A MODEL FOR FLOOD RISK ANALYSIS OF PESTICIDE STORAGES

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Abstract

The reason for writing this article is the issue with the storage of pesticides and fertilizers probably contaminated with pesticides and the frequent floods in the world in recent years and associated with the increasing consequences. The article proposes an approach for the analysis of environmental risks associated with floods of pesticide storages. The proposed approach is based on the modification of two methods of ISO 31010:2011, 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 pesticides stored inside.

Key words: *risk, pesticide, environmental, flood*

1. INTRODUCTION

In assessing the risk the following international standards are being used: ISO 31000:2009 "Risk management - Principles and guidelines" and ISO 31010:2011 "Methods for risk assessment". The main stages of risk assessment for the identification, analysis and evaluation of the risk. These two standards are the base of best practices for assessing and managing any kind of risk, including and all possible environmental risks. The choice of a suitable method of risk analysis for a specific object of a hazard is depending upon the complexity of the problem, the uncertainty of the target information and danger, the necessary resources and expertise.

Pesticides are chemicals for plant protection. There are different classifications of pesticides. Chemical composition are:

- Inorganic compounds - compounds of copper, sulfur, phosphorus, aluminum, etc.
- From the plant, bacterial and fungal origin – pyrethrins, nabazin, nicotine and other
- Organic Compounds - organochlorine compounds, organophosphorus compounds, derivatives of carbamic, thiocarbamic and ditiocaramic acid, nitro derivatives, heterocyclic compounds and others.

By way of applying pesticides are divided into several groups:

- Acaricidal - to combat arachnid pests
- Fungicides - Anti-fungal and bacterial diseases
- Herbicide - for weed control
- Algaecides - Anti-algae

Usually flood of industrial site means temporarily flooding of a particular part of the site with water. The reasons for increasing the amount of water per square meter may be different - heavy rains, melting snow, breaking of a dam walls and others.

Particularly topical and insufficiently investigated is the environmental risk associated with the flooding problems in storages, storing pesticides. In such storages can be stored only one kind of pesticide or different types of pesticides.

Chemicals depending on their chemical composition when interacted with water lead to higher concentrations of solutions, toxic gases are released, or they may fall directly into the soil, posing variety of risks to the environment, i.e. in small amounts they harm small areas, but in large quantities they can cover a large perimeter, even fall into water.

The purpose of this article is to propose an approach for the analysis of environmental risks associated with floods of pesticide storages. The proposed approach is based on the modification of two methods of ISO 31010:2011, 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 pesticides stored inside.

2. "FAULT TREE ANALYSIS" METHOD USED BY FLOODING OF STORAGES CONTAINING CHEMICAL SUBSTANCES

This method identifies and analyzes the factors that can contribute to a specific adverse event. Causal factors are determined by the method of deduction, are organized in a logical manner and are built in a tree diagram.

This method can give quality level for determining the causes or quantitative level to calculate the probability of the final event.

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

- Determination of the final event that should be analyzed.
- The possible reasons leading to the final event.
- The consecutive establishment of the adverse effects transitioning to next levels. The graphical representation of the occurrence of extreme events, showing the interacting ways in which two or more simultaneous events occur.

The method can be used for pesticide storages. This will help prevent or reduce the risk posed by the negative impact of various natural disasters. This article examines flooding of the pesticide storage from three possible sources of risk: ground, over-ground and underground.

Sources of risk depend from various hazards - natural disasters influence directly and/or indirectly due to malfunctioning of the related technical systems.

It should be noted that more than one type of hazards for each of sources of risk can occur, thus leading to floods in the storage. On the other hand several sources of risk can cause flooding in the storage.

Fig. 1 is an example of the Fault Tree Analysis by a flooded storage from three different sources.

The shown scheme gives an idea of the impact of potential types of hazards (root causes).

In the Fault Tree Analysis in Fig. 1 natural disasters, which directly and/or indirectly are the primary cause of flooding of the storage are as follows:

- Heavy rain, snow and hail by over-ground sources of risk;
- Critical levels of river flows, malfunctioning drainage facilities, due to various natural disasters;
- High groundwater level and malfunctioning drainage systems due to various natural disasters.

