial accidents, such as notification, major accident prevention policy, safety reports, safety management systems, consultation to the public, inspections, and land-use planning. Establishments that are within the scope of the Directive are determined according to their chemical inventories by using a two-tier approach. Lower and upper qualifying quantities are designated by the Directive for specific dangerous substances and generic hazard categories. Establishments holding specified dangerous substances more than the lower but less than the upper threshold are covered by "lower tier" requirements, whereas establishments holding dangerous substances above the upper threshold are covered by all requirements of the Directive. The establishments covered by the Directive should notify the competent authority about the quantity, hazard characteristics and storage conditions of dangerous substances found in the establishments. Accidents should also have to be notified. For the purposes of the application of the directive, EU operates two databases (MARS for accidents, and SPIRS for industrial facilities) and a chemical database (CLASSLAB). But unlike United States, tools to facilitate application of the Directive at facility level, such as one for determination of lower/upper tier status, do not exist. Therefore, legislative measures are available in the EU, but supporting tools are not sufficient.

Although Turkey has a developing industry, legislative measures for control of major industrial accidents are lacking [14]. As details will be given in Chapter 2, there exist a few regulations, which include some provisions for land-use planning and reporting. However, none of these regulations are specifically targeted on industrial accidents and can only partially cover the requirements. Many important aspects of the management and control process, such as notification, emergency planning, and information to the public, are lacking. Although starting from the second half of 1990s several ministries, scientific organizations, and public authorities had conducted studies to overcome deficiencies in this respect, satisfactory results could not have been obtained. Recently, studies on adoption of the 96/82/Directive to the Turkish legislation have been performed under the supervision of the Ministry of Environment and Forestry (MoEF) in order to fulfill the requirements in this topic for the membership to the EU [15]. A draft regulation and communications thereof have been ready as of 2006, however they could not be brought into force ever since.

Mainly due to lack of a legislative provisions, information regarding past industrial accidents are mostly unknown in Turkey. A national listing or database containing systematically collected information on date, place and nature of industrial accidents that had happened, together with their causes and consequences, does not exists. Although relevant information can be found in several international databases, extent of available data is very limited and significant data quality problems exist due to erroneous or misclassified entries as it will be shown in Chapter 3. Since databases (or publicly accessible parts thereof) only contain summary data and original references are not explicitly indicated, it is not possible to determine the reasons of invalid or erroneous entries. Since they are proprietary and closed systems, means of data editing are not available and corrections can not be done or denoted in-place. Although doubts about such data quality and completeness problems are known [16], these databases are widely used for statistical studies due to ease of accessibility and lack of alternatives. As a natural result, errors are transferred to the referring studies, sometimes even become exaggerated as it will be shown in Chapter 3 for the case of Turkey.

In addition to above mentioned reasons,

If the candidacy of Turkey to be a member of the EU and the obligation of the EU member states to prepare reports on major accidents are considered together with the above mentioned reasons, the need for a national database of industrial accidents can be listed as follows:

- Keeping track of industrial accidents, for the analysis of causes and consequences to develop preventive measures (learn lessons),
- Establishing a reliable data source on industrial accidents that had taken place in Turkey, which may be used to correct invalid information in the literature,
- Fulfilling multilateral or international reporting obligations.

Similar to the case of past industrial accidents, current status of the industrial facilities with respect to major accident potential are also mostly unknown. Although large industrial establishments having considerable accident potential, such as petroleum refineries, are well known, quantitative information on accident potentials and probable hazards are not available for the majority of the industrial installations. Locations of such facilities can only be stated regionally, e.g. Gulf of İzmit-Kocaeli, Aliağa-İzmir, Ambarlı-İstanbul. Due to lack of relevant regulations, substances in inventories of the facilities are not registered and can not be tracked centrally. Therefore, nature and quantities of hazardous substances that are found in the facilities are largely unknown to the authorities. The inhabitants are also not very well, in fact very little, informed about the hazards and risks that they face by the mere fact of living near a certain industrial facility. Therefore, lack of information on industrial accident hazards is significant at all levels.

As mentioned before, although the 96/82/EC Directive, which will be sooner or later put into practive in Turkey, has provisions for collection of information on industrial facilities, including detailed description on chemicals in inventories, major accidents risks, and possible consequences, tools to support application of the Directive are not readily available. Taking the fact that several thousands of industrial facilities exists only in chemical manufacturing industry [17], need for analytical tools to support the application of the 96/82/EC Directive is evident. Requirements in this respect can be listed as follows:

- Keeping track of industrial facilities and chemicals in inventories thereof, including information on hazardous characteristics, quantities and storage conditions,
- Calculating status of industrial facilities with respect to application of the Directive, i.e. determining whether the facilities as lower tier, upper tier, or out of scope.

In addition to needs for a national accident database and tools for the application of the 96/82/EC Directive, modeling tools for assessment of the extent and severity of the consequences of possible accidents are also required for preparation of safety reports and emergency plans. A wide variety of models and software packages are available both publicly and commercially for assessing accidental hazards [18, 19]. Hence, based on the scope and requirements of the modeling, different models can be selected. However, especially for regulatory works, having a standard model, which is sufficient to fulfill the requirements with minimum data input, can be both effective and useful. RMP*Comp model of the U.S. EPA can be given as a solid example of this. Therefore, requirements in this respect can be listed as follows:

- Assessing extent and severity of possible accidents with minimum data requirement,
- Presenting the results of the assessments in an apparent manner

1.1 Objectives of the Study

Taking the requirements mentioned in the previous section, the objectives of the study are designated as follows:

1. Development of an information system to collect and share information on industrial as well as other technological accidents:
    - Allowing accident type specific, structured data to be stored systematically,
    - Gathering documents and visual materials related to accidents,
    - Featuring complete referencing of data sources,
    - Facilitating participation and collaboration of interested parties,
    - Providing compatibility with international databases,
    - Providing initial data.
2. Development of analytical tools to support application of the 96/82/EC Directive of the EU:
    - Containing chemical substance and hazard classification data,
    - Allowing information on industrial facilities and chemicals in inventories thereof to be stored,
    - Calculating the 96/82/EC Directive statuses (lower tier, upper tier, and out of scope) of industrial facilities based on rules set by the Directive,
    - Updating 96/82/EC Directive statuses according to changes in substance quantities and hazard classifications.
3. Development of an accident modeling framework to support rapid consequence analysis of industrial accidents:
    - Providing user friendly interface,
    - Minimizing data requirements.

1.2 Dissertation Outline

Studies performed to fulfill the objectives of the study are presented as separate chapters of this dissertation. Outline of the chapters is as follows:

In Chapter 2, selected international legislations are reviewed to determine provisions and control mechanisms put into practice for control of industrial accidents involving hazardous substances. Details of USA and EU regulations are given. In order to describe provisions that are currently addressed in national regulations of Turkey, related regulations are summarized. Existing gaps and recent studies performed to lessen the gaps are discussed.

In Chapter 3, selected international databases are reviewed in terms of data availability on industrial accidents that had taken place in Turkey. Insufficiencies of databases in properly expressing past industrial accidents are pointed out. Need for a national database is discussed.

In Chapter 4, detailed information is given on the web-based, collaborative decision support system developed in the study. Architecture and subcomponents of the system are explained. General features, such as multilingual support, change history, fuzzy statistics, and mapping are described. Working principles and capabilities of accident, document, chemical, and facility subsystems are given in detail. Algorithms developed for determination of 96/82/EC Directive statuses of the industrial facilities, and mechanisms of automated status update are presented. Studies performed for data collection are summarized.

In Chapter 6, general description and technical background information are given for the off-site consequence model developed as part of the study. Applied methods and equations are described for source term and atmospheric dispersion calculations. Relations of the modeling framework with other system components and details of the user interface are also explained.

The dissertation ends with conclusions and recommendations for further studies in Chapters 7 and 8, respectively.

CHAPTER 2

INTERNATIONAL AND NATIONAL LEGISLATION

In order to determine provisions and preventive measures those are currently addressed in Turkish legislation and to find out gaps compared to the EU directives, both Turkish and EU regulations and directives were reviewed.

In this chapter, first, a short history of the 96/82/EC Directive of the EU on the control of major-accident hazards involving dangerous substances is given. Details of calculations required to determine the scope of industrial facilities with respect to the Directive are explained. Following the 96/82/EC Directive, national regulations, which have provisions related to control of industrial accidents, are described in detail. Studies performed so far for putting a regulation similar to the 96/82/EC Directive into practice are reviewed.

2.1 96/82/EC Directive

Because of rising concern following incidents such as Flixborough in 1974 and Seveso in 1976, the EEC issued in 1982 a Council Directive on the major-accident hazards of certain industrial activities (82/501/EEC), which is generally called as the Seveso Directive [20]. This modern legislation includes measures designed to increase the safety of chemical installations and the security of the public, as well as making it obligatory to inform the local population of the risks that they face by the mere fact of living near a certain industrial facility. In the light of severe accidents at the Union Carbide factory at Bhopal, India in 1984 and at the Sandoz warehouse in Basel, Switzerland in 1986, the Seveso Directive was amended twice, in 1987 by Directive 87/216/EEC of 19 March 1987 and in 1988 by Directive 88/610/EEC of 24 November 1988. Both amendments aimed at broadening the scope of the Directive, in particular to include the storage of dangerous substances [21].

After gaining experience with the implementation of the 82/501/EEC Directive, the Council Directive on the control of major-accident hazards involving dangerous substances (96/82/EC) was issued in 1996 [11]. The Directive, which is also known as Seveso II Directive, forms the current legislative framework in the EU for the control of major accident hazards in industrial facilities. Similar to the case of amendments of the previous 82/501/EEC Directive, the 96/82/EC Directive was amended in 2003 by Directive 2003/105/EEC of 16 December 2003 in the light of recent major accidents at Baia Mare, Romania in 2000, at Enschede, Netherlands in 2000 and at Toulouse, France in 2001. Its scope is broadened to cover risks arising from mining activities, pyrotechnic and explosive substances, and ammonium and potassium nitrate based fertilizers.

Major aims of the 96/82/EC Directive are prevention of major accident hazards involving dangerous substances, and in case of their occurrence, reducing adverse consequences both for man and the environment. The Directive is specifically targeting fixed industrial facilities, and the following activities are exempted from its coverage:

- Military establishments, installations or storage facilities,
- Hazards created by ionizing radiation,
- Transport of dangerous substances and intermediate temporary storage by road, rail, internal waterways, sea or air,
- Transport of dangerous substances in pipelines,
- Exploitation of minerals in mines, quarries, or by means of boreholes, except chemical and thermal processing operations and storage involving dangerous substances,
- Offshore exploration and exploitation of minerals, including hydrocarbons,
- Waste landfill sites, except tailings containing dangerous substances.

Member States have the obligation to report major accidents, fulfilling the consequence criteria designated by the Directive, to the Commission. In order to facilitate notification and reporting of accidents by the Member States, the Commission has established a Major-Accident Reporting System (MARS) and the Community Documentation Centre on Industrial Risks (CDCIR) at the Major-Accident Hazards Bureau established within its Joint Research Centre (JRC) in Ispra, Italy.

The establishments that are falling within the scope of the Directive are determined solely according to type and amount of hazardous substances found at the establishments. The Directive lists lower and upper qualifying quantities of hazardous substances, as to which the obligations and responsibilities of the operators are designated. Two different qualifying quantity lists exist. In the first list, hazardous substances are listed by name and qualifying quantities are given for each substance or group of substances separately (Table 2.1). In the second list, categories of hazardous substances are listed according to the nature of their hazard and qualifying quantity limits are given for these categories (Table 2.3).

The operators of establishments holding quantities of dangerous substances above the lower threshold levels (lower tier establishments) should notify the competent authority about the location and activity of the establishment, and dangerous substances present. Notification on dangerous substances should include quantity and physical form information and should be sufficient to identify the dangerous substances and hazard categories thereof. The operator of the establishment should also setup a major-accident prevention policy and should ensure that the policy is properly implemented.

Establishments holding dangerous substances even larger quantities above the upper thresholds (upper tier establishments) are required to prepare detailed safety reports and emergency response plans for major-accidents. They should also implement fully-functional safety management systems. A comprehensive description of the related articles of the Directive can be found in Wetting et al. [21].

Although qualifying quantity limits specified by the Directive appear to be simple at first sight, their application is not simple due to special conditions and rules required by the Directive.

As it can been seen in Table 2.1, majority of the specifically named substances are pure chemicals. But for some substances, minimum concentrations are also indicated, below which the substances are assumed to have no major-accident potential (e.g.

Table 2.1: Named substances of the 96/82/EC Directive [22]

Dangerous substance	Qualifying quantity (*tonnes*) Lower	Upper
Ammonium nitrate (fertilizers capable of self-sustaining decomposition)[1]	5 000	10 000
Ammonium nitrate (fertilizer grade)[1]	1 250	5 000
Ammonium nitrate (technical grade)[1]	350	2 500
Ammonium nitrate (off-specs material and fertilizers not fulfilling the detonation test)[1]	10	50
Potassium nitrate (composite fertilizers, in prilled/granular form)[1]	5 000	10 000
Potassium nitrate (composite fertilizers, in crystalline form)[1]	1 250	5 000
Bromine	20	100
Chlorine	10	25
Nickel compounds in inhalable powder form (nickel monoxide, nickel dioxide, nickel sulphide, trinickel disulphide, dinickel trioxide)		1
Ethyleneimine	10	20
Fluorine	10	20
Formaldehyde (concentration $\geq 90\%$)	5	50
Hydrogen	5	50
Hydrogen chloride (liquefied gas)	25	250
Lead alkyls	5	50
Liquefied extremely flammable gases (including LPG) and natural gas	50	200
Acetylene	5	50
Ethylene oxide	5	50
Propylene oxide	5	50
Methanol	500	5 000
4,4-Methylenebis (2-chloraniline) and/or salts, in powder form		0.01
Methylisocyanate		0.15
Oxygen	200	2 000
Toluene diisocyanate	10	100
Carbonyl dichloride (phosgene)	0.3	0.75
Arsenic trihydride (arsine)	0.2	1
Phosphorus trihydride (phosphine)	0.2	1
Sulphur dichloride		1
Sulphur trioxide	15	75
Polychlorodibenzofurans and polychlorodibenzodioxins (including TCDD), calculated in TCDD equivalent[2]		0.001
The following CARCINOGENS at concentrations above 5% by weight: 4-Aminobiphenyl and/or its salts, Benzotrichloride, Benzidine and/or salts, Bis (chloromethyl) ether, Chloromethyl methyl ether, 1,2-Dibromoethane, Diethylsulphate, Dimethyl sulphate, Dimethylcarbamoyl chloride, 1,2-Dibromo-2-chloropropane, 1,2-Dimethylhydrazine, Dimethylnitrosamine, Hexamethylphosphoric triamide, Hydrazine, 2-Naphthylamine and/or salts, 4-Nitrodiphenyl, and 1,3 Propanesultone	0.5	2
Petroleum products: (a) gasolines and naphthas, (b) kerosenes (including jet fuels) (c) gas oils (including diesel fuels, home heating oild, and gas oil blending streams)	2 500	25 000

[1] See consolidated text [22] for the complete description.
[2] See Table 2.2 for equivalence factors.

Table 2.2: International Toxic Equivalent Factors for the congeners of concern [22]

Substance	Factor	Substance	Factor
2,3,7,8-TCDD	1	2,3,7,8-TCDF	0.1
1,2,3,7,8,-PeDD	0.5	2,3,4,7,8-PeCDF	0.5
		1,2,3,7,8-PeCDF	0.05
1,2,3,4,7,8-HxCDD	0.1	1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDD		1,2,3,7,8,9-HxCDF	
1,2,3,7,8,9-HxCDD		1,2,3,6,7,8-HxCDF	
		2,3,4,6,7,8-HxCDF	
1,2,3,4,5,7,8-HpCDD	0.01	1,2,3,4,5,7,8-HpCDF	0.01
		1,2,3,4,7,8,9-HpCDF	
OCDD	0.001	OCDF	0.001

Table 2.3: Categories of dangerous substances of the 96/82/EC Directive [22]

Category		Qualifying quantity (*tonnes*) Lower	Upper
1.	Very toxic	5	20
2.	Toxic	50	200
3.	Oxidizing	50	200
4.	Explosive where the substance, preparation or articles falls under UN/ADR Division 1.4	50	200
5.	Explosive where the substance, preparation or articles falls under any of: UN/ADR Divisions 1.1,1.2,1.3,1.5,1.6 or risk phrase R2 or R3	10	50
6.	Flammable where the substance or preparation falls under risk phrase R10	5 000	5 0000
7a.	Highly Flammable where the substance or preparation falls under risk phrase R17; where the substance or preparation have a flash point lower than 55°C and remain liquid under pressure, where particular processing conditions, such as high pressure or high temperature, may create major-accident hazards	50	200
7b.	Highly Flammable where the substance or preparation falls under risk phrase R11 second indent	5 000	50 000
8.	Extremely Flammable where the substance or preparation falls under risk phrase R12 first and second indents; where the substance or preparation is flammable and highly flammable liquid maintained at a temperature above its boiling point	10	50
9.	Dangerous for Environment risk phrases		
i)	R50: Very toxic to aquatic organisms (including R50/53)	100	200
ii)	R51/53: Toxic to aquatic organisms; may cause long term adverse effects in the aquatic environment	200	500
10.	Any classification not covered by those given above in combination with risk phrases:		
i)	R14: Reacts violently with water (including R14/15)	100	500
ii)	R29: In contact with water liberates toxic gas	50	200

formaldehyde, C $\geq$ 90%). Therefore in addition to quantity information, concentration information is also required for calculation of lower/upper tier status.

With latest amendments by the 2003/105/EC Directive, more than one qualifying quantity limits has been specified for selected substances, which are ammonium nitrate and potassium nitrate. These substances are generally used as fertilizers and detailed classifications are given according to percentage by weight composition and nature of the substances as fertilizer. Up to 4 classes exists, each having a different lower and upper qualifying quantity limits.

Some substances are not listed individually, but in groups (e.g. nickel compounds, liquefied extremely flammable gases). For these substances, qualifying quantities are also given for the groups. Therefore, quantities of substances are not directly compared. Sum of quantities of all substances in a group is used for comparison instead. Minimum concentration limit may also present, which should be checked for all substances in a group separately (e.g. carcinogens, C $\geq$ 5%). The case for polychlorodibenzofurans and polychlorodibenzodioxins is even more complicated. In addition being groups of substances, each substance in these groups have an equivalence factor according to its level of toxicity. Physical quantities of the substances should be multiplied with equivalence factors during summation and resulting overall quantity should be used for comparison to the given qualifying quantity limits.

For substances, which are not specifically named, but still having dangerous characteristics which may result in adverse consequences in case of accidents, qualifying quantities are given according to hazard categories given in Table 2.3. In order to determine hazard categories of substances, the Directive refers to 67/548/EEC Directive on approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labeling of dangerous substances [23]. 67/548/EEC Directive lists harmonised classification and labelling information for approximately *3 300* substances, an example of which is given in Table 2.4. Therefore, total number of substances covered by the 96/82/EC Directive is not several, but about *3 500.* In case of substances with properties giving rise to more than one classification, which is generally the case, a natural question arises on which classification should be used for determination of the qualifying quantity limits. The answer is given in the Directive as the classification category having lowest qualifying quantities. Therefore all classifications of a substance should be examined for deciding which category to choose.

Table 2.4: Example hazard classification from the 67/548/EC Directive

Cyclopentyl chloroformate	
R10	Flammable
T: R23	Toxic by inhalation
Xi: R41	Risk of serious damage to eyes
R43	May cause sensitization by skin contact
Xn: R22-48/22	Harmful if swallowed
	Danger of serious damage to health by prolonged explosure

In case of diluted solutions or preparations of substances, concentration specific hazard classifications given in the 67/548/EEC Directive should be used. However, concentration limits are available only for about *500* substances (~15%) that are listed in the 67/548/EEC Directive. For the remaining substances, corresponding hazard classifications should be calculated according to the provisions of the 1999/45/EC Directive concerning the approximation of laws, regulations and administrative provisions of the Member States relating to the classification, packaging and labelling of dangerous preparations [24]. The 1999/45/EC Directive contains tables of hazard classifications and specific concentration limits, which determine the classification of the preparation in relation to the individual classification of the substance and its concentration. An example table is given in Table 2.5.

Table 2.5: Example hazard classification table from the 1999/45/EC Directive

Classification of the substance	Classification of the preparation		
	T+	T	Xn
T+ with R26, R27, R28	C $\geq 7\%w$	$1\%w \leq C < 7\%w$	$0.1\%w \leq C < 1\%w$
T with R23, R24, R25		C $\geq 25\%w$	$3\%w \leq C < 25\%w$
Xn with R20, R21, R22			C $\geq 25\%w$

Hence, starting from the hazard classification of the pure substance and by using the concentration value, hazard classification of the preparation or diluted substance can be found by refering to the hazard classification tables of the 1999/45/EC. If the substance has multiple hazard classifications, each hazard classification should be separately assessed and gathered at the end to obtain the final classification. The

1999/45/EC Directive has two sets of tables, one for gaseous substances which is based on percentage by volume concentrations and another for non-gaseous substances which is based on percentage by weight concentrations. Appropriate table should be used according to the phase of the substance. Therefore, phase information is also required for selected substances for the designation of the 96/82/EC status.

If no individual substance or preparation is present in a quantity above or equal to the relevant qualifying quantities, the establishment is not simply regarded as out of scope. Instead, overall hazards associated with toxicity, flammability and eco-toxicity are evaluated for all substances and preparations by using the summation rule defined by the Directive. The following equations are used for the summarion rule:

$$\frac{q_1}{Q_{L1}} + \frac{q_2}{Q_{L2}} + \frac{q_3}{Q_{L3}} + \cdots + \frac{q_n}{Q_{Ln}} \geq 1 \tag{2.1}$$

$$\frac{q_1}{Q_{U1}} + \frac{q_2}{Q_{U2}} + \frac{q_3}{Q_{U3}} + \cdots + \frac{q_n}{Q_{Un}} \geq 1 \tag{2.2}$$

where:

q_x = the quantity of dangerous substance

Q_{Lx} = the relevant lower qualifying quantity for substance or category

Q_{Ux} = the relevant upper qualifying quantity for substance or category

If a substance has more than one overall hazard (e.g. toxicity *and* flammability), it is added to all corresponding summation rule incides. After summation of all substances in the same overall hazard, if any of the lower or upper indices is found to be greater than one, then the facility is designated to be covered by the Directive.

In addition to these rules related to hazard classification of substances, the Directive also has special provisions for:

- Explosive substances, preparations and articles covered by the European Agreement concerning the International Carriage of Dangerous Goods by Road (UN/ADR),
- Substances and preparations, which are not classified as dangerous by the 67/548/EEC and 1999/45/EC Directives, but still possess or likely to possess major-accident potential (e.g. waste),
- Dangerous substances which are present in very small quantities and cannot act as an initiator of a major-accident.

As described so far, the 96/82/EC Directive is closely linked to other EU directives and international agreements. In addition to amendments to the Directive, which directly affect list of chemicals of concern and methodology of status calculations, amendments and adaptation to technical progress (ATP) of related directives and agreements also influence application of the Directive significantly. They can be even more significant then the own amendments of the Directive. For example, Annex I of the 67/548/EEC Directive, has been updated 9 times since the publication of the 96/82/EC Directive as listed in Table 2.6.

Table 2.6: ATPs of the 67/548/EEC Directive amending Annex I

OJ Date	OJ No	Directive	Description	Number of classifications[1]
30.09.1996	L248	96/54/EC	22nd ATP	304
13.12.1997	L343	97/69/EC	23rd ATP	2
16.11.1998	L305	98/73/EC	24th ATP	106
30.12.1998	L355	98/98/EC	25th ATP	387
08.06.2000	L136	2000/32/EC	26th ATP	135
21.08.2001	L225	2001/59/EC	28th ATP	472
30.04.2004	L152	2004/73/EC	29th ATP	886

[1] Source: ECB CLASSLAB [25]

Each time, new substances have been added to the list or existing classifications or concentration limits have been modified. If number of classifications originating from the latest ATPs given in Table 2.6 are examined, it is seen although 96/82/EC Directive did not changed in time, hundredths of chemical substances added to the list of chemicals of concern to the Directive. Therefore, not only the Directive it self, but all related Directives should be taken into consideration during the application of the Directive, especially at the administration level.

2.2 Turkish Legislative Framework

In Turkey, the first comprehensive legislative approach to disaster management dates back to the Disaster Law, which was published in 1959 [26]. Although updated in time, especially as regards the economic burdens of disaster damages and the compensation thereof, the skeleton of the legislation remained the same. Although it is prepared to cover all kinds of natural disasters, the primary focus is, on earthquakes. Two major weaknesses of the legislation are lack of measures for industrial and technological hazards and lack of consideration of environmental aspects of disasters, e.g. environmental damage and pollution. No precautions or arrangements are described in the legislation to deal with environmental problems that may occur as a result of the disasters.

Currently, there is no comprehensive Turkish legislation on the control of major industrial accidents. A recent MEDA funded project conducted by Carl Bro Global Environment Consortium, which aimed to analyze environmental legislation of Turkey for the compliance with the EU legislation, concludes that no Turkish legislation transposes any of the requirements of the 96/82/EC Directive [14]. However, there are a number of environmental regulations which are tightly related to the control of major industrial accidents. These regulations can be listed as follows:

- Regulation on Environmental Inspection
- Regulation on Non-hygienic Establishments
- Regulation on Environmental Impact Assessment
- Regulation on Hazardous Chemicals

2.2.1 Regulation on Environmental Inspection

Regulation on Environmental Inspection (RoEI), which was published in 2002, specifies the principles and the methods for inspection of industrial establishments for the compliance to the environmental rules and regulations [27]. According to RoEI, establishments that are covered by selected environmental regulations (Regulations on Environmental Impact Assessment, Control of Air Quality, Control of Water Pollution, Control of Medical Wastes, Control of Solid Wastes, Control of Hazardous Wastes, and Hazardous Chemicals) should fill-in a set of information forms and send them to the MoEF for reporting purposes. The forms include detailed information on the environmental protection measures adapted, air and water emissions, hazardous chemical inventories, solid and hazardous waste management practices, and treatment plants. The MoEF evaluates these forms and prepares yearly on-site inspection programs to validate reported information and to investigate environmental compliance of the establishments to the regulations. The establishments also have to carry out regular internal inspections.

Although none of the rules and regulations referred in RoEI aims to control industrial accidents, RoEI, in fact, includes a detailed section on accidents. In general information part, the number of accidents occurred in the facility within the last 5 years and also existence of accident reports are asked. Presence of an emergency response plan for the facility is also questioned. More detailed information is requested in the Annex 1B of the Regulation, which is entitled "Industrial Accidents Notification/Reporting Form". Main sections of the form that should be completed for each accident separately are as follows:

- Date, type and extent of the accident,
- State of the installation and the environment,
- Hazardous chemicals involved in the accident,
- Factors causing and influencing the accident,
- Emergency response activities,
- Consequences (fatalities, injuries, damage to property and environment, material loses, interruption to public services),
- Experience gained from the accident (technical and management aspects).

RoEI also aims to collect information on hazardous chemicals found at the establishments in the context of Regulation on Hazardous Chemicals. Annex 1A of the regulation includes notification forms for produced, consumed, refilled, and stored substances and preparations. Information on by-products originating from the principal production is also requested. Although the notification forms are different for each category, name of the substance, CAS number, concentration, quantity, physical form, and storage conditions are the fields which are common.

If had been properly implemented, RoEI could provide valuable information not only on the past industrial accidents, but also for the classification of industrial establishments, for example as lower and upper tier installations according to the 96/82/EC Directive. However, amendments to the original regulation have hindered effective data collection by limiting information forms, which should be submitted to the MoEF, to general information form only. Although forms are still prepared by the establishments, they are stored in-situ to be presented on request during inspections. In the original version of the Regulation, submission of all information forms to the MoEF was mandatory.

2.2.2 Regulation on Non-hygienic Establishments

In Turkey, Articles 268-275 of the Law on Public Hygiene are related to control of establishments causing health and environmental problems (non-hygienic establishments). According to the Law, such establishments are classified into three classes:

- *Class 1* installations should be located definitely far away from the settlements,
- *Class 2* installations should be located at a specified distance away from the settlements,
- *Class 3* installations can be located close to the settlements, but they will be inspected regularly by the competent authorities.

The Ministry of Health (MoH) is the national competent authority for the application of the Law.

In order to determine the criteria for the above mentioned classification, the MoH published the Regulation on Non-hygienic Establishments (RoNHE) in 1995 [28]. Annex 5 of the Regulation includes lists of industrial activities for each non-hygienic class respectively. For Class 1 and 2 establishments, an inspection committee formed by the representatives of relevant authorities and organizations designates the minimum distance that should be leaved as non-settled around the establishment (health protection zones). The committee takes the possible adverse effects of the establishment on the environment and human health into consideration while determining the width of the health protection zones. Hence, this regulation directs land-use practices around the industrial establishments. Since establishments dealing with dangerous substances are listed as Class 1 and 2 installations, it can be deduced that RoNHE also determines land-use practices around the establishments which should be covered by the 96/82/EC Directive. Land-use planning is an important component of the 96/82/EC Directive, thus RoNHE is important for the control of industrial accidents.

2.2.3 Regulation on Environmental Impact Assessment

Preparation of an Environmental Impact Assessment (EIA) report before the establishment of an industrial facility is required by the Law to prevent possible adverse impacts on human health and environment during the construction, operation, and post-operation phases. Regulation on Environmental Impact Assessment (RoEIA) lists the industries for which an EIA report is mandatory and for which a preliminary reporting study is required for the competent authority to decide on if an EIA report is required or not. The regulation also determines the format of the EIA report.

Preparation of an EIA report is obligatory for the industries that are listed in Annex 1 of the regulation, whereas for those listed in Annex 2, a preliminary report should be prepared. According to the format given in the regulation, this preliminary report should include information on possible accident risks. Hence, a risk assessment study on industrial accidents should be done for each new establishment that is listed in Annex 2 of the regulation. Moreover, if the EIA report prepared for an industrial establishment contains suggestions for the dimensions of health protection zones, then these dimensions are used for the application of the RoNHE without further consultation to the inspection committee. Therefore, although not as much as RoNHE, RoEIA also has some effect in land-use planning regarding control of industrial accidents. Risk assessment part of the EIA and Preliminary EIA can also be used as a reference for emergency response plans.

2.2.4 Regulation on Hazardous Chemicals

Regulation on Hazardous Chemicals (RoHC) published by the MoEF in 1993 and last amended in 2001, is an adoption of the 67/548/EEC Directive of the EU in Turkey. Similar to 67/548/EEC Directive, the RoHC contains provisions for classification, labeling, and packaging of dangerous substances, and lists hazard classifications for dangerous substances. Number of substances listed by the Regulation is about 900. Compared to 3 500 substances in the current ATP of the 67/548/EEC Directive, this number is significantly low but not unexpected becase the list have not been updated since the first publication of the Regulation. Many ATPs were published for the 67/548/EEC Directive meanwhile. Although it is not up-to-date, the RoHC is still important because it forms the basis for hazard classification of dangerous substances in Turkey.

2.2.5 Recent Studies on Control of Industrial Accidents

In 1996, MoEF published a circular on emergency planning for major industrial accidents [29]. Inspired by the 82/501/EEC Directive and UNEP APELL (Awareness and Preparedness for Emergencies at Local Level) Programme, this circular aims at preparation of local emergency plans. Besides how local emergency response plans should be prepared, this draft also specifies which industrial facilities should be evaluated according to the plan and the tasks of so called "Emergency Committee". Since the circular is not as legally binding as regulations and do not have the force of sanction, it could not be effectively put into practice. However, it is referred in the RoEI and in the reports of Emergency Center project prepared in 2001 by the MoEF to build an emergency response center for the control and management of environmental emergencies. It should be noted that the center could not be realized so far.

A draft regulation entitled "Regulation on Prevention of Major Industrial Accidents" was prepared by a commission including the representatives of the MoH and Ministry of Labor and Social Security (MoLSS) in 1999 [30]. This draft legislation, which is based on 74th clause of Labor Law, was in fact an adaptation of the 82/501/EEC Directive of the EU to local conditions. MoLSS was specified as the administrative authority. The draft suggests that emergency response plans for accidents be prepared by the industrial facilities, but it does not mention about external emergency plans that should be applied by the local authorities if the effects of the accident goes beyond the boundaries of the facility. The draft legislation could not be put into practice since the required approval could not be taken from the Committee of the Ministries.

"Environmental Emergency Response Plan for Marmara Region" is another project, which is related to industrial accidents [31]. The project is mainly developed for the management of industrial accidents that are triggered by the natural disasters. However, together with a comprehensive local emergency response plan, it also includes principles for facility-wide emergency plans based on the 96/82/EC Directive and U.S. National Response Team's Integrated Contingency Plan. Prepared regional plan is compatible with the current national legislation related to emergency response of natural disasters and instead of building a new emergency response structure, it proposes modifications to the current structure for covering industrial accidents. The project is distinguished from the other studies by the inclusion of environmental aspects to the management cycle and development of a regional information system. The information system, which is based on desktop GIS, features a user-friendly interface to store information on industrial facilities and natural disasters [32]. The system allows facility-wide emergency response plans, hazardous substances in inventories, and meteorological data to be stored together with general information on the establishments. By using capabilities of the GIS, natural disasters risk maps, such as earthquake risk zones, flood regions, forest fire regions; settlements; transportation network; and environmental resources, such as rivers, lakes, groundwater aquifers, and monitoring stations are provided as interactive maps, which can be easily accessed from establishment information forms (Figure 2.1). Although both the regional emergency plan and the information system were useful for control of industrial accidents, the results of the project were not put into practice by the MoEF.

By far, the most comprehensive study on approximation of the EU legislation on control of major industrial accidents to the Turkish legislation is the "Approximation of Seveso-II Directive in Turkey" project, which is supported by EU LIFE Programme [15]. The aims of the project were development of the strategy for implementation of 96/82/EC Directive in Turkey, preparation of corresponding implementation plan, preparation of a draft regulation and communiqués thereof, and establishment of an information system to support the application of the proposed regulation. At the end of the project, which was completed in the beginning of 2006, Directive Specific Implementation Plan for the 96/82/EC Directive, draft By-Law on Control of Major Industrial Accident Hazards, Communiqué on Safety Report and Emergency Plans, Communiqué on Public Information, and Communiqué on Inspection have been prepared, which are concordant with the 96/82/EC Directive and take local conditions of Turkey into consideration. A web-based information system also has been developed, which can be used to collected data from industrial establishments on dangerous substances listed in the 96/82/EC Directive. A simple establishment classification tool is also provided. During the project period, about 500 establishments have made preliminary reporting on chemicals in inventories by using the information system [33]. Since, extent of chemical information that can be collected by the information system was limited to the 96/82/EC Annex 1 Part 1 substances and Part 2 categories by design, status calculations could not be performed as required. But data collection was suc-

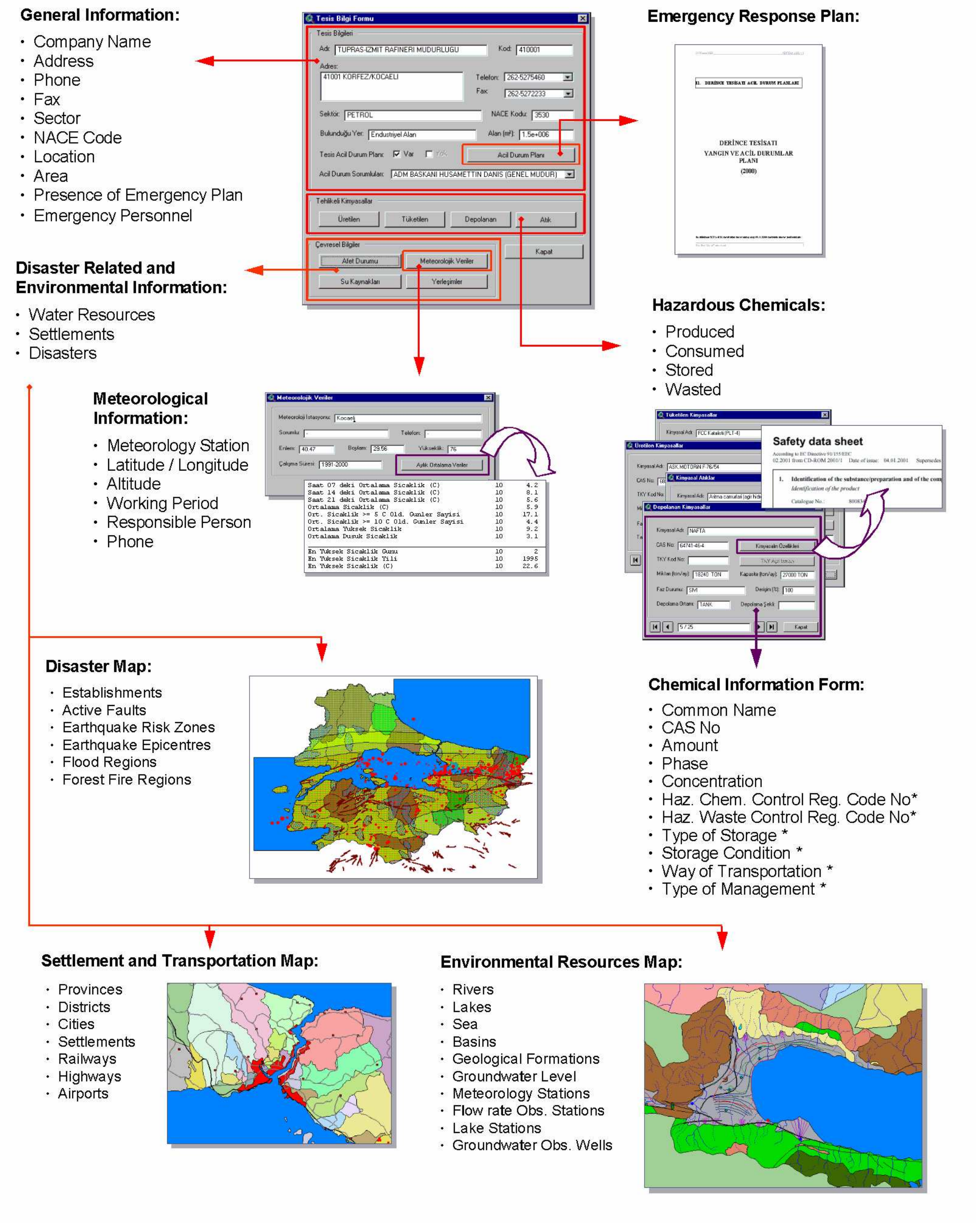


Figure 2.1: Structure of information system developed for the Marmara Region [32]

cessful and promising for real-life applications. Although considerable time has passed since the completion of the project, neither the draft regulation and its communiqués, not the information system could have been put into practice by the MoEF. Detailed information on the outcomes of the project and the information system can be found on the project webpage [34].

2.3 Discussion

Review of current environmental legislation shows that legislative measures for control of major industrial accidents are lacking in Turkey. Although there are a few regulations, which are partially related to the topic and include some provisions for land-use planning and reporting, many aspects such as establishment of safety management systems and information to the public are not covered by any of the regulations.

Although several studies had been performed in the past, covering wide range of topics such as approximation of EU Directives on control of major industrial accidents, preparation and implementation of local emergency plans for industrial accidents, development of regional emergency response plans considering industrial accident originated from natural hazards (natechs), outcomes of the studies could not be put into practice. Especially, the most recent approximation project is a comprehensive study and prepared draft regulation and communiqués thereof can be a solution to the lack of national legislation on control of industrial accidents for Turkey. However, capabilities of the competent authority (MoEF) seems to be limited, which results in a slow progress towards the goal.

Despite these problems, candidacy of Turkey to the EU is still a strong driving force behind the environmental studies. Hence, it is evident that sooner or later a regulation similar to the 96/82/EC Directive will come into force. As describe in detail in the 96/82/EC Directive part, provisions of the Directive is not simple even for the determination of industrial facilities that will be within the scope of the Directive. Taking the capabilities of the MoEF into consideration and considering past experience with related studies, it is clear that there is a serious need for analytical tools (databases, information systems and calculation tools), which will support the application of the Directive. If such tools can be ready before the awaited Regulation put into force, administration and application of the Regulation could be significantly facilitated.

CHAPTER 3

INTERNATIONAL DATABASES

In this chapter, international databases were reviewed in terms of the records which are available on industrial accidents that had taken place in Turkey. The primary aims of the review are to determine the extent of available data and to assess their quality and completeness. For this purpose, the following databases have been reviewed:

- EU Major Accident Reporting System (MARS),
- EM-DAT Emergency Disasters Database, and
- UNEP APELL Technological Disaster Database.

Selection of these databases for review is due to their widespread use in the literature. EM-DAT and UNEP APELL databases have been utilizing many other national and international data sources for data collection purposes, hence they have a broad coverage as well.

3.1 EU Major Accident Reporting System

MARS is an information system which was established to handle the information on major industrial accidents submitted by the Member States to the European Commission in accordance with the provisions of the Seveso Directives, which are the directives of 82/501/EEC and 96/82/EC [35]. The system is being administrated by the Major Accident Hazards Bureau (MAHB), which is affiliated with the EU Joint Research Center and located in Ispra, Italy. In addition to the EU member states, the database is also used by OECD countries within the scope of the Chemical Accidents Programme and by the signatory countries of the UN/ECE Convention on the Transboundary Effects of Industrial Accidents (TEIA), in order to report the industrial accidents in the MARS standard format and to exchange information on this basis. The system includes both accident profiles, which are short reports intended for use for immediate notification of an accident, and full reports, which are comprehensive reports prepared when the accident has been investigated and contain detailed information on the causes, occurrence and consequences [36]. Accident reports are first submitted to a local database by the competent authorities of each country, then they are transferred to the central system. The notification criteria defining which accidents are to be submitted to the system are listed in the 96/82/EC Directive [11]. Short accident profiles can be accessed publicly thorugh the Internet, whereas detailed reports are open to authorized users only.

Currently, MARS holds data on more than 450 major accident events. However, no records exist for Turkey [37]. Among the reasons for this, delay in adopting the 96/82/EC Directive to the national legislation as a candidate to the EU and being not a signatorty of TEIA can be listed for Turkey.

3.2 EM-DAT Emergency Disasters Database

Since 1988, Center for Research on the Epidemiology of Disasters (CRED) in the Catholique de Louvain University, Belgium, has been maintaining an Emergency Events Database (EM-DAT) [38]. EM-DAT, which is one of the most extensive information sources on technological disasters, was created with the initial support of the WHO and the Belgian Government and also has been supported by the Office of U.S. Foreign Disaster Assistance (OFDA). The main objective of the database is to serve the purposes of humanitarian action at national and international levels. EM-DAT contains essential core data on the occurrence and effects of over 16 250 mass disasters in the world from 1900 to present, and is being updated regularly.

In the database there are many types of disasters and a broad geographical scope. The accessible information is being classified by: country; date; disasters type; number of died, injured, homeless, affected (in need of emergeny aid, evacuation, etc.) persons and the amount of damage in USD. EM-DAT database classifies disasters into natural and technological disasters. Technological disasters are further divided into three subclasses: accidents of industrial origin or involving industrial installations (industrial accidents), accidents involving mechanized modes of transport (transport accidents), and technological accidents of a non-industrial or transport nature (miscellaneous accidents).

For a disaster to be entered into the database at least one of the following four criteria has to be fulfilled [39]:

- $\geq$ 10 people reported killed,
- $\geq$ 100 people reported affected,
- Call for international assistance,
- Declaration of a state of emergency.

Based on these criteria, summary of available data in the EM-DAT database on the technological disasters that had taken place in Turkey for the period of 1922–2006 is given in Table 3.1.

Table 3.1: Technological disasters listed in EM-DAT for Turkey (1922-2006) [40]

	Industrial	Transportation	Miscellaneous
Number of Events	17	76	12
Fatalities	809	2 043	2 458
Injured	296	1 533	1 196
Homeless	3	0	0
Affected	175	11	0
Total Affected	474	1 544	1 196
Damage ($\times$1000 USD)	0	0	278 000

Among the technological disasters listed in Table 3.1, industrial accidents have been taken into consideration and examined in detail in this study. Complete listing of the 17 industrial accidents mentioned in the EM-DAT is given in Table 3.2. Table 3.2 include all information available in the EM-DAT database on the accidents. Since available information is limited and does not give insight to some accidents, detailed information is also collected from articles published in national newspapers and presented as explanatory notes in the table for each accident.

Table 3.2: Industrial accidents listed in EM-DAT for Turkey [41] [1]

Date	Location	Installation	Type of Accident	Damage
10.15.1979	Istanbul	-	Oil Spill, Fire	50 fatalities, 3 homeless
	Romanian oil tanker Independenta and Greek cargo ship Evryali crashed in Bosporus near Haydarpaşa Pier. 51 sailors were killed and about 95 000 tons of crude oil spilled to the sea. Resulting fire lasted almost one month.			
10.24.1980	Ankara–Danacıobası	-	Explosion	97 fatalities
	A gas cylinder exploded during an engagement ceremony in a house at Danacıobası village, Keskin–Ankara. 97 people, with the majority of women and children, were killed in the fire after the explosion.			
03.07.1983	Armutçuk	Mine	Explosion	98 fatalities, 86 injuries
	Firedamp explosion in Armutçuk Mine at Kandilli, Zonguldak. 102 workers killed, 86 injured.			
03.03.1989	İstanbul	Paint Factory	Explosion	11 fatalities, 34 injuries
	3 buildings were collapsed after the explosion and fire in a paint factory at 4. Levent in Istanbul. 14 people were killed and 44 were injured.			
02.07.1990	Amasya–Merzifon	Coal Mine	Explosion	68 fatalities
	Firedamp explosion in Yeniçeltek Mine at Merzifon, Amasya. 68 workers were killed. It took months to reach 58 of the bodies, which lie 340 meters deep underground.			
10.20.1990	-	-	Food Poisoning	23 fatalities
	25 people died after eating poisonous mushrooms within two weeks in Istanbul.			
03.03.1992	Zonguldak	Coal Mine	Explosion	272 fatalities
	Firedamp explosion in İncirharmanı Mine at Kozlu, Zonguldak. 263 workers were killed, 52 were injured. 147 of the casualties located underground could not be reached because of the fire after the explosion.			
08.08.1992	Tekirdağ–Çorlu	Textile Factory	Explosion	32 fatalities, 27 injuries
	32 were killed and 84 were injured in the explosion at Konyalılar textile factory in Çorlu. Explosion was to due methane accumulated in the water storage tank located under the factory and caused by a cigarette fire.			
09.15.1993	Gaziantep	Cleaning Factory	Explosion	10 fatalities
	Methane explosion at Hekimbaşı dumping site in Ümraniye, İstanbul. Tons of garbage crumbled over 11 houses. 39 people were killed under the debris.			
04.28.1993	Istanbul	-	Explosion	40 fatalities, 3 injuries
	Paint thinner boxes exploded in the fire at a carpet washing factory at Şehreküstü, Gaziantep. The explosion resulted in partial collapse of the carpet washing factory and the neighboring lentil factory. 10 were killed and 25 were injured.			
10.18.1994	-	-	Food Poisoning	18 fatalities, 175 affected
	29 people were poisoned, 2 died after eating poisonous mushrooms at Beykoz, Sultanbeyli and Ümraniye in İstanbul.			
03.26.1994	Sorgun	Coal Mine	Explosion	37 fatalities, 11 injuries
	Firedamp explosion in a mine at Sorgun, Yozgat. 40 were killed and 9 were injured.			
07.09.1998	Istanbul	Egyptian Bazaar	Explosion	7 fatalities, 118 injuries
	Gas cylinder exploded in Egyptian Bazaar, Istanbul. 10 people died, including 2 children and 1 tourist. 7 tourists and 120 people were injured.			
12.29.1999	Istanbul	Marmara Sea	Chemical Spill	
	Russian oil tanker Volganeft-248 teared apart because of heavy storm near Bakırköy. The front part was drifted to Menekşe coast. Almost 1 200 tons of fuel-oil spilled to the Marmara Sea.			
11.22.2003	Ermenek	Mine	Explosion	10 fatalities
	Firedamp explosion in a private coal mine at Ermenek, Karaman. 10 of the 13 workers who were buried under dent were killed.			
08.09.2004	Küre	Copper Mine	Fire	19 fatalities, 17 injuries
	Fire started during a welding operation in the Eti Copper Mine at Küre, Kastamonu. 19 workers were killed and 19 were injured.			
01.06.2006	Odaköy–Balıkesir	Coal Mine	Explosion	17 fatalities
	Firedamp explosion in a mine at Odaköy Village of Dursunbey, Balıkesir. 18 workers were killed, 7 were injured.			

[1] Descriptions of the accidents were collected from newspaper articles.

3.3 UNEP APELL Technological Disasters Database

Awareness and Preparedness for Emergencies at a Local Level (APELL) is a programme developed by the United Nations Environment Programme (UNEP) in conjunction with governments and industry, which aims minimizing the occurrence and harmful effects of technological accidents and environmental emergencies [10]. Within the scope of the programme, a database of technological disasters involving dangerous chemicals has been prepared [42]. The origin of the database is a list compiled by the OECD, which includes technological disasters for the years 1970-1989 [43]. By utilizing several data sources, UNEP has corrected the mistakes in the initial list and extended it to cover the years 1990–1998. Latest version of the list includes information for 316 accidents that had taken place world-wide.

All types of technological accidents, except oil spills from ships, mining accidents, voluntary destruction of ships or airplanes and accidents caused by defective products, were included to the list. Inclusion criteria are as follows [42]:

- $\geq$ 25 death,
- $\geq$ 125 injured,
- $\geq$ 10000 evacuated,
- $\geq$ 10000 deprived of water.

Similar to the EM-DAT database, the APELL database also includes very brief data on accidents. But information on type of the accident (e.g. BLEVE, fireball, runaway reaction), type of the industry (e.g. general chemical manufacture, fireworks) and name of the chemical substance involved to the accident are also available.

There are only 5 technological disasters in the APELL database, which are listed for Turkey. Available information on the accidents is given in Table 3.3. Similar to Table 3.2, explanatory notes that are based on articles published in national newspapers are also given in Table 3.3.

3.4 Results of Data Analysis

It has been noticed that there are discrepancies in terms of numbers of affected people between the national data sources (newspaper articles) and international databases.

Table 3.3: Technological disasters listed in APELL database for Turkey [44] [1]

Date	Location	Substance	Type of Accident	Damage
11.15.1979	Istanbul	Crude oil	Explosion (marine transport)	52 fatalities, 2 injuries
	Independenta-Evryali collusion. See Table 3.2.			
05.07.1983	Istanbul	-	Explosion (use/application)	42 fatalities, 50 injuries
	Fire in Hotel Washington at Laleli, Istanbul. Mostly tourist 37 were killed and 65 were injured.			
11.24.1980	Ankara	Butane	Use/application	107 fatalities
	Gas cylinder explosion during an engagement ceremony. See Table 3.2.			
08.08.1992	Çorlu	Methane	Explosion	32 fatalities, 64 injuries
	Explosion at Konyalılar textile factory. See Table 3.2.			
07.03.1997	Kırıkkale	Ammunitions fireworks	Explosion (Ammunitions)	1 fatalities, 1 injuries, < 200000 evacuated
	Explosion in the ammunition repository of Mechanical and Chemical Industry Corp. at Kırıkkale. 2 were killed, many were injured. Most of the city was evacuated.			

[1] Descriptions of the accidents were collected from newspaper articles.

But the differences are not critical in range. The reasons of the differences may be subsequent fatalities or the variety of the reference information sources. It is specifically mentioned in the databases that there may be some uncertainties in the available information. Similarly, newspaper articles based local information may have a level of dubiety as well. Therefore, these discrepancies are acceptable.

When the industrial accidents listed in the EM-DAT database are examined, it is seen that most of them are actually not within the scope of the definition of industrial accidents (Table 3.2). The accidents which had taken place at November 15th, 1979 and December 29th, 1999 are Romanian oil tanker Independenta and Russian oil tanker Volganeft-248 accidents, respectively. They are marine accidents in the course of oil transportation. Although both of them are considered as serious marine accidents, they should be listed as transportation accidents instead of industrial accidents. Similarly, the accidents dated November 24th, 1980 at Danacıobası Village of Ankara and July 9th, 1988 at Egyptian Bazaar in Istanbul are gas cylinder explosions, both of which had occurred within settlements. Hence, they may not be considered as industry related. The methane explosion at Hekimbaşı dumping site in Ümraniye, Istanbul on April 28th, 1993, after which tons of garbage mass crumbled over the houses located nearby, may not be defined as an industrial accident as well. Incidents that had happened on November 20th, 1990 and October 18th, 1994 are also not industrial accidents, but food poisonings.

As a conclusion, it can be stated that, a significant amount of the 17 accidents which are listed in EM-DAT database as industrial accidents, are actually not industrial in origin. Only 10 accidents of the list are related with an industrial activity. Most of these 10 accidents are firedamp explosions at mines. The number of the accidents that happened at the industrial installations are only three Figure 3.1.

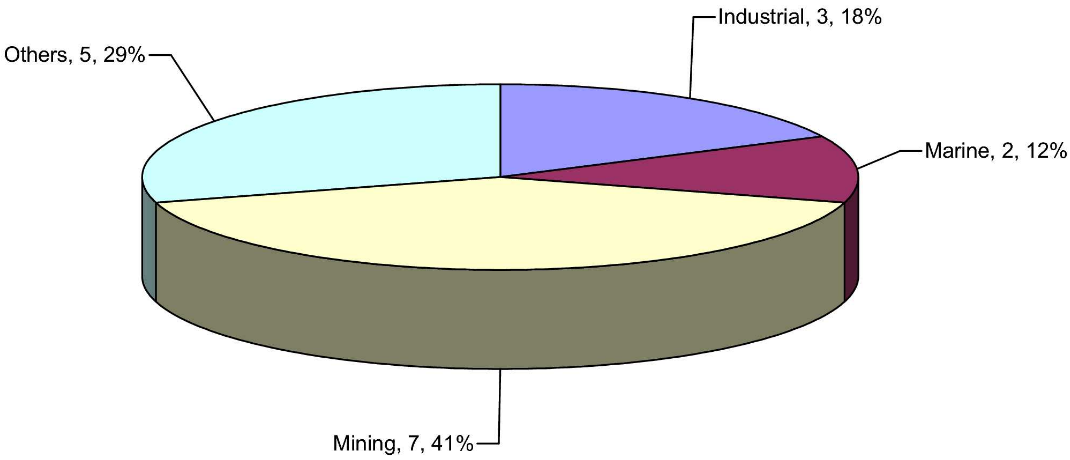


Figure 3.1: Actual distribution of accidents reported as industrial accidents in EM-DAT

As it can be seen in Table 3.1, material losses due to industrial accidents is reported as none, which is not realistic even for three incidents. This indicates lack of information. Although accidents in transportation and miscellaneous categories has not been examined in detail, summarized values reveal that similar problems are also present in these categories. Cost of transportation accidents, number of affected and homeless people, all of which were stated as none, are indicators of the problems.

When compared to the EM-DAT database, the APELL database has higher threshold values for the number of fatalities and injured. The criteria of being effected by the inevitable evacuation and being deprived of water are listed as separate criteria in APELL. Whereas, in EM-DAT those criteria are covered by the category “affected”, which has a lower threshold value. Higher threshold values are reflected to the number of accidents and only a limited number (five) of accidents are listed in APELL. Examining those accidents shows that three of them are the same with the accidents, which are listed in EM-DAT, and one of the other two (fire at Washington Hotel) is in the category of "miscellaneous" within the technological accidents. The ammunition explosion at Mechanical and Chemical Industry Corporation is included only in the APELL list. Only two of the five accidents may be classified as industrial accidents, whereas others are incidents that happened in urban settlements and during transportation.

The erroneous information on these on-line databases eventually is reflected to the studies in which they are referred. The "Europe's environment: the third assessment" report, which was released in 2003 by the European Environment Agency (EEA), may be given as an example. In addition to the EU member states, the report also covers all continental European countries and Turkey. In the chapter, entitled "Technological and natural disasters" of the report, the APELL database was used as one of the main sources [45]. In consequence of this, the fires at the Washington Hotel in Istanbul and Danacıobası village in Ankara have been listed as industrial accidents in the report.

Similar records are listed in a report, which EEA released in 2003, covering the 1998-2002 five year period and entitled, "Mapping the impacts of recent natural disasters and technological accidents in Europe". The report referred to the EM-DAT and MARS as data sources [46]. As it has been mentioned before, the MARS database currently does not cover any information on Turkey, and on the other hand the information on Turkey in the EM-DAT database does not reflect the actual situation for the stated period. Eventually, it is seen that there is no relevant information on Turkey in the report. However, the big fire at the TÜPRAŞ oil refinery in İzmit on August 17th, 1999 should be defined as a large scale industrial accident, especially when the size of the affected people, the state of emergency declaration and the scope of the international aid call are considered.

This study aims neither to list all the major industrial accidents that had taken place in Turkey nor to define which accidents should be listed in the EM-DAT and APELL databases. However the present situation already exhibits the insufficiency of the international databases without additional proof, since existence of incomplete and misclassified information is obvious.

3.5 Discussion

Evaluation of data availability in selected international databases on industrial accidents that had happened in Turkey shows that available data is erroneous and incomplete. Hence, these databases do not reflect the actual situation well.

The insufficiency of the international sources should not be considered as the result of the deficiency and mistakes in the listing processes only. The inventory studies, which cover long time periods and broad geographical scopes, work with various types of sources which have different structures and characteristics. The inventories should endeavor to consolidate all these various kinds of information with certain limits and certain criteria. Data collection efforts, with no doubt, would end up with a certain amount of uncertainty and deficiency, which are reasonably acceptable in every sense. Many studies state this situation clearly at the beginning and warns that available data should be used with care. However, the information gap caused by the lack of the information sources, should be assessed separately apart from these deficiencies. Without available information sources, inventories and databases may not be complete.

The only way to eliminate the data gap is to develop new and enriched information sources. It is assumed that the insufficiency of the international databases stemmed from the information gaps, and this should be considered as a strong hypothesis.

When Turkey is concerned, there are no easily accessible, systematically collected and updated inventories or databases which contain information on causes, formation mechanisms and consequences of industrial accidents. If present, such a database would constitute a fundamental information source for industrial accident related studies, and would enable sharing and transfer of experience gained from past accidents. In addition to national uses, the database can also be used to update related international databases and listings. Especially in accordance with the EU membership and the 96/82/EC Seveso directive, Turkey's engagement of regular declaration and reporting of the industrial accidents will begin in the near future. It is equally important to be able to report past accidents besides the ones that will occur in the future for learning lessons to control of industrial accidents. The database to be formed would be beneficial to this purpose as well.

CHAPTER 4

DECISION-SUPPORT SYSTEM

> "Simply because open content leads
> to better knowledge"
>
> Wikipedia

The decision-support system is an integrated, collaborative, open-access and open-content application with a web based client-server architecture. It is specifically developed to serve multiple aspects of industrial as well as technological accidents. The server side includes a database component for data storage and retrieval, and a rich set of tools for numerical calculation, statistical analysis and modeling. The client side has data entry forms with advanced user interface components, reporting tools, and a mapping component for spatial data display.

The following objectives were considered during the design and implementation of the decision-support system:

- *User-friendliness:* During the development of the system, special emphasis was given to user-friendliness. Visual elements are used wherever possible, comprehensive data entry and update interfaces are made available, and number of data fields is minimized to avoid duplicate or redundant data input. Client side data validation is applied before submission of data to the server to prevent unnecessary data transfer.

- *Accessibility:* It is aimed that the system to be accessible by a wide range of users, including industrial facility operators, civil servants, and the public. For this purpose a web based design has been applied that is capable of multiuser authentication and authorization. Following open-access and open-content philosophy all content of the information system is made available to the public and means of data entry and update are provided for the users to share information in a collaborative manner.

- *Integration:* The system provides an integrated framework, which gathers multiple aspects of industrial accidents under a single roof. Accidents that occurred in the past and adverse consequences thereof on human health and environment, current status of the industrial facilities with respect to major- accident potential, and risks arising from probable accidents in the future according to accident scenarios and modelling results can be assessed and analysed by using the system.

- *Multilingual support:* An important feature of the decision-support system is its support of multiple languages. Not only the user interface could be displayed in different languages, but also the database has the capability to support multiple languages concurrently, i.e. data can be stored in different languages. An important outcome of multi language support is the ability to create reports in different languages without confusion and addition work requirement.

- *Decision support:* The information system includes several automation, analysis and decision-support tools in order to help the users in industrial accident related studies. Selected features of the system can be listed as follows:

  - Automatic labeling and classification of substances according to risk phrases in compliance with the 67/548/EEC Directive.
  - Automatic labeling and classification of preparations according to concentration limits in compliance with the 1999/45/EC Directive.
  - Calculation of overall hazard indices associated with toxicity, flammability, and eco-toxicity of substances stored in the industrial facilities according to the Summation Rule of the 96/82/EC Directive.
  - Calculation of major-accident status of industrial facilities as lower or upper tier according to the 96/82/EC Directive.
  - Automatic update of the 96/82/EC status of industrial facilities according to changes in quantities, hazard classifications and qualifying quantity limits of substances.

- Detailed reporting of 96/82/EC status calculations, with special emphasis on status changes.
- Support of fuzzy numbers in accident statistics, allowing partial and uncertain quantitative information on accident consequences to be analysed statistically.
- Comprehensive chemical property data analysis framework with the ability to provide standardized property data for desired reference conditions by analysing all available chemical property datasets, property equations and property estimation methods.
- Integrated off-site consequence model, capable of modeling and mapping spill, evaporation and atmospheric dispersion of hazardous substances, for rapid assessment of industrial accident hazards

4.1 System Components

The information system is composed of four major components, which are called subsystems. The subsystems are as follows:

- Accident subsystem
- Document subsystem
- Chemical subsystem
- Facility subsystem

The subsystems are actually self-competent information systems on specific topics, which are closely linked to each other. Each subsystem covers several record types and includes all data entry interfaces, database queries, analysis methods and reporting tools regarding those record types. Simplified structure of the information system showing subsystems and records thereof is given in Figure 4.1.

Accident subsystem stores information on technological accidents and covers tasks related thereto. Types of technological accidents supported by the information system are industrial, military, marine transportation, land transportation, pipeline transportation, mining accidents, and urban disasters.

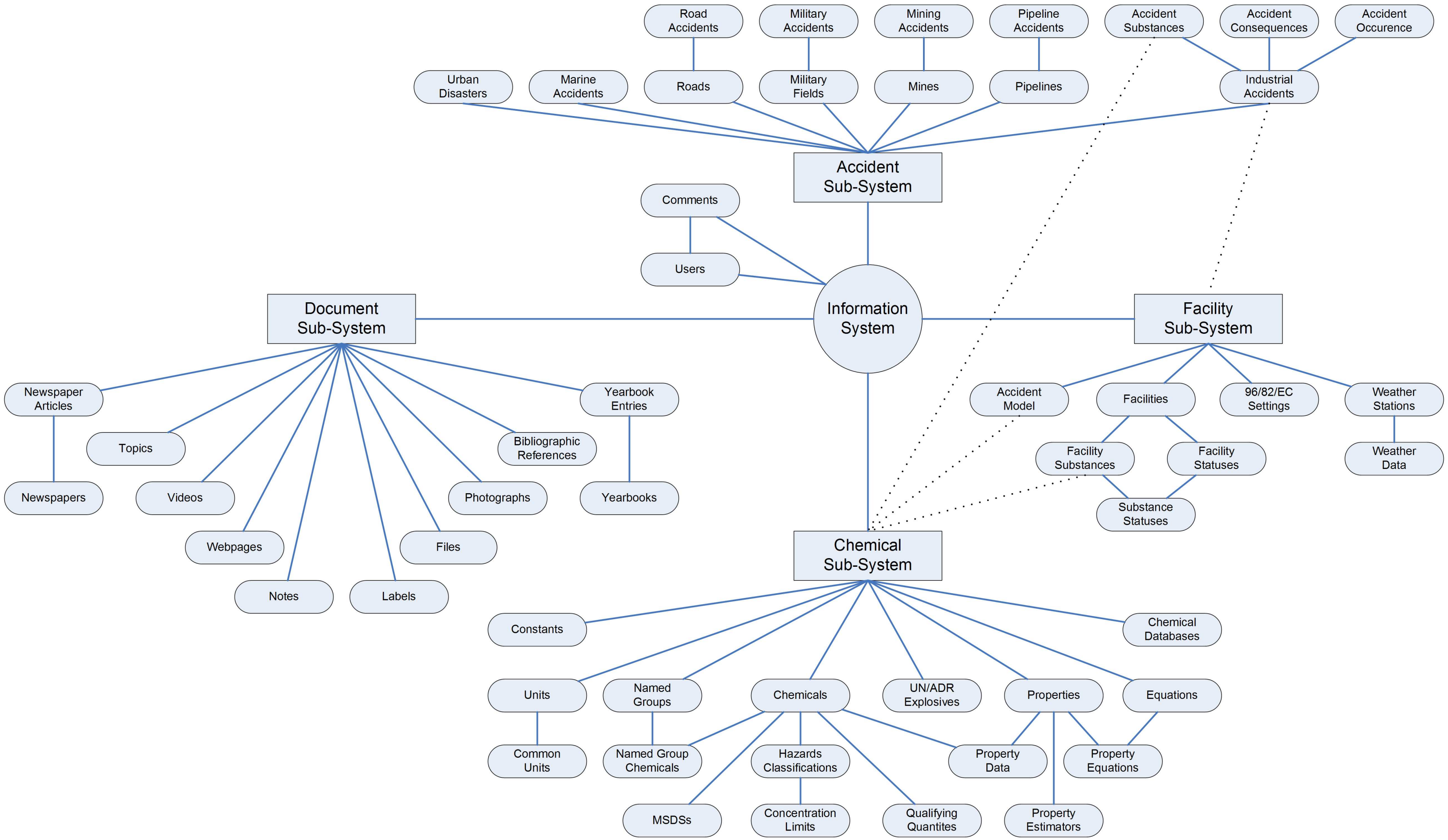


Figure 4.1: System components

For all accident types, except marine and urban, location information is stored as separate records such as mines, pipelines and military fields, allowing location based classification and statistics. Special emphasis is given to industrial accidents. Detailed information on events of occurrence, consequences on human health, environment and property, and hazardous substance involved can be stored for industrial accidents. Details on the accident subsystem are given in Section 4.4.

Document subsystem covers bibliographic references, information sources and multimedia documents. Newspaper articles, yearbook entries, webpages, video recordings, photographs and bibliographic references such as journal articles, books, technical reports and manuals can be stored in this subsystem. Records can be labelled for rapid classification or can be grouped under topics. Files can be linked to records to store original papers, articles or photographs. Notes can be added to compile personal thoughts. Document records can be made related to other documents, accidents, accident locations and chemical records resulting a network of relations revealing conceptional connections between the records. They may also be used for referencing purposes. Details on the document subsystem, which is the library of the information system, are given in Section 4.5.

Chemical subsystem stores information on chemicals and explosive substances. It is one of the most developed subsystems of the information system, supplying information on hazard classification of chemicals according to the 67/548/EEC and 1999/45/EC Directives, and qualifying quantities of named substances and groups of substances according to the 96/82/EC Directive. Information on explosive substances listed in international UN/ADR agreement is also available. Data on chemical properties and chemical specific property equations can be archived in the system and analysed statistically. Material safety data sheets (MSDS) of the hazardous chemicals can be stored as well. The subsystem features tools for automatic hazard classification based on risk phrases, chemical property data estimation, and seamless unit conversion. Both accident and facility subsystems use chemical subsystem for retrieval of chemical specific data. Details on the chemical subsystem are given in Section 4.6.

Facility subsystem covers information on industrial installations. Detailed hazardous substance inventories of the facilities can be created and stored in the database. Comprehensive tools are provided for calculation of the 96/82/EC Directive status of the facilities. Facility subsystem also includes information on meteorological stations and archives weather data from online resources. Weather data is used by the accident modeling framework developed as part of the study. Details on the facility subsystem are given in Section 4.7.

4.2 System Architecture

The information system has been developed with a web-based, client-server architecture. It is publicly accessible on the Internet, at `http://www.teknolojikkazalar.info`. All data storage and processing are done on the server side, while data input and display are done on the client side. Server application works on a web server and supported by a relational database management system (DBMS) and the native file system for data storage and retrieval. Client application works on web browsers and communicates with the server application synchronously and asynchronously through the Internet. For mapping purposes an external Internet Map Server is used. Simplified architecture of the information system is given in Figure 4.2.

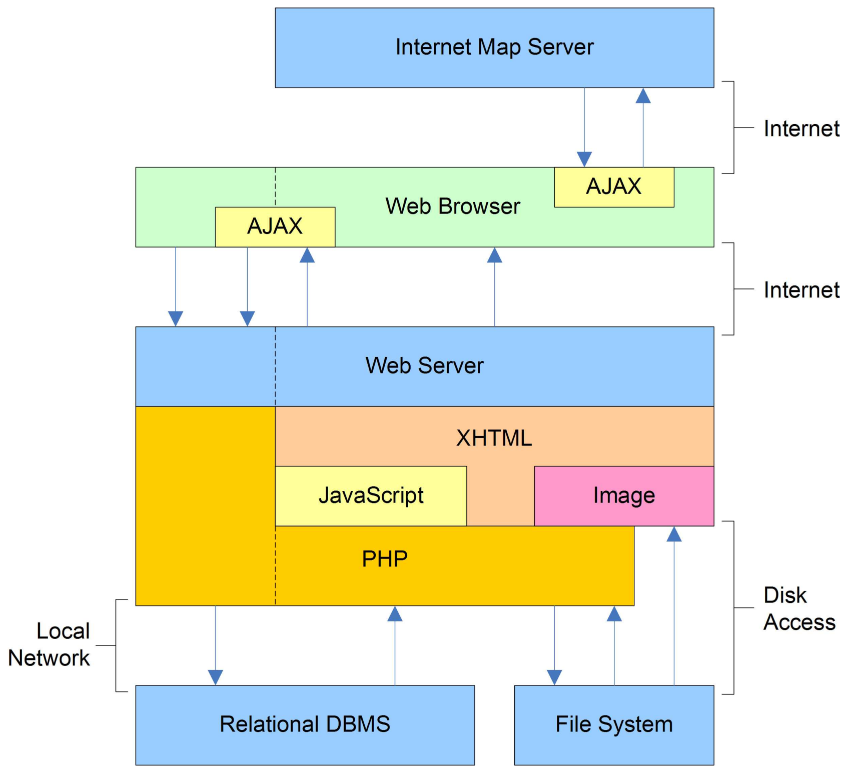


Figure 4.2: System Architecture

Server application of the information system works on Apache Web Server and has been developed using PHP programming language, which is widely used for development of web based applications [47]. Advanced features of Apache Web Server are not used by the information system, therefore it can also work on other web servers currently available on the market. Client side application (user interface) of the system has been prepared using XHTML markup language and supported by DOM (Document Object Model) Level 1 based, interactive scripts in JavaScript programming language. XHTML codes describing the user interface elements and behaviour are generated dynamically by the server application. Similarly, graphical elements, such as line plots, histograms and icons are either generated by the system or loaded from files stored in the native file system. In order to provide asynchronous data flow between client and server, AJAX technology has been utilized [48]. Client side application is fully XHTML 1.0 Transitional compliant [49] and works on all major web browsers, independent of the operating system and hardware configuration. Compatibility tests have been made with Mozilla Firefox, Microsoft Internet Explorer and Opera web browsers on Microsoft Windows operating system.

