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Risk Analysis of Natech Accidents Trigged by Lightnings and Floods

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Abstract

Natural Hazard Triggered Technical Accidents (Natech) cause serious loss of life, environment and property and affect life negatively. Risk analysis studies of these accidents are important. In this study, it was aimed to analyze the risk of Natech accidents for Türkiye. Statistical evaluation of Natech accidents was made through various databases for selecting the province and organization where the application will be made. Because of these evaluations, two exemplary gas storage organizations (Organization 1: includes 5 cylindrical tanks of the same volume, Organization 2: includes 4 cylindrical tanks of the same volume and 1 large volume spherical tank) were selected within the scope of the legislation in Erzurum, which stands out in terms of flood and lightning risk. Flood-triggered Natech accidents were analyzed using the preliminary hazard list and Fine-Kinney methods, and lightning-triggered Natech accidents were analyzed through the YILKOMER and RADSAN programs. For Organization 1 and Organization 2, the protection level was determined as 3 and 4, respectively, according to the effectiveness value. While 34 hazard effects were graded with the preliminary hazard list for Organization 1 and 22 hazard effects by Fine-Kinney; for Organization 2, hazard effects were graded 37 with the preliminary hazard list and 28 with Fine-Kinney. Because of the analyses carried out, Organization 2 was found to be more risky in terms of Natech accidents triggered by both lightning and flooding. It can be said that this situation is because the relevant organization is located in a more congested area and within the organized industry, and that it contains more voluminous tanks. It is important that emergency plans be prepared by considering the Natech risks, based on the characteristics of the industrial facility and the type of natural disaster in the region.

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1. INTRODUCTION

A disaster is defined as a natural, technological, or human-induced event that affects the whole or a certain part of the society, cause economic, social and physical losses in the society, interrupts normal life, and in which the local opportunities are insufficient. Natural hazards such as earthquakes, floods, storms, extreme temperatures can trigger fires, explosions, toxic or radioactive releases in facilities that process, store, or transport hazardous materials, and these are called Natural Hazard Triggered Technical Accidents (Natech) (eNatech, 2022). Natech causes serious life, economic and environmental losses. Natech risk assessment is extremely important to identify areas where such accidents can occur, to identify possible risks and to take the necessary measures to reduce risk. In Türkiye, with the Gölcük Earthquake on August 17, 1999, a fire occurred in TÜPRAŞ and it was determined that there were 80 million dollars of damage because of the fire. Then, because of the LPG explosion in Akçagaz in July 2002, 3 trillion Turkish liras damage occurred (Çetinyokuş, 2018; Güneş & Çetinyokuş, 2020). The increase in industrial facilities and population in the risky area will increase the damage that may occur in the region in case of disaster (Krausmann & Musthaq, 2008). This situation reveals the importance of planning and supervised settlement.

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There is no special regulation for Natural Hazard Triggered Technical Accidents in Türkiye. However, Natural Hazard Triggered Technical Accidents can be evaluated within the scope of the "Regulation on the Prevention of Major Industrial Accidents and Reduction of Their Effects" prepared and published on March 2, 2019 by the Ministry of Family, Labor and Social Services, the Ministry of Environment and Urbanization and the Ministry of Interior (Official Gazette, 2019) .The regulation emphasizes the necessity of considering natural disasters in the determination of industrial accident risks in the relevant annexes.

Studies on the analysis of Natech accident data are remarkable. The trend of Natech events, their geographical distribution, final technological scenarios were evaluated in terms of life and property losses by Ricci et al. (2021). In the study, data were analyzed using eMARS, MHIDAS, NRC, TAD IChemE, ARIA and CONCAWE databases. In another study by Ricci et al. (2020), the trend of Natech accidents caused by cold air and heat waves over the years was evaluated in terms of geographical location, final scenarios and related industrial sectors, through ARIA, eMARS, MHIDAS and FACTS databases. Moreno et al. (2019) analyzed the data of accidents affecting the chemical and process industry through ARIA, FACTS and eMARS databases by grouping them in terms of geographical location, type of disaster that triggered and type of asset affected, and graphs were obtained. The ARIA, NRC, MHIDAS, FACTS, MARS and TAD databases were used by Renni et al. (2010) to contribute to the development of a quantitative approach for assessing lightning risk in industrial facilities. The data obtained were evaluated according to the criteria of loss of hazardous materials, industrial activity containing hazardous materials, major accident scenarios on or off the field. Krausmann and Musthaq (2008) analyzed past cases and used expert opinions to demonstrate major flood-induced technological damage or failure pathways that have the potential to cause hazardous material releases. The potential impact of flood severity on specific industrial facilities that store and/or process toxic, flammable, or explosive materials has been qualitatively analyzed.

