International Proceedings of Chemical, Biological and Environmental Engineering, Vol. 88 (2015)
DOI: 10.7763/IPCBEE. 2015. V88. 17

An Approach for Environmental Risk Assessment from Flood in Chemicals Substances Storages

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Abstract. The actuality of this paper is the issue with the storage of chemicals substances and the frequent floods in the world in recent years and associated with the increasing consequences. The paper proposes an approach for the analysis of environmental risks associated with floods of chemicals substances storages. The proposed approach is based on the modification of two methods of ISO/IEC 31010:2009, more specifically „Fault Tree Analysis" and "Tree of events". The first method is modified to determine the likelihood of flooding the storage from potential sources of flood. The second modified method enables with the occurrence of negatively event - flooding of the storage, to analyze possible scenarios of manifestation of the environmental risk caused by the interaction of water with the different types of chemicals substances stored inside.

Keywords: environmental risk assessment, flood, fault tree analysis, tree of events, chemicals substances

1. Introduction

Frequent floods worldwide (2013-2015) and the increasing consequences of the floods are the reason to write this article. Risk assessments are usually made for the population directly affected by the floods. However, based on literature data, there are not sufficient risk assessments for flooding of industrial and commercial sites, their farms and storage as well as other non-residential buildings. Furthermore, insufficient attention is paid to the environmental damages that are consequences of flooding of industrial sites, storing hazardous materials.

The main stages in the risk assessment are identification, analysis and risk evaluation. Some international standards are used in assessing risk: ISO 31000: 2009 "Risk management - Principles and guidelines" [1] and ISO/IEC 31010:2009 " Risk management – Risk assessment techniques " [2]. These two standards are based on the best practices for assessing and managing any kind of risk, including all possible environmental risks [3]. There are several factors that determine the choice of a suitable method of risk analysis for a specific object of a hazard: complexity of the problem, the uncertainty of the target information and the danger, the necessary resources and expertise [4], [5].

Flood of an industrial site can be defined as a temporarily flooding of a particular part of the site with water due to a tremendous amount of water mass entrance. The reasons for increasing the amount of water per square meter might be different: heavy rainfall, rapid melting of a thick snow pack, ice jams, or more rarely, the failure of a natural or man-made dam [6], [7]

The environmental risk concerning the flooding problems in storing chemicals storages is problem of particular interest that is insufficiently investigated. Storages can store one or more types of chemical substances with different properties. Depending on the physicochemical properties of the chemicals, reaction

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with water of these chemicals can form compounds with different degree of danger to the environment. Note that some of these compounds could be extremely dangerous for the environment. Dangerous chemical substance is a chemical substance that upon reaction with water or other chemical compound, would release or form harmful substances that will have a negative impact on the environment [8], [9]. Examples of such substances are acids, bases, and chemical compounds that could react with water, gases, pesticides, and other oxidizing agents [10].

The aim of this study is to propose an effective approach for the analysis of environmental risks associated with flooding in chemicals substances storages. The proposed approach is based on the modification of two methods of ISO/IEC 31010:2009, in particular "Fault tree analysis" and "Tree of events." The first method is modified to determine the likelihood of flooding the storage taking into account potential sources of risk for flooding. The second modified method enables in case of negative event (flooding of the storage) to analyze possible scenarios for the manifestation of the environmental risks caused by the interaction of water with the stored (deposited) chemicals with different properties.

2. Modification and Application of "Fault Tree Analysis" Method for Environmental Risk Assessment from Flood in Chemicals Substances Storages

The Fault Tree analysis method identifies and analyzes the factors that may contribute to a specific undesired event. Causal factors are determined by the method of deduction, organized in a logical manner and are built in a tree diagram. The method can provide a high quality level to determine the causes or quantitative level for the calculation of the probability of the final event.

In the process the main steps to be carried out are:

In the process the main steps to be carried out are:

- Determination of the final event that sold be analyzed;
- Possible immediate causes leading to the final event;
- Consecutively establishment of the undesired effects leading to the next levels.

