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Analysis and control of major accidents from the intermediate temporary storage of dangerous substances in marshalling yards and port areas

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Abstract

This paper deals with the major accident hazards associated with the intermediate temporary storage of dangerous substances in transportation-related activities. In particular, the hazards related to the presence of dangerous substances in port areas and marshalling yards are identified and analysed. Furthermore, a number of past accidents in transport interfaces have been collated from various sources and have been statistically analysed. Finally, the framework for major accident control in these activities is reviewed and discussed. © 1998 Elsevier Science Ltd. All rights reserved.

Keywords: Major accidents; Transport of dangerous substances; Transport interfaces; Statistical analysis of past accidents

1. Introduction

The risk of major accidents is associated with the presence of dangerous substances at such quantities and under such conditions that an uncontrolled release, fire or explosion can take place, with potential adverse effects to human health and the environment. In order to protect the population and the environment, the principles of prevention of major accidents and mitigation of their consequences are applied. These principles should in general apply to the whole lifecycle of dangerous substances, from their production through the transport chain to their end uses, wherever their quantities and conditions can cause a major accident. In that sense, an adequate level of safety should be ensured not only during production, storage or end use of the substances, but also during their transport.

Within the various activities present in the whole transportation chain of dangerous goods from production to end use, there is a special category of activities characterised as "intermediate temporary storage". This concerns the presence of dangerous substances in marshalling yards and port areas for onward transport purposes, i.e. awaiting further transport. In more detail, intermediate temporary storage is defined as the keeping or simply the presence of goods, including dangerous substances, at docks, wharves and marshalling yards, during their transport from the point of origin to the point of destination stipulated in the transport document (e.g. bill of lading, forwarding order) for the purpose of changing the mode or means of transport or at stops necessitated by the circumstances of transport. The above apply provided that containers/packaging for dangerous substances are not opened during transport, except for control purposes by the competent authorities. Intermediate temporary storage does not include warehousing for distribution purposes or storage for industrial purposes.

The "Seveso Directive" (Directive 82/501/EEC) (Council Directive, 1982), which provides the regulatory framework for control of major accident hazards across Europe, does not take the temporary storage of dangerous substances in transportation-related activities into consideration. These activities are also excluded from the scope of the follow-up of the above Directive, the so-called "Seveso II Directive" (Directive 96/82/EC) (Council Directive, 1996).

Traditionally, the transport interfaces and the relevant hazards have always been controlled through directives, regulations and guidelines originating from the transportation sector. These are summarised in the so-called "Orange Book" (UN/ECOSOC, 1993), while special rec-

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ommendations for each transport mode are also in use (such as the ADR recommendations for road transport (UN/ECE, 1992a), RID for railway (OCTI, 1992), IMDG for marine transport (IMO, 1995), and ADN for inland navigation (UN/ECE, 1992b)). This regulatory framework, which will be discussed in detail in Section 4 of the paper, seems in principle to be efficient, especially as far as avoiding the disruption of the "transportation chain" is concerned. However, scepticism has recently been raised on whether the adoption of controls from the "Seveso Directive" could enhance this framework.

Moreover, a number of incidents that have occurred during the past years in marshalling yards, port areas and other transport interfaces, has increased the public awareness on the subject. It would therefore be interesting to investigate whether these activities present a significant hazard for the neighbouring populations and, if so, what the necessary measures are, to increase their safety.

The concern of authorities and the public on the hazards related with transport interfaces—and transportation of dangerous goods in general—is mirrored in the performance of a number of studies in order to assess the level of risk and investigate the most appropriate way for its management. These studies include the early works focusing on transportation of chlorine, ammonia, LPG and other substances (Rijnmond area, Netherlands (Technica Ltd., 1985), United States of America (Andrews et al., 1980), Lyon, France (Hubert and Pages, 1989) and the United Kingdom (Health and Safety Commission, 1991), the comparisons between different transportation modes (Health and Safety Commission, 1991; Saccomanno & Kassidy, 1992; Saccomanno et al., 1993; Purdy, 1993), or between fixed installations and transportation activities (Vilchez et al., 1995), and the area risk studies focusing on the assessment of the contribution of each source to the overall risk. It was one of the main findings of the ARIPAR study (Egidi et al., 1995) performed for the Ravenna area, Italy, that the risk associated with the operation of the marshalling yard was high, and indeed one of the main contributors to the overall risk. Based on the conclusions of these studies, special methodologies were developed for the assessment of risk in marshalling yards (Eidos s.a., 1995; SNCF, 1995) and ports (Chapron, 1993; Rao & Raghavan, 1996) and guidelines were published (CCPS, 1995). When appropriate, and depending on the national policy on the subject, special controlling measures were discussed (Tan, 1992; van den Brand, 1995, 1996).

This paper focuses exactly on the above issue. In particular, its objective is threefold:

- to identify potential accident sources (hazards) in the description of typical activities in marshalling yards and port areas,
- to select and review a number of past accidents related to these activities, and
- to summarise and discuss the existing framework for control of major accidents in these activities.