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

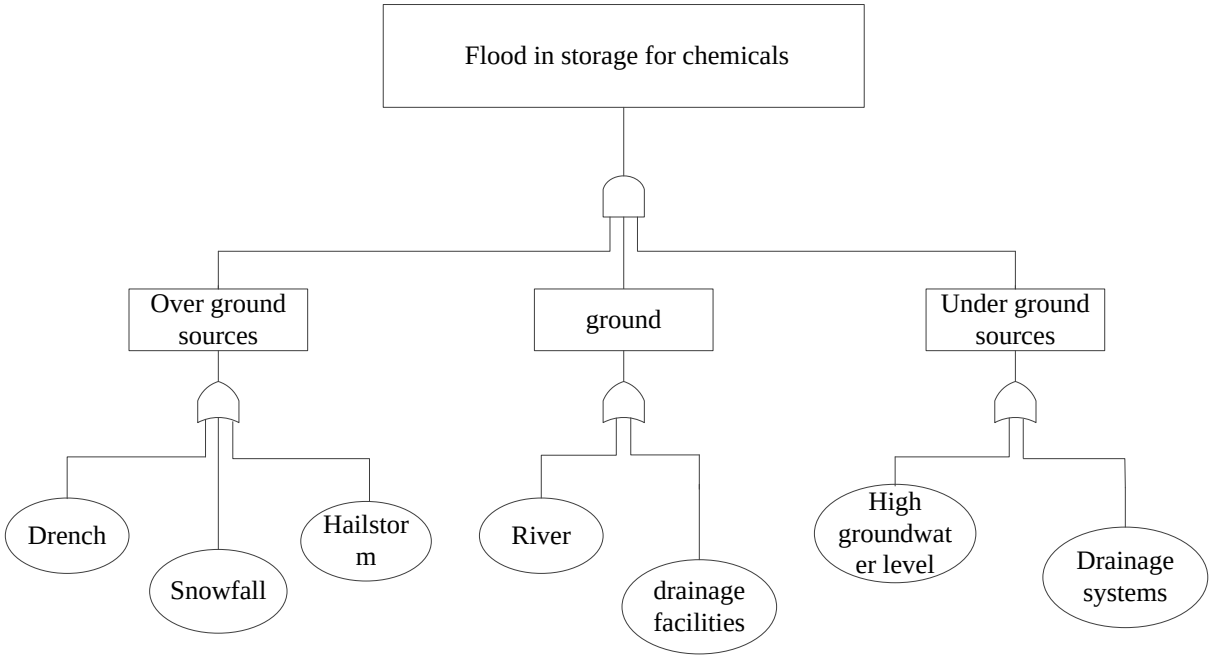


Fig. 1. Exemplary scheme “Fault tree analysis”

The results from the analysis of risk on the basis of the proposed method can be successfully used in the selection of preventive actions to reduce the risk of flooding of the storage.

For example, by over-ground sources roofs must not be damaged and made of durable materials. Further, the pesticides should be packed or additionally covered with waterproof material for better protection against water penetration.

By ground sources of flooding in chemical storages it is desirable a holding pond to be built in order to prevent water interacting with pesticides, also to build barriers for instantaneous influx of water storage.

3. ANALYSIS OF THE ECOLOGICAL RISK WITH A MODIFIED METHOD THROUGH THE “TREE OF EVENTS”

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.

Problems that may occur by floods of pesticide storages are predetermined by the type of pesticide stored and whether it is soluble in water and whether it releases toxic gases.

In some types of pesticide interaction with water toxic gases are being released. For example, metal phosphides (calcium, aluminum, zinc) in interaction with water release phosphorus hydrogen, consisting of the following equations:

- $Ca_3P_2+6H_2O \rightarrow 3Ca(OH)_2 + 2PH_3$
- $AlP+3H_2O \rightarrow Al(OH)_3 + PH_3$
- $Zn_3P_2+6H_2O \rightarrow 3Zn(OH)_2 + 2PH_3$

Phosphorus hydrogen is highly toxic gas.

In other pesticides toxic gases are not released, but depending on the amount that is dissolved in the water they can seriously influence the environment. Depending on the type and quantity of the stored pesticides their concentration varies. If quantities are large, concentration is high and when the pesticides penetrate into the soil vast areas are being damaged and in depth as well.

