Impacts of major accidents for the environment

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Storage, processing and use of dangerous substances, which are present in the economic activity, involve risk of occurrence of major industrial accidents. According to the experience of recent history the accidents could result in catastrophic effects on environment of dangerous establishment and citizens living there. A discussion about some events, which caused serious environmental impact and a short description and evaluation about the environmental risk assessment methods are given.

Introduction

Many activities in a modern society are connected to the production and use of man-made chemicals. After World War Two intensive work in chemical laboratories resulted in a dramatic increase in the synthesis and isolation of new chemical compounds. In 1942, a mere 600 000 chemical compounds were known. In 1947, this number had increased to 4 million and since then the total number of identified chemical compounds has risen to around 11 million. At many stages during the production, transportation, storage and use of many of these chemicals there is a risk that accidents will occur, both the possibility of occurrence and the severity of possible accidents depending on the chemicals concerned.

The largest overall environmental impact of chemicals is due to diffuse and continuous discharges from human activities such as industry, transport and agriculture. These activities are also the most intensively investigated. Nevertheless, chemicals released through accidents and other sudden, isolated events also affect the environment (and human health). Many severe chemical accidents in recent history have affected the environment (and humans).
Environmental effects caused by major industrial accidents

Seveso accident, 1976 Italy

The Seveso accident happened in 1976 at a chemical plant manufacturing pesticides and herbicides. Poisonous and carcinogenic dioxin was released from a reactor. The contamination concerned some ten square miles of land and vegetation. More than 600 people had to be evacuated from their homes and as many as 2,000 were treated for dioxin poisoning.

Sandoz accident, 1986 Switzerland

During the night of November 1, 1986, the Upper Rhine River near Basel in Switzerland turned blood red. There was a large fire in the storehouse of the Basel chemical company Sandoz. Along with 20,000 m³ of water used to fight the fire, approx. 30 metric tons of pesticides and dyes entered the Rhine. As a consequence, in the southern Upper Rhine, 150,000 eels and countless other types of fish and small animals were estimated to have died. This “pesticide death” in the Upper Rhine developed into an immense media and political event. Only one year later, poisonous “killer algae” proliferated in the North and Baltic Seas, killing thousands of seals. The resonance in the media – and following in politics – of the disaster in the North and Baltic Seas was even greater than that of the “Sandoz poison wave”. In the face of public outrage, quick political action was essential; and legislation concerning water protection was significantly heightened.³

Cianide spill in Baia Mare, 2000 Romania

On January 30 at 22:00, there was a break in a dam encircling a tailings pond at a facility operated by Aurul SA Company in Baia Mare, northwest Romania. The result was a spill of about 100,000 cubic meters of liquid and suspended waste containing about 50 to 100 tonnes of cyanide, as well as copper and other heavy metals. The break was probably caused by a combination of design defects in the facilities set up by Aurul, unexpected operating conditions and bad weather. The contaminated spill travelled into the rivers Sasar, Lapus, Somes, Tisza and Danube before reaching the Black Sea about four weeks later. Some 2,000 kilometres of the Danube’s water catchment area were affected by the spill. Romanian sources said that, in Romania, the spill caused interruptions to the water supply of 24 municipalities, and costs to sanitation plants and industries, because of interruptions in their production processes. Romania also reported that the amount of dead fish was very small in Romania.
Hungary estimated the amount of dead fish in Hungary at 1,240 tonnes. Yugoslavian authorities reported large amounts of dead fish in the Yugoslavian branch of the Tisza River and no major fish kills in the Danube River.²

**Regulations relating to prevention of environment in case of industrial accident**

The complexity and increasing flow of chemicals has resulted in more rigorous demands being placed on both authorities and industrial facilities that handle chemicals to estimate the risks involved. Industry is responsible for taking appropriate measures to handle chemicals safely and the authorities are responsible for giving appropriate guidelines.