2. Hazard identification in transport interfaces

2.1. Marshalling yards

Rail transportation can be performed either directly, from the producer to the final destination, or through a number of marshalling yards, in which various operations take place. The latter are used in order to assemble wagons, which have been loaded with goods elsewhere, into trains for travel to their final destinations. Marshalling yards are therefore "selection-and-delivery" points, stations in which the initial train is split, cargoes are sorted according to their destination and form new trains. In most cases they are situated near railway stations, actually being a direct continuation of them. The hazards connected with the activities in a marshalling yard originate from the hazardous nature of the substances handled. Parameters affecting the extent of these hazards are the substances themselves, their quantity and duration of presence in the marshalling yard, the level of complexity of operations, and the proximity of these facilities with population centres. The marshalling yards are usually close to—or even part of—the main (passengers') railway stations, which for practical reasons have been developed in close proximity to population centres. This proximity could cause high consequences and increased number of fatalities/injuries in the case of an accident.

While loading and unloading of tankwagons does not usually take place, a number of complicated operations are part of the everyday operation in a marshalling yard. These operations, schematically depicted in Fig. 1, vary from a simple change of the locomotive and/or the crew up to the shunting procedure (i.e. the splitting of old trains and the formation of new ones). Moreover, the duration of presence of the hazardous substances in the marshalling yard varies widely, from a few hours to several weeks.

In general, accidents can occur in a marshalling yard due to collision between a train or part of a train with a moving or stationary object, due to derailment of a train or part of it, due to intrinsic mechanical failures, or finally due to external events. The following list summarises the various ways an accident may occur:

1. Collision of a moving train with another moving or stationary train, a moving or stationary shunting rake of wagons, or with a stationary obstacle.
2. Collision of a moving shunting rake of wagons with the same objects described above.

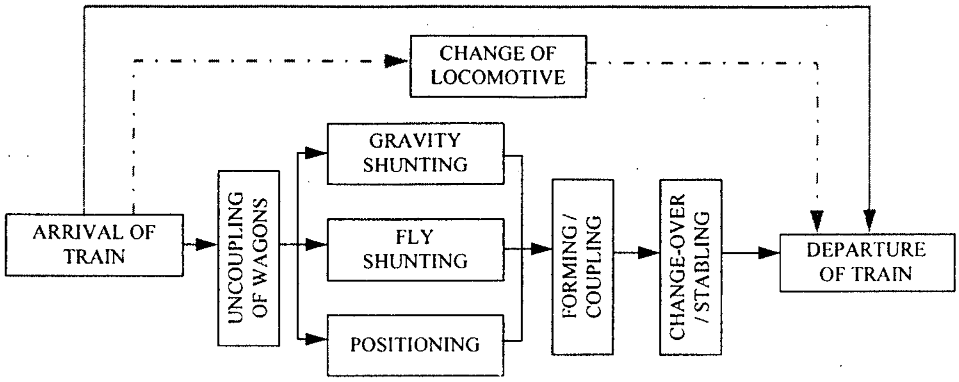

Fig. 1. The activities in a marshalling yard.

3. Derailment of the train or of some wagons.
4. Puncture of a wagon by the locomotive during the change-over of locomotive.
5. Intrinsic mechanical failures, such as corrosion, presence of undesirable substances in the tank (addition of wrong substances), omissions during modification/repair works, overfilling of the tank, and fatigue fractures.
6. External events, such as external fire (which, under certain circumstances, can also lead to a BLEVE) or external explosion.

2.2. *Port areas*

To avoid giving a formal definition of the term, and for the purposes of the present paper, port is defined as the interface between different transportation modes, one of which is marine transportation. The other transportation modes that interact with marine can be road, rail, inland navigation or pipeline. In the area of a port it is possible that more than two modes are present, the presence of all modes also being possible. From the safety point of view it is an important characteristic of ports that they constitute the meeting point of different transportation modes. Each mode may be subject to various regulatory requirements, safety practices and supervisory bodies. Consequently, at the port there may be—and usually there is—overlapping of jurisdictions/standards as well as the potential for gaps between jurisdictions/standards.

Another noteworthy characteristic of the ports is the variety of the bodies involved. These include:

- The port authorities.
- The masters and owners of the ships entering, departing or being moored at the port.
- The berth operators.
- Workers of both sides, working at the port and on-board.
- The owners/operators of other transport modes entering the port area (rail, road, inland navigation).
- The operators of terminals and warehouses in the port area.

The co-operation of all the above bodies, who sometimes have different/conflicting interests, is necessary for the achievement of a satisfactory level of safety in the port areas.

Port areas, as well as other transport interfaces are not covered by the "Seveso" type of legislation. However, since a variety of establishments is usually included in the ports—such as terminals, storage facilities, warehouses, etc.—parts of the ports can be covered by the "Seveso Directive".

