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Waste Risk Assessment in SEVESO Establishment - "Case Study"

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The goal of this paper is to aim at issue of hazardous waste management from the perspective of major accident prevention. Hazardous wastes usually perform a relatively small part from a total amount of dangerous substances used and stored in certain industrial activities classified under the SEVESO III Directive (European Commission, 2013). In case of hazardous waste establishment (e.g. hazardous waste incineration), completely different quantities of wastes with similar dangerous chemical properties (e.g. HP3-flammable, HP14-ecotoxic) are stored for purposes of next liquidation. This paper will focus on selected hazardous wastes which present the risk of a major accident, either alone or in the event of the formation of mixtures thereof, which may cause dangerous reactions.
A characteristic feature of the process of burning industrial waste is to mix various types of waste to achieve the required combustion temperature. For case study was selected hazardous wastes which are imported frequently and occur in the largest amount in the area of hazardous waste incineration. Identification of risk sources was realized within the establishment where hazardous wastes are accepted, reloaded and stored. In case of major accident which can lead to serious danger to human health or the environment were identified these accident scenarios:

- major fire on the facility containing flammable waste (liquid, solid)
- major release of ecotoxic liquid waste to the environment

First scenario can be caused by traffic accident inside the establishment, incident during the process of loading/unloading, hole in pipeline etc. Second scenario can lead to water contamination due to leakage on hard surface and next distribution via sewerage system. In case of flood direct release to the nearest watercourse can be considered. Finally, soil environment together with underground water can be endangered through the infiltration of liquid hazardous waste being escaped from the facility.

1. Introduction

Chemicals were well-known and used throughout history, but their use in large quantities are related with the Industrial Revolution. Currently, the development of the chemical industry continues and there is an increase in the amount of chemical substances being processed and also an increase in the number of variety of uses. Many chemical substances are characterized by hazardous properties, such as explosivity, flammability, toxicity and ecotoxicity. During of whole life cycle of chemicals, i.e. production, packaging, transport, storage, use and disposal, the hazardous properties of chemicals are related to accidents and disasters, whose consequences grow with the hazardous properties intensity and with the quantity of chemicals involved. In the last stage of life cycle of chemicals, these chemicals are considered as a waste and their hazardous properties are classified by requirements of Directive 2008/98/EC of the European Parliament and of the Council on waste and repealing certain Directives (European Commission, 2008a).
Some of wastes with hazardous properties are classified as dangerous substances even by SEVESO III (European Commission, 2013). With regard to increases amount of wastes and hazards accompanying their treatment of large quantities, reduction of waste generation is considered as more efficient measurements than the dominant waste management practices of landfilling, energy recovery and recycling (Johansson and

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Corvellec, 2018). There is a lot of ways of treatment and disposal of hazardous waste. Rosenfeld et al. worked out a detailed overview of disposal methods and their use in accordance with the characterization of waste in question (Rosenfeld et al., 2011). The waste elimination by combustion is one of the direct uses of the thermal recovery of waste. From the point of view of environmental protection, this is one of the safest ways of removing hazardous waste and for some types of waste the only possible way of safe disposal. Incineration of waste, for example, municipal solid waste, reduces their volume by 90 % and appropriate technologies can reduce the amount of harmful fly ashes (Huber et al., 2016). Industrial facilities intended for thermal treatment of waste, incinerators, use the combustion processes based on sustained high-temperature to destroy potentially harmful substances, although, there are some doubts about health impact of emissions on the surrounding population health and the environment, especially in their long-term effects (Reis, 2011). With regard to increase demands of renewable energy sources uses, exploitation of waste as an alternative energy sources gives an opportunity to decrease the consumption of primary energy sources. System of optimization of waste thermal energy is designed by (Bolis et al., 2018). Their work proposes a new approach for the estimation of hazardous properties of waste and new classification system including the energy content. Moreover, proposed system delivers information about spatial dimension of dangerous goods transport, and hence it is an asset to increase of safety handling with dangerous waste.