It is seen that different methods are used for risk assessment and analysis of Natech accidents in the literature. In the study by Wang and Weng (2021), a simplified methodology is presented to quickly assess the vulnerability of atmospheric storage tanks in Natech events. In this study, deterministic and probabilistic analyzes were applied using Uncertain Parameter Set (UPS) and Monte Carlo Simulation methods. Girgin et al. (2019) demonstrated that the National Risk Assessment (NRA) can be developed in the assessment of Natech risks, and although it is national, it can be evaluated to a lesser extent regionally. Naderpour et al. (2019) used Geographic Information System (GIS) based analysis to predict the amount of air and humidity in forest fires according to the probability of fire and to model Natech events. In the study by Olivar (2018), the vulnerability of industrial storage equipment that may be exposed to Natech events was analyzed with a computer tool called Natech Tank Analyzer (NaTanks). A methodology for Quantitative Risk Assessment (QRA) of lightning-induced accidents was developed by Necci et al. (2016). To this end, a model was created to assess the probability of lightning strikes on process equipment and certain equipment vulnerability models and combined these into event trees that allow the measurement of risk indices. Hazardous liquid pipeline system incidents on land reported to The Pipeline and Hazardous Materials Safety Administration (PHMSA) by Girgin and Krausmann (2016) were investigated using data mining.

In this study, it is aimed to analyze the risk of Natech Accidents, which has not been studied before in Türkiye. For this purpose, first, Natech accidents were analyzed through various disaster/accidents databases, and then sample industrial organizations that had obligations on the relevant legal legislation were determined. Then, risk analysis was carried out by using various risk analysis methods for Natech accidents triggered by floods and lightning. The results obtained were compared and organizations were evaluated in terms of Natech risk.

2. MATERIAL AND METHOD

The study started with the analysis of Natech accidents that occurred in the last 15 years through various databases, and the dominant natural disaster types and the process equipment they affected were evaluated. Then, the selection of provinces and organizations, which include the prominent types of natural disasters and process equipment, and where risk analysis studies will be conducted, were made. In the last stage, risk analysis studies of Natech accidents were conducted in selected organizations using different risk analysis methods.

Statistical Evaluation of Natech Accidents

For the statistical evaluation of Natech accidents, eMARS, EM-DAT and eNatech databases were analyzed and Natech accidents that occurred between 2006–2021 were determined.

Selection of Provinces and Organizations for Risk Analysis

The types of natural disasters and the equipment affected by Natech accidents were evaluated. The province containing these disaster types in Türkiye and the organizations in this province hosting the mentioned equipment types within the scope of the relevant Regulation was selected (Official Gazette, 2019).

Risk Analysis of Natech Accidents Triggered by Lightning in Organizations

Natech accidents triggered by lightning were analyzed in selected organizations with the YILKOMER and RADSAN programs. It has been observed that the YILKOMER risk analysis program has been put into practice for the Faraday cage and the RADSAN (2021) risk analysis program has been put into practice for the lightning rod system. The assumption of both programs is to reach the efficiency level of the systems on the facility in the event of a lightning strike. In the lightning risk calculation, the structure, environmental condition, occupancy, structural features, usage parameters are considered. The analysis is carried out through the formulas defined in the program by processing the height, length, width and number of lightning days of the area to be studied. Everything is defined and clearly stated in the program. This provides ease of use. Parameters for the program are listed in Table 1.

Table 1. *Parameters in the program*

Environmental Coefficients (C1)				
C1	0.25	If the structure is the same or between higher trees and structures		
	0.5	if it is surrounded by buildings of low height		
	1	If the distance to the nearest building is 3h		
	2	If it is the highest in the area		
Structural Coefficients (C2)				
C2	Structure/Roof	Metal	Brick	Flammable/Combustible
	Metal	0.5	1	2
	Brick/Concrete	1	1.5	2.5
	Flammable	2	2.5	3
Structural Coefficients (C3)				
C3	0.5	Insignificant, Non-Flammable		
	1	Normal, Flammable		
	2	Important, Flammable		
	3	Flammable, Combustible		
Building Occupancies (C4)				
C4	0.5	Unemployed building		
	1	Normal crowd		
	3	Risky of panic, difficulty evacuating		
Building Occupancies/Lightning Results (C5)				
C5	1	No continuous use, worthless in the environment		
	5	In continuous use, worthless in the environment		
	10	Valuable in the environment		