The information system uses MySQL Database Management System for data storage and retrieval [50]. Being the most popular Open Source SQL database management system worldwide, MySQL has been selected primarily due to ease of use and widespread support. Among the data storage engines provided by MySQL, InnoDB storage engine, which supports relational database tables with transaction-safe (ACID compliant) queries, has been used that. Owing to relational database structure with foreign key constraints, all actions on records have been controlled at the database level and overall data integrity has been protected. Textual data is stored in universal Unicode UTF-8 encoding, which supports mathematical operators, Greek symbols and Turkish characters besides all other major alphabets used worldwide. Collations implemented in MySQL allow comparisons of characters in character sets to be done according to the rules of selected collation language, including Turkish. Hence, textual information can be queried and sorted property.

In order to display geographic information, the information system utilizes Google Maps, which is a widely used, free online mapping service provided by Google [51]. Owing to Google Maps integration over the Internet, detailed base maps and satellite images for many city centers and industrial regions of Turkey are made available to the users of the system. A custom dynamic map window gadget has been developed, which allows maps displayed on the user interface to be moved and resized freely for better navigation. The system also supports data entry in multiple coordinate formats. Details on mapping sub-component are given in Section 4.3.7.

During the development of the system no automatic code generation or templating systems has been used and all code has been written manually in 3 years. The system includes over 55 000 lines of PHP and JavaScript code, excluding external programming libraries. Programming libraries are mainly used to perform data visualization (e.g. mapping, chart plotting, video playback) and enhancement of user interface elements (e.g. sortable tables, richtext editing). None of the programming libraries used for development are commercial, i.e. all libraries have licenses that are of free of use. Complete listing of programming libraries utilized in the information system is given in Table 4.1. In order to follow the progress of development and create code history, Subversion versioning system has been used [52]. For project management and bug-tracking purposes, web based Trac software has been utilized, which allow hyperlinking of information between bug database and revision control [53].

The database of the information system includes 107 data tables, which are organized in a relational structure. 67 tables store data entered to the system through data entry forms. Hence, they are dynamic in size and number of records in the tables are growing within the life time of the information system. Remaining 40 tables contain supplementary data, which do not change frequently, such as provinces, districts, chemical risk and safety phrases. Data entry forms are not provided for these tables, but contents thereof can be updated using common database query tools if needed. Complete listing of database tables with detailed information on data fields and primary key-foreign key relations is given in Appendix A. Database model diagram with table-to-table relations is given in Figure A.1. A more simplified representation of the table relations is also illustrated in Figure 4.3 by using a schemaball.

4.3 General Features

4.3.1 Multiuser Support

The basic design objective of the information system is to facilitate data sharing on technological accidents by creating a collaborative, open-content environment. For this

Table 4.1: Software packages and libraries used for the development

Name	Description	Version	License	Author	URL
Software packages					
PHP	Programming language	5.2.0	PHP	PHP Group	`http://php.net`
MySQL	Database management system	4.1.21	GNU GPL	MYSQL AB	`http://mysql.com`
CacTVS	Chemoinformatics toolkit	3.352	Academic	W.D. Ihlenfeldt et al.	`http://xemistry.com/academic`
Programming libraries					
Google Maps API	Web mapping library	2.71	Google	Google	`http://code.google.com/apis/maps`
Clusterer	Marker clustering library for Google Maps	2	ACME	Jef Poskanzer	`http://acme.com/javascript`
Whatever:hover	Hover support for Internet Explorer	1.42	GNU LGPL	Peter Nederlof	`http://xs4all.nl/~peterned`
FlowPlayer	Adobe Flash video player	1.15	GNU GPL	Anssi Piirainen	`http://flowplayer.sourceforge.net`
GWindow	Docking window library	0.2	GNU LGPL	Serkan Girgin	`http://cografiveri.com/gwindow`
JPGraph	Graph generation library	1.20.4	QPL 1.0	Aditus Consulting	`http://aditus.nu/jpgraph`
JSCalendar	DHTML calendar library	1.0	GNU LGPL	Mihai Bazon	`http://dynarch.com/projects/calendar`
Nanotree	DHTML tree library	1.4	GNU LGPL	Martin Mouritzen	`http://nanotree.sourceforge.net`
PHPMailer	E-mail Transfer Class for PHP	1.73	GNU LGPL	Brent R. Matzelle	`http://phpmailer.sourceforge.net`
PNGFix	Transparent PNG support for IE	-	-	Bob Osola	`http://homepage.ntlworld.com/bobosola`
Sorttable	Sortable table library	2	X11	Stuart Langridge	`http://kryogenix.org/code/browser/sorttable`
TabContent	Tabular content library	29/06/06	Dyn. Drive	Dynamic Drive	`http://dynamicdrive.com`
TextDiff	Text-based difference engine	1.17	LGPL	C. Hagenbuch et al.	`http://pear.php.net/package/Text_Diff`
TinyMCE	Richtext editor library	2.0.6.1	LGPL	Moxiecode Sys. AB	`http://tinymce.moxiecode.com`
Development environment					
PSPad	Unicode programmers editor	4.5.4	Jan Fiala	Jan Fiala	`http://pspad.com`
Subversion	Version control system	1.3	Apache	CollabNet	`http://subversion.tigris.org`
Trac	Project management tool	0.10.4	Mod. BSD	Edgewall Software	`http://trac.edgewall.org`
FireFox	Web browser	2.0.0.12	MPL 1.1	Mozilla Foundation	`http://firefox.com`
FireBug	HTML,DOM,CSS,JavaScript debugger	1.05	MPL 1.1	Joe Hewitt	`http://getfirebug.com`

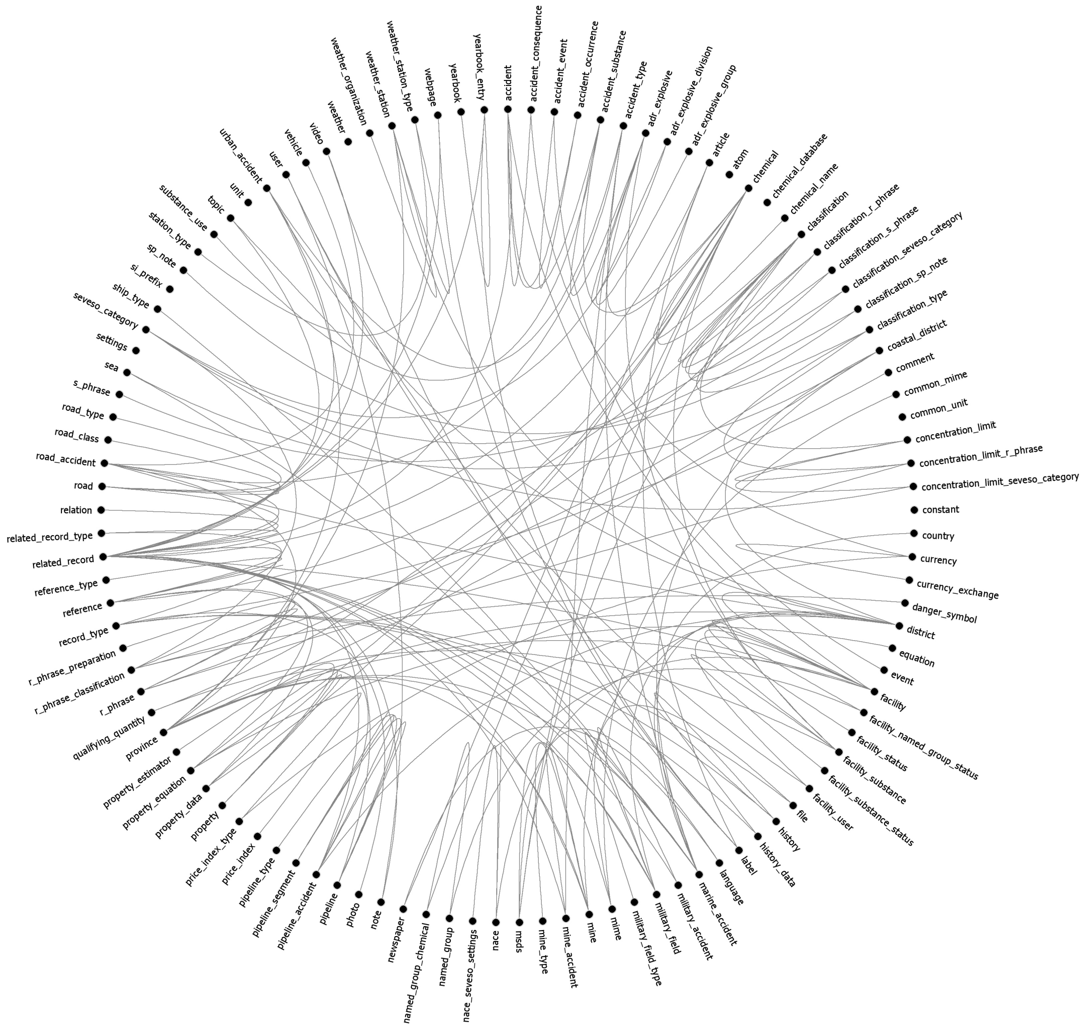


Figure 4.3: Schemaball representation of the database relations

purpose, the system has been developed to support multiple users concurrently. There are four different user types with different levels of user rights and privileges:

- Administrators
- Editors
- Registered users
- Anonymous users

Administrators are responsible from the management of the information system and have complete control over the system components. They can add, update and delete all kinds of records regardless of record specific user privileges and locking mechanism applied by the system. There are also particular record types and tasks that can only be edited and performed by the administrators, respectively.

Main duties of the administrators can be listed as follows:

- Updating the list of UN/ADR explosive substances according to changes and amendments to the UN/ADR agreement,
- Updating the list of chemicals and qualifying quantity limits thereof, which are specifically named in Annex I Part 1 of the 96/82/EC Directive, according to amendments to the Directive.
- Managing the property estimators supported by the system,
- Managing the registered users by setting editor privileges and assigning users as responsible persons of facilities,
- Managing the generic and industry specific parameters that are used for calculation of 96/82/EC status of facilities,
- Keeping track of records entered or updated by the editors and correction of improper entries,
- Following up weather data collection process and verification of data integrity,

Regular users of the information system may register to the system by providing basic personal information. Registration allows users to enter data in the system and customize system settings. Personal name and a valid e-mail address are required for registration. Optionally, title and company/organization information may also be specified to guide administrators for assigning appropriate user privileges, which restrict the extent of data entry by the user.

Registered users without editor privileges are not allowed to enter or update records except personal notes. But they can comment on existing records including technological accidents, chemicals and hazard classifications, and document archive entries. Details on comments and personal notes are given in Sections 4.5.7 and 4.5.8, respectively.

Registered users can customize system settings according to their preferences. For example, mapping component can be disabled to speed-up system performance, or display formats of date and coordinate values can be changed. User settings are stored in the database and maintained between sessions. General system settings, which overwrite user preferences, can be specified by the administrators.

Registration allows the system to collect usage and performance statistics, which can be used for fine-tuning of the system.

Editors are a special class of registered users who have data entry and update rights, hence can contribute to the contents of the information system. The information system includes more than 60 record types for which data can be entered by the users. Following the basic principle of open-content systems, most of these record types are allowed to be added and updated by the editors as listed in Table 4.2. Restricted record types are those that result from legally binding documents, such as directives or international agreements, and can be created or updated only by administrators to protect compliance with the regulations. Editors are designated by the administrators from the registered users. Following open-content philosophy, majority of the users are allowed to have editor privileges. Users having e-mail addresses ending with ".tr" suffix (country code of Turkey) are automatically made editors by the system.

To maintain the system integrity, records can only be deleted by the users who created the records, i.e. the owners. But, majority of the records are open for editing by the other editors. For example, a chemical added by Editor A can be edited by Editor B and incomplete information on the chemical, such as missing CAS No, SMILES or InChI values, can be completed. Similarly, mistakes in an entry by Editor B can be corrected by Editor C. This results in a collaborative framework for information

Table 4.2: User privileges

Record type	List	Show	Add	Update	Delete
Industrial Accident	All	All	Editor	Editor⋆	Owner
Accident Consequences	-	-	Editor	Editor⋆	Owner
Accident Occurrence	-	-	Editor	Editor⋆	Owner
Accident Substance	-	All	Editor	Editor⋆	Owner
Marine Accident	All	All	Editor	Editor⋆	Owner
Military Accident	All	All	Editor	Editor⋆	Owner
Military Field	All	All	Editor	Editor⋆	Owner
Mine	All	All	Editor	Editor⋆	Owner
Mine Accident	All	All	Editor	Editor⋆	Owner
Pipeline	All	All	Editor	Editor⋆	Owner
Pipeline Accident	All	All	Editor	Editor⋆	Owner
Pipeline Segment	-	All	Editor	Editor⋆	Owner
Road	All	All	Editor	Editor⋆	Owner
Road Accident	All	All	Editor	Editor⋆	Owner
Urban Accident	All	All	Editor	Editor⋆	Owner
UN/ADR Explosive	All	All	Admin	Admin	Admin
Chemical	All	All	Editor	Editor⋆	Owner
Chemical Database	All	All	Editor	Editor⋆	Owner
Classification	-	All	Editor	Editor⋆	Owner
Common Unit	All	All	Editor	Owner	Owner
Concentration Limit	-	-	Editor	Editor⋆	Owner
Constant	All	All	Editor	Owner	Owner
Equation	All	All	Editor	Owner	Owner
MSDS	All	All	Editor	Editor⋆	Owner
Named Group	All	All	Admin	Admin	Admin
Named Group Chemical	-	-	Admin	Admin	Admin
Property	All	All	Editor	Owner	Owner
Property Data	All	All	Editor	Editor⋆	Owner
Property Equation	All	All	Editor	Owner	Owner
Property Estimator	All	All	Admin	Admin	Admin
Qualifying Quantity	-	-	Admin	Admin	Admin
Unit	All	All	Editor	Owner	Owner
Comment	Admin	Admin	User	Owner	Owner
File	Admin	Admin	Editor	Editor⋆	Owner
Label	All	All	Editor	Owner	Owner
Newspaper	All	All	Editor	Editor⋆	Owner
Newspaper Article	All	All	Editor	Editor⋆	Owner
Note	Owner	Owner	Editor	Owner	Owner
Photo	All	All	Editor	Editor⋆	Owner
Reference	All	All	Editor	Editor⋆	Owner
Relation	-	-	Editor	-	Owner
Topic	All	All	Editor	Editor⋆	Owner
User	Admin	Owner	All	Owner	Admin
Video	All	All	Editor	Editor⋆	Owner
Webpage	All	All	Editor	Editor⋆	Owner
Yearbook Entry	All	All	Editor	Editor⋆	Owner
Facility	All	All	Editor	Editor†	Owner
Facility Substance	-	All	Editor†	Editor†	Owner
Facility User	-	-	Admin	Admin	Admin
Seveso Settings	-	Admin	Admin	Admin	Admin
Weather Station	All	All	Editor	Editor⋆	Owner

⋆ Only if not locked by the owner (see Section 4.3.2)

† Only if no responsible user is assigned to the facility (see Section 4.7.3)

sharing and facilitates accumulation of validated data. Primitive record types, such as constants, equations, units and labels, generally do not require further editing once created. Therefore, such record types are allowed to be edited only by their owners.

Anonymous users are users who are not registered to the system. Until they login to the system, registered users are also treated as anonymous users. Anonymous users are neither allowed to enter any data, including comments and personal notes, nor customize the system settings. Following open-access philosophy, no additional restrictions have been put on extent of information that can be accessed by the anonymous users. Therefore, users are not obliged to register to the system to access information.

Major problems of open content, collaborative systems are their susceptibility to addition of inconsistent, spurious or unverified information, and vandalism, such as insertion of dummy text into articles or wipe-out of existing information [54]. Multi level user privileges is one of the measures provided by the information system to minimize such problems. Other measures are locking support, referencing and change history.

4.3.2 Locking Support

The information system normally lets existing records to be edited or updated by registered users with editor privileges. This allow missing information to be completed or existing information to be corrected in a collaborative way. However, this freedom may also be misused to erase record contents or enter junk information into the system. In order to prevent these situations records can be locked for editing by the owners or administrators. Locked records can only be updated by their owners. In addition to textual content of the records, linked files and photographs can also be locked for modification. Locked files and photographs may not be replaced. Besides preventing vandalism, locking may also be used to indicate that the content of a record is reached the final state. Locked records are indicated with a padlock at the top of information pages.

4.3.3 Referencing

The information system includes a wide variety of record types ranging from simple notes to comprehensive newspaper articles with photographs and chemical property sets with many data values. In order to increase the reliability of the data and provide means of quality checking, data sources from which information in the records originate should be specified. Otherwise it would be impossible to turn back to the original documents once data is entered to the system.

For this purpose, means of referencing are provided for every record type that may have a reference. Several record types, such as newspaper articles, include reference information internally. For other record types, such as chemical property data, reference information can be specified by selecting a bibliographical reference record from the document subsystem or entering textual reference data. For online documents, URL address and access date can be specified. Whenever available, reference information is displayed together with the record information. Links to original locations are provided for online documents.

In addition to referencing original data sources, the information system also supports auto-referencing of records created in the database. While displaying a record information, creation date and name of the user who created the record is indicated. If record is updated, latest update date and name of the user who updated the record is also shown (Figure 4.12). Hence, summary of the record history can be easily followed. This information is shown in record listings as well. For this purpose, special information icons are put to the last column of the listing tables (Figure 4.12). Record history summary can be obtained as tooltips by hovering the mouse cursor over the information icons. The information system also provides reporting tools for following changes in records in detail as explained in Section 4.3.4.

4.3.4 Change History

An important feature of the information system is its integrated change history. Before processing data update requests on a record, including deletion, first a snapshot of the record data is taken from the database with all related entities. Then, update requests are evaluated and final data is compared with the snapshot data to determine whether any changes had occurred or not. If changes are found, snapshot data is compressed and stored in the database together with information on type, date and user of the request.

Data display functions of the information system, which retrieve data from the database and generate output for presentation, are developed in a way that they can work on both current and historical data. In other words, they can process historial data and create outputs as if they are processing current data in the database. The system is capable of comparing outputs generated by these functions and can automatically determine and mark differences in between. These capabilities are used to create change reports, which highlight sections of a record that are added, changed or simply removed between two time instants. An example of change report is given in Figure 4.4.

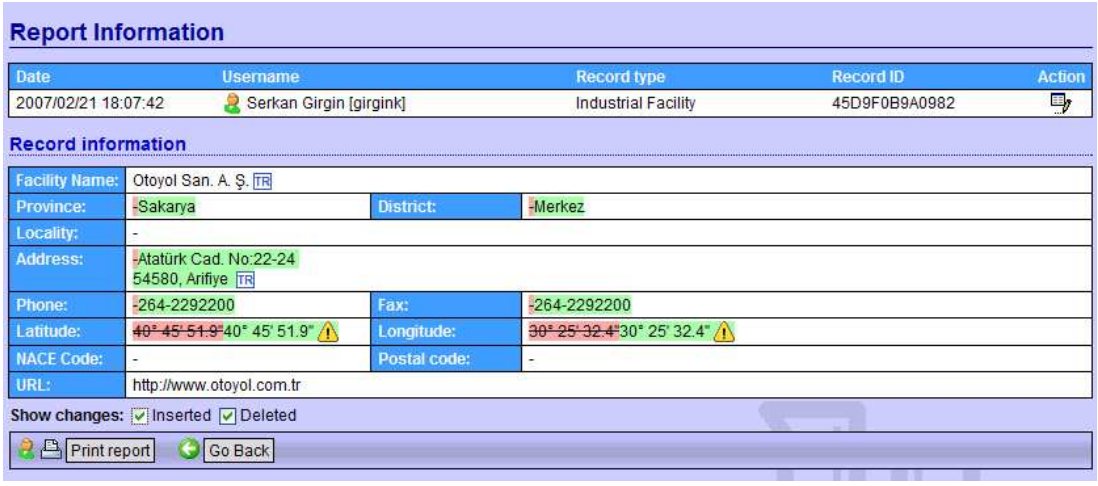


Figure 4.4: An example change report

Change reports allow administrators to follow actions of editors and evolvement of the data stored in the database. In case improper actions are noticed, such as deletion of valuable information or insertion of dummy data, they can be rolled-back using historical data in the database. Date and type of action (insert, update and delete) and name of the user are indicated in each report. Inserted or deleted sections can be toggled on and off to display only the initial and final states of the record.

Change reports are also used to display changes in the 96/82/EC status of the substances and facilities. For example, change of hazard classification of a chemical may affect 96/82/EC status of all facilities storing the chemical. Therefore, if a classification is changed the system is obliged to renew related calculations and report latest status to the user. A special type of change report is used by the system for this purpose. Details on 96/82/EC status reports are given in Section 4.7.7.

4.3.5 Data Validation

All data entry to the information system is done through data forms working on web browsers. Data forms include standard user interface elements, such as text inputs, selection lists, radio and check boxes, and also enhanced elements such as rich text editors and calendars. Some of the form elements are dynamic in nature and their contents change according to selections of the user. Text inputs are made limited to entry of specific type of data, such as integer, decimal, scientific or fuzzy numbers, based on their purposes and the user is not allowed to enter other type of data. Input fields that should not be leaved empty are indicated with asterisks. Fuzzy fields are marked with a special *f* symbol (Figure 4.5). Form data is validated on the client side before submission of information to the server. If missing or invalid entries are determined, they are indicated by exclamation marks next to related input elements as shown in Figure 4.5 and the user is warned to correct those problems.

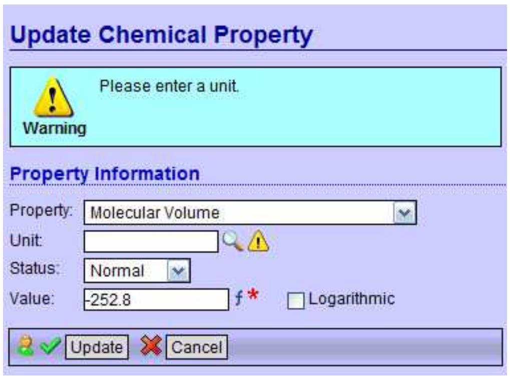


Figure 4.5: Validation of form data

Form data are also validated on the server side for possible mistakes or invalid entries that can not be determined on client side. Server side validation of data prevents possible data-intrusion attacks, to which online information systems are susceptible, as well. Found errors are indicated at the top of the page (Figure 4.5).

4.3.6 Multilingual Support

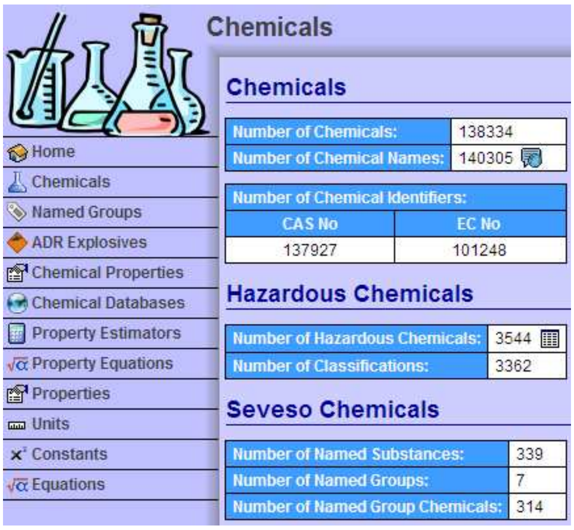
Another important feature of the information system is its multilingual support. Although the components of the information system have been designed taking the local conditions of Turkey into consideration, best effort has been made to make it universal as well. The information system, with all its subsystems, can be used for other countries, even for international organizations, with little modifications. Multilingual support is one of the features allowing this flexibility.

There are two levels of multilingual support in the information system. First level is the user interface level. Similar to many other software packages supporting localization, user interface language can be changed as shown in Figure 4.6. While programming the information system, symbolic constants are used instead of language specific labels. During initialization of data display pages and entry forms, the information system loads the symbolic constant definition file corresponding to the selected language. English and Turkish are fully supported, and additional languages can be supported simply by translation of the definition file into requested language.

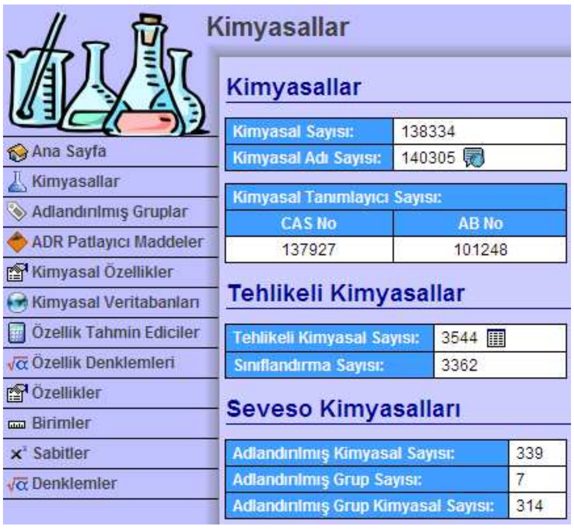
Second level of multilingual support is at the database level. Low-level data access functions have been developed that can read and write data to and from the database tables in multiple languages concurrently. If data is queried from a textual field supporting multiple languages, the information system first checks whether data is available in the requested language, which is by default the active language of the user interface. If data is found, it is returned as the result of the query. If no data is available in the requested language, other languages are tried, for which data fields exist in the database table. If data is found in one of the available languages, it is returned as the result of the query together with information on the language of the data. All these operations are done seamlessly, as if a single query has been processed.

Data display functions of the information system are multi-language aware and are able to notice if data is returned in a language different from the requested one. In such a case, the language of the data is indicated with a tiny language box next to the data value. An example of multilingual data display is given in Figure 4.7.

Supported languages can be specified for each data field separately, i.e. different data fields may have different number supported languages. To support an additional language for a data field, the only requirement is insertion of a new field to the database

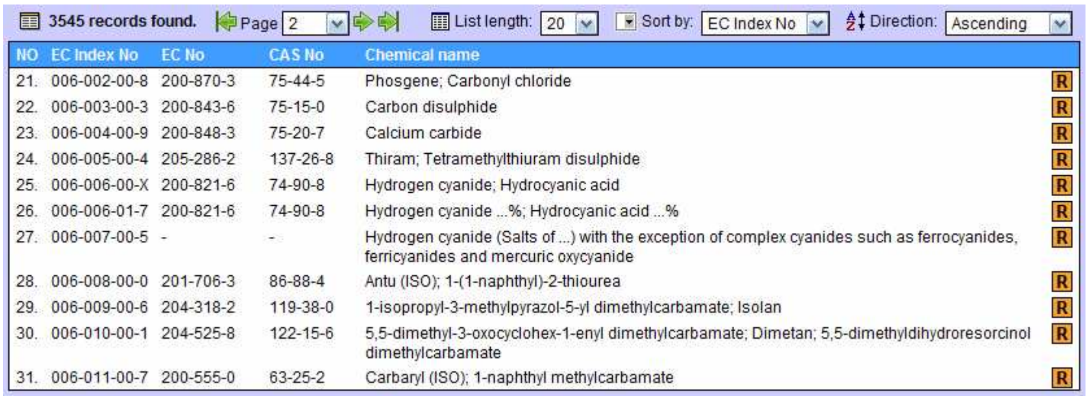


(a) English



(b) Turkish

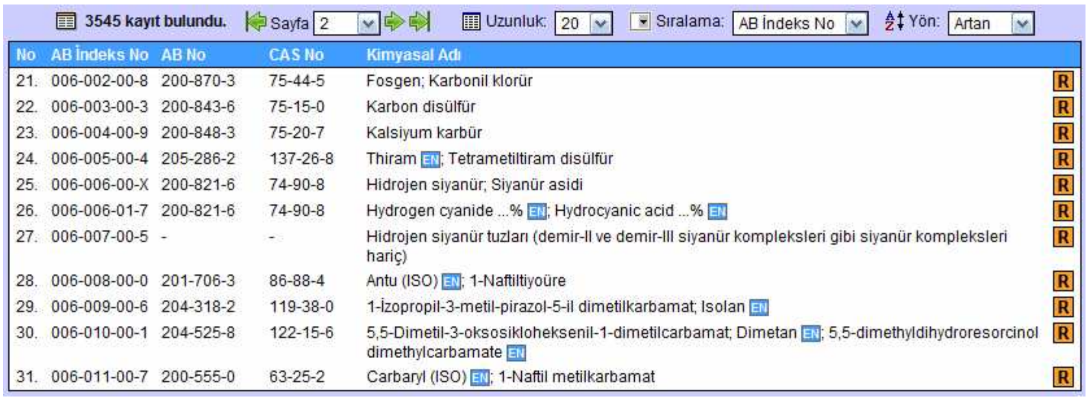
Figure 4.6: Multilingual interface support



3545 records found. Page 2 List length: 20 Sort by: EC Index No Direction: Ascending

NO	EC Index No	EC No	CAS No	Chemical name	
21.	006-002-00-8	200-870-3	75-44-5	Phosgene; Carbonyl chloride	R
22.	006-003-00-3	200-843-6	75-15-0	Carbon disulphide	R
23.	006-004-00-9	200-848-3	75-20-7	Calcium carbide	R
24.	006-005-00-4	205-286-2	137-26-8	Thiram; Tetramethylthiuram disulphide	R
25.	006-006-00-X	200-821-6	74-90-8	Hydrogen cyanide; Hydrocyanic acid	R
26.	006-006-01-7	200-821-6	74-90-8	Hydrogen cyanide ...%; Hydrocyanic acid ...%	R
27.	006-007-00-5	-	-	Hydrogen cyanide (Salts of ...) with the exception of complex cyanides such as ferrocyanides, ferricyanides and mercuric oxycyanide	R
28.	006-008-00-0	201-706-3	86-88-4	Antu (ISO); 1-(1-naphthyl)-2-thiourea	R
29.	006-009-00-6	204-318-2	119-38-0	1-isopropyl-3-methylpyrazol-5-yl dimethylcarbamate; Isolan	R
30.	006-010-00-1	204-525-8	122-15-6	5,5-dimethyl-3-oxocyclohex-1-enyl dimethylcarbamate; Dimetan; 5,5-dimethyldihydroresorcinol dimethylcarbamate	R
31.	006-011-00-7	200-555-0	63-25-2	Carbaryl (ISO); 1-naphthyl methylcarbamate	R

(a) English



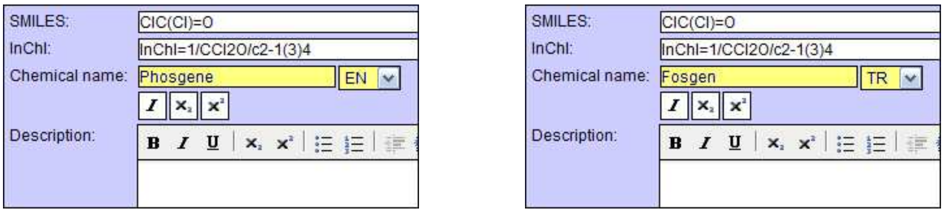
3545 kayıt bulundu. Sayfa 2 Uzunluk: 20 Sıralama: AB İndeks No Yön: Artan

No	AB İndeks No	AB No	CAS No	Kimyasal Adı	
21.	006-002-00-8	200-870-3	75-44-5	Fosgen; Karbonil klorür	R
22.	006-003-00-3	200-843-6	75-15-0	Karbon disülfür	R
23.	006-004-00-9	200-848-3	75-20-7	Kalsiyum karbür	R
24.	006-005-00-4	205-286-2	137-26-8	Thiram EN; Tetrametiltiram disülfür	R
25.	006-006-00-X	200-821-6	74-90-8	Hidrojen siyanür; Siyanür asidi	R
26.	006-006-01-7	200-821-6	74-90-8	Hydrogen cyanide ...% EN; Hydrocyanic acid ...% EN	R
27.	006-007-00-5	-	-	Hidrojen siyanür tuzları (demir-II ve demir-III siyanür kompleksleri gibi siyanür kompleksleri hariç)	R
28.	006-008-00-0	201-706-3	86-88-4	Antu (ISO) EN; 1-Naftiltiyoüre	R
29.	006-009-00-6	204-318-2	119-38-0	1-İzopropil-3-metil-pirazol-5-il dimetilkarbamat; Isolan EN	R
30.	006-010-00-1	204-525-8	122-15-6	5,5-Dimetil-3-oksosikloheksenil-1-dimetilcarbamat; Dimetan EN; 5,5-dimethyldihydroresorcinol dimethylcarbamate EN	R
31.	006-011-00-7	200-555-0	63-25-2	Carbaryl (ISO) EN; 1-Naftil metilkarbamat	R

(b) Turkish

Figure 4.7: Multilingual display of data stored in the database

table, the name of which is the name of the original field postfixed by underscore and 2-character language code. The information system features special data input elements supporting multi languages. Language codes are listed next to data input elements and selection of a language from the list results the value of the input field to change reflecting the value in the selected language (Figure 4.8). If a form containing multilingual input elements is submitted, values in all languages are processed and sent to the server concurrently.



(a) English (b) Turkish

Figure 4.8: Multilingual data input

Multilingual support of the information system is valuable from several aspects. Firstly, it allows information that is not available in local language to be used without any confusion. For example, chemical names in English are generally available from many sources, including electronic databases and online web sites. However, there is no such resource for chemical names in Turkish. Hence, if one wants to work with or needs to reference to high number of chemicals, which is the case for the current information system, use of English names is a necessity. A solution to this problem could be entering English names as if they are Turkish. However, this results in a mixture of names which are difficult to separate later. Multilingual support of the information system solves this problem in a convenient way by supplying missing information in one language with the one available in other language without mixing them.

Another advantage of the multilingual support is the ability of generating reports in various languages. Information available in or calculated by the information system can be reported in Turkish for national needs. Without any additional process steps, the same reports can also be obtained in another languages such as English and can be used to fulfill international obligations and requirements.

4.3.7 Mapping

Geographic location information is an important and integral part of technological accident related studies. Such information can be used to display geographic distribution of past accidents and reveal accident prone zones. Accidents involving toxic, explosive and flammable substances generally have off-site consequences as well, the extent of which can be best shown on maps. Besides already affected areas, results of accident models can be overlayed on the map to determine areas that may be affected from adverse effects such as overpressure, heat wave and exposure to hazardous substances over thresholds limits. Hence, availability of mapping tools is a requirement for decision support and information systems and modeling frameworks on technological accidents.

Taking this requirement into consideration, an open source Internet map server called MapServer has been integrated to the information system in the early stages of the development. Originally developed by the University of Minnesota (UMN) in cooperation with NASA and Minnesota Department of Natural Resources, MapServer supports a multitude of raster and vector data formats and features advanced cartographic output [55].

Landsat GeoCover 2000/ETM+ satellite images from Global Land Cover Facility (GLCF) of University of Maryland sponsored by U.S. NASA were used to form the base map for MapServer [56]. Being freely available, these satellite images provided approximately 15m ground resolution (1:50.000 scale) in color and offered up-to-date spatial information on settlements, water resources, vegetation and also large industrial areas and establishments. Eight Landsat GeoCover 2000/ETM+ mosaics covering Turkey were provided from the GLCF, re-projected into Lambert Conformal Conic map projection from their original Universal Transverse Mercator projection, merged into a single image, cropped to the study area boundaries and finally compressed into Enhanced-Compression Wavelet (ECW) format to decrease storage requirement and facilitate rapid map serving. Data preparation and processing took several days and resulted in a compressed image of 1.5Gb in size, whereas uncompressed size was more than 30Gb. For easy navigation and location finding, 1:250.000 scale vector province and district maps were also provided in addition to Landsat ETM+ satellite imagery.

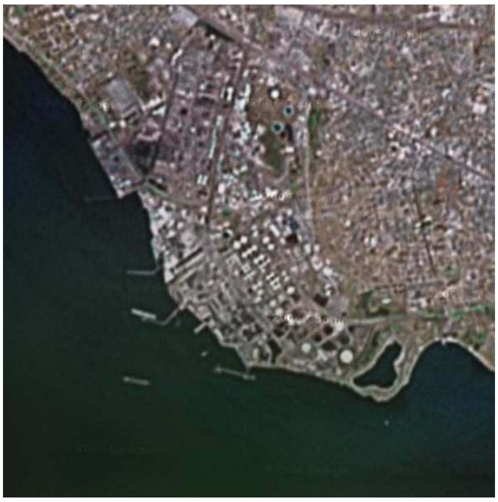
During the development period of the information system, web mapping technology evolved significantly and major IT companies such as Google, Yahoo and Microsoft initiated free web mapping services providing world-wide data including high-resolution satellite images and thematic maps for majority of the urbanized areas of the World [51, 57, 58]. These services not only show maps on their own sites, but also provide programming libraries and interfaces that allow integration of mapping services into external web sites. Although UMN MapServer together with Landsat GeoCover 2000/ETM+ satellite imagery was adequate for basic mapping purposes, evaluation of web services provided by aforementioned companies revealed that those services can be easily integrated to the information system, feature more advanced and user friendly interfaces for map navigation, and provide more detailed and up-to-date maps.

In order to illustrate the improvement in the image quality, comparison of Landsat GeoCover 2000/ETM+ and Google Maps satellite images for two regions of primary interest, TÜPRAŞ İzmit and Aliağa Refineries, are given in Figure 4.9. Map scale is set as the raster resolution scale (i.e. scale with highest detail) of the Landsat images.

As it can be seen from Figure 4.9a and Figure 4.9b, detail of satellite imagery provided by Google Maps is not uniform and varies from location to location. Images are almost identical for the Gulf of İzmit, where TÜPRAŞ İzmit Refinery is located. General layout of the refinery is visible, however details of process units and storage tanks are not distinct in both images. In case of Aliağa Refinery, Google Maps is clearly superior over Landsat imagery with more detailed image provided (Figure 4.9c and Figure 4.9d). Improvement of the image quality is much more clear when Google Maps image is displayed at its full resolution scale, as shown in Figure 4.10. At this scale every process unit, even pipings, are distinct and dimensions can be measured. Currently there is no national map source available with this much detail. Even if there would be such a source, the cost of data would have been definitely very high since none of the national map sources are freely available.

In general, Google Maps is found to be superior to existing UMN MapServer and Landsat GeoCover 2000/ETM+ solution for web mapping purposes. Therefore, in the final stages of the development period, mapping component is changed from UMN MapServer to Google Maps. In order to increase ease of use, a custom windowing interface has been developed, which allow map display having a fixed dimension and position on the page to be undocked from its location and resized freely. Ability to enlarge map display size without effecting other data entry elements greatly enhances user friendliness of the mapping component and facilitates marking locations on the

(a) Landsat ETM+, İzmit Refinery



(b) Google Maps, İzmit Refinery

(c) Landsat ETM+, Aliağa Refinery

(d) Google Maps, Aliağa Refinery

Figure 4.9: Comparison of Landsat EMT+ and Google Maps data

Figure 4.10: Detail of map resolution in Google Maps, Aliağa Refinery

map. Docked and undocked states of the map window are illustrated in Figure 4.11

Mapping component is primarily used by the accident subsystem for designation of geographic locations of accidents. The component is linked to province and district inputs of data entry forms. The information system has built-in lists of provinces and districts with data on geographic boundaries thereof. Once a province or district is selected, boundary information is retrieved from the server and map extents are updated to display the selected administrative unit.

Locations can be marked on the map as points or rectangular areas depending on the record types. Industrial facilities, military fields and mines can be marked as rectangular areas, whereas locations of marine, road, pipeline and urban accidents can be marked as points. Point locations can be selected on the map by a single mouse click and can be easily moved by dragging the marker. For rectangular areas, a custom extension has been developed for Google Maps that allows rectangular areas to be drawn on the map. Rectangular areas can be resized by dragging upper left and lower right boundary markers and can be moved by dragging central marker. Mapping tools are available for expanding, contracting, zooming and removing rectangular areas (Figure 4.11). Latitude and longitude of the marked location are indicated on the corresponding data form elements. Users can modify coordinate information by entering latitude and longitude values manually. Map is updated automatically to display manually entered location. To facilitate manual entry of coordinate information, mapping component allows coordinates to be entered as decimal degrees, degrees-minutes-seconds or degrees-minutes-decimal seconds formats. Format of the coordinates is automatically determined by the system and converted into decimal degrees during data storage. If there is an uncertainty in the coordinates, uncertainty flag shown by a question mark next to the coordinate input elements can be set.

Mapping component is also used to display results of hazardous gas dispersion, explosion and fire models of the information system. Details on models and use of mapping component for display of output data are given in Chapter 6.

4.3.8 Record Relations

Another important feature of the information system is its ability to define relations between different record types. In addition to implicity related records, such as industrial facilities and industrial accidents, or mines and mining accidents, records can also

(a) Docked

(b) Undocked

Figure 4.11: States of map window gadget

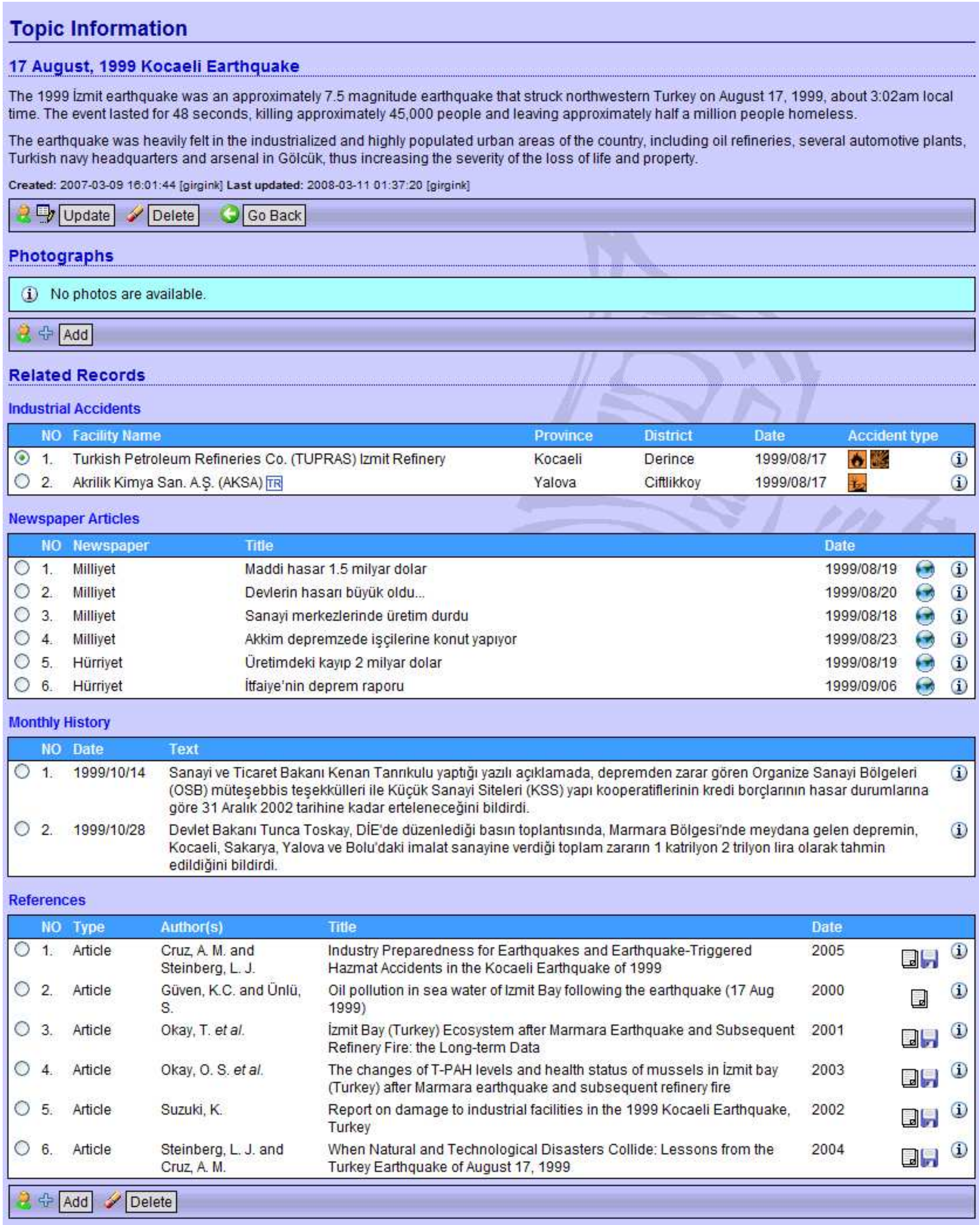
be made related to each other explicitly. Owing to this feature, various accidents can be grouped under a topic or many document records can be linked to an accident.

Record relation mechanism implemented by the system allow one record to be related to multiple records. For example, major fire incident that happened at TÜPRAŞ İzmit Refinery in 1999 can be made related to both İzmit Bay and 1999 Kocaeli Earthquake topics. Relations between the records are bi-directional, i.e. it is possible to access one record from the other and vice versa. Related records are listed on the information pages of records as grouped by record types. An example of related record listing is given in Figure 4.12.

Editors are allowed to create relations among records regardless of the ownership or lock status thereof. Existing relations can not be modified, but creators (owners) have the right to delete the relations. In order to add a new relation, "Add Relation" button should be clicked on the base record's information page and type of the other record should be selected from the list provided by the system. According to the selected record type, the information system lists all available records, from which the user may select the related record.

Record relation mechanism is limited to selected record types and there are some restrictions on pairs of record types that can be related to each other. Relatable record types are divided into three classes, namely document, accident and location records. Since there are implicit relations between location and accident records, they are not allowed to be related each other using external relation mechanism. This prevents unlogical relations to be created, such as a relation between a military accident and a mine. Relatable record classes are given in Table 4.3, whereas individual record types that support relations are listed in Table 4.4.

Record relation mechanism is an important component of the document subsystem and links this subsystem to other subsystems. The primary aim of document records is to provide information on other records, such as accidents, facilities or chemicals. Hence, a document record that is not related to any other record is a passive member of the information system. Document subsystem and records thereof reveal their strength with record relation mechanism.



Topic Information

17 August, 1999 Kocaeli Earthquake

The 1999 İzmit earthquake was an approximately 7.5 magnitude earthquake that struck northwestern Turkey on August 17, 1999, about 3:02am local time. The event lasted for 48 seconds, killing approximately 45,000 people and leaving approximately half a million people homeless.

The earthquake was heavily felt in the industrialized and highly populated urban areas of the country, including oil refineries, several automotive plants, Turkish navy headquarters and arsenal in Gölcük, thus increasing the severity of the loss of life and property.

Created: 2007-03-09 16:01:44 [girgink] **Last updated:** 2008-03-11 01:37:20 [girgink]

Update Delete Go Back

Photographs

No photos are available.

Add

Related Records

Industrial Accidents

NO	Facility Name	Province	District	Date	Accident type
1.	Turkish Petroleum Refineries Co. (TUPRAS) Izmit Refinery	Kocaeli	Derince	1999/08/17	
2.	Akrilik Kimya San. A.Ş. (AKSA) TR	Yalova	Ciftlikkoy	1999/08/17	

Newspaper Articles

NO	Newspaper	Title	Date
1.	Milliyet	Maddi hasar 1.5 milyar dolar	1999/08/19
2.	Milliyet	Devlerin hasarı büyük oldu...	1999/08/20
3.	Milliyet	Sanayi merkezlerinde üretim durdu	1999/08/18
4.	Milliyet	Akkim depremzede işçilerine konut yapıyor	1999/08/23
5.	Hürriyet	Üretimdeki kayıp 2 milyar dolar	1999/08/19
6.	Hürriyet	İtfaiye'nin deprem raporu	1999/09/06

Monthly History

NO	Date	Text
1.	1999/10/14	Sanayi ve Ticaret Bakanı Kenan Tanrıkulu yaptığı yazılı açıklamada, depremden zarar gören Organize Sanayi Bölgeleri (OSB) müteşebbis teşekkülleri ile Küçük Sanayi Siteleri (KSS) yapı kooperatiflerinin kredi borçlarının hasar durumlarına göre 31 Aralık 2002 tarihine kadar erteleneceğini bildirdi.
2.	1999/10/28	Devlet Bakanı Tunca Toskay, DİE'de düzenlediği basın toplantısında, Marmara Bölgesi'nde meydana gelen depremin, Kocaeli, Sakarya, Yalova ve Bolu'daki imalat sanayine verdiği toplam zararın 1 katrilyon 2 trilyon lira olarak tahmin edildiğini bildirdi.

References

NO	Type	Author(s)	Title	Date
1.	Article	Cruz, A. M. and Steinberg, L. J.	Industry Preparedness for Earthquakes and Earthquake-Triggered Hazmat Accidents in the Kocaeli Earthquake of 1999	2005
2.	Article	Güven, K.C. and Ünlü, S.	Oil pollution in sea water of Izmit Bay following the earthquake (17 Aug 1999)	2000
3.	Article	Okay, T. *et al.*	İzmit Bay (Turkey) Ecosystem after Marmara Earthquake and Subsequent Refinery Fire: the Long-term Data	2001
4.	Article	Okay, O. S. *et al.*	The changes of T-PAH levels and health status of mussels in İzmit bay (Turkey) after Marmara earthquake and subsequent refinery fire	2003
5.	Article	Suzuki, K.	Report on damage to industrial facilities in the 1999 Kocaeli Earthquake, Turkey	2002
6.	Article	Steinberg, L. J. and Cruz, A. M.	When Natural and Technological Disasters Collide: Lessons from the Turkey Earthquake of August 17, 1999	2004

Add Delete

Figure 4.12: Example listing of related records

Table 4.3: Relatable record classes

	Document	Accident	Location
Document	$\surd$	$\surd$	$\surd$
Accident	$\surd$	$\surd$	
Location	$\surd$		

Table 4.4: Record types grouped by record classes

Record class	Record type
Location	Facility
	Military Field
	Mine
	Pipeline
	Road
Accident	Industrial Accident
	Marine Accident
	Military Accident
	Mine Accident
	Pipeline Accident
	Road Accident
	Urban Accident
Document	Newspaper Article
	Note
	Reference
	Topic
	Video
	Webpage
	Yearbook Entry

4.3.9 Fuzzy Dates and Times

Especially for past accidents, of which limited information is available, date and time of occurrence may not be known exactly. Although it is common to have year and month information, day of month data is sometimes missing. It is also rare to have exact starting times of accidents, since they are generally given as approximate values rounded to nearest hour or half hour. Time information may be available as rough textual descriptions as well, such as "in the morning", "about the evening", "around midnight". Ending times are mostly not stated explicitly, but should be inferred from duration information which is itself fuzzy and approximate. Enforcing the users to enter exact date and time, without giving means of indicating uncertainty, may result in estimated or assumed values to be perceived as actual values by other users. In the opposite, leaving date and time fields blank in case of uncertainty may result in lack of information although it is partially available.

In order to get rid of difficulties mentioned above, the information system supports partial and fuzzy date and times. Besides complete dates including year, month and day information, partial dates containing only year and month, or year alone can be entered in the date fields. Uncertain dates can be indicated by a question mark at the end, whereas approximate dates can be indicated by a tilde at the beginning of a date. Similar to dates, time information can also be entered partially with hour information only. Uncertain and approximate time values are supported. Examples of fuzzy date and time values are given in Table 4.5.

4.3.10 Fuzzy Numbers and Statistics

Similar to dates, uncertainties also present for quantitative data on accident consequences. Although number of people died or severely injured as result of an accident are mostly known in exact figures, number of lightly injured or evacuated people are generally stated as approximate values like "about fifty" or "more than five thousand". Number and extent of damaged buildings, durations of interruptions in public services such as telecommunication, transportation and electricity, amount of material losses, and many other quantitative measures of accident consequences can only be specified with explicit uncertainty.

Although not as frequent as accidents, there are also cases for chemicals in which

Table 4.5: Examples of fuzzy date and time values

Date	Description
1998/06/12	12th June, 1998 (exact)
1998/06/12?	12th June, 1998 (uncertain)
~1998/06/12	about 12th June, 1998
1998/06	June, 1998
1998/06?	June, 1998 (uncertain)
1998	1998
Time	**Description**
14:20	2:20 PM (exact)
14:20?	2:20 PM (uncertain)
~14:30	about 2:30 PM
~14:30?	about 2:30 PM (uncertain)
~12	about noon

available scientific data is not exact. Considering limits of instrumental analysis, embedded uncertainty of measurement methods or errors in measurements, chemical property data may be given as range of values or boundary values such as $2.0-2.2$, $< 10^{-3}$ or ≥ 0.8. Converting such data values into exact values may result in loss of precision.

Taking all these into consideration, the information system allows fuzzy numbers to be entered to selected numerical data fields and conducts numerical calculations on these fields using fuzzy arithmetic. Signed and unsigned integer, decimal and scientific fuzzy numbers are supported.

Trapezoidal Fuzzy Numbers

If Ω is some set, then a fuzzy number $\overline{A}$ defines a subset of Ω by its membership function $\overline{A}(x)$, which produces values in $[0,1]$ for all x in Ω [59]. So, $\overline{A}(x)$ is a function mapping Ω into $[0,1]$. If $\overline{A}(x_0) = 1$, then x_0 belongs to $\overline{A}$, if $\overline{A}(x_1) = 0$ x_1 does not belong to $\overline{A}$, and if $\overline{A}(x_2) = 0.6$ the membership value of x_2 in $\overline{A}$ is 0.6 which is denoted by α. An example triangular shaped fuzzy number is given in Figure 4.13

Taking simple requirements of the information system and insufficient availability of detailed fuzziness information of data into consideration, trapezoidal fuzzy numbers are used to represent fuzzy values. A trapezoidal fuzzy number $\overline{M}$ is defined by four numbers $a \leq b \leq c \leq d$ where the base of the trapezoid is the interval $[a,d]$ and its

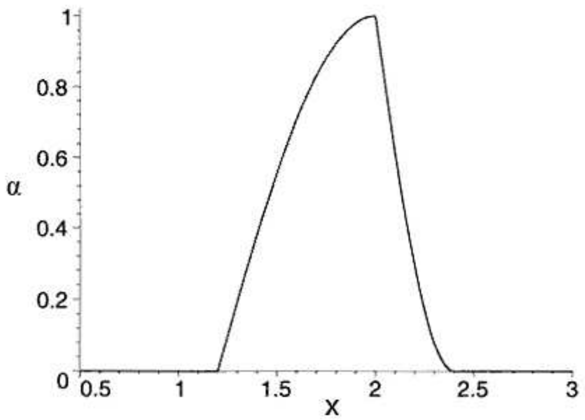


Figure 4.13: Triangular shaped fuzzy number

core (top) is the interval $[b, c]$.

Five different fuzzy number types are defined, which describe little than, greater than, in between, about and exact value conditions that are frequently encountered in accident statistics. Since case specific fuzziness information is generally not available, triangular fuzzy numbers with constant slopes are used to define less than, greater than and about conditions. A value of 10% is selected as the default fuzziness amount, which results in 10% slope for one sided conditions (little than and greater than) and 5% slope at each sides for the two sided condition (about). Examples of fuzzy numbers supported by the system are given in Table 4.6.

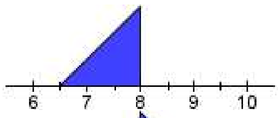
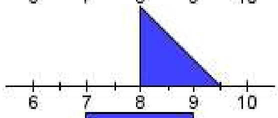
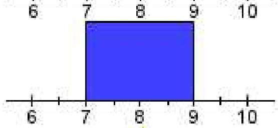
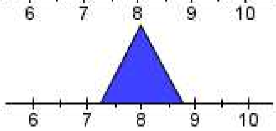
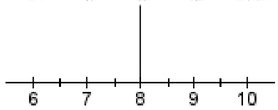
Interval Arithmetic

Fuzzy number calculations of the information system are based on closed interval arithmetic. A closed interval is a bounded interval containing all numbers from lower bound to upper bound, inclusive and defined as:

$$[a, b] = \{x \in \mathbb{R}, a \leq x \leq b\} \tag{4.1}$$

Where classical arithmetic defines operations on individual numbers, interval arithmetic defines a set of operations on intervals. An operation in interval arithmetic is

Table 4.6: Fuzzy number type supported by the information system

Fuzzy number	Description		Definition
< 8	Less than 8		[7.2,8.0,8.0,8.0]
> 8	Greater than 8		[8.0,8.0,8.0,8.8]
$7 - 9$	Between 7 and 9		[7.0,7.0,9.0,9.0]
~ 8	About eight		[7.6,8.0,8.0,8.4]
8	Exactly eight		[8.0,8.0,8.0,8.0]

defined as [60]:

$$[a, b] \odot [c, d] = [Min(a \odot c, a \odot d, b \odot c, b \odot d), Max(a \odot c, a \odot d, b \odot c, b \odot d)] \quad (4.2)$$

Based on Equation 4.2, basic operations of interval arithmetic are defined as follows:

$$[a, b] + [c, d] = [a + c, b + d] \quad (4.3)$$

$$[a, b] - [c, d] = [a - d, b - c] \quad (4.4)$$

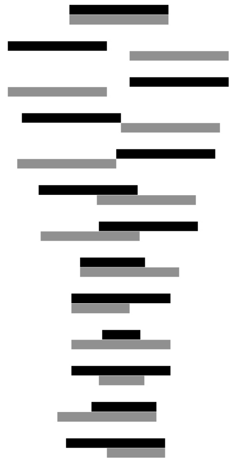
$$[a, b] \times [c, d] = [Min(ac, ad, bc, bd), Max(ac, ad, bc, bd)] \quad (4.5)$$

$$[a, b]/[c, d] = [Min(a/c, a/d, b/c, b/d), Max(a/c, a/d, b/c, b/d)] \quad (4.6)$$

Similar to arithmetic operations, relations between intervals are also special and different from ordinary (point-like) numbers. Whereas there are only three elementary relations between two ordinary numbers (little than, equal and greater than), there are many relations between two intervals according to the degree of overlap. There is no single, well established standard for naming and definition of relations [60]. Therefore, a custom set of 13 relations are used for calculations in the information system. Conditions of relations are listed and illustrated in Table 4.7.

Table 4.7: Relations of two intervals $[a, b]$ and $[c, d]$

Relation	Operator	Condition
Equals	eq	$a = c \wedge b = d$
Less than	lt	$b < c$
Greater than	gt	$a > d$
Meets	m	$b = c$
Met by	mi	$a = d$
Overlaps	o	$a < c \wedge c < b < d$
Overlapped by	oi	$a > c \wedge b > d > a$
Starts	s	$a = c \wedge b < d$
Started by	si	$a = c \wedge b > d$
During	d	$a > c \wedge b < d$
Contains	di	$a < c \wedge b > d$
Finishes	f	$b = d \wedge a > c$
Finish by	fi	$b = d \wedge a < c$



In order to sort a set of intervals in the ascending or descending order, which is a requirement for statistical calculations, intervals should be compared to each other in pairs and a decision should be made on whether the elements of a pair are equal or not. If they are not equal, larger (or smaller) element of the pair should also be determined. Similar to the case of relations, there is no universally accepted way to do this [59]. The approach followed in this study is to convert interval relations into ordinary relations, which makes ordering straightforward as if intervals are real numbers. Relation mappings given in Table 4.8 are used for this purpose.

Table 4.8: Mapping of interval relations to ordinary relations

Interval Relation	Ordinary Relation
lt, m, o, s, fi	$<$
gt, mi, oi, si, f	$>$
eq	$=$
d, di	$> \mid \; a + b > c + d$
	$< \mid \; a + b < c + d$

Fuzzy Arithmetic

An operation in fuzzy arithmetic can be defined by using interval arithmetic as:

$$\overline{A} \odot \overline{B} = Base(\overline{A}) \odot Base(\overline{B}) \cup Core(\overline{A}) \odot Core(\overline{B}) \tag{4.7}$$

where $Base$ is the base of the fuzzy number, $Core$ is the core of the fuzzy number, and:

$$\overline{A} = [a_1, b_1, c_1, d_1]$$
$$\overline{B} = [a_2, b_2, c_2, d_2]$$

Based on Equation 4.7, the information system is capable of doing fuzzy arithmetic using Equations 4.2- 4.6. Fuzzy arithmetic is mainly used for calculating fuzzy statistics. Given a set of fuzzy numbers, sum, mean, geometric mean, maximum, minimum, range, 1st quartile, 3rd quartile, interquartile range, interquartile mean, and mild and extreme outliers can be calculated as fuzzy numbers. Values in the set can also be ordered from the smallest to the largest according to Table 4.8. The system is capable of calculating point estimates of fuzzy values by finding center of weights of the trapezoids. Fuzzy number represented by 4 real numbers can be simplified as well.

An example fuzzy statistics illustrating the fuzzy arithmetic capabilities of the information system is given in Table 4.9.

Table 4.9: Example fuzzy statistics

```
Fuzzy values:
-------------------------------------------------------------------------------
 20         5-8         <15         ~30        4       25-30         >35      6-10?
~15          22       50-60        <20?      >10       16-18         >12         9?


                                                            Simple        Point
Fuzzy statistics:                                           Fuzzy:        Value:
-------------------------------------------------------------------------------
n                      = 16
Sum                    = [282.50,294.00,318.00,333.90]                   307.23
Mean                   = [ 17.66, 18.38, 19.88, 20.87]                    19.20
Geometric Mean         = [ 14.22, 14.82, 16.23, 17.99]                    15.57
Max                    = [ 50.00, 50.00, 60.00, 60.00]     50-60          55.00
Min                    = [  4.00,  4.00,  4.00,  4.00]     4               4.00
Median                 = [ 14.75, 15.50, 16.50, 17.25]                    16.00
                         (Average of ~15 and 16-18)
Range                  = 56

1st Quartile           = [  9.75,  9.75,  9.75, 11.25]                    10.25
                         (Average of 9? and >10)
3rd Quartile           = [ 22.75, 22.75, 24.00, 24.00]     22.75-24       23.38
                         (Average of 22 and 25-30)
Interquartile Mean     = [ 14.21, 15.43, 15.71, 16.56]                    15.45
Quartile Range         = 14.25

Mild Outlier Limits    = < [-11.63,-11.63,-11.63,-10.13]                 -11.13
                         > [ 44.13, 44.13, 45.38, 45.38]   44.13-45.28    44.75
Extreme Outlier Limits = < [-33.00,-33.00,-33.00,-31.50]                 -32.50
                         > [ 65.50, 65.50, 66.75, 66.75]   65.5-66.75     66.13

Mild Outliers
-------------------------------------------------------------------------------
50-60

Extreme Outliers
-------------------------------------------------------------------------------
None

List of In-Quartile Values
-------------------------------------------------------------------------------
20, <15, ~15, <20?, >10, 16-18, >12

Ordered List of Values
-------------------------------------------------------------------------------
4, 5-8, 6-10?, 9?, >10, >12, <15,~15, 16-18, <20?, 20, 22, 25-30,~30, >35, 50-60
```

4.4 Accident Subsystem

In order to learn lessons and develop accident prevention measures, past industrial accidents should be analyzed from multiple aspects. Technical reports prepared after the accidents usually provide basic information for such analyses. However, due to lack of obligatory reporting regulations or difficulties in accessing to such reports, it is also common to make use of other information sources. This is even a necessity to access non-technical information, such as extent and nature of public reaction, social and political impacts, and juridical progress resulting in penalties due to adverse effects. Information sources used for these purposes can be of various types, diverse in quantity, and widen in a long time period. This emphasizes the importance of management of information and data.

Coupled with the document subsystem, accident subsystem of the information system aims to facilitate effective collection and analysis of accident information. Although primary focus is on industrial accidents, the subsystem has been designed to cover different types of technological accidents as well. Accident types supported by system are listed in Table 4.10.

Table 4.10: Accident types supported by the information system

Accident type	Description
Industrial	Accidents that occurred in industrial facilities, where dangerous substances are produced and/or stored.
Military	Accidents that occurred in military facilities, where explosive and flammable substances are stored, such as arsenals and munition warehouses.
Pipeline	Accidents that occurred during transportation of dangerous substances through pipelines.
Land	Accidents that occurred during transportation of dangerous substances through roads and highways.
Marine	Accidents that occurred during marine transportation.
Mining	Major accidents that occurred during mining activities.
Urban	Major disasters with technological origin, such as explosions and fires, that occurred in urbanized areas and city centers.

4.4.1 Industrial Accidents

Basic information on industrial accidents include location, date and accident type data (Figure 4.14). Industrial facilities stored in the facility subsystem can be selected as the location of the accident. Details on industrial facilities are given in Section 4.7.1. The starting and ending date and time of the accident can be specified. Date and time fields support fuzzy values as explained in Section 4.3.9. Duration information is automatically calculated. Type of the accident can be indicated as fire, explosion or spill of toxic substance. Combinations of accident types are also possible, such as concurrent fire and toxic substance spill.

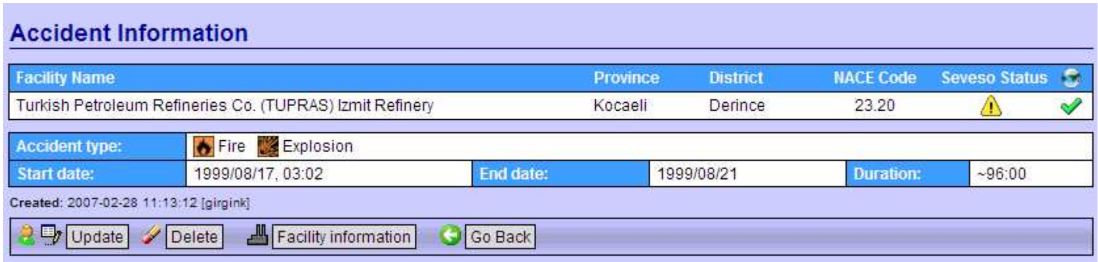


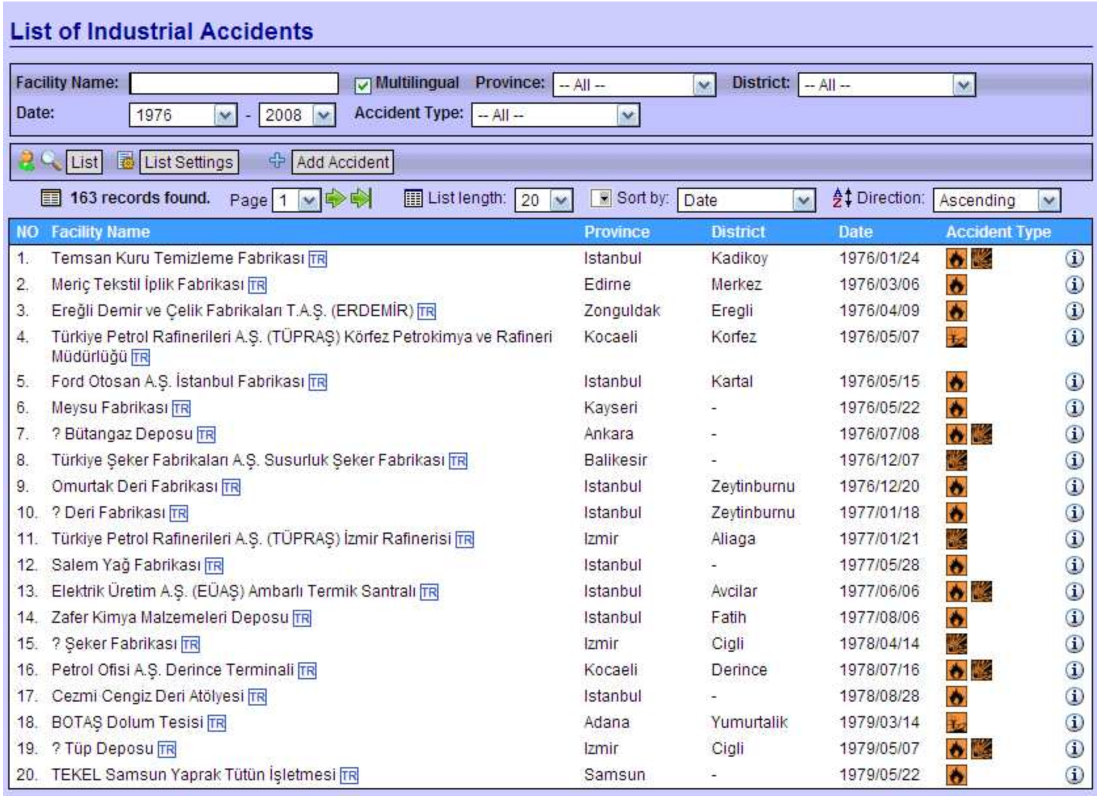
Figure 4.14: Basic industrial accident information

Industrial accidents can be listed according to several criteria, including name, province and district of the industrial facility, and type and date of the accident. Multilingual facility names are supported in queries (Figure 4.15).

In addition to basic accident information, detailed information on the following aspects of industrial accidents can be systematically stored in the information system:

- Occurence, including list of initiating, major and associated events,
- Nature and amount of hazardous substances involved,
- Consequences, including extent of effected areas, harm to human health, environment and property, community life disruption, and material losses.

Taking a possible collaboration in the future, industrial accident related data fields of the information system are made compatible with the MARS database of the EU [35].



List of Industrial Accidents

Facility Name: [ ] Multilingual Province: -- All -- District: -- All --
Date: 1976 - 2008 Accident Type: -- All --

List | List Settings | Add Accident

163 records found. Page 1 List length: 20 Sort by: Date Direction: Ascending

NO	Facility Name	Province	District	Date	Accident Type
1.	Temsan Kuru Temizleme Fabrikası TR	Istanbul	Kadikoy	1976/01/24	
2.	Meriç Tekstil İplik Fabrikası TR	Edirne	Merkez	1976/03/06	
3.	Ereğli Demir ve Çelik Fabrikaları T.A.Ş. (ERDEMİR) TR	Zonguldak	Eregli	1976/04/09	
4.	Türkiye Petrol Rafinerileri A.Ş. (TÜPRAŞ) Körfez Petrokimya ve Rafineri Müdürlüğü TR	Kocaeli	Korfez	1976/05/07	
5.	Ford Otosan A.Ş. İstanbul Fabrikası TR	Istanbul	Kartal	1976/05/15	
6.	Meysu Fabrikası TR	Kayseri	-	1976/05/22	
7.	? Bütangaz Deposu TR	Ankara	-	1976/07/08	
8.	Türkiye Şeker Fabrikaları A.Ş. Susurluk Şeker Fabrikası TR	Balikesir	-	1976/12/07	
9.	Omurtak Deri Fabrikası TR	Istanbul	Zeytinburnu	1976/12/20	
10.	? Deri Fabrikası TR	Istanbul	Zeytinburnu	1977/01/18	
11.	Türkiye Petrol Rafinerileri A.Ş. (TÜPRAŞ) İzmir Rafinerisi TR	Izmir	Aliaga	1977/01/21	
12.	Salem Yağ Fabrikası TR	Istanbul	-	1977/05/28	
13.	Elektrik Üretim A.Ş. (EÜAŞ) Ambarlı Termik Santralı TR	Istanbul	Avcilar	1977/06/06	
14.	Zafer Kimya Malzemeleri Deposu TR	Istanbul	Fatih	1977/08/06	
15.	? Şeker Fabrikası TR	Izmir	Cigli	1978/04/14	
16.	Petrol Ofisi A.Ş. Derince Terminali TR	Kocaeli	Derince	1978/07/16	
17.	Cezmi Cengiz Deri Atölyesi TR	Istanbul	-	1978/08/28	
18.	BOTAŞ Dolum Tesisi TR	Adana	Yumurtalik	1979/03/14	
19.	? Tüp Deposu TR	Izmir	Cigli	1979/05/07	
20.	TEKEL Samsun Yaprak Tütün İşletmesi TR	Samsun	-	1979/05/22	

Figure 4.15: List of industrial accidents

Accident Occurrence

Occurrence of an accident can be described in the information system by listing series of events that occurred at different stages of the accident. The system includes a predefined set of events, which are listed in Table 4.11. Events can be grouped according to their nature as follows:

- Chemical release to the environment
- Fire (pool fire, jet flame, etc.)
- Explosion (BLEVE, dust explosion, etc.)
- Release of combustion products and firewater runoff

Following the methodology used in the MARS database, events are also classified as initiating, major occurrence and associated events. Initiating events are events which cause the accident, whereas major occurrence events are events with greatest amount

Table 4.11: Accident events

Code	Event
1101	Gas/vapour/mist/etc. release to air
1102	Fluid release to ground
1103	Fluid release to water
1104	Solid release to ground
1105	Solid release to water
1201	Conflagration (a general engulfment fire)
1202	Pool fire (burning pool of liquid, contained or uncontained)
1203	Jet flame (burning jet of fluid from orifice)
1204	Flash fire (burning vapour cloud, subsonic flame front)
1205	Fireball (burning mass rising in air, often after BLEVE)
1301	Pressure burst (rupture of pressure system)
1302	BLEVE (boiling liquid expanding vapour explosion)
1303	Rapid phase-transition explosion (rapid change of state)
1304	Runaway reaction explosion (usually exothermic)
1305	Dust explosion
1306	Explosive decomposition (of unstable material)
1307	VCE (vapour cloud explosion, supersonic wave front)
1401	Combustion products into air
1402	Combustion products into ground
1403	Combustion products into water
1404	Firewater runoff into ground
1405	Firewater runoff into water
1999	Other

of adverse consequences. Associated events are secondary events with noteworthy, but little effects compared to major occurrences. By selecting appropriate pairs of events and event classes, an ordered list of events describing the occurrence of the accident can be obtained (Figure 4.16).