With regard to the hazard associated with the handling of hazardous materials, chemical substances and their mixtures, the relevant activities are governed by a number of regulations aimed at ensuring the safety of persons and property and the protection of the environment. The list of waste properties, which render it hazardous, is included in the Annex III to Directive 2008/98/EC (European Commission, 2008b). This Annex III has been amended to adapt the definitions of the hazardous properties and references accordingly aligning them with Regulation (EC) No 1272/2008 (European Commission, 2008a). Annex III to Directive 2008/98/EC has been replaced by the text set out in the Annex to Regulation (EC) No 1357/2014 (European Commission, 2014). Hazard Class and Category Codes and Hazard statement Codes for waste constituents for their classification as hazardous wastes by properties of wastes found in the concerned incinerator establishment are listed in the Table 1.

Table 1: Hazard Class and Category Codes and relevant Hazard statement Code accordingly with Regulation (EC) No. 1272/2008

Wastes classified as hazardous by	Hazard Class and Category Codes	Hazard statement codes
HP2 „Oxidizing	Ox. Liq. 1, Ox. Sol. 1	H 271
HP3 „Flammable	Flam. Gas 2	H 221
	Flam. Liq. 2	H 225
HP6 „Acute Toxicity“	Acute Tox. 1 (Oral)	H 300
	Acute Tox. 2 (Oral)	
	Acute Tox. 1 (Inhal.)	H 330
	Acute Tox. 2 (Inhal.)	
	Acute Tox. 3 (Inhal.)	H 331
HP14 „Ecotoxic“	NA	H 400, H410

Note: Attribution of the hazardous property HP14 is made on the criteria laid down in Annex VI to Directive 67/548/EEC. Hazard Class and Category Codes and Hazard statement Codes for waste classified as hazardous by HP 14 as „Ecotoxic“ are not listed in the Annex III to Regulation (EC) No 1357/2014.

2. Methodology

In the first stage of the risk assessment, a selection of major accident risk sources was carried out using the CPR 18E Purple Book selection method. The method for identifying and selecting risk sources has been developed by the Netherlands Industrial Safety Institute (TNO) and published in the Guidelines for Quantitative Risk Assessment (Purple Book, 2005). The second method for a case study was the Czech Hazard & Vulnerability Index methodology (Danihelka et al., 2006). H&V Index is based on the evaluation of the hazard index of the substance for the environment and the vulnerability index of the territory against the potential accident involving the dangerous substance (Sikorova et al., 2017). The hazard index performs combination of the ecotoxic properties of the substance, the physical-chemical properties of the substance and the potential spread of the substance. The vulnerability index can be determined separately for the different parts of the environment (e.g. surface and groundwater, soil environment, biotic component of the landscape. It includes the characteristics of these parts of the environment (e.g. soil permeability, permeability of hydrogeological subsoil, land use, use of underground and surface water, specially protected nature areas, protection zones etc.). Using synthesis of both indexes (hazard index and vulnerability index) partial indexes are obtained that inform about the hazards of selected substance for the site being evaluated. In conclusion of the evaluation the consequence of the environmental impact is determined. Consequence (A-E) is calculated as a combination of the amount of released substance and partial indexes.

3. Applicative case study

New SEVESO establishment, where hazardous wastes are stored and modified for purposes of their liquidation by combustion in the rotary kiln, was selected for purposes of this case study. The incinerator is designed for the safe disposal of hazardous wastes from industrial plants, allows the incineration of wastes of all states (see Figure 1). A characteristic feature of the industrial waste incineration process is the mixing of different types of waste to achieve the required combustion temperature (Silva and Lopes, 2017). Therefore, typical representatives of large amounts and most often imported hazardous wastes were selected.

Figure 1: Location of the incinerator area and its surroundings

3.1 Risk site identification

By the identification of risk sources, which they can cause a major accident, were selected 4 storages, where different wastes of various states can be stored (see Table 1). Among the identified objects belong the storage of liquid wastes (S1), the import of solid wastes - the bunker (S2), the storage of solid wastes in the packages (S3) and the storage of liquid wastes situated in containers or barrels (S4).

