CONSIDERATIONS ON RISKS POSED BY MAJOR ACCIDENTS INVOLVING DANGEROUS SUBSTANCES AND SCENARIOS TECHNIQUE FOR PREVENTION AND REDUCTION IN THEIR CONSEQUENCES FOR PROCESS INDUSTRIES

DURBACĂ ION[1*], DURBACĂ ADRIAN-COSTIN[1]

[1]*POLITEHNICA University of Bucharest, Spl. Independenței, 313, Bucharest, Romania*

Abstract: This paper aims to define specific elements of major risk management and represents a necessary technical support for people involved in analysis and risk assessment and as well a guidance material and information to other persons and organizations directly involved in the operation of any industrial activities working with hazardous substances which are used in quantities sufficient to produce major accidents.

Keywords: accidental risks, risk management, risk assessment, hazardous substances

1. INTRODUCTION TO ISSUES UNDER CONSIDERATION

A major accident could be defined as "*an unforeseen event as a major emission, fire or explosion resulting from uncontrolled development of an industrial process and leading to serious danger to human health and / or to environment, immediate or delayed hazard, inside or outside the site and involving one or more hazardous substances*" [1].

Major accidents are catastrophic for both - victims and the affected environment and cause socio-economic consequences of the most severe. Major accidents are not limited either in space or time. Because the most are caused by substances or dangerous products, substances to be stored in liquid and gaseous phase, the accident-gene wave can propagate long distances, affecting everything in its path.

After the occurrence of such accidents in the years 1970-1980 at both EU and U.S. and third world countries where there were settlements and industrial installations belonging to EU and U.S. firms, the EU agreed the need of a common approach referring to general industrial accidents issue and major accidents in particular. *SEVESO Directives* have emerged as the reference documents, along with several other acts of lesser magnitude.

Major technological accidents are particularly important in terms of impact and risk to public health and the environment. Currently in the EU's main legislative regulation for accident prevention technology is *SEVESO III Directive* (105/EC/2003), which was implemented in Romania by Government Decision 804 of 2007 with later amendments and additions. This Directive covers measures on prevention and control of major accident hazards involving dangerous substances. The development process has resulted in growth industries where technological and chemical incidents and accidents in particular. *SEVESO Directives* have been developed in the EU in the historic technological accidents Flixborough (1974), SEVESO (1976), Bhopal (1984), Baia Mare (2000), Toulouse (2001), etc. These accidents have shown the need for more rigorous control of chemical processes, to prevent technological disasters.

* Corresponding author, email: ion.durbaca@yahoo.com

The paper addresses a topic of great interest both nationally and internationally because in many process industries working with large quantities of dangerous substances, as well as dangerous process parameters (pressure, high temperature, etc.). *SEVESO III Directive* applied in EU countries governs the activities where dangerous substances are used in quantities sufficient to cause major accidents. Thus, risk evaluation has a major role in all industrial activities covered by the Seveso Directive.

The literature shows that there are two major risk categories:

- *process major risks* arising in the systems covered by the *SEVESO III Directive* (chemical, petrochemical, refinery, etc.), i.e. for locations where hazardous substances are present, according to regulations and documentation required to be compiled technique called "security report";
- *major risks in other industries*, resulting in systems that are not covered by the *SEVESO III Directive*, which has been proposed a minimum content of technical documentation; in this category are included biological hazards as well as SME-type activities.

In accordance with Government Decision no. 804/2007, as amended by Government Decision 79/2009, the local government responsible for establishment planning and land field use, in collaboration with public authorities at regional and local level, authorities must take necessary measures as land development policy is taken into account the objectives of preventing major accidents and limiting their consequences. In many European Union countries are well established risk assessment methodologies for planning and land use. In Romania, in 2007 industrial units were registered 202 *Seveso*, but after four years after joining the EU there is still no single accepted methodology to be used by risk assessors for land use planning.

Because the risks are a daily presence in the industrial economic activities, their bad action is marked both by economic loss, damage plants, machinery and by incidents and accidents at work resulting in injuries and deaths, and environmental accidents which in most cases are irreversible.