There is no restriction on the classification of events. Hence, they can be put into all classes regardless of their nature. An event can also be listed multiple times. But there should be no duplicate events in a class, i.e. an event should be in a particular class each time. For example, the event of gas release to air can be both an initiating event and a major occurrence of an accident. In addition to the list of events, textual description of the occurrence can also be entered (Figure 4.16).

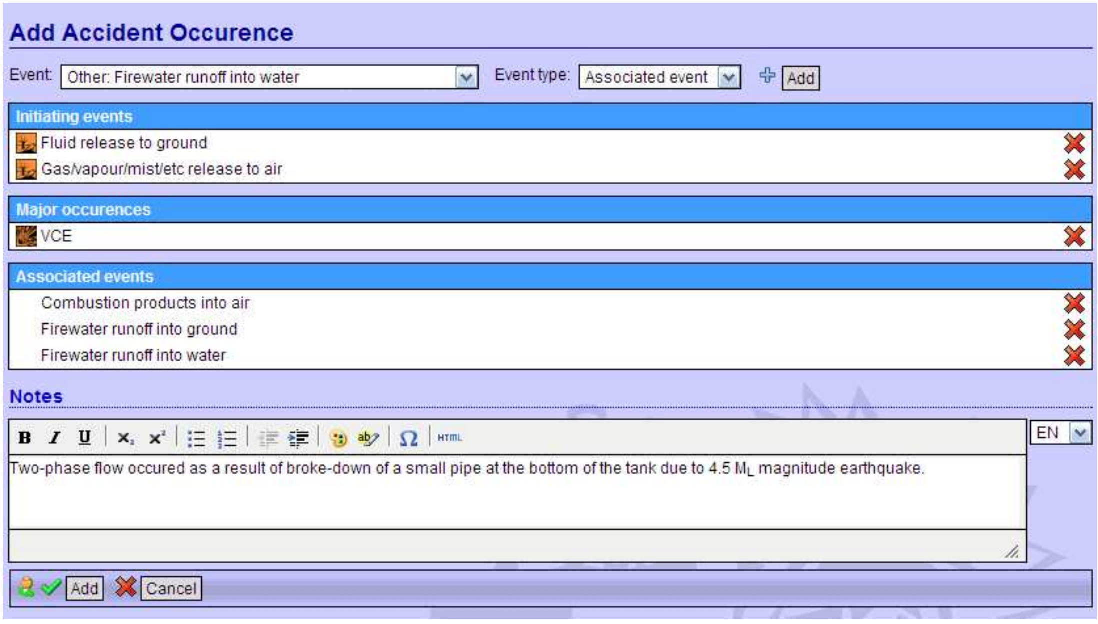


Figure 4.16: Accident occurence data entry form.

Chemicals Involved

The information system allows substances involved in the accident to be specified quantitatively. More than one chemical or UN/ADR explosive substance can be specified for an accident, with their purpose of use in the production process and role in the accident.

Possible chemical uses are as follows:

- Starting material,
- On-site intermediate,
- Normal finished product,
- Possible abnormal product,
- Unknown.

For each substance, not only the actual quantity involved in the accident, but also the quantity that was present in the unit during the accident (potential quantity) and the overall quantity that present in the facility during the accident (total quantity) can be specified (Figure 4.17). These quantities can be used as measures of how worse the consequences could have been if there is no mitigation or timely response.

Fuzzy values can be entered for quantities and units thereof can be specified. Whether the chemical is directly involved in the accident (i.e. primary substance responsible from adverse consequences) or not can be stated. Textual notes can also be entered for each substance.

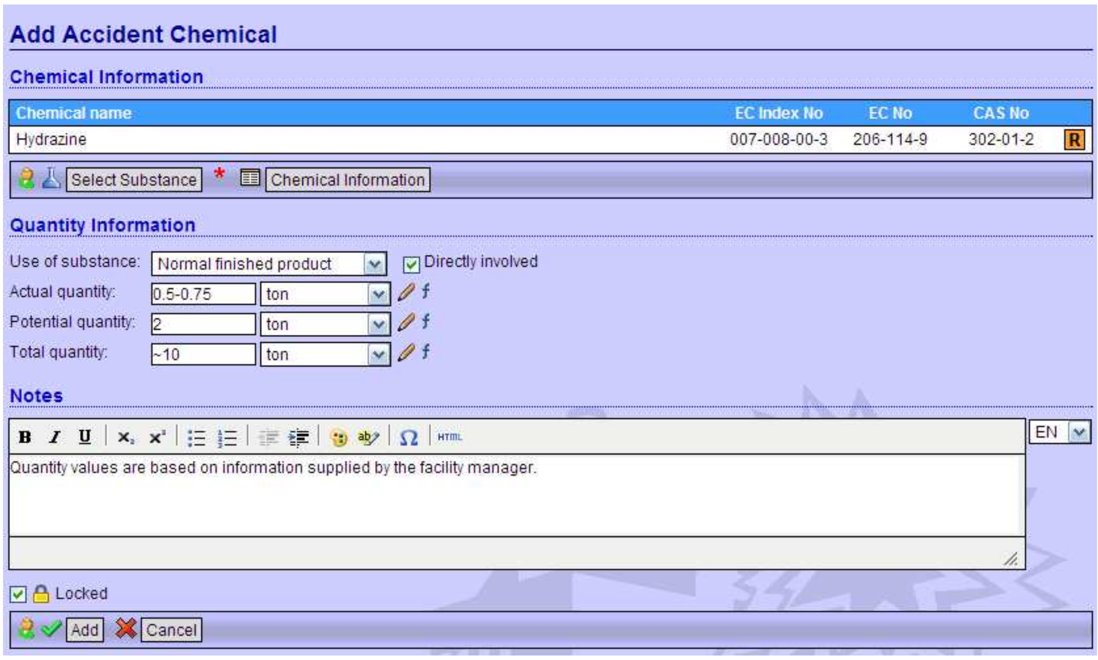
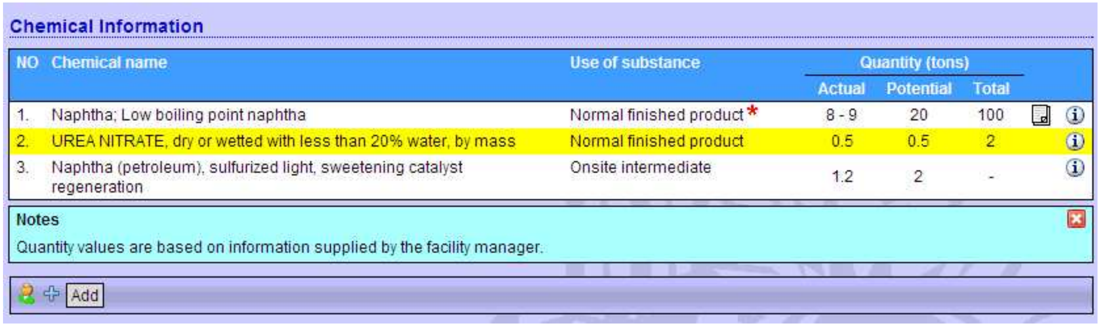


Figure 4.17: Accident substance data entry form.

All substances involved in an accident are listed under "Chemical Information" section of the accident information page by substance name and type of use (Figure 4.18). Directly involved substances are indicated with an asterisk. Actual, potential and total quantities are converted into tonnes to allow easy comparison. Substances having custom notes are also specified.


Chemical Information

NO	Chemical name	Use of substance	Quantity (tons) Actual	Potential	Total
1.	Naphtha; Low boiling point naphtha	Normal finished product *	8 - 9	20	100
2.	UREA NITRATE, dry or wetted with less than 20% water, by mass	Normal finished product	0.5	0.5	2
3.	Naphtha (petroleum), sulfurized light, sweetening catalyst regeneration	Onsite intermediate	1.2	2	-

Notes
Quantity values are based on information supplied by the facility manager.

Add

Figure 4.18: List of chemicals involved in an accident

Accident Consequences

The information system features detailed data entry forms for consequences of industrial accidents, which are divided into five major sections as listed below:

- Areas affected
- People affected
- Community life disruptions
- Ecological harms
- Material losses

Areas affected section includes information on the extents of an accident. Five levels of impact zones have been defined to specify the extent of effects, which are installation, establishment, local, regional and transboundary levels. Installation level indicates that damage is limited to process units only (e.g. capsizing of a storage tank), whereas establishment level means that entire facility has been affected (e.g. collapse of majority of the units). Local level shows that the accident affected areas beyond the establishment boundaries and off-site consequences present, such as cracks on the walls of neighbouring buildings. Regional level represents an impact area covering several settlements or considerable amount of land. The accident which had occurred in Seveso, Italy on July 10, 1976 (Seveso Disaster) involving 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) can be given as an example of an accident having regional effects [4]. If effects of the accident goes beyond the country boundaries, transboundary level should be specified. Failure of a tailing dam containing wastewater contaminated with cyanide and heavy metals at Baia Mare, Romania on January 30, 2000 can be given as an example [61]. For each level of impact zones, degree of effects can be designated as no effect, suspected effect or affected. If no information is available on a specific level, it can be left as unknown (Figure 4.19).

People affected section includes information on consequences of an accident on human health. Three groups of target populations has been defined, which are staff of the establishment, emergency personnel (hazmat, fire brigade and first response units) and off-site population. For each group, number of dead (immediate and subsequent), injured (slight and hospitalizing), health monitored and evacuated persons and total population at risk can be specified. Fuzzy values can be used to designate the values (Figure 4.20). Additional remarks on effects on human health can also be entered.

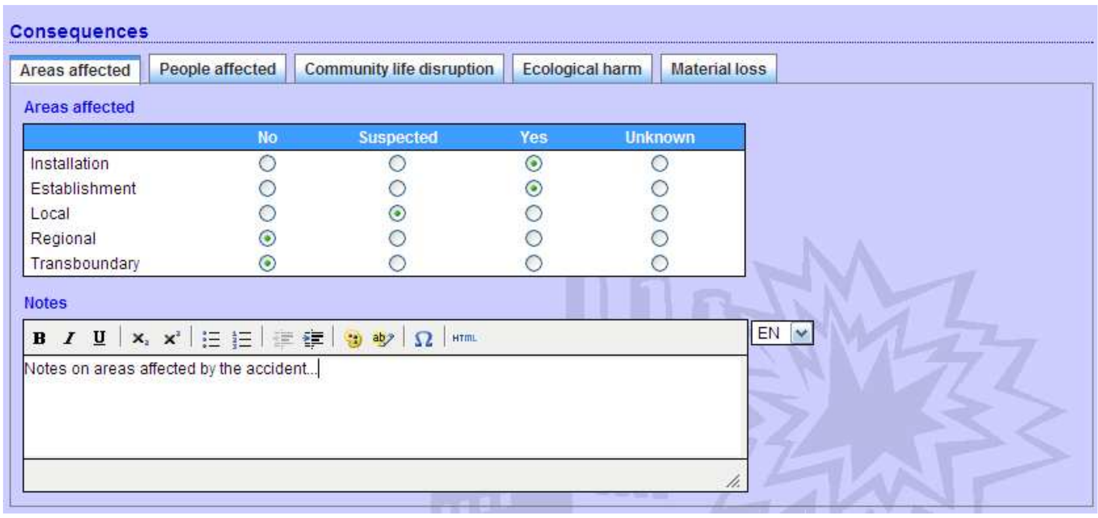
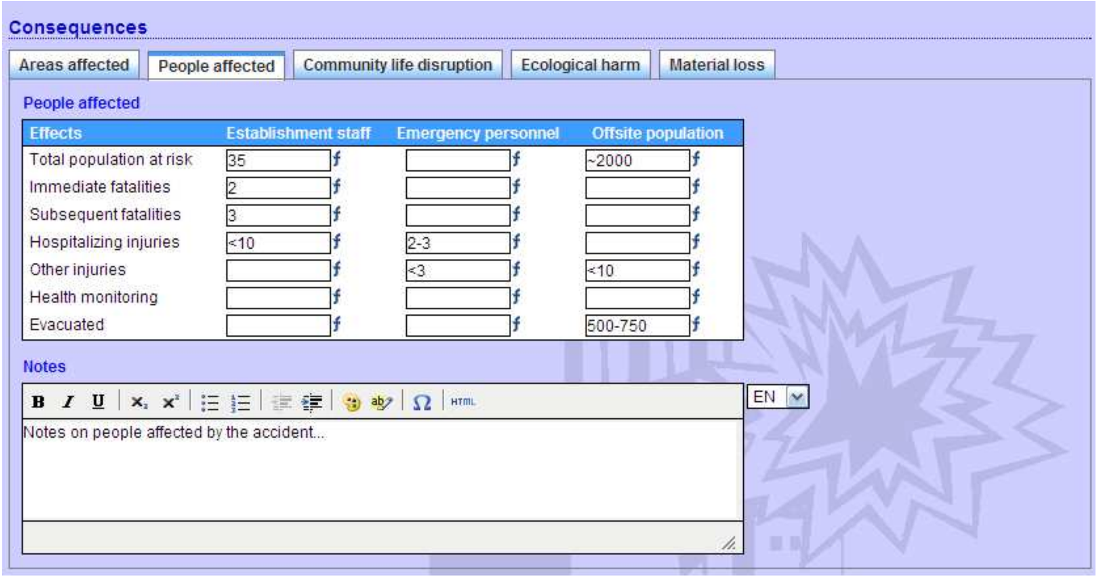


Figure 4.19: Areas affected data entry form


Consequences

Areas affected | People affected | Community life disruption | Ecological harm | Material loss

People affected

Effects	Establishment staff	Emergency personnel	Offsite population
Total population at risk	35		~2000
Immediate fatalities	2		
Subsequent fatalities	3		
Hospitalizing injuries	<10	2-3	
Other injuries		<3	<10
Health monitoring			
Evacuated			500-750

Notes

Notes on people affected by the accident...

Figure 4.20: People affected data entry form

Community life disruption section includes information on public utility interruptions, disruptions to public areas, and extent of public concern. Durations of interruptions to public utilities and services, such as electricity, telecommunications and transportation, can be specified. Fuzzy duration values can be entered. Disruption to off-site establishments can be indicated for different areas including residential, commercial and public areas. Status of each area can be pointed out as evacuated, unoccupiable or destroyed. Presence of public, media, and political interests on local, national and international levels are used as measures of public concern on the accident (Figure 4.21).

Similar to areas affected section, damages can be specified for the following ecologically important areas:

- Common wild flora and fauna
- Rare or preserved flora and fauna
- Specially preserved areas
- Water supplies
- Water habitat

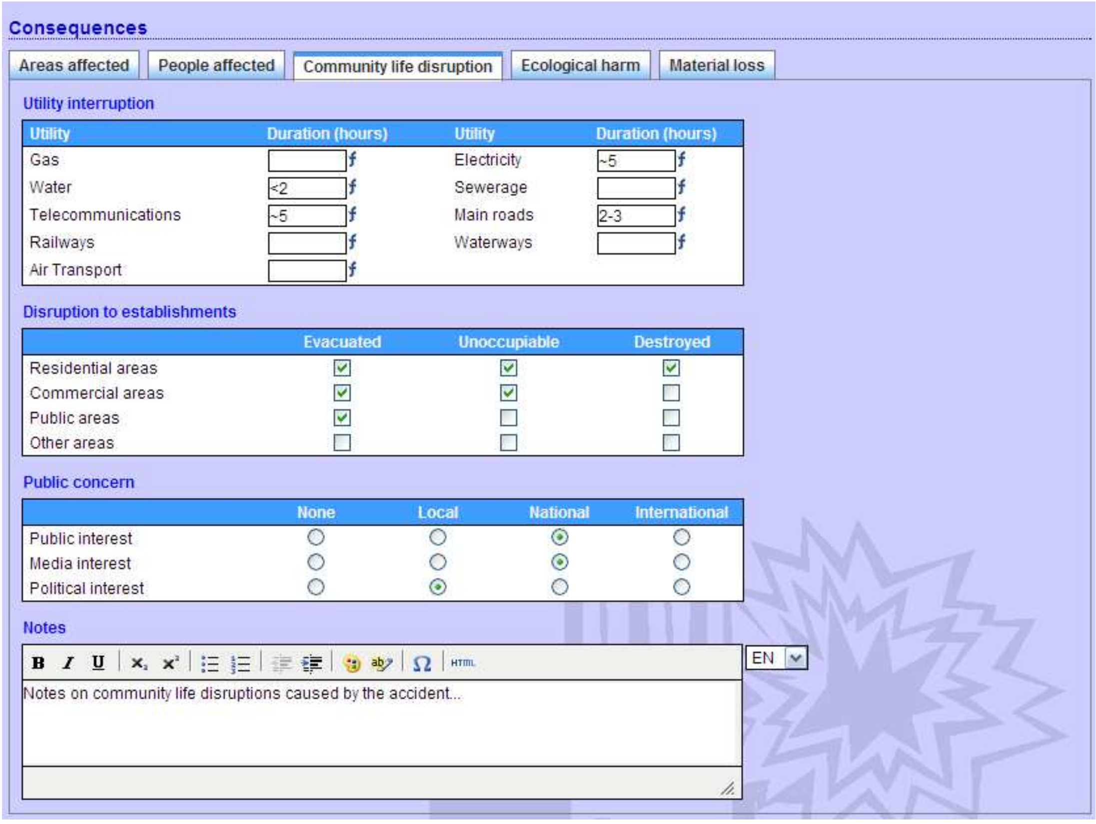


Figure 4.21: Community life disruption data entry form

- Land

Degree of effects can be indicated as no effect, suspected effect, affected and unknown. Detailed description of consequences to ecological compartments can be denoted as well (Figure 4.22).

Last section on accident consequences covers economical aspects. On-site and off-site material losses, and response and restoration costs can be specified as fuzzy values (Figure 4.23). Currency and date of cost values can also be indicated.

Data collected on accident consequences described above are processed by the information system and presented to the users in tabular form (Figure 4.24). In order to attract attention to important consequences, visual icons are used wherever possible. Material loss section also provides a cost conversion tool, which can be used to exchange the cost values into a common currency unit or to convert historical cost figures into current (or desired) date values taking inflation and other economic factors into account.

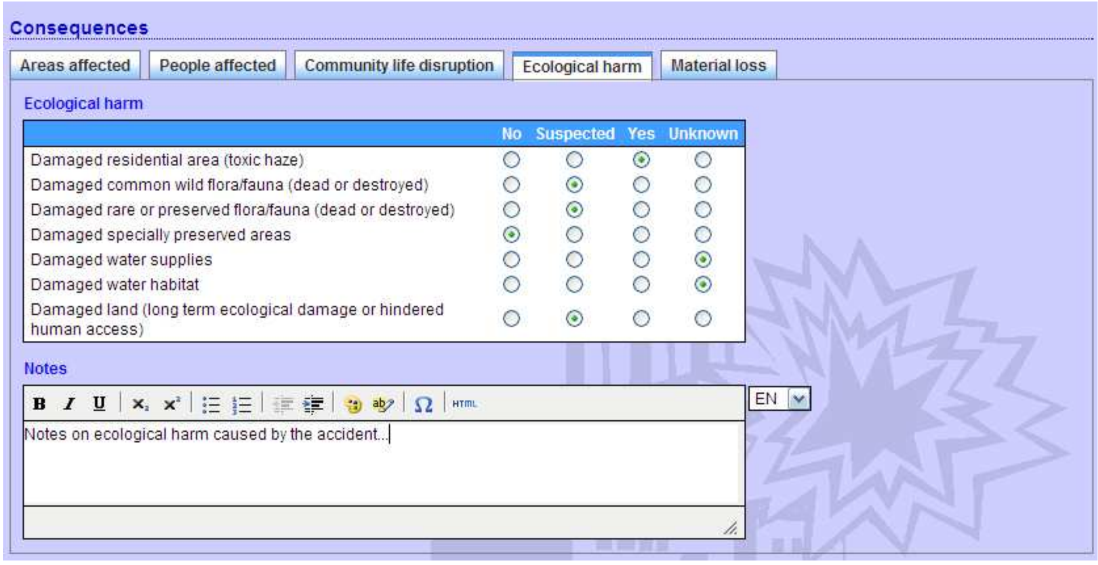


Figure 4.22: Ecological harm data entry form

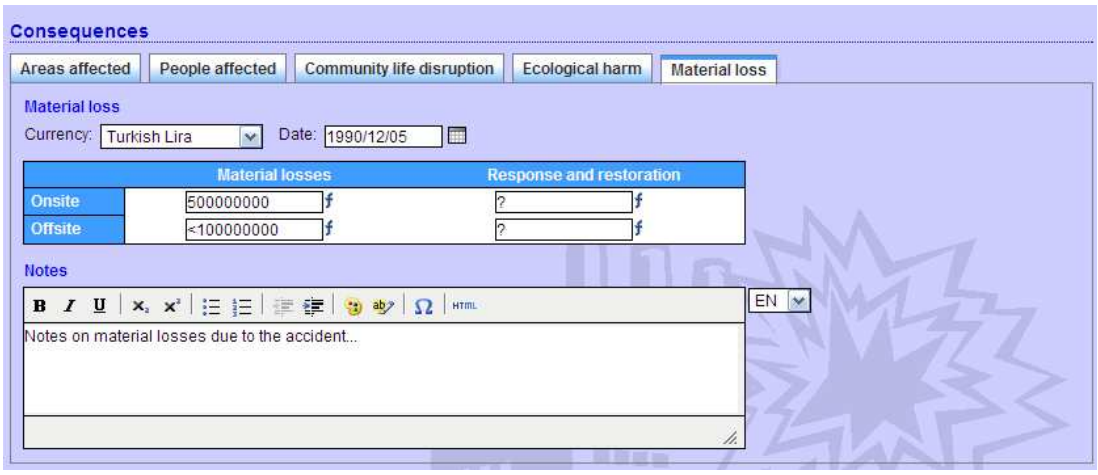
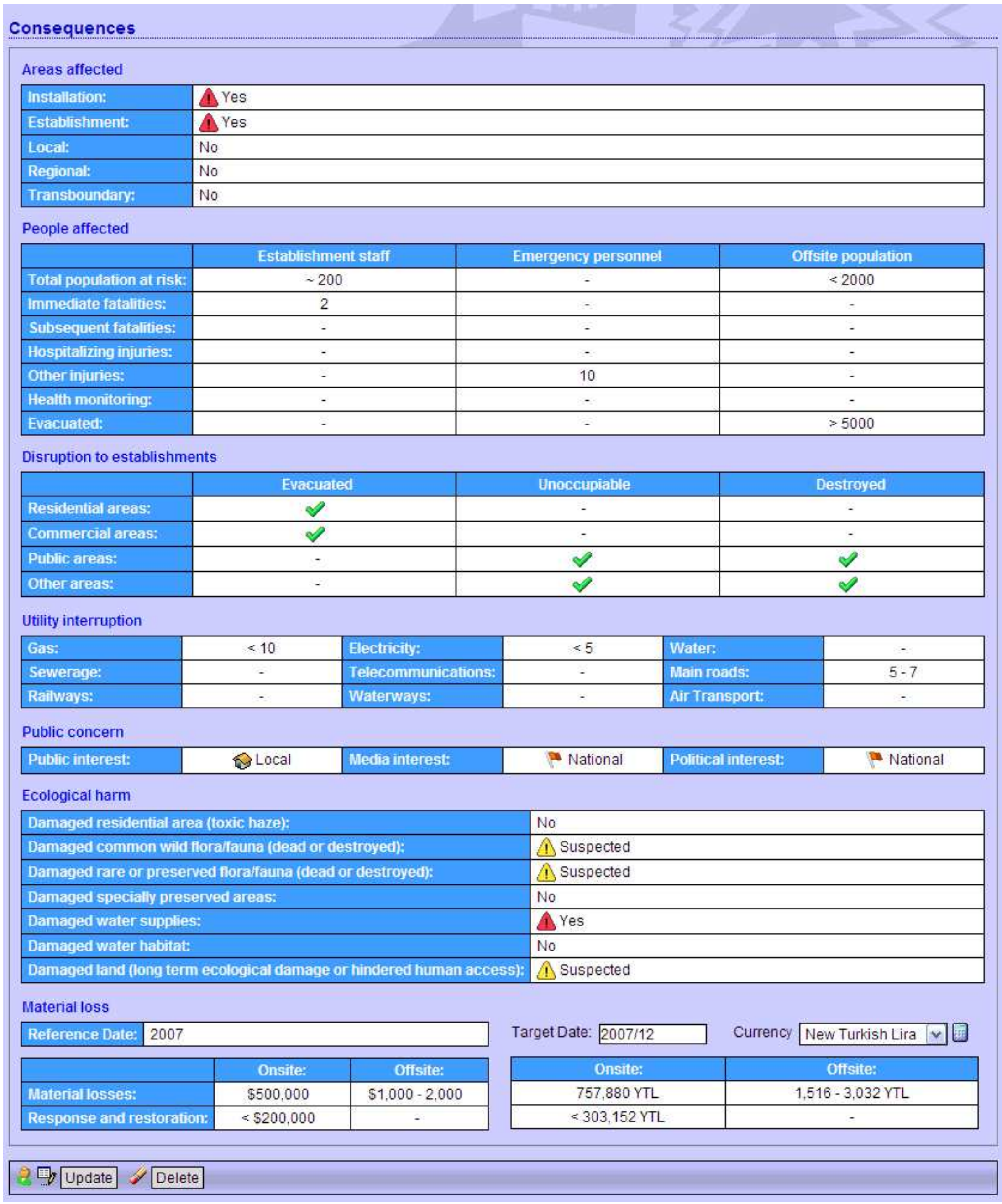


Figure 4.23: Material loss data entry form



Consequences

Areas affected

Installation:	Yes
Establishment:	Yes
Local:	No
Regional:	No
Transboundary:	No

People affected

	Establishment staff	Emergency personnel	Offsite population
Total population at risk:	~ 200	-	< 2000
Immediate fatalities:	2	-	-
Subsequent fatalities:	-	-	-
Hospitalizing injuries:	-	-	-
Other injuries:	-	10	-
Health monitoring:	-	-	-
Evacuated:	-	-	> 5000

Disruption to establishments

	Evacuated	Unoccupiable	Destroyed
Residential areas:	✔	-	-
Commercial areas:	✔	-	-
Public areas:	-	✔	✔
Other areas:	-	✔	✔

Utility interruption

Gas:	< 10	Electricity:	< 5	Water:	-
Sewerage:	-	Telecommunications:	-	Main roads:	5 - 7
Railways:	-	Waterways:	-	Air Transport:	-

Public concern

Public interest:	Local	Media interest:	National	Political interest:	National

Ecological harm

Damaged residential area (toxic haze):	No
Damaged common wild flora/fauna (dead or destroyed):	Suspected
Damaged rare or preserved flora/fauna (dead or destroyed):	Suspected
Damaged specially preserved areas:	No
Damaged water supplies:	Yes
Damaged water habitat:	No
Damaged land (long term ecological damage or hindered human access):	Suspected

Material loss

Reference Date: 2007 Target Date: 2007/12 Currency New Turkish Lira

	Onsite:	Offsite:	Onsite:	Offsite:
Material losses:	$500,000	$1,000 - 2,000	757,880 YTL	1,516 - 3,032 YTL
Response and restoration:	< $200,000	-	< 303,152 YTL	-

Update Delete

Figure 4.24: Accident consequences information

Currency conversion and exchange

Costs of material losses and response/restoration works are important factors in studying socioeconomic aspects of accidents. Cost values can also be used as criteria to rank accidents. However, cost figures of two different dates are usually not direcly comparable due to changing interest rates and inflation, especially if the difference between the dates is more than a few years. It is also possible to have costs in different currencies, hence currency conversion may be required. Evaluation should be done particularly carefully in Turkey, since it is a country which has very high inflation history, devaluation incidents, change of currency, and habit to use currencies other than national currency in declaration of cost figures.

In order to facilitate working with cost figures, the information system features tools for currency exchange between different currencies and conversion of cost figures between two dates.

For currency exchange, daily exchange rates of various currencies are obtained from Electronic Data Delivery System of the Central Bank of the Republic of Turkey (CBRT) for a period of 1970-2007 [62]. Monthly average exchange rates are calculated from daily values and stored in the database. Equation 4.8 is used to convert a cost value in one currency unit into another one for a given date.

$$C_d = \frac{C_f}{r_{fd}} \tag{4.8}$$

where

C_d = Cost in target currency at reference date

C_f = Cost in source currency at reference date

r_{fd} = Exchange rate between source and target currencies for reference date rounded to the nearest month.

The information system is capable of generating all possible currency exchange rates for currencies stored in the database, given a basic set of exchange rates in a few currencies. Using available data, exchange rates as calculated recursively until all exchange rates are calculated or no additional exchange rate can be calculated. Table 4.12 illustrates an example input set and resulting exchange rate table calculated by the system. New Turkish Lira is always taken as equal to 10^6 Turkish Lira.

Table 4.12: Source and calculated currency exchange tables

(a) Source exchange table

	EUR	GBP	USD	TRL	TRY
EUR	-	-	-	-	1.66
GBP	-	-	-	-	2.48
USD	-	-	-	-	1.36
TRL	-	-	-	-	-
TRY	-	-	-	-	-

(b) Calculated exchange table

	EUR	GBP	USD	TRL	TRY
EUR	1.00	0.67	1.22	1660000	1.66
GBP	1.49	1.00	1.82	2480000	2.48
USD	0.82	0.55	1.00	1360000	1.36
TRL	6.02e-7	4.03e-7	7.35e-7	1.00	1.00e-6
TRY	0.60	0.40	0.74	1000000	1.00

In order to convert cost values between two dates, monthly price indices published by the Turkish Statistical Institute (TURKSTAT) are used. Among available indices, which differ in purpose of use and set of products used for calculations, Wholesale Price Index (WPI) is selected as the primary index for calculations due to its long coverage period and ability to reflect general trend in change of industrial product prices [63]. To be able to use WPI, cost value is first converted into Turkish Lira for the initial date using Equation 4.8. Using Equation 4.9, cost value in Turkish Lira corresponding to the target date is found. Finally, cost is converted back to the original currency.

$$C_d = C_i \frac{I_d}{I_i} \tag{4.9}$$

where

C_d = Cost at target date (in Turkish Lira)

C_i = Cost at initial date (in Turkish Lira)

I_d = Price index at target date rounded to the nearest month

I_i = Price index at inital date rounded to the nearest month

4.4.2 Marine Transportation Accidents

The Turkish Straits system, which is one of the world's busiest and most difficult-to-navigate waterways, includes Straits of Istanbul and Dardanelles connected by the inner Sea of Marmara and is only half a mile wide at its narrowest point [64]. The ports of the Black Sea, along with those in the Baltic Sea, were the primary oil export routes of the former Soviet Union, and the Black Sea is still the largest outlet for Russian oil exports. Exports through the Turkish Straits are growing steadily and newly-developed oil and natural gas resources of the Caspian region and the surrounding countries rise concerns about the assimilation capacity of the Straits to the increasing traffic [65]. Major accidents, such as massive Independenta oil tanker fire that lasted more than 30 days, had been occurred in the past. Increase in the traffic also inevitably increases the risk of a catastrophic accidents, especially in the Istanbul Strait. Therefore, marine accidents are important for Turkey.

Due to this importance and considering the fact that no public inventory of marine accidents exists for Turkey, the information system supports storage of marine accidents in the database. For each marine accident, starting and ending dates, primary consequences (fire, explosion and chemical release) and initiating event can be indicated (Figure 4.25). List of initiating events given in harmonized reporting format of the International Marine Organization (IMO) on marine casualties and incidents is used as the basis for initiating events [66]. As location description, sea or strait on which the accident occurred, nearest coastal province and district, locality, latitude and longitude can be stated. Name, flag country, type and tonnage of ships which involved in the accident can be stated up to two ships. Similar to initiating events, classification of ship types is also based on IMO reporting format. It should be noted that ship type information that can be obtained from common information sources, such as newspaper articles, are generally too general and rarely concordant with IMO classification. Uncertain ship type flag can be set if ship type can not be determined exactly.

Marine accidents can be searched for location (sea or strait), ship name, type of accident, primary consequences and date of accident. Resulting list of accidents can be sorted by the same criteria.

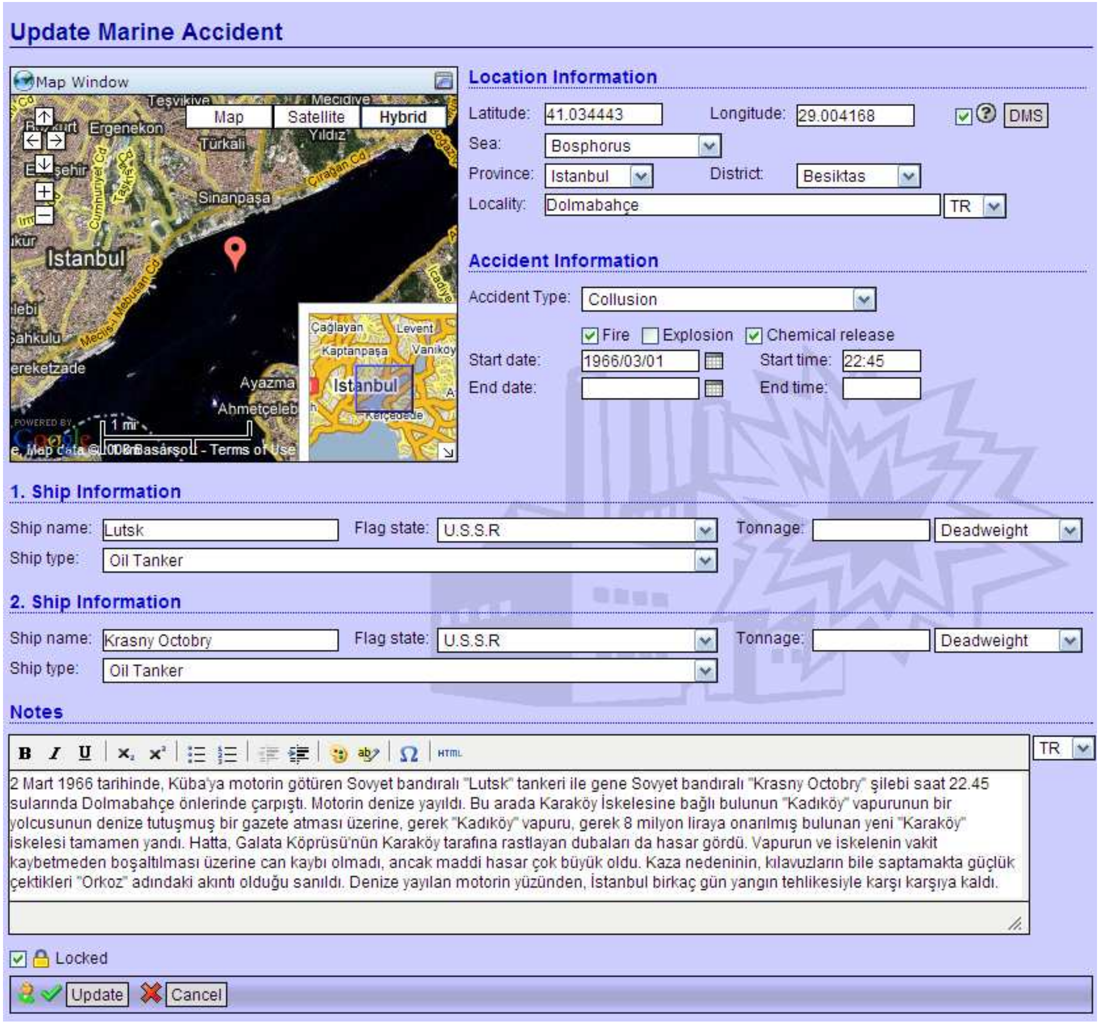


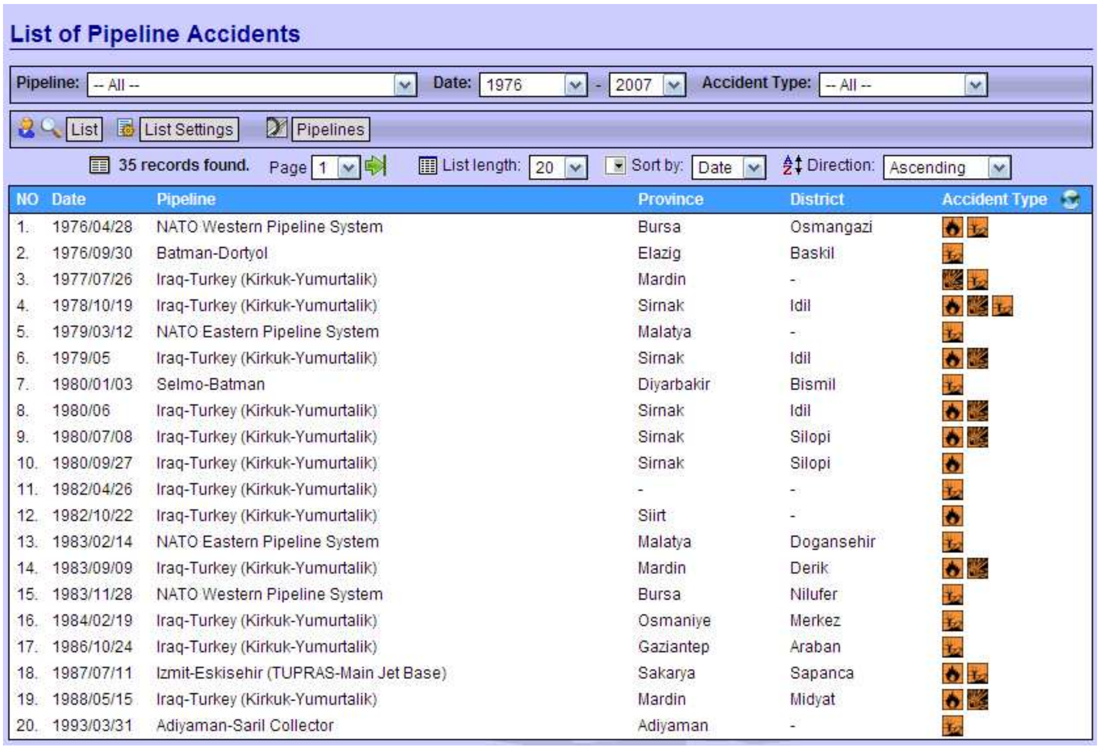
Figure 4.25: Marine accident data entry form

4.4.3 Pipeline Transportation Accidents

Similar to the case in marine transportation, Turkey is becoming an energy bridge for the transportation of oil and natural gas through pipelines. Baku-Tbilisi-Ceyhan (BTC) pipeline, which is the second longest oil pipeline in the world, is operational since 2006 and when working at normal capacity, it transports 1 000 0000 barrels of oil per day from Sangachal Terminal near Baku in Azerbaijan to Haydar Aliyev Marine Terminal near Ceyhan, Adana [67]. Of its total length of 1 768 kilometers, 1 076 kilometers are in Turkey. Kirkuk-Ceyhan pipeline (Iraq-Turkey crude oil pipeline), which is 970 kilometers long and consists of two pipes with total designed capacity of 1 600 000 barrels per day, is operational since 1977. Although Iraqi part of the pipeline has been a principal sabotage target since Iraq-Iran War, it is still operational. There are also Iran-Turkey Pipeline running from Tabriz in North-West Iran to Ankara; South Caucasus Pipeline running from Shah Deniz gas field in Azerbaijan to Erzurum; Turkey-Greece pipeline running from Karacabey, Bursa to Komotini in Greece; and Blue Stream pipeline running from Russia to Turkey, all of which are international pipelines transporting natural gas. There are other natural gas and oil transmission lines, including two major oil pipelines of NATO in western and eastern parts of Turkey. When the planned pipelines are also considered, it can be easily concluded that pipeline safety is gradually becoming an important subject for Turkey.

In order to support data on pipeline accidents, the information system allow information on pipeline networks to be stored as pipeline and pipeline segment records. Pipeline records cover general information on pipeline networks, whereas pipeline segments include information on specific parts thereof. In addition to name and type (e.g natural gas, crude oil) of the pipeline, diameter, length and transportation capacity can also be stated. International pipelines can be specifically indicated and their total length including international segments can be specified. Similar to pipelines, pipeline segments have name, length, diameter and capacity values. Pipeline to which the pipeline segment belong to and number of lines in the segment can be specified (Figure 4.26). In order to describe the structure of the pipeline network, preceding pipeline segment can be specified for each pipeline segment. A pipeline segment may have only one preceding segment. Pipeline segments without preceding segments are starting segments of a network, whereas segments without successors are ending segments.

Figure 4.26: Pipeline segment data entry form



List of Pipeline Accidents

Pipeline: -- All -- Date: 1976 - 2007 Accident Type: -- All --

List | List Settings | Pipelines

35 records found. Page 1 | List length: 20 | Sort by: Date | Direction: Ascending

NO	Date	Pipeline	Province	District	Accident Type
1.	1976/04/28	NATO Western Pipeline System	Bursa	Osmangazi	
2.	1976/09/30	Batman-Dortyol	Elazig	Baskil	
3.	1977/07/26	Iraq-Turkey (Kirkuk-Yumurtalik)	Mardin	-	
4.	1978/10/19	Iraq-Turkey (Kirkuk-Yumurtalik)	Sirnak	Idil	
5.	1979/03/12	NATO Eastern Pipeline System	Malatya	-	
6.	1979/05	Iraq-Turkey (Kirkuk-Yumurtalik)	Sirnak	Idil	
7.	1980/01/03	Selmo-Batman	Diyarbakir	Bismil	
8.	1980/06	Iraq-Turkey (Kirkuk-Yumurtalik)	Sirnak	Idil	
9.	1980/07/08	Iraq-Turkey (Kirkuk-Yumurtalik)	Sirnak	Silopi	
10.	1980/09/27	Iraq-Turkey (Kirkuk-Yumurtalik)	Sirnak	Silopi	
11.	1982/04/26	Iraq-Turkey (Kirkuk-Yumurtalik)	-	-	
12.	1982/10/22	Iraq-Turkey (Kirkuk-Yumurtalik)	Siirt	-	
13.	1983/02/14	NATO Eastern Pipeline System	Malatya	Dogansehir	
14.	1983/09/09	Iraq-Turkey (Kirkuk-Yumurtalik)	Mardin	Derik	
15.	1983/11/28	NATO Western Pipeline System	Bursa	Nilufer	
16.	1984/02/19	Iraq-Turkey (Kirkuk-Yumurtalik)	Osmaniye	Merkez	
17.	1986/10/24	Iraq-Turkey (Kirkuk-Yumurtalik)	Gaziantep	Araban	
18.	1987/07/11	Izmit-Eskisehir (TUPRAS-Main Jet Base)	Sakarya	Sapanca	
19.	1988/05/15	Iraq-Turkey (Kirkuk-Yumurtalik)	Mardin	Midyat	
20.	1993/03/31	Adiyaman-Saril Collector	Adiyaman	-	

Figure 4.27: List of pipeline accidents

4.4.4 Road Transportation Accidents

Accidents that occurred during transportation of dangerous substances on roads and highways are another class of technological accidents supported by the information system. Although they do not occur frequently, their consequences in terms of environmental pollution and loss of human life can be significant [68].

Date, time and primary consequences (fire, explosion and chemical release) can be stated for a road transportation accident (Figure 4.28). Type of the accident, such as collusion, strike or overturn, can be indicated together with types of vehicles involved in the accident. Chain accidents can be specifically denoted. Location of the accidents can be marked on the map

The specific road, on which the accident occurred, can be selected from the roads stored in the database. Similar to other record types, the information system features data entry and listings forms for roads. Besides name and code of the road, class (e.g. highway, provincial way) and type (e.g. asphalt, stabilized) according to the classifications used by General Directorate of Highways can be indicated [69].

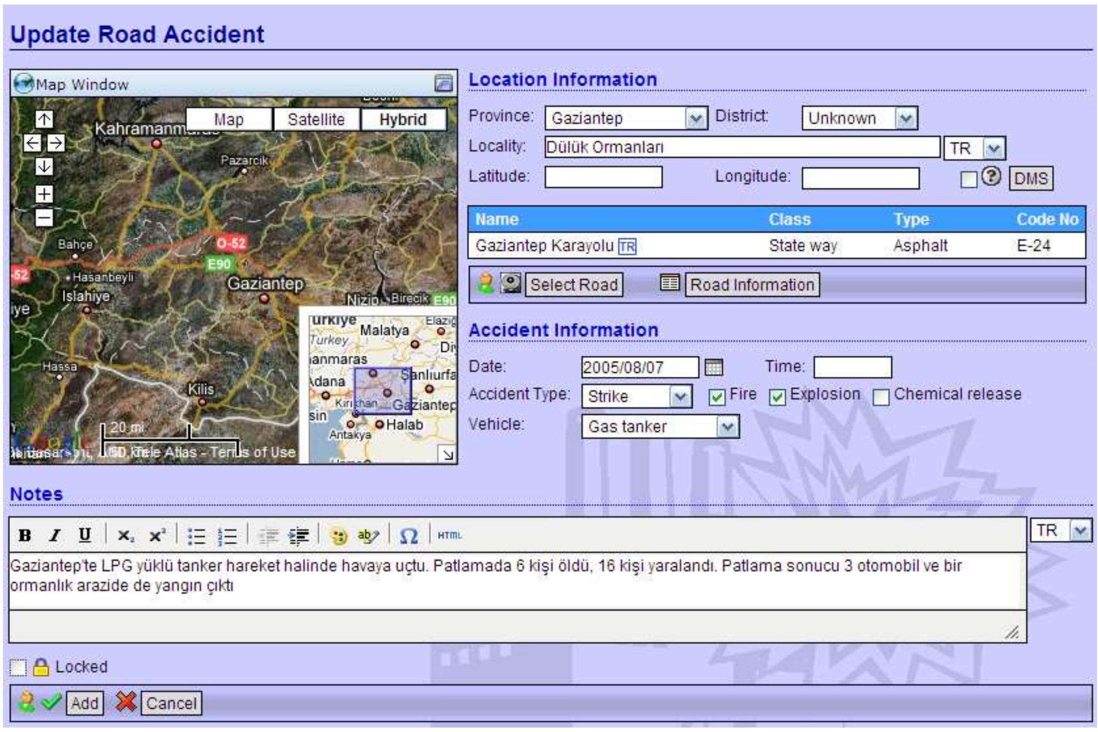


Figure 4.28: Road accident data entry form

4.4.5 Military Accidents

Because of their activity, military fields store significant amount of explosive and flammable articles. Although military has a well established safety culture and high level of safety measures, accidents may happen with considerable off-site consequences. For example, explosions that had happened in munition warehouses of the Land Forces at Yahşihan, Kırıkkale in 1986 and Pamukkale, Sakarya in 1995 resulted in complete evacuation of the settlements in the vicinity, affecting tens of thousands of people.

Similar to other technological accidents, military accidents are also supported by the information system. Starting and ending dates, primary consequences, and military field at which the accident occurred can be indicated for a military accident. Descriptive notes can be entered in multiple languages (Figure 4.29).

Military fields are stored separately in the database and can be selected from the list provided by the information system. Data on military fields include name of the field and its location as province, district and textual locality description. Like industrial facilities, rectangular boundaries of the military fields can be specified on the map. Type of the military field (e.g. arsenal, shipyard) and owner military force can be indicated.

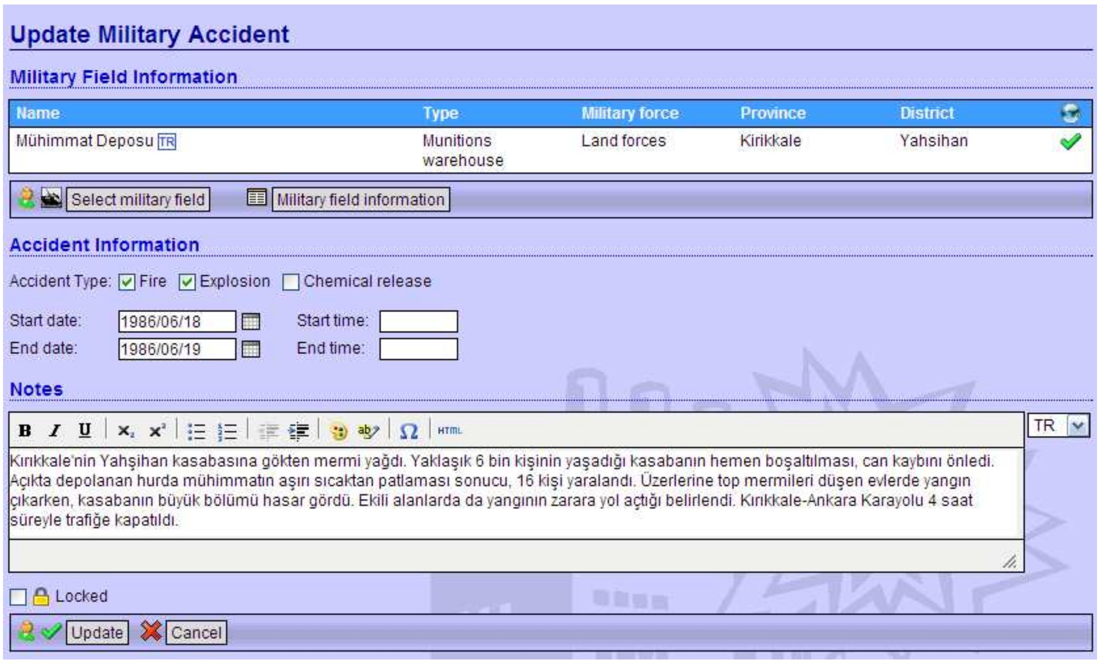


Figure 4.29: Military accident data entry form

4.4.6 Mining Accidents

Although their main characteristics are different from other technological accidents, accidents that occur during mining activities are important in terms of their aftermaths. Without any doubt, mining accidents are the most deadly and grievous accidents ever occurred in Turkey. Number of casualties of just three mining accidents illustrate the agony: Armutcuk, 1983: 103; Yeniçeltek, 1990: 67; and Kozlu, 1992: 263 deads.

Information on mining accidents include name of the mine and date, time, and type of the accident. Accident types specific to mining activities, such as firedamp, subsidence, coal spray can be indicated. Location information is stored in separate mine records. Name of the mine and type of the mineral to be mined (e.g. coal, lignite, precious metal) can be stated for each mine. In addition to geographic coordinates, province and district of the mine and textual locality description can be entered. Similar to industrial facilities, rectangular boundaries of the mines can be marked on the map.

Mining accidents can be listed by mine, province, district, date and type of the accident (Figure 4.30).

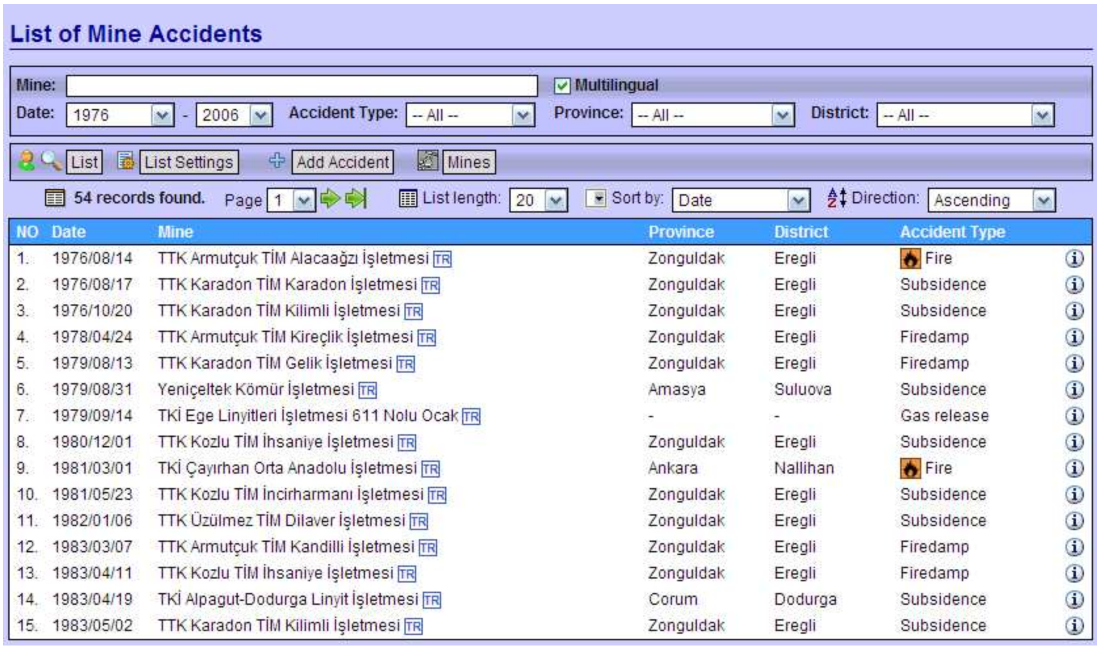


Figure 4.30: List of mining accidents

4.4.7 Urban Disasters

Although they are not industrial in origin, major fires, explosions and other disasters that occurred in urbanized areas are also supported by the information system. These incidents are generally misclassified as industrial accidents in international listings and databases as shown in Chapter 3. Therefore, detailed information on these accidents can be helpful for verification purposes. Their historical importance for the community is also high, because they occur within settlements, number of casualties are usually large in quantity, and media coverage is broad.

Type, date, and time of the disaster together with name, province, district, latitude and longitude of its location can be stored in the information system. (Figure 4.31). Type of the disaster can be specified as fire, explosion, and building collapse.

Figure 4.31: Urban disaster entry form

4.5 Document Subsystem

Accident subsystem of the information system allows general information on technological accidents and detailed information on industrial accidents to be collected in a collaborative manner and shared with interested parties and the public. Since currently there exists no national inventory or listing of technological accidents in Turkey, the information system is considered to be a first step in reducing the deficiencies on this topic. Therefore, its design is kept as simple as possible and aimed to deal with basic accident data. Detailed information on accidents could not be stored in the accident subsystem in a structured manner, except occurrence and consequence information on industrial accidents for which detailed data fields exist.

In order to allow detailed, but unstructured information related to accidents to be stored in the system, the document subsystem has been developed. Document subsystem allows informative documents, such as newspaper and journal articles, books, manuals, yearbook entries and web pages to be stored in the database. Besides being reference of the information stored in the accident subsystem, records in document subsystem also provide detailed information on main causes, adverse consequences, long term effects of accidents. In addition to textual documents, the system also support multimedia documents, such as photographs and video recordings, which may provide considerable amount of information on accidents that is not available or inferred from other sources.

4.5.1 Newspaper Articles

Main component of the document subsystem is newspaper articles section. Most detailed information on past accidents can be obtained from newspaper articles of the date. Although minor incidents are not always available, almost all major incidents can be found within the newspaper articles.

Detailed information that is generally not available from other information resources, such as main causes of the accident, events occurred during the accident, adverse consequences on human health, society and environment, emergency response activities, juristical process and long term socioeconomic effects can be collected from newspaper articles. In addition to textual information, photographs published with the articles also provide precious visual information. Articles published in different newspapers on the same incident can be used for cross checking of available information to increase data quality.

The major disadvantage of newspaper articles is their availability. Although the online versions of major newspapers exist for the last decade and articles can be easily accessed for this time period and be searched by keywords, printed copies of the articles containing high quality photographs, or older articles are difficult to obtain. They can only be found in selected libraries with bounded newspaper collections. Mostly special permissions are required to work in these collections.

The document subsystem allow a digital library of newspaper articles to be constructed, which significantly enhances and speeds up studies related thereto. For each newspaper article, heading, title and subtitle can be specified. Newspaper of the article can be selected from the list provided by the system. Detailed information on newspapers, such as publication type (printed and/or online), coverage (local, national or international) and language, are stored in the database. If desired, additional newspapers can be added to the system during entry of a newspaper article. Author(s) of the article can be indicated together with the news agency and location the article originates. Body of the article can be divided into introduction and main text sections, and stored separately for proper display afterwards. Publication type of the article can be selected as printed or online. For printed articles page number(s) and publication date can be specified, whereas for online articles URL address and access date can be indicated. Fuzzy dates can be entered into date fields for articles with partial date information.

Original text of the article can be stored together with the article as linked files. A printed article can be stored as scanned document or photograph. Likewise, an online article can be stored as plain text file, compressed archive or special web page archive containing all content elements in a single file. Photographs found in articles can be added to the information system as separate records and linked to the article. While displaying article information, the information system gathers all files and photographs of the articles, and generates an arranged digital copy thereof. An example article is shown in Figure 4.32. Details on photographs and files are given in Sections 4.5.4 and 4.5.11, respectively.

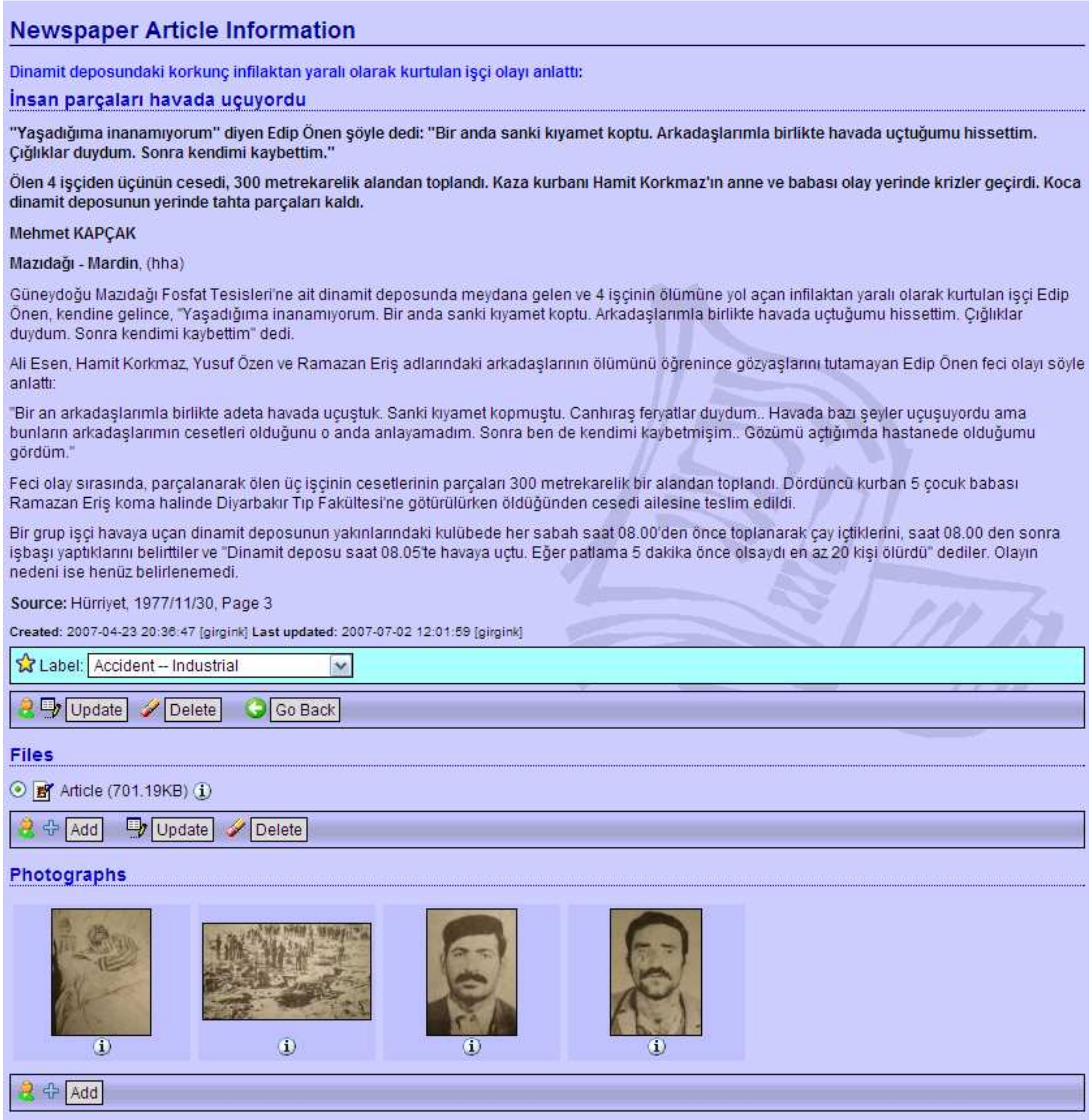


Figure 4.32: Newspaper article information

4.5.2 Yearbook Entries

Although they contain very brief summary information, another important data resource on technological accidents is yearbooks. Yearbooks published monthly or yearly by governmental and private organizations include daily highlights of national and international news. Since technological accidents attract media interest, they are generally listed in these yearbooks. While detailed information is not available, date, type and location information can be gathered. Limited information on consequences, such as number of casualties or injured, can also be obtained for major incidents.

Main advantages of yearbooks are their long time period coverage and less time required for data mining compared to other information resources. Yearbooks covering almost 50 years (1950 onwards) of daily news are available for Turkey [70]. That much time period could be searched for technological accidents in a couple of days if looked in yearbooks. However, as mentioned in Section 5, several months of intensive work is required if newspapers are to be examined for a similar time period. Therefore, yearbooks can be used for screening level data gathering on technological accidents. Particular incidents which are spotted can be investigated in more detail in other resources. Absence of minor incidents and limited detail of information for other incidents are major disadvantages that can be listed.

Yearbook entries can be stored in the information system with their date and textual content. Similar to other document records, they can be labeled and related to other records. Yearbook entries can be searched for keywords found in their content and found records can be listed sorted by date (Figure 4.33).

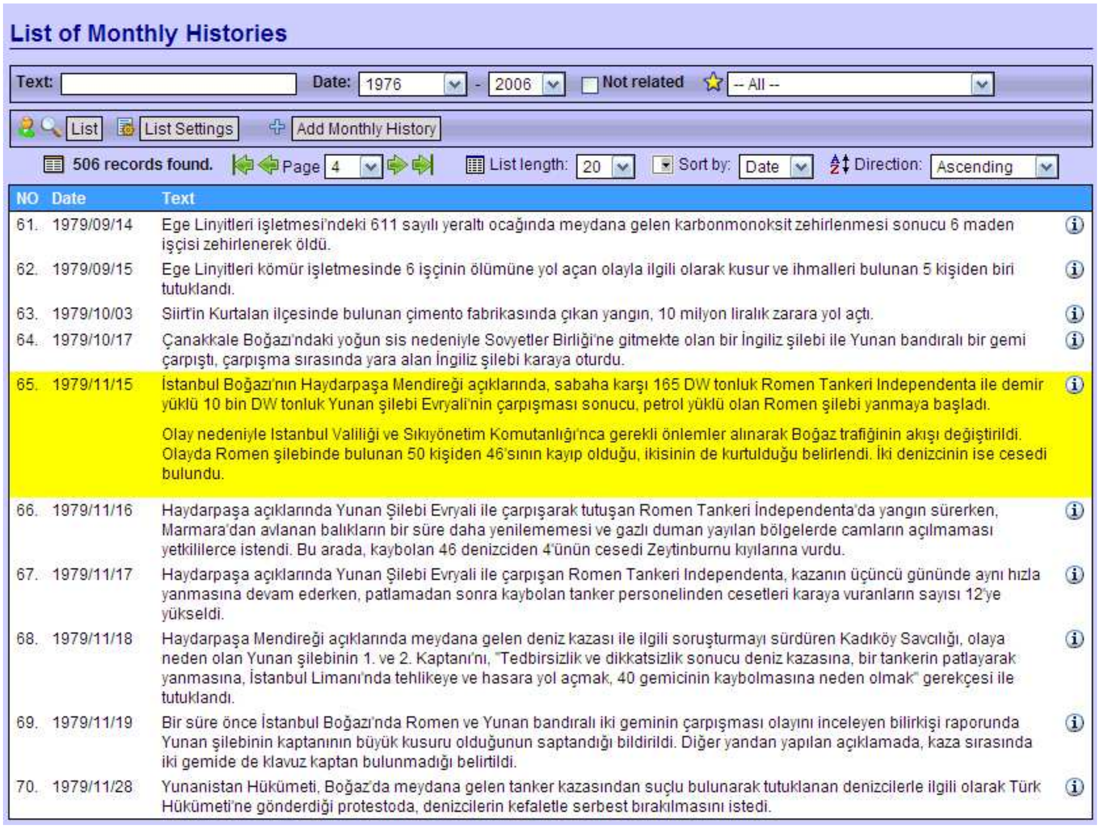


Figure 4.33: List of yearbook entries

4.5.3 Webpages

With the increase in number of web sites available in the Internet, especially those providing commentary or news on particular subjects, web pages are becoming more and more consulted for obtaining information. Availability of powerful and fast search engines, such as Google, allow easy search through millions of web pages for specific keywords to reach the desired topic. Hyperlinked elements, together with tables, images, photographs, animations and supplementary files, provide rich content that can be hardly substituted by conventional, printed material.

Being a web-based application, the information system supports storage of web pages in the document subsystem at first place. Name of the website and title, date and URL address of the webpage can be indicated. Textual content of the web page together with access date can be stored for further referencing. Similar to other document types, webpages can also be labelled. Photographs or figures that are found on the webpage can be added to the system as records linked to the webpage. Complete webpage content can be stored as compressed (e.g. ZIP, RAR) or webpage archive (MHT) files as well (Figure 4.34).

Webpages stored in the system can be searched for URL address, access date and keywords in title and content. Found records can be sorted by web site, title and access date.

Figure 4.34: Webpage information

4.5.4 Photographs

Generally found as attached to articles, photographs are the primary source of visual information on accidents. Besides illustrating aftermath of accidents in detail, they can also be used to infer or approximate quantitative information. For example, size and elevation of a fireball can be found from its photograph, and by using this information amount of explosive substance involved in the explosion can be estimated.

Photographs can be stored in the system with full reference information. Image of the photograph can be uploaded to the system, and date, time and photographer can be stated. If the date on which photograph had taken is unknown or not certain, but publication date is known then date can be indicated as publication date. Title, description, location and agency of the photograph can be stated if available. Type of the photograph can be selected as online or printed. For online photographs, URL address and access date can be denoted. Photographs can be searched by date, photographer, type, agency and description text, and can be sorted by date, image size and file size. Found photographs are listed with their thumbnail images as shown in Figure 4.35.

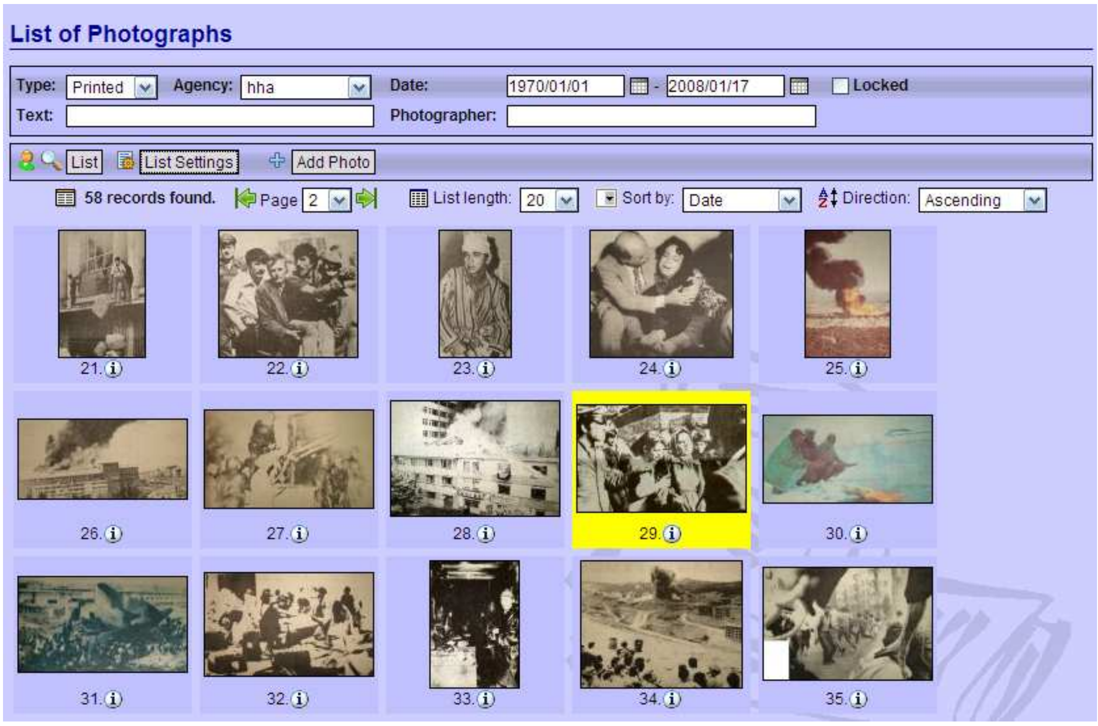


Figure 4.35: List of photographs

Generally, photographs reside in the system as linked to another records, such as accident, location, and document records. Complete listing of record types to which photographs can be linked are given in Table 4.13. Information on related record is displayed on photograph information page (Figure 4.36).

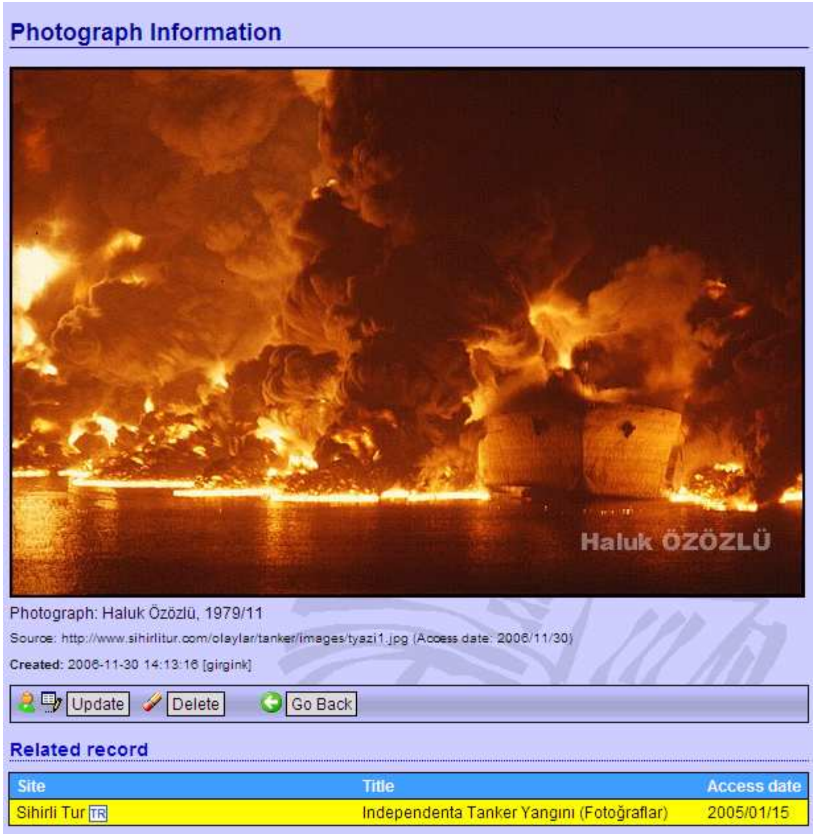


Figure 4.36: Photograph information

Access to the photographs can be restricted to protect copyrighted material by setting an appropriate access level. Three access levels have been defined for photographs, which are:

- Thumbnail,
- Preview, and
- Original.