*Seveso Directives*

The release of dioxin from a plant near Seveso had severe consequences for both the environment and human beings. This accident, and subsequent incidents, resulted in Council Directive 82/501/EEC, more commonly known as the Seveso Directive, following three years of negotiation in the European Council and European Parliament. This directive was reviewed and updated in 1996 resulting in the implementation of the Seveso II Directive (Council Directive 96/82/EC). The Seveso Directives are “… aimed at the prevention of major accidents which involve dangerous substances, and the limitation of their consequences for man and the environment, with a view to ensuring high levels of protection throughout the Community in a consistent and effective manner.”²


*Helsinki Convention*

The Convention on the Transboundary Effects of Industrial Accidents was adopted in Helsinki on 17 March 1992. It is designed at protecting human beings and the environment against industrial accidents by preventing them as far as possible, by reducing their frequency and severity and by mitigating their effects. It promotes active international cooperation between the contracting Parties, before, during and after an industrial accident.

Environmental Impact Assessment

Environmental Impact Assessment (EIA) is a well-established method, which can be used as a tool to harmonise the granting procedures for planned projects and certain human activities.

The purpose of the rules on EIA is to assess possible impacts of projects on the environment as early as possible in the decision-making processes and to ensure a proper information and consultation of the public about the project. This procedure is carried out for certain types of projects that are likely to have significant environmental impacts.

A European Council directive, 97/11/EEC, is the basis for rules on EIA in the member states of the European Union.

The adoption of the Convention is ordered in the Government Decree 20/2001. (II. 14.) in Hungary.

Integrated Pollution Prevention Control (IPPC)

The Council of the European Union adopted the IPPC Directive in September 1996, to bring about an improved and more consistent approach to environmental protection across the European Control. The Directive was based on the UK System of IPC, although it contains some important differences and new elements. In particular, alongside the release of polluting substances the Directive is concerned with further issues such as energy efficiency, consumption of raw materials, noise, prevention of accidents, waste minimisation and recovery, and restoration of the site after use. It also embraces a wider range of industrial operations, bringing in activities such as intensive animal rearing, food production and waste management to the framework of integrated control. Additionally, it regulates the installation as a whole rather than the individual industrial process, which was the focus of IPC. Furthermore, the setting of permit conditions under the Directive is to be based on in Best Available Techniques (BAT).

Within this overall aim, PPC has a number of specific objectives: It takes into account the risk of accidents affecting the environment. The need to prevent accidents and minimise their consequences will be reflected in identifying BAT and determining permit conditions for PPC installations.4

The role of authorities in preventing environment in case of industrial accident

The authorities responsible for dealing with chemical accidents at a local level in Hungary are the Environmental (EPO) and Health Protection Departments (HPD) and the Organisations of Disaster Management (DMO) of the 19 counties and the capital. Unless the accident is very large and complex, in which case other authorities could also be involved; personnel from the EPO, HPD and the DMO are responsible for taking all the appropriate decisions. An alarm notifies the DMO, which is usually the first authority to arrive at the accident site. The DMO must respond to accidents in order to prevent and restrict damage to people, property and the environment. The HPD is usually the second authority to send representatives to the accident site, and they are in charge as soon as the DMO personnel have completed their tasks.

The DMO takes the first damage-limiting measures and at the same time notifies the EPO that the accident has occurred. The objective for the EPO is to assess the potential hazards to the environment at the accident site and to make sure that proper actions are taken to limit damage. This quick assessment is based on information about both chemical and site-specific properties, including the likely spread and impact of the chemical.

The responders have to consider at an accident site a lot of factors. Some of these factors include: the type of chemical(s) involved, the amount spilled, the properties of the chemical, the likely routes and rapidity of its dispersal in the environment, its toxicity, and features that it may affect.

Other important actors at the accident site may include staff from the facility that was handling the chemical (e.g. factory or chemical warehouse). In most cases these people have extensive knowledge about the chemicals and their behaviour, and can thus give essential information about the environmental risks they pose. The industries involved are of course also responsible for the precautionary measures taken to avoid accidents and limit the damage in case of an accident. Due to the number and wide range of existing chemicals it is unfeasible to assess the environmental effects of each and every one of them. Furthermore, data related to factors such as their toxicity, bioavailability, degradation and potential synergistic and antagonistic effects are only available for a minor fraction of the chemicals. Thus, making a proper assessment of the environmental risks after a chemical accident is not straightforward.