C1 Environmental Coefficient is the parameter of the location of the building in the environment relative to the buildings and trees close to the building. It was evaluated from 0.25 to 2. C2 Structural coefficient is the coefficient parameter of the building according to the type of material used in the construction phase and the type of roof. C3 Structural coefficient is the parameter in which the fire risk of the building is determined. It was evaluated from 0.5 to 3. C4 Building Occupancy is the parameter of the building's hazard status for people. It was evaluated from 0.5 to 3. C5 Structure Occupancy/Lightning Result is used for the Faraday cage. The parameter evaluates the importance of a building in the environment from 1 to 5.

Within the Efficiency and Protection parameter, the efficiency level of the system used as a maximum of 0.98 and a minimum of zero is classified as the protection level and area of effect. The scenario with the strongest lightning strikes with a current value of 200 kA at protection level 1 is considered. Such strong lightning strikes are rarely experienced in Türkiye. Petrochemical plants located in areas that receive strong lightning strikes are in the high hazard class. Protection level 2 covers lightning strikes with a current value of 150 kA. Incoming strong blows involve a high risk for buildings from hospitals to factories. Protection levels 3 and 4 cover lightning strikes with a current rating of 100 kA. Many regions in Türkiye frequently receive lightning strikes of this strength; industrial enterprises and factories in these regions carry serious risks (YILKOMER, 2022).

Lightning current parameters according to the protection levels within the scope of the Lightning Protection Regulation are given in Table 2. The peak value of the current I(kA) parameter is the highest value of the lightning current, the total electric charge Q_{top} (C) parameter is the electron charge in the lightning occurring between the opposite electrically charged cloud and the ground, the pulse electric charge Q_{pulse} (C) parameter is the electron charge of the effect resulting from the lightning strike. The specific energy parameter expresses the time integral of the square of the lightning current during the lightning discharge period, and the mean steepness parameter expresses the perpendicularity of the lightning current to the front. Damages caused by the induced voltage depend on the facade steepness and for design purposes, an average slope of 30%-90% of the current peak value is used in the average steepness parameter.

Table 2. *Lightning current parameters according to protection levels (YILKOMER, 2020)*

Lightning parameter	Protection level		
	1	2	3–4
Peak value of current I (kA)	200	150	100
Total electric charge Q_{top} (C)	300	225	150
Pulse electric charge Q_{pulse} (C)	100	75	50
Specific energy W/R (kJ/Ω)	10000	5600	2500
Average steepness $di/dt_{\%30\text{-}90}$(kA/µs)	200	150	100

In the calculations section of the program, the length, width and height of the building and the numerical values determined above for C1, C2, C3, C4, C5 are processed, and the next stage is the formula section. The formulas and definitions defined in the program are given in Table 3.

Table 3. *Formulas and definitions*

Formulas	Definitions
$Ae=LxW+6xHx\ (L+W)+9x\pi xH^2$	Effective equivalent area
$Ng=0.04xNk^{1.25}$	Lightning intensity
$Nd=NgxAexC1x10^{-6}$	Expected number of lightning strikes at the facility
Nk=17.8	The number of lightning days for the selected province
C=C2xC3xC4xC5	Product of the coefficients
$Nc=5.5x10\ ^{-3}/C$	Approved lightning strike count
E=1-(Nc/Nd)	Efficiency

The value of N_k in the region to be studied was defined according to the Türkiye Thunderstorm Map given in the program for the average number of lightning days in the formulas section. After this identification, analysis occurred, the efficacy value and protection level were obtained.

Risk Analysis of Natech Accidents Triggered by Flood in Organizations

Pre-hazard list and risk analysis with Fine Kinney were carried out in selected organizations. With the information obtained, first, a preliminary hazard list was prepared to determine the potential hazards and mishaps that may occur. Potentially hazarded elements, subsystems and hazardous situations were used as data in the determination of hazards. The effects of hazards were also considered (Demirdöğen & Çetinyokuş, 2021).