The hazards connected with the handling and temporary storage of dangerous goods in port areas mainly originate from the complicated nature of the activities taking place, the possibility of a hardware failure either in the ship or in the inland and loading/unloading equipment, or from external events, such as bad weather conditions or fire/explosion in a ship close-by. The main causes of marine major accidents can therefore be identified as follows:

1. Collision, either between two moving ships, or between a moored ship and a moving one, or between a ship and the dock wall.
2. Grounding of a ship.
3. Fire/explosion on the ship or of the cargo.
4. Cargo transfer failure, during loading or unloading.
5. Structural failure of the cargo tanks (due to fatigue, wave loads, etc.).
6. Corrosion of the cargo tanks or other machinery by the cargo.
7. Overpressure of the tanks, in liquefied gases under pressure, or refrigeration failure, in liquefied by refrigeration gases.
8. Domino effect, including the ignition of a small release by open fire during repair works (e.g. welding).
9. Release from a storage facility, or from a pipeline in the port area (if any) due to overpressure, refrigeration failure, corrosion, human errors, etc.

10. Accident involving other transport modes (road, rail, inland navigation) present in the port area.

The effects of the above accidents are similar to the ones in fixed facilities and they depend on the nature of the hazardous substances involved and the conditions of the accident. These can be:

- release of flammable or toxic substance
- formation and dispersion of a toxic gas cloud, if the substance is toxic gas
- immediate or delayed ignition, for flammable gases
- pool fire or explosion of vapour, for flammable liquids
- flash fire, BLEVE or VCE for flammable gases

3. Review of past accidents

In order to achieve a better understanding of the situation in the transport interfaces and the size of the problem, a review of past accidents was performed. The analysis is focused on the number and characteristics of accidents, as well as the extent of their consequences, mainly in terms of human fatalities and injuries. Information on the causes of accidents has also been collected and useful results are expected to be drawn in a further stage of the analysis.

3.1. Data collection

An extended investigation was performed among some of the most well-known and reliable accident databases in Europe. Table 1 summarises the databases consulted. The outcome of this investigation (after cross-checking and elimination of duplicates) was a *total number of 617 accidents* retrieved for all four transport interfaces under study (marshalling yards, sea and river ports, and lorry stopover places), covering the period 1934–1995. Most of the accidents have occurred recently (later than 1970).

A very important issue in the analysis of historical data is the *quality* parameters: source reliability and level of detailed description. Concerning the first parameter it should be noted that all the consulted organisations (JRC, HSE, AEA, TNO, BARPI) are considered as highly reliable. Therefore, it is assumed that reliability checks of the information sources have been performed by the organisations themselves before entering the data into their systems. As far as the level of detail is concerned, the retrieved accident data vary widely between entries based on thorough and complete investigations and others based just on an article in the local newspaper. From one point of view, this is unavoidable, given the extent of the industrial activities and the individualities characterising the dissemination of information across the world. Another important issue concerns the geographic origin of the consulted databases: they are all operated by European organisations. Although most of them report accidents which occurred worldwide, it is reasonable to be focused on accidents in Western Europe. This issue is expected to influence the results.

3.2. Analysis

The investigation of accidents related to transport interfaces revealed 617 accidents occurred all over the world during the last 60 years. The consequences of these accidents were 2494 fatalities and 17943 injuries. These consequences are distributed among the various transportation modes as presented in Table 2. In this table the number of accidents occurred, number of fatalities and number of injuries are depicted. The contribution of each mode is presented both as a number and

Table 1
Data sources

Database	Full name	Location	Content
MARS	Major Accident Reporting System (Drogaris, 1993; Kirchsteiger, 1998)	MAHB, EC-JRC, Ispra, Italy	Accidents notified by the national Competent Authorities, according to Seveso Directive[a]
Chemax	Chemical accidents database (Haastrup et al., 1994)	T.A. sector, EC-JRC, Ispra, Italy	Accidents from open literature mainly on transportation accidents
MHIDAS	Major Hazard Incident Data Service	AEA Technology Cheshire, UK	Major chemical incidents with potential off-site impact
FACTS	Failure and ACcidents Technical information System	TNO, Apeldoorn, The Netherlands	Accidents from various sources, both open literature and classified sources
ARIA	Analyse, Recherche et Information sur les Accidents	BARPI, Ministry of Environment, Lyon, France	Major industrial accidents and incidents
Open literature	CDCIR, EC-JRC, Ispra, Italy	Incidents	Incidents described in journals and books (Lees, 1992; IchemE, 1974–1998; Hazardous Cargo Bulletin, 1998)

[a]For more details on the MARS database see also the paper "The functioning and status of the EC's Major Accident Reporting System on industrial accidents" by C. Kirchsteiger, in this issue of J. Loss Prev. Process Ind.

Table 2
Summary of past accident analysis for transport interfaces

	Accidents		Fatalities			Injuries		
	Number	%	Number	%	Average	Number	%	Average
Marshalling yards	236	38.2	167	6.7	0.71	6068	33.8	25.71
Sea ports	338	54.8	2293	91.9	6.78	10158	56.6	30.05
River ports	36	5.8	32	1.3	0.89	1594	8.9	44.28
Lorry stopovers	7	1.2	2	0.1	0.28	123	0.7	17.57
Total	617	100	2494	100	—	17943	100	—

as a percentage. Moreover, an additional index was calculated presenting the "average" fatalities per accident and "average" injuries per accident. As derived from Table 2—but also from the analysis of F–N curves for each transportation mode—the most "high-consequence" mode is marine (sea ports). Marshalling yards should be characterised as "medium–low fatalities/high injuries", while any characterisation for the remaining two modes should take into consideration their very small sample.

