Risk and Risk Management in Chemical Industry

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Abstract

Chemical industry shows a continuing risk to human health and the environment. Risk management with technology can prevent accidents and can keep people healthy. In this work some managerial actions of prevention, risk assessment and mitigation are presented. These activities involve: the knowing the nature and limits of occupational exposure to hazardous chemical agents at work; choosing appropriate technology; determining measures for risk mitigation; development of work instructions, labor protection and first aid.

Keywords: *risk, risk management, industrial chemistry, dangerous pollutant*.

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Introduction

Risk is defined as a probable event that may generate losses and may be potential danger [1]. ISO 31000 standard [2] defines risk as the effect of uncertainty on performing objectives; it may be either positive or negative.

Risk management can therefore be considered the identification, assessment, and prioritization of **risks** followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities. Risks can come from uncertainty in financial markets, project failures, legal liabilities, credit risk, accidents, natural causes and disasters, as well as deliberate attacks from an adversary. Several risk management standards have been developed including those of the **Project Management Institute**, **National Institute of Science and Technology**, actuarial societies, and ISO standards [2].

The risk management is an important component of overall management and seeks to introduce measures to reduce risk activities contributing to the clearance operation of facilities, to analyze the manufacture of new products, reducing waste etc. Together with risk analysis, the risk management contributes to protection of both environment and people and also to GDP (gross domestic product) growth in a country (for example, in U.S. a 10-15% increase in GDP is estimated, resulting from accident prevention).

The risk analysis [3] appeals to the engineering sciences, biology, ecology and medicine. In the frame of this analysis it will be established the maximum permitted concentrations (in appropriate units) for each type of pollutant regardless of its nature, even from the beginning; at higher concentrations the pollutant have adverse effects biotic and abiotic environment. Also, the actions that can be done later, as alarm, warning, declaring a state of emergency or major injuries beginning may be established.

The management of accidents prepares in advance the plans for industrial enterprises with a high probability of occurrence of accidents to mitigate adverse consequences. To compare objectively different situations, the EU uses a scale of assessment of industrial accidents from 1 to 6, containing also three parameters D, C, M. Thus, the accidents in industry are classified into:

1 – incident;
2 – notable incident;
3 – major accident;
4 – severe accident;
5 – very serious accident;
6 – catastrophic accident.

The parameter D represents a potential danger expressed as percentage or as equivalent TNT (trinitrotoluene in tons) for the quantity that reacted or could react chemically.

The parameter C expresses the real consequences of the accident, such as number of wounded or dead persons, contaminated surface, number of destroyed houses, livestock or fish mortality and other damages.

The parameter M represents the means of intervention and number of persons involved in intervention.

In international practice there are three kinds of methods for risk assessment [4]: qualitative, quantitative and semi-quantitative methods. The qualitative assessment methods use the qualifiers to describe the proportions of possible consequences and the probability of their occurence. In the semi-quantitative assessment methods qualitative scales are utilized. The quantitative assessment methods use numerical values for both the consequences and their probability of occurrence.

Throughout the world the industrial activities are engaged in serious risks. Since July 10, 1976, when from the accident in a small enterprise producing pesticides in Seveso (Italy) over 600 people were evacuated from their homes and more than 2,000 were treated after dioxin poisoning, in 1982, the Europe Council adopted the Directive 85/501/CEE about major accidents recorded by certain industrial activities (Seveso Directive) [5].

Following the occurence of other major accidents, Seveso Directive was amended twice, in 1987 by Directive 87/216/CEE and in 1988 by Directive 88/610/CCE. The amendments included stipulatons relating to the storage regime of hazardous substances. European Union Member States have requested later a complete overhaul of Seveso Directive, seeking, *inter alia*, the broadening application sphere and a better management of risks and accidents. As a result, the

Directive 96/82/EC was adopted in December 1996 regarding the control of major accidents caused by dangerous substances, this being called Directive *Seveso II*. For EU member countries were recommended two years to transpose the legislation and administrative framework in national legislation, in order to comply with this Directive.

The legislation about major hazards was implemented in Romania since 2003, when the industrial plants were classified in two categories: with major risks and minor risks. The decrease in time of the number of installations covered by Directive is due to the closure or interruption of the business. It is worth to mention that new risks have arisen as a result of retraining and economic development activities in SMEs.

1. Chemical industry – characteristic features

The chemical industry stands virtually all sectors of the economy and its strategies have a direct effect on downstream users of chemicals. Great industrial consumers of chemicals are metallurgical industries, mechanical and electrical, textile and clothing sectors, automotive industry, stationery and printing products manufactures.

The contribution of chemical industry to the EU gross domestic product amounts to 2%, this industry being a source of jobs for about 4 million people from Europe [6]. EU chemical industry (excluding pharmaceuticals) includes about 27,000 companies, of which 96% have fewer than 250 employees and can be considered small and medium enterprises. These companies represent 30% of sales and 37% of jobs. A 4% percentage of EU chemical companies that have more than 249 employees generate a 70% of the total sales of chemicals.