The grading of risks with the Fine-Kinney Method is made by multiplying the numerical values of the probability of occurrence of the risks, the severity of the hazard and frequency of exposure to the hazard. Probability, frequency, severity scales (Table 4) and risk-level table (Table 5) are used for calculating the risk value and classifying the risks. The priority of the measures to be taken is determined according to the risk value determined by the probability, frequency and severity values. When making risk analysis with the Fine-Kinney method, it is critical for the people exposed to risk, the relations of exposure to risk, the possibilities of taking precautions, the continuity of the safety measures and the reliability of the safety measures.

Table 4. *Probability, frequency and severity scales of the Fine-Kinney method (Demirdöğen&Çetinyokuş, 2021)*

	POSSIBILITY
Value	Definition
0.2	Unexpected
0.5	Unexpected but possible
1	Possible but unlikely
3	Possible
6	High/highly possible
10	Definitely expected
	FREQUENCY
Value	Definition
0.5	Very rare (annually or less frequently)
1	Rare (several times a year)
2	Not often (once or several times a month)
3	Occasionally (once or several times a week)
6	Often (once or several times a day)
10	Almost constantly (several times an hour)
	SEVERITY
Value	Definition
1	No near misses, no lost work hours, no first aid required, no environmental damage
3	Minor injury, minor damage, no loss of working days, requires first aid, limited environmental damage
7	Injury, significant damage, outpatient treatment, external first aid, lost working days, low environmental impact
15	Permanent damage, serious injury, long-term treatment, occupational disease, lost work/workday, moderate environmental damage
40	Fatal accident/environmental damage
100	Multiple fatal accidents/environmental disasters

Table 5. *Risk-level values and actions to be taken according to the risk level of Fine-Kinney method (Demirdöğen & Çetinyokuş, 2021)*

Risk Index		Actions to be Taken
Value	The risk category	
R<20	Acceptable Risk	Additional control processes may not be needed to eliminate the identified risks.
20<R<70	Possible Risk	Existing controls should be maintained and audited
70<R<200	Significant Risk	Corrective/preventive actions should be initiated in the long term to reduce the identified risks.
200<R<400	High Risk	For these risks, measures should be taken in the short term and corrective/preventive action should be initiated.
R>400	Very High Risk	Work should not be initiated until the identified risk is reduced to an acceptable level, and if there is an ongoing activity, it should be stopped. If it is impossible to reduce the risk despite the activities carried out, the activity should be blocked.

Damages that may occur in and around the facility because of the flood disaster triggering Natech events in LPG storage and distribution facilities are presented in Table 6.

Table 6. *A qualitative damage scale of flood triggering Natech events for LPG storage and distribution facilities (Krausmann & Musthaq, 2008)*

Flood severity levels	Low	Moderate	High
Wholesale and retail storage and distribution (including LPG, fuel, etc.)	• No stop of operations. • No flood protection measures were implemented. • Warehouse buildings do not have embankments around the warehouses. • No displacement of tanks. • Small cylindrical tanks have a low risk of displacement.	• There is damage to the warehouse buildings. • Dangerous substances are carried by flood waters. • Small storage tanks have buoyancy and displacement. • There is a potential release of hazardous materials at the site. • There is little potential for off-site pollution. • There are fires and explosions in the presence of an ignition source.	• There is severe damage to the warehouse buildings. • Tanks have buoyancy and displacement. • There is damage to the equipment. • There is a potentially large release of toxic substances into the water or air from defective tanks or ruptured pipe connections. • There is potential for serious off-site pollution. • There is a risk of fire and explosion if flammable and/or explosive substances are released in the presence of an ignition source. • There is an increased risk of release, fire and/or explosion due to collisions between tanks and vessels and with debris. • There is a risk of unexpected side reactions due to the wide variety of substances present.

Floods are difficult to control by their nature and large volumes of water can reach industrial facilities by overcoming obstacles and causing negative consequences. Industrial facilities have unique characteristics in terms of production processes and hazardous materials used or produced. As a result, LPG storage and distribution facilities also have certain danger potential and vulnerability in terms of the hazardous materials they use.

3. RESULTS AND DISCUSSION

Statistical studies conducted for risk analysis of technological accidents triggered by natural disasters, and details of risk analysis studies of Natech accidents caused by floods and lightning in selected organizations, over different methodologies, are presented in the following sections.