Assessment of risk levels stimulates economic incentives to improve working and environmental conditions, and also to take action to transit from high risk levels to below acceptable. Application and generalization of such methods enable the establishment of social insurance rates vary according to the level of risk: economic security, the security criteria of inclusion in the payroll, along with labor productivity and complexity criteria.

Risk management activity has developed both conceptually, but also practically, becoming an industry in countries with functional financial markets, but few organizations in Romania have developed their own mechanisms for measuring and hedging, and others do not know the benefits they would get by applying well established procedures. To estimate the risk there are three types of methods: qualitative, semi-quantitative and quantitative. Active participants in the process of harmonization of risk assessment methods recommended for major accident risk of a method for quantitative estimation. Depending on the possible consequences of a major accident there are established security systems installation and protection of workers and population in the area of incidence. An accurate estimate of the risk of major accident insurance offers better protection for potential receptors.

The risk of an activity, industrial or not, has two components, the ordinary risk - related to the normal activity progress and great risk - related to the accident states. Extraordinary risk assessment is required for all different types of economic activities (anthropogenic) to protect the population, environment and property. In accordance with European directives, major accident risk assessments are necessary also for zonal development studies in order to correct land use planning. Furthermore, quantitative evaluation of major accident risk has become mandatory for sites that fall under the scope of *SEVESO III Directive.*

Thus, this paper presents technique layout scenarios for the development of major accident hazards that could be produced in those locations where hazardous substances are involved, as well as measures to limit the effects of accidents which may occur, however.

2. PROCESS TECHNOLOGY SCENARIOS FOR PREVENTING THE RISK OF MAJOR ACCIDENTS

When preparing the accident prevention policy, technical requirements scenario approach to major accident hazards involving dangerous substances are based on estimates more meaningful and necessary to compile the safety report will be required calculations detailed. This is valid for assessing whether a possible major accident hazard due to a *Domino effect*.

Technical performance of major accident hazards scenarios are used routinely in the *SEVESO III Directive*, and for this detailed information should be provided in different ways (see Figure 1).

Scenarios serve major hazards proof that industrial operators are fulfilled obligations under *SEVESO Directive III*. Without knowing the possible effects of accidents, identified by the scenario approach, limiting their action to prevent and cannot be properly established. Data on the effects of accidents in the safety report documenting the results serve not only from the systematic analysis of security, but is the necessary expression of a partial step in the security report, which should result in identifying the sources of danger to be taken into account, such as and the events that can lead to a major accident and what steps are eliminated. This is to include the following *types of accident scenarios* [2]:

- to conduct accident scenarios to determine the effectiveness of measures to prevent accidents;
- to conduct accident scenarios to determine the effectiveness of measures to limit the effects;
- to conduct accident scenarios to determine the information required under *SEVESO III Directive* external alarm and hazard prevention of major accidents and to describe effects that can be used to limit their necessary action.

In order sizing and quantification of major-accident scenarios of ongoing cases are designed independently and must be reflected in the following range:

- upper limit of these scenarios represent leakage, fire or explosion of a large mass of hazardous substance (*CMI*) falling within a defined volume;
- lower limit will be adequately offset by the so-called critical mass (M_k), which is that quantity at which leak, fire or explosion is relevant assessment reached a critical point of reference accident (subject matter / area nearby).

When developing scenarios of major accidents will be taken into account:

- objective conditions and site specific and reciprocal response to its surroundings;
- possible hazard situations for employees;
- quantities of dangerous substances present in the target disrupted, or one from a faulty installation;
- specific properties of substances, the influence of which may result in jeopardizing a functioning line;
- modeling (dispersion models), according to the current state of science and technology in the field emission peak, fires and explosions;
- dispersion of substances in air, water or soil after leaks, fires or explosions, including other possible consequences;
- efficiency and ability to carry out countermeasures;
- showing the evolution of space (and as appropriate chronological), peak concentrations, dosage amounts, the maximum overpressure, etc. surface concentrations.