Table 4.13: Records supporting photographs, files and comments

Record type	Photograph	File	Comment
Industrial Accident	√		√
Accident Consequences			
Accident Occurrence			
Accident Substance			
Marine Accident	√		√
Military Accident	√		√
Military Field	√		√
Mine	√		√
Mine Accident	√		√
Pipeline	√		√
Pipeline Accident	√		√
Pipeline Segment			
Road	√		√
Road Accident	√		√
Urban Accident	√		√
UN/ADR Explosive			√
Chemical			√
Chemical Database			
Classification			
Common Unit			
Concentration Limit			
Constant			
Equation			
MSDS			√
Named Group			
Named Group Chemical			
Property			
Property Data			√
Property Equation			
Property Estimator			
Qualifying Quantity			
Unit			
Comment			
File			
Label			
Newspaper			
Newspaper Article	√	√	√
Note	√	√	√
Photo			√
Reference		√	√
Relation			
Topic	√		√
User			
Video			√
Webpage	√	√	√
Yearbook Entry			√
Facility	√		√
Facility Substance			√
Seveso Settings			
Weather Station		√	√

Thumbnails are tiny copies of original photographs, which are by default 128×96 pixels in size. They are primarily used to represent photographs in listing pages. They are always available to all users. Hence, if it is required to restrict access to a photograph completely, as in the case of copyrighted photographs without permission to re-publish, access level can be set to thumbnail. This allows other users to know that at least such a photograph exists.

Previews are mid-sized reproductions of original photographs. Default size of preview images is 640×480 pixels. They are displayed in photograph information pages in place of the original photographs to speed-up data retrieval from the server. If the owner of the photograph wants to restrict access to the original, access can be limited to preview image. In this case, original photograph is stored in the information system and can be accessed by the owner; but other users can only access to the preview image.

Setting access level to original allow everyone to access to the original photograph by clicking on the preview image. The information system supports JPEG, PNG, GIF and BMP images. Thumbnail and preview images are automatically generated once original photograph is uploaded to the system.

4.5.5 Videos

Similar to photographs, video recordings may also provide considerable amount of information on accidents. Video recordings of an incident may show mistakes during response activities, from which lessons can be learned. They may also give clues on reaction of the public to the accident and their behaviour during the initial phases of the incident, both of which are important in studying societal aspects of the accidents. Extent of damage to property can be easily inferred from video recordings as well.

With the advances in video recording technology and invention of small sized video capture devices integrated to daily used personal equipments, such as cellular phones, availability of video recordings increased significantly. There even exist video sharing websites hosting millions of videos uploaded by ordinary people [71]. Hence, accident videos can also be easier found.

Investigation of media coverage of recent technological accidents occurred in Turkey also reveals that accidents are handled in more detail in visual media (TV) compared to printed media (newspapers). Therefore, importance of videos as an information source on technological accidents is increasing.

Taking these facts into consideration, the information system supports uploading, viewing and sharing videos. For each video record, title, date, time and duration information can be indicated and textual description can be entered. Type of the video can be selected as amateur video recording or TV broadcast, and reference information can be stated accordingly. TV channel and type of broadcast (e.g. news, documentary) can be specified for TV broadcasts, whereas type of the recording (raw or edited) and name of the cameraman can be specified for amateur recordings. For on-line videos, URL address and access date can be denoted. Similar to other document records, videos can be labelled and commented. Video information can be locked for editing by owners and if required, access to the video file can also be restricted.

The information system supports on-demand video broadcasting using Adobe Flash Video technology [72]. Hence, if video is available in Flash Video format it can be uploaded to the system and viewed afterwards (Figure 4.37). In addition to the video file, a thumbnail image can also be uploaded to give an insight of the video content. This thumbnail image is used in video listing page. Videos can be searched for date, type, textual description and TV channel (Figure 4.38).

Figure 4.37: Display of video and related information

Figure 4.38: List of videos

4.5.6 Topics

Although the records can be queried and sorted by their explicit properties, more general or specific classifications are also required occasionally. For example, industrial accidents which had occurred in a province or newspaper articles published for a specific time period can be easily listed in the information system. However, combined list of industrial and pipeline accidents that resulted from a specific event, such as a major natural disaster, can not be directly obtained. Topics are provided in order to make such listings possible and to group different records based on a common property thereof.

Topics have a basic structure and contain name and description information only. They can be simply viewed as folders that organize other records, similar to folders in a file system organizing files. Topics may have subtopics and can be arranged in a tree structure as shown in Figure 4.39. Record relation mechanism of the information system can be used to relate different records to a topic. Records related to a topic can be listed in "Topics" section of the document subsystem, whereas related topics of a record can be listed on the information page of the record.

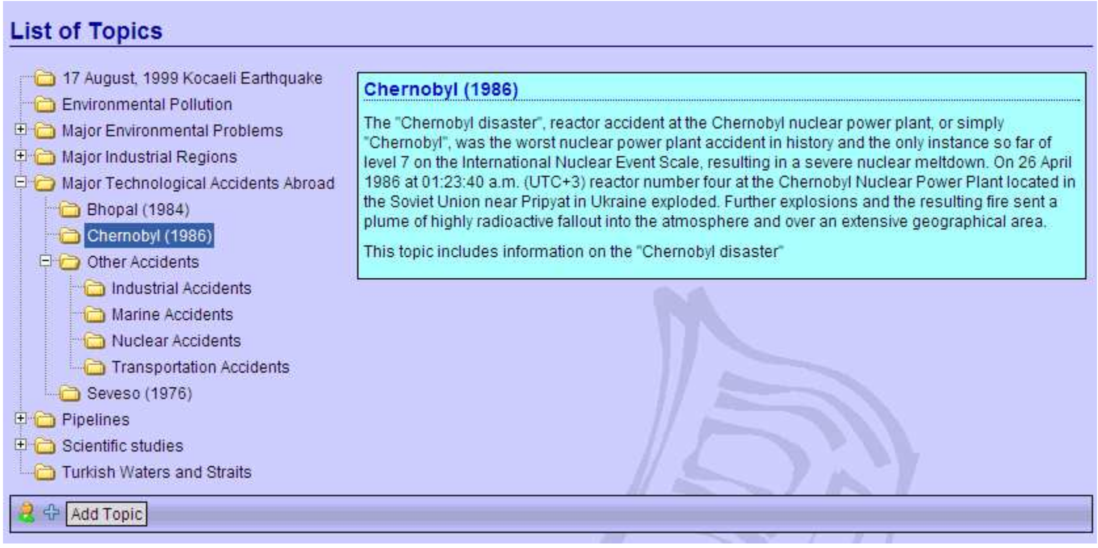


Figure 4.39: List of topics

4.5.7 Comments

Comments provide valuable information that is mostly missing in other sources: eyewitness of the public. They allow influence of accidents on ordinary people living in the vicinity of incidents and their perception thereon to be obtained at first hand. Currently, there is no setting which allow eyewitnesses of the incidents to tell and share their experiences, opinions and thoughts. Valuable information can be inferred from these comments, such as level of achievement in information to public, behaviour of public in the initial phases of the incident, perception of risks and altitude of fears arising thereon. With the widespread use of Internet and development of social networking sites, such as Blogs and Online Forums, people are more willing to collaborate and share their information [73]. Comments section of the information system is considered to be a tool of cooperation in this respect. Since developed information system is not in widespread use yet, genuine comments are currently not available. But to support this idea, some comments on Independenta-Evryali collusion and major fire afterwards are given in Table 4.14, which are taken from a collaborative hypertext dictionary [74]. As it can be seen from the comments, authors of which are made anonymous, interesting stuff can be obtained even from such general sites if opportunity is given for information sharing. For a website which is specific to industrial and technological accidents, level of collaboration is thought to be higher if sufficiently promoted.

Table 4.14: Selected comments on Independenta-Evryali collusion (1979)

Person A, 13.09.2001 I wasn't born at that time. But, I can understand the shock of citizens, who had been afraid of even walking in the streets because of the threat of anarchy. That's why, just after the incident most of the people panicked saying "Anarchists should had exploded all the gas station in İstanbul!" On the other hand some people, who had hoped hunting down of some fuel-oil, had tried to approach the ship by rowing boats and get on board, even while the ship had been still on fire.
Person B, 02.09.2002 The ship accident, at which all glasses at Ataköy had been shaken and we thought like "The Vita Factory should have been exploded totally!".
Person C, 19.03.2003 It is the ship, after its explosion glasses of many houses in İstanbul had been broken. The occupants in Üsküdar and Harem had thought that it was a terrorist attack to the barracks. The incident had been the major issue of all the chats for weeks. The picture which I had drawed about the incident had been on display at the school exhibition.
Person D, 04.07.2003 After the explosion the exterior surface of the Haydarpaşa Station house had been seriously damaged. With the restoration works 80 percent of it had been fixed through several years.
Person E, 10.01.2004 It was our childhood fantasy, in which we imagined that we built a new ship by ourselves from the parts of the ship fallen down to our garden. It had burned for days. We used to go watching the fire, and we had believed that the fire balls had been the sailor on fire, jumping to the sea...
Person F, 18.11.2004 It is the tanker disaster, after which I had been waked up by the sound of the explosion looking through the window and had thought the glasses of the window had been on fire. We had never seen the Istanbul sky that crimson! Some of the people at the dormitory had thought the "doomsday" had arrived and had begun praying. It was a disaster for sure, but I would like to picture that Bosphorus scene, which had lasted long in my mind. It was amazing...
Person G, 16.04.2005 Our house was at Kızıltoprak and was facing Moda. We had waked up with smaller explosions, following the big one. Through the window we could see the crimson sky behind Moda, but I couldn't figure out what it was. I was only 10. In fact the cause of the red sky was the big fire which had started after the collusion. While I had been preparing to go back to bed, a second and bigger explosion had taken place. When I had looked through the window there had been Moda view on fire before me. We had been curious about my sister who lived in Moda. My father had rushed out to see what was happening, had not turned back for hours. Later we learned that he had climbed Çamlıca hill and had watched everything with binoculars. After the accident, there was the ship which gave out smoke for months, the thick oil sheet which had stranded and dirt...
Person H, 14.06.2005 I was a third class student and we were living in Maltepe. Two days after the explosion, my father had taken us to cinema at Kadıköy and to see the fire. When we had left the cinema it had been becoming dark, but the sky was almost yellowish red. My dad had not allowed us to step out the dock, since small explosion had been continuing. At that time of the year and at that distance we had still feeling the heat of the fire. On the ground there was cracked glass everywhere... Three or four years after, at the beginning of elementary school, we had an essay assignment at Turkish class. I remember writing of myself as being the cook of Independanta. A cook, who had survived the crash with his soup ladle in hand. The teacher had appreciated my essay a lot and had congratulated me because of having concerns about our recent history.
Person I, 16.01.2006 When I had heard the news about the explosion form the radio, first I had the joy of the possibility of the schools being suspended. Although here had been a couple of broken glasses at the school building, the classes had not been suspended. But we still had the opportunity to waste the lessons. The pieces of Independenta on Kadıköy dock had been as precious as the pieces of Berlin wall!

The information system allows registered users to comment on many record types. In addition to all accident and location records, selected document records such as newspaper articles, photographs, bibliographic references and selected chemical records such as chemical properties, MSDSs and chemicals itself are commentable. Complete listing of the record types on which it is possible to comment are listed in Table 4.13.

Comments are listed as the last item on the information pages. Without leaving the page, users can add new comments or update existing ones written by themselves by using the provided user interface (Figure 4.40).

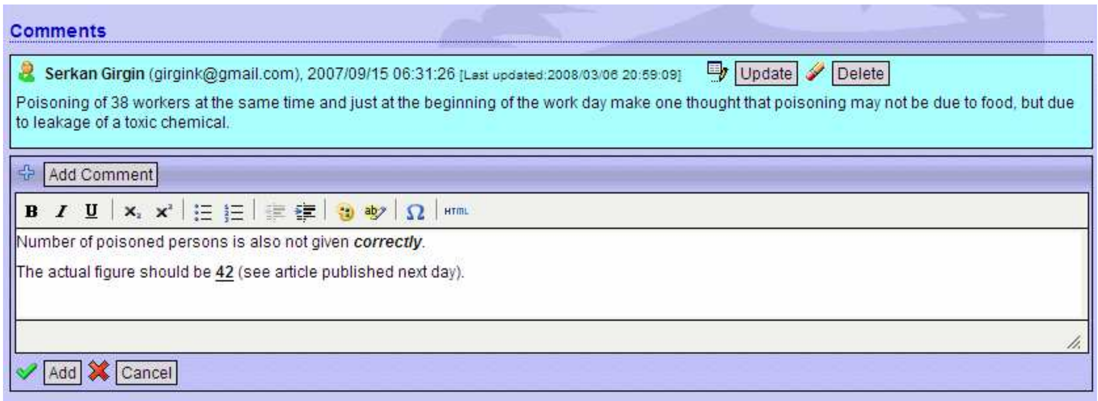


Figure 4.40: Commenting interface

4.5.8 Notes

While working on past technological accidents, especially during data mining studies, it is generally required to record personal thoughts or remarks on specific accidents or topics. In order to facilitate such studies utilizing the information system and note taking of frequent users, the information system features note records.

Unlike comments, which can be related to a single record, notes can be related to several records. They can also made private if needed, allowing access by the owners only. Notes can be listed in “Notes” section of the document subsystem. Similar to comments, public notes are displayed on information pages of related records as well.

4.5.9 Bibliographical References

In addition to aforementioned document records, the information system also supports a wide variety of bibliographic references, such as journal articles, books and technical reports. Similar to newspaper articles, detailed information on title, content, authors, publisher and publication date can be stored for each reference record. Data fields (entities) of reference records are reference type dependent, i.e. different data field combinations are requested and stored for each reference type. For example, journal name is requested for journal articles, whereas institution name is asked for technical reports. Depending on importance of a data field for the completeness of the reference information, its status is set as required or optional by the system. Required fields are not allowed to be left blank in the data entry form.

List of bibliographic reference types supported by the information system together with required and optional data fields thereof are given in Table 4.15. Reference types and data fields are based on the format of BibTeX, which is a tool commonly used for formatting lists of references [75]. Besides standard BibTeX types, legislation type is also supported to store information on national and international legislative documents, such as regulations and directives.

In addition to entities providing reference information, data fields indicating availability of reference documents also exist. Presence of the reference as electronic and/or printed copy can be specified. For electronic documents, URL address or Digital Object Identifier (DOI) can be entered, which is a permanent identifier given to an electronic document that is not dependent upon the electronic document's location.

According to type of the reference and available entities, reference information is produced by the system and displayed to the user. If there is one, the abstract of the reference is also shown (Figure 4.41). Electronic copies of the reference can be linked to the reference record as auxiliary files. Similar to other document records, references can be related to other records. There are also record types with explicit link to reference records, such as classification, property data and property equation records.

References can be searched for type of reference, authors, keywords in title and abstract, and publication date. Resulting list of references can be sorted by title, type and publication date (Figure 4.42).

Table 4.15: Types of bibliography entries and required/optional entities

Name	Description	Required Entities	Optional Entities
Article	An article from a journal of magazine.	Author, Title, Journal, Year	Volume, Number, Pages, Month, DOI, Keywords, URL, Publisher, Address, Abstract
Book	A book with an explicit publisher.	Author/Editor, Title, Publisher, Year	Volume, Series, Address, Edition, Month
Booklet	A work that is printed and bound, but without a named publisher or sponsoring institution.	Title	Author, Address, Month, Year, Organization
In Book	A part of a book, which may be a chapter (or section) and/or a range of pages.	Author/Editor, Title, Year, Publisher, Chapter/Pages	Volume, Series, Address, Edition, Month
In Collection	A part of a book having its own title.	Author, Title, Booktitle, Year	Editor, Pages, Organization, Publisher, Address, Month
In Proceedings	An article in a conference proceedings.	Author, Title, Booktitle, Year	Editor, Pages, Organization, Publisher, Address, Month
Legislation	A regulation and legislative document.	Title, Year, Number	Month, Organization
Manual	Technical documentation.	Title	Author, Organization, Address, Edition, Month, Year
M.Sc. Thesis	A Master's thesis.	Author, Title, School, Year	Address, Month, Abstract
Miscellaneous	Documents that do not fit other listed types.	Title	Author, Month, Year, Key
Ph.D. Thesis	A Ph.D. thesis	Author, Title, School, Year	Address, Month, Abstract
Proceedings	The proceedings of a conference.	Title, Year	Editor, Publisher, Organization, Address, Month
Technical Report	A report published by a school or other institution, usually numbered within a series	Author, Title, Institution, Year	Number, Address, Month
Unpublished	A document having an author and title, but not formally published.	Author, Title	Month, Year

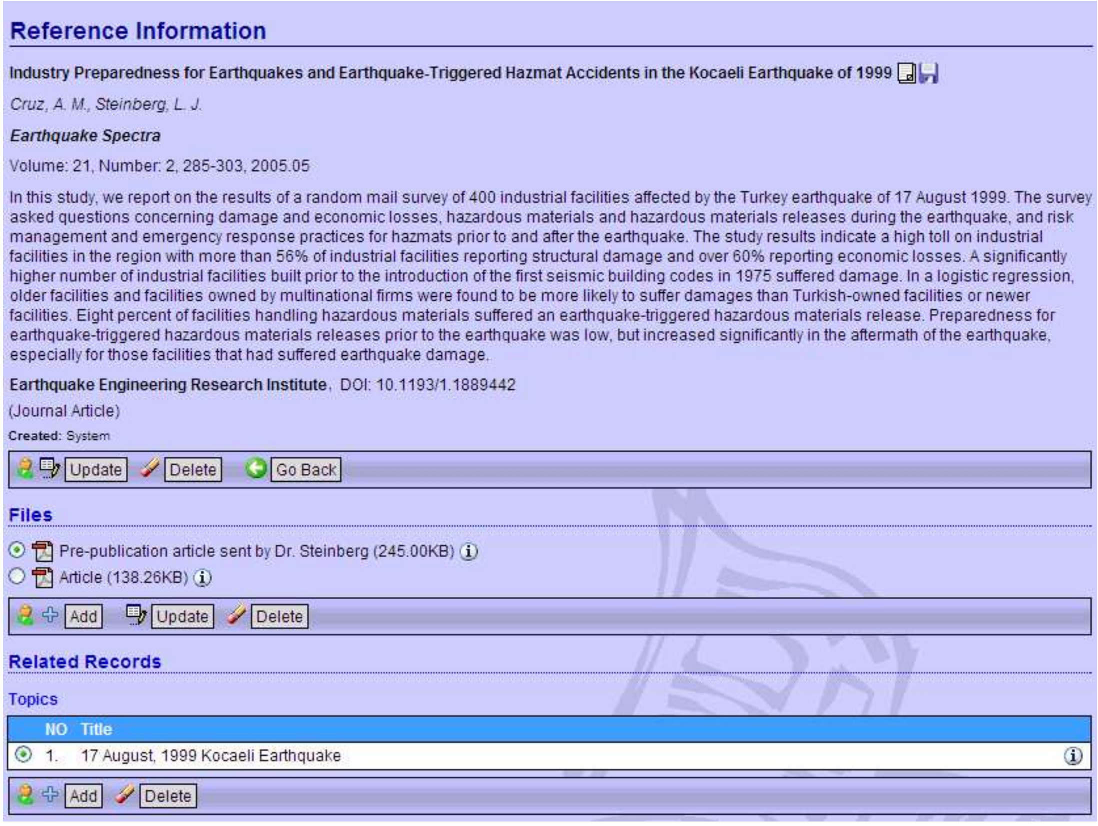
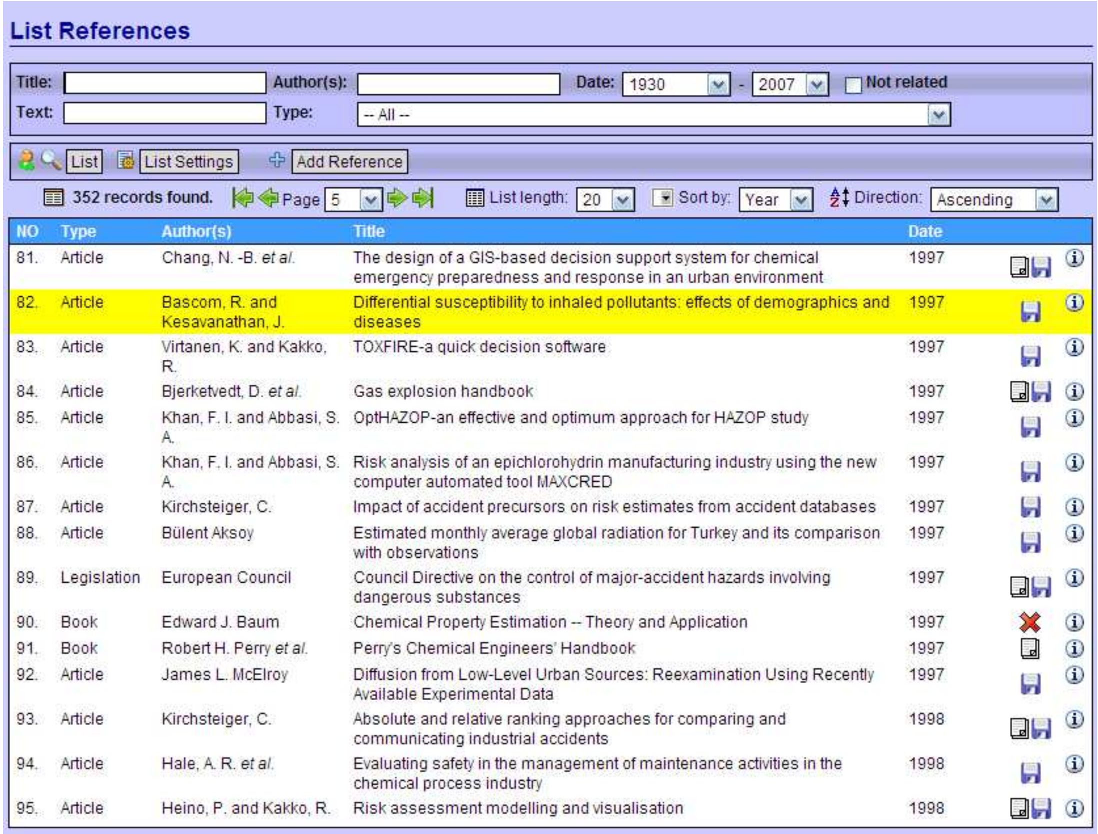


Figure 4.41: Bibliographic reference information

4.5.10 Labels

For rapid classification and query of documents, the information system features a labelling system. Although topics can be used together with record relation mechanism to classify documents, they are not primarily designed for queries. While it is technically possible to query documents for their related topics, transaction performance is slow. Labels are introduced to increase transaction performance and to allow categorization in listing of documents, e.g. listing of newspaper articles on pipeline accidents, or videos on urban disasters. Main differences between labels and topics are as follows:

- Labels are single level (i.e. sub-labels are not allowed).
- Labels are available only for selected document records.
- Changes in record labels are not stored in the record history.
- A record may have only one label.



NO	Type	Author(s)	Title	Date
81.	Article	Chang, N. -B. *et al.*	The design of a GIS-based decision support system for chemical emergency preparedness and response in an urban environment	1997
82.	Article	Bascom, R. and Kesavanathan, J.	Differential susceptibility to inhaled pollutants: effects of demographics and diseases	1997
83.	Article	Virtanen, K. and Kakko, R.	TOXFIRE-a quick decision software	1997
84.	Article	Bjerketvedt, D. *et al.*	Gas explosion handbook	1997
85.	Article	Khan, F. I. and Abbasi, S. A.	OptHAZOP-an effective and optimum approach for HAZOP study	1997
86.	Article	Khan, F. I. and Abbasi, S. A.	Risk analysis of an epichlorohydrin manufacturing industry using the new computer automated tool MAXCRED	1997
87.	Article	Kirchsteiger, C.	Impact of accident precursors on risk estimates from accident databases	1997
88.	Article	Bülent Aksoy	Estimated monthly average global radiation for Turkey and its comparison with observations	1997
89.	Legislation	European Council	Council Directive on the control of major-accident hazards involving dangerous substances	1997
90.	Book	Edward J. Baum	Chemical Property Estimation -- Theory and Application	1997
91.	Book	Robert H. Perry *et al.*	Perry's Chemical Engineers' Handbook	1997
92.	Article	James L. McElroy	Diffusion from Low-Level Urban Sources: Reexamination Using Recently Available Experimental Data	1997
93.	Article	Kirchsteiger, C.	Absolute and relative ranking approaches for comparing and communicating industrial accidents	1998
94.	Article	Hale, A. R. *et al.*	Evaluating safety in the management of maintenance activities in the chemical process industry	1998
95.	Article	Heino, P. and Kakko, R.	Risk assessment modelling and visualisation	1998

Figure 4.42: List of references

In order to set the label of a document, label selection box in the document information page can be used (Figure 4.32). Labels can be changed by editors if the document is not locked by the owner. Selected label is displayed at the end of document information and indicated with a star. Labels can be listed, added, updated or deleted from "Labels" section of the document subsystem. Editors can add new labels, whereas owners can update and delete existing ones. Record types supporting labelling are as follows:

- Newspaper articles
- Yearbook entries
- Videos
- Webpages

4.5.11 Files

Besides classified and structured information stored in the database as tables, additional information can be added to selected records as auxiliary files, such as MS Word or PDF documents (Figure 4.41). Record types that support auxiliary files are listed in Table 4.13. A record may have multiple files, but a file may belong to a single record only. Multilingual description of the file together with file type and size information is stored in the database, whereas file itself is stored in a folder in the file system. Files can be locked by their owners to prevent further change by the other users. Long-term meteorological data, electronic copies of references (e.g. articles, technical reports), original texts of newspaper articles are examples of information that can be stored as files in the information system.

4.6 Chemical Subsystem

The aim of the chemical subsystem is to store information on chemical substances, including physical, structural, thermodynamical and toxical properties, and hazard classifications. The subsystem processes available data on substances and provides single, standardized values to other system components, mainly for the 96/82/EC Directive calculations and accident modeling purposes.

Chemical subsystem includes information on the following record types:

- Chemicals
- UN/ADR explosive substances
- Hazard classification and labelling
- Qualifying quantity limits of the 96/82/EC Directive
- Chemical property data
- Chemical property equations
- Chemical property estimators
- Material safety data sheets
- Chemical databases
- Constants
- Units

4.6.1 Chemicals

Basic information stored in the information system on chemicals include name, identifier and structure data. Because a chemical compound may have many names according to different naming conventions and notations, multiple name entries are supported by the system (Figure 4.43). Also each name can be entered in different languages. Supported languages are Turkish, English, German, Spanish, and French. Greek symbols can be directly entered in chemical names. Italic, subscript and superscript formating is supported as well.

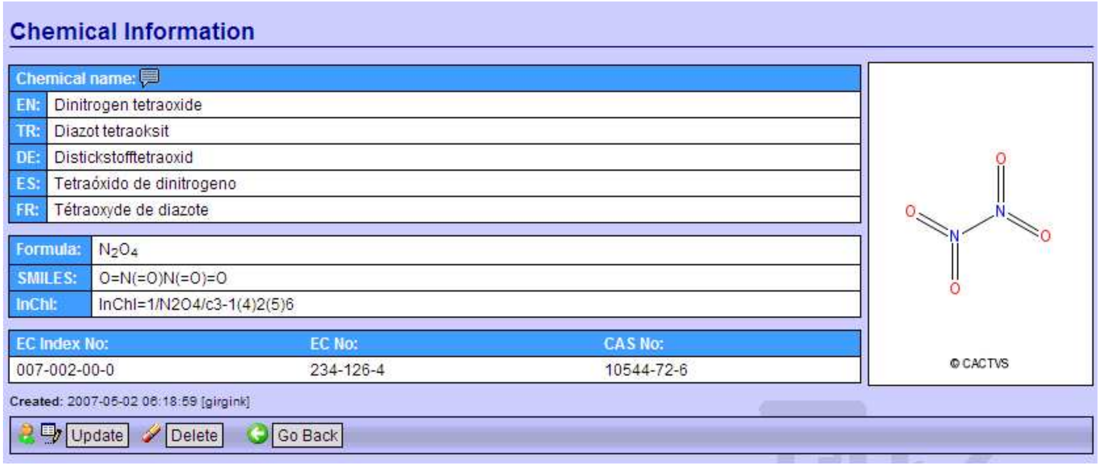


Figure 4.43: Basic chemical information

Since chemical names are not unique and difficulties exists in finding a chemical solely from its known name to the user (e.g. due to unavailability of the name in the database or misspelling), frequently used unique identifiers of chemicals are included to the chemical information. Available identifiers are:

- Chemical Abstracts Service (CAS) Registry No of the American Chemical Society,
- European Inventory of Existing Chemical Substances (EINECS) and European List of Notified Chemical Substances (ELINCS) No (EC No) of the European Union,
- 67/548/EEC Directive Annex I Index No (EC Index No).

These identifiers are mainly used as parameters to search auxiliary online chemical databases listed in Section 4.6.13. Chemical subsystem is capable of checking validity of identifiers and prevents invalid entries to be stored in the database.

Information on structure of the chemical is stored as chemical formula and compact linear strings in International Chemical Identifier (InChI) and Simplified Molecular Input Line Entry Specification (SMILES) notations.

Developed recently by International Union of Pure and Applied Chemistry (IUPAC) and U.S. National Institute of Standards and Technology (NIST), InChI aims to provide a standard and human-readable way to encode molecular information and to facilitate the search for such information in databases and on the web [76]. Substances are expressed in terms of information layers, which are the atoms and their bond connectivity, tautomeric information, isotope information, stereochemistry, and electronic charge information.

SMILES is a specification which had been developed in 1980s for describing chemical structures using short text strings [77]. It is based on graph theory and obtained by depth-first tree traversal of graph created from chemical structure. Unlike InChI there may be more than one SMILES specifying a compound, but algorithms exist to generate unique SMILES which are called Canonical SMILES [78]. SMILES has a wide support in chemical society and used for computational chemistry, searching in chemical databases, structure diagram generation and quantitative structure-activity relationship (QSAR) methods.

In addition to textual information, 2-dimensional diagram of the chemical structure is also shown on chemical information page. Structure diagrams are generated on-demand from SMILES data using CACTVS software package [79]. Therefore, they are available for chemicals with SMILES only.

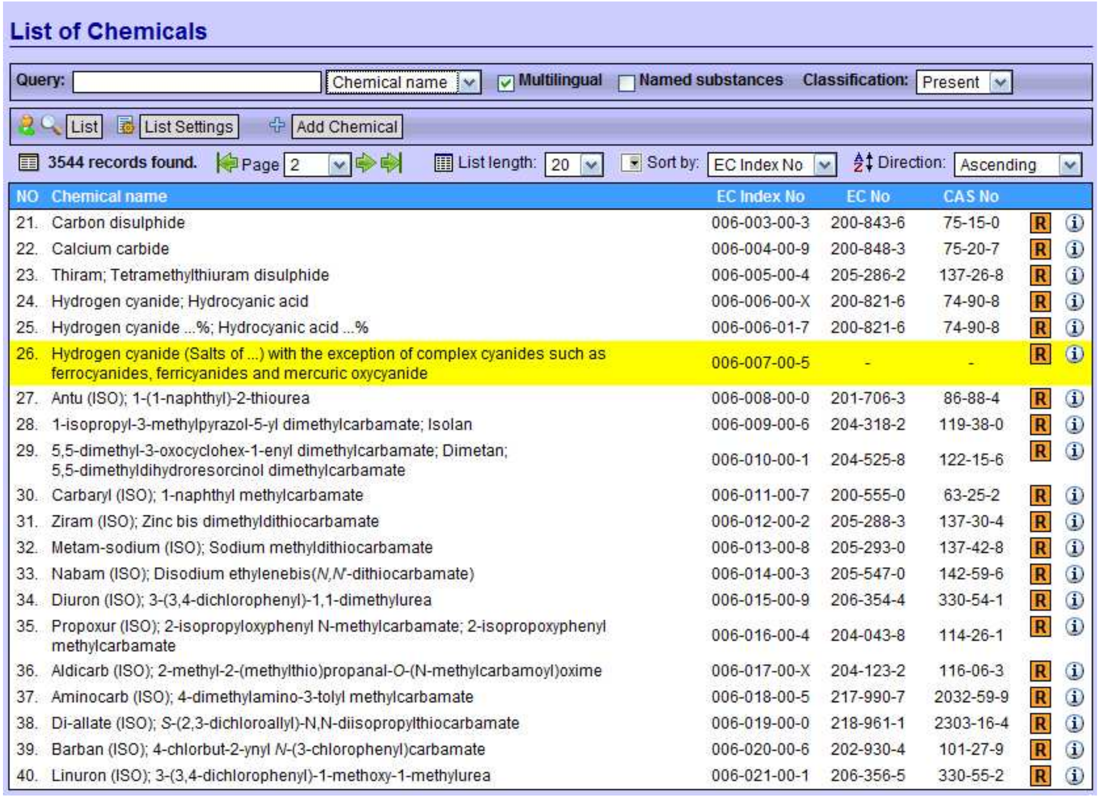
Chemicals can be searched for chemical names, identifiers and structure information. Chemical names can also be queried in multiple languages. Named substances stored in the database can be listed separately. Resulting list of chemicals is presented as a table, columns of which can be sorted freely (Figure 4.44).

4.6.2 Hazard classification and labelling

Classification and labeling section contains detailed information on hazard classification and labeling of the chemical substances and preparations according to the following EU Directives and their current adaptation to technical progresses:

- Council Directive 67/548/EEC of 27 June 1967 on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labeling of dangerous substances [23],

- Directive 1999/45/EC of the European Parliament and of the Council of 31 May 1999 concerning the approximation of laws, regulations and administrative provisions of the Member States relating to the classification, packaging and labelling of dangerous preparations [24].



NO	Chemical name	EC Index No	EC No	CAS No
21.	Carbon disulphide	006-003-00-3	200-843-6	75-15-0
22.	Calcium carbide	006-004-00-9	200-848-3	75-20-7
23.	Thiram; Tetramethylthiuram disulphide	006-005-00-4	205-286-2	137-26-8
24.	Hydrogen cyanide; Hydrocyanic acid	006-006-00-X	200-821-6	74-90-8
25.	Hydrogen cyanide ...%; Hydrocyanic acid ...%	006-006-01-7	200-821-6	74-90-8
26.	Hydrogen cyanide (Salts of ...) with the exception of complex cyanides such as ferrocyanides, ferricyanides and mercuric oxycyanide	006-007-00-5	-	-
27.	Antu (ISO); 1-(1-naphthyl)-2-thiourea	006-008-00-0	201-706-3	86-88-4
28.	1-isopropyl-3-methylpyrazol-5-yl dimethylcarbamate; Isolan	006-009-00-6	204-318-2	119-38-0
29.	5,5-dimethyl-3-oxocyclohex-1-enyl dimethylcarbamate; Dimetan; 5,5-dimethyldihydroresorcinol dimethylcarbamate	006-010-00-1	204-525-8	122-15-6
30.	Carbaryl (ISO); 1-naphthyl methylcarbamate	006-011-00-7	200-555-0	63-25-2
31.	Ziram (ISO); Zinc bis dimethyldithiocarbamate	006-012-00-2	205-288-3	137-30-4
32.	Metam-sodium (ISO); Sodium methyldithiocarbamate	006-013-00-8	205-293-0	137-42-8
33.	Nabam (ISO); Disodium ethylenebis(*N,N'*-dithiocarbamate)	006-014-00-3	205-547-0	142-59-6
34.	Diuron (ISO); 3-(3,4-dichlorophenyl)-1,1-dimethylurea	006-015-00-9	206-354-4	330-54-1
35.	Propoxur (ISO); 2-isopropyloxyphenyl N-methylcarbamate; 2-isopropoxyphenyl methylcarbamate	006-016-00-4	204-043-8	114-26-1
36.	Aldicarb (ISO); 2-methyl-2-(methylthio)propanal-*O*-(N-methylcarbamoyl)oxime	006-017-00-X	204-123-2	116-06-3
37.	Aminocarb (ISO); 4-dimethylamino-3-tolyl methylcarbamate	006-018-00-5	217-990-7	2032-59-9
38.	Di-allate (ISO); *S*-(2,3-dichloroallyl)-N,N-diisopropylthiocarbamate	006-019-00-0	218-961-1	2303-16-4
39.	Barban (ISO); 4-chlorbut-2-ynyl *N*-(3-chlorophenyl)carbamate	006-020-00-6	202-930-4	101-27-9
40.	Linuron (ISO); 3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea	006-021-00-1	206-356-5	330-55-2

Figure 4.44: List of chemicals

Regulation on Control of Hazardous Chemicals of the MoEF, which is an adoption of the 67/548/EEC Directive to the Turkish national legislation, is also covered [80].

Hazard classification and labelling data includes indications concerning special risks (risk phrases), indications giving safety advice (safety phrases), hazard classification, indications of the dangers involved in the usage, and danger symbols for the chemical (Figure 4.45). Hazardous substance categories of the chemical according to the 96/82/EC Directive Annex I, Part 2 are also indicated.

The information system allows existing classifications to be modified or new classifications to be added. For this purpose, a comprehensive classification data entry interface has been developed (Figure 4.46).

Designation of hazard classification primarily depends on selection of appropriate risk phrases indicating the nature of hazards of the chemical and safety phrases indicating the safety advice concerning thereof. Chemical subsystem includes complete listings of risk and safety phrases in various languages as given in Annex 3 and 4 of the

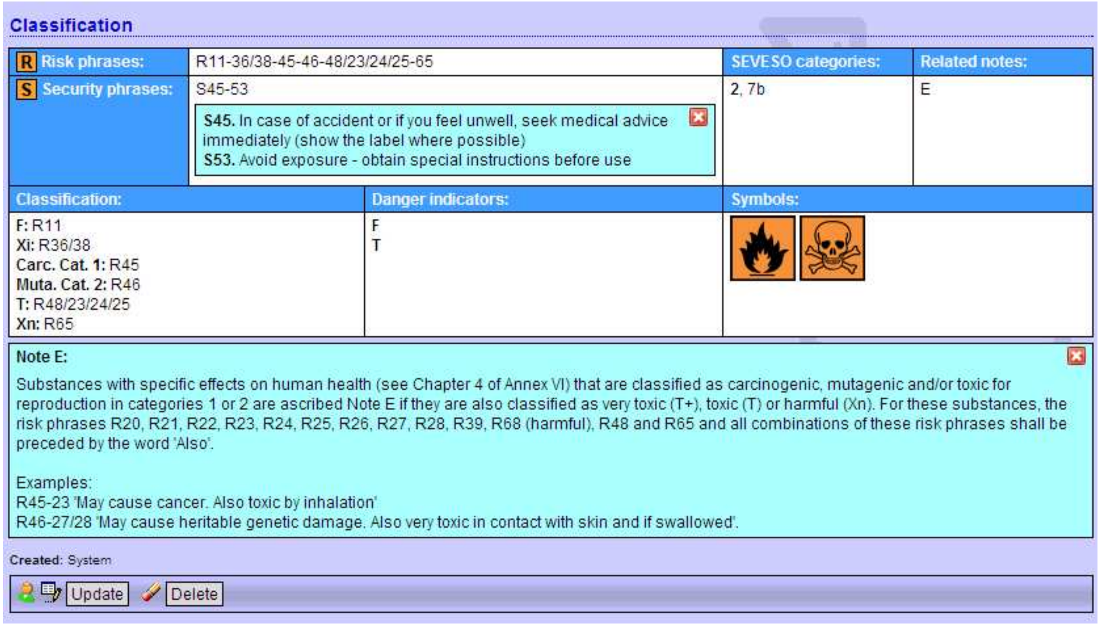


Figure 4.45: Hazard classification and labelling information

67/548/EEC Directive, respectively, from which the user can make the selection easily.

According to selected risk phrases, the information system is capable of automatically determining hazard classification. For this purpose, hazard classification mappings of risk phrases given in Table B.1 (Appendix B) are used. Table B.1 has been prepared by examination of the definitions of risk phrases, and hazard classifications and corresponding risk phrases given for hazardous chemicals in 67/548/EEC Annex 1B and its ATPs. If a risk phrase has more than one possible classification, e.g. R45 with possible classifications of Carcinogenic Category 1 or 2, it is specially marked with an asterisk and the user is required to select the proper classification manually. Based on final classification, relevant danger symbols are determined using data given in Table B.1 and displayed together with matching indicators of danger. Available symbols and indications of danger for hazardous substances originated from 67/548/EEC Annex 2 are listed in Table B.3.

Similar to hazard classification, 96/82/EC categories that the chemical falls into are also automatically determined from risk phrases. For this purpose, 96/82/EC categories corresponding to risk phrases given in Table B.1 are used. If required, the user is allowed to change the substance categories determined by the system. Categories determined by the system are indicated by asterisks (Figure 4.46).

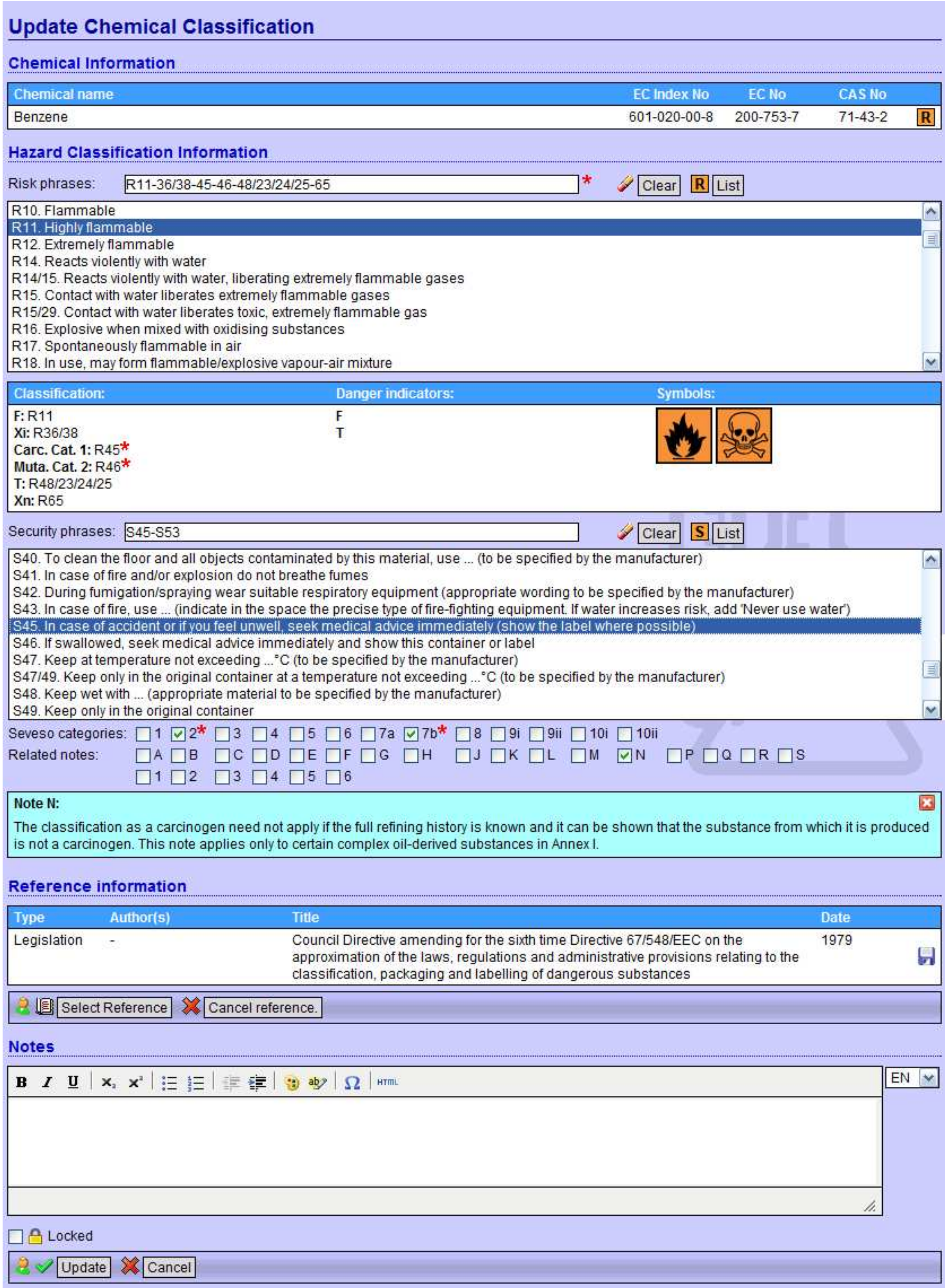


Figure 4.46: Classification data entry form

Explanatory notes relating to the identification, classification and labelling of substances, and labelling of preparations as listed in 67/548/EEC Annex 1A can be selected for the classification. If needed, custom notes can also be entered.

Hazard classifications of substances are primarily based on results of standard test methods [23]. Test methods are continuously evolving in time, and experimental methods and instruments with higher accuracies are made available. As a result of this progress and increased availability of more accurate or new experimental data, hazard classification of substances are also changing. Therefore, specification of the source of classification information is a requirement for systematic follow-up and further referencing. For this purpose, the information system allow the user to specify the reference of the classification by making a selection from bibliographic references in the document subsystem or MSDSs available for the chemical Figure 4.46.

In addition to basic hazard classification, hazard classifications for specific concentration ranges can also be specified to classify dangerous preparations containing the substance or diluted solutions thereof in accordance with Directive 1999/45/EC. Concentration specific classifications are based on risk phrases similar to basic classification. Hence, data input interfaces are alike. Automatic hazard classification, labelling and 96/82/EC category determination works for concentration specific classifications as well. But, safety phrases and explanatory notes are not available. Unless otherwise stated, the concentration limits are in percentage by weight of the substance calculated with reference to the total weight of the preparation. Lower concentration limit is obligatory, but upper limit can be left blank and assumed as 100% by weight at that case. Coincident concentration limits are not allowed by the system, hence limits should be mutually exclusive. An example set of concentration specific hazard classifications from the information system is given in Figure 4.47.

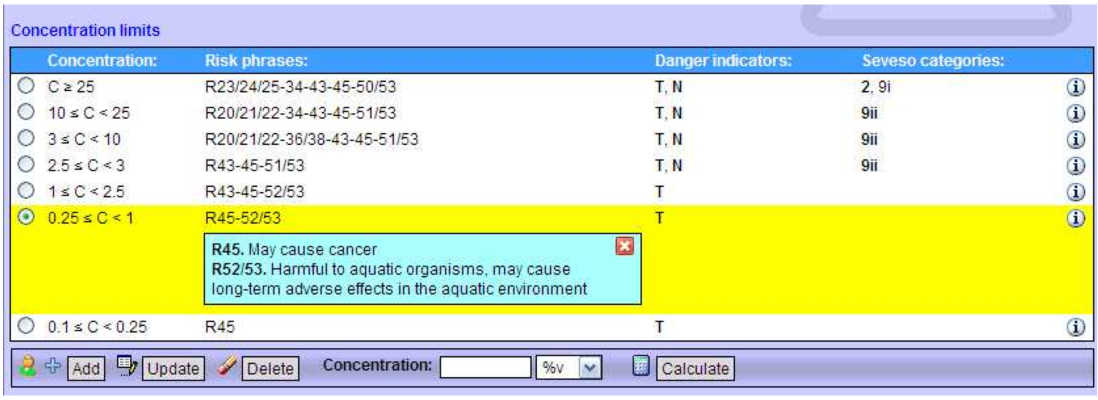


Figure 4.47: Concentration limits and corresponding hazard classifications

4.6.3 96/82/EC Directive Substances

The chemical subsystem has a special section for substances that are considered as dangerous with respect to major-accident potential and specifically named in 96/82/EC Directive Annex I Part 1. In order to handle 96/82/EC Directive substances, two different record types has been developed. Named substance records cover substances for which there exists chemical specific qualifying quantity limits. Named substance groups on the other hand cover groups of substances for which overall qualifying quantity limits have been set for the total amount of substances in the group. Complete listing of current named substances and named substance groups are given in Table 2.1.

Named Substances

The information system allows specific lower and upper qualifying quantity limits to be entered for a chemical stored in the database. Qualifying quantities of a chemical are listed under "Named Substance Qualifying Quantity" section of the chemical information page (Figure 4.48).

The chemical subsystem features qualifying quantity entry form for adding or updating qualifying quantities. Since qualifying quantities are designated by the Directive, only the administrators are allowed to use these forms. In addition to qualifying quantity limits, lower and upper concentrations can also be specified, for which the limits are valid. Multilingual short description that is used to define the qualifying quantity limit and detailed notes thereon can be entered (Figure 4.49).

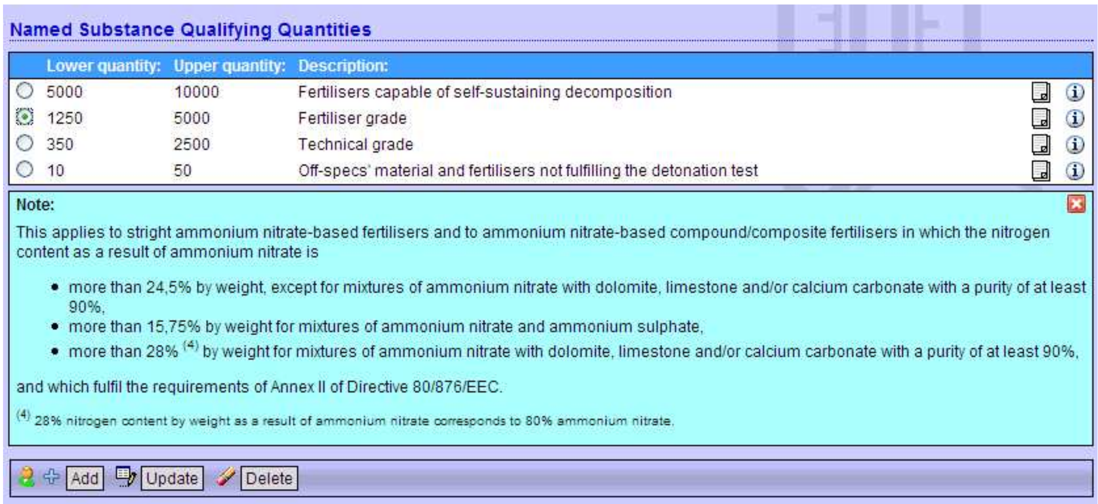


Figure 4.48: List of qualifying quantities for a named chemical

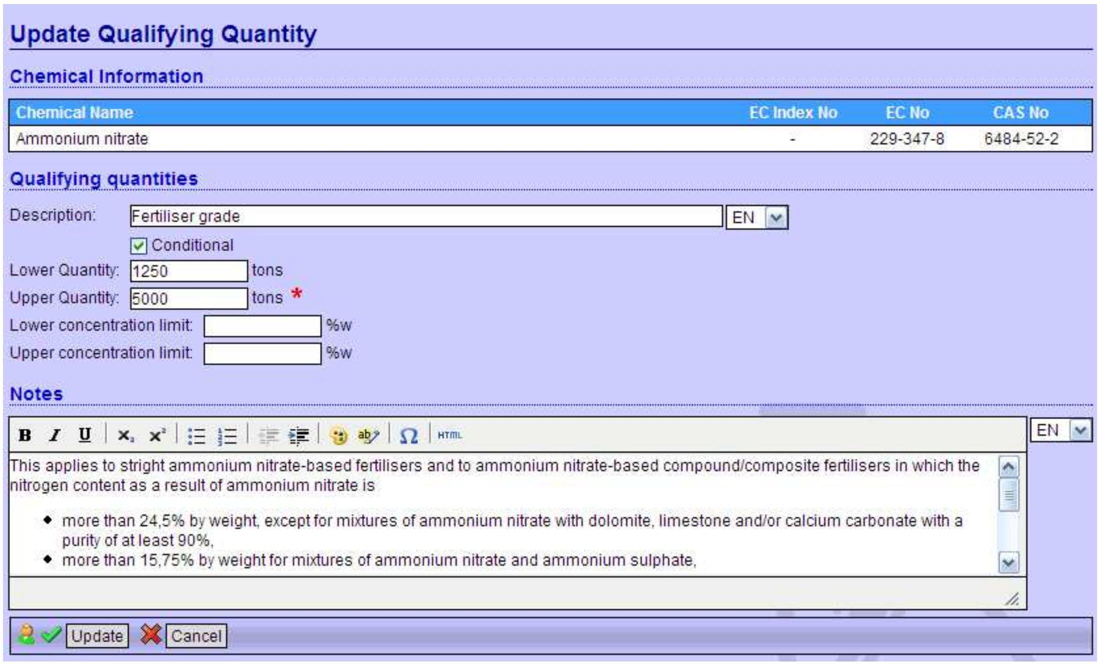


Figure 4.49: Qualifying quantity entry form

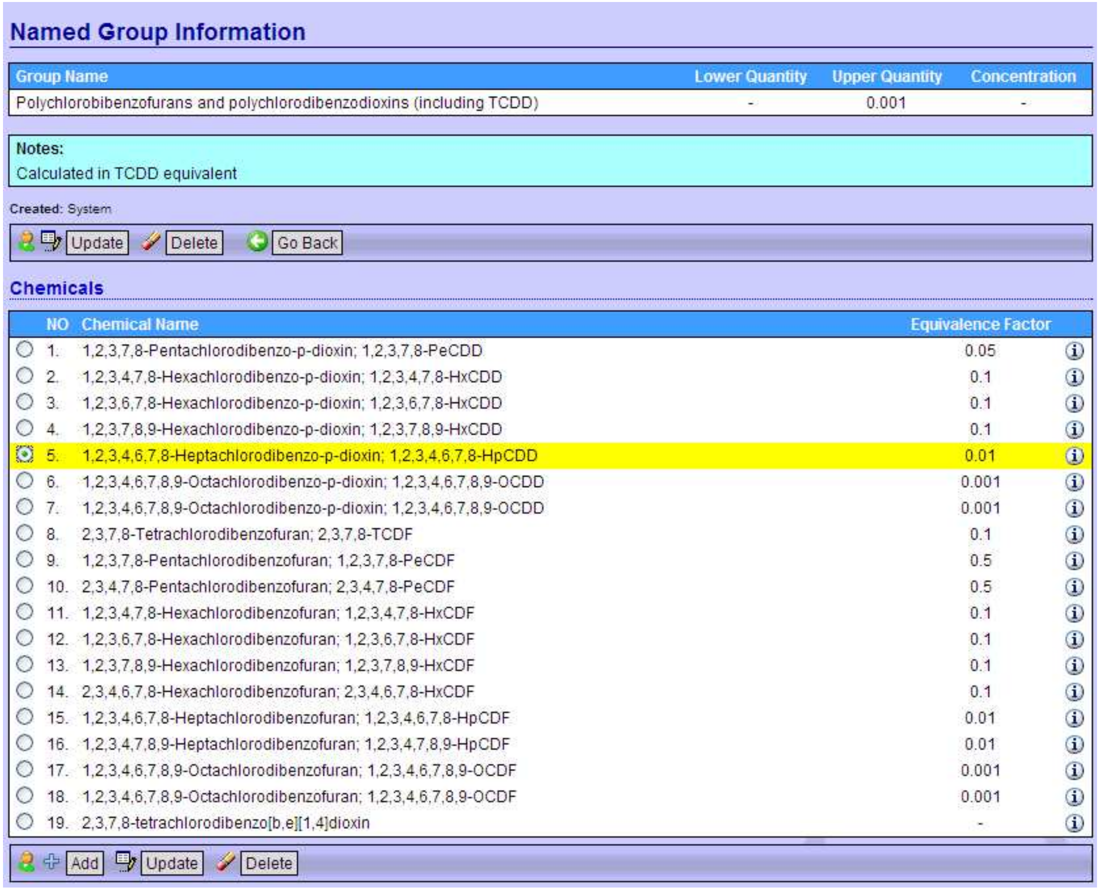
Since for some chemicals listed in Annex I Part 1 there exists several qualifying quantities limits, the system is designed to support multiple limits for a chemical. Qualifying quantities for a chemical are not always mutually exclusive, i.e. there may be qualifying quantities with overlapping limits. In case of multiple qualifying quantities, the user is responsible from selecting the proper limit for the 96/82/EC Directive calculations. For a few qualifying quantities, special conditions are required to be fulfilled, such as presence of powder form or specific composition for fertilizers. For such qualifying quantities a conditional flag could be set to indicate that designation of a qualifying quantity is not obligatory for calculations. In those cases, the information system allows selection of no qualifying quantity option during the 96/82/EC Directive calculations as explained in Section 4.7.5.

Named Substance Groups

In addition to named substances, 96/82/EC Directive Annex I Part 1 also lists groups of substances. A single qualifying quantity limit is given for each group, which is based on total quantity of all chemicals belonging to the group. For selected group substances, equivalence factors are also given, which define the weights of individual quantities of substances in calculating the total quantity. Hence, calculations with named groups of substances is not simple as named substances and require special attention.

Named groups and substances thereof are stored separately in the information system. Similar to named substances, name and description can be specified for a named group and lower and upper qualifying quantities can be set. If there are any, lower and upper concentrations can also be specified. Substances can be added to the named group one by one from the list of chemicals available in the chemical subsystem. Equivalence factor can be specified for each chemical. The factor is assumed to be equal to unity if it is left blank.

Like named substances, named groups and named group substances can only be added or updated by the administrators. Chemical subsystem has a special section for the management of named groups, at which available named groups can be listed. Properties of a named group, together with all chemicals belonging thereto, can be obtained from named group information page (Figure 4.50).



Named Group Information

Group Name	Lower Quantity	Upper Quantity	Concentration
Polychlorobibenzofurans and polychlorodibenzodioxins (including TCDD)	-	0.001	-

Notes:
Calculated in TCDD equivalent

Created: System

Update Delete Go Back

Chemicals

NO	Chemical Name	Equivalence Factor
1.	1,2,3,7,8-Pentachlorodibenzo-p-dioxin; 1,2,3,7,8-PeCDD	0.05
2.	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin; 1,2,3,4,7,8-HxCDD	0.1
3.	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin; 1,2,3,6,7,8-HxCDD	0.1
4.	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin; 1,2,3,7,8,9-HxCDD	0.1
5.	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin; 1,2,3,4,6,7,8-HpCDD	0.01
6.	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin; 1,2,3,4,6,7,8,9-OCDD	0.001
7.	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin; 1,2,3,4,6,7,8,9-OCDD	0.001
8.	2,3,7,8-Tetrachlorodibenzofuran; 2,3,7,8-TCDF	0.1
9.	1,2,3,7,8-Pentachlorodibenzofuran; 1,2,3,7,8-PeCDF	0.5
10.	2,3,4,7,8-Pentachlorodibenzofuran; 2,3,4,7,8-PeCDF	0.5
11.	1,2,3,4,7,8-Hexachlorodibenzofuran; 1,2,3,4,7,8-HxCDF	0.1
12.	1,2,3,6,7,8-Hexachlorodibenzofuran; 1,2,3,6,7,8-HxCDF	0.1
13.	1,2,3,7,8,9-Hexachlorodibenzofuran; 1,2,3,7,8,9-HxCDF	0.1
14.	2,3,4,6,7,8-Hexachlorodibenzofuran; 2,3,4,6,7,8-HxCDF	0.1
15.	1,2,3,4,6,7,8-Heptachlorodibenzofuran; 1,2,3,4,6,7,8-HpCDF	0.01
16.	1,2,3,4,7,8,9-Heptachlorodibenzofuran; 1,2,3,4,7,8,9-HpCDF	0.01
17.	1,2,3,4,6,7,8,9-Octachlorodibenzofuran; 1,2,3,4,6,7,8,9-OCDF	0.001
18.	1,2,3,4,6,7,8,9-Octachlorodibenzofuran; 1,2,3,4,6,7,8,9-OCDF	0.001
19.	2,3,7,8-tetrachlorodibenzo[b,e][1,4]dioxin	-

Add Update Delete

Figure 4.50: Named group and chemicals information

4.6.4 UN/ADR Explosive Substances

In addition to substances and preparations classified as explosive (risk phrase R2 or R3) according to 67/548/EEC and 1999/45/EC Directives, explosive substances, preparations or articles covered by the European Agreement concerning the International Carriage of Dangerous Goods by Road (UN/ADR) are also taken into consideration by the 96/82/EC Directive.

UN/ADR is an international agreement that designates dangerous goods that shall not be accepted for international transport by road, and lays down conditions for packaging and labelling of other dangerous goods, and construction, equipment and operation of the vehicle carrying thereof [81]. Although there is no overall enforcing authority, it is signed by the EU countries as well as a number of non-EU countries such as Russian Federation, Ukraine and Kazakhstan. As of 2008, Turkey is not a signatory of the agreement. But there are studies for application of the provisions laid out by the agreement. Turkish Chemical Manufacturers Association's effort on this topic, should be especially noted [82].

Similar to the 67/548/EEC and 1999/45/EC Directives, the UN/ADR classifies dangerous goods according to their hazard characteristics, such as explosive, flammable, toxic, infectious, radioactive substances and materials. There are 13 classes of dangerous goods according to the UN/ADR, Class 1 being explosive substances and articles. For each substance and article of Class 1, a division number and a compatibility group letter has been assigned, which together form the classification code. There are 6 divisions and 13 compatibility groups as listed in Table 4.16 and Table 4.17, respectively. Divisions are based on explosion, fire and projection hazards, and sensitivity of substances and articles, hence describe the explosive characteristics. Complementary to the divisions, compatibility groups express the composition thereof.

Since they are used in the 96/82/EC Directive calculations, the information system provides data entry forms to store UN/ADR explosive substances in the database and update as required. For each UN/ADR explosive, substance name and code number given by the UN/ADR (UN No) should be entered. Division and compatibility group of the explosive can be selected from the lists provided by the system. If set by the agreement, lower and upper concentration limits by weight can be indicated, for which the substance should be accepted as an UN/ADR explosive (Figure 4.51).

Table 4.16: UN/ADR explosive divisions

Division	Description
1.1	Substances and articles which have a mass explosion hazard (a mass explosion is an explosion which affects almost the entire load virtually instantaneously
1.2	Substances and articles which have a projection hazard but not a mass explosion hazard.
1.3	Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard: (a) combustion of which gives rise to considerable radiant heat; or (b) which burn one after another, producing minor blast or projection effects or both.
1.4	Substances and articles which present only a slight risk of explosion in the event of ignition or initiation during carriage. The effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire shall not cause virtually instantaneous explosion of almost the entire contents of the package.
1.5	Very insensitive substances having a mass explosion hazard which are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions of carriage. As a minimum requirement they must not explode in the external fire test.
1.6	Extremely insensitive articles which do not have a mass explosion hazard. The articles contain only extremely insensitive detonating substances and demonstrate a negligible probability of accidental initiation or propagation.

Table 4.17: UN/ADR explosive compatibility groups

Group	Description
A	Primary explosive substance.
B	Article containing a primary explosive substance and not having two or more effective protective features. Some articles, such as detonators for blasting, detonator assemblies for blasting and primers, cap-type, are included, even though they do not contain primary explosives.
C	Propellant explosive substance or other deflagrating explosive substance or article containing such explosive substance.
D	Secondary detonating explosive substance or black powder or article containing a secondary detonating explosive substance, in each case without means of initiation and without a propelling charge, or article containing a primary explosive substance and having two or more effective protective features.
E	Article containing a secondary detonating explosive substance, without means of initiation, with a propelling charge (other than one containing a flammable liquid or gel or hypergolic liquids).
F	Article containing a secondary detonating explosive substance with its own means of initiation, with a propelling charge (other than one containing a flammable liquid or gel or hypergolic liquids) or without a propelling charge.
G	Pyrotechnic substance, or article containing a pyrotechnic substance, or article containing both an explosive substance and an illuminating, incendiary, tear- or smoke-producing substance (other than a water-activated article or one which contains white phosphorus, phosphides, a pyrophoric substance, a flammable liquid or gel or hypergolic liquids).
H	Article containing both an explosive substance and white phosphorus.
J	Article containing both an explosive substance and a flammable liquid or gel.
K	Article containing both an explosive substance and a toxic chemical agent.
L	Explosive substance or article containing an explosive substance and presenting a special risk (e.g. due to water activation or the presence of hypergolic liquids, phosphides or a pyrophoric substance) necessitating isolation of each type.
N	Articles containing only extremely insensitive detonating substances.
S	Substance or article so packed or designed that any hazardous effects arising from accidental functioning are confined within the package unless the package has been degraded by fire, in which case all blast or projection effects are limited to the extent that they do not significantly hinder or prevent fire-fighting or other emergency response efforts in the immediate vicinity of the package.

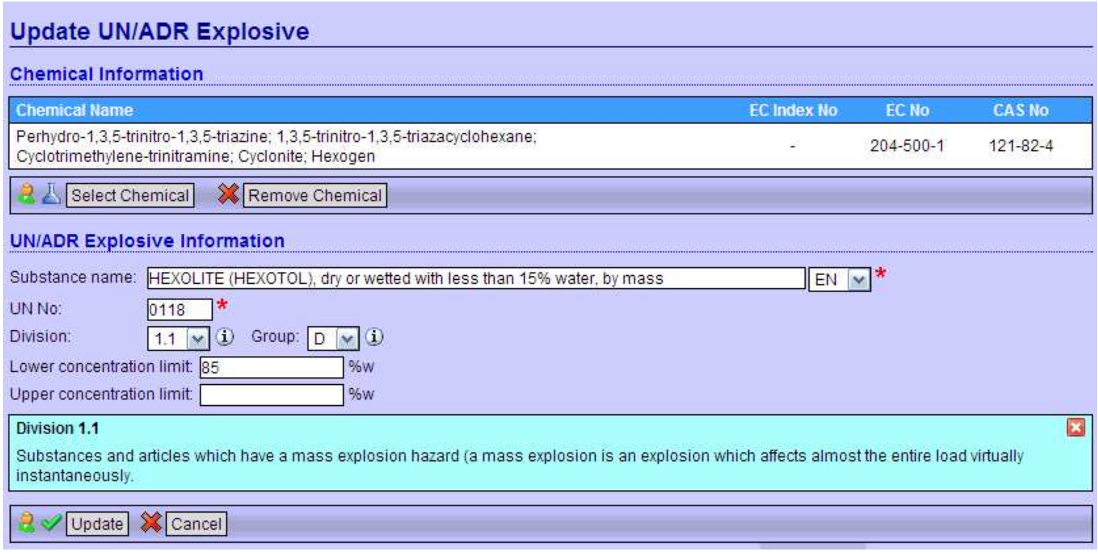
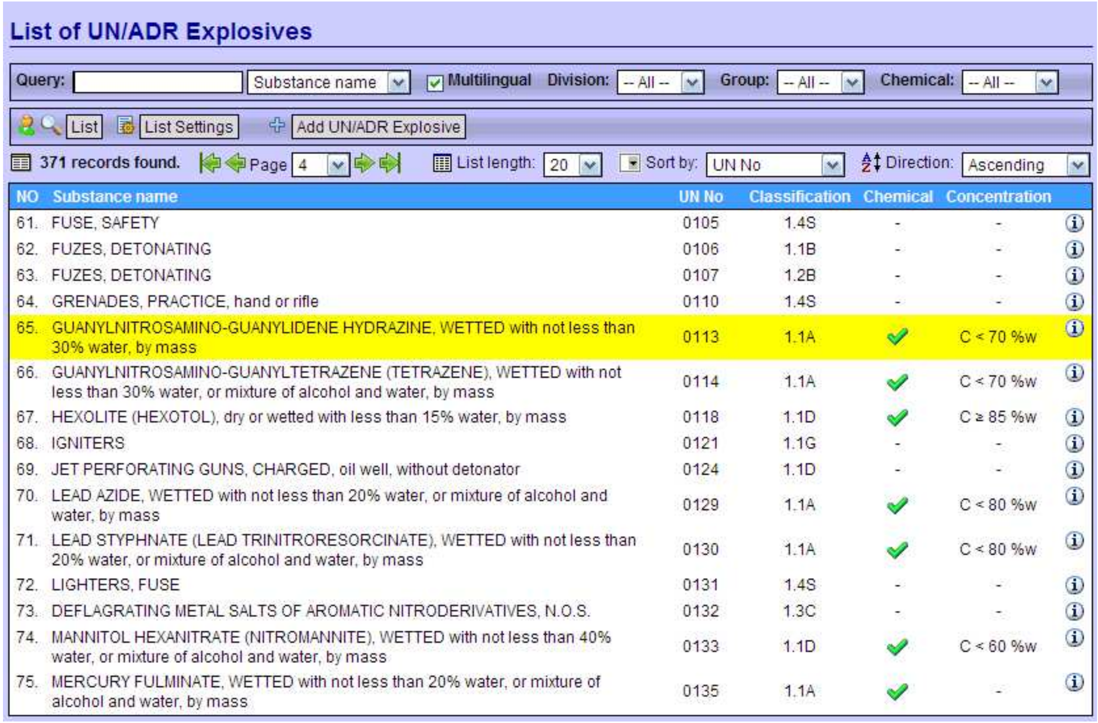


Figure 4.51: UN/ADR explosive data enty form

List of the UN/ADR Class 1 explosives as defined by the agreement contain two different kinds of explosive materials. The first kind of explosives are substances and preparations that are named by specific chemicals, such as lead azide wetted not less than 20% water, nitroglycerin solution in alcohol, and tetrazene. The second kind of explosives are articles that are named according to their product names, such as fuses, bombs, charges, and igniters. For explosive substances and preparations, the information system allows the corresponding chemical to be selected from the list of chemicals available in the chemical subsystem (Figure 4.51). Hence, UN/ADR explosives and chemicals can be linked to each other. This relation information is used during the 96/82/EC Directive calculations, as explained in Section 4.7.5.

List of the UN/ADR explosives can be accessed from "UN/ADR Explosives" section of the chemical subsystem. UN/ADR explosives can be searched according to name, UN no, explosive division and compatibility group information. Resulting list of UN/ADR explosives can be sorted by name, UN No, explosive classification and presence of linked chemical. Explosives that are linked to chemicals are specifically indicated in the list. Valid concentration limits are also specified (Figure 4.52).