Statistical Evaluation of Natech Accidents

21 Natech accidents have been detected in the last 15 years. The data obtained from the databases were processed into the SPSS program based on the titles of date, location, natural disaster subgroup, natural disaster type, affected facility and affected equipment type. When the statistics of the data processed in the program were evaluated, it was seen that meteorological disasters were more important than geological disasters with a rate of 57% in terms of natural disaster subgroup. Considering the types of natural disasters that occurred, it was seen that among the meteorological disasters, flood and lightning stood out with a rate of 19.0%, while among the geological disasters, landslides with a rate of 19.0% and tsunami with a rate of 14% came to the fore (Kurt & Çetinyokuş, 2021) (Figure 1).

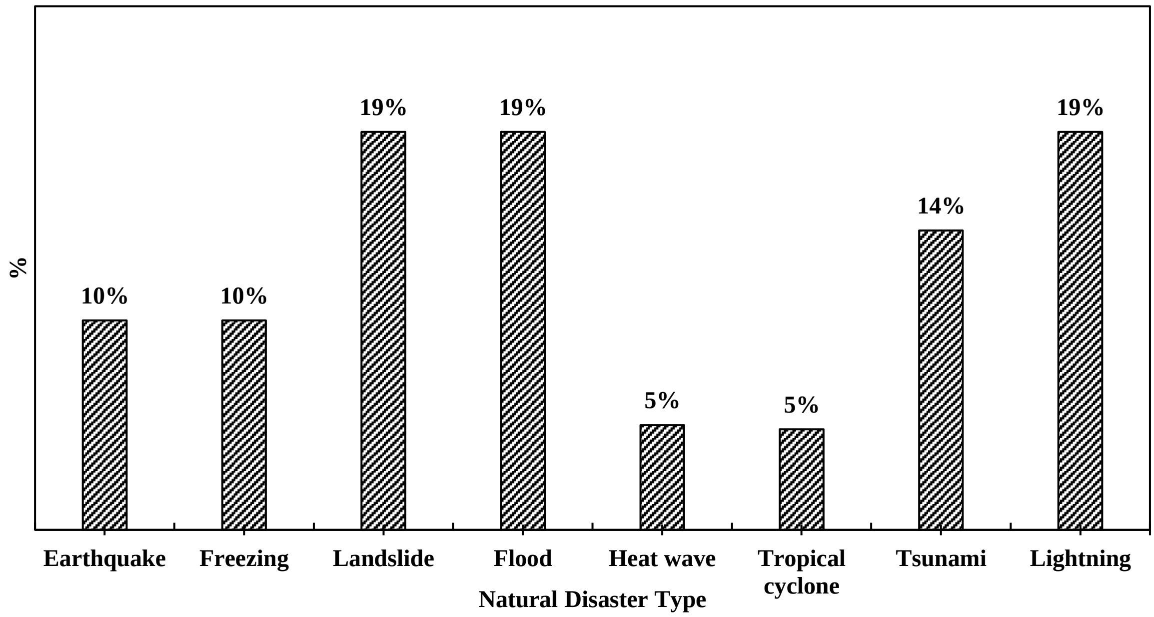

Figure 1. *Distribution of types of natural disasters causing Natech accidents*

Equipment with loss of containment, which causes technological accidents because of triggering natural disasters, was also evaluated. The distribution of equipment affected in the Natech accidents is presented in Figure 2.

It was seen from Figure 2 that atmospheric storage tanks were the type of equipment that is most affected by the effects of natural disasters and had a loss of containment (19%). This was followed by the pipeline (14%). It was stated in the literature that 85% of Natech accidents in the world were triggered by meteorological disasters and the equipment most affected by this process was storage tanks (Renni et al., 2010; Ricci et al., 2021). Additionally, it was stated that 36% of meteorological disasters caused Natech accidents in the dangerous liquid pipeline system on land (Girgin et al., 2019).