To establish hazardous areas will be taken always as the basis for development of accident scenarios with maximum range and to achieve their assumptions will be considered for workflow scenarios that can reasonably be excluded because it was "*hypothetical accidents which still may occur*". Regarding the possible causes will not approach because they deviate from the purpose of scenarios, since they would get through other security measures to prevent cases in the circuit approach.

3. PROCESS APPROACH CONCEPT SCENARIOS ON RISK OF ACCIDENT PREVENTION OF CAUSES MAJOR INDEPENDENT

To limit risk scenarios on the prevention of major accidents which may occur, however, suggests a concept that combines the assessment values of specific accident sites, which points to overcome a major threat to the existence of specific plants i.e. data with mass flows, i.e. quantities hazardous substances released in the event of malfunction of the plant (see Figure 2) [3].

Terms relevant to the concept are defined as follows [2]:

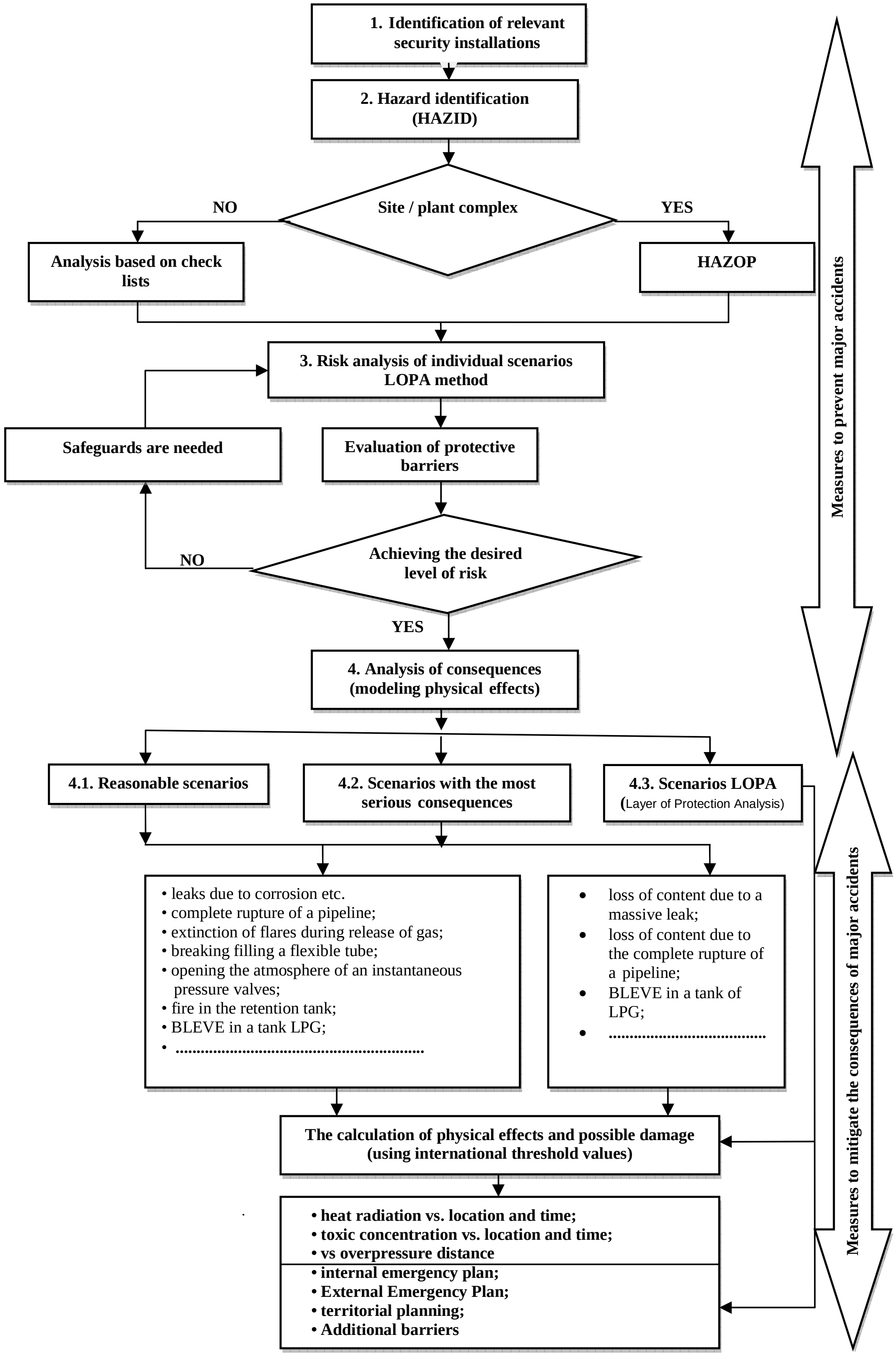
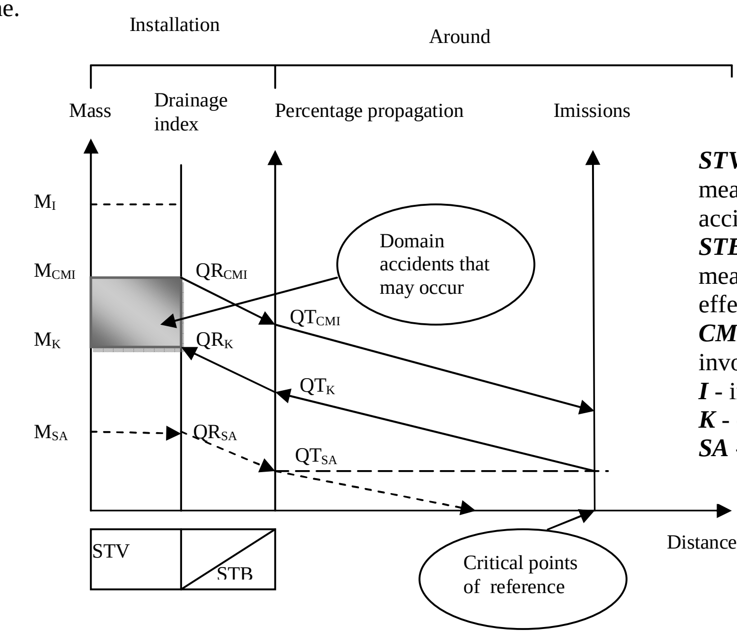