For example, flooding in the storage can be caused by several sources of risk and different hazards: heavy rain as a ground source may be accompanied by an influx of water from the river flows as ground source.

The more sources of danger to flood the store and associated natural disasters, the greater is the possibility to adverse consequential risk of flooding.

An application of the "Fault Tree Analysis" method in case of flooded storage with chemicals substances due to three different sources is shown on Fig. 1.

The results of the risk analysis based on the proposed method can be successfully used in the choice of preventive measures to reduce the risk of flooding of the storage.

For example, in case of above-ground sources of risk the roof's constructions should be constructed from sustainable materials and substantial. Furthermore, the stored chemicals should be further covered with waterproof cloaks in order to better protect the site from water penetration.

In the case of land-based sources of flood, it is desirable to build collector vessels in the storage for chemicals in order to prevent further interaction between the water and the chemicals. It is also necessary to build a barrier against the immediate swelling of water into the storage.

The chemicals should be arranged in groups by their chemical reference as following: acids, bases, oxidizing substances, combustible substances, etc. The aim of these to prevent mixing of the compounds in in case of an accident. When the sources of flood are underground all of the substances must be stored within a distance of 30 cm from the floor of the store.

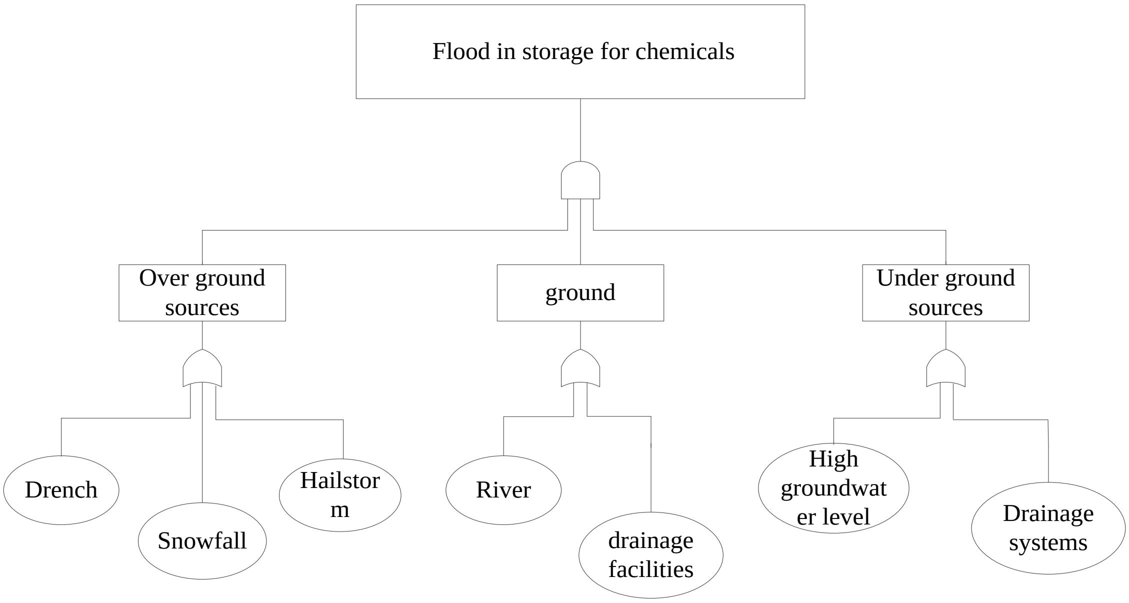

Fig. 1: An exemple for an application of ”Fault tree analysis” method for environmental risk assessment from flood in chemicals substances storages

3. Modification and Application of “Tree of Events” Method for Environmental Risk Assessment from Flood in Chemicals Substances Storages

The method of analysis through the “tree of events” is a graphical method of representing mutual excluding sequence of events following the initial event, in accordance with how a process works and what direction it can be directed in order to prevent the negative consequences. It can be applied qualitatively as well as quantitatively. The nodes are in a tree form, and indicate the level of the events in response to the initial event, respectively, higher or lower levels.