List of UN/ADR Explosives

Query: Substance name Multilingual Division: -- All -- Group: -- All -- Chemical: -- All --

List | List Settings | Add UN/ADR Explosive

371 records found. Page 4 List length: 20 Sort by: UN No Direction: Ascending

NO	Substance name	UN No	Classification	Chemical	Concentration
61.	FUSE, SAFETY	0105	1.4S	-	-
62.	FUZES, DETONATING	0106	1.1B	-	-
63.	FUZES, DETONATING	0107	1.2B	-	-
64.	GRENADES, PRACTICE, hand or rifle	0110	1.4S	-	-
65.	GUANYLNITROSAMINO-GUANYLIDENE HYDRAZINE, WETTED with not less than 30% water, by mass	0113	1.1A	✓	C < 70 %w
66.	GUANYLNITROSAMINO-GUANYLTETRAZENE (TETRAZENE), WETTED with not less than 30% water, or mixture of alcohol and water, by mass	0114	1.1A	✓	C < 70 %w
67.	HEXOLITE (HEXOTOL), dry or wetted with less than 15% water, by mass	0118	1.1D	✓	C ≥ 85 %w
68.	IGNITERS	0121	1.1G	-	-
69.	JET PERFORATING GUNS, CHARGED, oil well, without detonator	0124	1.1D	-	-
70.	LEAD AZIDE, WETTED with not less than 20% water, or mixture of alcohol and water, by mass	0129	1.1A	✓	C < 80 %w
71.	LEAD STYPHNATE (LEAD TRINITRORESORCINATE), WETTED with not less than 20% water, or mixture of alcohol and water, by mass	0130	1.1A	✓	C < 80 %w
72.	LIGHTERS, FUSE	0131	1.4S	-	-
73.	DEFLAGRATING METAL SALTS OF AROMATIC NITRODERIVATIVES, N.O.S.	0132	1.3C	-	-
74.	MANNITOL HEXANITRATE (NITROMANNITE), WETTED with not less than 40% water, or mixture of alcohol and water, by mass	0133	1.1D	✓	C < 60 %w
75.	MERCURY FULMINATE, WETTED with not less than 20% water, or mixture of alcohol and water, by mass	0135	1.1A	✓	-

Figure 4.52: List of UN/ADR explosive substances and articles

4.6.5 Units and Unit Conversion

In order to facilitate calculations related to chemicals, the information system provides a generic unit conversion mechanism that is able to determine whether two units are compatible to each other and how to convert a value given in one unit into its corresponding value in the other unit.

Units are stored in the database and identified by unique codes. These codes are used to refer units in calculations. Similar to other record types, units have multilingual support. Symbols (including Greek symbols) and names of the units can be specified in different languages. Unit conversion mechanism recognizes International System of Units (SI) prefixes. Therefore, SI prefixed units are not needed to be stored separately in the database.

There are three types of units in the information system:

1. *Base units* are nominally dimensionally independent units. SI defines seven base units, which are metre (m), kilogram (kg), seconds (s), ampere (A), kelvin (K), mole (mol), and candela (cd). All other units are derived from these base units.

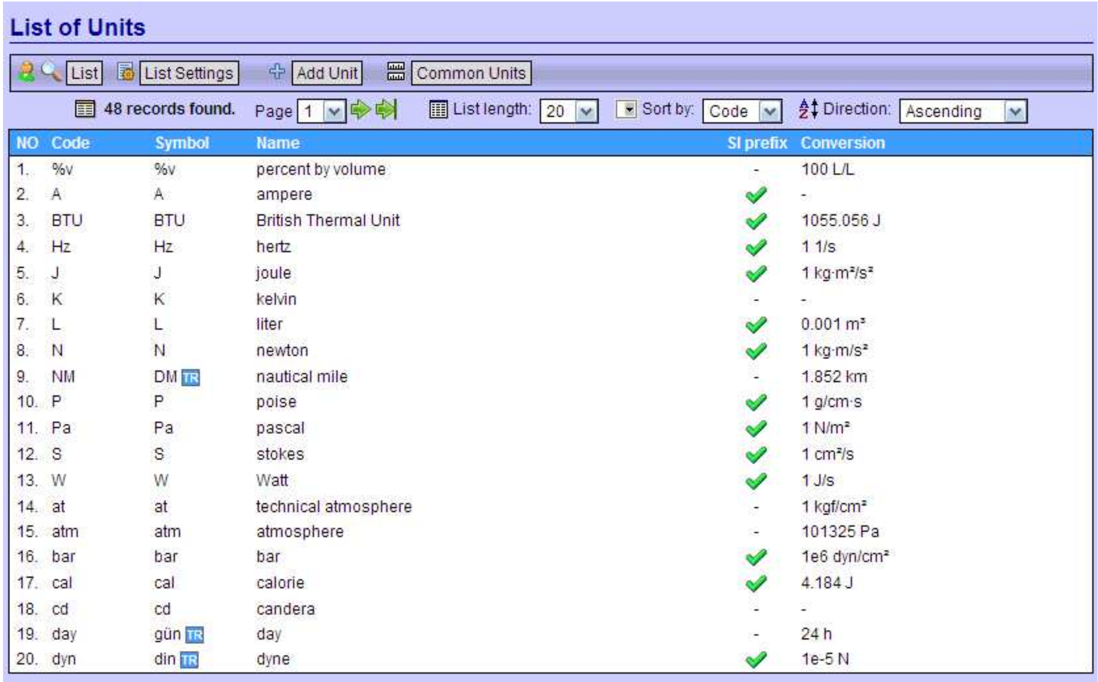
2. *Units with conversion factors* are units that can be converted to another units by simple multiplication with specific conversion constants. For example, 1 Pascal (Pa) is 1 N/m^2 and 1 atmosphere (atm) is 101325 Pa.

3. *Units with special conversion functions* are units that can be converted to other units only by custom defined functions. Conversion of a temperature value from $^{\circ}F$ to $^{\circ}C$ can be given as an example.

The system can determine whether two units are similar (i.e. convertible) to each other. If the units are similar, a value in the source unit is converted to its corresponding value in the destination unit using appropriate combinations of conversion factors and conversion functions. The system is capable of converting derived units. For example, $lbs/cm^2 \cdot min$ can be converted to $kg/L \cdot s$.

Units recognised by the information system can be listed in the "Units" section of the chemical subsystem (Figure 4.53). Editors are allowed to add new units. In order to add a new unit, code and name of the unit should have to be specified. Symbol denoting the unit and whether the unit is SI prefixable or not can be stated. If the unit is not a base unit, its compatible unit and method of conversion thereto can be entered. For custom conversion functions, the name of the function, and for conversion factors, the value of the conversion factor must be entered (Figure 4.54).

The information system is capable of listing all compatible units if a unit is given as the reference. This capability is frequently used in data entry forms for allowing the user to enter data in most convenient unit to himself, without enforcing manual conversion to a specific unit. However, number of listed compatible units may be too high if reference unit is a derived unit composed of several base units, or SI prefixable. Majority of compatible units may be rarely used by the scientific society, hence unnecessary to list. Taking the fact that short lists containing frequently used units increase user friendliness of the system, common units are introduced. A common unit is a compatible unit of a unit, which is entered manually by an editor. If a request for listing compatible units is received, the information system first checks common units table to find out whether or not such units exist for the given base unit. If common units are found they are listed as compatible units, otherwise system generated compatible units are listed. Common units can be added and updated from "Common Units" section of chemical subsystem.



List of Units

List | List Settings | Add Unit | Common Units

48 records found. Page 1 | List length: 20 | Sort by: Code | Direction: Ascending

NO	Code	Symbol	Name	SI prefix	Conversion
1.	%v	%v	percent by volume	-	100 L/L
2.	A	A	ampere	✓	-
3.	BTU	BTU	British Thermal Unit	✓	1055.056 J
4.	Hz	Hz	hertz	✓	1 1/s
5.	J	J	joule	✓	1 kg·m²/s²
6.	K	K	kelvin	-	-
7.	L	L	liter	✓	0.001 m³
8.	N	N	newton	✓	1 kg·m/s²
9.	NM	DM TR	nautical mile	-	1.852 km
10.	P	P	poise	✓	1 g/cm·s
11.	Pa	Pa	pascal	✓	1 N/m²
12.	S	S	stokes	✓	1 cm²/s
13.	W	W	Watt	✓	1 J/s
14.	at	at	technical atmosphere	-	1 kgf/cm²
15.	atm	atm	atmosphere	-	101325 Pa
16.	bar	bar	bar	✓	1e6 dyn/cm²
17.	cal	cal	calorie	✓	4.184 J
18.	cd	cd	candera	-	-
19.	day	gün TR	day	-	24 h
20.	dyn	din TR	dyne	✓	1e-5 N

Figure 4.53: List of units

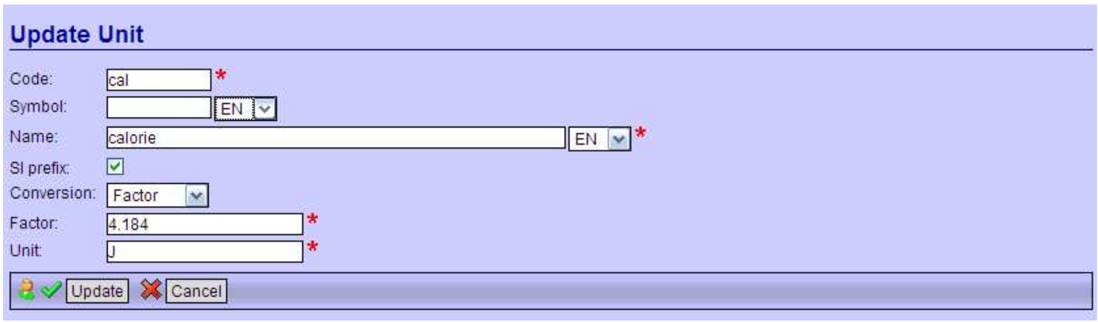


Figure 4.54: Unit entry form

4.6.6 Constants

The information system allows universal constants frequently used in calculations, such as standard gravity (g) or gas constant (R), to be stored in the database and supplied to the calculation functions whenever needed instead of redefining each time. Using unit conversion feature of the information system, constants can be obtain in different units according to the requirements of relevant equations. Similar to other record types, data entry forms are available for constants. Since values of constants are critical and directly affect the results of calculations, only administrators are allowed to add or update constants. Common constants stored in the database and used for calculations are listed in Table 4.18.

Table 4.18: Common constants used for calculations

Symbol	Name	Value
G	Gravitational constant	$6.67428 \cdot 10^{-11}\ m^2/kg \cdot s^2$
N_a	Avagadro constant	$6.02214179 \cdot 10^{23}\ mol^{-1}$
R	Universal gas constant	$8.314472471\ J/K \cdot mol$
g	Standard gravity	$9.80665\ m/s^2$
k_b	Boltzmann constant	$1.3806504 \cdot 10^{-23}\ J/K$

4.6.7 Equations

In addition to units and constants, the information system supports equations comprised of mathematical expressions. Equations form the basis of chemical property equations, which are used to supply temperature and pressure dependent chemical property data, such as heat capacity or density.

Mathematical equations commonly used in the literature, such as DIPPR [83] and TNO [19] equations, are made available as the basic set of equations. Similar to other record types, new equations can also be added through the equation entry form. Equation syntax is similar to the one being used in Calculus and includes numbers, operators, and functions in combination with constants and variables. Constants and variables are denoted with single upper and lower case alphanumeric characters, respectively. In the current implementation, equations are limited to a single variable denoted with x

and up to 6 constants denoted with A to F. Numbers consist of optional sign, any number of digits, optional decimal part and optional exponential part in scientific notation, e.g. $-123.45e6$. Arithmetic operators and mathematics functions supported by the system are listed in Table 4.19 and Table 4.20, respectively. Arithmetic operators are listed in the order of their precedence from lower to higher.

Table 4.19: Arithmetic operators supported by equations

Operator	Description	Example	Result
+	Addition	a+b	Sum of a and b
-	Subtraction	a-b	Difference of a and b
/	Division	a/b	Quotient of a and b
*	Multiplication	a*b	Product of a and b
^	Exponential	a^b	a raised to power b
( )	Grouping	a*(b+c)	Product of a and sum of b and c

Table 4.20: Mathematical functions supported by equations

Operator	Description
log()	Logarithm (base 10)
ln()	Natural logarithm (base e)
exp()	Exponent of e
sin()	Sine (in radians)
cos()	Cosine (in radians)
sinh()	Hyperbolic sine
cosh()	Hyperbolic cosine

During entry of an equation, the equation is checked by the system for validity to the syntax and existence of proper number of constants. Invalid equations are not allowed to be added to the database. Example expressions and their equivalent mathematical expressions are given in Table 4.21.

Table 4.21: Example equations and equivalent mathematical expressions

Equation	Mathematical expression
A+B*x+C*xˆ2	$A + Bx + Cx^2$
A/Bˆ(1+(1-x/C)ˆD)	$\frac{A}{B^{(1+(1-\frac{x}{C})^D)}}$
(A*xˆB)/(1+C/x+D/xˆ2)	$\frac{Ax^B}{1+\frac{C}{x}+\frac{D}{x^2}}$

4.6.8 Chemical Properties

An important part of the chemical subsystem is chemical properties section. Comprehensive data entry and analysis tools are provided for chemical properties that can be quantified by numerical values, such as melting point, molecular weight, and flammability limits. In addition to fuzzy property data values, property equations and property estimators are also supported. Property data analysis algorithm of the information system analyses all available information on chemical properties and provide single and standardized values for selected reference conditions.

Similar to other record types, data entry forms are provided for entering new chemical properties to the system (Figure 4.55). For each chemical property a unique identifier should be given, which is used to refer the property in calculations. Besides the identifier, multilingual name and symbol of the property can also be specified. Symbols support italic, subscript and superscript formatting and are used to denote the property during data display.

The unit of the property can be indicated or left blank if the property is unitless (e.g. Bioconcentration factor). Properties with multiple units are also supported. For example, four different units can be specified for Henry's Law constant, which are $L \cdot atm/mol$, $mol/L \cdot atm$, atm, and dimensionless. Units are used to control whether or not proper unit is given during chemical property data entry, and to group data values during chemical property data analysis. Detailed information on chemical property data analysis is given in 4.6.12.

Dependence of the chemical property to reference conditions, such as temperature,

Figure 4.55: Chemical property entry form

pressure and chemical phase, is taken into consideration by the information system. In order to designate conditions that the property depends on, default values of the reference conditions should be entered. Reference temperature and pressure can be specified numerically together with relevant units. Reference phase can be selected as gaseous, liquid and solid from the list provided by the system. The property is considered to be independent of conditions that are left blank.

Chemical properties can be searched for property name and listed by property name, symbol and unit (Figure 4.56).

4.6.9 Chemical Property Data

The information system has a chemical property data section, which allow chemical property data available in the scientific literature to be stored in the database and supplied to relevant subsystems for chemical specific calculations and modelling purposes. Both single property values and datasets containing multiple data values are supported.

Chemical property data entry starts with selection of the chemical and the desired chemical property. According to the selected chemical property, input elements regarding reference conditions and numerical property data entry are updated by the system to reflect chemical property specific settings (Figure 4.57).

For properties that do not depend on reference conditions (e.g. molecular weight, melting point) a single data value is allowed to be entered. For properties that depend on temperature and/or pressure, multiple data values can be entered each of which

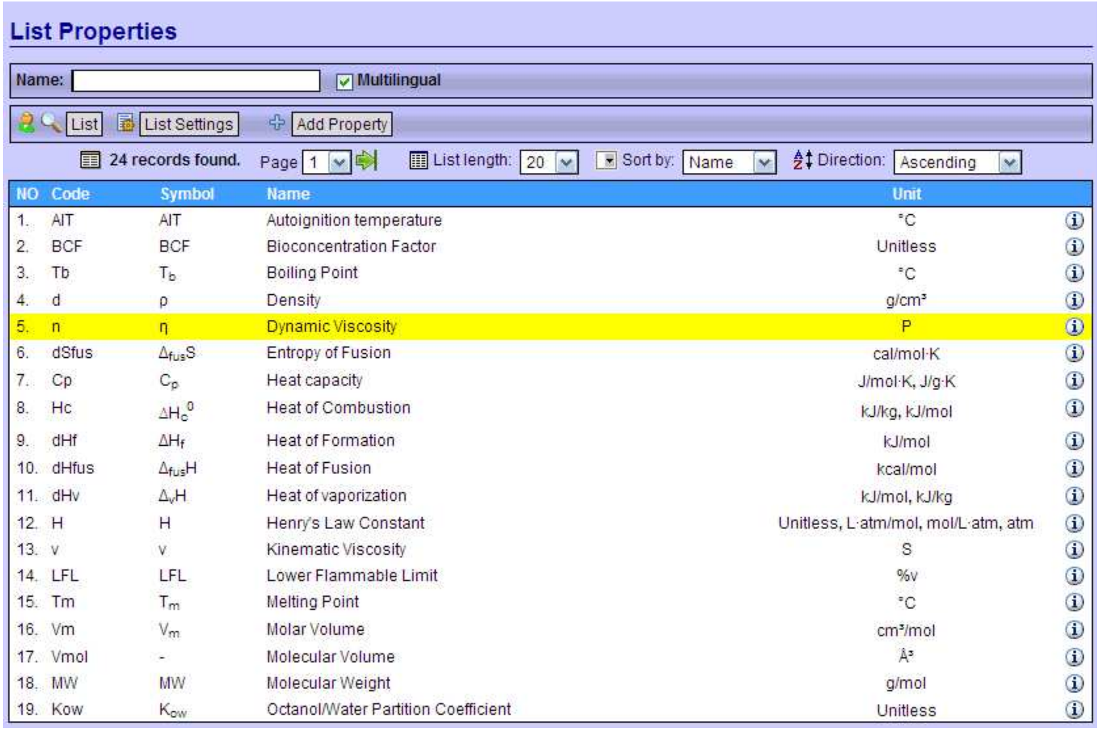


Figure 4.56: List of chemical properties

corresponds to chemical property value at different conditions (Figure 4.57). According to dependence of the property on temperature and pressure, reference temperature and pressure values are asked by the system. Reference values are not obligatory and are assumed to be equal to the default values of the property if they are left blank. Units of the reference temperature and pressure can be selected. In case of multiple property data values, reference conditions can not be left blank and should be entered for each data value separately. If data values are available in logarithmic scale, they can be directly entered to the system by setting logarithmic flag. For phase dependent properties, such as density and molecular volume, reference phase of the property data can be specified.

Unit of the chemical property data can be selected from the list provided by the system according to the units of the property. The list includes not only the property units, but also similar units generated automatically by the system or available as common units. If required, the unit can also be specified manually.

Source of the property data can be stated either by selecting a bibliographical reference from the list provided by the document subsystem, or entering textual refer-

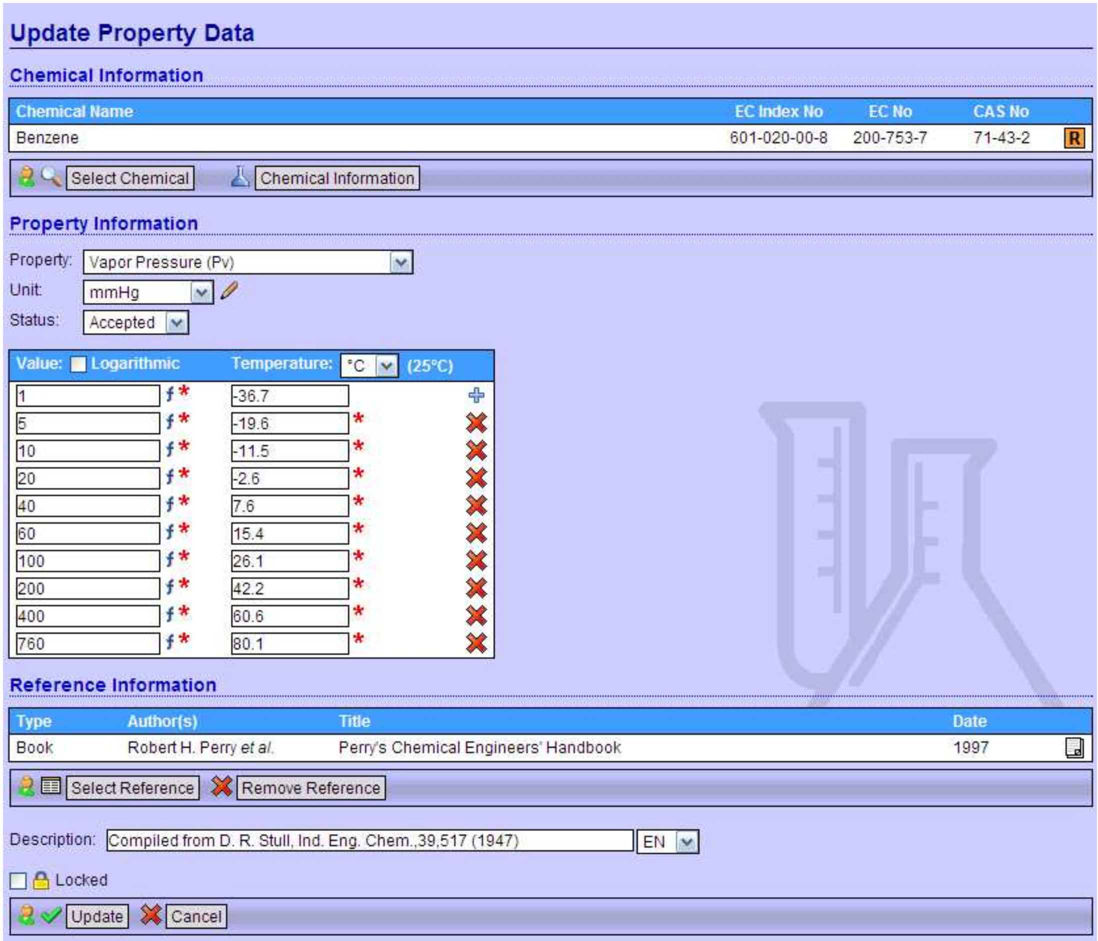


Figure 4.57: Chemical property data entry form

ence information. Bibliographical references provide more detailed information, hence should be preferred over textual reference input, which is mainly offered for rapid and mass data entry. In addition to the source of the property data, detailed descriptive information such as method of measurement or estimation can also be denoted.

How the chemical property data should be handled during data analysis by the information system can be explicitly specified. Not all data properties stored in the system should have to be used for calculations. If it is known that quality of data is poor or erroneous, the data can be excluded from calculations and held in the system for informative purposes only. On the contrary, if the data is known to be the best value among the available alternatives, it can be selected as the default data enforcing the system to use the value for calculations skipping other data values. The property data can also left as it is. In that case, the information system decides whether or not to use the data by doing a statistical analysis. Property data status can be selected as rejected, default or normal, to specify type of data handling methods mentioned above.

Similar to other record types, property data records can be added or updated by editors, and locked by the owners to prevent further editing. There is no restriction on the number of chemical property data values that can be added to the system for a specific chemical and chemical property pair. Reference conditions may also be the same. Chemical property data analysis algorithm of the information system is capable of dealing with coincident data values.

Chemical property data entered to the system can be displayed on chemical property information page (Figure 4.58). Chemical property data is also shown on the chemical information page, together with other property related information (equations, estimators, etc.) and results of statistical analysis, including standardized values for reference conditions that can be stated by the user. Details on property data analysis are given in Section 4.6.12.

4.6.10 Chemical Property Equations

A common approach to quantify chemical properties, which are significantly affected by temperature and pressure, is to fit available experimental data to specific mathematical expressions to obtain a unique equation [84]. The equation, constants of which depend on source data and method of data fitting applied, is generally a good representative of the trend of the chemical property values within its validity range. Hence,

Figure 4.58: Chemical property information

it allows value of the dependent variable (chemical property) to be easily calculated given the value(s) of independent variable(s) (temperature and/or pressure). Property equations are widely used for accident modelling purposes, because hazardous substances are generally stored under high pressure or low temperature conditions, which may change their nature rapidly during an accident [19]. Change in pressure or temperature may be in the order of several magnitudes, therefore calculation of reference condition dependent values of chemical properties is unavoidable if reliable results are needed.

Taking this into consideration, the information system supports chemical property equations and provides data entry forms thereof. In order to add or update a chemical property equation, first the property and chemical to which the property equation belongs should be selected (Figure 4.59).

According to the units and phase dependence of the property, unit and reference phase of the equation are asked. Unit is not requested for properties that are unitless. If the property has unit(s), all similar units including common units are listed for selection. The unit can also be specified manually. For properties that are phase dependent, reference phase of the equation is also requested.

Type of the property equation can be selected from the equation list provided by the system, which includes equations stored in the system as described in Section 4.6.7. According to the number of constants defined in the selected equation, numeric

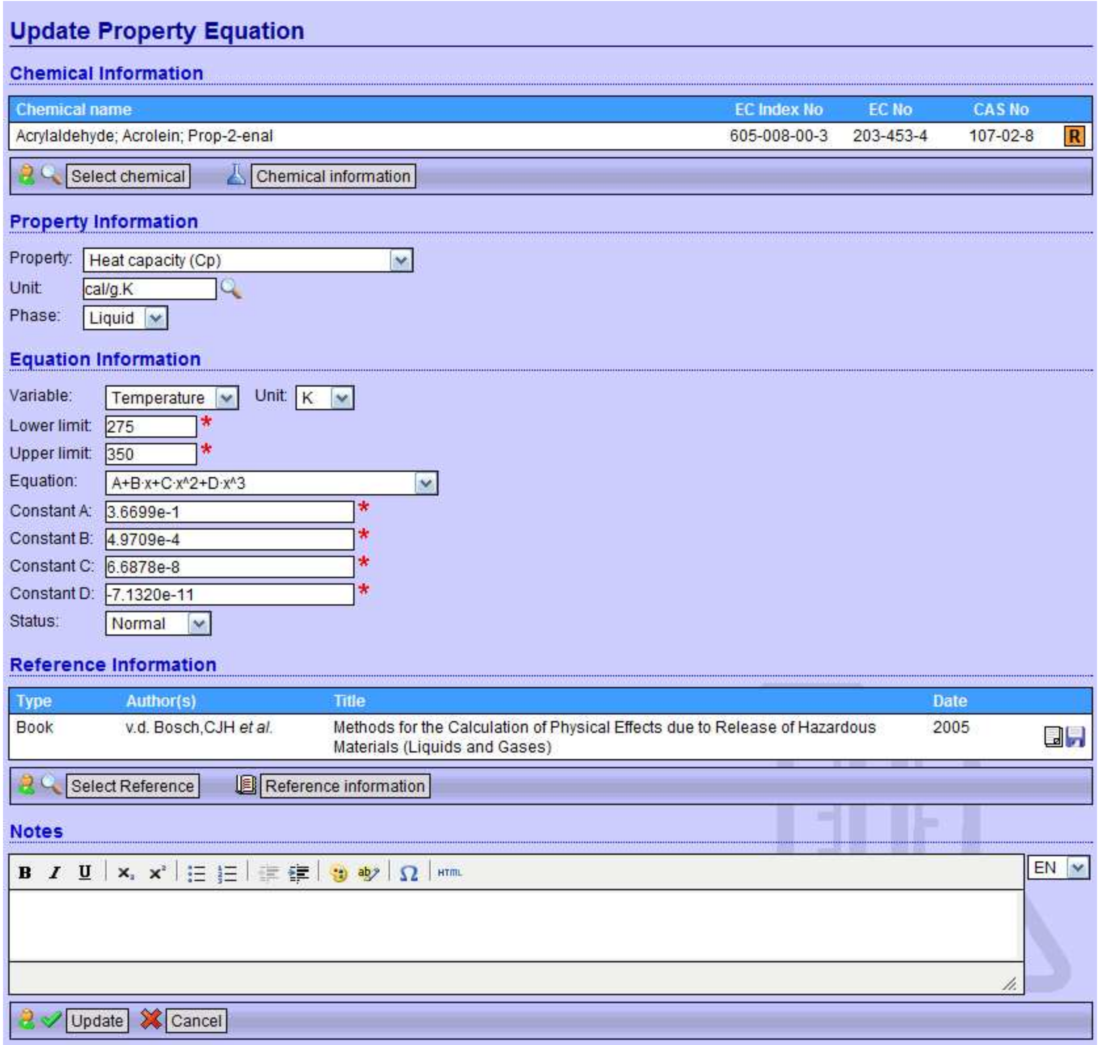
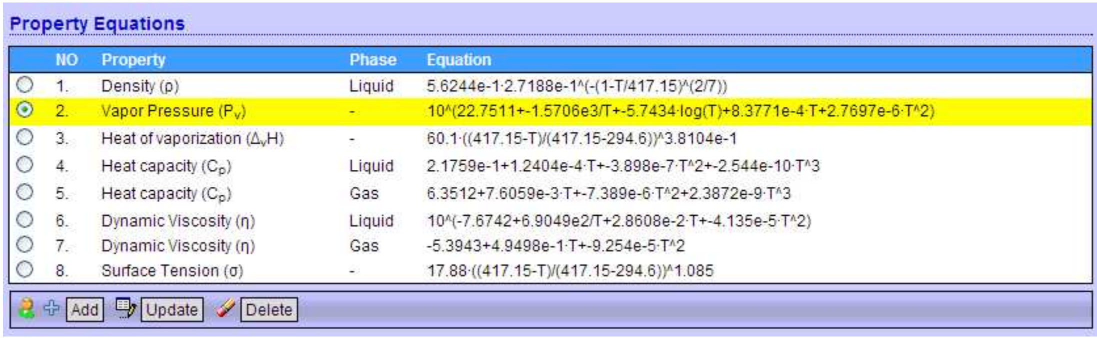


Figure 4.59: Property equation entry form

input elements are shown for input of equation constants. Constants can be entered in scientific notation, but fuzzy values are not supported. Independent variable of the equation can be selected as temperature or pressure, and unit of the equation can be specified accordingly. Validity range of the equation should be specified as lower and upper limits in terms of selected independent variable and unit. Similar to property data, status of the property equation can be selected as default, normal, or rejected. Rejected equations are not used in chemical property calculations, whereas default equations are used for calculating property values within their validity limits overwriting all other property equations and also property data values falling within the limits (equations have higher priority compared to data values).

Source of the property equation can be specified by selecting a reference from the document subsystem. Custom notes on accuracy or method of curve fitting used to obtain the property equation can be indicated as well.

Property equations available for a chemical are listed under “Property Equations” section of the chemical information page. Name of property, reference phase and final form of the equation including constants and independent variable (temperature or pressure) are listed for each property equation (Figure 4.60).



Property Equations

NO	Property	Phase	Equation
1.	Density (ρ)	Liquid	5.6244e-1·2.7188e-1^(-(1-T/417.15)^(2/7))
2.	Vapor Pressure (P_v)	-	10^(22.7511+-1.5706e3/T+-5.7434·log(T)+8.3771e-4·T+2.7697e-6·T^2)
3.	Heat of vaporization ($\Delta_v H$)	-	60.1·((417.15-T)/(417.15-294.6))^3.8104e-1
4.	Heat capacity (C_p)	Liquid	2.1759e-1+1.2404e-4·T+-3.898e-7·T^2+-2.544e-10·T^3
5.	Heat capacity (C_p)	Gas	6.3512+7.6059e-3·T+-7.389e-6·T^2+2.3872e-9·T^3
6.	Dynamic Viscosity (η)	Liquid	10^(-7.6742+6.9049e2/T+2.8608e-2·T+-4.135e-5·T^2)
7.	Dynamic Viscosity (η)	Gas	-5.3943+4.9498e-1·T+-9.254e-5·T^2
8.	Surface Tension (σ)	-	17.88·((417.15-T)/(417.15-294.6))^1.085

Figure 4.60: Chemical property equations of a chemical

Detailed information on property equations can be obtained from property equation information page, which can be accessed by selecting a property equation from the list of property equations. In addition to tabulated information on the property equation, line plot of the equation for its validity range is also made available for visual inspection (Figure 4.61)

A chemical may have multiple property equations for a specific property. Selection of the proper property equation is done automatically by the system, as explained in Section 4.6.12.

4.6.11 Chemical Property Estimators

In addition to supporting chemical property datasets and property equations, the information system is also capable of estimating chemical properties by using scientific estimation methods. For this purpose the system features a generic property estimation framework that allows the administrators to register unlimited number of property

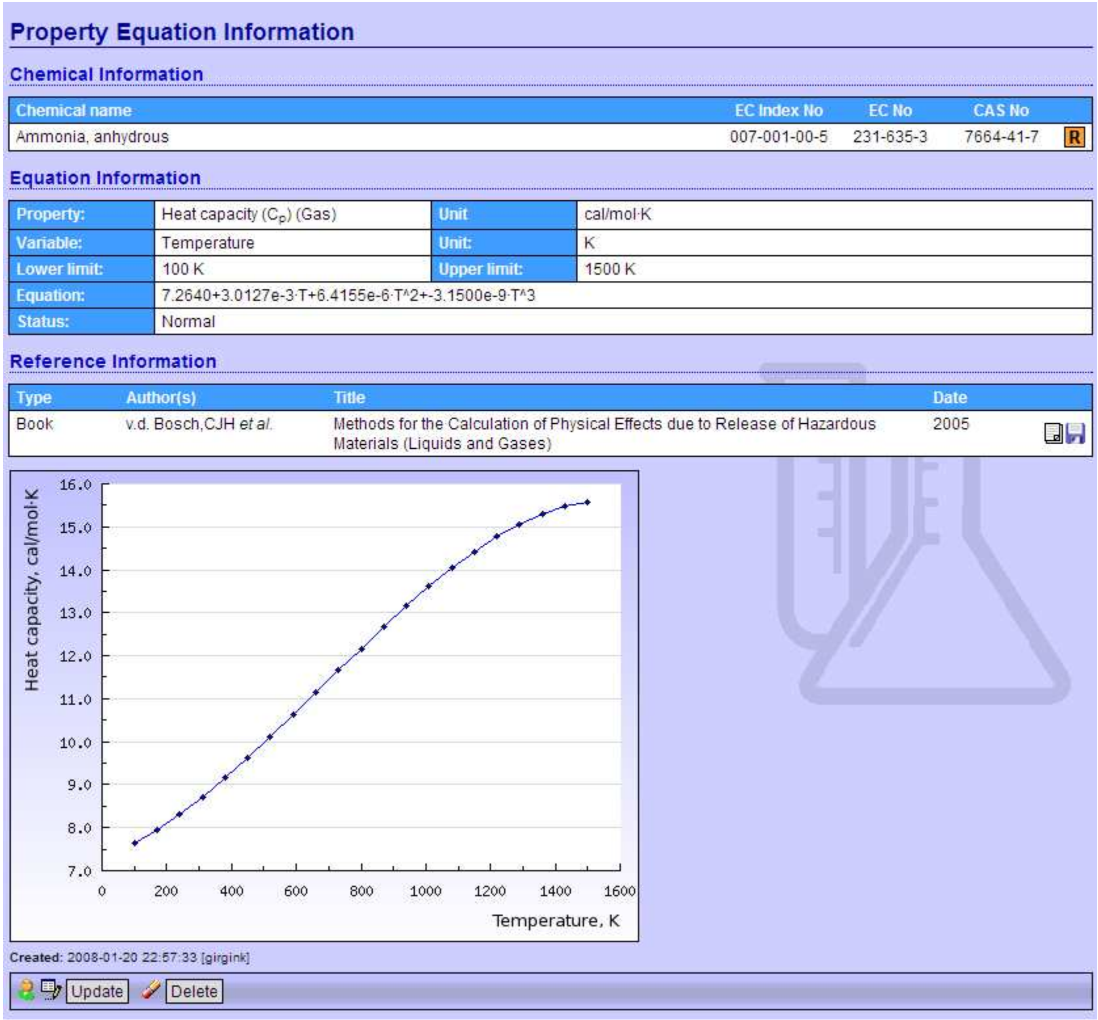


Figure 4.61: Property equation information

estimators. Each property estimator is identified by a unique code, which is used to indicate the estimator in calculations. The property to be estimated and chemical phase should be specified together with the unit of the estimate and the estimation function. The name of the estimation method and descriptive notes thereon can be stated and used by the system for referencing purposes (Figure 4.62).

An estimation function takes the chemical and reference conditions as input, and tries to estimate the property using other available chemical properties by applying a scientific estimation method. If there is sufficient information available for estimation, the function returns an array containing estimated property value and unit. If estimation could not be done, the function returns false. Estimation functions retrieve property values required for estimation through standard property data supply mechanism of the information system. As it will be explained in Section 4.6.12, the information system uses property data sets, equations and estimators concurrently to provide the best available chemical property value. Hence, an estimator function may evoke other estimation functions recursively until required property value is calculated. The information system prevents infinite loops by checking the presence of the estimator is in the estimation stack and does not allow to call the estimator if it is already in the stack. Property estimators are taken out of the stack when they return a value (either the estimate or false).

Currently implemented property estimators are listed in Table 4.22.

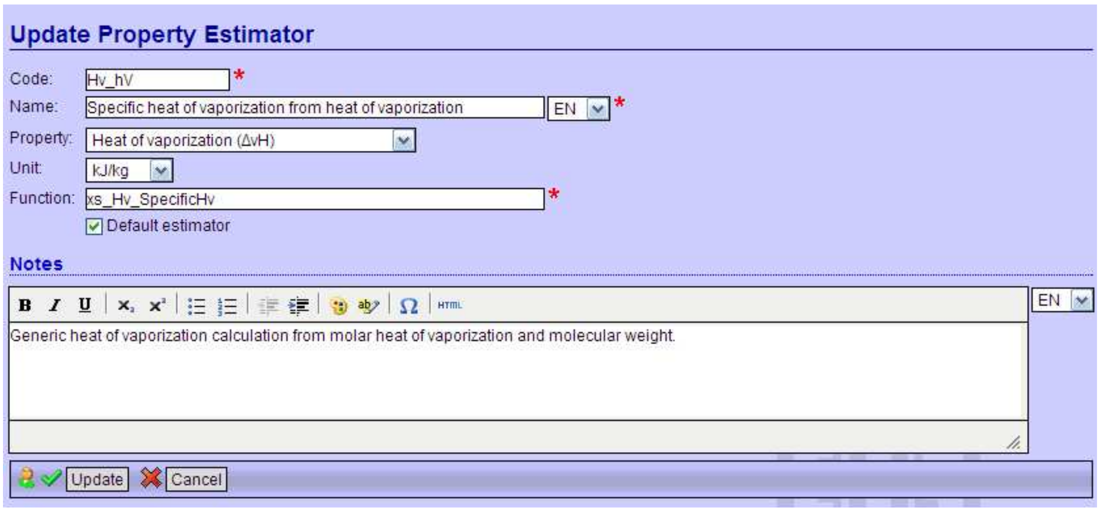


Figure 4.62: Property estimator data entry form

Table 4.22: Property estimators implemented in the system

Estimator	Phase	Unit	Requirements
Density from molar volume	-	g/cm^3	V_m, MW
Heat of vaporization from specific heat of vaporization	-	kJ/mol	$\Delta_v H, MW$
Ideal gas molar volume	Gas	cm^3/mol	-
Molar volume from density	-	cm^3/mol	ρ, MW
Molecular weight calculation from chemical formula	-	g/mol	Formula
Specific heat of vaporization from heat of vaporization	-	kJ/kg	$\Delta_v h, MW$
⋮	⋮	⋮	⋮

4.6.12 Chemical Property Data Analysis

The aim of the chemical property data analysis framework is to provide single and standardized values of chemical properties by processing all available chemical property datasets, equations and estimators. Results of the chemical property data analysis are made available to the other system components, mainly to the modelling component, for calculations and displayed to the end users for informative purposes.

Chemical property data analysis starts with statistical analysis of chemical property data records. For this purpose, chemical property values are first grouped according to the reference conditions that the property depends on, including temperature, pressure and chemical phase. The following steps are followed during the grouping process for a single data record:

- If the record contains more than one data value, i.e. contains a dataset, values are separated from each other and converted into single values with their own reference conditions.

- Fuzzy values are parsed and corresponding linear trapezoidal fuzzy numbers are calculated.

- Logarithmic values are converted into ordinary values by taking the exponential.

- Values are converted from their custom unit into the corresponding base property unit.

- If exists, reference temperature and pressure values are converted into base units, which are K and Pa, respectively.

- Reference conditions, which are left blank, are replaced with the default reference conditions of the property.

- Standardized values are put into the appropriate group according to their corresponding reference conditions.

At the end of the grouping process, all chemical property data values in a group become comparable to each other. In the next step, fuzzy statistics are calculated for each group and data values are sorted in the increasing order according to fuzzy relations given in Section 4.3.10.

The following rules are applied in the order of their appearance to calculate the standard value of a group:

- If there is only one value in the group, it is selected as the standard value.
- If a record containing multiple data values is set as default, all records with single data values falling within the range of the dataset are excluded from the data analysis, including those belonging to other groups.
- If there exists a chemical property data in the group, which is set as default, it is selected as the standard value of the group.
- If there exists no default value in the group, fuzzy median value is designated as the standard value of the group.

Obtained standard values are stored in the temporary chemical property cache of the information system for further processing.

If a chemical property value is requested from the chemical subsystem for a specific chemical and reference conditions, the system first checks whether a chemical property equation is available in the database for the requested chemical that is valid for the given reference conditions. If a chemical property equation is found, it is used to calculate the chemical property value and the result is returned as the standard value. If more than one equation is found, the default one or if there is no default one, the first one, is used for the calculation.

If no equation is found, the system checks the availability of standard values calculated from chemical property data records. If a standard value matching requested reference conditions exists, it is returned as the result. Otherwise, standard values are used to approximate the property value for the given reference conditions by interpolation or extrapolation, whichever is appropriate. The following rules are applied for interpolation and extrapolation:

- If there is only one standard value, it is returned as the nearest (hence, best) approximation.
- If there are two standard values, 1^{st} order linear polynomial equation calculated from standard values is used for both interpolation and extrapolation.

- If there are three standard values, 2^{nd} order linear polynomial equation calculated from standard values is used for both interpolation and extrapolation.
- If there are more than three standard values,
  - 2^{nd} order linear polynomial equation calculated by using nearest three standard values is used for extrapolation,
  - Average of two 2^{nd} order linear polynomial equations calculated by using nearest three standard values to the right and to the left, respectively, is used for interpolation. While determining nearest standard values, reference condition is tried to be centralized for each equation.

Interpolation and extrapolation rules listed above guarantee that the best estimate is calculated for each case. Especially, the averaging method yields the smoothest value of all possible estimates, since two equations used for averaging are the smoothest of all possible curves.

If requested chemical property value could not be calculated from standard values, the information system tries to estimate the value by using chemical property estimators. As explained in 4.6.11, all available estimators of the chemical property are tried until a valid value is calculated or no property estimator is left. If a value can be estimated, it is returned as the standard value. Otherwise, chemical property analysis process is finished denoting no value can be calculated for the requested property from the available information in the database.

In addition to providing standard values to other system components, chemical property data analysis is also used to summarize and display chemical property data. "Chemical Properties" section in chemical information page uses the analysis framework to extract all available chemical property data for a chemical and list them with full reference information (Figure 4.63). The end users can easily select reference conditions for which chemical properties are to be calculated.

Fuzzy statistics calculated chemical property data values are also utilized for chemical property data display (Figure 4.64). While listing available data values for a property, values are shown as grouped by their analysis groups and in the ascending order. Default values are indicated with asterisks. Rows containing data values are colored according to statistical properties of the values (Figure 4.64). Different colors are used for the following data values:

Chemical Properties

Boiling Point (T_b):	⊞ 102.24 °C (1 atm) [EPA, 2000, Adapted Stein and Brown Method]
Density (ρ) (Gas):	⊞ 0.003193 g/cm³ (25 °C) [Estimated, Density from molar volume]
Density (ρ) (Liquid):	⊞ 0.8786 g/cm³ (25 °C) [Wikipedia]
Heat of Combustion (ΔH_c^0):	⊞ 40170 kJ/kg (25 °C) [Wikipedia]
Henry's Law Constant (H):	⊞ 5.4774 L·atm/mol (25 °C) [Interpolated]
Lower Flammable Limit (LFL):	⊞ 1.4 %v (20 °C, 1 atm) [NTP, 1992]
Melting Point (T_m):	⊞ 5.5 °C [EPA, 2000 *]
Molar Volume (V_m) (Gas):	⊞ 24465 cm³/mol (25 °C, 1 atm) [Estimated, Ideal gas molar volume]
Molar Volume (V_m) (Liquid):	⊞ 88.7 cm³/mol (20 °C, 1 atm) [McAuliffe 1966, Calculated-density *]
Molecular Weight (MW):	⊞ 78.11 g/mol [MacKay et al. 1992]
Total Surface Area (TSA):	⊞ 110.36 Å² [Median, 10 data]
Upper Flammable Limit (UFL):	⊞ 8 %v (20 °C, 1 atm) [NTP, 1992]
Vapor Pressure (P_v):	⊞ 12674 Pa (25 °C) [Interpolated]
Water Solubility (C^S_w):	⊞ 1718 g/m³ (25 °C) [Interpolated]

Temperature: 25 °C Pressure 1 atm Calculate Add

Figure 4.63: Summary of chemical property data analysis

Water Solubility (C^S_w):	⊟ 1770.8 g/m³ (27 °C) [Interpolated]
	⊟ 1718 g/m³ (25 °C) [Morrison & Billett 1952, Shake flask-UV *]
	1402 g/m³ (25 °C) (Booth & Everson 1948, Residue-volume method)
	1718 g/m³ (25 °C) (Morrison & Billett 1952, Shake flask-UV) *
	1740 g/m³ (25 °C) (Andrew & Keefer 1949, Shake flask-UV)
	1755 g/m³ (25 °C) (McDevit & Long 1952, Shake flask-UV)
	1760 g/m³ (25 °C) (Brady & Huff 1958)
	1780 g/m³ (25 °C) (Lindenburg 1956, Selected)
	1786 g/m³ (25 °C) (Stearns et al. 1947, Shake flask-turbidimetric)
	1790 g/m³ (25 °C) (Bohon & Claussen 1951, Shake flask-UV)
	1796 g/m³ (25 °C) (Hayashi & Sasaki 1956)
	1823 g/m³ (25 °C) (Lindenburg 1956, Calculated-molar volume)
	1860 g/m³ (25 °C) (Klevens 1950, Shake flask-UV)
	1850 g/m³ (30 °C) [Gross & Saylor 1931, Shake flask-interferometer *]

Figure 4.64: Statistical analysis of chemical properties

- Extreme outliers, located outside of 3.0 × Interquartile range,
- Mild outliers, located outside of 1.5 × Interquartile range,
- Values in the interquartile range,
- 1^{st} quartile value,
- 3^{rd} quartile value,
- Median value,
- Minimum value,
- Maximum value.

4.6.13 Chemical Databases

Although chemical subsystem provides means of storage, advanced statistical analysis and estimation of chemical property data, collection of property data itself is a huge, time intensive task, which is beyond the scope of the study. Best effort has been made to provide a basic set of chemical property data. Still, available data is limited and adequate for demonstrative purposes only. Open nature of the information system facilitates collection of data, but use of other online chemical databases is also recommended. By using available chemical identifiers and structure information of the chemicals, links to selected online databases are made available to facilitate this process (Figure 4.65).

Similar to other records, chemical databases can be added or updated by the editors. In addition to the name of the database, an icon representing the database can also be specified. Data fields found in basic chemical information (i.e. name, identifier and structure data fields) can be used for queries to chemical databases. In order to add a new query, data field should be selected as the search parameter and corresponding URL address should be entered (Figure 4.66). Value of the parameter is automatically added to the end of URL address during queries. The information system supports multiple query URLs to be specified for each chemical database. While displaying links to chemical databases, the system checks the availability of parameter values for the chemical. Corresponding link is not shown if a parameter is not available. If multiple parameters are available for a chemical database, the parameters are listed next to

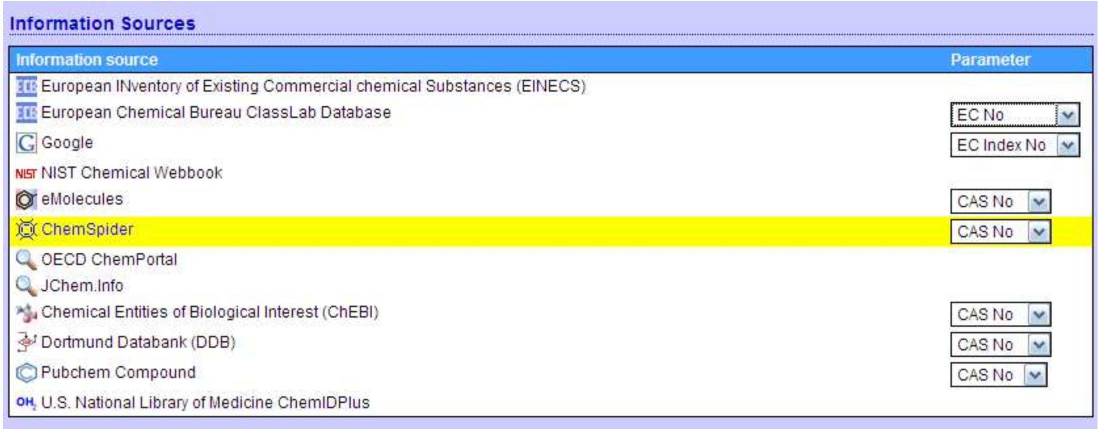


Figure 4.65: List of online chemical databases

the chemical database name (Figure 4.65). Search query is updated according to the selected parameter.

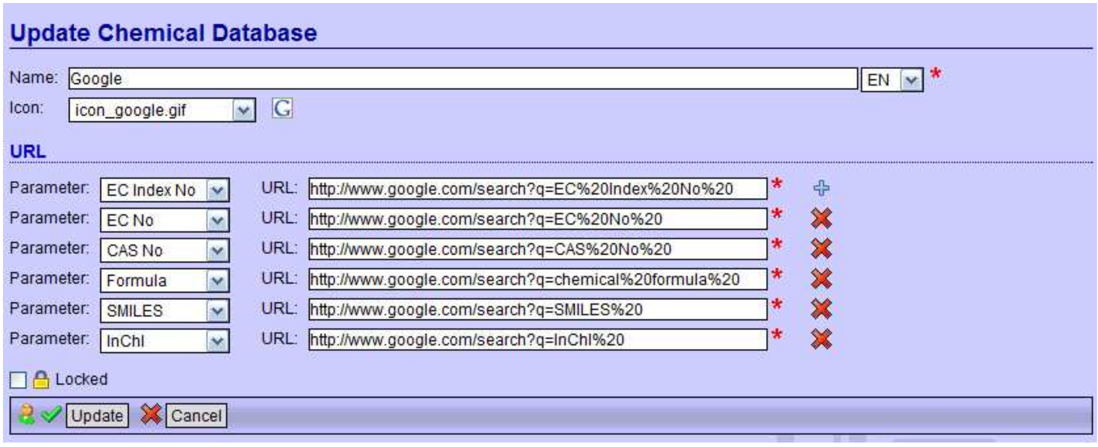


Figure 4.66: Chemical database entry form

List of available online chemical databases is given in Table 4.23.

4.6.14 Material Safety Data Sheets

Besides information on hazard classification and chemical properties stored in the database, more detailed or other kind of information on chemicals can be included to the system as Material Safety Data Sheets (MSDS). MSDSs can be added as separate

Table 4.23: Selected online chemical databases and search criteria

Database	Institution	Base URL	EU Index No	EU No	CAS No	Formula	SMILES	InChI
ChEBI	Eur. Bioinf. Ins.	http://www.ebi.ac.uk/chebi/			√	√	√	√
Chemical Webbook	U.S. NIST	http://webbook.nist.gov/			√			
ChemIDPlus	U.S. Nat. Lib. of Med.	http://chem.sis.nlm.nih.gov/chemidplus/			√			
ChemPortal	OECD	http://webnet3.oecd.org/eChemPortal/			√			
ChemSpider	ChemZoom Inc.	http://www.chemspider.com/			√	√	√	
ClassLab	ECB	http://ecb.jrc.it/classification-labelling/	√	√	√			
Dortmund Databank	DDBST GmbH.	http://134.106.146.148/DDBSearch			√	√		
EINECS	ECB	http://ecb.jrc.it/esis-pgm/		√				
eMolecules	eMolecules Inc.	http://emolecules.com/			√	√	√	
Google	Google Inc.	http://google.com/	√	√	√	√	√	√
JChem.Info	Black iD Solutions	http://www.jchem.info/			√			
Pubchem Compound	U.S. Nat. Ins. of Health	http://www.ncbi.nlm.nih.gov/			√			√

files in common document formats, such as PDF or MS Word. Date of publication, publisher (chemical producer) and language of MSDSs can be specified. MSDSs available for a chemical is listed in a separate section on chemical information page. Moreover, they can be searched for different criteria such as chemical name and publisher.

4.7 Facility Subsystem

Facility subsystem has been designed in order to systematically collect information on industrial facilities and hazardous chemicals present therein to make rapid assessment of their status with respect to the 96/82/EC Directive of the EU. Although it is currently not legally binding for Turkey, studies on adopting the Directive to the Turkish legislation have been completed and draft regulation and communications thereof are ready as of the end of 2006 [15]. Results of assessments that can be done by the decision-support system may be used as gross indicators of major accident potential of Turkey and reveal spatial distribution of probable risk zones in the context of the 96/82/EC Directive.

4.7.1 Industrial Facilities

The data required on facilities is simple and covers facility name, location and industrial activity information only (Figure 4.67). Name of the facility can be stated as multilingual. Location and contact information includes province and district, textual locality description, address, postal code, phone and fax numbers. Web site of the facility or owner company can also be stated. As explained in Section 4.3.7, location of the facility can be marked on the map with a rectangular bounding box and geographic coordinates can be indicated as latitude and longitude.

In order to designate the industrial activity of the facility, its Statistical Classification of Economic Activities in the European Community (NACE) code can be specified, which is the standard used by the EU [85]. It is also commonly used worldwide and in Turkey [86]. Although NACE codes up to 6 digits are available, 4 digit version is used by the system since last two digits are not standard and vary from country to country. NACE code can be entered manually or it can be selected from the interactive list provided by the system. Uncertain NACE code can be indicated by an uncertainty flag. Designation of correct NACE code is important, since it is used for the calculation of the 96/82/EC Directive status of the facilities as it will be explained in Section 4.7.5. If industrial activities carried out in the facility fall under several NACE categories, the NACE category of the primary activity of the facility should be stated.

Industrial facilities present in the information system can be listed by facility name, province, district, NACE code and the 96/82/EC Directive status (Figure 4.68). Search

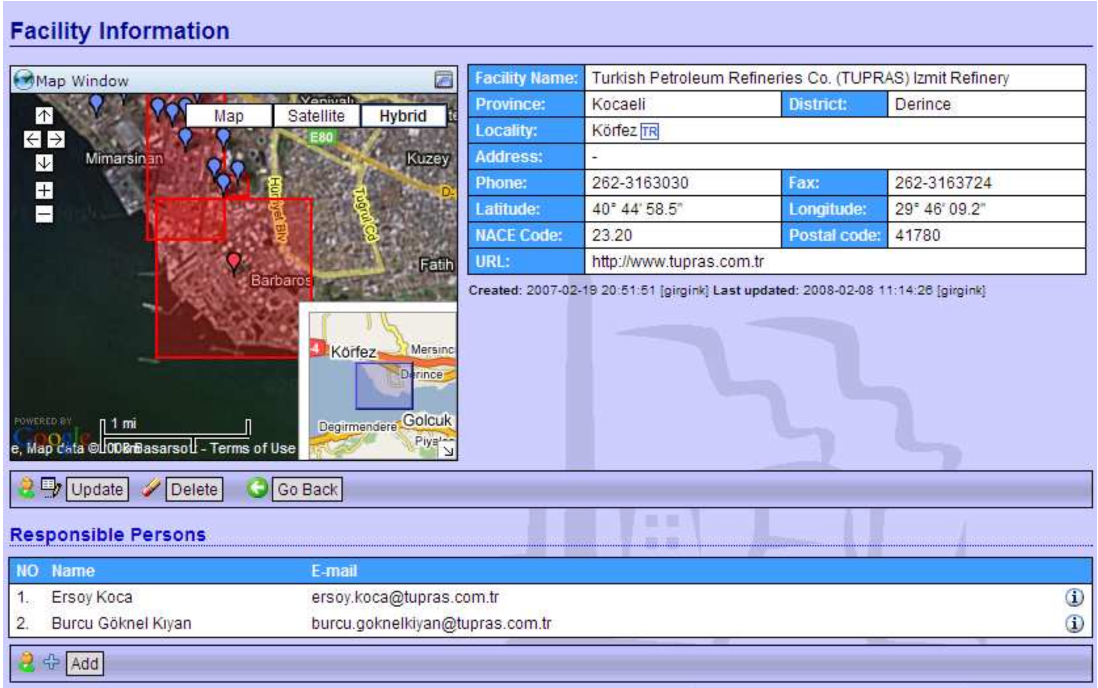


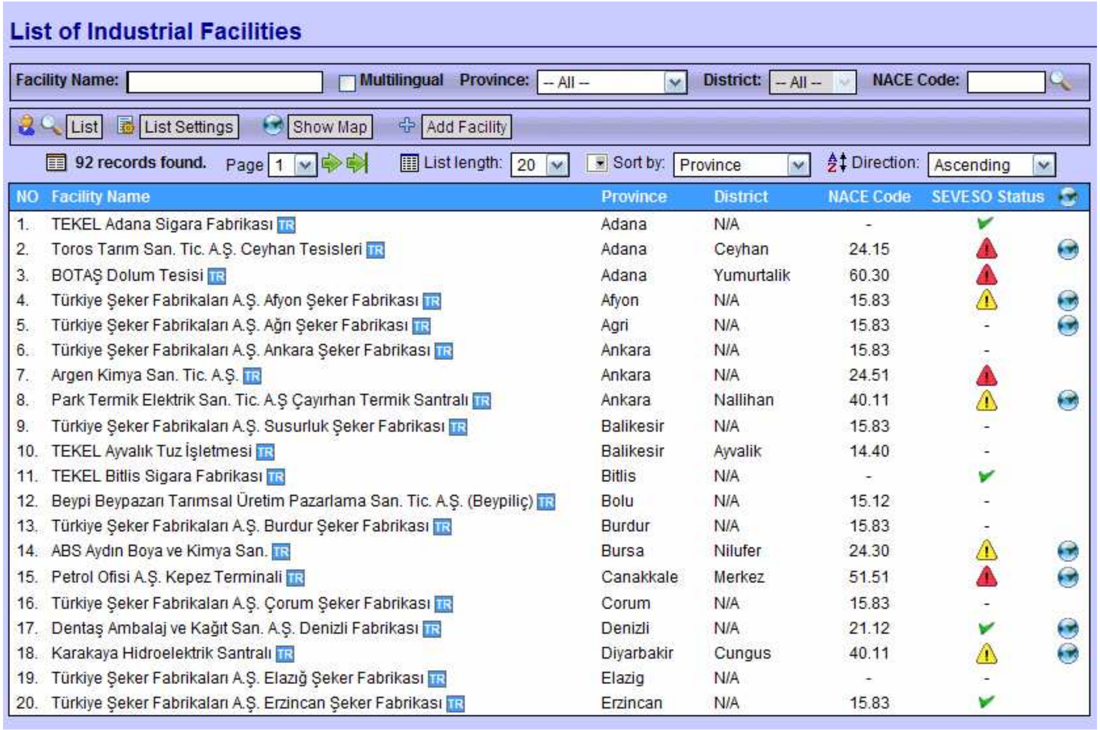
Figure 4.67: Basic facility information

results can be displayed on the map to reveal geographic distribution of the facilities. Symbology used for map markers represent the 96/82/EC Directive status of the facilities. Therefore, the map also reveals regions where upper and lower tier facilities are located. Since the 96/82/EC Directive status is an indicator of major-accident potential, those regions can be considered as areas with medium to high accident potential.

4.7.2 Chemicals Stored in the Facilities

The facility subsystem has a special section for keeping information on chemical substances stored in the facilities. Similar to facility information, data fields regarding chemicals found in facilities are kept simple and do not include detailed information on individual storage tank level. Based on the needs of the 96/82/EC Directive calculations, it is focused on total quantities of the substances and their overall storage conditions.

In order to designate a substance stored in the facility, a chemical can be selected from the chemical listing of the chemical subsystem. If the substance is an explosive listed in the UN/ADR, it can also be selected from the list of UN/ADR explosives.



NO	Facility Name	Province	District	NACE Code	SEVESO Status
1.	TEKEL Adana Sigara Fabrikası TR	Adana	N/A	-	
2.	Toros Tarım San. Tic. A.Ş. Ceyhan Tesisleri TR	Adana	Ceyhan	24.15	
3.	BOTAŞ Dolum Tesisi TR	Adana	Yumurtalik	60.30	
4.	Türkiye Şeker Fabrikaları A.Ş. Afyon Şeker Fabrikası TR	Afyon	N/A	15.83	
5.	Türkiye Şeker Fabrikaları A.Ş. Ağrı Şeker Fabrikası TR	Agri	N/A	15.83	-
6.	Türkiye Şeker Fabrikaları A.Ş. Ankara Şeker Fabrikası TR	Ankara	N/A	15.83	-
7.	Argen Kimya San. Tic. A.Ş. TR	Ankara	N/A	24.51	
8.	Park Termik Elektrik San. Tic. A.Ş Çayırhan Termik Santralı TR	Ankara	Nallihan	40.11	
9.	Türkiye Şeker Fabrikaları A.Ş. Susurluk Şeker Fabrikası TR	Balikesir	N/A	15.83	-
10.	TEKEL Ayvalık Tuz İşletmesi TR	Balikesir	Ayvalik	14.40	-
11.	TEKEL Bitlis Sigara Fabrikası TR	Bitlis	N/A	-	
12.	Beypi Beypazarı Tarımsal Üretim Pazarlama San. Tic. A.Ş. (Beypiliç) TR	Bolu	N/A	15.12	-
13.	Türkiye Şeker Fabrikaları A.Ş. Burdur Şeker Fabrikası TR	Burdur	N/A	15.83	-
14.	ABS Aydın Boya ve Kimya San. TR	Bursa	Nilufer	24.30	
15.	Petrol Ofisi A.Ş. Kepez Terminali TR	Canakkale	Merkez	51.51	
16.	Türkiye Şeker Fabrikaları A.Ş. Çorum Şeker Fabrikası TR	Corum	N/A	15.83	-
17.	Dentaş Ambalaj ve Kağıt San. A.Ş. Denizli Fabrikası TR	Denizli	N/A	21.12	
18.	Karakaya Hidroelektrik Santralı TR	Diyarbakir	Cungus	40.11	
19.	Türkiye Şeker Fabrikaları A.Ş. Elazığ Şeker Fabrikası TR	Elazig	N/A	-	-
20.	Türkiye Şeker Fabrikaları A.Ş. Erzincan Şeker Fabrikası TR	Erzincan	N/A	15.83	

Figure 4.68: List of industrial facilities

Figure 4.69: Map of industrial facilites

Storage phase, pressure and temperature are requested for each substance to denote the storage conditions. Phase can be selected as gaseous, liquid or solid. For pressure or temperature controlled systems, custom values can be entered for storage pressure and temperature in desired units. Otherwise, they should be indicated as equal to ambient conditions (Figure 4.70).

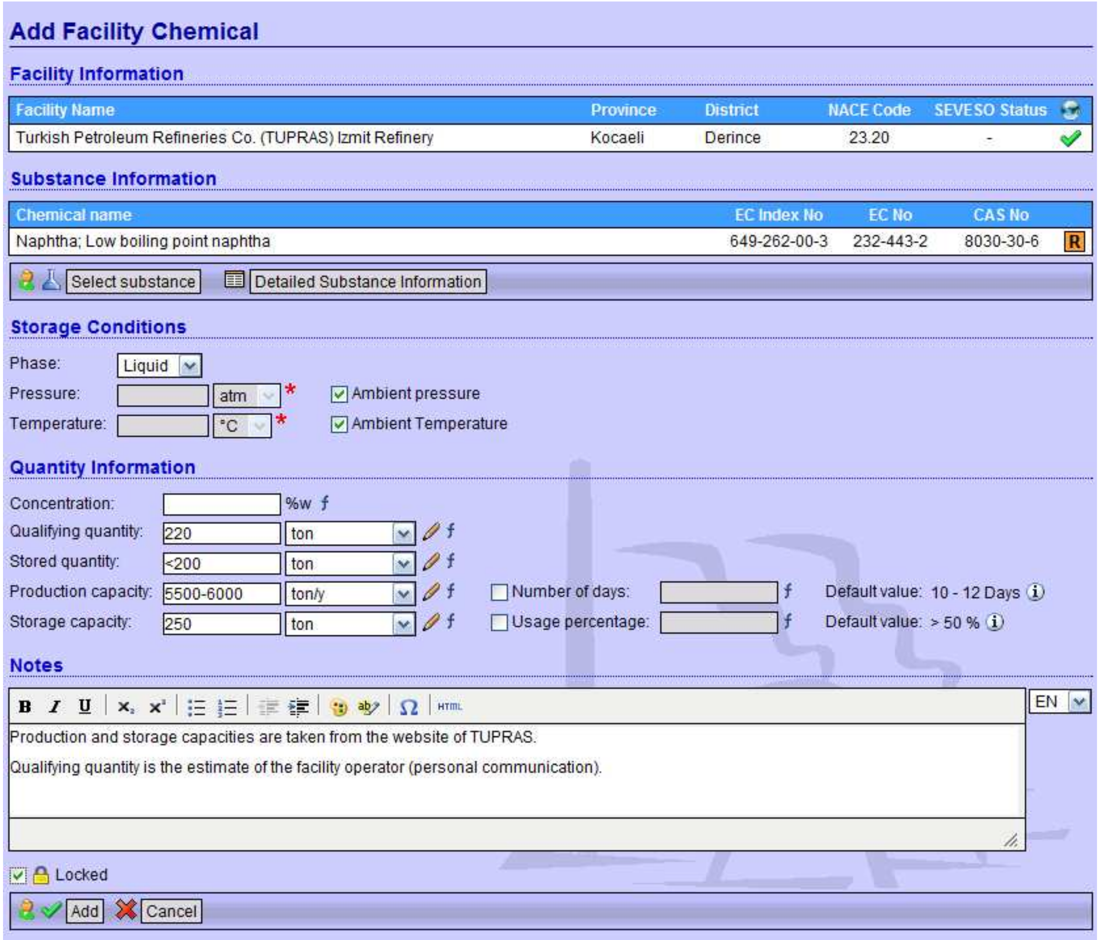


Figure 4.70: Facility substance entry form

Four different quantitative values can be entered to specify the amount of substance actually or likely to be present in the facility:

- *Qualifying quantity*, which is the quantity defined by the 96/82/EC Directive as the maximum amount of the substance that is present or is likely to be present at any one time, including "out of control" situations.

- *Stored quantity*, which is the actual amount of substance stored in the facility at a specific time.
- *Production capacity*, which is the production capacity of the facility for the substance. Multiplied by a specific number of days, it can be converted to quantity information.
- *Storage capacity*, which is the storage capacity of the facility for the substance. Multiplied by a specific percentage value as a measure of usage ratio of the available capacity, it can be converted to quantity information.

Qualifying and stored quantities are direct measures of the storage amount of the substance, whereas production and storage capacities provide indirect information. But, capacity values can also be used to infer the size of the facility, such as small enterprise or high volume producer. Additional data required for calculating quantity values from capacities can be manually entered, which are number of days of production, products of which as assumed to be stored in the facility, and usage percentage of the available storage capacity. The information system also has the ability to use industrial activity specific or global values for these data fields, if facility specific values are not available. Details on quantity calculations are given in Section 4.7.4 and 4.7.5.

Quantity and capacity values, as well as number of days and usage percentage, support fuzzy numbers (Figure 4.70). Concentration of the substance can also be specified using a fuzzy number. Concentration value is taken as percentage by weight ($\%w$) and percentage by volume ($\%v$) for liquid and solid, and gaseous substances, respectively. Multilingual descriptive notes can be entered as well.

4.7.3 Responsible Users

Similar to other record types of the information system, facilities and substances present therein can be added or updated by the editors. Therefore, people interested in industrial accidents from academia, municipalities or non-governmental organizations (NGOs) can enter data for specific regions to study major-accident potential using the tools provided by the system. Although detailed chemical data is generally confidential and not publicly available for industrial facilities, storage or production capacities can be found from public reports and may be adequately used for rough calculations. However, it is also a fact that best information can only be supplied by the personnel of the facilities. If it is known that such people exist, data entry on facilities could be limited to those people. This will guarantee that information is entered from first hand and protected from modifications by third parties.

In order to establish a data flow similar to that described above, the concept of responsible users is introduced for the facilities. If a responsible user is defined for a facility, the facility record and all related facility substance records are locked by the system for modification by the editors. They are also not allowed to add new substances to the facility. Hence, facility and substance data are protected.

Responsible persons are assigned from editors by the administrators. Several users can be assigned as responsible persons of an industrial facility and listed on facility information page (Figure 4.67). All responsible persons of a facility have the same level of user privileges and may change facility and chemical data without any restrictions. They can also limit access to detailed facility substance data. If access is made limited, substance information is stored in the database but it is not displayed on facility information page. Only total qualifying quantities and the results of the 96/82/EC Directive calculations are shown. Unless a responsible person has been assigned, editors may update facility and chemical data, but can not limit access thereto.

4.7.4 96/82/EC Directive Settings

The information system allows facility specific production days and capacity usage percentage values to be entered in the facility substance section. Since it may be difficult to state these values separately for each facility, the system also let generic values to be specified as shown in Figure 4.71.

Two different levels of generic values exist. First level is the industrial activity level that is based on NACE codes. Independent of the substance type, special production days and capacity percentage values can be set for NACE codes. NACE specific values are valid not only for the specified NACE code, but also for all sub-categories of NACE codes, for which custom values are not indicated. For example, if production days is specified as 30 days for *Manufacture of chemicals, chemical products and man-made fibres* (NACE Code: 24) but no value is set for *Manufacture of basic chemicals* (24.1), production days value for *Manufacture of basic chemicals* and all its sub categories (e.g. *Manufacture of industrial gases* (24.11), *Manufacture of dyes and pigments* (24.12)) is taken as 30 days. Some examples of NACE specific values are given in Table 4.24.

Table 4.24: Example NACE specific 96/82/EC Directive settings

(a) Stored settings

NACE Code	Industrial Activity	Production Days	Capacity Usage Percentage
24	Manufacture of chemicals and chemical products	$30 - 45$	75
24.1	Manufacture of basic chemicals	–	80
24.11	Manufacture of industrial gases	15	–
24.2	Manufacture of pesticides and other agro-chemical products	> 45	80
24.6	Manufacture of other chemical products	30	–
24.61	Manufacture of explosives	15	85

(b) Calculated settings

NACE Code	Industrial Activity	Production Days	Capacity Usage Percentage
24	Manufacture of chemicals and chemical products	$30 - 45$	75
24.1	Manufacture of basic chemicals	$30 - 45$	80
24.11	Manufacture of industrial gases	15	80
24.12	Manufacture of dyes and pigments	$30 - 45$	80
⋮	⋮	⋮	⋮
24.2	Manufacture of pesticides and other agro-chemical products	> 45	80
24.20	Manufacture of pesticides and other agro-chemical products	> 45	80
24.3	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	$30 - 45$	75
⋮	⋮	⋮	⋮
24.6	Manufacture of other chemical products	30	75
24.61	Manufacture of explosives	15	85
24.62	Manufacture of glues and gelatines	30	75
⋮	⋮	⋮	⋮

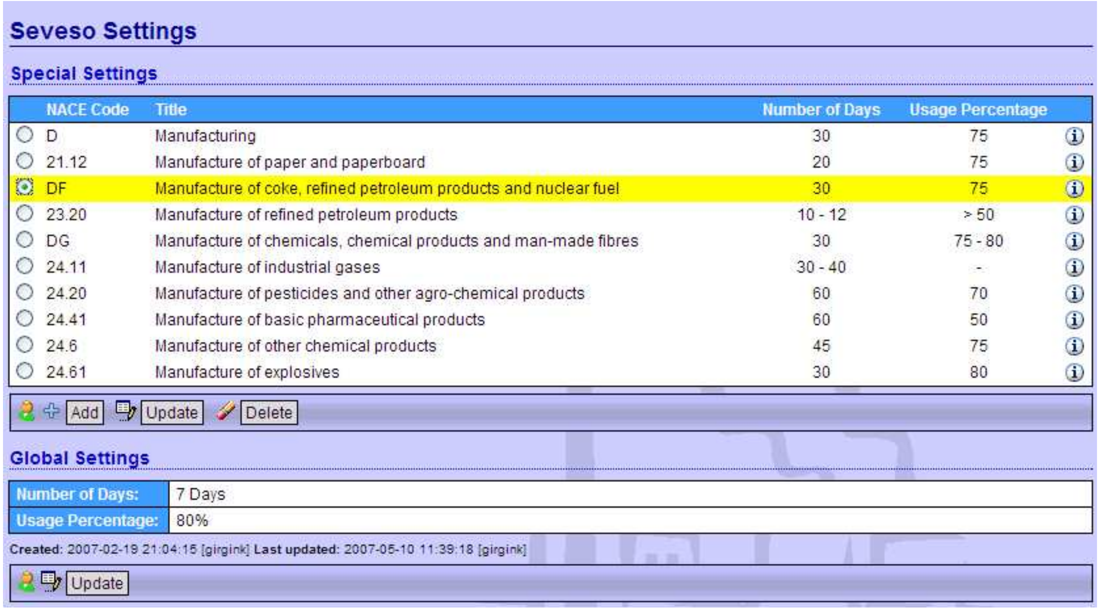


Figure 4.71: Special and generic 96/82/EC settings

4.7.5 96/82/EC Directive Calculations

Calculation of the 96/82/EC Directive status of a facility begins with determination of the qualifying quantities of the substances stored in the facility. Once qualifying quantities are calculated, status assessment is done in two steps following the methodology set out by the Directive. In the first step, status calculations are made for each substance separately and substance specific statuses are found. In the second step, overall hazards of all substances are evaluated by using summation rule indices. Statuses according to groups of named substances are also calculated. Details of the calculations are given in the following sub-sections.