However, the chemical industry is an area with a high risk to personnel and environment because, more than in other fields, it works with *hazardous chemical agents* with potential risk for the health and safety (due to physico-chemical or toxicological properties and use procedures). Dangerous emissions result continuously or discontinuously from either technological accidents or technical manipulations required for safe operation.

Chemicals of gaseous, liquid or solid nature exist in raw materials, intermediate products, finished products and wastes, in different forms: powders, grains, solvents, aerosols, gases, vapors, etc. They have different toxicity, in a large range (Table 1). Effects are manifested as irritation, fibrosis, asphyxiation, allergies, cancer, genetic mutations, according to the pollutant concentration, exposure time, presence of pollutant mixtures, as well as influence of other external factors.

The accidents can be classified as:

- *simple accidents*, if the risk is low, affecting a limited area; the causes of such accidents can be foreseen, and the intervention can be done manually or automatically, acquiring an experience worthwhile for the future;
- *major accidents*, when the losses consist in large quantities of hazardous substances; in these cases the risk is higher, affecting the company and

outside, beyond administrative boundaries. The consequences of major risks may be immediate or longer, and the causes are not known on the whole.

Effects of chemical products on human health

Table 1

No.	Pollutant	Effects
1	Benzene	Anemia, aberrations cromozoidale
2	Dichloro ethane	Liver, kidney ill, heart disorders and central nervous system
3	Formaldehyde	Eye irritation, dermatitis, respiratory infections, aberrations cromozoidale
4	Black carbon	Dermatitis, eye irritation, skin cancer, respiratory disorders
5	Carbon disulfide	Neurological, psychiatric and gastrointestinal disorders
6	Pesticides	Carcinogenic action and sometimes cocancerigene
7	Tetrachlorethylene	Kidney, skin, genital cancer, liver dysfunction, central nervous system disorders
8	Organochlorine compounds, phosphoric compounds, mercury compounds, fluorides, nitrogen oxides	Mutagenic and teratogenic (birth defects, mental delays)

Some agents may become dangerous by increasing the risk of fire, explosion, by possible synergistic effect with other pollutants in the area etc. In such cases, there may be immediately affected, in different periods of time, people, industry, urban and natural environment.

2. Some problems in the risk management

In chemical industry, the management activities for prevention, risk assessment and mitigation consist in the followings:

- selection the appropriate products and working methods;
- knowledge of the hazardous chemical agents existing at work place;
- knowledge of the occupational exposure limits for each chemical agent;
- establishing the measures for risk mitigation;
- development the work instructions and job protection;
- setting the instruments and procedures for first aid.

a. The choice of product and method of work must take into account all possible risks that may arise from chemical agents. It is therefore sometimes recommended the replacement of dangerous products or technologies with variants less dangerous to employees or to environment.

b. The knowledge of nature of hazardous chemical agents means that the manager must to identify those jobs where are used (or which may arise) such agents and to estimate which dangerous substances are expected to result in phases of the technological process, how groups of workers will be exposed and the way of contamination.

The chemical agents should be identified by labels for packing and transport, that provide information on hazards, risks and warnings. The orange labels draw attention to hazards substances, and the icons provide information about risk. The purchased chemical agents must be accompanied by a *safety data sheet*, which gives complete information on risks and means of protection (according to ISO 11014-01 standard).

Also, the producers of reagents are obliged to deliver *safety data sheets* to National Agency for Dangerous Substances and Materials and the users. The National Agency sends to all companies a list of dangerous commercialized substances existent in the market. Also, the National Institute for R&D on Work Protection can deliver *safety data sheets* for over 450 chemical substances and materials.

The manager of a company may require medical information regarding occupational chemical risks, means of prevention and potential health surveillance. To employees at work should be own list of hazardous chemical agents of the enterprise, together with work instructions and labor protection.

c. Knowledge of the limit values for occupational exposure to each chemical agent is important because hazardous chemical agents (and pollutants, too) can cause accidents at work and / or occupational diseases. It is therefore necessary to know some of their characteristics such as:

- maximum permissible concentrations required to be obeyed;
- limit value of occupational exposure;
- biological limit value;
- the permissible limit value for dust, powders etc.

d. Risk mitigation measures. If the hazardous chemical agent could not be eliminated entirely by technological change, or could not be replaced with other less harmful chemical agents it is necessary to be reduced the exposure time of personnel. Risk prevention measures include:

- the use of carcasses for equipment, in which the vacuum is created;
- automatically control of the process;
- local and general ventilation;
- reduced time of exposure to harmful factors and decrease of the number of people exposed;
- development of instructions for work procedures and work protection;
- development of emergency procedures;
- information and training employees;
- endowment with individual equipment and collective protection equipment.

Measures to prevent accidents and diseases should be applied during the technological process, revisions and repairs, packing and marking steps, storage,

transport as well as during the processing of wastes. In addition to technical measures and protective equipment, the warning systems are needed to indicate high-risk places and immediate protection (e.g. using a mask, visors, or protective suits).