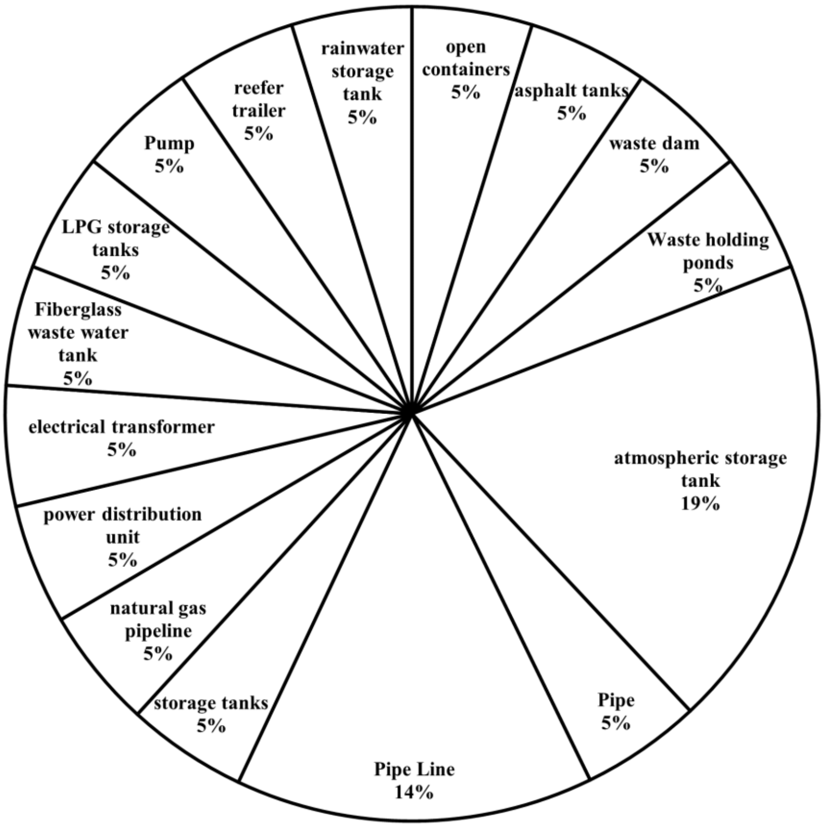

Figure 2. *Distribution of equipment affected in Natech accidents*

Risk Analysis of Natech Accidents Triggered by Lightning in Organizations

The statistical evaluation showed that natural disaster types such as landslide, flood and lightning stood out in the Natech accidents. For this reason, the intensities of landslides, floods and lightning that occurred in Türkiye were examined on the basis of provinces and it was desired to determine a province containing all the prominent disasters. Considering the Türkiye landslide disaster map and Türkiye flood map, it was determined that Erzurum was among the most risky provinces in terms of landslide and flood intensity. No information could be obtained for lightning, but it was predicted that it would be compatible with flood and landslide data. To conduct the risk analysis study of technological accidents triggered by natural disasters in Erzurum province, sample organizations within the scope of the Regulation were selected in two different locations. The selected organizations carried out gas storage and filling facility operations. They represent high-level organizations within the scope of the relevant regulation. It is also stated in the literature that gas filling and storage facilities are one of the risky facilities most damaged by overvoltage and lightning strikes (Acikgoz, 2012). This makes it important to analyze and evaluate such facilities. Hazardous chemicals in gas filling and storage facilities such as propane, butane and LPG were also considered in the selection of the organizations.

Risk Analysis of Natech Accidents Triggered by Lightning in Organizations

In the literature, it has been stated that jet fire will occur in pressurized storage tanks where flammable materials are stored due to lightning strikes and puncture (Misuri et al., 2020). An analysis of Natech historical accidents also showed that many accidents resulted in jet fires (35%) (Renni et al., 2010). The analyses made on the relevant programs for the sample organizations in Erzurum are presented in two sub-titles.

Organization 1

In Organization 1, there are 5 storage tanks with a volume of 115 m^3 with 85% fill rate. Among these, three tanks contained 70% butane-30% propane, one of the remaining two tanks contained 50% butane-50% propane and the other 100% propane. All the tanks have the same properties, except for the chemical in them, and data on the chemical is not requested in the program. For this reason, it was found to be sufficient to enter the information of any tank into the program. Since the protection system of the organization is the faraday cage, the risk analysis program of the faraday cage obtained from YILKOMER was applied:

- ✓ When the environmental location was examined, the breeding cattle farm was located in the closest and the C1 value was taken as 1 because it was 3h away.
- ✓ The C2 value was determined as 2 by choosing metal and combustible options since the structure was a tank.
- ✓ Because of the presence of flammable and combustible materials in the tanks, the C3 value of the building's fire risk was chosen as 3.
- ✓ The C4 value was chosen as 3 since the building may cause panic and evacuation difficulties on people due to the presence of flammable and combustible materials.
- ✓ The C5 value was taken as 10 because the building contained hazardous materials and may cause fire and explosion because of a lightning strike.