Qualifying Quantity Calculations

Quantities of dangerous substances to be considered for the application of the 96/82/EC Directive are the maximum quantities, which are present or *likely* to be present at any one time. Determination of qualifying quantities may not be straight forward for all the time and requires expertise and knowledge on storage and process conditions. Especially, likely to be present quantities are difficult to predict and quantify, since they require loss-of-control situations to be considered [87]. In order to determine the qualifying quantity of a substance, the steps given in Figure 4.72 are followed.

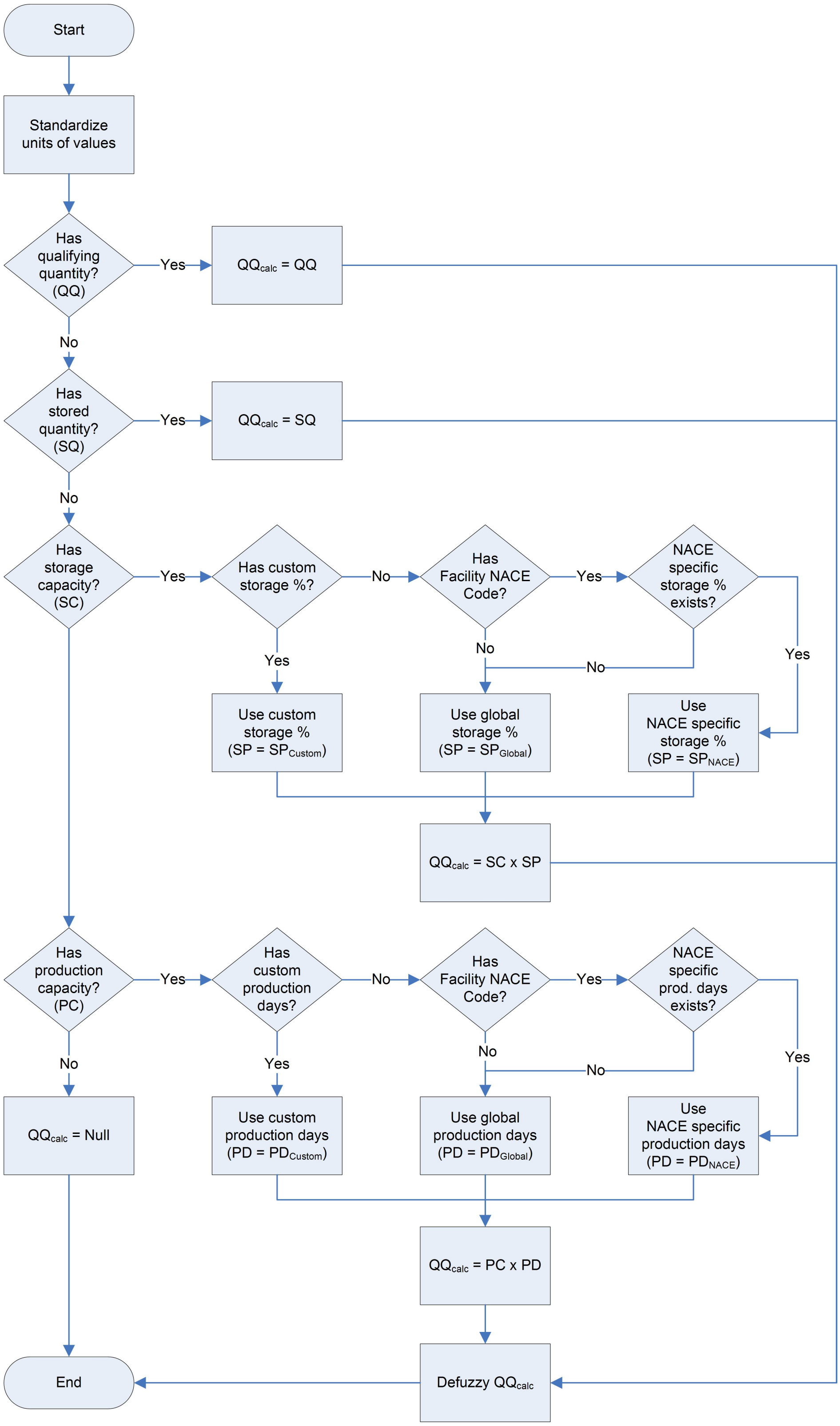


Figure 4.72: Flowchart of qualifying quantity calculation

As the first step, availability of manually entered qualifying quantity is checked. If available, it is used as the qualifying quantity. Otherwise, stored quantity is used as the qualifying quantity if it is available. If both quantities are unavailable, the information system tries to estimate the qualifying quantity from the production and storage capacities for the substance. In order to calculate the qualifying quantity, storage capacity is multiplied with the capacity usage percentage. Similarly, production capacity is multiplied with number of days of production that is considered to be stored temporarily at the facility. Priority is on the storage capacity, i.e. it is preferred over production capacity if both are available. Manually entered production days and usage percentage values are used for calculations if they are available. Otherwise, industrial activity specific or global values are utilized, as explained in Section 4.7.4. Since selected qualifying quantity may be a fuzzy number, its point estimate value is calculated as the last step.

Status Calculations for Substances

Once the qualifying quantity is calculated for a substance, the information system calculates the 96/82/EC Directive status of the substance by following the steps given in Figure 4.73.

First, the type of the substance is checked. If the substance is an UN/ADR explosive, 96/82/EC category of the explosive is determined. 96/82/EC Directive divides UN/ADR explosives into two categories based on UN/ADR divisions. First category (4) covers UN/ADR Division 1.4, i.e. substances and articles which present only a slight risk of explosion with limited effects largely confined to the package. All other UN/ADR divisions are included to the second category (5), together with explosive substances falling under risk phrases R2 and R3. More lenient limits are given for Division 1.4 explosives as shown in Table 2.3. According to the designated category, lower and upper flammability indices are calculated, which will be used for summation rule as explained later on. If UN/ADR explosive is linked to a chemical, the substance is set equal to the chemical and calculations are continued.

If the substance is a chemical (either explicitly defined or set by the UN/ADR explosive), the qualifying quantity is compared with the lower and upper limits given in the 96/82/EC Directive Annex I and it is determined whether limits are exceeded or not.

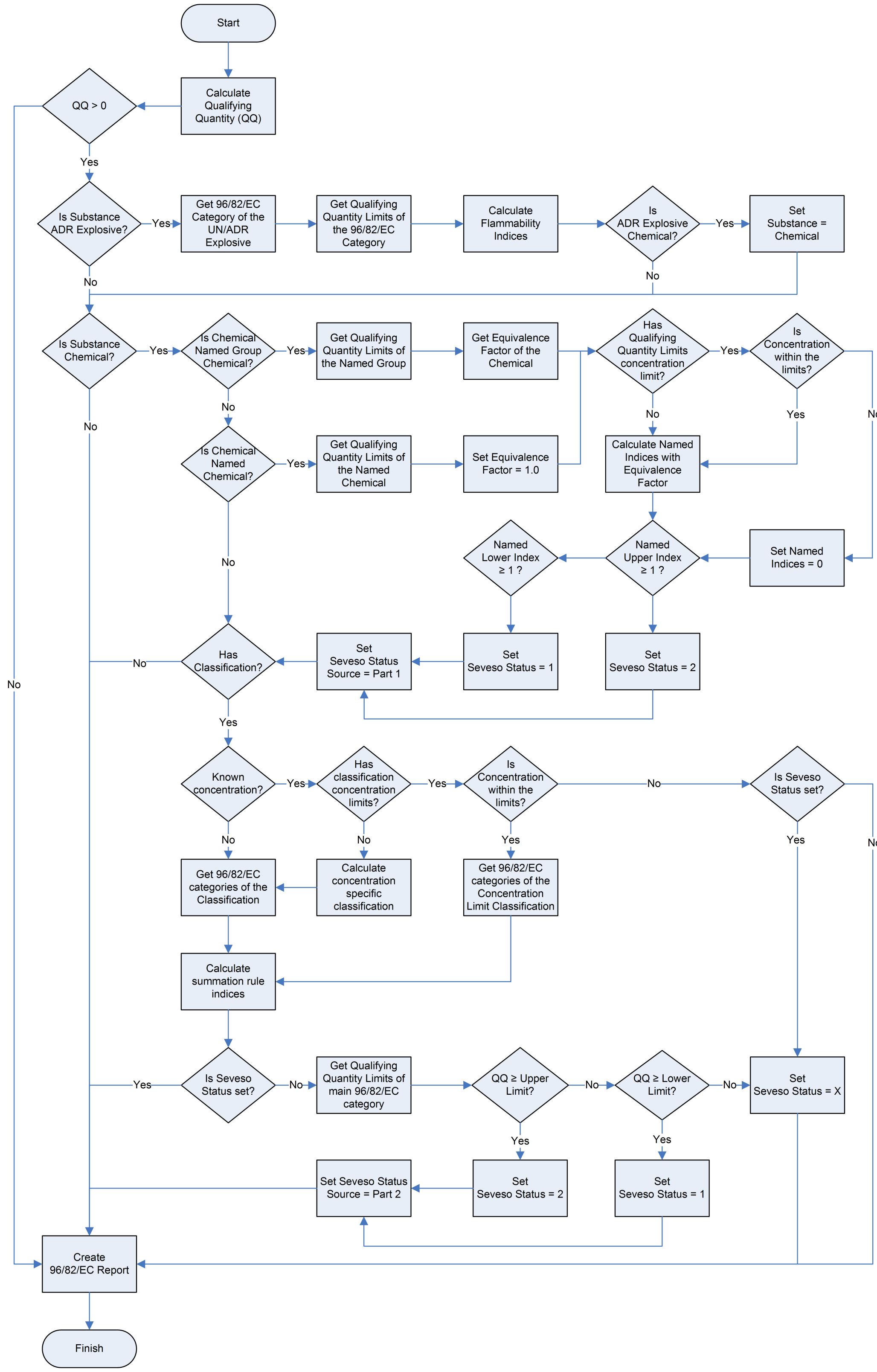


Figure 4.73: Flowchart of 96/82/EC status calculation of a facility substance

If the substance is a named substance or a member of a named group, qualifying quantity limits given in Part 1 are used for comparison. Limiting quantities are directly used for named substances. For substances listed under a named group, limits of the group is used. But the qualifying quantity is multiplied with equivalence factor of the substance, if it is specifically set by the Directive. During the comparison, concentration of the substance is also taken into consideration. If specific concentration limits are indicated in Part 1 and the concentration of the substance is outside of these limits, the substance is not considered as a named substance. Otherwise, the 96/82/EC Directive status of the chemical is set according to the result of the comparison. Ratios of the qualifying quantity to the lower and upper limits are also recorded as named substance indices to be used for summation rule calculations.

In order to calculate summation indices, which are required for facility status calculations and determination of the 96/82/EC Directive status of substances which are not listed in Annex I Part 1, hazard classification of the chemical is determined. For this purpose, availability of chemical specific hazard classification is checked from the database. If no hazard classification is available, i.e. chemical is not listed in the 67/548/EEC Directive, status calculation finishes. Otherwise, appropriate hazard classification according to the concentration of the substance is found.

If the concentration of the substance is not specified, hazard classification of the substance is directly used for calculations. Otherwise, availability of concentration specific hazard classifications are checked from the database. If the substance has concentration specific hazard classifications, hazard classification corresponding to the specified concentration is found. If the concentration is found to be outside of the available concentration limits, the substance is considered to be non-hazardous. Hence, status calculation is finished. Otherwise, found hazard classification is used for calculations.

If the substance has no concentration specific hazard classifications, then concentration specific hazard classification is calculated from the hazard classification of the substance by applying rules designated by the 1999/45/EC Directive. For this purpose, hazard classification of risk phrases given in Table B.1 (Appendix B) and risk phrase mappings of substances and preparations for specific concentration ranges which are given in Table B.2 are utilized. Table B.2 has been prepared specially for the study by examination of the 1999/45/EC rules. If calculated classification is empty, the substance is considered to be non-hazardous and status calculation is finished.

By using the designated classification, the summation rule indices are calculated. Summation rule is based on overall hazards associated with substances, which are grouped as toxicity, flammability and eco-toxicity. Distribution of the 96/82/EC Directive categories into overall hazard groups are given in Table 4.25

Table 4.25: Overall hazards and corresponding 96/82/EC Directive categories

Overall hazard	Categories
Toxicity	1, 2
Flammability	3, 4, 5, 6, 7a, 7b, 8
Eco-toxicity	9i, 9ii

According to overall hazards of the classification and by using the categories having the lowest qualifying quantity limits among the categories of the overall hazards, indices are calculated for each overall hazard by taking the ratios of the qualifying quantity of the substance to the lower and upper limit values. If flammability indices were calculated before (for UN/ADR explosives), they are not re-calculated.

If the 96/82/EC Directive status was not determined before, main category of the substance is found and generic limits thereof are used for the comparison. Main category is the one having lowest qualifying quantity among the categories of the substance. If the qualifying quantity is equal or above the relevant limits, the facility is designated to be covered by the 96/82/EC Directive and its status, as lower or upper tier, is determined by the type of limit exceeded.

Complete algorithm of substance specific 96/82/EC Directive calculations explained above is given in Algorithm 1.

Results of 96/82/EC Directive calculations for the substance are presented to the user in the form of a 96/82/EC Directive status report. The results can also be viewed at any time on the facility substance information page (Figure 4.74). In addition to calculated 96/82/EC Directive status and indices, qualifying quantity used for calculations and source of 97/82/EC Directive status decision (Part 1, Part 2, or both) are also indicated.

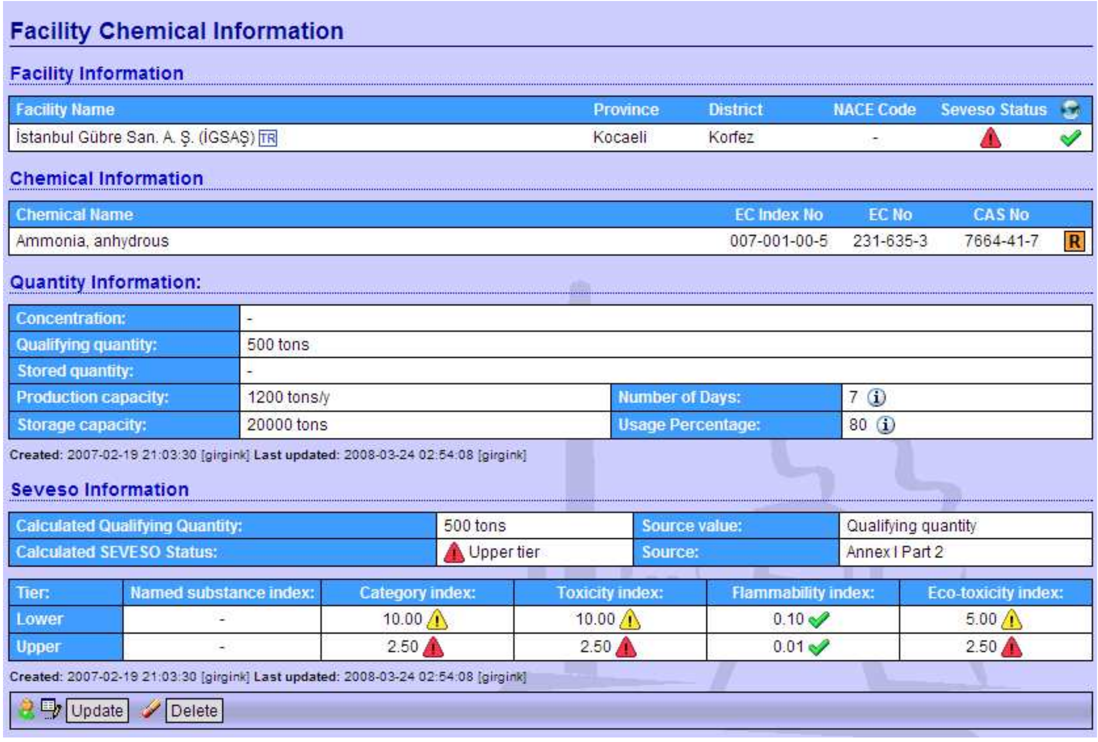
Algorithm 1 96/82/EC status calculation of a facility substance

```
procedure FacilitySubstanceStatus(Substance, Concentration, Quantities)
    Quantity ← Calculate qualifying quantity(Substance,Quantities)
    Status ← Out of Scope
    Indices ← ∅
    if Substance is UN/ADR Explosive then
        Division ← Get UN/ADR division(UN/ADR Explosive)
        Category_Explosive ← Get 96/82/EC category(Division)
        Limits ← Get qualifying quantity limits(Category_Explosive)
        Indices_Flammability,Upper ← Quantity/Limits_Upper
        Indices_Flammability,Lower ← Quantity/Limits_Lower
        if UN/ADR Explosive is Chemical then
            Substance ← Get chemical(UN/ADR Explosive)
        end if
    end if
    if Substance is Chemical then
        Limits ← ∅
        if Chemical is Named Group Chemical then
            Named Group ← Get named group(Chemical)
            Concentration Limits ← Get concentration limits(Named Group)
            if (Concentration Limits = ∅) ∨ (Concentration ⊂ Concentration Limits) then
                Limits ← Get qualifying quantity limits(Named Group)
                if Chemical has Equivalence Factor then
                    Factor ← Get equivalence factor(Chemical)
                else
                    Factor ← 1.0
                end if
            end if
        else if Chemical is Named Chemical then
            Concentration Limits ← Get concentration limits(Named Chemical)
            if (Concentration Limits = ∅) ∨ (Concentration ⊂ Concentration Limit) then
                Limits ← Get qualifying quantity limits(Chemical)
                Factor ← 1.0
            end if
        end if
        if Limits ≠ ∅ then
            Indices_Named,Upper ← Quantity · Factor/Limits_Upper
            Indices_Named,Lower ← Quantity · Factor/Limits_Lower
            if Indices_Named,Upper ≥ 1.0 then
                Status ← Upper Tier
            else if Indices_Named,Lower ≥ 1.0 then
                Status ← Lower Tier
            end if
        end if
        if Chemical has Classification then
            Classification ← Get classification(Chemical)
            if Concentration ≠ ∅ then
                if Classification has Concentration Limits then
                    Concentration Limits ← Get concentration limits (Classification)
                    Classification ← ∅
                    for all Concentration Limit ∈ Concentration Limits do
                        if Concentration ⊂ Concentration Limit then
                            Classification ← Get classification (Concentration Limit)
                        end if
                    end for
```

▷ Continues on page 167

▷ Continued from page 166

```
            else
                Classification ← Calculate classification (Classification, Concentration)
            end if
        end if
        if Classification ≠ ∅ then
            Categories ← Get 96/82/EC categories(Classification)
            if Categories ≠ ∅ then
                if Categories ⋂ (1,2) then
                    Category_Toxicity = Get main category(Categories, (1, 2))
                    Limits = Get qualifying quantity limits (Category_Toxicity)
                    Indices_Toxicity,Upper = Quantity/Limits_Upper
                    Indices_Toxicity,Lower = Quantity/Limits_Lower
                end if
                if Category_Explosive = ∅ then
                    if Categories ⋂ (3,4,5,6,7a,7b,8) then
                        Category_Flammability ← Get main category (Categories,(3,4,5,6,7a,7b,8))
                        Limits ← Get qualifying quantity limits (Category_Flammability)
                        Indices_Flammability,Upper ← Quantity/Limits_Upper
                        Indices_Flammability,Lower ← Quantity/Limits_Lower
                    end if
                end if
                if Categories ⋂ (9i,9ii) then
                    Category_Ecotoxicity ← Get main category (Categories,(9i,9ii))
                    Limits ← Get qualifying quantity limits (Category_Ecotoxicity)
                    Indices_Ecotoxicity,Upper ← Quantity/Limits_Upper
                    Indices_Ecotoxicity,Lower ← Quantity/Limits_Lower
                end if
                Category_Main ← Get main category(Categories)
                if (Category_Explosive ≠ ∅) ∧ (Category_Main ⋂(3, 4)) then
                    Indices_Main,Upper ← Max(Indices_Upper)
                    Indices_Main,Lower ← Max(Indices_Lower)
                else
                    Limits ← Get qualifying quantity limits (Category_Main)
                    Indices_Main,Upper ← Quantity/Limits_Upper
                    Indices_Main,Lower ← Quantity/Limits_Lower
                end if
                if Seveso Category = Out of Scope then
                    if Indices_Main,Upper ≥ 1.0 then
                        Seveso Category ← Upper Tier
                    else if Indices_Main,Lower ≥ 1.0 then
                        Seveso Category ← Lower Tier
                    end if
                end if
            end if
        end if
    end if
    end if
    return (Quantity, Seveso Category, Indices)
end procedure
```



Facility Chemical Information

Facility Information

Facility Name	Province	District	NACE Code	Seveso Status
İstanbul Gübre San. A. Ş. (İGSAŞ) TR	Kocaeli	Korfez	-	

Chemical Information

Chemical Name	EC Index No	EC No	CAS No
Ammonia, anhydrous	007-001-00-5	231-635-3	7664-41-7 R

Quantity Information:

Concentration:	-		
Qualifying quantity:	500 tons		
Stored quantity:	-		
Production capacity:	1200 tons/y	Number of Days:	7
Storage capacity:	20000 tons	Usage Percentage:	80

Created: 2007-02-19 21:03:30 [girgink] Last updated: 2008-03-24 02:54:08 [girgink]

Seveso Information

Calculated Qualifying Quantity:	500 tons	Source value:	Qualifying quantity
Calculated SEVESO Status:	Upper tier	Source:	Annex I Part 2

Tier:	Named substance index:	Category index:	Toxicity index:	Flammability index:	Eco-toxicity index:
Lower	-	10.00	10.00	0.10	5.00
Upper	-	2.50	2.50	0.01	2.50

Created: 2007-02-19 21:03:30 [girgink] Last updated: 2008-03-24 02:54:08 [girgink]

Update Delete

Figure 4.74: Facility substance information with 96/82/EC status summary

Status Calculations for Facilities

Once 96/82/EC Directive statuses are calculated for all substances stored in a facility, the overall 96/82/EC Directive status of the facility can be determined. For this purpose, substance statuses are examined one by one, by following the steps given in Figure 4.75.

If status of a substance is upper tier, the facility status is directly designated as upper tier and source is specified as the substance. If the status of the substance is lower tier and the status of the facility has not been set as upper tier before, it is set as lower tier.

If the substance is a named group substance, its lower and upper named indices calculated before are added to the indices of the named group. If upper index of the named group is found to be equal or greater than unity and the status of the facility has not been set as upper tier before, it is set as upper tier and source is specified as the named group. If the lower index of the named group is found to be equal or greater than unity and the status of the facility has not been set before, it is set as lower tier.

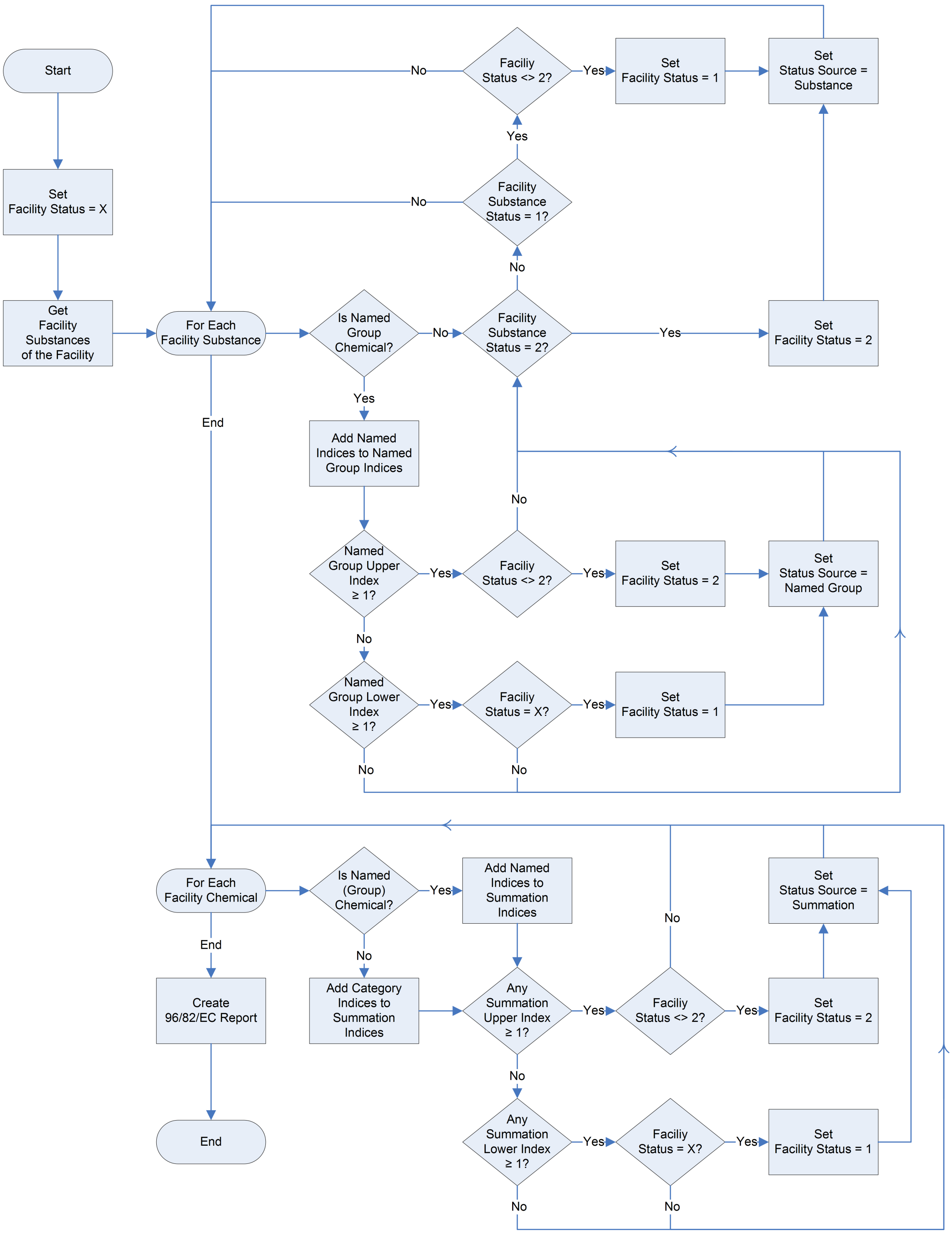


Figure 4.75: Flowchart of 96/82/EC status calculation of a facility

If the status of the facility could not be set in the first pass of the substance statuses, summation rule is applied to determine whether the facility is covered by the 96/82/EC Directive. For this purpose, indices of all substances are summed together. During the summation, named indices are used instead of overall hazard indices for named and named group substances. For other substances overall hazard indices are used directly. If any of the upper summation indices are found to be equal or greater than unity at the end of summation, the facility status is set as upper tier. If any lower summation index is found to equal or greater than unity, the status is set as lower tier.

Results of the 96/82/EC Directive status calculations for the facility are presented to the user in the form of a 96/82/EC Directive status report. The results can also be viewed at any time on the facility information page (Figure 4.76). In addition to the calculated 96/82/EC Directive status and summation indices, named group specific indices are also indicated.

Complete algorithm of facility-wide 96/82/EC Directive calculations explained above is given in Algorithm 2.

4.7.6 96/82/EC Status Update

96/82/EC Directive status calculation capabilities of the information system reveals its power in the case of automatic 96/82/EC Directive status updates. The system continuously monitors chemical, UN/ADR explosive, hazard classification, concentration specific hazard classification, named substance qualifying quantity, named group, named group substance, NACE specific 96/82/EC Directive settings, global 96/82/EC Directive settings, facility and facility substance records. If any change in records,

Figure 4.76: Facility 96/82/EC status summary

Algorithm 2 96/82/EC status calculation of a facility

```
procedure FacilityStatus(Facility)
    Status ← Out of Scope
    Indices ← ∅
    Group Indices ← ∅
    Facility Substances ← Get facility substances(Facility)
    for all Facility Substance ∈ Facility Substances do
        Chemical Indices ← Get 96/82/EC category indices (Facility Substance)
        if Facility Substance is Named Group Chemical then
            Named Group ← Get named group(Facility Substance)
            Add Chemical Indices_{Named,Lower} to Group Indices_{Named Group,Lower}
            Add Chemical Indices_{Named_{Upper}} to Group Indices_{Named Group,Upper}
            if (Group Indices_{Named Group,Upper} ≥ 1) ∧ (Status ≠ Upper Tier) then
                Status ← Upper Tier
            else if (Group Indices_{Named Group,Lower} ≥ 1) ∧ (Status = Out of Scope) then
                Status ← Lower Tier
            end if
        end if
        Chemical Status ← Get 96/82/EC status(Facility Substance)
        if Chemical Status = Upper Tier then
            Status ← Upper Tier
        else if (Chemical Status = Lower Tier) ∧ (Status ≠ Upper Tier) then
            Status ← Lower Tier
        end if
    end for
    for all Facility Substance ∈ Facility Substances do
        Chemical Indices ← Get 96/82/EC category indices (Facility Substance)
        if Chemical Indices_{Named} ≠ ∅ then
            Add Chemical Indices_{Named} to Indices_{Toxicity}
            Add Chemical Indices_{Named} to Indices_{Flammability}
            Add Chemical Indices_{Named} to Indices_{Ecotoxicity}
        else
            Add Chemical Indices_{Toxicity} to Indices_{Toxicity}
            Add Chemical Indices_{Flammability} to Indices_{Flammability}
            Add Chemical Indices_{Ecotoxicity} to Indices_{Ecotoxicity}
        end if
        for all Index ∈ Indices do
            if (Index_{Upper} ≥ 1) ∧ (Status ≠ Upper Tier) then
                Status ← Upper Tier
            else if (Index_{Lower} ≥ 1) ∧ (Status = Out of Scope) then
                Status ← Lower Tier
            end if
        end for
    end for
    return (Status, Indices, Group Indices)
end procedure
```

which may affect 96/82/EC Directive statuses of related records is determined, then 96/82/EC Directive calculations are renewed for all related records and statuses are updated. For example, if a new concentration limit specific hazard classification is added to a chemical, all facilities storing the chemical are found. First, 96/82/EC Directive statuses of the stored substances are updated. Then, the statuses of the facilities are calculated and updated. By this way, 96/82/EC Directive statuses assessed by the information system are always kept current. Changes in statuses are reported in the format of 96/82/EC Directive status reports.

There are many actions, which trigger automatic 96/82/EC Directive status update by the system. Flowchart containing triggering actions and steps followed during the update process is given in Figure 4.77. Complete listing of triggering actions and update steps is also listed in Table 4.26.

4.7.7 96/82/EC Directive Status Reports

96/82/EC Directive status reports are a special form of the change reports explained in Section 4.3.4. In addition to changes in the primary record, they also show changes in the 96/82/EC Directive statuses of all records that are affected by the changes in the primary record. For example, if 96/82/EC Directive categories of a classification is changed, 96/82/EC Directive status report lists status changes of all facility substances belonging to the classification, as well as all facilities storing the substances. Hence, overall effect of the change can be easily followed. Printout of the report can also be taken. An example 96/82/EC Directive status report is shown in Figure 4.78.

4.7.8 Meteorological Stations

Weather conditions, such as wind speed, wind direction and cloud cover, significantly affect dispersion of hazardous gases in the atmosphere. The extent of dispersion mainly depends on wind speed and atmospheric stability [88]. Weather conditions are also important for evaporation of hazardous liquids, which greatly enhances transport of such substances in case of spills [89]. Therefore, availability of reliable weather information is a requirement for accident modeling and consequence analysis studies. Near real-time weather data can also be used for emergency management purposes, such as warning or evacuation of the public in the vicinity.

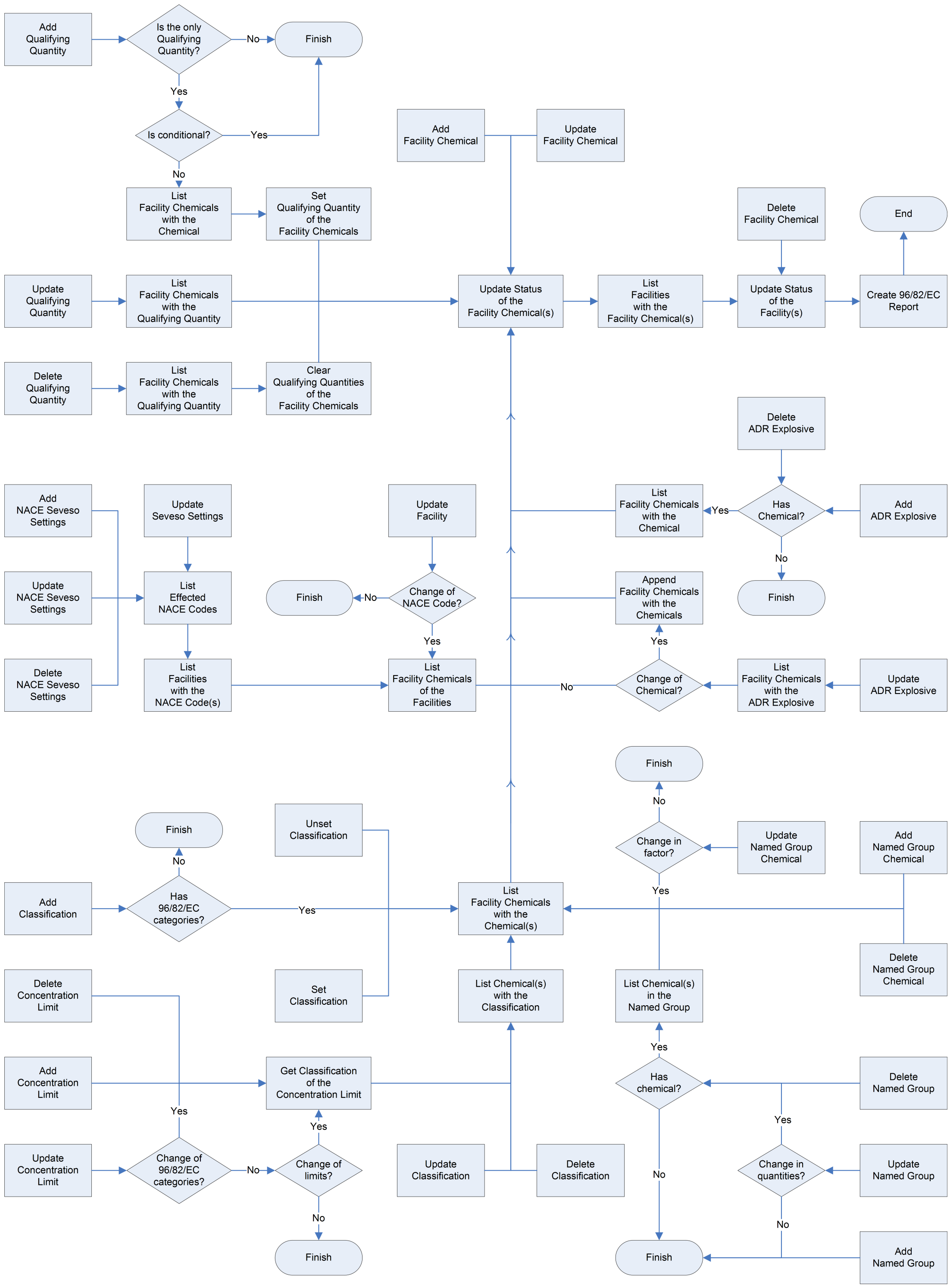


Figure 4.77: Flowchart of actions triggering 96/82/EC status update

Table 4.26: Actions triggering 96/82/EC status update

	Action		
Record type	Add[*]	Update	Delete[†]
Facility	-	If NACE code changed: ▷ Find affected facility substances ▷ Update statuses of the facility substances ▷ Update status of the facility	Delete facility substances Delete status of the facility
Facility Substance	Update status of the facility substance Update facility status	Same as *Add Facility Substance*	Update status of the facility
Chemical	-	-	-
UN/ADR Explosive	If is Chemical: ▷ Find facility substances of the chemical ▷ Update statuses of the facility substances ▷ Find facilities of the facility substances ▷ Update statuses of the facilities	List facility substances of the Explosive If Chemical is changed: ▷ Append facility substances of chemicals to the list Update statuses of the facility substances Find facilities of the facility substances Update statuses of the facilities	Same as *Add UN/ADR Explosive*
Classification	If has 96/82/EC categories: ▷ List facility substances of the chemical ▷ Update statuses of the facility substances ▷ Find facilities of the facility substances ▷ Update statuses of the facilities	Find chemicals of the Classification List facility substances of the chemicals Update statuses of the facility substances Find facilities of the facility substances Update statuses of the facilities	Same as *Update Classification*
Concentration Limit	Get classification of the concentration limit Find chemicals of the Classification List facility substances of the chemicals Update statuses of the facility substances Find facilities of the facility substances Update statuses of the facilities	If change of limits or 96/82/EC categories: ▷ Same as *Add Concentration Limit*	Same as *Add Concentration Limit*

[*] Equal to *Set* action for Classification record type

[†] Equal to *Unset* action for Classification record type

Table 4.26: Actions triggering 96/82/EC status update (continued)

	Action		
Record type	Add	Update	Delete
Qualifying Quantity	If the only qual. quantity and not conditional: ▷ List facility substances of the chemical ▷ Set qual. quantity of the facility substances ▷ Update statuses of the facility substances ▷ Find facilities of the facility substances ▷ Update statuses of the facilities	List facility substances of the qual. quantity Update statuses of the facility substances Find facilities of the facility substances Update statuses of the facilities	List facility substances of the qual. quantity Clear qual. quantity of the facility substances Update statuses of the facility substances Find facilities of the facility substances Update statuses of the facilities status
Named Group	-	If qualifying quantities changed: Same as *Delete Named Group*	If has chemicals: ▷ List chemicals in the named group ▷ List facility substances of the chemicals ▷ Update statuses of the facility substances ▷ Find facilities of the facility substances ▷ Update statuses of the facilities
Named Group Chemical	List facility substances of the chemical Update statuses of the facility substances Find facilities of the facility substances Update statuses of the facilities	If equivalence factor changed: ▷ Same as *Add Named Group Chemical*	Same as *Add Named Group Chemical*
Seveso Settings	-	List affected NACE codes List facilities with the NACE codes List facility substances of the facilities Update statuses of the facility substances Update statuses of the facilities	-
NACE Seveso Settings	List affected NACE codes List facilities with the NACE codes List facility substances of the facilities Update statuses of the facility substances Update statuses of the facilities	Same as *Add NACE Seveso Settings*	Same as *Add NACE Seveso Settings*

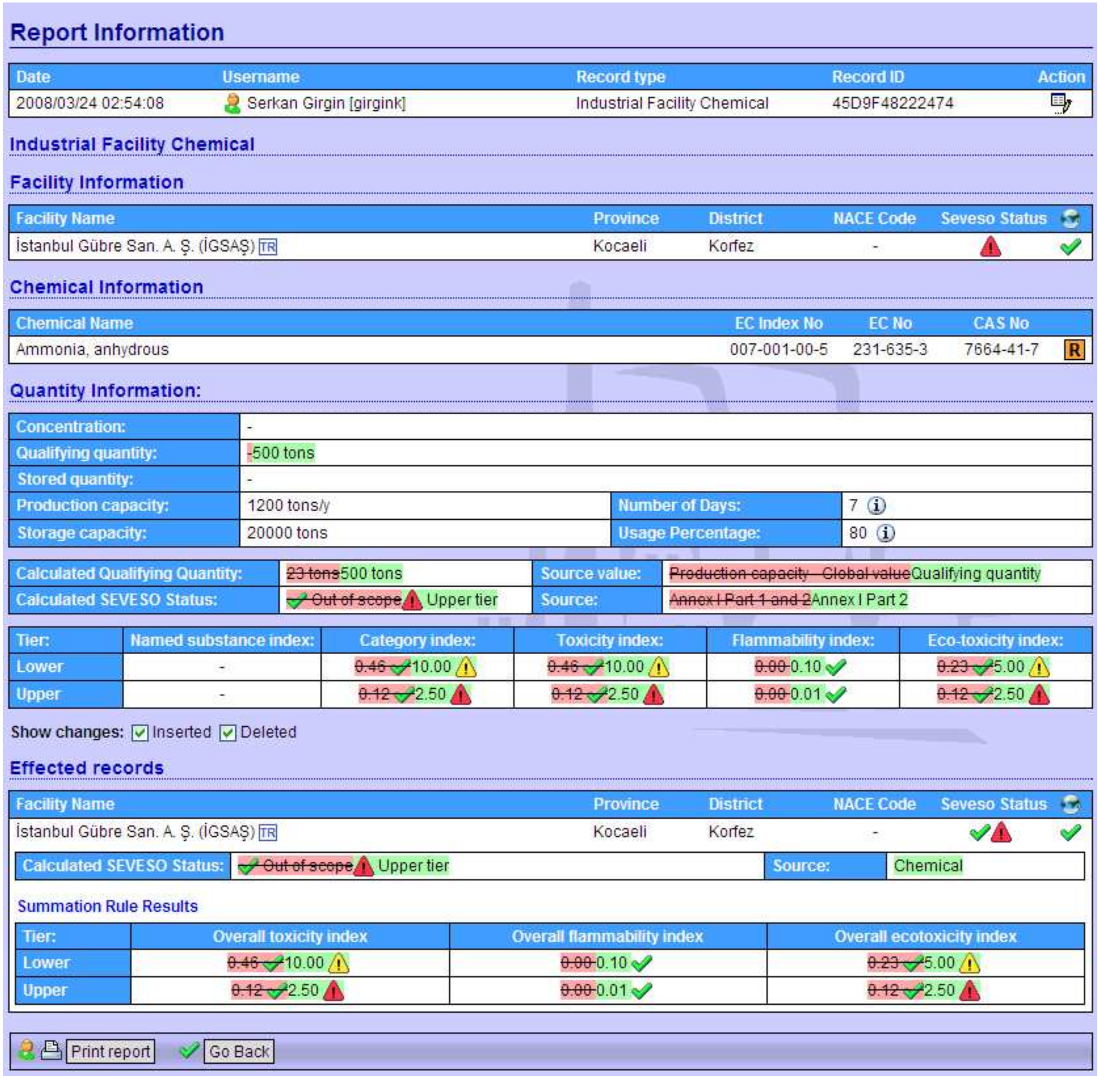


Figure 4.78: An example 96/82/EC status report generated by the information system

Taking these facts into consideration, the decision-support system supports meteorological stations and weather data thereof to be stored in the database. All active stations of the State Meteorological Service (SMS) are available in the system. Private stations can also be added.

Meteorological station information includes code, international identifier, name and region of the station and the organization that operates the station. In order to designate the location of the station, province, district, latitude, longitude and elevation can be specified. Location can also be marked on the map (Figure 4.79). Type of the weather station (e.g. synoptic, minor climate, major climate) and information on meteorological observations done at the station can be indicated.

Long-term statistical or daily meteorological data can be stored in the system as files linked to the meteorological stations (Figure 4.79). The system also features a web robot application named Weather Spider, which periodically collects weather data from the SMS website. If data collected by the Weather Spider is available for a station, most recent data is retrieved from the database and displayed on the information page of the station. Details on the Weather Spider are given in Section 5.3.

Figure 4.79: Meteorological station information

CHAPTER 5

DATA COLLECTION

In order to meet the objectives of the study, a comprehensive decision-support system has been developed, which provides a state of the art, integrated framework for studies on control of industrial accidents and equipped with a rich set of features and tools. However, presence of the decision-support system as software and hardware is not sufficient to have an effectively working system, which serve the needs of the users properly. In addition to the technological infrastructure, availability of data is also important in this respect. Without sufficient data, none of the information or decision-systems can be functional.

Although the developed system has easy to use data entry interfaces and facilitates sharing of information by providing an open-access, open-content environment, it is certain that build up of data will be slow at beginning and having a useful content will take quite a long time if collaborative data collection should start from scratch. Taking these into consideration, several data collection tasks have been performed in order to supply an initial dataset, which will allow to:

- Shorten time required to have a functional system,
- Demonstrate usefulness of the system,
- Draw attention of visitors and first time users of the system to make them regular users,
- Encourage users of the system to participate in data collection,
- Support scientific studies.

5.1 Collection of Chemical Substance Data

In order to support the 96/82/EC Directive calculations, dangerous substances and harmonised classification and labelling information thereof as listed in Annex 1B of the 67/548/EEC Directive is made available. For this purpose, latest version of the consolidated list of substances maintained by the European Chemicals Bureau (ECB), which covers all ATPs up to 29th ATP published in OJ L 152 of 30/04/2004, has been used. Consolidated list is downloaded from the ECB web site as MS Word document. Chemical name, index no, EC no, CAS no, classification, labelling, concentration limits and notes related to substances and preparations given in tabular form is extracted from the document. Extracted information is processed and converted automatically into SQL statements according to the database structure of the decision-support system as given in Appendix A. After validation of generated SQL statements, data is inserted into the database. Classification and labelling information of *3 544* dangerous substances is currently available.

In order to support storage of chemicals, which are not listed in the 67/548/EEC Directive, in inventories of industrial facilities data on EINECS and ELINCS substances are gathered from the European Chemical Substances Information System (ESIS) of the ECB [90]. EINECS is an inventory of chemical substances commercially available in the EU between 1 January 1971 and 18 September 1981. The inventory was created by the 67/548/EEC Directive. ELINCS is the complementary inventory of the EINECS and contains new substances brought on to the European market after 18 September 1981. There are *100 204* and *4 381* substances in EINECS and ELINCS, respectively. For each substance, web page containing substance information is downloaded from the ESIS. Substance names (in English, German, French and Spanish), EC no, CAS no and formula are extracted from the web page, relevant SQL statements are created and data is inserted into the database.

In order to complete missing SMILES data, which is used to draw 2D chemical structures, two data sources were utilized both of which are rely on CAS numbers. First data source is SMILES database of the SPARC (Sparc Performs Automated Reasoning in Chemistry) system developed by University of Georgia [91]. Web-based SPARC database has been searched for available CAS numbers in the chemical subsystem and found SMILES were inserted to the database. SMILES data for about *35 000* chemicals has been provided by this way. Second data source is EPI Suite (Estimator Programs Interface for Windows) developed by U.S. EPA's Office of Pollution Prevention and Toxics and Syracuse Research Corporation [92]. CAS numbers and corresponding chemical name and SMILES data were obtained for about *105 000* chemicals from CAS number database of the EPI Suite. By using CAS numbers, SMILES of chemicals stored in the chemical subsystem were updated. Chemicals which were not available before (i.e. not listed in EINECS, ELINCS and 67/548/EEC Directive) were added to the database as well.

Temperature dependent equations given in the TNO Yellow Book [19] for selected substances frequently involving in industrial accidents are made available in the information system. Equations for liquid density, vapor pressure, heat of vaporization, liquid heat capacity, vapor (ideal gas) heat capacity, liquid viscosity, vapor viscosity and surface tension of *23* chemical substances are provided.

In order to demonstrate chemical property data analysis capabilities of the information system, a small set of property data is entered to the system for selected substances, such as Benzene and Chlorine. Handbook of physical-chemical properties and environmental fate of organic chemicals published by Taylor & Francis is used as the reference [93].

5.2 Collection of Accident Data

For the purpose of assisting the researchers, General Directorate of Press and Information of the Prime Ministry compiles political, economic and social news from daily newspapers. Daily summaries of compiled news are published as 3-monthly periodicals entitled "History of the Month" in the form of yearbooks. Archive of the periodicals is also available on the Internet [70] for a time period starting from January, 1947. Information up to current date is present, except for the period of September, 1957 to October, 1976, during which periodicals had not been published. In order to gather information on industrial and technological accidents, all available periodicals are examined in detail and found information is transferred to the information system as yearbook entries. Gathered data formed the basis for the comprehensive newspaper article survey. Currently, there are more than *500* yearbook entries in the system, all categorized according to accident types.

Online editions of national newspapers on the Internet are utilized to collect information. Although texts of the news are generally shorter compared to the printed versions and visual materials are seldom, significant amount of information can be gathered in a short time owing to searching features of the web sites. Major newspapers used for the survey are Milliyet [94], Hürriyet [95] and Radikal [96]. One drawback of online newspapers is their limited time spans, which date back to late 1990s at most. Hence, only information on relatively recent technological accidents could be collected from these sources.

In order to provide historical data on accidents, which is not available in online resources and only briefly available in yearbook entries, printed newspaper articles are utilized. In the newspaper archive of the Library of Faculty of Political Sciences, Ankara University, bounded newspapers for a time period of 20 years (1976-1996) have been examined visually page by page. If average number of pages in a newspaper issue is taken as 20 for the given period, total number of pages examined is about *146 000* and has been completed in 8 weeks.

If an article related to technological accidents was found during examination, a digital copy was taken by means of digital photography. Date, title and page numbers were also denoted. Each photograph was processed manually by using Paint Shop Professional v9.0 image editing software and distortion, skewness, perspective and rotation problems were corrected to obtain a proper article image. Images have been cropped to the article boundaries and sections that were not related to the article have been deleted. Obtained images were imported into ABBYY FineReader Professional v8.0 optical character recognition (OCR) software. Text blocks in the images have been marked manually taking natural text flow into consideration and translated into machine-editable text by the OCR software. Although the OCR software has Turkish support and able to recognise Turkish characters, translated texts were not proper most of the time containing dummy characters and invalid words. Therefore, all OCR translated texts were read and corrected by voluntary human operators. Resulting text files were processed and special sections, such as title, subtitle, author, introduction and main body were marked according to data fields defined in the database. Final text files were processed by a special software and all available data were transferred to the database of the information system. Similar to textual sections of the articles, digital copies of figures and photographs belonging to the articles have also been taken, geometrically corrected, cropped, resized and transferred to the database. Links between the photographs and articles were also created. A summary of process steps described above is given in Figure 5.1.

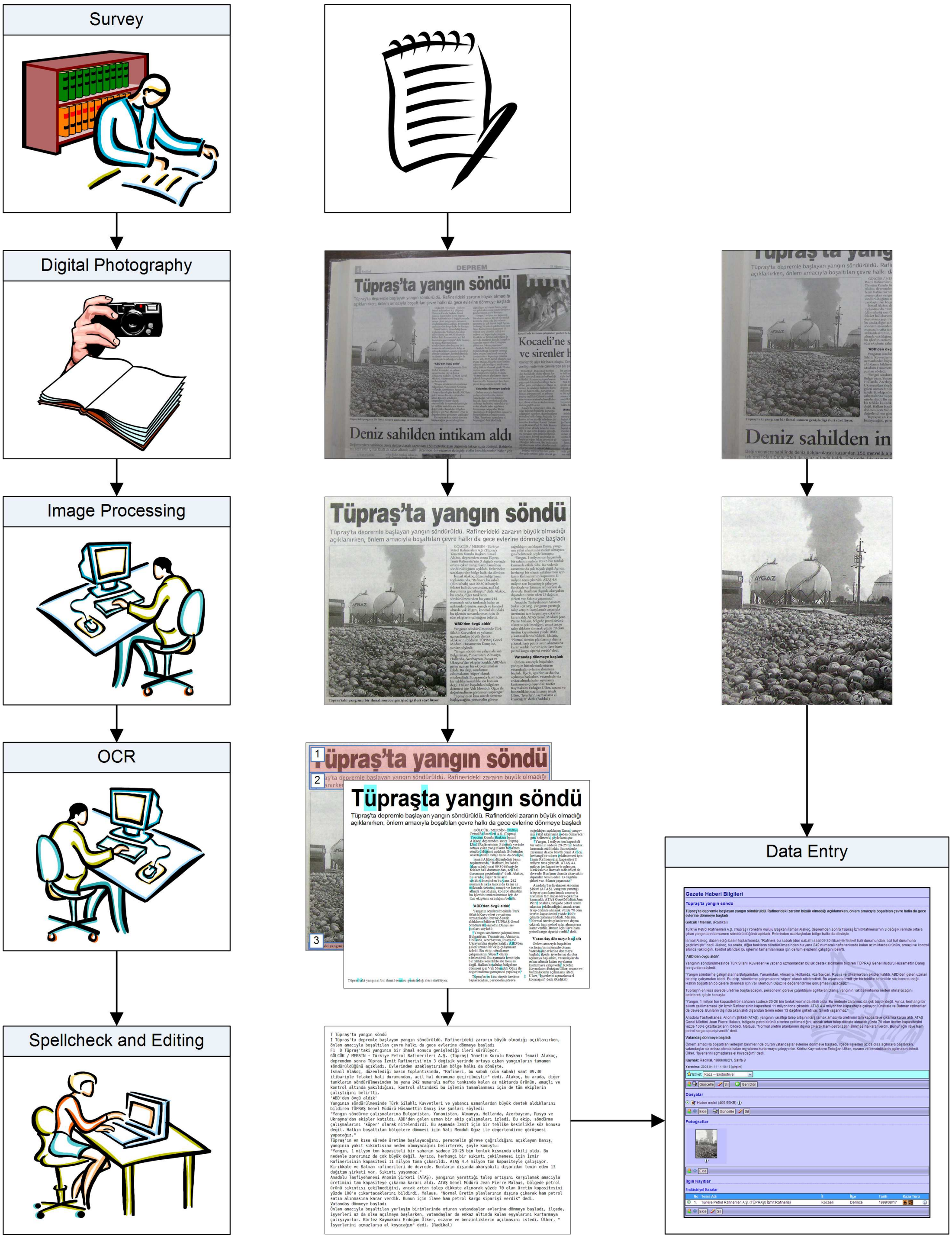


Figure 5.1: Newspaper article processing steps

Almost *2 500* newspaper articles, mostly having multiple pages and photographs, have been processed. Total time spent for processing is about *1 800* hours. As the result, information that was lying in the bounded newspaper volumes have been converted into fully searchable, classified and open electronic data accessible on the Internet.

5.3 Collection of Meteorological Data

With the advances in on-line measurement systems and the Internet, information on current weather conditions as well as short to medium range weather forecasts are made available to the public. There are several websites, which provide worldwide weather data [97]. In Turkey, SMS is the only authority responsible from collection of weather data and weather forecasting. For informative purposes, data for selected city centers and meteorological stations are published periodically on the web site of the SMS.

The decision-support system has a web robot application, which collects weather data from the SMS web site. Collected data is used to supply current weather data as input to the accident model. Historical data is also analysed to reveal dominating wind speed and direction and obtained information is supplied to the accident model.

Weather Spider is a console application developed in PHP. It can be run as a cron job or as a background service on Unix or MS Windows servers, respectively. For a predefined time interval (default is 30 minutes) the spider retrieves webpages containing weather data from the SMS website and checks whether new data is available or not. If new data is found it is extracted from the pages and stored in the database.

Weather data collected by the Weather Spider includes the following parameters:

- Temperature ($^\circ C$)
- Relative humidity (%)
- Pressure ($mbar$)
- Visibility (km)
- Wind direction ($^\circ$)
- Wind speed (km/h)
- Weather condition (see Table 6.4)

All weather data, except visibility, are utilized by the information system for accident modelling purposes.

Examination of weather data available for city centers and meteorological stations revealed that there is no one to one correspondence between city centers and meteorological stations. For several provinces, there are more city centers than meteorological stations for which weather data is available, and vice versa. Therefore, weather data is collected for city centers and meteorological stations separately. If it is known that there exists a meteorological station at the city center, weather data is stored under the weather station. Otherwise it is stored under the city center.

In order to provide weather data for a specific location, such as an industrial facility, first its geographic coordinates are determined. If exact coordinates of the location are known, they are used directly. Otherwise, geographic coordinates are approximated from district and province coordinates available in the system. According to the selected coordinates, nearest weather station or city center is determined, for which data is available in the database. Flowchart of the nearest weather data retrieval algorithm is given in Figure 5.2.

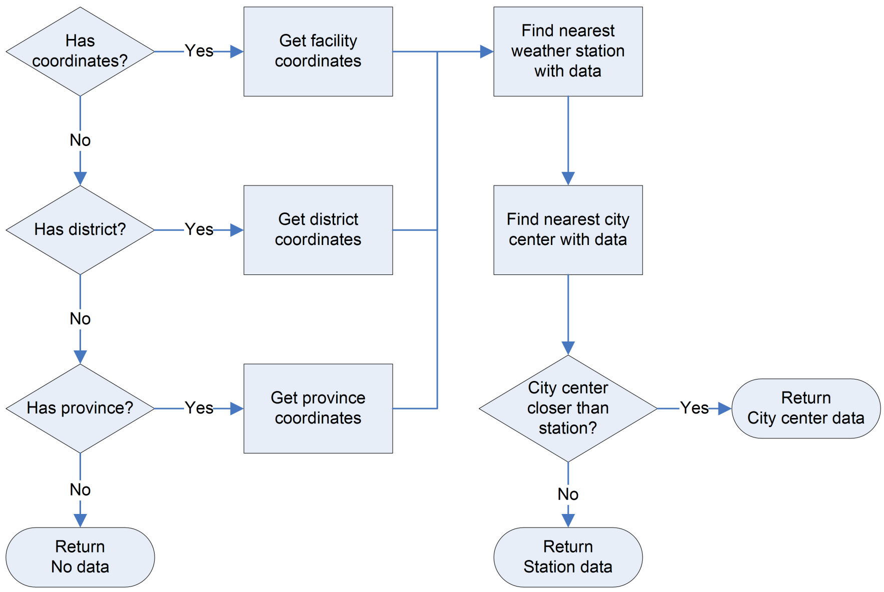


Figure 5.2: Flowchart of nearest weather data retrieval

CHAPTER 6

ACCIDENT MODEL

In addition to open-content, open-access industrial and technological accident inventory, industrial facility database with the capability of the 96/82/EC Directive calculations and chemical database with comprehensive chemical property analysis and estimation tools, the information system also features an off-site consequence model specifically designed for industrial accidents. The model is integrated to the other components of the information system and features a user-friendly data input interface with mapping support.

In this chapter, a technical description of the model, which includes approaches and equations used for the model, is given. Then, the user interface of the model is explained.

6.1 Technical Description

Off-site consequence model developed in the study is based on Gaussian puff model and uses Pasquill-Gifford horizontal and vertical dispersion parameters. In order to model the dispersion process, source term is divided into small intervals, in which the source is assumed to be instantaneous. Puff model is solved for each time interval and results are superimposed numerically on a 2D mesh to model continuous release.

Modeling calculations start with substitution of default values instead of missing values which are not critical for the calculations. Then values of intermediate parameters are calculated. From the location and date information, the position of the Sun is determined, which is used for atmospheric stability calculations. Phase and amount of the chemical are calculated, if they are not manually entered. If the substance is found to be in liquid form and source is a tank, presence of a two-phase flow is assessed and source term calculations are done accordingly. In order to calculate outflow from the tank, mass and heat balance equations are solved concurrently. If the substance is in liquid form, puddle dimensions are calculated and evaporation from the puddle is simulated. Source terms for gaseous phase, either calculated as direct outflow from the tank or evaporation from the puddle, are used as input to the atmospheric dispersion model.

Equations used for the model are summarized in the following sections.

6.1.1 Equations of state

In order to calculate the gas density as a function of pressure and temperature, the model uses equations of state. If critical pressure and temperature data is available, Redlich-Kwong equation of state is used for calculations. Ideal gas law is used otherwise.

Ideal gas law

$$P = \frac{nRT}{V} \tag{6.1}$$

where

P = Pressure (Pa)

V = Volume (m^3)

n = Number of moles of the gas (mol)

R = Universal gas contant (8.314472 $J/mol.K$)

T = Temperature (K)

Redlich-Kwong equation of state

$$P = \frac{RT}{V_m - b} - \frac{a}{\sqrt{T} V_m (V_m + b)} \tag{6.2}$$

$$a = 0.42748 \left(\frac{R^2 T_c^{5/2}}{P_c} \right) \tag{6.3}$$

$$b = 0.08662 \left(\frac{RT_c}{P_c} \right) \tag{6.4}$$

where

V_m = Molar volume of the gas (m^3/mol)

P_c = Pressure at the critical point (Pa)

T_c = Temperature at the critical point (K)

Redlich-Kwong equation is adequate for calculation of gas phase properties when the ratio of reduced pressure to the reduced temperature is less than 0.5.

$$P_r = \frac{P}{P_c} \tag{6.5}$$

$$T_r = \frac{T}{T_c} \tag{6.6}$$

where

P_r = Reduced pressure (unitless)

T_r = Reduced temperature (unitless)

6.1.2 Source Model

The following models are available:

1. Compressed gas
   - Outflow from vessel through a hole in vessel wall
   - Totally ruptured vessel
2. Pressurised liquefied gas
   - Outflow from vessel through a hole in vessel wall
   - Totally ruptured vessel
3. Non-boiling liquid
   - Outflow from vessel through a hole in vessel wall
   - Totally ruptured vessel

A total rupture of a vessel containing compressed gas results in a gas cloud that expands to atmospheric pressure. During expansion, air surrounding the cloud gets entrained to the cloud resulting in dilution. For the modeling purposes, initial cloud is assumed to be *non-diluted.*

γ ratio

γ, which is also known as the isentropic expansion factor, is used as a parameter to calculate whether the flow will be chocked or unchocked.

$$\gamma = \frac{C_p}{C_v} \tag{6.7}$$

where

γ = Heat capacity ratio (unitless)

C_p = Heat capacity at constant pressure (J/mol.K)

C_v = Heat capacity at constant volume (J/mol.K)

For an ideal gas, the heat capacity is constant with temperature and heat capacities can be expressed in terms of heat capacity ratio and the universal gas constant.

$$C_p = \frac{\gamma R}{\gamma - 1} \tag{6.8}$$

$$C_v = \frac{R}{\gamma - 1} \tag{6.9}$$

This results in a simple relation between C_p and C_v, allowing to estimate one knowing the other.

$$C_v = C_p - R \tag{6.10}$$

Criteria for choked-unchoked flow

Whether the flow will be choked or unchoked depends on the ratio of vessel pressure to atmospheric pressure (R_p). Flow is unchoked if this ratio is less than the critical pressure ratio (R_c) and choked otherwise. For small holes, critical pressure ratio depends only on the ratio of specific heats. However, for big holes the hole-to-tank length scale ratio is also important.

$$R_p = \frac{P_t}{P_a} \tag{6.11}$$

$$\begin{aligned} R_p &< R_c \quad \text{Unchoked flow} && (6.12) \\ R_p &\geq R_c \quad \text{Choked flow} && (6.13) \end{aligned}$$

$$\begin{aligned} R_c &= \left(\frac{\gamma+1}{2}\right)^{\frac{\gamma}{\gamma-1}} \qquad \beta_c < 0.2 && (6.14) \\ R_c^{\frac{\gamma-1}{\gamma}} + \frac{\gamma-1}{2}\beta_c^4 R_c^{-\frac{2}{\gamma}} &= \frac{\gamma+1}{2} \qquad \beta_c \geq 0.2 && (6.15) \end{aligned}$$

where

R_c = Critical pressure ratio (unitless)

β_c = Hole-to-tank length scale ratio (unitless)

$$\beta_c = \frac{L_h}{L_t} \tag{6.16}$$

where

$$L_h = \begin{cases} 2r_h & \text{circular hole} \\ \sqrt{w_h h_h} & \text{rectangular hole} \end{cases} \tag{6.17}$$

$$L_t = \begin{cases} 2r_t & \text{spherical tank} \\ 2r_t & \text{cylindrical tank} \end{cases} \tag{6.18}$$

Unchoked flow

The flow velocity is subsonic. The mass flow is given by:

$$q = C_d A_h \sqrt{2\rho_g P_t \frac{\gamma}{\gamma-1}\left(\left(\frac{P_a}{Pt}\right)^{2/\gamma} - \left(\frac{P_a}{P_t}\right)^{(\gamma+1)/\gamma}\right)} \tag{6.19}$$

Choked flow

The flow velocity is constant at the speed of sound, and further reduction of downstream pressure does not change the flow rate to a noticeable degree. The mass flow rate is given by:

$$q = C_d A_h \sqrt{\rho_g P_t \gamma \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma+1}{\gamma-1}}} \tag{6.20}$$

Estimation of Evaporation Rate

In order to estimate the evaporation rate, the following equation is used:

$$E = \frac{AK_m(M_w P_v)}{RT} \tag{6.21}$$

where

E = Evaporation rate (kg/s)

A = Pool area (m^2)

K_m = Mass transfer coefficient (m/s)

M_w = Molecular weight of the chemical $(kg/kmol)$

P_v = Vapor pressure (Pa)

R = Universal gas constant $(8314 J/kmol \cdot K)$

T = Ambient temperature (K)

The following equation can be used to calculate K_m, the mass transfer coefficient:

$$K_m = 0.0048 U^{\frac{7}{9}} Z^{-\frac{1}{9}} S_c^{-\frac{2}{3}} \tag{6.22}$$

where

U = Wind speed at a height of *10 m* (m/s)

Z = Pool diameter in the along-wind direction (m)

S_c = Laminar *Schmidt* number for the selected chemical

The *Schmidt* number can be estimated from:

$$S_c = \frac{v}{D_m} \tag{6.23}$$

where

v = Kinematic viscosity of the air ($1.5 \cdot 10^{-5} m^2/s$)

D_m = Molecular diffusivity of the chemical in air (m^2/s)

Graham's Law can be used to approximate the molecular diffusivity of the chemical in air:

$$D_m = D_{m(H_2O)} \left(\frac{M_{w(H_2O)}}{M_w} \right)^{\frac{1}{2}} \tag{6.24}$$

where

$D_{m(H_2O)}$ = Molecular diffusivity of water ($2.4 \cdot 10^{-5} m^2/s$ at $8°C$)

$M_{w(H_2O)}$ = Molecular weight of water ($18 kg/kmol$)

6.1.3 Dispersion Model

Atmospheric Turbulence

In order to define the atmospheric turbulence, the Pasquill stability categories are used. Being the most commonly used method, the Pasquill stability categories divide the atmospheric turbulence into 6 categories:

Table 6.1: The Pasquill stability categories

Stability class	Definition
A	Very unstable
B	Unstable
C	Slightly unstable
D	Neutral
E	Slightly stable
F	Stable

Conditions that define the Pasquill stability categories are as follows [98]:

Table 6.2: Conditions that define the Pasquill stability categories

Wind speed (m/s)	Daytime incoming solar radiation			Nighttime cloud cover	
	Strong	Moderate	Slight	Thinly overcast ($> 4/8$)	Clear ($< 3/8$)
< 2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
≥ 6	C	D	D	D	D

For the application of the Pasquill stability categories, the following notes are valid:

1. Strong insolation corresponds to sunny midday in midsummer in England; slight insolation to similar conditions in midwinter.
2. Night refers to the period from 1 hour before sunset to 1 hour after sunrise.
3. The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night and for any sky conditions during the hour preceding or following night as defined above.

Criteria used for classification of insolation values are as follows:

Table 6.3: Criteria for insolation classes

Insolation Class	Incoming Solar Radiation (W/m^2)	Solar Altitude ($^\circ$)
Strong	> 700	> 60
Moderate	$350 - 700$	$35 - 60$
Slight	< 350	< 35

In order to calculate incoming solar radiation, cloud cover is used. Weather conditions announced by the SMS are utilized as a measure of cloud cover. Weather conditions and corresponding cloud covers used for calculations are given in Table 6.4.

Table 6.4: Cloud cover equivalence of weather conditions

Weather Condition	Cloud Cover	Weather Condition	Cloud Cover
Clear	0	Heavy fog	10
Partly cloudy	3	Heavy rain	10
Heavy wind	5	Heavy rain shower	10
Intermittent clouds	5	Heavy rain with thunder	10
Intermittent fog	5	Heavy snow	10
Mild fog	7	Light hail shower	10
Mostly cloudy	7	Light rain shower	10
Partly foggy	7	Light snow shower	10
Freezing fog	8	Lightning flash	10
Haze	8	Mild hail with thunder	10
Sand	8	Mild rain with thunder	10
Smoke	8	Misty shower	10
Drizzle	9	Misty shower with thunder	10
Dust or sand storm	9	Misty with thunder	10
Dust storm	9	Rain shower	10
Hazy with thunder	9	Rain shower with thunder	10
Mild drizzle	9	Rainy	10
Mild rain	9	Show shower	10
Mild snow	9	Shower with thunder	10
Mild snow grains	9	Sleet	10
Misty	9	Snow	10
Shower	9	Snow shower	10
Cloudy	10	Snowy	10
Foggy	10	Thunder	10
Hail	10	Thunderrain	10
Hazy shower	10	Tornado	10

Wind

Due to frictional effect by the roughness elements on the ground surface, the wind slows at heights close to the ground. Increase in wind speed with altitude can be approximated by a logarithmic or power-law profile.

Power-law wind profile

$$u_z = u_m \left(\frac{z}{z_m} \right)^n \tag{6.25}$$

where:

u_z = wind speed at height z (m/s)

u_m = wind speed at measurement height z_m (m/s)

z = height (m)

z_m = measurement height (m)

n = power-law exponent

Power-law wind profile is often used when surface roughness or stability information is not available. For neutral stability conditions, power-law exponent is approximately 1/7 or 0.143 over open land. For different stability classes and surface conditions, the values given in Table Table 6.5 can be used.

Table 6.5: Power–law wind profile exponents [99]

Pasquill Stability	Power-law wind profile exponent	
Class	Rural	Urban
A	0.07	0.15
B	0.07	0.15
C	0.10	0.20
D	0.15	0.25
E	0.35	0.30
F	0.55	0.30

Dispersion parameters

The model supports different dispersion parameters for modeling atmospheric dispersion. Support parameters are as follows:

Slade's Dispersion Parameters

Slade's original parameters are given in Table 6.6. Power function approximations by Turner are given in Table 6.7.