Fig. 1. The general scheme of measures to prevent and limit the consequences of major accidents.

- accidents must be prevented, according to security analysis (*SA*) is based on the operational failures that could extend in an accident because of sources of danger that cannot be excluded in a reasonable manner if changes were not stopped or limited by the accident prevention measures so that it no longer poses any major threat;
- accidents that may occur, however, are to extend the operational failure, causing a major hazard, despite measures to prevent accidents, but due to the activation of a source of danger or reasonably excluded concomitant activation of several sources of danger to an independent the other, to limit the effects of accidents of this kind should be made specific to each facility, and special measures for protection against hazards;
- exceptional accidents (which may occur in war situations and events) result from sources of danger, which are not found in any of the experiences and methods of calculation for the prevention of accidents of this kind will not take specific additional facilities;
- accident assessment values are concentrations or doses identified in a hazardous substance which, when exceeded can create a major hazard, the assessment values for hazardous substances accidents held in the air will be taken into account in particular: the values guiding concentration and dosage for the emergency plan in case of an accident and driving times, to assess the impact on soil and water may be of importance: Critical values of soil pollution, water pollution intervention values and the ratio (*CA*) water polluted "the danger of major accidents due to fire and explosion effects, we will take into account the value evaluation of accidents: the critical heat flux densities, ie the critical pressure maximum pressure wave which propagates, for the effects produced by explosion fragments are not known values assessment of the accident;
- critical point of reference is there a facility adjacent to a major hazard that can occur, this is especially true for a place that is continuously or temporarily a large number of people (housing, hospital, school etc.).
- largest amount involved (*CMI*) is the maximum amount of hazardous substance may be in a given volume of a delineated area (vessel, pipe) that can be closed or closing, a consistent operation of the facility, to determine *CMI* can be taken into account closures outside of the active faults of the plant;
- flow rate (*QR*) is the total mass flow out of a dangerous substance during a limited amount of operational failure, it is dependent on specific characteristics of the product and installation parameters (pressure, temperature, geometry).
- propagation rate (*QT*) is the percentage of total mass flow which spreads actually do after the passage of limited volume.