Some examples of past accidents are presented in Tables 3 and 4, for marshalling yards and ports, respectively. The examples selected are well-known accidents, also described in the open literature. The information in these tables concerns the year and location of the accident, the substances involved, an indication on the cause of the accident, its type, a brief description and the numbers of fatalities and injuries. The reason for including some very old accidents (see for example the first two accidents in Table 4) is the size of their consequences and the fact that they constitute "typical" examples, well-described in the literature.

The distribution of consequences is presented in the

Table 3
Examples of accidents in marshalling yards

Year	Location	Substance	Cause	Accident type	Description	Fatalities	Injuries
1988	U.S.S.R.	Explosives		Explosion	Explosion on a railway station created crater 30 m deep and 55 m wide.	73	230
1983	INDIA	Kerosene	Leakage	Explosion	Explosion of leaking rail tanker at the station.	47	
1985	CHINA	Chlorine	Workers failure	Toxic release	Chlorine released from tank-wagon by damaged safety valve.		2000
1986	U.S.A.	Phosphorus (yellow)			Derailment of freight-train.		569
1963	U.S.A.	Chlorine	Burst of unload line	Toxic release	Rupture of copper loading line during transhipment		400
1974	U.S.A.	Isobutane, oil	Overspeed due to operator's error	Explosion	In a marshalling yard, an operator's error led to the puncture of a tank-wagon from behind. 63 tonnes of isobutane were released and formed a cloud that dispersed in a zone about 800 m. The product ignited and 7 employees were killed from the explosion and 349 persons were injured. Glasses up to 4.8 km were broken. At total 700 buildings were damaged, 283 other tank-wagons were destroyed and 312 were damaged.	7	349
1974	U.S.A.	Monomethylamine nitrate solution	Decomposition	Explosion	Spontaneous explosion of a tank-wagon in the yard during switching operations.	2	113
1947	FRANCE	Chlorine	Get loose cylinder	Toxic release	Chlorine cylinder fell from freight-wagon.	1	104
1988	USSR	Explosives	Collision–shunting	Explosion	Collision between two trains in the switching yard.	4	100

Table 4
Examples of accidents at port areas

Year	Location	Substance	Cause	Accident type	Description	Fatalities	Injuries
1944	INDIA	Oil, explosives, cotton	Fire	Explosion	Explosion of a vessel in the harbour.	1250	2884
1947	U.S.A.	Ammonium nitrate fetrilizer, Sulphur molten	Fire in ship due to smoking—domino	Explosion	Fire in ship in the harbour, leading to explosion of another ship and storage tanks of a chemical plant.	546	5000
1989	IRAN	Kerosene	Explosion	Explosion	During unloading operations a tanker exploded.	62	
1979	IRELAND	Crude oil	Improperly ballasted	Fire, explosion, fireball	During unloading oil at a terminal, a tanker broke and caught fire followed by an explosion. Fragments reported to travel up to 10 km.	50	
1985	SPAIN	Gasoline, Naphtha		Explosion, fire	Explosion and fire on two ships and the jetty during transhipment.	32	40
1975	U.S.A.	Crude oil	Pilot's error		Collision between two tankers.	26	11
1980	MALAYSIA	Vegetable oil, ammonia, acethylene, oxygen (gas)	Fire	Fire, explosion	Fire and explosion of a warehouse caused damage to half of the harbour.	3	200
1979	GREECE	Benzine, explosives, flammable liquefied gas		Fire and explosion	Fire and explosion on a vessel during transhipment of drums.	7	140
1974	SPAIN	Chlorine	Tank failure during unloading—broken valve	Toxic release	While loading onto ship, tank-valve damaged, releasing chlorine.	4	120
1985	ITALY	Gasoline, gas-oil, fuel oil	Operator's error	UVCE, fire, explosion	During ship unloading operations, operators lost control of the gate valve position. Overfilling of the tank and overflow of the product, whose vapours ignited leading to a violent explosion followed by fire. Extended damage to the site and nearby buildings. Many people were hit by debris.	4	100
1986	PHILIPPINES	Ammonia		Toxic release	Release of ammonia during unloading.		100

form of F-N curves for total fatalities and total injuries in Fig. 2a and b, respectively. The Frequency–Fatalities (F–N) curve represents the frequency F with which accidents of N fatalities or more occurred among accidents with at least 1 fatality (i.e. $P[x \geq N|N \geq 1]$). Similarly, the Frequency–Injuries curve represents the frequency with which accidents of N injuries or more occurred among accidents with at least 1 injury. Therefore, the number of accidents with no fatalities or injuries, which however are considered as major accidents (release of a dangerous substance, evacuation, environmental consequences), are not depicted in the F–N curves.