Table 6.6: Dispersion parameters by Slade [100]

Dispersion Parameter	Stability	Downwind distance 100 m	4000m
σ_y	Unstable	10.0	300.0
	Neutral	4.0	120.0
	Stable	1.3	35.0
σ_z	Unstable	15.0	220.0
	Neutral	3.8	50.0
	Stable	0.75	7.0

Table 6.7: Power function constants for dispersion parameters by Slade [99]

Pasquill Stability	σ_y		σ_z	
Class	a	b	c	d
A	0.18	0.92	0.72	0.76
B	0.14	0.92	0.53	0.73
C	0.1	0.92	0.34	0.72
D	0.06	0.92	0.15	0.70
E	0.045	0.91	0.12	0.67
F	0.03	0.90	0.08	0.64
G	0.02	0.89	0.05	0.61

Briggs' Dispersion Parameters

Briggs' urban and rural dispersion parameters are given in Table 6.8 and Table 6.9, respectively. Briggs' urban dispersion parameters are based on tracer experiments conducted in St. Louis by McElroy and Pooler [101]. Valid along wind distance (x) ranges between 100 and 10000 meters [99].

Table 6.8: Urban dispersion parameters by Briggs

Pasquill Stability Class	σ_y (m)	σ_z (m)
A-B	$0.32x(1+0.0004x)^{-0.5}$	$0.24x(1+0.001x)^{0.5}$
C	$0.22x(1+0.0004x)^{-0.5}$	$0.20x$
D	$0.16x(1+0.0004x)^{-0.5}$	$0.14x(1+0.0003x)^{-0.5}$
E-F	$0.11x(1+0.0004x)^{-0.5}$	$0.08x(1+0.0015x)^{-0.5}$

Table 6.9: Rural dispersion parameters by Briggs

Pasquill Stability Class	σ_y (m)	σ_z (m)
A	$0.22x(1+0.0001x)^{-0.5}$	$0.20x$
B	$0.16x(1+0.0001x)^{-0.5}$	$0.12x$
C	$0.11x(1+0.0001x)^{-0.5}$	$0.08x(1+0.0002x)^{-0.5}$
D	$0.08x(1+0.0001x)^{-0.5}$	$0.06x(1+0.0015x)^{-0.5}$
E	$0.06x(1+0.0001x)^{-0.5}$	$0.03x(1+0.0003x)^{-1}$
F	$0.04x(1+0.0001x)^{-0.5}$	$0.016x(1+0.0003x)^{-1}$

Pasquill-Gifford Dispersion Parameters

Horizontal dispersion parameter:

$$\sigma_y = \frac{1000}{2.15}\tan(a - b\ln x) \qquad (6.26)$$

Table 6.10: Pasquill-Gifford horizontal dispersion parameters [99]

Stability	a	b
A	24.167	2.5334
B	18.333	1.8096
C	12.5	1.0857
D	8.3333	0.72382
E	6.25	0.54287
F	4.1667	0.36191

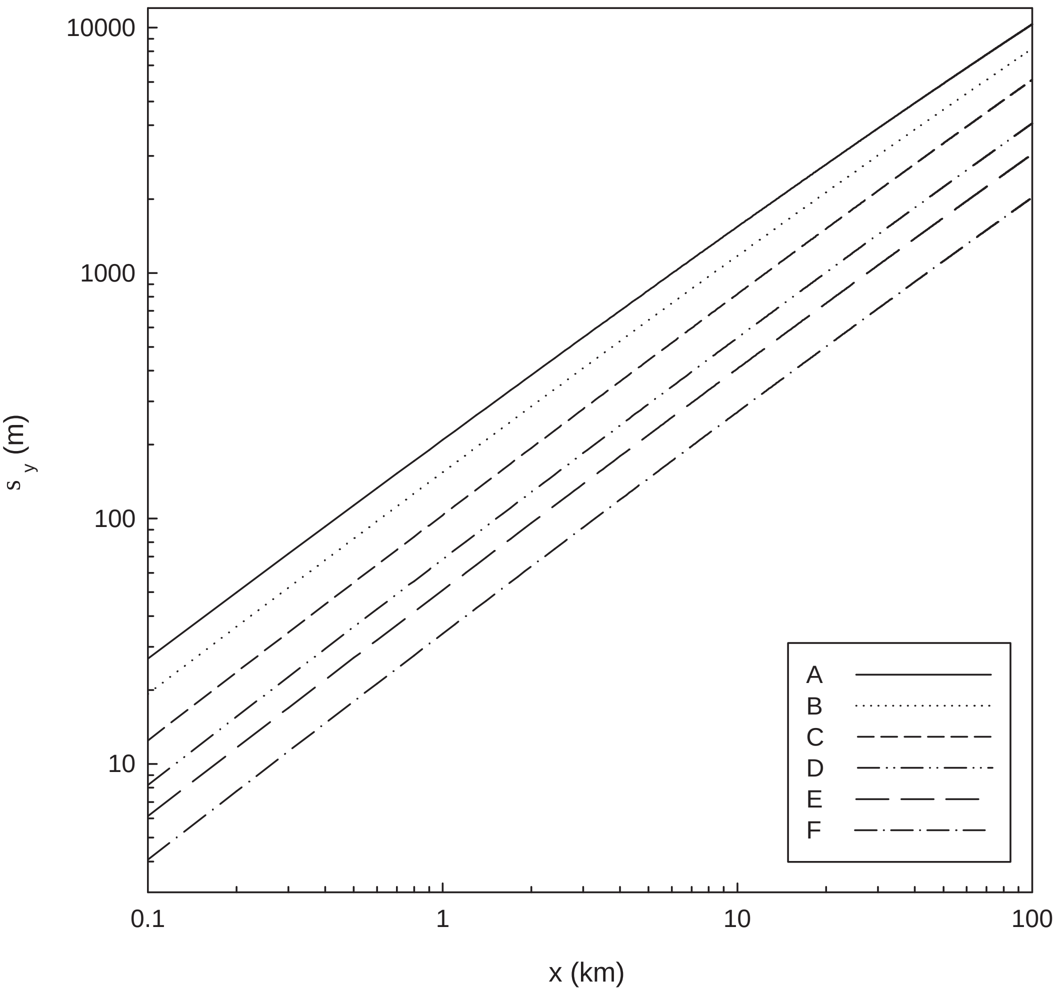


Figure 6.1: Pasquill-Gifford horizontal dispersion parameter (σ_y)

Vertical dispersion parameter:

$$\sigma_z = ax^b \tag{6.27}$$

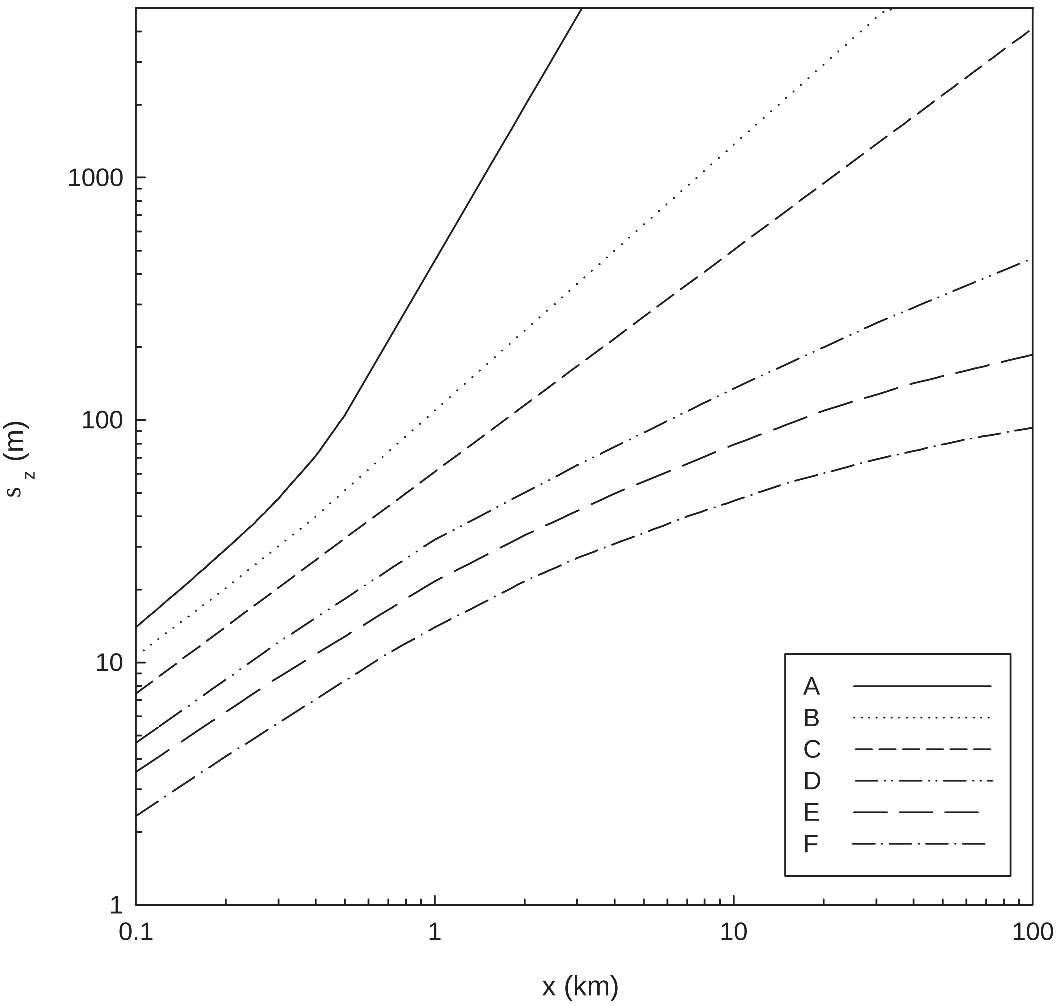


Figure 6.2: Pasquill-Gifford vertical dispersion parameter (σ_z)

Pasquill-Gifford dispersion parameters given in Figure Figure 6.1 and Figure 6.2 are considered to be appropriate for rural areas with a surface roughness length (z_0) of 3cm [99].

Table 6.11: Pasquill-Gifford vertical dispersion parameters [99]

Stability	Distance (km)	a	b
A	>3.11	$\sigma_z = 5000$	
	0.5 - 3.11	453.85	2.1166
	0.4 - 0.5	346.75	1.7283
	0.3 - 0.4	258.89	1.4094
	0.25 - 0.3	217.41	1.2644
	0.2 - 0.25	179.52	1.1262
	0.15 - 0.2	170.22	1.0932
	0.1 - 0.15	158.08	1.0542
	<0.1	122.8	0.9447
B	>35.0	$\sigma_z = 5000$	
	0.4 - 35.0	109.30	1.0971
	0.2 - 0.4	98.483	0.98332
	<0.2	90.673	0.93198
C	$\forall x$	61.141	0.91465
D	>30.0	44.053	0.51179
	10.0 - 30.0	36.650	0.56589
	3.0 - 10.0	33.504	0.60486
	1.0 - 3.0	32.093	0.64403
	0.3 - 1.0	32.093	0.81066
	<0.3	34.459	0.86874
E	>40.0	47.618	0.29592
	20.0 - 40.0	35.420	0.37615
	10.0 - 20.0	26.970	0.46713
	4.0 - 10.0	24.703	0.50527
	2.0 - 4.0	22.534	0.57154
	1.0 - 2.0	21.628	0.63077
	0.3 - 1.0	21.628	0.75660
	0.1 - 0.3	23.331	0.81956
	<0.1	24.260	0.83660
F	>60.0	34.219	0.21716
	30.0 - 60.0	27.074	0.27436
	15.0 - 30.0	22.651	0.32681
	7.0 - 15.0	17.836	0.41500
	3.0 - 7.0	16.187	0.46490
	2.0 - 3.0	14.823	0.54503
	1.3 - 2.0	13.953	0.63227
	0.7 - 1.0	13.953	0.68465
	0.2 - 0.7	14.457	0.78407
	<0.2	15.209	0.81558

Turner's rural dispersion coefficients can be approximated by the equation of McMullen [102].

$$\sigma_{y,z} = exp[I + J(\ln x) + K(\ln x)^2] \tag{6.28}$$

Table 6.12: Dispersion constants for McMullen equation [102]

Stability	σ_z			σ_y		
	I	J	K	I	J	K
A	6.035	2.1097	0.2770	5.357	0.8828	-0.0076
B	4.694	1.0629	0.0136	5.058	0.9024	-0.0096
C	4.110	0.9201	-0.0020	4.651	0.9181	-0.0076
D	3.414	0.7371	-0.0316	4.230	0.9222	-0.0087
E	3.057	0.6794	-0.0450	3.922	0.9222	-0.0064
F	2.621	0.6564	-0.0540	3.533	0.9191	-0.0070

Gaussian Dispersion Equation

Gaussian dispersion equation used for the study is as follows:

$$C = \frac{Q}{u} \frac{f}{\sigma_y \sqrt{2\pi}} \frac{g_1 + g_2 + g_3}{\sigma_z \sqrt{2\pi}} \tag{6.29}$$

where

$$f = exp\left(\frac{-y^2}{2\sigma_y^2}\right) \tag{6.30}$$

$$g_1 = exp\left(\frac{-(z-H)^2}{2\sigma_z^2}\right) \tag{6.31}$$

$$g_2 = exp\left(\frac{-(z+H)^2}{2\sigma_z^2}\right) \tag{6.32}$$

$$g_3 = \sum_{m=1}^{\infty}\left[exp\left(\frac{-(z-H-2mL)^2)}{2\sigma_z^2}\right) + exp\left(\frac{-(z-H-2mL)^2)}{2\sigma_z^2}\right)\right] \tag{6.33}$$

6.2 User Interface

Similar to other components of the decision-support system, off-site consequence model also has a web-based user interface. Based on the scenario settings selected by the user, relevant data input elements are displayed on the page. Data input elements are also dynamic in nature, and update themselves according to the status of other input elements. They are also capable of validating data entered by the user. Once all required data is entered and the model output is requested, preliminary data checks are made on the client side (user's computer) first. Then input data is submitted to the server, where all mathematical calculations are performed. Modeling results are presented to the user as tabular data, as well as 2D footprint which is mapped to the source location using the mapping component of the system.

Input data required for modeling off-site consequences are grouped under 5 headings, which are:

- Location information
- Date information
- Substance information
- Source information
- Meteorological information

Location of the accident can be selected from one of the industrial facilities available in the facility subsystem. If desired, a custom location can also be specified. For custom locations, the name of the location should be entered to identify the location. Province and district can be selected from the lists provided by the system. According to the selected province and district, latitude and longitude denoting the geographic coordinate and elevation are updated. The location can also be specified by using the map window (Figure 6.3).

Date and time of the accident can be indicated together with the type of time as local or UTC (Coordinated Universal Time). During the model calculations, local time is converted to the UTC time using automatically calculated time zone (summer/winter time) information from the date. If date and/or time are left blank, current values are used as default.

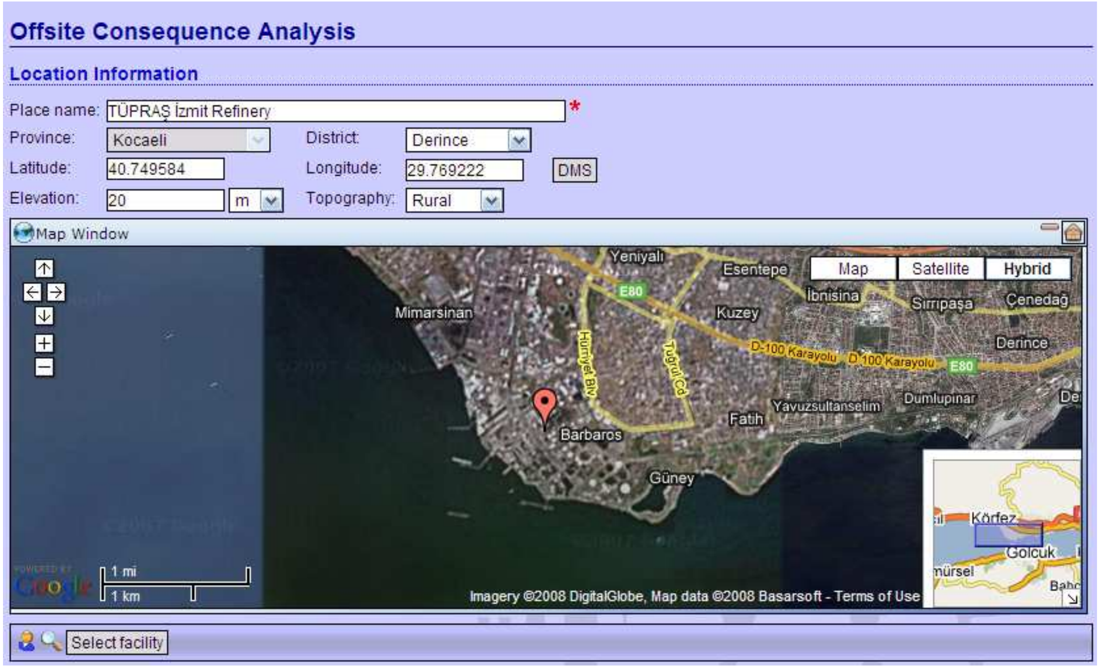


Figure 6.3: Location input for the model

The chemical substance to be modelled can be selected from the chemicals and UN/ADR explosive substances available in the information system. If classification information is available, the system is capable of determining whether the substance is flammable and/or toxic. UN/ADR explosives are always considered to be flammable. If they are linked to a chemical, toxicity status is also evaluated. The user is allowed to overwrite substance types determined by the system.

Substance quantity can be stated in mass or volume units. If volume is specified, mass is tried to be calculated from the density data available for the substance. If available data is not sufficient to calculate the quantity, the user is warned. The information system also gives an option for calculating quantity information from storage conditions. If this option is selected, quantity is tried to be calculated from the storage conditions and storage tank dimensions.

Phase, pressure and temperature can be indicated to determine the storage conditions. Phase can be selected as gaseous, liquid or solid. Similar to quantity data, phase can also be calculated from storage conditions by the system. In addition to reference temperature and pressure, critical temperature and pressure values are also required for phase estimation. Instead of entering custom values for pressure and temperature, they can also be selected as equal to ambient conditions as specified in weather information section (Figure 6.4).

Chemical properties required for calculations are asked under "Chemical Properties" section. If information is available in the system for a required property as property data, equations or estimators, most appropriate data value is calculated and used by the system automatically as explained in Section 4.6.12. The system also allows custom values to be entered for chemical properties. However, since only a single data can be entered for each custom property value, temperature or pressure dependence of the properties can not be modeled if data is entered in this way. Therefore, use of chemical property analysis framework of chemical subsystem is always recommended for proper modeling calculations.

Source term of the model supports direct and tank sources (Figure 6.5). Direct sources are considered to be instantaneous or short duration releases. Instantaneous releases are assumed to occur in 1 minute. For short duration releases, release duration (time) or rate (mass/time) can be specified. Height of the release can be indicated and used by the calculations if substance is in gaseous phase.

Tank sources are considered to originate from a hole on the tank body. Hole type can be selected as circular or rectangular. Dimensions of the hole can be specified in areal or length units . If surface area is given, dimensions are calculated automatically and vice versa. Rectangular holes are assumed to be square for dimension calculations. Diameter for circular holes, and length and width for rectangular holes can be entered to indicate dimensions. Similar to direct source case, hole height can be specified. It

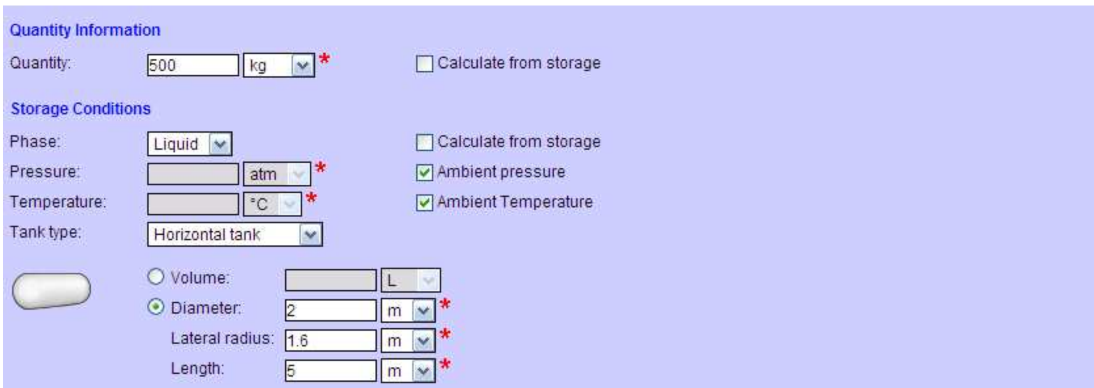


Figure 6.4: Quantity and storage conditions input for the model

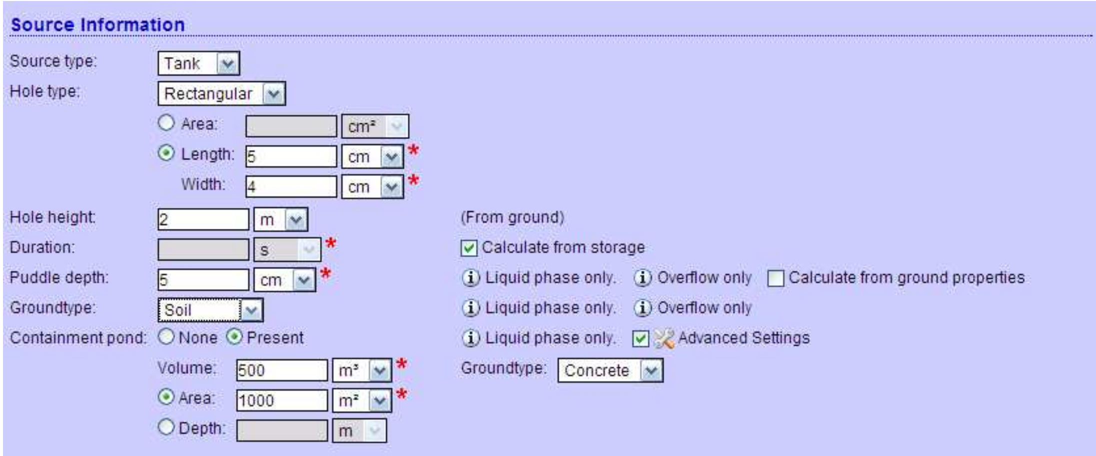


Figure 6.5: Source input for the model

is used for source terms calculations if phase of the substance is liquid, otherwise it is taken as the release height for gaseous dispersion. Duration of release from a tank source can be explicitly indicated. It can also be calculated by the system using mass balance equations.

The modeling system supports 4 different tank types, which are:

- Vertical cylinder,
- Horizontal cylinder,
- Horizontal tank with spherical ends, and
- Sphere.

Tank dimensions can be given in volume or length units. If length units are selected, required dimension input fields are displayed by the system according to the selected tank type.

For releases in liquid phase, formation of a puddle on the ground and evaporation thereon are considered. Depth of puddle can be manually entered or calculated from ground type specified by the user. In addition to puddle depth, ground type also affects rate of evaporation by changing heat transfer constant. Presence of a containment pond can be modelled. If selected as present, the volume and also area or depth of the pond should be entered. Ground type of the containment pond can also be selected in advanced settings. Presence of a containment pond enforces the model to calculate overflow condition.

Last section of the model input is weather information (Figure 6.6). Temperature, pressure and relative humidity data are used for heat balance and source term calculations, whereas wind speed, wind direction and cloud cover data are used for atmospheric dispersion calculations. Presence of inversion layer and its height, height of meteorological measurements, custom stability class to overwrite the one automatically calculated by the system, and soil temperature can be set in advanced settings. If left blank, measurement height is assumed to be $10m$ and soil temperature is taken as equal to the air temperature. Default values are also used for other missing weather data.

According to the selected accident location, the information system lists the meteorological stations that are located within a specified range. Search range can be selected by the user. If any stations are found, they are marked on the map and summary information is given about the station. For stations, for which weather data is available in the database from the Weather Spider described in Section 5.3, latest weather data is also displayed. Displayed data can be automatically entered to the weather data input elements. By using all wind speed and wind direction data available in the database for the station, windrose of the station is also generated and displayed by the system, which can be used to determine dominating wind speed and direction. Dominating wind speed and direction can be used instead of latest weather data for general modelling purposes.

Once the input values are entered, model calculations can be started. As the first step, all input values are controlled by the system on the client-side and missing or invalid entities that are critical for calculations are determined. Found errors are reported to the user for correction. If all required data is available and valid for the selected scenario, it is submitted to the server as input to the model described in 6.1. Results of the model run are processed and presented to the user in tabular form, which allows input and output values to be compared side by side (Figure 6.7). In addition to results of the final calculations, the ones of the intermediate calculations are also displayed. Line plots of liquid and gaseous source terms are provided. Raw data can also be obtained. Finally footprint of the resulting plume is displayed on the map (Figure 6.8).

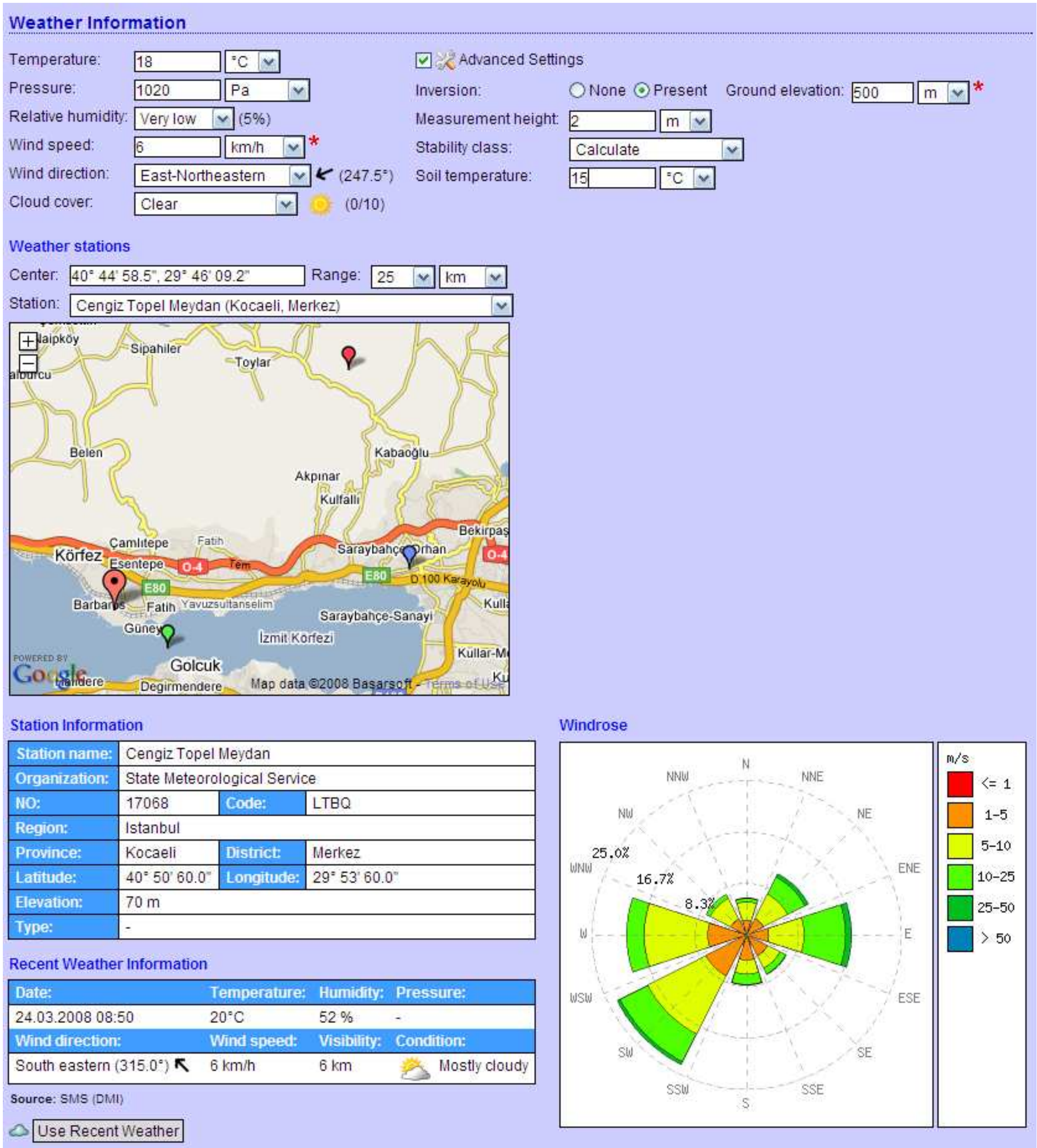


Figure 6.6: Weather data input for the model

Location Information

Facility Name	Province	District	NACE Code	Seveso Status	
Facility A [Test]	Ankara	Cankaya	-	✓	✓

Latitude:	39.887108	Longitude:	32.783096
Elevation:	1050 m	Topography:	Rural

Date Information

Local time:	2008-03-24 10:09
Time zone:	GMT+02:00
Daylight saving:	No
UTC time:	2008-03-24 08:09
Julian date:	2454549.8395833

Sunrise:	05:45	Sunset:	18:05
Hour angle:	-26.51°	Solar azimuth:	141.05°
Solar zenith:	45.2°	Solar elevation:	44.8°

Substance Information

Chemical Name	EC Index No	EC No	CAS No	
Chlorine	017-001-00-7	231-959-5	7782-50-5	R

Substance type:	-

Chemical Properties

Molecular weight:	70.91 g/mol
Density:	1.3975
Boiling point:	745.66 K (472.51°C)
Vapor pressure:	780703.35839529 Pa

Source Information

Quantity Information

Quantity:	5.98 kg
Volume:	200 m³

Storage Conditions

Phase:	Gas
Pressure:	1020 Pa (Ambient pressure)
Temperature:	291.15 K (18°C, Ambient Temperature)

Tank type:	Horizontal tank
Volume:	200 m³

Source Information

Source type:	Tank

Weather Information

Temperature:	291.15 K (18 °C)
Pressure:	1020 Pa
Relative humidity:	5%
Wind speed:	1.67 m/s @ 2 m (2.1 m/s @ 10 m)
Wind direction:	East-Northeastern (247.5°)
Cloud cover:	Clear (0/10)
Insolation:	667.57 W/m²
Inversion:	500 m
Stability class:	B (Unstable)
Measurement height:	2 m
Soil temperature:	288.15 K (15 °C)

Figure 6.7: Example model output

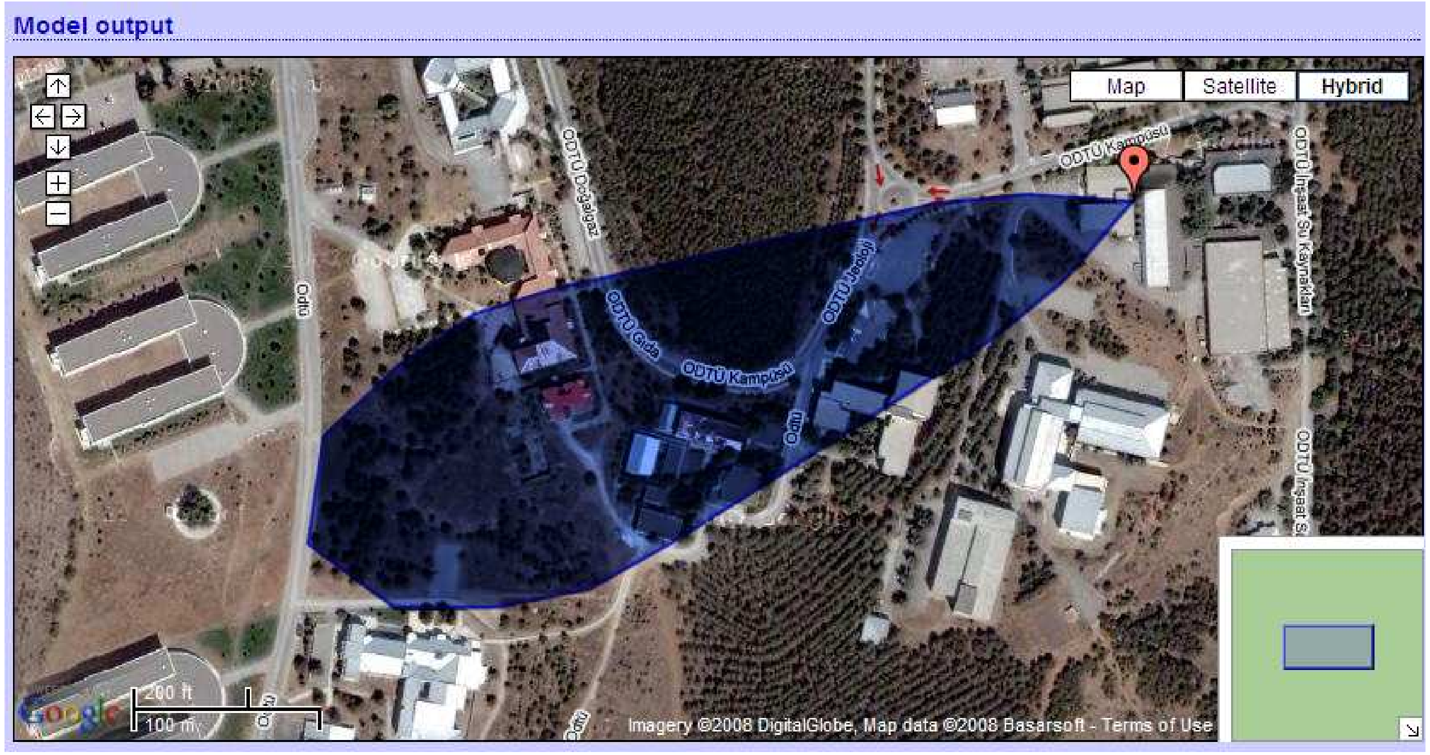


Figure 6.8: Example model output

CHAPTER 7

CONCLUSIONS

In this study, a decision support system has been developed with the objectives of systematic collection and analysis of information on past industrial as well as other technological accidents, facilitating determination of the statuses of industrial installations storing hazardous substances according to the 96/82/EC Directive of the EU, and rapid modeling of probable accident scenarios to reveal risks possessed thereby.

The developed system supports a web-based, multilingual and multiuser environment, which allows contribution of all interested parties to the information sharing in a collaborative manner, by following open-content, open-access philosophy.

Information on industrial and other technological accidents can be archived in a structured manner together with reference and visual materials. Detailed information on chemicals involved, events of occurrence, and consequences on human health, environment and property can be stated for industrial accidents. Uncertainty in the data can be indicated by using fuzzy numbers. Means of arrangement and grouping have been provided to link diverse textual and visual information that are related to each other. Summary graphs, statistics and reports can be also obtained.

Basic set of data on accidents and related topics has been collected from several data sources, including online and printed newspapers, websites, and yearbooks. For this purpose, about *146 000* pages have been examined solely for printed newspapers. Collected data has been processed, classified and entered to the system to support scientific studies and to allow public access on the Internet [1]. Available data is unique in content and covers more than 30 years of technological accident history of Turkey.

[1] Current address is `http://www.teknolojikkazalar.info`

The system provides a comprehensive chemical substance database, which is capable of storing hazard classification, labelling and chemical property data, including physico-chemical, structural, thermodynamical and toxicological properties. Hazard classifications and 96/82/EC Directive categories of substances can be automatically determined from the risk phrases according to definitions and provisions of the 67/548/EEC and 1999/45/EC Directives. Analysis tools are available, which can handle and concurrently use experimental datasets, temperature or pressure dependent equations and data estimation methods to calculate standardized chemical properties for user-defined reference conditions. Calculated data can be used for modeling purposes.

Basic information for about *140 000* chemicals has been collected from several resources, 90 000 of which include structural data. Detailed information is available for all hazardous substances listed in the latest (29th) ATP of the 67/548/EEC Directive, and explosive substances listed in the UN/ADR. Although limited in extent, data on chemical properties is also offered, especially for substances that are frequently involving in industrial accidents. Means of custom data entry and update are present.

The system supports collection and analysis of information on industrial facilities. Activities and geographic locations of the facilities can be specified, and chemicals in inventories thereof can be listed systematically together with storage conditions and quantities. Based this data, the 96/82/EC Directive statuses of the facilities can be determined according to the methodology set by the Directive. Calculated statuses are automatically updated if there is a change in quantities, hazard classifications, or qualifying quantity limits of the substances. Changes in statuses and related indices are documented as standard reports, which can be created in different languages and printed. In addition to industrial facilities, the system also contains information on meteorological stations and archives weather data from online resources systematically.

The system also features an easy to use, screening level accident model for rapid assessment of off-site consequences of industrial accidents based on user-defined scenarios. The model makes use of chemical and meteorological data analysis capabilities of the system to reduce data input requirements. It is also capable of mapping impact areas of the accidents.

To the best knowledge of the author, the following features of the developed decision support system are unique in the field of control of industrial accidents and were implemented for the first time:

- Web-based *collaborative* and *open-content* approach to accident data collection,
- Flexible *record relation* mechanism allowing reference documents, visual materials and associated incidents of an accident to be linked to each other and to be accessible from a single location,
- Calculation of *96/82/EC Directive statuses* from hazardous substances inventories with minimum effort and *automated update* thereof in the case of changes not only in quantities but also hazard classifications and qualifying quantity limits of substances.

Chemical database and chemical property data analysis capabilities of the system are also very comprehensive, and together with the developed off-site consequence model they form a special, if not unique, framework for modeling of industrial accidents.

In overall, it can be concluded that the decision support system allows integrated management of fundamental information required for the control of industrial accidents and provides tools for assessing current and future accident potential of industrial facilities, which can be used for national as well as the EU needs. Basic support for other kinds of technological accidents is also given for completeness.

Most of the environmental regulations in Turkey require considerable amount of data to be collected periodically, generally yearly. When current practice related with the regulations is examined, significant deficiencies may be observed in relation with the absence of supporting tools. For example, general information declaration forms submitted by the industrial facilities to the MoEF in the scope of Regulation on Environmental Inspection could not be examined properly and are currently not easily accessible, since they are collected in paper forms and in large quantities [103]. It is clear that such problems would not occur if data may be collected in electronical form. Information systems are important tools in this respect, and should be available before regulations or reporting obligations come into force. Developed decision support system meets the majority of the requirements of the 96/82/EC Directive, hence the possibility of its use should be considered by the MoEF, which aims to put a regulation similar to the 96/82/EC Directive into practice.

Web-based and open structure of the information system allows the collection of accident data in a collaborative manner, even if a competent authority (i.e. MoEF) is not involved in the process. Performed data collection survey resulted in collection of considerable amount of data not only on industrial accidents but also on other technological accidents and related topics, which are later organized and made publicly accessible. In the current state, the system is a unique information source in terms of available content. As usage of the system improves, its content will be also be enriched with contributions by the users. Hence, it will become a more valuable resource. Continuity of the system is important in this respect. Main reasons behind the unsatisfactory results of previous studies and short life span of information systems developed so far are lack of sense of ownership responsibilities by the administrative units and insufficient number of technical personnel to maintain the systems. The architecture and working principles of the system introduce advantages for solution of these problems. Open systems form their own communities, which are self-motivated in sustaining the continuity and development of the systems. Administrative tasks can also be distributed among several voluntary users, which lessens burdens per person. Therefore, developed system may avoid problems faced with the information systems developed in the past.

Although the components of the information system have been designed taking the local conditions of Turkey into consideration, best effort has been made to make it universal as well. With little modifications, the information system can be used by other countries, even by international organizations, to facilitate control of industrial accidents and to collect data on technological accidents. Owing to support of multiple languages in data storage and reporting, both local and international needs can be fulfilled without additional burden. This is especially important for the members states of international communities like the EU, where community wide notification and reporting obligations exist, which should be done in a common language (English) different from the native language of the state. For the EU member states, 96/82/EC Directive status calculation and automatic update capabilities of the system are also very beneficial. Especially automatic update feature significantly facilitates administrative duties and seamlessly handle cases like changes in hazard classifications of substances due to adaptation of the 67/548/EEC and 1999/45/EC Directives to the technical progress, which may be difficult to cope with otherwise. Hence, the developed decision-support system is a valuable tools not only for Turkey, but also for the EU member states

CHAPTER 8

RECOMMENDATIONS

Accident data collected during the study can be used to prepare an official industrial accident inventory of Turkey. Currently, there is no study in the literature, which comprehensively reviews industrial accidents that occurred in Turkey. As shown in Chapter 3, existing international databases do not contain valid information as well. Therefore, such a study will be useful in filling the information gap and can help to improve data quality of the international databases. In addition to industrial accidents, other types of technological accidents can also be included in the review. The role of Turkey as an energy bridge between Asia and Europe is growing year by year and transportation of hazardous substances through the Turkish Straits and pipelines is increasing. Although there are studies on marine accidents, interest on pipeline accidents is low. Similar to industrial accidents, no reviews are available on pipeline accidents even though they occur frequently. Therefore, a general review covering all types of technological accidents can be beneficial. In addition to past accidents, current sources and degrees of risks arising from technological activities can also be studied.

Developed decision support system can be used to make regional or national assessments on major-accident potential of industrial facilities. For this purpose, information on facilities and chemical inventories should be systematically collected. Owing to multiuser support and presence of special facility user (responsible person) class, data entry may be significantly facilitated if operators of the facilities enter related information voluntarily or by legal obligation. Cooperation with professional associations and trade unions may provide voluntary participation, whereas support of the MoEF may provide required legal framework. In the absence of specific data flow from the facilities, it is also possible to make use of existing data sources such as facility information forms submitted by the facilities to the MoEF in the context of Regulation on Environmental Auditing [27], Technical Commission Reports of Development Plans published by the State Planning Organisation [17, 104], and Industrial Database of the Union of Chambers and Commodity Exchanges of Turkey [105]. Although likely to be feasible for small sized studies, significant amount of data can be collected from these resources.

Algorithms developed in the study to determine the 96/82/EC Directive statuses of industrial facilities do not calculate only the final status (lower tier, upper tier, out of scope), but also all intermediate substance specific named substance and hazard category qualifying quantity ratios and and facility-wide summation rule (toxicity, flammability, and eco-toxicity) indices. Especially summation rule indices can be used as criteria to rank industrial facilities. Since higher index values show presence of high amounts of dangerous substances with major-accident potential, facilities with high indices can be considered to be more important then those having lower values for the purposes of accident control and prevention. Authorities responsible from inspections may plan site visits accordingly, or pilot studies for the implementation of control measures can be concentrated on facilities with higher indices. Indices may also be used as an input to more sophisticated ranking methods.

It is also possible to use the system for the purposes of informing the public. With user authentication provided by the system, access to critical information such as production capacities and chemical inventories may be restricted while continuing to provide summary information on 96/82/EC Directive statuses and summation indices. Information on past accidents and hazard classification of chemicals, which are publicly available, can also be considered as means of information to public.

Experience gained during data collection on accidents showed that the best information source is newspaper articles. Especially printed newspaper articles are rich in textual content and contain high quality of visual materials. Currently, document archive of the system contains newspaper articles from 1976 onwards. As described in Section 5, survey of newspaper articles in bounded archives is a labour intensive and time consuming task. Therefore, within the scope of the study only one particular newspaper (Hürriyet) could have been surveyed. Additional reference materials can be obtained from other newspapers to enrich the content of the document archive and provide more information on past accidents. Instead of examining newspapers for all days, accidents can be selected from the current inventory and newspapers can be examined based on their occurrence dates by applying a safety margin of several days.

Like newspaper articles, TV broadcasts are also becoming an important data source. National media coverage of recent accidents that had occurred in Turkey reveals that accidents are handled in more detail in TV broadcasts compared to print media (newspapers). Therefore, TV broadcasts should also be followed and recorded. Professional media monitoring services can be used for this purpose if adequate funding is available.

In the current implementation of the information system, detailed information on consequences of accidents, such as number of people affected, areal extent of effects and economical loses, can only be stored for industrial accidents. Accident type specific consequence data forms, similar to that of industrial accidents, can be designed for other technological accidents as well. This will allow complete statistical analysis of technological accidents, results of which can be obtained as summary tables or charts.

Off-site consequence model developed in the study is based on proven and frequently used equations and methods. During the implementation, correctness of calculations have been verified systematically at each step. Therefore, it is considered that modeling results are correct within the accuracy limits designated by the modeling assumptions and precision of equations. However, a formal validation process, preferably including case-studies, should be performed in order to prove this consideration. Full-scale experimental data on accidental releases, which can be used for validation purposes, is very limited in the literature [106]. Consequently, the method of inter-model comparison of the developed model to the existing (verified) models (e.g. ALOHA) can be used for validation purposes. By using similar accident scenarios, outputs of models can be compared and order of differences can be used as a measure correctness.

The off-site consequence model is a simple and easy to use model requiring little input data. In the favor of simplicity advanced topics, such as dense gas releases, low wind speed conditions, and complex land surfaces were not taken into consideration. Explosions and fire are also modelled by using simple equations. Modeling component of the system can be strengthened by incorporating more sophisticated and state of the art modeling techniques in the future. Since atmospheric dispersion model equations are solved numerically on a 2-D grid by superimposing values calculated at different time steps, multiple sources, which may occur as result of domino effects, can also be supported.

Although programming language used to develop the information system is not object oriented, functions comprising the system has been written in a modular manner. Together with generic database design, modular functions result in open-ended and reusable components for specific tasks such as multiuser authentication and authorization, record history, multilingual support and mapping. Based on these components and supporting function library, the code base of the information system can be easily used for the development of other web-based applications, such as environmental information systems. One of such applications has already been developed to support data collection and analysis for a proposed regulation on soil pollution control, which includes interfaces for preparation and submission of state of environment and inspection reports and automatic scoring system [107].

REFERENCES

[1] F.P. Lees. *Loss Prevention in Chemical Process Industries*. Butterworth, London, 2nd edition, 1996.

[2] F.I. Khan and S.A. Abbasi. Major accidents in process industries and an analysis of causes and consequences. *Journal of Loss Prevention in the Process Industries*, 12(5):361–378, 1999.

[3] T. A. Kletz. *What Went Wrong? Case Histories of Process Plant Disasters*. Gulf Professional Publishing, Houston, Texas, 4th edition, 1998.

[4] P. Mocarelli. Seveso: a teaching story. *Chemosphere*, 43(4-7):391–402, 2001.

[5] J.P. Gupta. The Bhopal gas tragedy: could it have happened in a developed country? *Journal of Loss Prevention in the Process Industries*, 15(1):1–4, 2002.

[6] ILO. Convention concerning the Prevention of Major Industrial Accidents, 1993.

[7] UN/ECE. Convention on the Transboundary Effects of Industrial Accidents, 1992.

[8] ILO. *Prevention of Major Industrial Accidents*. Code of Practice. International Labour Office, Geneva, 1988.

[9] OECD. *OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response*. Number 10 in Chemical Accidents. OECD, France, 2nd edition, 2003.

[10] UNEP. *APELL Awareness and Preparedness for Emergencies at Local Level: A Process for Responding to Technological Accidents*. Industry and Environment Office, United Nations Environment Programme, 1988.

[11] Council Directive. 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances. *Official Journal of the European Communities*, 10(14), 1997.

[12] U.S. EPA. Emergency Planning and Community Right to Know Act, 1986.

[13] U.S. EPA, Emergency Management. Databases and Tools [online]. Available from: `http://www.epa.gov/emergencies/tools.htm` [last visited 5 March 2008].

[14] Carl Bro Environment Consortium. Analysis of Environmental Legislation for Turkey - Final Report. Report LOHAN-23-MEDA/TUR/ENLARG/D4-01, Carl Bro International, Granskoven 8, DK-2600 Glostrup, Denmark, 2002.

[15] Ekodenge. Approximation of Seveso-II Directive in Turkey - Final Report. Report LIFE03 TCY/TR/000064, Ekodenge Environment Consultany and Engineering Inc., Hacettepe Univerty Technopark No:17, Beytepe, Ankara, 2006.

[16] D. Guha-Sapir and R. Below. *The Quality and Accuracy of Disaster Data: A Comparative Analyses of Three Global Data Sets*. World Bank, Disaster Management Facility, ProVention Consortium, 2002.

[17] State Planning Organisation. Chemical Industry Speciality Commission Report. 8th Development Plan OIK 580, State Planning Organisation, Ankara, 2001.

[18] R. E. Britter. The Evaluation of Technical Models Used for Major-accident Hazards Installations. Technical Report EUR 14774 EN, EU Joint Research Center, 1993.

[19] C.J.H Van den Bosch and R.A.P.M Weterings. *Methods for the Calculation of Physical Effects Due to Releases of Hazardous Materials (Liquids and Gases)*. TNO - The Netherlands Organization of Applied Scientific Research, 2nd edition, 2005.

[20] Council Directive. 82/501/EEC of 24 June 1982 on the major accident hazards of certain industrial activities. *Official Journal of the European Communities*, L 230, 1982.

[21] J. Wettig, S. Porter, and C. Kirchsteiger. Major industrial accidents regulation in the European Union. *Journal of Loss Prevention in the Process Industries*, 12(1):19–28, 1999.

[22] Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances. Concolidated Text, 31.12 2003.

[23] Council Directive. 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances. *Official Journal of the European Communities*, 196(16.8), 1967.

[24] Council Directive. 1999/45/EC of the European Parliament and of the Council of 31 May 1999 concerning the approximation of laws, regulations and administrative provisions of the Member States relating to the classification, packaging and labelling of dangerous preparations. *Official Journal of the European Communities*, 1999.

[25] European Chemical Bureau. CLASSLAB Database [online]. Available from: `http://ecb.jrc.it/classification-labelling/search-classlab/` [last visited 12 July 2006].

[26] Prime Ministry. Law on actions in consequence to disasters affecting the public. *Official Journal*, No.10213, 25.05 1959.

[27] Ministry of Environment and Forestry. Regulation on Environmental Inspection. *Official Journal*, No.24631, 05.01 2002.

[28] Ministry of Health. Regulation on Non-Hygienic Establishments. *Official Journal*, No.22416, 29.09 1995.

[29] Ministry of Environment and Forestry. Circular of 29.07.1996 on Emergency Planning for Major Industrial Accidents, 29.07 1996.

[30] N. Arıkan, Y. Söyleriz, A. Erdevir, and M. Asma. Draft Regulation on Prevention of Major Industrial Accidents, 1999.

[31] Ü. Yetiş. Preparation of Environmental Emergency Action Plan for the Marmara Region. Final report, Middle East Technical University, Department of Environmental Engineering, 2001.

[32] S. Girgin, K. Ünlü, and Ü. Yetiş. Use of GIS as a Supporting Tools for Environmental Risk Assessment and Emergency Response Plans. In *Comparative Risk Assessment and Environmental Decision Making*, volume 38 of *NATO Science Series*, pages 267–274. Elsevier, 2005.

[33] Secretariat General for EU Affairs. Industrial Pollution Control and Risk Management Questionnaire, 2006.

[34] Ekodenge and MoEF. Approximation of Seveso II Directive in Turkey Project Webpage [online]. Available from: `http://seveso.cevreorman.gov.tr` [last visited 10 February 2008].

[35] C. Kirchsteiger. The functioning and status of the EC's major accident reporting system on industrial accidents. *Journal of Loss Prevention in the Process Industries*, 12(1):29–42, 1999.

[36] C. Kirchsteiger. Technical Guideline on Reporting Accidents to the MARS Database. Report EUR 19768, European Commission, DG JRC, 2001.

[37] F. Mushtaq. Personal communication, 2004.

[38] Belgium Université Catholique de Louvain, Brussels. EM-DAT: Emergency Events Database [online]. Available from: `http://www.em-dat.net` [last visited 16 June 2007].

[39] Belgium Université Catholique de Louvain, Brussels. EM-DAT: Criteria and Definition [online]. Available from: `http://www.em-dat.net/criteria.htm` [last visited 10 June 2004].

[40] Belgium Université Catholique de Louvain, Brussels. EM-DAT: Country Profile - Technological Disasters - Turkey [online]. Available from: `http://www.em-dat.net/disasters/countryprofiles.php` [last visited 18 January 2007].

[41] Belgium Université Catholique de Louvain, Brussels. EM-DAT: Country Profile - Technological Disasters - Turkey [online]. Available from: `http://www.em-dat.net/disasters/emdat_display_list.php` [last visited 18 January 2007].

[42] UNEP APELL. Disasters Database [online]. Available from: http://www.uneptie.org/pc/apell/disasters/database/disastersdatabase.asp [last visited 7 June 2004].

[43] OECD. *The State of the Environment*. OECD Publications and Information Center, 2001 L Street, N.W. Suite 700, Washington, DC 20036, 1991.

[44] UNEP APELL. Disasters by Location [online]. Available from: http://www.uneptie.org/pc/apell/disasters/lists/disasterloc.html [last visited 18 January 2007].

[45] European Environment Agency. Europe's Environment: The Third Assessment. Environmental Issue Report 35, European Environment Agency, 2003.

[46] European Environment Agency. Mapping the Impacts of Recent Natural Disasters and Technological Accidents in Europe. Environmental Assessment Report 10, European Environment Agency, 2003.

[47] M. Achour, F. Betz, A. Dovgal, N. Lopes, P. Olson, G. Richter, D. Seguy, and J. Vrana. *PHP Manual*. PHP Documentation Group, 2005.

[48] J.J. Garrett. Ajax: A New Approach to Web Applications. *Adaptive Path*, 18, 2005.

[49] W3C HTML Working Group. *XHTML 1.0 The Extensible HyperText Markup Language*. World Wide Web Consortium (W3C), 2nd edition, 2003.

[50] D. Axmark and M. Widenius. *MySQL Reference Manual*. MySQL AB, 2003.

[51] Google Inc. Google Maps [online]. Available from: http://maps.google.com [last visited 2 July 2007].

[52] B. Collins-Sussman, B.W. Fitzpatrick, and C.M. Pilato. *Version Control with Subversion*. O'Reilly Media, Inc., 2004.

[53] Edgewall Software. Trac [online]. Available from: http://trac.edgewall.org [last visited 5 March 2006].

[54] F.B. Viégas, M. Wattenberg, and K. Dave. Studying cooperation and conflict between authors with history flow visualizations. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 575–582, 2004.

[55] R.R. Vatsavai, S. Shekhar, T.E. Burk, and S. Lime. *UMN-MapServer: A High-Performance, Interoperable, and Open Source Web Mapping and Geo-Spatial Analysis System*, volume 4197 of *Lecture Notes in Computer Science*, pages 400–417. Springer Berlin/Heidelberg, 2006.

[56] C.J. Tucker, D.M. Grant, and J.D. Dykstra. NASA's global orthorectified Landsat data set. *Photogrammetric Engineering and Remote Sensing*, 70(3):313–322, 2004.

[57] Yahoo Inc. Yahoo Local Maps [online]. Available from: http://maps.yahoo.com/ [last visited 2 July 2007].

[58] Microsoft Corp. Live Search Maps [online]. Available from: http://maps.live.com/ [last visited 2 July 2007].

[59] J.J. Buckley. *Fuzzy Probability and Statistics*. Springer, 2006.

[60] B. Hayes. A Lucid Interval. *American Scientist*, 91(6):484–488, 2003.

[61] C. Lucas. The Baia Mare and Baia Borsa Accidents: Cases of Severe Transboundary Water Pollution. *Environmental Policy and Law*, 31(2):106–111, 2001.

[62] Central Bank of the Republic of Turkey. Electronic Data Delivery Systems [online]. Available from: http://evds.tcmb.gov.tr [last visited 5 January 2008].

[63] State Institute of Statistics. *The Wholesale Price Index and Consumer Price Index*, volume 2 of *Statistics with Questions*. State Institute of Statistics, 1997.

[64] C.L. Rozakis and P.N. Stagkos. *The Turkish Straits*. Number 9 in International Straits of the World. Martinus Nijhoff Publishers, 1987.

[65] A. Öztürk. From oil pipelines to oil Straits: the Caspian pipeline politics and environmental protection of the Istanbul and the Canakkale Straits. *Journal of Southern Europe and the Balkans*, 4(1):57–74, 2002.

[66] IMO. Reports on Marine Casualties and Incidents – Revised Harmonized Reporting Procedures for Reports Required Under SOLAS Regulation I/21 and MARPOL 73/78, Articles 8 and 12. Circular MSC-MEPC.3/Circ.1, International Maritime Organization, 4 Albert Embankment, London, SE1 7SR, 10.13 2005.

[67] S.F. Starr and E. Svante, editors. *The Baku-Tbilisi-Ceyhan Pipeline: Oil Window to the West*. Central Asia-Caucasus Institute and Silk Road Studies Program, 2005.

[68] J.A. Vílchez, S. Sevilla, H. Montiel, and J. Casal. Historical analysis of accidents in chemical plants and in the transportation of hazardous materials. *Journal of Loss Prevention in the Process Industries*, 8(2):87–96, 1995.

[69] General Directorate of Highways. Inventory of State and Provincial Roads [online]. Available from: http://www.kgm.gov.tr/fr5.asp?tt=1601 [last visited 10 February 2006].

[70] General Directorate of Press and Information. History of the Month Periodical [online]. Available from: http://www.byegm.gov.tr/YAYINLARIMIZ/AyinTarihi/Ayintarihi.htm [last visited 10 February 2008].

[71] Google Inc. YouTube [online]. Available from: http://www.youtube.com [last visited 19 March 2007].

[72] Adobe Systems Inc. Video Technology Center [online]. Available from: http://www.adobe.com/devnet/video [last visited 3 March 2008].

[73] B.A. Nardi, D.J. Schiano, and M. Gumbrecht. Blogging as social activity, or, would you let 900 million people read your diary? In *Proceedings of the 2004 ACM Conference on Computer Supported Cooperative Work*, pages 222–231, New York, USA, 2004. ACM Press.

[74] Sourtimes Entertainment. Sourtimes [online]. Available from: `http://sozluk.sourtimes.org/` [last visited 8 September 2007].

[75] L. Lamport. *Latex: A Document Preparation System*. Addison-Wesley Longman Publishing Co., Inc. Boston, MA, USA, 1989.

[76] S.E. Stein, S.R. Heller, and D. Tchekhovskoi. An Open Standard for Chemical Structure Representation: The IUPAC Chemical Identifier. In *Proceedings of the 2003 International Chemical Information Conference*, pages 131–143, 2003.

[77] D. Weininger. SMILES, a chemical language and information system. 1. Introduction to methodology and encoding rules. *Journal of Chemical Information and Computer Sciences*, 28(1):31–36, 1988.

[78] D. Weininger, A. Weininger, and J.L. Weininger. SMILES. 2. Algorithm for generation of unique SMILES notation. *Journal of Chemical Information and Computer Sciences*, 29(2):97–101, 1989.

[79] W.D. Ihlenfeldt, Y. Takahashi, H. Abe, and S. Sasaki. CACTVS: A Chemistry Algorithm Development Environment. In K. Machida and T. Nishioka, editors, *Proceedings of the 15th Symposium on Chemical Information and Computer Sciences/20th Symposium on Structure-Activity Relationships*, pages 102–105. Kyoto University Press, 1992.

[80] Ministry of Environment and Forestry. Regulation on Hazardous Chemicals (Consolidated), Oct 2001.

[81] United Nations. European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR), 2007.

[82] CANUTEC. *Emergency Response Guidebook for Road Transportation Accidents (Turkish translation)*. Turkish Chemical Manufacturers Association, 2005.

[83] DIPPR. *DIPPR Project 801 - Data Compilation of Pure Compound Properties*. Design Institute for Physical Property Data/AIChE, 2005.

[84] R.H. Perry, D.W. Green, and J.O. Maloney. *Perry's chemical engineers' handbook*. McGraw-Hill New York, 7th edition, 1997.

[85] Council Regulation. No 3037/90 of 9 October 1990 on the statistical classification of economic activities in the European Community. *Official Journal of the European Communities*, 293(24.10), 1990.

[86] State Institute of Statistics. *Statistical classification of economic activities in the European Community: NACE Rev. 1.1*. Office of Statistical Classifications and Standards, State Institute of Statistics, 2005.

[87] V. Cozzani and S. Zanelli. Precursors of dangerous substances formed in the loss of control of chemical systems. *Journal of Hazardous Materials*, 65(1-2):93–108, 1999.

[88] F. Pasquill and F. B. Smith. *Atmospheric Diffusion*. Ellis Horwood, Chichester, 2nd edition, 1983.

[89] J. Peress. Estimate evaporative losses from spills. *Chemical engineering progress*, 99(4):32–34, 2003.

[90] European Chemical Bureau. ESIS: European chemical Substances Information System [online]. Available from: http://ecb.jrc.it/esis [last visited 12 July 2006].

[91] Department of Chemistry University of Georgia. SPARC Online [online]. Available from: http://ibmlc2.chem.uga.edu/sparc/ [last visited 5 August 2007].

[92] W. Meylan and P.H. Howard. *User's Guide for EPIWIN EPI Suite, EPI–Estimation Programs Interface for Microsoft Windows*, 1999.

[93] D. Mackay. *Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals*. CRC Press, 2006.

[94] Milliyet [online]. Available from: http://www.milliyet.com.tr [last visited 20 February 2008].

[95] Hürriyet [online]. Available from: http://www.hurriyet.com.tr [last visited 18 February 2008].

[96] Radikal [online]. Available from: http://www.radikal.com.tr [last visited 19 February 2008].

[97] D. Kottlowski, J. Candor, and J. Ferrell. The Internet as a Source of Weather Information. In *Proceedings of 16th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*. AMS, 2000.

[98] F. Pasquill. The estimation of the dispersion of windborne material. *Meteorological Magazine*, 90(1063):33–49, 1961.

[99] D. B. Turner. *Workbook of Atmospheric Dispersion Estimates: An Introduction to Dispersion Modeling*. CRC Press, 2nd edition, 1994.

[100] D.H. Slade. Meteorology and Atomic Energy, 1968. Technical report, TID–24190, Environmental Science Services Administration, Silver Spring, Md. Air Resources Labs., 1968.

[101] J.L. McElroy and F. Pooler. *St. Louis Dispersion Study*. US Dept. of Health, Education, and Welfare; Public Health Service, Consumer Protection and Environmental Health Service; National Air Pollution Control Administration, 1968.

[102] R.W. McMullen. The change of concentration standard deviations with distance. *Journal of the Air Pollution Control Association*, 25(10):1057–1058, 1975.

[103] Head of Environmental Inspection Section. Personal communication, 2007.

[104] State Planning Organisation. Petrochemical Industry Speciality Commission Report. 8th Development Plan OIK 579, State Planning Organisation, Ankara, 2001.

[105] Union of Chambers and Commodity Exchanges of Turkey. Industry Database [online]. 2003. Available from: http://sanayi.tobb.org.tr [last visited 12 October 2007].

[106] M.R. Beychok. *Fundamentals of stack gas dispersion.* Beychok, M.R., Irvine, California, 4th edition, 2005.

[107] S. Girgin, M. Güvener, Ş. Polat, B. Büyüker, Ü. Yetiş, F. Dilek, A. Aksoy, and K. Ünlü. Development of an Information Management System for Lands Contaminated by Point Sources. In *Proceedings of 11th Industrial Pollution Control Symposium*. ITU, In Press.

[108] United Nations. Second Administrative Level Boundaries [online]. Available from: http://www.who.int/whosis/database/gis/salb/salb_home [last visited 8 August 2006].

APPENDIX A

DATABASE STRUCTURE

A.1 General Information

Complete database structure of the information system is given in this Appendix. Each table in the database is listed together with detailed description of their table columns, i.e. data fields. Properties of data fields are summarized in a single information line using the following notation:

name type Not Null Unique Multilingual() Default(value) *PK* *FK* → **table**.*field*
Description
⋮

where:

name	Name of the field
type	Data type of the field (see Table A.1)
Not Null	Indicates that the field value could not be blank
Unique	Indicates that the field value should be unique in the table
Multilingual(langs)	Indicates that the field is multilingual (supported languages are indicated in parenthesis)
Default(value)	Default value of the field
PK	Indicates that the field is (part of) the primary key
FK → **table**.*field*	Indicates that the field is a foreign key referencing *field* in **table**
Description	Description of the field

Data types used in the data fields are listed in Table A.1. As unique identifiers of records, 13 characters long strings are used that are generated using *uniqid()* function of the PHP. Fuzzy numbers are stored as variable length strings. If not stated otherwise, all numeric fields including fuzzy numbers are *unsigned*, i.e. positive.

For fields indicated as multilingual, there exists several fields in the table having names equal to the base field name prefixed by underscore and 2-letter language code. Prefixed fields have the same properties as the base field. Supported languages are indicated in parenthesis next to Multilingual descriptor. Base fields without prefixes are in Turkish.

Strings (char and varchar data types) are stored in ASCII encoding by default. Unicode UTF-8 encoding is used for data fields requiring special characters or storing multilingual data.

Table A.1: Data types used in data fields

Data type	Description
bool	Boolean. A value of zero is considered false. Non-zero values are considered true.
int(n)	Integer with n digits. If n is omitted, maximum allowable value is 2^{32}.
float(n, m)	Floating point number with n total digits and m digits after decimal point. If n and m are omitted, values are stored to the limits allowed by the hardware.
char(n)	String with n characters.
varchar(n)	Variable-length string with up to n characters. Used for Unicode string
text	Long variable-length string.
enum	Enumerated list of values. Allowable values are listed in description of data fields.