CAPTION:

STV - the effectiveness of measures to prevent accidents;
STB - the effectiveness of measures to limit the effects of accidents;
CMI - the largest amount involved;
I - inventory;
K - critical;
SA - safety analysis.

Fig. 2. Scheme for planning purposes the effects of accidents.

To achieve a blend of plant-specific parameters and the specific surroundings in an accident, it takes only a concept in calculating the percentage of spread of flow rate, taking into account conditions on the ground (drainage, natural chemical, chronological and spatial) and a dispersion calculation for determining the impact derived from the relevant percentage spread its surroundings.

On the issue of a mixture of substances is appropriate for addressing the conduct of accident scenarios to be performed on the most dangerous substances, a substance that the substance considered as directories.

Scenarios ongoing application of the concept of independent accident cases are identified by determining upper and lower limit corresponding to the boundary, however, accidents can occur, as follows [2]:

a) to determine the upper limit, is proposed as a criterion, the largest quantity of hazardous substance involved in the installation and demarcation will take place in *three steps*:

- *step 1*: determining the largest quantities of hazardous substance involved (*CMI*), within a defined volume, which is or may be closed separately from other parts of the facility during an operation to conform;
- *step 2*: calculating the percentage of *CMI* / QT_{CMI} dispersion, considering the same flow conditions on the ground;
- *step 3*: calculation of dispersion, considering the specific circumstances surrounding the propagation QT_{CMI} percentage calculated to determine the place that distance transmission, the value assessment of the accident will not be exceeded, as it establishes and hazard area which extends over defense against external threats. Leakage or explosion, the burning question of multiple parties CMI_1 quantities of hazardous substances, CMI_2, so the volume defined separately from each other should not be classified as an accident may occur, however. Address the potential interaction between plants may be important but in terms of a domino effect. Hazard prevention plan, it is relevant that *CMI* leads to the greatest extent of the hazard area.

b) to determine the lower limit, applying the concept of separation of accidents can occur, however, will be in the next five steps:

- *Step 1*: determination of assessment for the substance analyzed accident;
- *Step 2*: definition of critical reference points and determining the distance to potential emissions from the installation site;
- *Step 3*: determination of the percentage spread, however, in case of accidents which may occur (QT_K), the rate of propagation leads precisely a critical point of reference to the size of the immission value and value assessment of accidents, where the dispersion of the substance dangerous in bad conditions of dispersion. Since there are computer programs for direct calculation of post-immission concentrations in a critical point of reference for the propagation rate, should be carried out dispersion calculations using varying percentages in the reverse direction of propagation, as input parameters. Determination of the percentage spread (QT_K) may result and the diagram technique, because for many hazardous substances appropriate charts are available, which can be read for a given value assessment of the accident, the percentage of spread QT_K.
- *Step 4*: determine the total flow rate (QR_K) the percentage of spread QT_K the post-calculation of leakage under the base scenario of deployment of the accident (type of incident, type of flow, thus emissions);
- *Step 5*: Calculation of critical quantity (M_K) by integrating the flow rate during flow (QR_K) which represents the time required to achieve a just assessment of the accident in a critical point of reference.

If a facility's *CMI* exceeds a certain specified hazardous substances M_K, then the plant will be mainly considered appropriate, however, accidents may occur and will provide adequate measures.