The Figure 2 shows an exemplary scheme of the "Tree of events", related to the level of environmental risk. The possible scenarios for the manifestation of the environmental risks caused by the interaction of water with the stored substances with different properties is being analyzed.

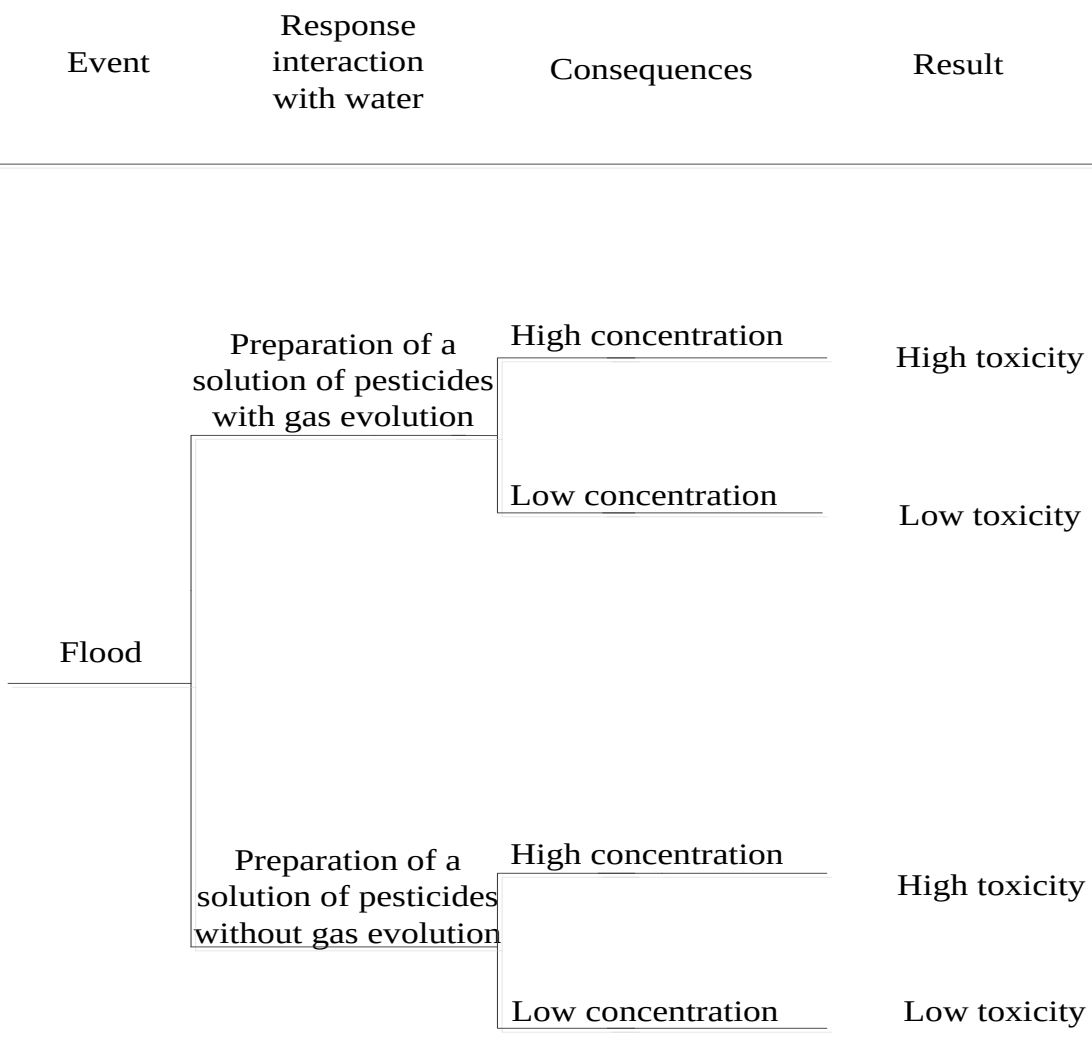


Fig. 2 Exemplary scheme of the "Tree of events"