A.2 Database Model

Complete database model showing relations between the database tables is given in Figure A.1

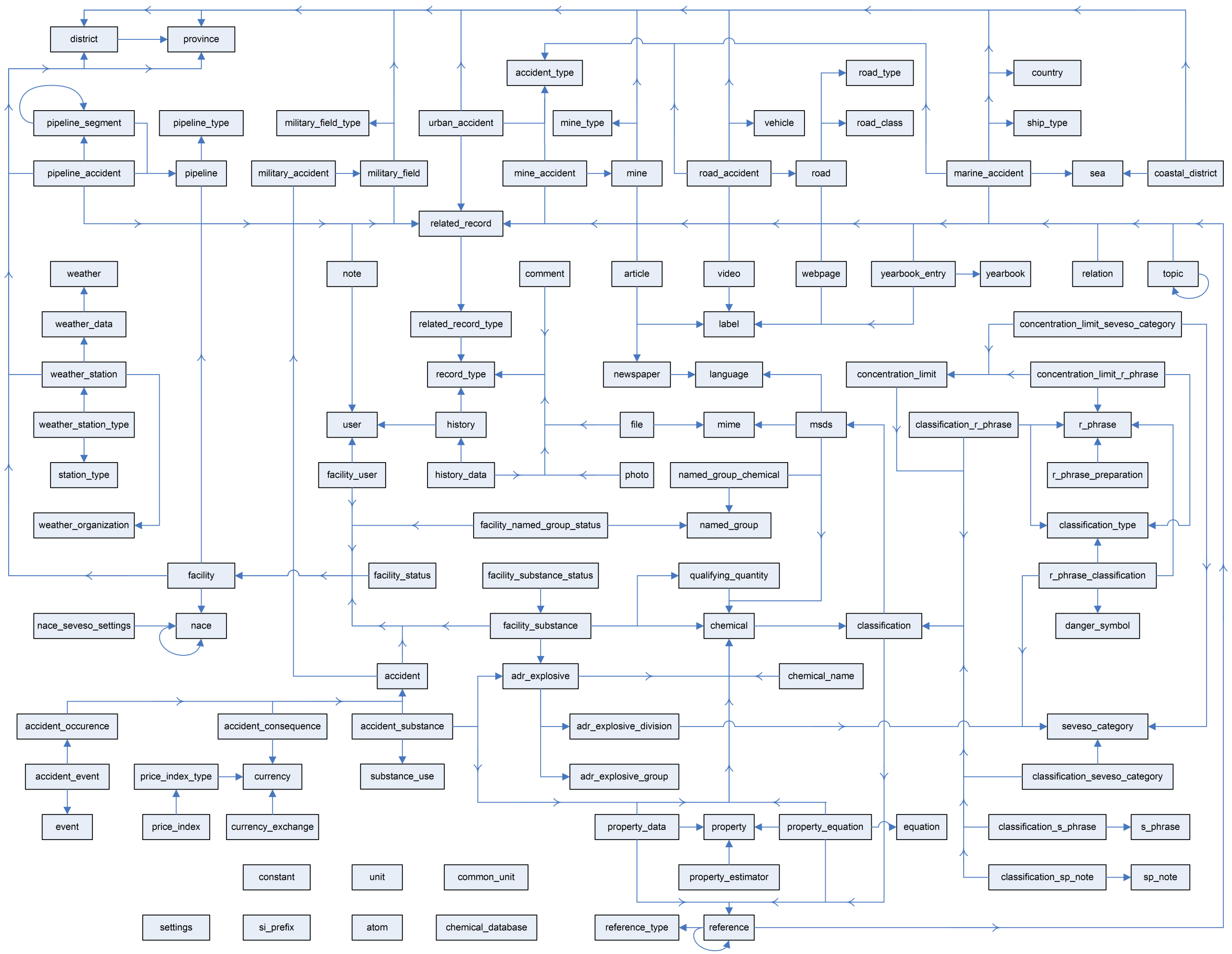


Figure A.1: Database model

A.3 Database Tables

accident table

This table stores industrial accident information.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
facility_id char(13) Not Null *FK* → **facility**.*id*
Facility identifier.
date varchar(12)
Starting date of the accident (fuzzy).
time varchar(7)
Starting time of the accident (fuzzy).
end_date varchar(12)
Ending date of the accident (fuzzy).
end_time varchar(7)
Ending time of the accident (fuzzy).
accident_fire bool Not Null Default(false)
Fire flag.
accident_explosion bool Not Null Default(false)
Explosion flag.
accident_release bool Not Null Default(false)
Chemical release flag.
notes text Unicode Multilingual(TR,EN)
Notes.
locked bool Not Null Default(false)
Locked flag.

accident_consequence table

This table stores information on accident consequences.

accident_id char(13) Not Null *PK* *FK* → **accident**.*id*
Accident identifier.
extent_unit enum
Flag indicating process units are affected.
Y = Yes
N = No
S = Suspected
Null = Unknown
extent_facility enum
Flag indicating facility is affected (see **accident_consequences**.*extent_unit*).
extent_local enum
Flag indicating local effects (see **accident_consequences**.*extent_unit*).
extent_regional enum
Flag indicating regional effects (see **accident_consequences**.*extent_unit*).
extent_international enum
Flag indicating international (see **accident_consequences**.*extent_unit*).
notes_extent text Unicode Multilingual(TR,EN)
Notes on areas affected.
staff_at_risk varchar(16)
Number of staff at risk (fuzzy).
staff_dead varchar(16)
Number of staff died (fuzzy).
staff_dead_later varchar(16)
Number of staff died later on (fuzzy).
staff_injured varchar(16)
Number of staff injured (fuzzy).
staff_injured_light varchar(16)

Number of staff lightly injured (fuzzy).
staff_monitored varchar(16)
Number of staff health monitored (fuzzy).
staff_evacuated varchar(16)
Number of staff evacuated (fuzzy).
responder_at_risk varchar(16)
Number of emergency responders at risk (fuzzy).
responder_dead varchar(16)
Number of emergency responders died (fuzzy).
responder_dead_later varchar(16)
Number of emergency responders died later on (fuzzy).
responder_injured varchar(16)
Number of emergency responders injured (fuzzy).
responder_injured_light varchar(16)
Number of emergency responders lightly injured (fuzzy).
responder_monitored varchar(16)
Number of emergency responders health monitored (fuzzy).
responder_evacuated varchar(16)
Number of emergency responders evacuated (fuzzy).
public_at_risk varchar(16)
Number of people from public at risk (fuzzy).
public_dead varchar(16)
Number of people from public died (fuzzy).
public_dead_later varchar(16)
Number of people from public died later on (fuzzy).
public_injured varchar(16)
Number of people from public injured (fuzzy).
public_injured_light varchar(16)
Number of people from public lightly injured (fuzzy).
public_monitored varchar(16)
Number of people from public health monitored (fuzzy).
public_evacuated varchar(16)
Number of people from public evacuated (fuzzy).
notes_people text Unicode Multilingual(TR,EN)
Notes on people affected.
utility_gas varchar(16)
Duration of gas interruption (hours, fuzzy).
utility_water varchar(16)
Duration of water interruption (hours, fuzzy).
utility_electricity varchar(16)
Duration of electricity interruption (hours, fuzzy).
utility_sewerage varchar(16)
Duration of sewerage interruption (hours, fuzzy).
utility_telecommunications varchar(16)
Duration of telecommunication interruption (hours, fuzzy).
utility_main_roads varchar(16)
Duration of main road interruption (hours, fuzzy).
utility_railways varchar(16)
Duration of railway interruption (hours, fuzzy).
utility_sea_transport varchar(16)
Duration of sea transportation interruption (hours, fuzzy).
utility_air_transport varchar(16)
Duration of air transportation interruption (hours, fuzzy).
notes_community text Unicode Multilingual(TR,EN)
Notes on community life disruptions.
concern_public enum
Degree of public interest.
L = Local
N = National

I = International
Null = None

concern_media enum
Degree of media interest (see **accident_consequence**.*concern_public*).

concern_political enum
Degree of political interest (see **accident_consequence**.*concern_public*).

cost_material_onsite varchar(16)
Cost of onsite material losses (fuzzy).

cost_material_offsite varchar(16)
Cost of offsite material losses (fuzzy).

cost_response_onsite varchar(16)
Cost of onsite response activities (fuzzy).

cost_response_offsite varchar(16)
Cost of offsite response activities (fuzzy).

currency_code char(3) *FK* → **currency**.*code*
Currency code of cost values.

currency_date varchar(12)
Date of cost values (fuzzy).

notes_cost text Multilingual(TR,EN)
Notes on material losses.

damage_residential enum
Damage to residential areas (see **accident_consequences**.*extent_unit*).

damage_common_wild enum
Damage to common wild flora (see **accident_consequences**.*extent_unit*).

damage_rare_wild enum
Damage to rare wild flora (see **accident_consequences**.*extent_unit*).

damage_water_supplies enum
Damage to water supplies (see **accident_consequences**.*extent_unit*).

damage_land enum
Damage to land (see **accident_consequences**.*extent_unit*).

damage_water_habitat enum
Damage to water habitats (see **accident_consequences**.*extent_unit*).

damage_special_area enum
Damage to special areas (see **accident_consequences**.*extent_unit*).

notes_damage text Unicode Multilingual(TR,EN)
Notes on damaged areas.

res_area_evacuated bool
Flag indicating residential areas being evacuated.

res_area_disabled bool
Flag indicating residential areas being disabled.

res_area_destroyed bool
Flag indicating residential areas being destroyed.

com_area_evacuated bool
Flag indicating commercial areas being evacuated.

com_area_disabled bool
Flag indicating commercial areas being disabled.

com_area_destroyed bool
Flag indicating commercial areas being destroyed.

pub_area_evacuated bool
Flag indicating public areas being evacuated.

pub_area_disabled bool
Flag indicating public areas being disabled.

pub_area_destroyed bool
Flag indicating public areas being destroyed.

oth_area_evacuated bool
Flag indicating other areas being evacuated.

oth_area_disabled bool
Flag indicating other areas being disabled.

oth_area_destroyed bool
Flag indicating other areas being destroyed.

locked bool Not Null Default(false)
Locked flag.

accident_event table

This table stores information on accident events.

accident_id char(13) Not Null *PK* *FK* → **accident**.*id*
Accident identifier.
event_code char(4) Not Null *PK* *FK* → **event**.*code*
Accident event code.
type enum Not Null *PK* Default(I)
Type of the accident event.
I = Initiating event
A = Associated event
M = Major occurrence

accident_occurrence table

This table stores information on accident occurrences.

accident_id char(13) Not Null *PK* *FK* → **accident_occurrence**.*id*
Accident occurrence identifier.
notes text Unicode Multilingual(TR,EN)
Notes.
locked bool Not Null Default(false)
Locked flag.

accident_substance table

This table stores information on substances involved to the accidents.

id char(13) Not Null *PK*
Unique identifier.
accident_id char(13) Not Null *FK* → **accident**.*id*
Accident identifier.
chemical_id char(13) *FK* → **chemical**.*id*
Chemical identifier.
adr_explosive_id char(13) *FK* → **adr_explosive**.*id*
UN/ADR explosive identifier.
substance_use_code char(2) Not Null *FK* → **substance_use**.*code*
Chemical use code.
actual_quantity varchar(32)
Actual quantity involved in the incident (fuzzy).
actual_quantity_unit varchar(8)
Unit of actual quantity.
potential_quantity varchar(32)
Potential quantity that can be involved in the accident (fuzzy).
potential_quantity_unit varchar(8)
Unit of potential quantity.
total_quantity varchar(32)
Total quantity present in the facility at the time of the accident.
total_quantity_unit varchar(8)
Unit of total quantity.
directly_involved bool Not Null Default(false)
Directly involved flag.
notes text Unicode Multilingual(TR,EN)
Notes.
locked bool Not Null Default(false)
Locked flag.

accident_type table

This table stores accident types.

code char(2) Not Null *PK*
Code of the accident type.
name varchar(128) Unicode Multilingual(TR,EN)
Name of the accident type.
description text Unicode Multilingual(TR,EN)
Textual description.
type enum
Accident type.
I = Industrial
L = Military
M = Marine transportation
P = Pipeline transportation
R = Road transportation
N = Mining
U = Urban
icon varchar(32)
Name of the icon (in `/images` folder).

adr_explosive table

This table stores UN/ADR explosives.

id char(13) Not Null *PK*
Unique identifier.
name text Unicode Multilingual(TR,EN)
Name of the UN/ADR explosive.
division_code char(3) Not Null *FK* → **adr_explosive_division**.*code*
UN/ADR explosive division code.
group_code char(1) Not Null *FK* → **adr_explosive_group**.*code*
UN/ADR explosive group code.
un_no char(4) Not Null
UN code number.
chemical_id char(13) *FK* → **chemical**.*id*
Chemical identifier
lower_concentration float
Lower concentration limit ($\%w$)
upper_concentration float
Upper concentration limit ($\%w$)

adr_explosive_division table

This table stores UN/ADR explosive divisions. See Table 4.16 for complete listing of divisions.

code char(3) Not Null *PK*
Explosive division code.
description text Unicode Multilingual(TR,EN)
Textual description.
seveso_category_code varchar(4) *FK* → **seveso_category**.*code*
Seveso category code

adr_explosive_group table

This table stores UN/ADR explosive group. See Table 4.17 for complete listing of groups.

code char(1) Not Null *PK*
Explosive group code.
description text Unicode Multilingual(TR,EN)
Textual description.

article table

This table stores newspaper articles.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
newspaper_id char(13) Not Null *FK* → **newspaper**.*id*
Newspaper identifier.
date varchar(12)
Date of the article (fuzzy).
publication_type enum Not Null Default(P)
Type of publication.
P = Printed
O = Online
pages varchar(32)
Pages of the article.
heading text Unicode
Heading of the article.
title text Unicode Not Null
Title of the article.
subtitle text Unicode
Subtitle of the article.
authors varchar(255) Unicode
Author(s) of the article (semicolon separated).
location varchar(64) Unicode
Location of the article
agency varchar(64) Unicode
News agency of the article
introduction_text text Unicode
Introduction text of the article
main_text text Unicode
Main body of the article
access_date varchar(12)
Access date to the article (fuzzy)
url varchar(255)
URL address of the article
label_id char(13) *FK* → **label**.*id*
Label identifier.
locked bool Not Null Default(false)
Locked flag.

atom table

This table stores information on atomic elements.

symbol char(3) Not Null *PK*
Symbol of the element.
number int(3)
Number of element in the periodic table.
weight float
Molar weight of the element (g/mol).
uncertainity bool
Uncertainty in the last digit of the molar weight.
group char(2)
Periodic table group of the element.
series char(2)

Periodic table series of the element.
period int(1)
Period of the element in the periodic table.
name varchar(128) Unicode Multilingual(TR,EN)
Name of the element.

chemical table

This table stores chemicals.

id char(13) Not Null *PK*
Unique identifier.
ec_index_no char(12)
EC Index No.
ec_no char(9)
EC No.
cas_no varchar(16)
CAS No.
formula varchar(255)
Chemical formula.
smiles text
SMILES of the chemical.
inchi text
InChI of the chemical.
classification_id char(13) Not Null *FK* → **classification**.*id*
Classification identifier.
description text Unicode Multilingual(TR,EN)
Textual description.
locked bool Not Null Default(false)
Locked flag.

chemical_database table

This table stores information on auxiliary online databases.

id char(13) Not Null *PK*
Unique identifier.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the chemical database.
urls text Not Null
List of query URLs (semicolon separated).
parameters text Not Null
List of query parameters (semicolon separated).
icon varchar(32)
Name of the icon (in `/images/icons` folder).
locked bool Not Null Default(false)
Locked flag.

chemical_name table

This table stores chemical names.

chemical_id char(13) Not Null *FK* → **chemical**.*id*
Chemical identifier.
name text Unicode Multilingual(TR,EN,DE,ES,FR)
Name of the chemical.
index int(10) Not Null Auto-increment *PK*
Internal field used for indexing.

classification table

This table stores information on hazard classifications of chemicals.

id char(13) Not Null *PK*
Unique identifier.
notes text Unicode Multilingual(TR,EN)
Notes.
reference_id char(13) *FK* → **reference**.*id*
Reference identifier.
msds_id char(13) *FK* → **msds**.*id*
MSDS identifier.
locked bool Not Null Default(false)
Locked flag.

classification_r_phrase table

This table stores risk phrases of hazard classifications.

classification_id char(13) Not Null *PK* *FK* → **classification**.*id*
Hazard classification identifier.
r_phrase_code varchar(16) Not Null *PK* *FK* → **r_phrase**.*code*
Risk phrase code.
classification_type_code char(2) *FK* → **classification_type**.*code*
Hazard classification type code.

classification_s_phrase table

This table stores safety phrases of hazard classifications.

classification_id char(13) Not Null *PK* *FK* → **classification**.*id*
Hazard classification identifier.
s_phrase_code varchar(16) Not Null *PK* *FK* → **s_phrase**.*code*
Safety phrase code.

classification_seveso_category table

This table stores 96/82/EC categories of hazard classifications.

classification_id char(13) Not Null *PK* *FK* → **classification**.*id*
Hazard classification identifier.
seveso_category_code varchar(4) Not Null *PK* *FK* → **seveso_category**.*code*
96/82/EC category code.

classification_sp_note table

This table stores safety and risk notes of hazard classifications.

classification_id char(13) Not Null *PK* *FK* → **classification**.*id*
Hazard classification identifier.
sp_note_code char(1) Not Null *PK* *FK* → **sp_node**.*code*
Safety and risk phrase note code.

classification_type table

This table stores hazard classification types.

code char(2) Not Null *PK*
Code of the classification type.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the classification type.
abbr varchar(16)
Abbreviation of the classification type.

coastal_district table

This table stores information of coastal districts.

province_code char(2) Not Null *PK* *FK* → **province**.*code*
Province code.
district_code char(2) Not Null *PK* *FK* → **district**.*code*
District code.
sea_code char(2) Not Null *PK* *FK* → **sea**.*code*
Sea code.

comment table

This table stores user comments.

id char(13) Not Null *PK*
Unique identifier.
record_id char(13) Not Null
Record identifier.
record_type varchar(32) *FK* → **record_type**.*type*
Record type.
comment text Unicode
Comment.

common_mime table

This table stores common MIME types.

type varchar(64) Not Null *PK*
MIME type.
mime_type varchar(64) Not Null
Corresponding MIME type.

common_unit table

This table stores common units.

id char(13) Not Null *PK*
Unique identifier.
unit varchar(32) Unicode Not Null Unique
Unit.

concentration_limit table

This table stores information on hazard classification concentration limits.

id char(13) Not Null *PK*
Unique identifier.
classification_id char(13) Not Null *FK* → **classification**.*id*
Hazard classification identifier.
lower_concentration float Not Null Default(0)
Lower concentration limit (decimal).
upper_concentration float
Upper concentration limit (decimal).
locked bool Not Null Default(false)
Locked flag.

concentration_limit_r_phrase table

This table stores risk phrases of hazard classification concentration limits.

concentration_limit_id char(13) Not Null *PK* *FK* → **concentration_limit**.*id*
Concentration limit identifier.
r_phrase_code varchar(16) Not Null *PK* *FK* → **r_phrase**.*code*
Risk phrase code.
classification_type_code char(2) *FK* → **classification_type**.*code*

Hazard classification type code.

concentration_limit_seveso_category table

This table stores 96/82/EC categories of hazard classification concentration limits.

concentration_limit_id char(13) Not Null *PK* *FK* → **concentration_limit**.*id*
Concentration limit identifier.
seveso_category_code varchar(4) Not Null *PK* *FK* → **seveso_category**.*code*
96/82/EC category code.

constant table

This table stores constants.

id char(13) Not Null *PK*
Unique identifier.
code varchar(16) Not Null Unique
Code of the constant.
value varchar(32) Not Null
Value of the constant (scientific).
unit varchar(32) Unicode
Unit of the constant.
symbol varchar(16) Unicode Multilingual(TR,EN)
Symbol of the constant.
name varchar(128) Unicode Multilingual(TR,EN)
Name of the constant.

country table

This table stores information on countries.

code char(2) Not Null *PK*
Code of the country.
name varchar(80) Unicode Multilingual(TR,EN)
Name of the country.
iso3_code char(3)
3-digit ISO code of the country.
un_code int(3)
UN code number of the country.

currency table

This table stores information on currencies.

code char(3) Not Null *PK*
Code of the currency.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the currency.
symbol varchar(4) Unicode Not Null
Symbol of the currency.
symbol_location enum Not Null Default(R)
Location of the symbol.

R = To the right

L = To the left

currency_exchange table

This table stores currency exchange rates.

currency_code char(3) Not Null *PK* *FK* → **currency**.*code*
Currency code.

year int(4) Not Null *PK*
Year of the date.
month int(2) Not Null *PK*
Month of the date.
base_currency_code char(3) Not Null *PK* *FK* → **currency**.*code*
Base currency code.
rate float Not Null
Exchange rate.

danger_symbol table

This table stores information on danger symbols.

code char(2) Not Null *PK*
Code of the danger symbol.
icon varchar(32) Not Null
Icon of the danger symbol (in `/icons` folder).

district table

This table stores information on districts.

province_code char(2) Not Null *PK* *FK* → **province**.*code*
Province code.
code char(2) Not Null *PK*
Code of the district.
name varchar(32) Unicode Multilingual(TR,EN)
Name of the district.
salb_code varchar(9)
UN Second Administrative Level Boundaries (SALB) code [108].
latmin float(9,6)
Minimum latitude of the bounding box (decimal degrees).
lonmin float(9,6)
Minimum longitude of the bounding box (decimal degrees).
latmax float(9,6)
Maximum latitude of the bounding box (decimal degrees).
lonmax float(9,6)
Maximum latitude of the bounding box (decimal degrees).
latitude float(9,6)
Latitude of the district center (decimal degrees).
longitude float(9,6)
Longitude of the district center (decimal degrees).
elevation int(4)
Elevation of the district center (m)

equation table

This table stores information on equations.

id char(13) Not Null *PK*
Unique identifier.
num_constants int(2) Not Null
Number of equation constants.
equation varchar(255) Not Null
Expression of the equation.

event table

This table stores industrial accident events.

code char(4) Not Null *PK*
Code of the accident event.

type enum Not Null Default(R)
Type of the accident event.
F = Fire
E = Explosion
R = Chemical release
O = Other
name varchar(100) Unicode Multilingual(TR,EN)
Name of the accident event.
description varchar(200) Unicode Multilingual(TR,EN)
Textual description.

facility table

This table stores information on facilities.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
nace_code varchar(6) *FK* → **nace**.*code*
NACE code.
nace_code_uncertain bool Not Null Default(false)
Uncertain NACE code flag.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the facility.
url varchar(255) Multilingual(TR,EN)
URL address of the facility.
province_code char(2) *FK* → **province**.*code*
Province code.
district_code char(2) *FK* → **district**.*code*
District code.
locality varchar(100) Unicode Multilingual(TR,EN)
Locality of the facility.
address text Unicode Multilingual(TR,EN)
Address of the facility.
latitude float(9,6)
Latitude of the facility.
longitude float(9,6)
Longitude of the facility.
latlon_uncertain bool Not Null Default(false)
Uncertain coordinate flag.
notes text Unicode Multilingual(TR,EN)
Notes.
hide_chemicals bool Not Null Default(false)
Hide chemicals flag.
phone varchar(32)
Phone number of the facility.
fax varchar(32)
Fax number of the facility.
postal_code char(5)
Postal code of the facility.
latmin float(9,6)
Minimum latitude of the bounding box (decimal degrees).
lonmin float(9,6)
Minimum longitude of the bounding box (decimal degrees).
latmax float(9,6)
Maximum latitude of the bounding box (decimal degrees).
lonmax float(9,6)
Maximum latitude of the bounding box (decimal degrees).
locked bool Not Null Default(false)
Locked flag.

facility_named_group_status table

This table stores information on 96/82/EC status of named groups chemicals in the facilities.

facility_id char(13) Not Null *PK* *FK* → **facility**.*id*
Facility identifier.
named_group_id char(13) Not Null *PK* *FK* → **named_group**.*id*
Named group identifier.
nam_index_l float
Lower named substance index (0–1).
nam_index_u float
Upper named substance index (0–1).
status enum Default(X)
96/82/EC Status (see **facility_substance_status**.*status*).
qual_quantity float Not Null
Qualifying quantity (tons).

facility_status table

This table stores information on 96/82/EC status of the facilities.

facility_id char(13) Not Null *PK* *FK* → **facility**.*id*
Facility identifier.
fla_index_l float
Lower flammability index (0–1).
fla_index_u float
Upper flammability index (0–1).
eco_index_l float
Lower eco-toxicity index (0–1).
eco_index_u float
Upper eco-toxicity index (0–1).
tox_index_l float
Lower toxicity index (0–1).
tox_index_u float
Upper toxicity index (0–1).
status enum
96/82/EC status (see **facility_substance_status**.*status*).
status_src enum
Source of 96/82/EC status.
C = Named substance
G = Named group of substances
S = Summation indices

facility_substance table

This table stores information on substances stored in the facilities.

id char(13) Not Null *PK*
Unique identifier.
facility_id char(13) Not Null *FK* → **facility**.*id*
Facility identifier.
chemical_id char(13) *FK* → **chemical**.*id*
Chemical identifier.
qualifying_quantity_id char(13) *FK* → **qualifying_quantity**.*id*
Qualifying quantity identifier.
adr_explosive_id char(13) *FK* → **adr_explosive**.*id*
UN/ADR explosive identifier.
qual_quantity varchar(32)
Qualifying quantity (fuzzy).
qual_quantity_unit varchar(16)
Qualifying quantity unit.

stor_quantity varchar(32)
Stored quantity (fuzzy).
stor_quantity_unit varchar(16)
Stored quantity unit.
prod_capacity varchar(32)
Production capacity (fuzzy).
prod_capacity_unit varchar(16)
Production capacity unit.
stor_capacity varchar(32)
Storage capacity (fuzzy).
stor_capacity_unit varchar(16)
Storage capacity unit.
prod_days varchar(16)
Number of production days for qualifying quantity calculations (fuzzy).
stor_percentage varchar(16)
Storage percentage for qualifying quantity calculations (fuzzy).
custom_prod_days bool Not Null Default(false)
Custom production days flag.
custom_stor_percentage bool Not Null Default(false)
Custom storage percentage flag.
conc varchar(16)
Concentration of the substance (fuzzy).
locked bool Not Null Default(false)
Locked flag.
ref_phase enum Not Null Default(G)
Reference phase (see **property_data**.*ref_phase*).
ref_t varchar(16)
Reference temperature (fuzzy).
ref_t_unit varchar(8)
Reference temperature unit.
ref_t_amb bool Not Null Default(false)
Ambient temperature flag.
ref_p varchar(16)
Reference pressure (fuzzy).
ref_p_unit varchar(8)
Reference pressure unit.
ref_p_amb bool Not Null Default(false)
Ambient pressure flag.
notes text Unicode Multilingual(TR,EN)
Notes.

facility_substance_status table

This table stores information on the 96/82/EC Directive status of substances stored in the facilities.

facility_substance_id char(13) Not Null *PK* *FK* → **facility_substance**.*id*
Facility substance identifier.
qual_quantity float Not Null
Qualifying quantity (tons).
qual_quantity_src enum
Source of qualifying quantity.
QQ = Qualifying quantity
SQ = Stored quantity
PCg = Production capacity (generic)
PCc = Production capacity (custom)
SCg = Storage capacity (generic)
SC = Storage capacity (custom)
fla_index_l float
Lower flammability index (0–1).

fla_index_u float
Upper flammability index (0–1).
eco_index_l float
Lower eco-toxicity index (0–1).
eco_index_u float
Upper eco-toxicity index (0–1).
tox_index_l float
Lower toxicity index (0–1).
tox_index_u float
Upper toxicity index (0–1).
nam_index_l float
Lower named substance index (0–1).
nam_index_u float
Upper named substance index (0–1).
nam_qual_quantity float
Named substance qualifying quantity (*tons*).
cat_index_l float
Lower category index (0–1).
cat_index_u float
Upper category index (0–1).
status enum
The 96/82/EC Directive status.
X = Out out scope
1 = Lower tier
2 = Upper tier
status_src enum
Source of the 96/82/EC Directive status.
P1 = Annex I Part 1
P2 = Annex I Part 2
P12 = Annex I Part 1 and 2

facility_user table

This table stores responsible persons of facilities.

id char(13) Not Null *PK*
Unique identifier.
facility_id char(13) Not Null *FK* → **facility**.*id*
Facility identifier.
user_id char(13) Not Null *FK* → **user**.*id*
User identifier.

file table

This table stores information on files.

id char(13) Not Null *PK*
Unique identifier
description varchar(255) Unicode Multilingual(TR,EN)
Textual description.
mime_type varchar(64) *FK* → **mime**.*type*
MIME type.
record_id char(13) Not Null
Record identifier.
record_type varchar(32) Not Null *FK* → **record_type**.*type*
Record type.
filename varchar(32) Not Null
Name of the file (in `/files` folder).
filesize int(10) Not Null
Size of the file.

access_level enum Not Null Default(P)
Access level.
P = Public
R = Restricted
filelocked bool Not Null Default(false)
File locked flag.
locked bool Not Null Default(false)
Locked flag.

history table

This table stores history of the records

id char(13) Not Null *PK*
Unique identifier
user_id char(13) Not Null *FK* → **user**.*id*
User identifier.
date datetime Not Null
Creation date.
record_id char(13) Not Null
Record identifier.
record_type varchar(32) Not Null *FK* → **record_type**.*type*
Record type.
action enum
History action.
C = Create
U = Update
D = Delete

history_data table

This table stores historical data of the records.

history_id char(13) Not Null *PK* *FK* → **history**.*id*
History identifier.
record_id char(13) Not Null *PK*
Record identifier.
record_type varchar(32) Not Null *PK* *FK* → **record_type**.*type*
Record type.
data blob
Historical record data (compressed).

label table

This table stores labels.

id char(13) Not Null *PK*
Unique identifier.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the label.

language table

This table stores information on languages.

code char(2) Not Null *PK*
Code of the language.
name varchar(48) Unicode Multilingual(TR,EN)
Name of the language.
local_name varchar(48) Unicode
Native name of the language.

icon varchar(16)
Name of the icon (in `/images/flag` folder).

marine_accident table

This table stores information on marine accidents.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
sea_code char(2) Not Null *FK* → **sea**.*code*
Sea code.
latitude float(9,6)
Latitude of the marine accident.
longitude float(9,6)
Longitude of the marine accident.
latlon_uncertain bool Not Null Default(false)
Uncertain coordinate flag.
accident_type char(2) Not Null *FK* → **accident_type**.*code*
Accident type code.
ship_name varchar(128) Unicode
Name of the ship.
ship_flag char(2) *FK* → **country**.*code*
Flag country of the ship.
ship_type int(2) *FK* → **ship_type**.*code*
Type of the ship.
ship_type_uncertain bool Not Null Default(false)
Uncertain ship type flag.
ship_tonnage int(10)
Tonnage of the ship (tons).
ship_tonnage_type enum Not Null Default(DWT)
Type of ship tonnage.
DWT = Deadweight
GT = Gross tonnage
province_code char(2) *FK* → **province**.*code*
Province code.
district_code char(2) *FK* → **district**.*code*
District code.
locality varchar(255) Unicode Multilingual(TR,EN)
Locality of the marine accident.
other_name varchar(128) Unicode
Name of the other ship.
other_flag char(2) *FK* → **country**.*code*
Flag country of the other ship.
other_type int(2) *FK* → **ship_type**.*code*
Type of the other ship.
other_type_uncertain bool Not Null Default(false)
Uncertain other ship type flag.
other_tonnage int(10)
Tonnage of the other ship (tons).
ship_tonnage_type enum Not Null Default(DWT)
Type of other ship tonnage (see *ship_tonnage*).
accident_fire bool Not Null Default(false)
Fire flag.
accident_explosion bool Not Null Default(false)
Explosion flag.
accident_release bool Not Null Default(false)
Chemical release flag.
date varchar(12)
Starting date of the marine accident (fuzzy).
time varchar(7)
Starting time of the marine accident (fuzzy).

end_date varchar(12)
Ending date of the marine accident (fuzzy).
end_time varchar(7)
Ending time of the marine accident (fuzzy).
notes text Unicode Multilingual(TR,EN)
Notes.
locked bool Not Null Default(false)
Locked flag.

military_accident table

This table stores information on military accidents.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
military_field_id char(13) Not Null *FK* → **military_field**.*id*
Military field identifier
accident_fire bool Not Null Default(false)
Fire flag.
accident_explosion bool Not Null Default(false)
Explosion flag.
accident_release bool Not Null Default(false)
Chemical release flag.
date varchar(12)
Starting date of the military accident (fuzzy).
time varchar(7)
Starting time of the military accident (fuzzy).
end_date varchar(12)
Ending date of the military accident (fuzzy).
end_time varchar(7)
Ending time of the military accident (fuzzy).
notes text Unicode Multilingual(TR,EN)
Notes.
locked bool Not Null Default(false)
Locked flag.

military_field table

This table stores information on military fields.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the military field.
type char(2) Not Null *FK* → **military_field_type**.*code*
Type of the military field.
force_code enum Not Null Default(A)
Military force code.
A = Air forces
M = Marine forces
L = Land forces
J = Gendarmerie
province_code char(2) *FK* → **province**.*code*
Province code.
district_code char(2) *FK* → **district**.*code*
District code.
locality varchar(255) Unicode Multilingual(TR,EN)
Locality of the military field.
latitude float(9,6)
Latitude of the military field.
longitude float(9,6)

Longitude of the military field.
latlon_uncertain bool Not Null Default(false)
Uncertain coordinate flag.
latmin float(9,6)
Minimum latitude of the bounding box (decimal degrees).
lonmin float(9,6)
Minimum longitude of the bounding box (decimal degrees).
latmax float(9,6)
Maximum latitude of the bounding box (decimal degrees).
lonmax float(9,6)
Maximum latitude of the bounding box (decimal degrees).
notes text Unicode Multilingual(TR,EN)
Notes.
locked bool Not Null Default(false)
Locked flag.

military_field_type table

This table stores military field types.

code char(2) Not Null *PK*
Code of the military field type.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the military field type.

mime table

This table stores information on MIME types.

type varchar(64) Not Null *PK*
MIME type.
name varchar(100) Unicode Multilingual(TR,EN)
Name of the MIME type.
icon varchar(32)
Name of the icon (in `/images/mime` folder).
extension varchar(16) Unique
Extension of the MIME type.

mine table

This information stores information on mines.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the mine.
type char(2) Not Null *FK* → **mine_type**.*code*
Mine type code.
province_code char(2) *FK* → **province**.*code*
Province code.
district_code char(2) *FK* → **district**.*code*
District code.
locality varchar(100) Unicode Multilingual(TR,EN)
Locality of the mine.
latitude float(9,6)
Latitude of the mine.
longitude float(9,6)
Longitude of the mine.
latlon_uncertain bool Not Null Default(false)
Uncertain coordinate flag.
latmin float(9,6)
Minimum latitude of the bounding box (decimal degrees).

lonmin float(9,6)
Minimum longitude of the bounding box (decimal degrees).
latmax float(9,6)
Maximum latitude of the bounding box (decimal degrees).
lonmax float(9,6)
Maximum latitude of the bounding box (decimal degrees).
notes text Unicode Multilingual(TR,EN)
Notes.
locked bool Not Null Default(false)
Locked flag.

mine_accident table

This table stores information on mining accidents.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
mine_id char(13) Not Null *FK* → **mine**.*id*
Mine identifier
accident_type char(2) Not Null *FK* → **accident_type**.*code*
Accident type code.
date varchar(12)
Date of the mining accident (fuzzy).
time varchar(7)
Time of the mining accident (fuzzy).
notes text Unicode Multilingual(TR,EN)
Notes.
locked bool Not Null Default(false)
Locked flag.

mine_type table

This table stores mine types.

code char(2) Not Null *PK*
Code of the mine type.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the mine type.

msds table

This table stores information on MSDSs.

id char(13) Not Null *PK*
Unique identifier.
chemical_id char(13) Not Null *FK* → **chemical**.*id*
Chemical identifier.
publisher varchar(128) Unicode Multilingual(TR,EN)
Name of the publisher.
date varchar(12)
Publishing date of the MSDS (fuzzy).
filename varchar(32) Not Null
Name of the MSDS file (in `/msds` folder).
filesize int(10) Not Null
Size of the MSDS file.
mime_type varchar(64) *FK* → **mime**.*type*
MIME type of the MSDS file.
url text
URL address of the MSDS.
access_date varchar(12)
Access date to the MSDS (fuzzy).
language_code char(2) *FK* → **language**.*code*

Language code.
access_level enum Not Null Default(P)
Access level (see **file**.*access_level*).
filelocked bool Not Null Default(false)
File locked flag.
locked bool Not Null Default(false)
Locked flag.

nace table

This table stores NACE categories.

code varchar(6) Not Null *PK*
Code of the NACE category.
name varchar(128) Unicode Multilingual(TR,EN)
Name of the NACE category.
parent_code varchar(6) *FK* → **nace**.*code*
Parent NACE category code.
isic_code varchar(6)
Code of corresponding UN International Classification of All Economic Activities (ISIC) category.
sort_order int(3) Not Null
Internal field used for ordering of NACE categories.

nace_seveso_settings table

This table stores the 96/82/EC Directive settings of the NACE categories.

nace_code varchar(6) Not Null *PK* *FK* → **nace**.*code*
NACE category code.
prod_days varchar(16)
Number of production days (fuzzy).
stor_percentage varchar(16)
Storage percentage (fuzzy).

named_group table

This table stores information on substance groups listed in the 96/82/EC Directive Annex I Part 1.

id char(13) Not Null *PK*
Unique identifier.
name varchar(200) Unicode Multilingual(TR,EN)
Name of the chemical group.
lower_quantity float
Lower qualifying quantity (tons).
upper_quantity float Not Null Default(0)
Upper qualifying quantity (tons).
lower_concentration float
Lower concentration limit (%w).
upper_concentration float
Upper concentration limit (%w).
notes text Unicode Multilingual(TR,EN)
Notes.

named_group_chemical table

This table stores information on chemicals listed in named groups of the 96/82/EC Directive Annex I Part 1.

chemical_id char(13) Not Null *PK* *FK* → **chemical**.*id*
Chemical identifier.
named_group_id char(13) Not Null *FK* → **named_group**.*id*
Named group identifier.
equi_factor float
Equivalency factor.

newspaper table

This table stores newspapers.

id char(13) Not Null *PK*
Unique identifier.
name varchar(32) Unicode Not Null Unique
Name of the newspaper.
language_code char(2) Not Null *FK* → **language**.*code*
Language code.
type enum Not Null Default(N)
Type of the newspaper.
N = National
L = Local
url varchar(200)
URL address of the newspaper.
printed bool Not Null Default(false)
Printed flag.
online bool Not Null Default(false)
Online flag.
locked bool Not Null Default(false)
Locked flag.

note table

This table stores user notes.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
user_id char(13) Not Null *FK* → **user**.*id*
User identifier.
date varchar(12)
Date of the note (fuzzy).
title varchar(128) Multilingual(TR,EN)
Title of the note.
notes text Unicode
Notes.
private bool Not Null Default(false)
Private note flag.

photo table

This table stores information on photographs.

id char(13) Not Null *PK*
Unique identifier.
record_id char(13)
Record identifier.
record_type varchar(32) *FK* → **record_type**.*type*
Record type.
type enum Not Null Default(P)
Type of the photograph.
P = Printed
O = Online
date varchar(12)

Date of the photograph (fuzzy).

photographer varchar(128) Unicode
Name of the photographer(s) (semicolon separated).

title varchar(128) Unicode Multilingual(TR,EN)
Title of the photograph.

description text Unicode Multilingual(TR,EN)
Textual description.

url varchar(255)
URL address of the photograph.

filetype enum Not Null Default(jpeg)
Type of the photograph file.
jpeg = JPEG Image
png = Portable Network Graphics image (PNG)
gif = Compuserve image (GIF)
bmp = Window Bitmap image (BMP)

access_date varchar(12)
Access date to the photograph (fuzzy).

time varchar(7)
Time of the photograph (fuzzy).

filename varchar(13) Not Null
Name of the photograph file (in `/photo` folder).

filesize int(10) Not Null
Size of the photograph file.

width int(5) Not Null
Width of the photograph (pixels).

height int(5) Not Null
Height of the photograph (pixels).

location varchar(64) Unicode
Location of the photograph.

agency varchar(32) Unicode
Name of the agency.

publication_date bool Not Null Default(true)
Flag indicating date is publication date

access_level enum Not Null Default(O)
Access level.
O = Original
P = Preview
T = Thumbnail

filelocked bool Not Null Default(false)
File locked flag.

locked bool Not Null Default(false)
Locked flag.

pipeline table

This table stores information on pipelines.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.

type char(2) Not Null *FK* → **pipeline_type**.*code*
Pipeline type.

name varchar(255) Unicode Multilingual(TR,EN)
Name of the pipeline.

length float
Length of the pipeline (km).

capacity float
Capacity of the pipeline.

international bool Not Null Default(false)
International pipeline flag.

total_length float
Total length of the pipeline including international segments (km)

diameter int(3)
Diameter of the pipeline (*inches*)
capacity_unit enum
Unit of the pipeline capacity.
Mton/y = Million tonnes per year
B/d = Barrels per day
hm3/y = Million cubic meters per year
locked bool Not Null Default(false)
Locked flag.
notes text Unicode Multilingual(TR,EN)
Notes.

pipeline_accident table

This table stores information on pipeline accidents.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
pipeline_id char(13) Not Null *FK* → **pipeline**.*id*
Pipeline identifier.
pipeline_segment_id char(13) *FK* → **pipeline_segment**.*id*
Pipeline segment identifier.
province_code char(2) *FK* → **province**.*code*
Province code.
district_code char(2) *FK* → **district**.*code*
District code.
locality varchar(255) Unicode Multilingual(TR,EN)
Locality of the pipeline accident.
latitude float(9,6)
Latitude of the pipeline accident.
longitude float(9,6)
Longitude of the pipeline accident.
latlon_uncertain bool Not Null Default(false)
Uncertain coordinate flag.
accident_fire bool Not Null Default(false)
Fire flag.
accident_explosion bool Not Null Default(false)
Explosion flag.
accident_release bool Not Null Default(false)
Chemical release flag.
date varchar(12)
Starting date of the pipeline accident (fuzzy).
time varchar(7)
Starting time of the pipeline accident (fuzzy).
end_date varchar(12)
Ending date of the pipeline accident (fuzzy).
end_time varchar(7)
Ending time of the pipeline accident (fuzzy).
notes text Unicode Multilingual(TR,EN)
Notes.
locked bool Not Null Default(false)
Locked flag.

pipeline_segment table

This table stores pipeline segments.

id char(13) Not Null *PK*
Unique identifier.
pipeline_id char(13) Not Null *FK* → **pipeline**.*id*
Pipeline identifier.

name varchar(255) Unicode Multilingual(TR,EN)
Name of the pipeline segment.
length float
Length of the pipeline segment (*km*).
diameter int(3)
Diameter of the pipeline segment (*inches*)
capacity float
Capacity of the pipeline segment.
capacity_unit enum
Unit of the pipeline segment capacity (see **pipeline**.*capacity_unit*).
num_lines int(2) Default(1)
Number of parallel pipelines.
head_id char(13) *FK* → **pipeline_segment**.*id*
Head pipeline segment identifier.
locked bool Not Null Default(false)
Locked flag.

pipeline_type table

This table stores pipeline types.

code char(2) Not Null *PK*
Code of the pipeline type.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the pipeline type.

price_index table

This table stores the CBRT price indices.

type varchar(4) Not Null *PK* *FK* → **price_index_type**.*code*
Price index type.
year int(4) Not Null *PK*
Year of the date.
month int(2) Not Null *PK*
Month of the date.
index float Not Null
Index value.

price_index_type table

This table stores price index types.

code char(2) Not Null *PK*
Code of the price index type.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the price index.
description text Unicode
Description of the price index.
currency_code char(3) Not Null *FK* → **currency**.*code*
Currency code.

property table

This table stores information on properties.

id char(13) Not Null *PK*
Unique identifier.
code varchar(16) Not Null Unique
Code of the property.
symbol varchar(32) Unicode
Symbol of the property.

unit varchar(255) Unicode
Units of the property (semicolon separated).
name varchar(255) Unicode Multilingual(TR,EN)
Name of the property.
ref_t float
Reference temperature.
ref_p float
Reference pressure.
ref_t_unit varchar(8)
Unit of reference temperature.
ref_p_unit varchar(8)
Unit of reference pressure.
ref_phase enum
Reference phase (see **property_data**.*ref_phase*).

property_data table

This table stores information on chemical property data.

id char(13) Not Null *PK*
Unique identifier.
chemical_id char(13) Not Null *FK* → **chemical**.*id*
Chemical identifier.
property_id char(13) Not Null *FK* → **property**.*id*
Property identifier.
value text Not Null
Property values (signed fuzzy, comma separated).
unit varchar(32) Unicode
Unit of the property.
ref_t text
Reference temperature values (comma separated).
ref_p text
Reference pressure values (comma separated).
reference varchar(128) Unicode
Textual reference information.
description text Unicode Multilingual(TR,EN)
Textual description (measurement method, etc.).
ref_t_unit varchar(8)
Unit of reference temperatures.
ref_p_unit varchar(8)
Unit of reference pressures.
log bool Not Null Default(false)
Logarithmic value flag.
reference_id char(13) *FK* → **reference**.*id*
Reference identifier.
ref_phase enum
Reference phase.
S = Solid
L = Liquid
G = Gas
status enum
Status of the property.
D = Default
X = Rejected
locked bool Not Null Default(false)
Locked flag.

property_equation table

This table stores information on property equations.

id char(13) Not Null *PK*
Unique identifier.
chemical_id char(13) Not Null *FK* → **chemical**.*id*
Chemical identifier.
property_id char(13) Not Null *FK* → **property**.*id*
Property identifier.
equation_id char(13) Not Null *FK* → **equation**.*id*
Equation identifier.
unit varchar(32)
Unit of the property equation.
variable enum Not Null Default(T)
Variable of the property equation.
T = Temperature
P = Pressure
variable_unit varchar(8)
Unit of the variable.
upper_limit varchar(16)
Upper validity limit (scientific)
upper_limit_unit varchar(8)
Unit of upper validity limit.
lower_limit varchar(16)
Lower validity limit (scientific)
lower_limit_unit varchar(8)
Unit of lower validity limit.
constant_a varchar(16)
Value of constant A (scientific)
constant_b varchar(16)
Value of constant B (scientific)
constant_c varchar(16)
Value of constant C (scientific)
constant_d varchar(16)
Value of constant D (scientific)
constant_e varchar(16)
Value of constant E (scientific)
constant_f varchar(16)
Value of constant F (scientific)
reference_id char(13) Not Null *FK* → **reference**.*id*
Reference identifier.
ref_phase enum
Reference phase (see **property_data**.*ref_phase*).
status enum
Status of the property equation (see **property_data**.*status*).
notes text Unicode Multilingual(TR,EN)
Notes.

property_estimator table

This table stores information on property estimators.

id char(13) Not Null *PK*
Unique identifier.
code varchar(16) Not Null Unique
Code of the property estimator.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the property estimator.
property_id char(13) Not Null *FK* → **property**.*id*
Property identifier.
unit varchar(32) Unicode
Unit of the property estimator result.
function varchar(255) Not Null Unique
Name of the property estimator function.

ref_phase enum
Reference phase (see **property_data**.*ref_phase*).
default bool Not Null Default(false)
Default property estimator flag.
notes text Unicode Multilingual(TR,EN)
Notes.

province table

This table stores information on provinces.

code char(2) Not Null *PK*
Code of the province.
name varchar(32) Unicode Multilingual(TR,EN)
Name of the province.
salb_code varchar(5)
SALB code (see **district**.*salb_code*).
latmin float(9,6)
Minimum latitude of the bounding box (decimal degrees).
lonmin float(9,6)
Minimum longitude of the bounding box (decimal degrees).
latmax float(9,6)
Maximum latitude of the bounding box (decimal degrees).
lonmax float(9,6)
Maximum latitude of the bounding box (decimal degrees).
latitude float(9,6)
Latitude of the province center (decimal degrees).
longitude float(9,6)
Longitude of the province center (decimal degrees).
elevation int(4)
Elevation of the province center (m)
phone_code varchar(16)
Phone codes of the province (comma separated).

qualifying_quantity table

This table stores information on the 96/82/EC Directive Annex I Part 1 qualifying quantity limits.

id char(13) Not Null *PK*
Unique identifier.
chemical_id char(13) Not Null *FK* → **chemical**.*id*
Chemical identifier.
lower_quantity float
Lower qualifying quantity ($tons$).
upper_quantity float Not Null
Upper qualifying quantity ($tons$).
lower_concentration float
Lower concentration limit ($\%w$).
upper_concentration float
Upper concentration limit ($\%w$).
description varchar(200) Unicode Multilingual(TR,EN)
Textual description.
conditional bool Not Null Default(false)
Conditional qualifying quantity flag.
notes text Unicode Multilingual(TR,EN)
Notes.

r_phrase table

This table stores risk phrases.

code varchar(16) Not Null *PK*
Code of the risk phrase.
phrase varchar(255) Unicode Multilingual(TR,EN)
Risk phrase.
sort_order int(3) Not Null Unsigned
Internal field used for ordering of risk phrases

r_phrase_classification table

This table stores information on hazard classification of risk phrases

r_phrase_code varchar(16) Not Null *FK* → **r_phrase**.*code*
Risk phrase code.
classification_type_code char(2) *FK* → **classification_type**.*code*
Hazard classification type code.
seveso_category_code varchar(4) Not Null *PK* *FK* → **seveso_category**.*code*
96/82/EC category code.
danger_symbol_code char(2) *FK* → **danger_symbol**.*code*
Danger symbol code.

r_phrase_preparation table

This table stores information on risk phrases and hazard classification mapping of preparations.

r_phrase_code varchar(16) Not Null *PK* *FK* → **r_phrase**.*code*
Risk phrase code.
prep_r_phrase_code varchar(16) Not Null *PK* *FK* → **r_phrase**.*code*
Risk phrase code of the preparation.
lower_concentration float
Lower concentration limit.
upper_concentration float
Upper concentration limit.
basis enum Not Null Default(%w)
Concentration unit.
%w = Percentage by weight
%v = Percentage by volume
reference_table varchar(16) Not Null
Reference table.

record_type table

This table stores information on record types

type varchar(32) Not Null *PK*
Record type.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the record type.
as_html varchar(128) Not Null
Name of the XHTML output function.
as_table varchar(128)
Name of the Table output function.

reference table

This table stores information on references.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
type varchar(32) Not Null *FK* → **reference_type**.*type*

Reference type.

title text Unicode
Title of the reference.

booktitle varchar(255) Unicode
Title of the book.

series varchar(255) Unicode
Name of the series.

journal varchar(255) Unicode
Name of the journal.

authors varchar(255) Unicode
Names of the authors (semicolon separated).

editors varchar(255) Unicode
Named of the editors (semicolon separated).

abstract text Unicode
Abstract of the reference.

keywords varchar(255) Unicode
Keywords of the reference (semicolon separated).

year int(4)
Year of the publication date.

month varchar(16)
Month(s) of the publication date.

volume varchar(16)
Volume of the reference.

number varchar(16)
Number of the reference.

pages varchar(16)
Pages of the reference.

edition varchar(16)
Edition of the reference.

chapter varchar(32)
Chapter of the reference.

school varchar(255) Unicode
School of the reference (for Ph.D. thesis, etc.)

organization varchar(255) Unicode
Organization of the reference.

institution varchar(255) Unicode
Institution of the reference.

publisher varchar(255) Unicode
Publisher of the reference.

address varchar(255) Unicode
Address related with the reference.

url varchar(255)
URL address of the reference.

doi varchar(128)
DOI (Digital Object Identifier) of the reference.

crossref_id char(13) *FK* → **reference**.*id*
Cross-reference identifier.

code varchar(32)
Code of the reference.

availability enum
Availability of the reference.
P = Printed
E = Electronic copy
B = Printed and electronic copy

notes text Unicode Multilingual(TR,EN)
Notes.

locked bool Not Null Default(false)
Locked flag.

reference_type table

This table stores information on reference types.

type char(32) Not Null *PK*
Reference type.
name char(64) Unicode Multilingual(TR,EN)
Name of the reference type.
req_entities text
Required data entities (comma separated).
opt_entities text
Optional data entities (comma separated).

related_record table

This table stores relatable records.

id char(13) Not Null *PK*
Unique identifier.
type varchar(32) Not Null *FK* → **related_record_type**.*type*
Related record type.

related_record_type table

This table stores information on related records.

type varchar(32) Not Null *PK* *FK* → **record_type**.*type*
Related record type.
class enum Not Null
Class of the related record type.
A = Accident
D = Document
L = Location
title varchar(64) Unicode Multilingual(TR,EN)
Title of the related record type.
as_list varchar(64) Not Null
Name of the listing page of the related record type.

relation table

This table stores relations.

id char(13) Not Null *PK*
Unique identifier.
record_id char(13) Not Null *FK* → **related_record**.*id*
Record identifier.
related_id char(13) Not Null *FK* → **related_record**.*id*
Related record identifier.

road table

This table stores information on roads.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the road.
code varchar(16)
Code of the road.
type_code char(2) *FK* → **road_type**.*code*
Road type code.
class_code char(2) *FK* → **road_class**.*code*
Road class code.
notes text Unicode Multilingual(TR,EN)

Notes.

locked bool Not Null Default(false)
Locked flag.

road_accident table

This table stores information on road transportation accidents.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
road_id char(13) Not Null *FK* → **road**.*id*
Road identifier.
date varchar(12)
Date of the accident (fuzzy).
time varchar(7)
Time of the accident (fuzzy).
accident_fire bool Not Null Default(false)
Fire flag.
accident_explosion bool Not Null Default(false)
Explosion flag.
accident_release bool Not Null Default(false)
Chemical release flag.
province_code char(2) *FK* → **province**.*code*
Province code.
district_code char(2) *FK* → **district**.*code*
District code.
locality varchar(255) Unicode Multilingual(TR,EN)
Locality.
latitude float(9,6)
Latitude of the accident (decimal degrees).
longitude float(9,6)
Longitude of the accident (decimal degrees).
latlon_uncertain bool Not Null Default(false)
Uncertain coordinate flag.
accident_type char(2) Not Null *FK* → **accident_type**.*code*
Accident type code.
vehicle_code char(2) Not Null *FK* → **vehicle**.*code*
Vehicle code.
other_vehicle_code char(2) *FK* → **vehicle**.*code*
Other vehicle code.
multiple_vehicles bool Not Null Default(false)
Chain accident flag.
locked bool Not Null Default(false)
Locked flag.
notes text Unicode Multilingual(TR,EN)
Notes.

road_class table

This table stores road classes.

code char(2) Not Null *PK*
Code of the road class.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the road class.

road_type table

This table stores road types.

code char(2) Not Null *PK*
Code of the road type.

name varchar(64) Unicode Multilingual(TR,EN)
Name of the road type.

s_phrase table

This table stores safety phrases.

code varchar(16) Not Null *PK*
Code of the safety phrase.
phrase varchar(255) Unicode Multilingual(TR,EN)
Safety phrase.
sort_order int(3) Not Null
Internal field used for ordering of safety phrases

sea table

This table stores information on seas.

code char(2) Not Null *PK*
Code of the sea.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the sea.
type enum Not Null Default(N)
Type of the sea.
N = National
I = International

settings table

This table stores system settings.

name varchar(64) Not Null *PK*
Name of the setting.
value varchar(255) Unicode
Value of the setting.

seveso_category table

This table stores the 96/82/EC Directive Annex 1 Part 2 categories.

code varchar(4) Not Null *PK*
Code of the category.
name varchar(100) Unicode Multilingual(TR,EN)
Name of the category.
lower_quantity float Not Null
Lower qualifying quantity limit (tons).
upper_quantity float Not Null
Upper qualifying quantity limit (tons).
sort_order int(2) Not Null
Internal field used for ordering of categories.

ship_type table

This table stores ship types.

code int(2) Not Null *PK*
Code of the ship type.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the ship type.

si_prefix table

This table stores SI prefixes.

prefix varchar(2) Unicode Not Null *PK*
SI prefix.
factor varchar(8) Not Null
Conversion factor to unity (scientific).
name varchar(8) Unicode Multilingual(TR,EN)
Name of the prefix.

sp_note table

This tables stores R and S phrase notes.

code char(1) Not Null *PK*
Code of the note.
type enum Not Null Default(S)
Type of the note.
S = Safety phrase
R = Rish phrase
note text Unicode Multilingual(TR,EN)
Note.

station_type table

This table stores weather station types.

code varchar(4) Not Null *PK*
Code of the weather station type.
name varchar(128) Unicode Multilingual(TR,EN)
Name of the weather station type.

substance_use table

This table stores uses of substances.

code char(2) Not Null *PK*
Code of substance use.
name varchar(128) Unicode Multilingual(TR,EN)
Name of the substance use.

topic table

This table stores information on topics.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
title varchar(200) Unicode Multilingual(TR,EN)
Title of the topic.
description text Unicode Multilingual(TR,EN)
Textual description.
parent_id char(13) *FK* → **topic**.*id*
Parent topic identifier.
locked bool Not Null Default(false)
Locked flag.

unit table

This table stores units.

id char(13) Not Null *PK*
Unique identifier.
code varchar(16) Unicode Not Null Unique
Code of the unit.

symbol varchar(16) Unicode Multilingual(TR,EN)
Symbol of the unit.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the unit.
prefix bool Not Null Default(false)
SI prefixable flag.
conversion enum
Type of conversion to the base unit.
C = Numeric factor
F = Custom function
factor varchar(32) Unique
Conversion factor (scientific).
unit varchar(32) Unicode
Base unit.
function varchar(64)
Name of the custom conversion function.

urban_accident table

This table stores information on urban disasters.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
name varchar(255) Unicode Multilingual(TR,EN)
Name of the urban site.
province_code char(2) *FK* → **province**.*code*
Province code.
district_code char(2) *FK* → **district**.*code*
District code.
locality varchar(255) Unicode Multilingual(TR,EN)
Locality of the urban site.
latitude float(9,6)
Latitude of the urban site (decimal degrees).
longitude float(9,6)
Longitude of the urban site (decimal degrees).
latlon_uncertain bool Not Null Default(false)
Uncertain coordinate flag.
date varchar(12)
Date of the disaster (fuzzy).
time varchar(7)
Time of the disaster (fuzzy).
accident_type char(2) Not Null *FK* → **accident_type**.*code*
Accident type code.
notes text Unicode Multilingual(TR,EN)
Notes.
locked bool Not Null Default(false)
Locked flag.

user table

This tables stores information on users

id char(13) Not Null *PK*
Unique identifier.
status enum Default(A)
Status of the user.
A = Active
W = Waiting for approval
S = Suspended
name varchar(32) Unicode Not Null
Name of the user.

surname varchar(32) Unicode
Surname of the user.
prefix varchar(32) Unicode
Prefix (title) of the user.
institution varchar(128) Unicode
Institution of the user.
email varchar(128) Not Null Unique
E-mail address of the user.
username varchar(32) Unicode Not Null Unique
Username.
password varchar(32) Not Null
Password of the user (hashed).
alternative_password varchar(32)
Alternative password generated by the system (hashed).
type enum Not Null Default(U)
Type of the user.
U = User
E = Editor
A = Administrator
show_email bool Not Null Default(true)
Show e-mail address in the comments.
send_news bool Not Null Default(true)
Send newsletter.
approve_id char(13)
Approval code generated by the system.
login_count int(10)
Number of logins to the system.
page_count int(10)
Number of pages viewed on the system.
date_login datetime
Date of last login.
date_created datetime
Registration date of the user.
show_maps bool Not Null Default(true)
Show maps.
coordinate_format enum Not Null Default(DD)
Coordinate format preference.
DD = Decimal degrees ($dd.dddddd$)
DM = Degrees decimal minutes ($dd^\circ mm.mmmm$)
DMS = Degrees minutes seconds ($dd^\circ mm' ss.ss''$)
date_format enum Not Null Default(Y/m/d)
Date format preference.
Y/m/d = Year-Month-Day
d/m/Y = Day-Month-Year
m/d/Y = Month-Day-Year

vehicle table

This table stores vehicles.

code char(2) Not Null *PK*
Code of the vehicle.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the vehicle.
type enum Not Null Default(P)
Type of the vehicle.
P = Public
H = Hazardous substance

video table

This table stores information of videos.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
title varchar(255) Unicode Multilingual(TR,EN)
Name of the video.
description text Unicode Multilingual(TR,EN)
Textual description
date varchar(12)
Date of video recording (fuzzy).
time varchar(7)
Time of video recording (fuzzy).
type enum Default(TV)
Type of the video.
TV = Television recoding
AV = Amateur video
tv_channel varchar(32) Unicode
Name of the TV channel.
tv_program_type enum
Type of the TV programme.
D = Documentary
N = News
O = Others
av_cameraman varchar(64) Unicode
Name of the cameraman.
av_record_type enum
Type of video recording.
R = Raw
E = Edited
duration varchar(8)
Duration of the video.
video_file varchar(32) Not Null
Name of the video file (in `/video` folder).
image_file varchar(32)
Name of the thumbnail image file of the video (in `/video` folder).
url varchar(255)
URL address of the video.
access_date varchar(12)
Access date to the video (fuzzy).
label_id char(13) *FK* → **label**.*id*
Label identifier.
access_level enum Not Null Default(P)
Access level (see **file**.*access_level*).
filelocked bool Not Null Default(false)
File locked flag.
locked bool Not Null Default(false)
Locked flag.

weather table

This table stores weather conditions.

code char(2) Not Null *PK*
Code of the weather condition.
name varchar(64) Unicode
Name of the weather condition.
icon_day varchar(16)
Name of the icon for day (in `/images/weather` folder).
icon_night varchar(16)

Name of the icon for night (in `/images/weather` folder).
cloud_cover int(2)
Cloud cover equivalence of the weather condition (0–10).

weather_organization table

This table stores weather organizations.

code char(3) Not Null *PK*
Code of the weather organization.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the weather organization.
abbr varchar(16) Unicode Multilingual(TR,EN)
Abbreviation of the weather organization.

weather_station table

This table stores weather station information.

id char(13) Not Null *PK*
Unique identifier.
no int(6)
No of the weather station.
code varchar(4)
Code of the weather station.
latitude float(9,6)
Latitude of the weather station (decimal degrees)
longitude float(9,6)
Longitude of the weather station (decimal degrees)
elevation int(4)
Elevation of the weather station (m).
region_code char(2) *FK* → **province**.*code*
Region of the weather station.
name varchar(64) Unicode Multilingual(TR,EN)
Name of the region.
province_code char(2) *FK* → **province**.*code*
Province of the weather station.
district_code char(2) *FK* → **district**.*code*
District of the weather station.
organization_code char(3) Not Null *FK* → **weather_organization**.*code*
Weather organization code.
notes text Unicode Multilingual(TR,EN)
Notes
locked bool Not Null Default(false)
Locked flag.

weather_station_type table

This table stores information on types of weather stations

weather_station_id char(13) Not Null *PK* *FK* → **weather_station**.*id*
Weather station identifier.
station_type_code varchar(4) Not Null *PK* *FK* → **station_type**.*code*
Weather station type code.

webpage table

This table stores information on webpages.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
site varchar(128) Unicode Multilingual(TR,EN)

Name of the website.
title varchar(255) Unicode
Title of the webpage.
url varchar(255) Not Null
URL address of the webpage.
date varchar(12)
Date of the webpage (fuzzy).
access_date varchar(12)
Access date to the webpage (fuzzy).
main_text text Unicode
Content of the webpage.
label_id char(13) *FK* → **label**.*id*
Label identifier.
locked bool Not Null Default(false)
Locked flag.

yearbook table

This table stores information on yearbooks.

id char(13) Not Null *PK*
Unique identifier.
name varchar(128) Unicode Multilingual(TR,EN)
Name of the yearbook.
publisher varchar(128) Unicode Multilingual(TR,EN)
Publisher of the yearbook.
url varchar(255)
URL address of the yearbook.

yearbook_entry table

This table stores information on yearbook entries.

id char(13) Not Null *PK* *FK* → **related_record**.*id*
Unique identifier.
yearbook_id char(13) Not Null *FK* → **yearbook**.*id*
Yearbook identifier.
date varchar(12) Not Null
Date of the yearbook entry.
main_text text Unicode Not Null
Content of the yearbook entry.
label_id char(13) *FK* → **label**.*id*
Label identifier.
locked bool Not Null Default(false)
Locked flag.

APPENDIX B

HAZARD CLASSIFICATION TABLES

Table B.1: Hazard classification and 96/82/EC categories of risk phrases

Code	Classification	96/82/EC Category	Danger Symbol
R1	-	-	-
R2	E	5	E
R3	E	5	E
R4	-	-	-
R5	-	-	-
R6	-	-	-
R7	-	-	-
R7	O	3	O
R8	O	3	O
R9	O	3	O
R10	-	6	-
R11	F	7b	F
R12	F+	8	F+
R14	-	10i	-
R14/15	F	10i	F
R15	F	-	F
R15/29	F	-	F
R16	-	-	-
R17	F	7a	F
R18	-	-	-
R19	-	-	-
R20	Xn	-	Xn
R20/21	Xn	-	Xn
R20/21/22	Xn	-	Xn
R20/22	Xn	-	Xn
R21	Xn	-	Xn
R21/22	Xn	-	Xn
R22	Xn	-	Xn
R23	T	2	T
R23/24	T	2	T

Table B.1: Hazard classification and 96/82/EC categories of risk phrases (continued)

Code	Classification	96/82/EC Category	Danger Symbol
R23/24/25	T	2	T
R23/25	T	2	T
R24	T	2	T
R24/25	T	2	T
R25	T	2	T
R26	T+	1	T+
R26/27	T+	1	T+
R26/27/28	T+	1	T+
R26/28	T+	1	T+
R27	T+	1	T+
R27/28	T+	1	T+
R28	T+	1	T+
R29	-	10ii	-
R30	-	-	-
R31	-	-	-
R32	-	-	-
R33	-	-	-
R34	C	-	C
R35	C	-	C
R36	Xi	-	Xi
R36/37	Xi	-	Xi
R36/37/38	Xi	-	Xi
R36/38	Xi	-	Xi
R37	Xi	-	Xi
R37/38	Xi	-	Xi
R38	Xi	-	Xi
R39	T	2	T
R39	T+	1	T+
R39/23	T	2	T
R39/23/24	T	2	T
R39/23/24/25	T	2	T
R39/23/25	T	2	T
R39/24	T	2	T
R39/24/25	T	2	T
R39/25	T	2	T
R39/26	T+	1	T+
R39/26/27	T+	1	T+
R39/26/27/28	T+	1	T+
R39/26/28	T+	1	T+
R39/27	T+	1	T+
R39/27/28	T+	1	T+
R39/28	T+	1	T+
R40	Carc. Cat. 3	-	Xn
R41	Xi	-	Xi
R42	-	-	Xn
R42/43	-	-	-
R43	-	-	Xi
R44	-	-	-
R45	Carc. Cat. 1	-	T
R45	Carc. Cat. 2	-	T
R46	Muta. Cat. 1	-	T

Table B.1: Hazard classification and 96/82/EC categories of risk phrases (continued)

Code	Classification	96/82/EC Category	Danger Symbol
R46	Muta. Cat. 2	-	T
R48	T	2	T
R48	Xn	-	Xn
R48/20	Xn	-	Xn
R48/20/21	Xn	-	Xn
R48/20/21/22	Xn	-	Xn
R48/20/22	Xn	-	Xn
R48/21	Xn	-	Xn
R48/21/22	Xn	-	Xn
R48/22	Xn	-	Xn
R48/23	T	2	T
R48/23/24	T	2	T
R48/23/24/25	T	2	T
R48/23/25	T	2	T
R48/24	T	2	T
R48/24/25	T	2	T
R48/25	T	2	T
R49	Carc. Cat. 1	-	T
R49	Carc. Cat. 2	-	T
R50	N	9i	N
R50/53	N	9i	N
R51	N	-	N
R51/53	N	9ii	N
R52	N	-	-
R52/53	N	-	-
R53	N	-	-
R54	N	-	N
R55	N	-	N
R56	N	-	N
R57	N	-	N
R58	N	-	N
R59	N	-	N
R60	Repr. Cat. 1	-	T
R60	Repr. Cat. 2	-	T
R61	Repr. Cat. 1	-	T
R61	Repr. Cat. 2	-	T
R62	Repr. Cat. 3	-	Xn
R63	Repr. Cat. 3	-	Xn
R64	-	-	-
R65	Xn	-	Xn
R66	-	-	-
R67	-	-	-
R68	Muta. Cat. 3	-	Xn
R68	Xn	-	Xn
R68/20	Xn	-	Xn
R68/20/21	Xn	-	Xn
R68/20/21/22	Xn	-	Xn
R68/20/22	Xn	-	Xn
R68/21	Xn	-	Xn
R68/21/22	Xn	-	Xn
R68/22	Xn	-	Xn

Table B.2: Concentration limits for evaluation of hazards of preparations

Substance risk phrase	Preparation risk phrase	Concentration %w	%v
R20	R20	> 5	> 25
R20/21	R20/21	> 5	> 25
R20/21/22	R20/21/22	> 5	> 25
R20/22	R20/22	> 5	> 25
R21	R21	> 5	> 25
R21/22	R21/22	> 5	> 25
R22	R22	> 5	> 25
R23	R20	$0.5 - 5$	$3 - 25$
R23	R23	> 5	> 25
R23/24	R20/21	$0.5 - 5$	$3 - 25$
R23/24	R23/24	> 5	> 25
R23/24/25	R20/21/22	$0.5 - 5$	$3 - 25$
R23/24/25	R23/24/25	> 5	> 25
R23/25	R20/22	$0.5 - 5$	$3 - 25$
R23/25	R23/25	> 5	> 25
R24	R21	$0.5 - 5$	$3 - 25$
R24	R24	> 5	> 25
R24/25	R21/22	$0.5 - 5$	$3 - 25$
R24/25	R24/25	> 5	> 25
R25	R22	$0.5 - 5$	$3 - 25$
R25	R25	> 5	> 25
R26	R20	$0.02 - 0.2$	$0.1 - 1$
R26	R23	$0.2 - 1$	$1 - 7$
R26	R26	> 1	> 7
R26/27	R20/21	$0.02 - 0.2$	$0.1 - 1$
R26/27	R23/24	$0.2 - 1$	$1 - 7$
R26/27	R26/27	> 1	> 7
R26/27/28	R20/21/22	$0.02 - 0.2$	$0.1 - 1$
R26/27/28	R23/24/25	$0.2 - 1$	$1 - 7$
R26/27/28	R26/27/28	> 1	> 7
R26/28	R20/22	$0.02 - 0.2$	$0.1 - 1$
R26/28	R23/25	$0.2 - 1$	$1 - 7$
R26/28	R26/28	> 1	> 7
R27	R21	$0.02 - 0.2$	$0.1 - 1$
R27	R24	$0.2 - 1$	$1 - 7$
R27	R27	> 1	> 7
R27/28	R21/22	$0.02 - 0.2$	$0.1 - 1$
R27/28	R24/25	$0.2 - 1$	$1 - 7$
R27/28	R27/28	> 1	> 7
R28	R22	$0.02 - 0.2$	$0.1 - 1$
R28	R25	$0.2 - 1$	$1 - 7$
R28	R28	> 1	> 7
R34	R34	> 5	> 10
R34	R41	< 5	< 10
R34	R36/38		$5 - 10$
R34	R36/37/38	$0.5 - 5$	
R35	R34	$0.2 - 1$	$5 - 10$
R35	R35	> 1	> 10

Table B.2: Concentration limits for evaluation of hazards of preparations (continued)

Substance risk phrase	Preparation risk phrase	Concentration %w	%v
R35	R41	< 0.2	< 5
R35	R36/38		$1 - 5$
R35	R36/37/38	$0.02 - 0.2$	
R36	R36	> 5	> 20
R36/37	R36/37	> 5	> 20
R36/37/38	R36/37/38	> 5	> 20
R36/38	R36/38	> 5	> 20
R37	R37	> 5	> 20
R37/38	R37/38	> 5	> 20
R38	R38	> 5	> 20
R39	R39	> 1	> 10
R39/23	R39/23	> 5	> 10
R39/23	R68/20	$0.5 - 5$	$1 - 10$
R39/23/24	R39/23/24	> 5	> 10
R39/23/24	R68/20/21	$0.5 - 5$	$1 - 10$
R39/23/24/25	R39/23/24/25	> 5	> 10
R39/23/24/25	R68/20/21/22	$0.5 - 5$	$1 - 10$
R39/23/25	R39/23/25	> 5	> 10
R39/23/25	R68/20/22	$0.5 - 5$	$1 - 10$
R39/24	R39/24	> 5	> 10
R39/24	R68/21	$0.5 - 5$	$1 - 10$
R39/24/25	R39/24/25	> 5	> 10
R39/24/25	R68/21/22	$0.5 - 5$	$1 - 10$
R39/25	R39/25	> 5	> 10
R39/25	R68/22	$0.5 - 5$	$1 - 10$
R39/26	R39/23	$0.2 - 1$	$1 - 10$
R39/26	R39/26	> 1	> 10
R39/26	R68/20	$0.02 - 0.2$	$0.1 - 1$
R39/26/27	R39/23/24	$0.2 - 1$	$1 - 10$
R39/26/27	R39/26/27	> 1	> 10
R39/26/27	R68/20/21	$0.02 - 0.2$	$0.1 - 1$
R39/26/27/28	R39/23/24/25	$0.2 - 1$	$1 - 10$
R39/26/27/28	R39/26/27/28	> 1	> 10
R39/26/27/28	R68/20/21/22	$0.02 - 0.2$	$0.1 - 1$
R39/26/28	R39/23/25	$0.2 - 1$	$1 - 10$
R39/26/28	R39/26/28	> 1	> 10
R39/26/28	R68/20/22	$0.02 - 0.2$	$0.1 - 1$
R39/27	R39/24	$0.2 - 1$	$1 - 10$
R39/27	R39/27	> 1	> 10
R39/27	R68/21	$0.02 - 0.2$	$0.1 - 1$
R39/27/28	R39/24/25	$0.2 - 1$	$1 - 10$
R39/27/28	R39/27/28	> 1	> 10
R39/27/28	R68/21/22	$0.02 - 0.2$	$0.1 - 1$
R39/28	R39/25	$0.2 - 1$	$1 - 10$
R39/28	R39/28	> 1	> 10
R39/28	R68/22	$0.02 - 0.2$	$0.1 - 1$
R40	R40	> 1	> 1
R41	R36	$0.5 - 5$	$5 - 10$

Table B.2: Concentration limits for evaluation of hazards of preparations (continued)

Substance risk phrase	Preparation risk phrase	Concentration %w	%v
R41	R41	> 5	> 10
R42	R42	> 0.2	> 1
R43	R43	> 0.2	> 1
R45	R45	> 0.1	> 0.1
R46	R46	> 0.1	> 0.1
R48	R48	> 5	> 10
R48/20	R48/20	> 5	> 10
R48/20/21	R48/20/21	> 5	> 10
R48/20/21/22	R48/20/21/22	> 5	> 10
R48/20/22	R48/20/22	> 5	> 10
R48/21	R48/21	> 5	> 10
R48/21/22	R48/21/22	> 5	> 10
R48/22	R48/22	> 5	> 10
R48/23	R48/20	$0.5 - 5$	$1 - 10$
R48/23	R48/23	> 5	> 10
R48/23/24	R48/20/21	$0.5 - 5$	$1 - 10$
R48/23/24	R48/23/24	> 5	> 10
R48/23/24/25	R48/20/21/22	$0.5 - 5$	$1 - 10$
R48/23/24/25	R48/23/24/25	> 5	> 10
R48/23/25	R48/20/22	$0.5 - 5$	$1 - 10$
R48/23/25	R48/23/25	> 5	> 10
R48/24	R48/21	$0.5 - 5$	$1 - 10$
R48/24	R48/24	> 5	> 10
R48/24/25	R48/21/22	$0.5 - 5$	$1 - 10$
R48/24/25	R48/24/25	> 5	> 10
R48/25	R48/22	$0.5 - 5$	$1 - 10$
R48/25	R48/25	> 5	> 10
R49	R49	> 0.1	> 0.1
R50/53	R53		> 25
R51/53	R51/53		> 25
R51/53	R52/53		$2.5 - 25$
R51/53	R53		> 25
R52	R52		> 25
R52/53	R52/53		> 25
R52/53	R53		> 25
R53	R53		> 25
R59	R59	> 0.1	> 0.1
R60	R60	> 0.2	> 0.5
R61	R61	> 0.2	> 0.5
R62	R62	> 1	> 5
R63	R63	> 1	> 5
R68	R68	> 1	> 1
R68/20	R68/20	> 5	> 10
R68/20/21	R68/20/21	> 5	> 10
R68/20/21/22	R68/20/21/22	> 5	> 10
R68/20/22	R68/20/22	> 5	> 10
R68/21	R68/21	> 5	> 10
R68/21/22	R68/21/22	> 5	> 10
R68/22	R68/22	> 5	> 10

Table B.3: Symbols and indications of danger for hazardous substances

Indicator		Symbol	Indicator		Symbol
E	Explosive		O	Oxidizing	
F	Highly flammable		F+	Extremely flammable	
T	Toxic		T+	Very toxic	
C	Corrosive		Xn	Harmful	
Xi	Irritant		N	Dangerous for the environment	

VITA

PERSONAL INFORMATION

Surname, Name: Girgin, Serkan

Nationality: Turkish (TC)

Date and Place of Birth: 19 October 1979, Ankara

Marital Status: Single

E-mail: girgink@gmail.com

EDUCATION

Degree	Institution	Year of Graduation
MS	METU Environmental Engineering	2003
MS	METU Geodetic and Geographic Inf. Tech.	2003
BS	METU Environmental Engineering	2000
High School	Ankara Anatolian High School, Ankara	1996

WORK EXPERIENCE

Year	Place	Enrollment
2006-2008	METU Department of Environmental Eng.	Researcher
2000-2005	METU Department of Environmental Eng.	Research Assistant
1996-2000	TUBITAK Bilten	Part-time Researcher

FOREIGN LANGUAGES

Advanced English, Fluent German

HOBBIES

Mountaineering (Khan Tengri-7010m, G2-8035m, Everest-8848m)

SCUBA, Outdoor Sports