The distribution of the selected accidents in time (i.e. number of accidents per time period) as well as in space (i.e. number of accidents per geographical region) are without doubt two very important parameters. These not only reveal whether the sample represents satisfactorily the reality, but also give an indication on the trends, i.e. whether increasing or decreasing trends appear. The above analysis is summarised in Figs. 3 and 4. The first figure gives the distribution of accidents per decade, whereas the latter depicts the number of accidents for each geographical region (Western Europe, USA, rest of world). These figures show that only 10% of the sample concerns the period before 1970. It is also important to avoid being misled from the interpretation of these figures: the high number of accidents during the last decades does not present an increasing trend. On the contrary, the trend is decreasing, if one compares the number of accidents selected from the 1980s with those from the 1990s (the 1990s are much less than the half of the 1980s). The reason for the increased presence of

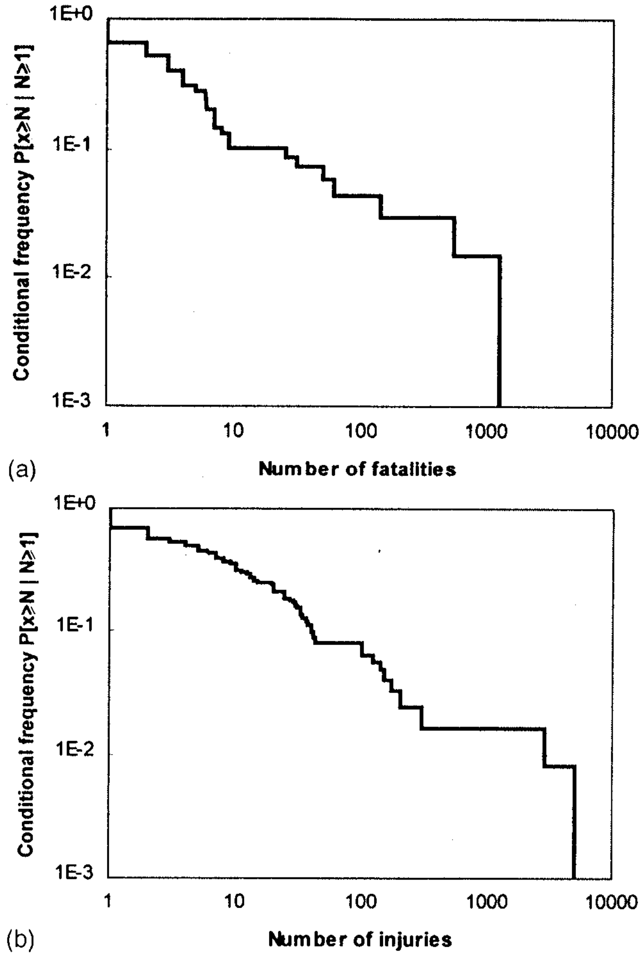

Fig. 2. (a) Accidents at transport interfaces (all modes): fatalities F–N curve (worldwide). (b) Accidents at transport interfaces (all modes): injuries F–N curve (worldwide).

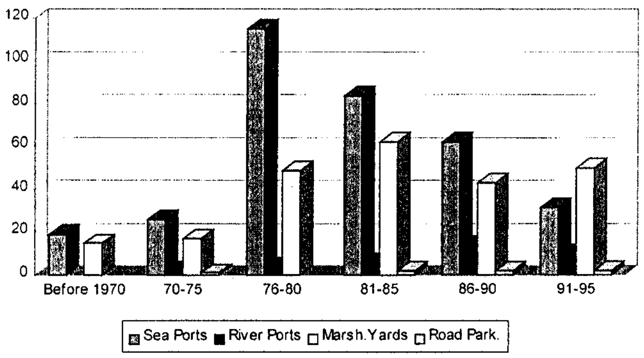

Fig. 3. Distribution of the accidents in time (worldwide).

recent accidents in the sample is the fact that during recent years, accidents are reported more frequently and more systematically than previously. Similarly, one should also not be misled concerning their geographical distribution: the number of accidents occurring in Western Europe is high because our sources of information are mainly located in Western Europe.

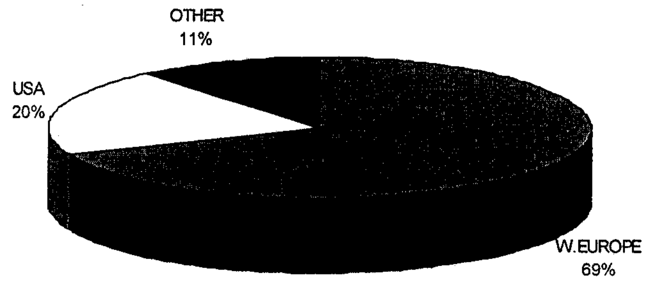

Fig. 4. Geographical distribution of the selected accidents.