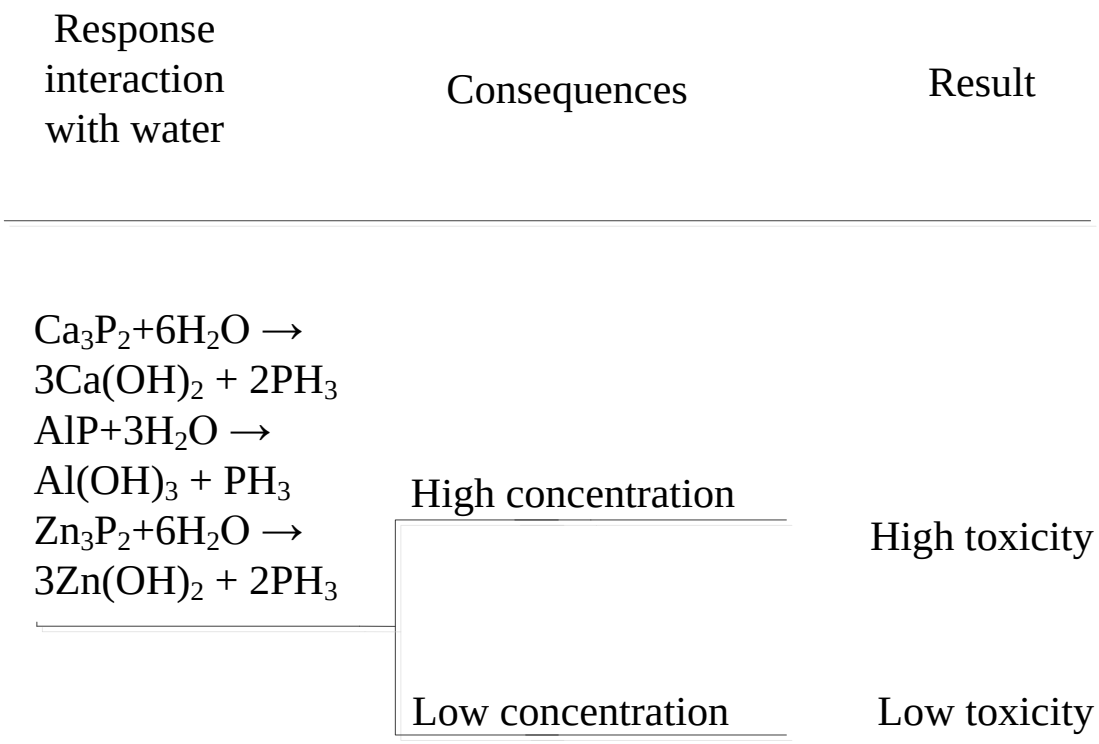


Fig. 3 Diagram of the "Tree of events" with specific chemicals

In Fig. 3 is shown a diagram of the "Tree of events" with specific chemicals and their effects after interaction with water. Specifically, levels of environmental risk regarding released gases are being analyzed. Following the branches of the tree, consecutive events are observed – gas is being released from a reaction to certain pesticide - aluminum phosphide with water, calcium phosphide, and zinc phosphide. Through the tree of events scenarios of the level of environmental risk can be applied, depending on the quantities of pesticides stored.

For example if amount of 10 kg. Aluminum phosphide is being stored in the storage, after calculations it turns out that if there is a flood 5.9 kilograms of the toxic gas Phosphorus hydrogen is being released. According to legislation single limit concentration of phosphorus hydrogen is 0.1 mg/m^3. I.e. the levels of released Phosphorous hydrogen are much higher than the permissible concentration, which is a premise for ecological risk. With the scheme it may be determined the outcomes of the damage to the environment, depending on the amount of stored pesticides.