Table 2: List of hazardous substances/hazardous wastes placed in selected incinerator

Storage No.	State	Hazardous properties	Quantity (tonnes)	Facility
S1	Liquid wastes	H225/HP3 “Flammable”	420	Tank
S2	Solid wastes	H225/HP3 “Flammable”	583	Bunker
S3	Solid wastes	H300, H330, H331/HP6 „Acute Toxicity“	70	Container, Barrel
S4	Liquid wastes	H400/HP14 “Ecotoxic”	70	Container, Barrel

3.2 Scenarios

The establishment of the selected incinerator is located in the industrial area, at a distance of about 400 m from the river bank and about 150 m from the highway (see Figure 1). The nearest residential area are the family houses at a distance of about 900 meters from the northwest.
In case of major accident which can lead to serious danger to human health or the environment were identified these accident scenarios:

- major fire on the facility containing flammable waste (liquid, solid)
- major release of ecotoxic liquid waste to the environment

In case of the possibility of fire, the storage of flammable liquid wastes (S1) was selected for the presentation in this paper. From the point of view of the negative environmental impact, storage of liquid ecotoxic wastes located on reinforced and secure surface (S4) was evaluated here.

Estimation of the frequency of representative scenarios was carried out in accordance with Guideline for quantitative risk assessment (Purple Book, 2005) and the results of the European project ARAMIS. First, fault trees (FTAs) were constructed to indicate possible causes of system failures (see Figure 2). Additionally, event trees (ETAs) were displayed, which develop a major accident scenario and determine the final event frequencies (see Figure 3).

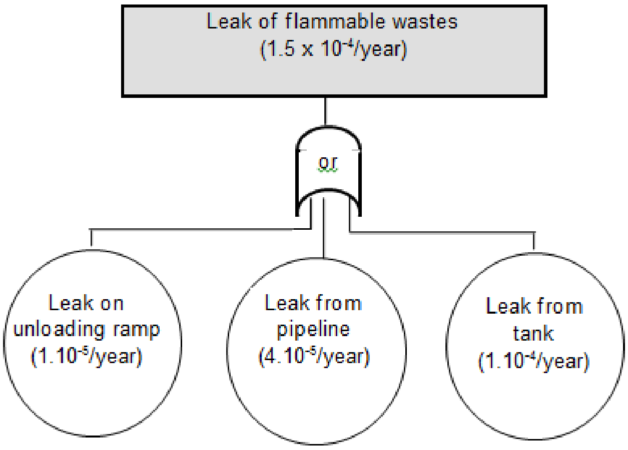

Figure 2: FTA for the leakage of flammable liquid wastes from the storage (S1)

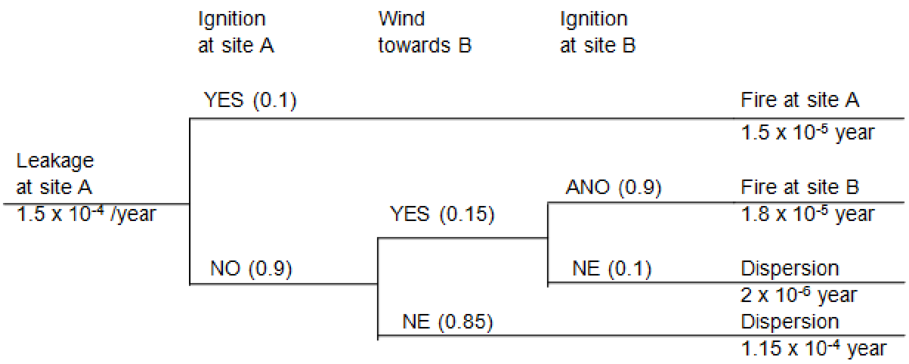

Figure 3: ETA for the leakage of flammable liquid wastes from the storage (S1)

3.3 Environmental impact assessment

H&V Index methodology was primarily developed for environmental impact assessment of short-term emergency releases into the environment with the presence of dangerous substance. The purpose of this methodology is a risk analysis related to the major accident from which follows the possibility of environmental threat. If the parts of the environment are not seriously affected, they will not be evaluated (Sikorova et al., 2017). Due to the classification of liquid wastes in storage S4 as a hazardous to the aquatic environment in category acute toxicity (H400), the environmental impact assessment was focused on the impact on surface water in this paper. Other possible impacts on the soil environment and groundwater can be characterized as negligible as there will be no possibility for the absorption of liquid wastes into the subsoil near the storage site.