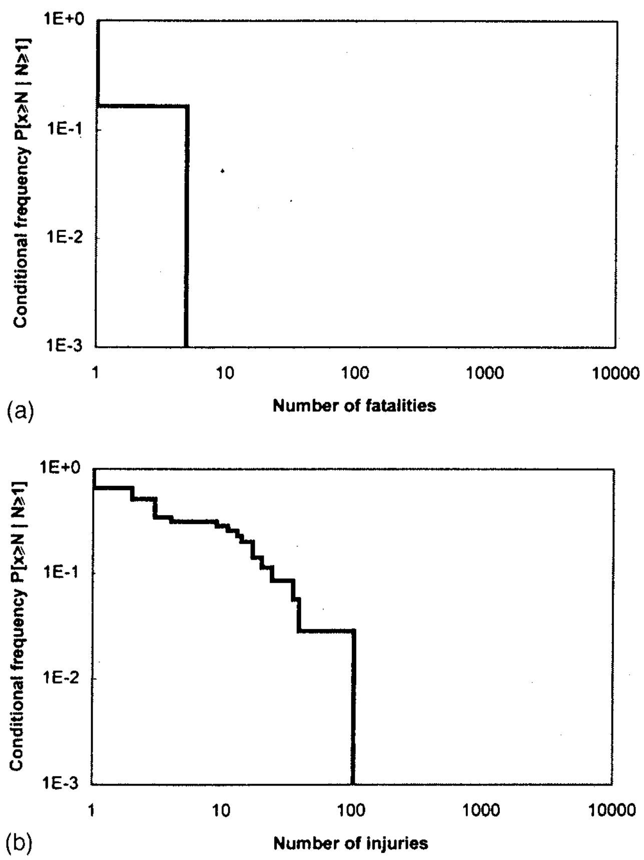

Fig. 5. (a) Accidents in marshalling yards: fatalities F–N curve (Western Europe). (b) Accidents in marshalling yards: injuries F–N curve (Western Europe).

In order to compare in a more comprehensible way the situation in Western European countries with the situation worldwide, the F–N curves for the accidents occurring only in Western Europe (EU countries, Norway and Switzerland) were constructed and compared with the relevant curves for the worldwide data. In general, the patterns and trends appear to be similar and only small differences can be found. However, in the case of marshalling yards there is an important difference, as presented in Figs. 5 and 6 (a and b, for fatalities and injuries, respectively). The analysis shows that the consequences of accidents occurring in Western European marshalling yards are an order of magnitude lower

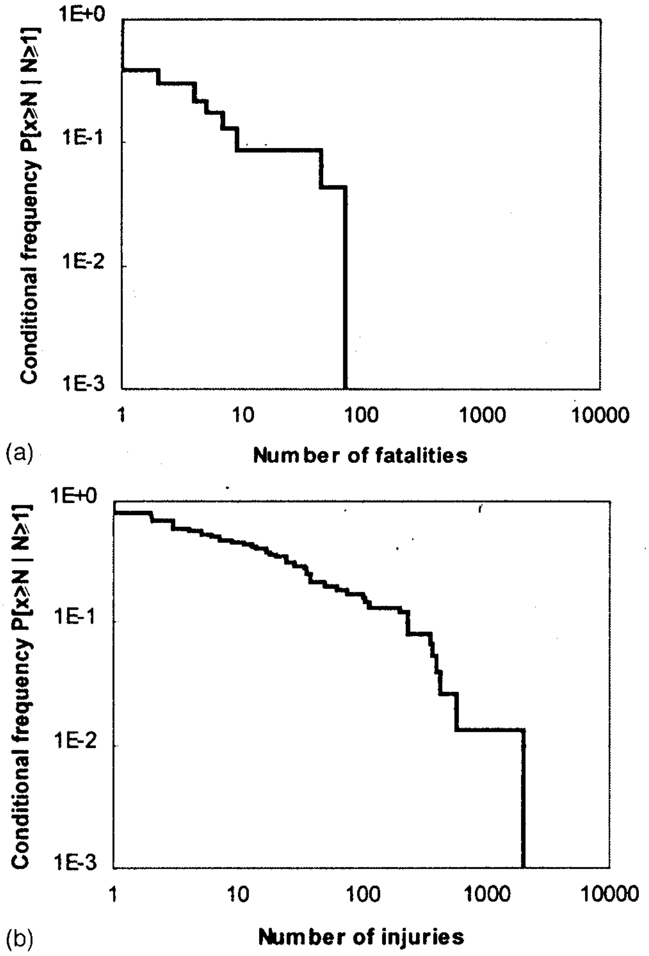

Fig. 6. (a) Accidents in marshalling yards: fatalities F–N curve (worldwide). (b) Accidents in marshalling yards: injuries F–N curve (worldwide).