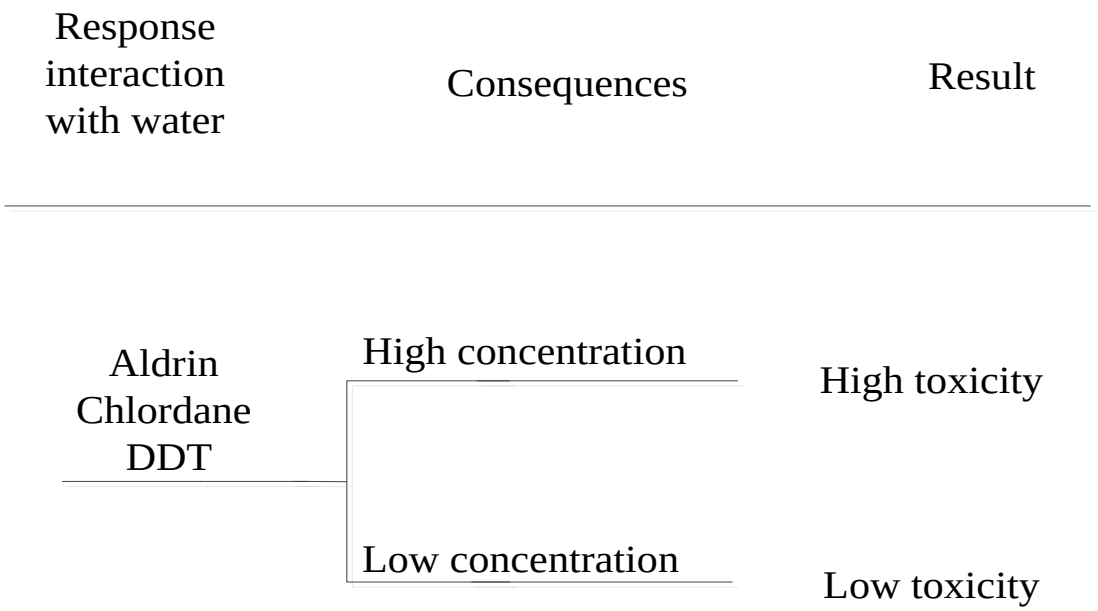


Fig. 4 Diagram of the "Tree of events" with specific chemicals soluble in water

The Figure 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 Aldrin, Chlordane, DDT and other substances 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.

4. MODEL TO CALCULATE TOXICITY

Based on modified methods of the tree of events was developed a computational model. On the basis of this model it is possible to provide quantitative consequences of flood storage of pesticides. The method is based on calculation of the amount of the resulting gas from the solution or the concentration of the solution of the pesticide itself.

The model can be represented as shown in Fig. 5

	Atomic weight of the compounds in g. per 1 mol				Atomic weight of the prepared compounds in g. per 1 mol			Amount of stored chemicals in g.	Theoretical yield starting material in mg.	Limit concentration in soils	Limit concentration in air	Limit concentration in water	Coefficient of pollution	Probit	Toxic dose
Compounds	**ALP**	**+**	**3H2O**	**→**	**AL(OH)3**	**+**	**PH3**	**ALP**	**PH3**						
Quantity in g per 1 mol	58	+	54	→	78	+	34	5000	2,93E+06	-	1,00E-05	-	2,93E+11	26,38	33,18
Quantity in g per 1 mol	58	+	54	→	78	+	34	10000	5,86E+06		1,00E-05		5,86E+11	27,77	34,57
Quantity in g per 1 mol	58	+	54	→	78	+	34	12000	7,03E+06		1,00E-05		7,03E+11	28,13	34,93
Quantity in g per 1 mol	58	+	54	→	78	+	34	15000	8,79E+06		1,00E-05		8,79E+11	28,58	35,38
Quantity in g per 1 mol	58	+	54	→	78	+	34	20000	1,17E+07		1,00E-05		1,17E+12	29,16	35,96

Fig. 5 Computational model

The first four columns illustrate the reaction of the pesticides with water. There is a certain amount of pesticide that is stored in the storage. In case of 5000 g Aluminum phosphide as pesticide it has been

found that a quantity of PH_3 as product will be $2.93.10^6$ milligrams. In the limit of air pollution 1.10^{-5} mg/m^3- pollution would exceed several times the permissible limits.

The graph below represents quantity of toxic gases that will be released in case of flooding as a result of the reaction of water with the pesticides.