The problems related to chemical accidents include the potential scale of their effects, their unpredictability and the uncertainties of their consequences. These problems, in combination with the lack of data and the complexity of the environment, make the task of environmental risk assessment (ERA) appear to be almost impossible. Therefore, tools such as indicators, indices and other models for ERA have been
developed to assist and facilitate such assessment. Risk assessment (RA) is not a new concept, although its application in a structured analytical format to environmental issues and policy is a relatively new development. Since the 1980s, ERA has not only advanced dramatically, but has also challenged the established views that science is inviolable and that experts are never wrong. Although systems for ERA have been under development for several decades, problems such as lack of knowledge about chemicals’ properties, their behaviour in the environment and site-specific properties, the complexity of the environment and the lack of a good system for assimilating lessons learned still need to be resolved. The next part of this article shows the current main environmental risk assessment models.

### Environmental risk assessment models

#### The chemical risk database

The chemical risk database, developed in Switzerland is a database for registering dangerous goods in a certain area. The information in the database is used to make risk assessments of the current situation, mainly from a health risk perspective. From this assessment it should be possible to prioritise the risks from the most to the least acute, and thus take appropriate safety precautions. The advantage with this model is that it is possible to handle large amounts of data in a relatively short time. The first step in the assessment process, using the chemical risk database, is to define the area to be assessed. The second step is to collect data about relevant chemicals (individually, not in classes) and the amount of each chemical involved. The next step is to calculate the damage-potential for each chemical, which depends on the amount and toxicity of the chemicals, and will always be the same for each specific chemical, regardless of the surrounding environment. The potential damage occurs only when the chemical is related to an accident scenario. Six accident scenarios are defined, based on the nature of the causal events spill, fire, explosion and flooding. A computer program, C-RISK handles the large amount of information generated, and calculates the damage potential automatically.

*Comments on the model:* The model is aimed to provide an overview of the accumulated specific risks within an area and give some order of priority. The damage potential is a useful tool for making a relative assessment of the potential hazard within an area, e.g. one factory compared to another. This comparison makes it easy to decide where to place the most effort. However, the model is primarily focused on humans rather than the environment. One disadvantage with this model is that it is limited to the
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specific scenarios, and does not cover other types of accidents. The model also distinguishes between different types of chemical accidents, and is designed to consider releases to air and fire scenarios. The model is quite complex to calculate because of the many intermediate steps that need to be calculated and special software is required for the storage of data and computation involved. This can be disadvantageous for the distribution of the model to authorities and other actors, as they may regard the model as too complex and expensive to use.

**Risk Index Z**

Risk Index Z or “Classification system of the substances endangering subsoil and groundwater quality: Criteria for the notification of major accidents and hazardous installations” was developed as part of an EU-project at the Joint Research Centre (JRC) in Ispra, Italy. The model was created for the prevention of soil and groundwater damage due to chemical spills. The model considers the inherent properties of the chemical(s), such as their toxicity, viscosity and water solubility. Risk Index Z has three components: toxicity (T), mobility (M) and Persistence (P). The toxicity component is based on the R-phrases, which are already in use within the EU; the mobility component includes terms for density, vapour pressure as well as viscosity and water solubility. The properties are judged according to different tables and assigned an index number. The different indices are then summarised and assigned a mobility class (less, moderate or very mobile), and different classes have different mobility indices. Finally, the persistency component assesses abiotic, anaerobic and aerobic degradation, and the different degradation paths are assigned different index numbers.

The Risk Index Z is the product of the three partial indices, T, M and P:

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\text{Risk Index } Z = T \times M \times P
\]

The index is then classified on a four-grade risk scale (classes 0-III).