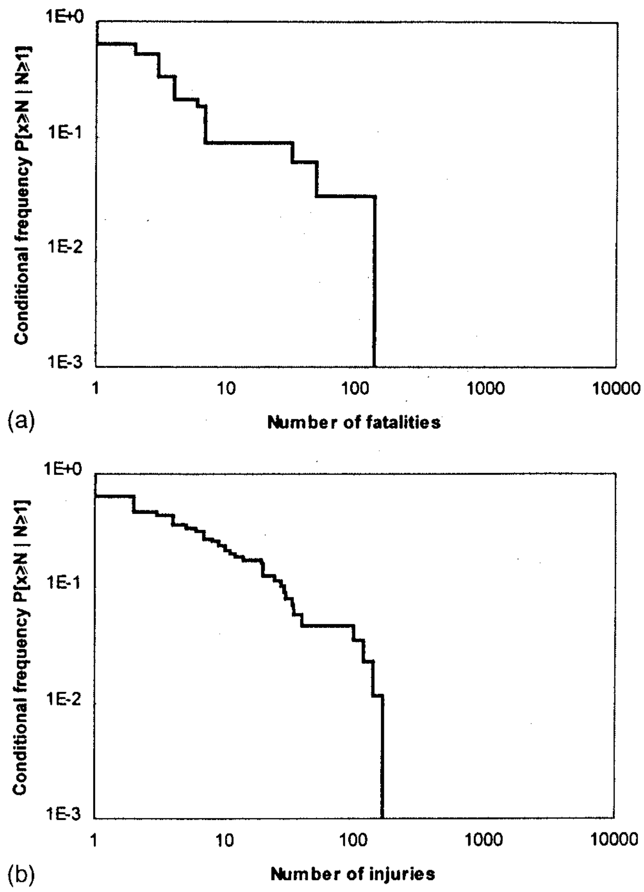

Fig. 7. (a) Accidents at sea ports: fatalities F–N curve (Western Europe). (b) Accidents at sea ports: injuries F–N curve (Western Europe).

than those occurring worldwide, thus representing a significantly lower level of risk. This fact is probably due to the different types of hardware (railroads, locomotives, tankwagons) and the different operating procedures followed in Europe (e.g. in Western Europe trains of 10 or more wagons carrying dangerous substances are rare, whereas in the U.S.A. such trains can have up to 100 wagons). A similar difference of one order of magnitude between Western European and worldwide data also appears for accidents in port areas, as Figs. 7 and 8 (a and b, for fatalities and injuries) indicate. However, this estimate is based on a smaller number of accidents and the resulting frequency values are statistically less significant. Moreover, such a behaviour should be expected since the concerned issue is typical of the "low frequency–high consequences" area of the F–N curve.

Finally, it should be underlined that the analysis of past accident statistics is a tool revealing the way industrial systems used to behave in the past. Technology has significantly changed throughout the data-collecting period. Applying their conclusions in decision making should take into consideration this fact, together with the fact that the analysed accidents have been collected from all the countries throughout the world. Most of these countries differ significantly from European countries, a fact that should be judged in decision making. The insights gained by the analysis may constitute a useful tool, given that possible differences between the systems providing the data and the actual systems, on which the decisions will be applied, have been acknowledged and have properly taken into consideration.

4. Control of major accidents in marshalling yards and port areas

4.1. Provisions in the "Seveso II Directive"

As mentioned at the beginning, the activities related to intermediate temporary storage of dangerous goods in marshalling yards and port areas are excluded from the Directive. More specifically, Council Directive 96/82/EC in Article 4(c) contains an exclusion for

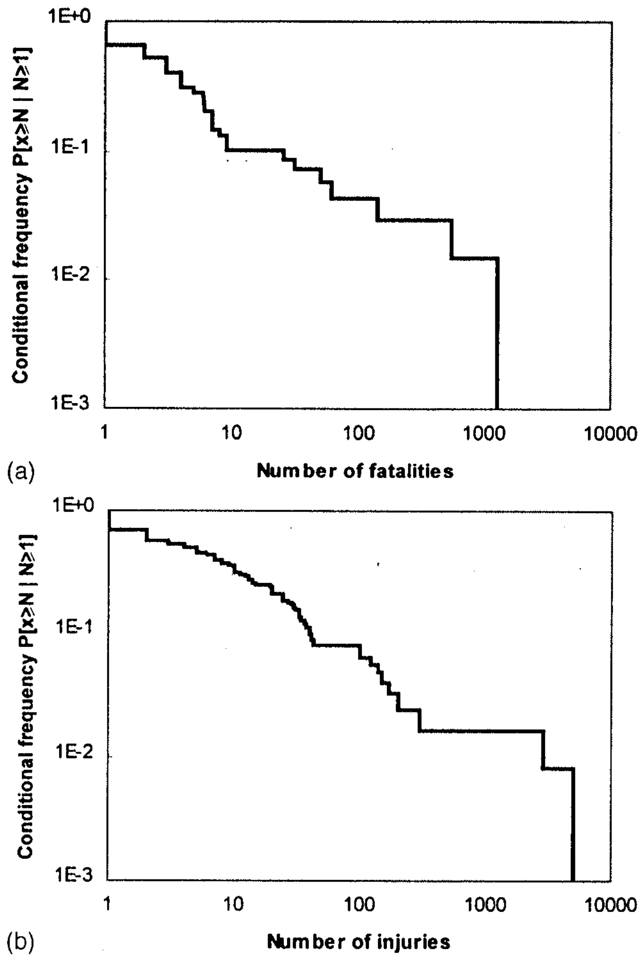

Fig. 8. (a) Accidents at sea ports: fatalities F–N curve (worldwide). (b) Accidents at sea ports: injuries F–N curve (worldwide).

the transport of dangerous substances and intermediate temporary storage by road, rail, internal waterways, sea or air, outside the establishments covered by this Directive, including loading and unloading and transport to and from another means of transport at docks, wharves or marshalling yards.