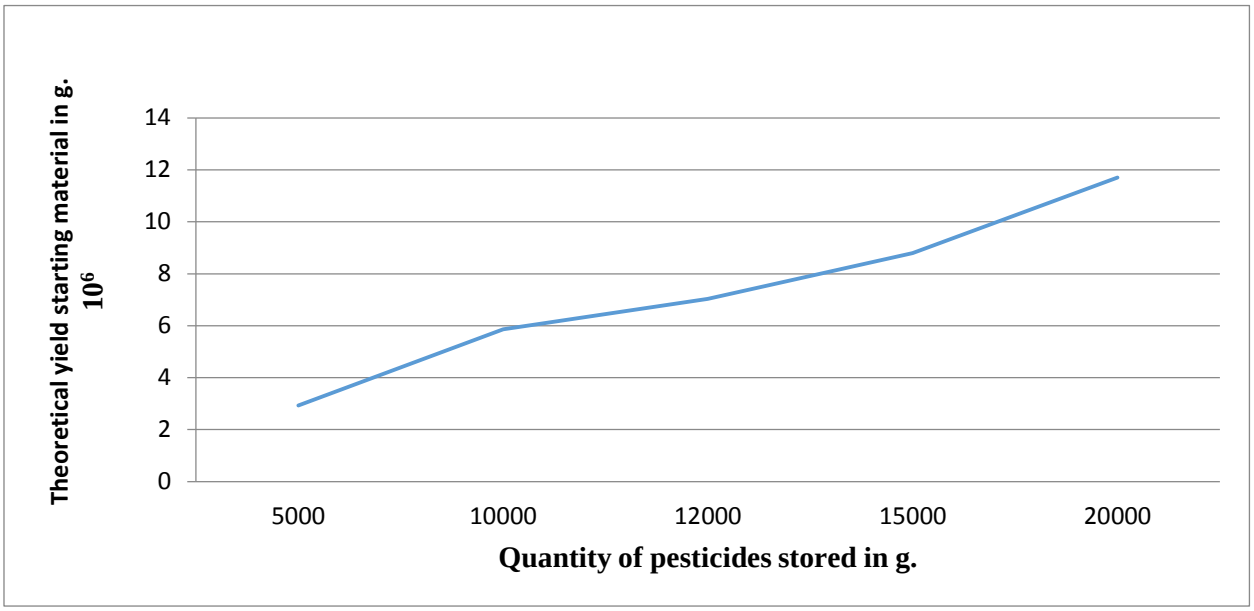


Fig. 6 Ratio pesticide - toxic gas

In case of 5000 g stored Aluminum phosphide the coefficient of pollution will be $2.93.10^{11}$ mg/m^3. This can be presented graphically and by the graph one can easily determine what is the amount of pollution in other quantities stored pesticides.