Building the tree of events starts with the selection of an output event. After which processes that reduce the consequences are built. For each line it may be given a probability chance by experts.

Events in the tree represent the probability that all will occur. Therefore, the frequency is typically expressed numerically as the product of individual conditional probabilities.

Fig. 2 shows a schematic diagram of the “Tree of events”, related to the level of environmental risk, analyzing possible scenarios for the manifestation of the environmental risks caused by the interaction of water with the stored chemicals having different properties.

Problems that may arise in case of flooding of storages for storage of chemicals are determined by the possible chemical interactions between substances stored in the stocks. Some chemical compounds react immediately with water with consequent emition of flammable gases. For instance in reaction of alkali metals (Lithium, Sodium, Potassium) with water are possible the following reactions of emition of Hydrogen:

$$2Li+2H_2O \rightarrow 2LiOH+H_2$$

$$2Na+2H_2O \rightarrow 2NaOH+H_2$$

$$2K+2H_2O \rightarrow 2KOH+H_2$$

Hydrogen is highly explosive gas in the presence of an obstacle (ceiling and wall of the storage) can lead to an explosion in the storage for storage of chemicals. This explosion may further rise to a chain of reactions of ignition of some of the other stored chemicals that do not react directly with water.

There are chemical substances which upon reaction with water release toxic gases. For example, reactions of a metal phosphide (calcium, aluminum phosphide) with water, proceed with evolution of phosphine which can be expressed by the following equations:

$$Ca_3P_2+6H_2O \rightarrow 3Ca(OH)_2 + 2PH_3$$

$$AlP+3H_2O \rightarrow Al(OH)_3 + PH_3$$

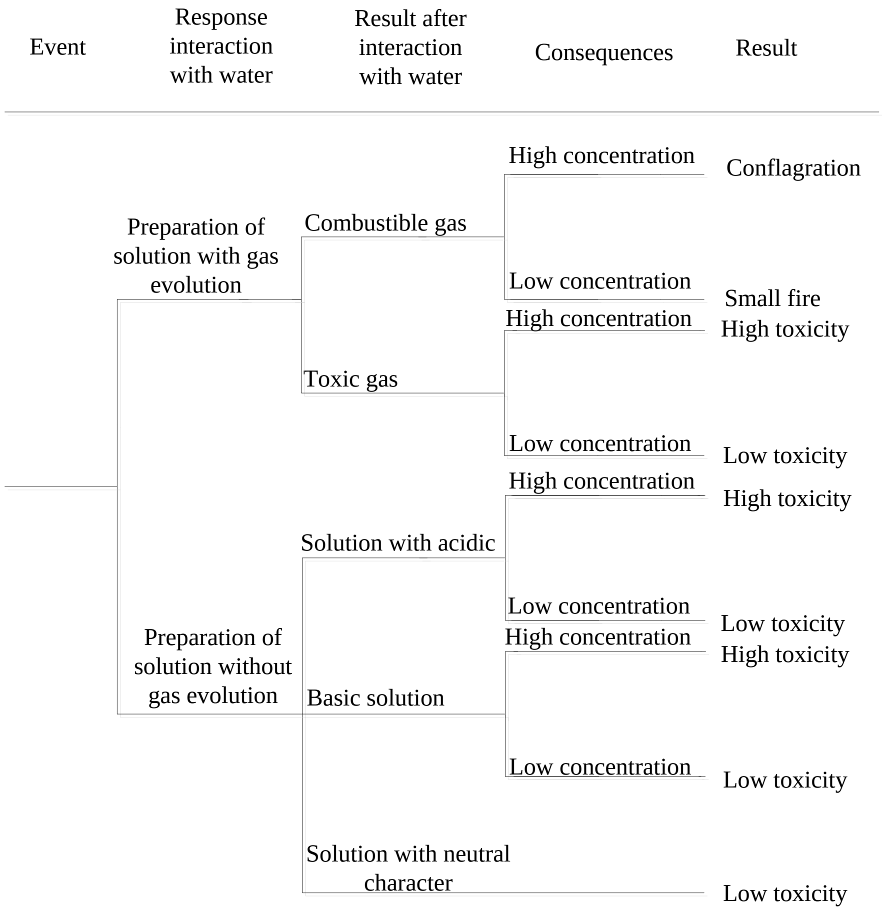

Fig. 2: An exemple for an application of ” Tree of events” method for environmental risk assessment from flood in chemicals substances storages

Phosphorus hydrogen is highly toxic gas. Some solid state chemical compounds are not flammable and do not release toxic gases. In contrast, such compounds (e.g. acids, bases, salts, pesticides, fertilizers, etc.) dissolved in water can harm the environment. In this case the concentration of the solution is of great importance. Large quantity of chemicals stored in storage in reaction with water (in case of flood) would penetrate into the soil thus causing annihilation of both flora and fauna.

The packaging of certain chemicals can be damaged under the force of the water, leading to chemical reactions among the substances. As a result of this interaction toxic gases would emit in the atmosphere which causing negative effect on the flora and fauna. An example of such interaction is a chemical reaction between strong oxidizing agents and acids. For example, the interaction between sodium hypochlorite and hydrochloric acid that can be described by the following equation:

$$NaClO + 2HCl \rightarrow NaCl + H_2O + Cl_2$$

As a result of this reaction chlorine, highly toxic gas for both humans and the environment, is emitted in the atmosphere.

Fig. 3 represents a diagram of a tree of events with specific chemicals, the effects of interaction of these substances with water, and the product obtained as a result of the chemical reactions. Levels of environmental risk are analyzed specifically in terms of emitted gases. By tracking the nodes of the tree one can observe consecutive events accompanying the process of gas evolution by the reaction of sodium with water and of aluminum phosphide with water. The tree of events may be applied to different scenarios of the level of environmental risk, depending on the quantities of stored starting chemicals.

For example, reaction of 10 kg sodium metal, stored in the storage, with water would release 0.434kg explosive gas (hydrogen). Based on literature data hydrogen is extremely explosive, though there are no data for the maximum permissible concentration of hydrogen. This means that the released amount of hydrogen would be enough to blow up part of the storage. When smaller quantities of sodium are stored in the storage, the reaction of sodium with water would result in evolution of hydrogen too. In this case this reaction would cause local damages only.

The quantity of the emitted toxic gas for reaction of 10 kg of aluminum phosphide with water (in case of flood) is calculated to be 5.9 kg. According legislation limit, concentration of phosphorus hydrogen is $0.1 mg/m^3$. This means that the released amount of phosphorus hydrogen described above is well above the permissible concentration, which is a precondition for ecological risk. The amount of gas evolved can be calculated based on the amount of the substances stored in the storage.