As a result, some transport-related activities are excluded, while other activities, such as warehousing and permanent storage of dangerous substances, are still covered by the Directive, even if they are located in a port area or a marshalling yard.

However, some EU Member States expressed the view that "Seveso" type provisions might be necessary to apply in certain cases for transport-related activities excluded from the Directive, in order to ensure a level of safety equivalent to "Seveso II". In order to accommodate this view, Recital (12) has been introduced in Council Directive 96/82/EC, which states that

Whereas, with due regard to the relevant Community legislation, Member States may retain or adopt appropriate measures for transport-related activities at docks, wharves and marshalling yards, which are excluded from this Directive, in order to ensure a level of safety equivalent to that established by this Directive.

4.2. Relevant European Community and international legislation

The legislation controlling transport interfaces and the relevant hazards usually originates from the transport sector. Important regulations/guidelines in the field include the UN/ECOSOC "Recommendations on the transport of dangerous goods" (UN/ECOSOC, 1993), the OCTI "Regulations for the international railway transport of dangerous goods" (OCTI, 1992) (RID, see also Council Directive 96/49/EC), the IMO "International Maritime Dangerous Goods Code" (IMO, 1995), and the recent "safety advisor" Directive (96/35/EC). Engineering standards, general safety regulations, such as the NFPA standards, and guidelines elaborated in several relevant Workshops (organised by OECD, UNEP and REMPEC, see for example, OECD, 1994a, b) complete the regulatory framework for transport-related activities. Special importance should be given to the recent OECD/IMO "Guidance concerning chemical safety in port areas" (OECD/IMO, 1996), which has been adopted for inclusion in the IMDG code.

This legislation, except for providing engineering standards, also deals with most of the topics of prevention of major accidents. Guidance for the establishment of programmes, policies and detailed procedures related to prevention, preparedness and response to accidents involving dangerous substances is also provided. The controlling measures and the responsibilities for each of the parties involved in the process of dealing with the hazardous substances in ports and in marshalling yards are extensively discussed. Topics such as education and training, community awareness and accident reporting are also addressed.

4.3. Discussion

After a recent request by the European Council, the relevant Commission's services dealing with environment and transport together with experts from the two sectors jointly examined the Community and international legislation, in order to assess whether a high level of protection is achieved with respect to major accident hazards related with ports and marshalling yards. The review involved contributions from authorities, industry and other interested parties, and two workshops were organised to bring together interested parties from different sectors and discuss the potential issues [Livorno, Italy, 1996 (EC, Joint Research Centre,

1996) and Barcelona, Spain, 1997 (European Commission, 1997)].

The approach followed consisted of the detailed examination and comparison of the main elements of "Seveso" and transport controls in order to focus on whether there was a "broadly equivalent" control measure already existing within the transport sector, or perhaps covered by other horizontal legislation. In general, it was possible to conclude that a "broad equivalence" could be found for many "Seveso" control measures in existing transport related legislation, particularly for "preventive" measures, while for "mitigating" measures such a broad equivalence could not always be found directly. For example, it was more difficult to find a broad equivalence for "Seveso" measures related to the "limitation of consequences", such as land-use planning and information to the public.

The recently issued OECD/IMO "Guidance concerning chemical safety in port areas" (OECD/IMO, 1996) addressed the mitigatory elements, while both the federations of port operators and European railways provided the necessary information facilitating a more detailed comparison of the two legislative frameworks (ESPO/FEPORT, 1997; CER, 1997). In the Barcelona workshop it became clear that progress has been achieved and broad equivalence exists in most elements of the two frameworks. Thus, it seemed appropriate to concentrate on the effective implementation of international policies covering this sector, and to monitor and evaluate this implementation. In the case of marshalling yards, it is recognised that the relevant experts need to further develop planning for emergencies. In this area of interest, a close co-operation of environment and transport and other relevant authorities in Member States is necessary.

5. Conclusions

In this paper, the hazards connected with the intermediate temporary storage of dangerous substances in transportation related activities were identified and a review of past accident statistics was performed. The analysis was focused on marshalling yards and port areas and revealed that these activities are not free from risk. Moreover, as appears in the relevant F–N curves, a number of accidents has occurred in the past, sometimes with high consequences. Although the study of past accidents in transport interfaces showed that there is a potentially significant risk involved in such activities, it is not yet clear if this evidence is strong enough to support the consideration of additional controlling measures. In any case, the relevant considerations should always take into account the existing control framework and should aim, as possible, at the integration of environmental protection requirements into the overall EU policy. It is also worth mentioning that consistent accident reporting criteria and a systematic data collection scheme would certainly enhance the statistical basis from which further regulatory conclusions could be drawn.

Concerning the regulatory framework for major accident control, "broad equivalence" appears to exist between the existing measures mainly originating from the transport sector and the "Seveso" type measures, as was the conclusion of two expert workshops. In cases where gaps were found, actions have been undertaken and the relevant experts have been encouraged to draft harmonised recommendations. As a final conclusion, on the basis of this statistical analysis, the need to achieve a high level of protection through an integrated control framework and the continuous monitoring of this framework is strongly underlined.

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