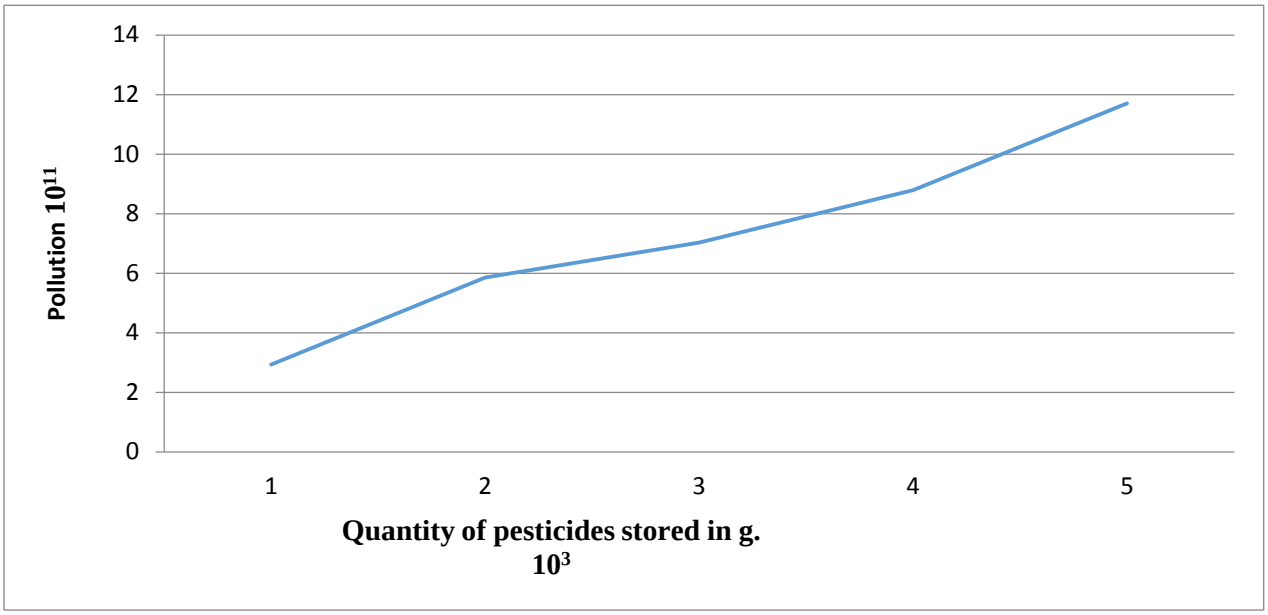


Fig. 7 Ratio pesticide - pollution

From the data of the table it can be calculated what are the toxic dose and the probability of death - Knock-magnitude Pr. Depending on the toxic dose is calculated the probability of death if corresponding toxicity of the gas in the air.

If the amount of pesticide is 5000 g it can be seen that the toxic dose of phosphine is 33.19 mg/m^3. Therefore the Probit will be 26.38 that is an extremely high value. Graphically we can show this by the following diagram.

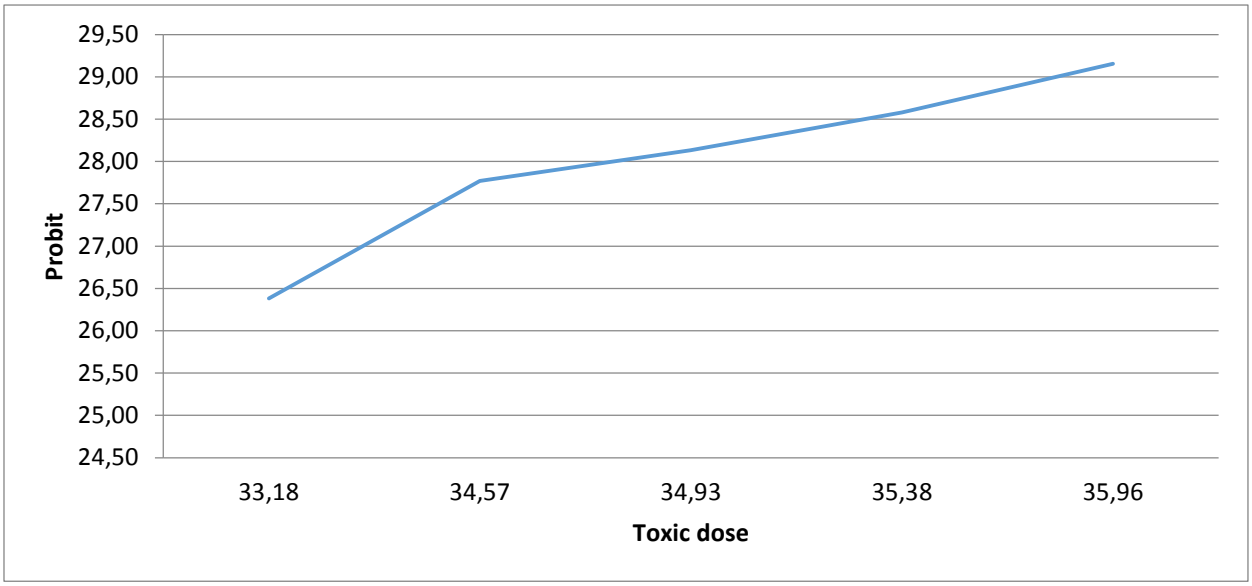


Fig. 8 Ratio Toxic dose - probit

5. CONCLUSIONS

By modeling scenarios for floods of hazardous chemical storages assessments of the risk for other natural disasters can be made. Following these models measures can be taken to reduce the negative effects on the environment.

From the article it can be concluded that the proper use of the known methods of the ISO 31010 standards can create scenarios useful by storage of hazardous chemicals, which can significantly reduce the effects of flooding and prevent the adverse impact on the environment.

The ever more often observed floods are a sign that these scenarios must not be ignored. Such conditions can cause major irreversible effect on the environment.

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