**Comments on the model:** This model is interesting as it is the only index-based model available that is focused on the environment. However, the model is probably developed rather for describing long-term effects than acute effects in the environment. The assessment of the toxicity is based on the R-phrases, which might be a good approach as long as there are expressions for all the types of chemicals that may be involved. The mobility component seems to be relatively thoroughly assessed because the sorption and retention of the chemicals are considered as well as more obviously mobility-related factors. The persistency component considers both abiotic and biotic degradation pathways, indicating a focus on long-term perspectives. The Risk Index Z, can be used to make assessments of mixtures as well as pure compounds, but it does not consider synergistic or antagonistic effects. The disadvantages with the model are that site-specific
properties and the spilled amount of the chemical are not included in the index, and must therefore be considered afterwards, together with the derived risk index. The model is probably quite complicated to use, and another concern is that R-phrases and degradation data are only available for a limited number of chemical compounds.

Environment-Accident Index

The majority of the models do not attempt to combine site-specific variables (e.g. soil and water variables) with inherent properties of the chemicals, (e.g. toxicity, density and volatility), but focus only on the chemicals and their inherent capacity to harm the environment. However, the Environment-Accident Index (EAI) is an exception, since the rationale for its development was to obtain an assessment tool combining properties of the chemicals with site-specific properties.

This model was deliberately formulated as a simple equation in order to facilitate and increase its applicability. The objective of the EAI is to provide a quick and simple tool to guide the identification and ranking of chemical accident scenarios in a planning process. The EAI can indicate the kind of further assessment that should be performed and what predictive measures should be taken for each specific scenario. The EAI can be used in planning processes by both appropriate authorities and industrial concerns that handle chemicals. The EAI is based on a few chemical variables and site-specific variables such as soil and groundwater conditions. It consists of three components: the acute toxicity to water-living organisms, represented by \( \text{Tox} \); the stored or transported amount of the chemical, represented by \( \text{Am} \); three factors affecting the spread of a chemical \( (\text{Con}, \text{Sol} \text{ and } \text{Sur}) \). \( \text{Con} \) is the consistency or viscosity/physical state of the chemical, \( \text{Sol} \) is the water solubility of the chemical while \( \text{Sur} \) describes its potential to penetrate soil, together with the depth and mobility of groundwater.

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EAI = \text{Tox} \cdot \text{Am} \cdot (\text{Con} + \text{Sol} + \text{Sur})
\]

In more detail, \( \text{Sur} \) expresses the properties of the surrounding environment (site-specific properties) in terms of

1) Distance, in metres, to the nearest well, watercourse or lake
2) Depth to the groundwater in metres
3) Whether the groundwater surface is inclined towards a well, lake or watercourse or if it is horizontal
4) The thickness, in metres, of the soil and the material it consists of, for example gravel, sand, moraine, silt, clay or frozen ground.

After the EAI has been calculated, it can be used to identify the level of risk assessment required for a given scenario according to a set classification scale. The
classification scale was constructed to facilitate the ranking and prioritisation of different accident scenarios to help prevent chemical accidents or to limit damage following an accident. Three classes, with different levels of action to be taken, were considered sufficient to spread the accident scenarios.

Three-graded classification scale to determine the need for further risk assessment:
- **EAI: 0-100** Hazard Analysis concerning the inherent properties of the chemical should be performed
- **EAI: 100-500** Hazard Analysis + Introductory ERA should be performed
- **EAI: > 500** Hazard Analysis + Introductory ERA + Advanced ERA should be performed

Comments on the model: The EAI is specifically related to Swedish organizations in terms of the agents involved and the recommended actions. Nevertheless, this does not hinder its implementation and use in countries with different administrative structures for handling chemical accidents. EAI is valid for discharges to ground, water or groundwater but it is not applicable to fires, explosions or accidents in which gases are released to the air. EAI can be used to assess the acute phase of an accident. Further, it can be applied to certain positions along a transport route as a particular location can be considered to have the same conditions as a permanent establishment, e.g. an industrial site. However, the EAI cannot be applied to entire transport routes, as such uses also require the consideration of probability aspects.³

Conclusion

Discussing and evaluating the different risk assessment methods it can be concluded that a generally usable method does not exist. The different methods can cover smaller or bigger segments of risk assessment and they can use to describe some risks but a lot of work needs to be done in this field.

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