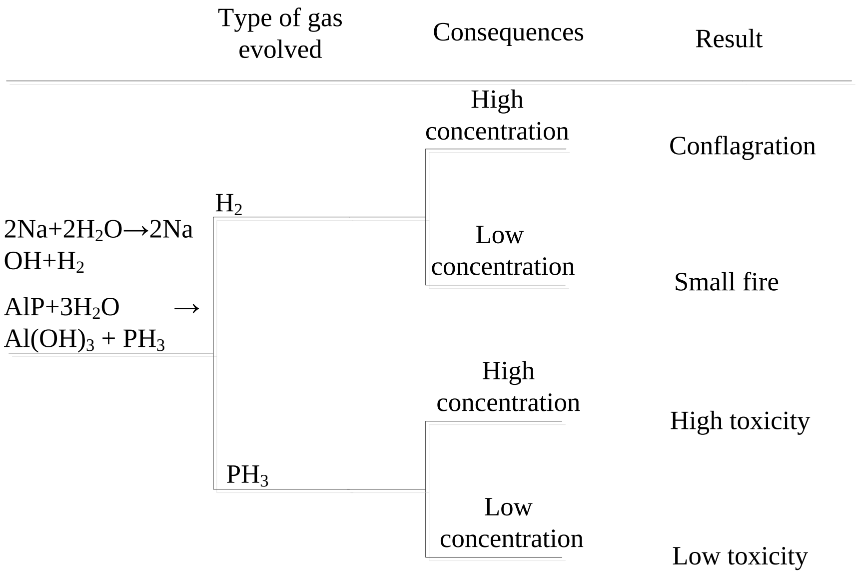

Fig. 3: A diagram of “Tree of events” with specific chemicals

The Fig. 4 draws the picture that by penetration of water in the storage substances fully or slightly soluble in water can be carried by it and chemicals such as HCL, NaOH, NaCL are likely to give a solution of high or low concentration. Depending on the concentration it can be judged if there is any eco toxicity. At high concentration of solutions and in dependence of the kind of the substance, destruction of flora and fauna will be monitored.

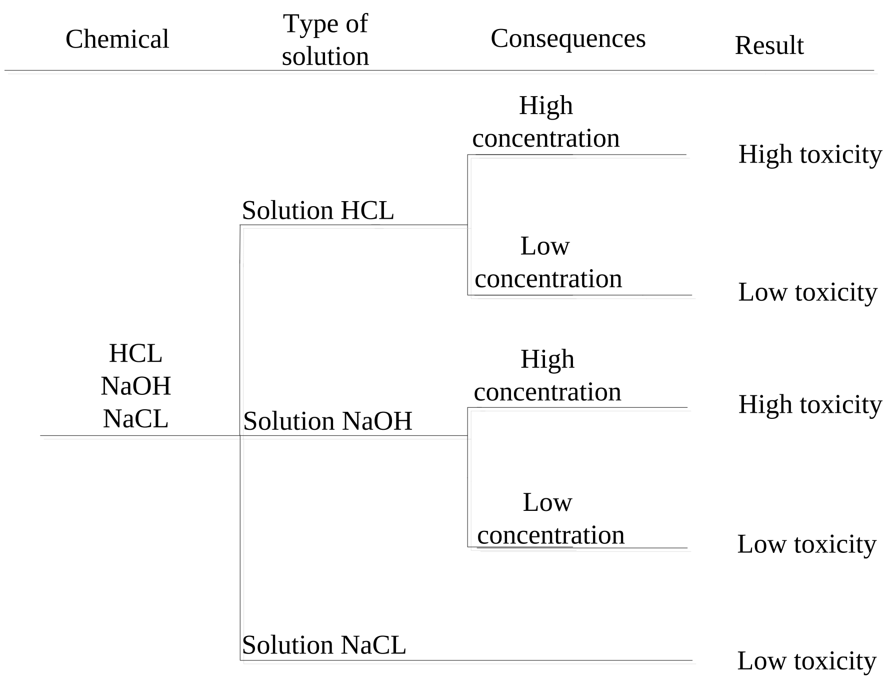

Fig. 4: A diagram of “Tree of events” with specific chemicals soluble in water

4. Conclusions

The study proposes an effective approach for the analysis of environmental risks associated with flooding in chemicals substances storages. This approach is developed on the basis of the modifications of two methods of ISO/IEC 31010:2009, in particular "Fault tree analysis" and "Tree of events." The first method is modified to determine the likelihood of flooding the storage taking into account potential sources of risk for flooding. The second modified method enables in case of negative event (flooding of the storage) to analyze possible scenarios for the manifestation of the environmental risks caused by the interaction of water with the stored (deposited) chemicals with different properties.

5. Acknowledgements

The authors express their gratitude to the Bulgarian National Science Fund for the considerable opportunity for Bulgarian – Chinese scientific cooperation under the Grant № DNTS/ China 01/6 from 2014 and for the partial financial support of this publication under the Grant № DFNI - I02/15 from 2014.

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