To prevent risks of fire or explosion, the measures aim to:

- prevent formation of explosive mixtures, by making ventilation, use of inert gases, control the storage of fuel containers etc.;
- elimination of fire sources (hot surfaces, flames, sparks, static electricity, etc.);
- limitation of effect of explosion and fire by workspace organizing and minimizing the amount of hazardous materials (supplied up to 48 hours), the existence of fire-fighting means and indications about the type of use.

For revisions and repairs must be made agreements with specialized labor protection services (specialized people), issued permits for work regarding the existence of protection and type of work. After performing works, the beneficiary shall check the work both technically-technologically and in terms of employment protection on the basis of documentation approved by competent institutions.

Packages must be made of suitable material, properly marked and sealed, thus avoiding the possibility of removal or spread of hazardous substances.

The storage of chemicals is performed in special places, equipped with ventilation, marked with warning signs; the substances that may enter the reaction are stored separately.

During the transport, in addition to general measures of risk prevention (standard packaging, appropriate means of transport, speed of movement, appropriate size and visibility of access roads), the driver must be trained for cases of damage to packaging or the spread of chemical agents. There are detailed indications in international laws on different types of transport: ADR for road transport, RID for rail, IMDG for shipping and ICAO-TI for air transport.

The wastes can result from the technological process, damaged packaging, worn-out means of protection or decontamination, etc. They must be registered and taken away from work. Also, their handling should be carried out safely by trained persons. Depending on their nature (toxic, caustic, corrosive, flammable, explosive) the wastes can be neutralized, destroyed, or stored in conditions obeying legal provisions for environmental protection, taking account possible incompatibilities.

e. Development the work instructions, labor protection and the procedures for first aid. If hazardous chemicals are involved in the work, the employers must provide to employees information on: safety and health risks due to hazardous chemical agents, identification, occupational exposure limit values and appropriate protection measures. This information should be updated taking into account any changes.

Training of employees is organized in three stages:

- the general introductory briefing for new employees and other involved persons, which is made theoretically or practically. The specific risks are shown for a period of at least 8:00;

- the briefing at the working place, for presentation the workplace risks and corresponding means. Sometimes, this training must be repeated at some time intervals and is accompanied by practical demonstrations;
- the training periodically made to work by the head master. It can be even made monthly.

The labor protection training is mandatory recorded in an individual protection sheet. At each individual workplace must be explicitly assigned work and safety instructions. For emergency situations, technical documentation is prepared, in which are mentionned:

- incidents that may occur (leakage / spills of dangerous chemicals, uncontrolled releases of gas / vapor, uncontrolled exothermic reactions, explosions, fires etc.);
- assessing the risks and repercussions on employees;
- necessary measures to minimize impacts; procedures for emergencies are written.

For jobs that are particularly dangerous, the rescue teams specially trained for first aid are organized. Whether or not meet the conditions of an occupational accident, the employer must notify the territorial Labor Inspectorate about the occurrence and gravity.

All management activities are conducted in accordance with existing legislation, including Law 90/1996 on labor protection [7], environmental protection laws [8], the regime of explosive materials, packaging of dangerous chemicals, regulations, decrees, orders emergency [9,10].

Unfortunately, in Romania there have been accidents with serious implications for environmental technical and local public health or the nearby border. Critical areas have been delimited, which systematically exceeded environmental quality indicators. It is estimated that most accidents are caused because of design errors, industrial installations, the high degree of wear, but also because of mismanagement [11].

In Bucharest and Alba, Constanta, Dolj and Timis counties there are the most economic agents that use highly toxic substances or materials with specific toxic properties, allergenic, carcinogenic or mutagenic, flammable or polluting the environment. The cities as Pitesti, Ploiesti, Craiova, Slatina, Alexandria, Bacau, Miercurea Ciuc, Focsani, Braila, Galati and Cugir are most vulnerable as technological accident. If Arpechim Company in Pitesti could cause an accident, taking into account the amount of harmful substances currently stored by the operator the area of intoxication would be spread over five kilometers distance. The most common industrial chemicals used in the chemical enterprises are: ammonia, chlorine, carbon dioxide, oxides of nitrogen and phosphorus, petroleum products and derivatives, sulfuric acid, hydrogen cyanide, carbon monoxide. Besides the immediate effects, long-term effects are not negligible because the formation of smog, acid rain, losses of valuable animal and vegetal species, sealing of agriculture or turistic lands, payment of compensation to national and international level. We can appreciate that completely genetic effects that affect human health and lifetime are unknown, yet.

Conclusions

The Council of Europe adopted Directive. 85/501/CEE on major accidents recorded in certain industrial activities (Seveso Directive is a representative). Major hazards legislation was implemented in Romania since 2003. The chemical industry is an industrial area with high-risk problems to be prevented in order to avoid catastrophic situations. For prevention the occupational accidents and occupational diseases is necessary to create a risk management system that includes: (i) ways and means for strictly regulated and effective communication with subordinates, suppliers, beneficiaries, the competent bodies; (ii) procedures for monitoring and evaluating activity; (iii) initial analysis and risk control assessment, audit and analyze the results of implementation of labor protection measures. Certainly, these risk management measures should be added to the technological measures as modernization of facilities, automation, replacement of hazardous technologies, cleaner technologies with low risk.

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