In the first step, hazard index T_W – Index of toxic hazard to the aquatic environment was calculated as a combination of acute toxicity and selected physical properties of substance ($T_W = 4$), where resulted index 4 performs high toxicity to the water environment.

The second step was to assess vulnerability to surface water, as this environmental compartment is most at risk from possible release of hazardous substances that are classified as toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment. The area of case study belongs to the

hydrological river basin of the boarder river, which flows to the northeast from the establishment. In the consideration of the evaluated surroundings area, the final vulnerability index was determined as I_{SW}= 4. The leakage of a hazardous substance will threat the close river; however the consequence can be relatively quickly eliminated.
By synthesis of indexes, both hazard and vulnerability indexes (T_W and I_{SW}), a final index of toxicity to the aquatic environment (I_{TSW}) was calculated (see Equation 1 and Table 3).

$$I_{TSW} = max\left(\frac{Isw + Tw}{2}\right) = \left(\frac{4+4}{2}\right) = 4 \tag{1}$$

In conclusion, consequence categories depending on considered amount release (Am) and toxicity to the aquatic environment (I_{TSW}) were estimated (see Table 3). Resulting consequence categories (A-E) perform the prediction of the impact to the aquatic environment, where “B category” presents small impact to the river, “C category” significant impact, “D category” very significant impact and “E category” maximal impact.

Table 3: Categories of major accident consequence caused by toxic release to surface water

		Amount of leakage [tonnes]				
		< 1	**1 - 10**	**10 - 50**	**50 - 200**	**> 200**
I_{TSW}	**1.**	A	A	B	B	C
	2.	A	B	C	C	D
	3.	B	C	C	D	E
	4.	B	C	D	E	E
	5.	C	D	E	E	E

For the scenario of leakage of maximum 70 tonnes of hazardous liquid waste from the storage (S4) was estimated the consequence category “E” presenting the maximum impact on surface water. However, this scenario was considerably overvalued. The instantaneous leakage of all stored containers and barrels at one time is not a realistic scenario. More accurate would be consequence category “C” predicting the significant impact to nearest surface water when one or more containers/barrels in amount of 1 to 10 tonnes would be damaged.

4. Conclusion

Hazardous wastes are collected and stored in area of incinerators before their treatment. In particular, storage of flammable or ecotoxic liquid and solid wastes raises the hazard of explosions, fire, environmental and property damage. The risk of major accidents varies with amount and hazardous properties of wastes being stored or is manipulated with them. The hundreds of accidents involving hazardous chemicals including wastes have happened in this area (Li et al., 2017).
In case of fire on facility with flammable liquid or solid waste will not be expected the serious impact to human health or lives. Due to the negative effects of thermal radiation, it can be assumed that the exposed people/staffs will leave the establishment spontaneously. This will only endanger the operator's assets. The cause of scenarios with the release of flammable wastes can be a traffic accident inside an establishment, an incidence on a tank during loading/unloading, leakage during the distribution in pipeline, etc. From the point of view of the potential undesirable impact to environmental compartments, surface water contamination can be considered in the case of leakage of hazardous liquid waste to paved areas and the next spread via sewer. In the event of a flood occurrence (Sikorova and Bernatik, 2012), hazardous wastes may escape into the river. It is more probable the release of the hazardous wastes into the sewerage system and their capture and next liquidation in wastewater treatment plant. Potentially, soil environment and groundwater may be endangered on unpaved areas, such as releases of liquid wastes from pipelines. All incinerator objects are adequately secured by safety and security protection elements, and fire brigade rescue team is involved in any intervention, including evacuation of employees. Evacuation of the population would then represent the ultimate solution in case of undesirable dispersion conditions. Risk of major accident in selected incinerator can be considered as a socially acceptable.

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