If instead, *CMI* of a particular hazardous substance is less than the M_K, then in terms of the impact an accident can still occur at a critical point of reference, no such measures are necessary to limit the impact of the accident. In this case, however, another approach is needed to impact a leak of *CMI* assumption, regardless of its cause, to see if the effect in the field of distance to the critical point of reference is ruled out a major threat to the protected objects under the *Seveso Directive*. As appropriate, measures are taken to limit the effects of the accident.

Setting the upper limit of the casualties, however, may occur in the form of *CMI* is based on the conclusion that the appearance of a leak, a fire or an explosion in two different parts of the plant independently of each other simultaneously and has a low probability of achievement and therefore not should be taken into account here.

In determining the rate of propagation of the flow rate in each case the physical effects, such as evaporation accumulation of leakage, are effective and can be regarded as reducing emissions or delay emissions. Also in this way, passive protection devices, such as tank walls capture or protection, may be deemed to be available continuously. The closing assets may be considered to operate as long as they are not part of the installation of defective parts.

For if $CMI < M_K$, then the concept of independent accident scenarios for the conduct of cases in a facility, would not occur under any circumstances, however, triggering an accident that might occur. Unaffected by the fact that in this case the critical point of reference can be triggered any major hazard, the operator has the obligation to mitigate the accident and safety reasons. These include measures to limit the effects of accidents.

4. MEASURES FOR LIMITING THE EFFECTS OF ACCIDENTS THAT COULD STILL BE PRODUCED

Technical and organizational protection measures to limit the effects of accidents which may occur, however, can be effective in different phases of an ongoing accident scenario. They are so obvious, the objective criteria for use as [4, 5]:

- tasks;
- compliance;
- efficiency;
- proportionality, progress-oriented scenarios of accidents that may occur, however, relevant for an installation. The following criteria are relevant for a systematic and unified handling of the selection of measures to limit the effects of accidents:
- effects of the accident which involved the largest possible, however, may occur (e.g. leaking hazardous substances subject to the *CMI*);
- limit the escape of dangerous substances defined volume;
- limit evaporation of hazardous substances released into a liquid;
- prevent ignition or ignition feature released hazardous substances, flammable and explosive prevention, i.e. preventing the spread of hazardous substances released into the gaseous or liquid form;
- effectiveness of technical and organizational measures separately for the foreseeable protected;
- effort for the measures provided in relation to their efficiency.

The choice of measures to limit the effects of accidents is preferred passive measures, which in any case must be recognized that are effective for its intended purpose. Because accidents can occur, however, the effects of accidents are limited, but cannot prevent an accident, as measures designed to reduce the effects of a limiter so that a major threat to be excluded.

A classification of security measures in the categories of accident prevention, namely to limit the effects of accidents is not always possible. This, however, does not limit the application of the proposed selection criteria for protective measures to limit the effects of accidents which may occur, however.

5. CONCLUSIONS

Since the organizational risk management activities under *SEVESO Directive* business owner has in mind for the following elements:

- major accident prevention policy (which should include the overall objectives and principles of action with respect to the control of major accident hazards);
- security management system (which includes organizational structure, responsibilities, practices, techniques, methods, procedures, processes and resources for determining and implementing the major accident prevention policy);
- that to limit the consequences of accidents on human health risk, a particularly important role technology must be given scenario for major accident hazards involving dangerous substances and require a rigorous approach to the preparation of any report of security.

REFERENCES

[1] ***, Council Directive 105/EC/2003 on the control of major accident hazards involving dangerous substances.

[2] Uth, H.J., Ghid pentru calcularea accidentelor majore (scenarii), Twinning Project Ro/2002/IB/EN/02, Bucharest and Berlin, June, 2004.

[3] ***, Metodologie pentru analiza riscurilor industriale ce implică substanțe periculoase, TÜV Austria, TWL Seveso II Assessment of Risks / Major Accident Effects.
[4] ***, SR CEI 60300-3-9, Managementul siguranței în funcționare, partea 3, Ghid de aplicare, secțiunea Analiza riscului sistemelor tehnologice.
[5] ***, HG nr. 804/25.07.2007, privind controlul asupra pericolelor de accident în care sunt implicate substanțele periculoase.