The length and width of the structure were taken from the tank information, the Nk value was specified as 17.8 for Erzurum, then the efficiency value was obtained as 0.882537. According to the efficiency value, the protection level was determined as 3, the cage spacing was 15 m*15 m, and the landing range was 20 m. This includes lightning strikes with a current value of 100 kA. Industrial enterprises and factories in this region carry serious risks. If new structures were built around the organization, attention should be paid to the distance to the relevant facility and the length of the facility, awareness of the employees should be raised on this issue, and periodic controls of the faraday cage, which is a protection system, should be made (Kurt & Çetinyokuş, 2021).

Organization 2

- ✓ In Organization 2, there are spherical tanks with a volume of 3000 m^3 and 4 horizontal cylindrical tanks with a volume of 115 m^3. The spherical tank contains 70% Butane-30% propane and has a 40% fill rate. Three of the horizontal cylindrical tanks store auto gas LPG and one stores commercial propane. Auto gas LPG tanks contain 60% Butane-40% Propane, and two have 50% and one 70% fill rate. The auto gas LPG tank with the highest fill rate (70% fill) was used for the analysis. Since the protection system of the organization is a lightning rod, the risk analysis program of the lightning rod system obtained from RADSAN was applied:
- ✓ C1 value was taken as 0.25 because the organization was among similar structures in terms of environmental location.
- ✓ The C2 value was chosen as 2 by choosing metal and combustible options because the structure was a tank.
- ✓ Because of the presence of flammable materials in the tanks, the C3 value of the building was taken as 3.
- ✓ The C4 value was chosen as 3 since the building may cause panic and evacuation difficulties due to the cramped environment, as well as the fact that the building contained flammable materials.
- ✓ The C5 value was taken as 10 because the building contained hazardous matter and may cause fire and explosion because of a lightning strike.

The length and width of the structure were taken from the tank information and processed, and the Nk value was specified as 17.8 for Erzurum, then the efficiency value was calculated as 0.605682. According to the efficiency value, the protection level was 4 and the radius of the lightning rod protection area was 107 m. In many places in Türkiye, lightning strikes of 100 kA corresponding to this value are frequently experienced, and similar to Organization 1, industrial enterprises and factories in this region carry serious risks. It was stated that for storage tanks of industrial importance, the probability of contingent damage from the impact of lightning strikes is higher than 10^{-2} for atmospheric tanks and at least one-fold lower in the case of pressurized tanks (Necci et al., 2013a). The lightning strike frequency and thus the lightning NaTech risk can be greatly reduced by the use of one (or more) lightning protection masts (Necci et al., 2013b).

The lightning rod, which attracts the lightning with the metal rod attached to its end at the highest point of the buildings and flows the lightning current to the ground, prevents the lightning from falling directly on the buildings and prevents the possible fire risk. However, it does not protect the electrical installations and the devices connected to the electrical installations against overvoltage and overcurrent due to lightning strikes. For this reason, since the lightning rod system alone will not provide high protection, additional measures should be taken to the system such as surge arresters (YILKOMER, 2020). The fact that Organization 2 is located in the organized industrial zone and in a more crowded area and has a larger tank compared to Organization 1 increases the risk of damage. It is necessary to raise awareness of the organization, the surrounding community, and all institutions and organizations that have a possible domino effect in the organized industrial zone (Kurt & Çetinyokuş, 2021).

Risk Analysis of Natech Accidents Triggered by Flood in Organizations

The analyses carried out specific to the determined organizations are presented under two separate headings.

Organization 1

Organization 1 has 3 pump suction pipelines with a diameter of 115 mm, 3 tank liquid pipelines with a diameter of 80 mm, gas phase suction and gas phase discharge pipelines with a diameter of 50 mm. Additionally, the organization has a return mix pipeline with a diameter of 80 mm and 2 return pipelines with a diameter of 50 mm, a tube filling mix with a diameter of 80 mm and a propane pipeline with a tube with a diameter of 50 mm. Pipeline pressures vary between 2.5 and 6.5 bar and its height from the ground is 1 meter. In line with these data, the preliminary hazard list applied specifically to the flood disaster triggering mechanism for Organization 1 is presented in Table 7.

Table 7. *Preliminary hazard list for Organization 1*

#	Source of Hazard	Effects of Hazard	Recommendations
D1	Storage tank	Environmental pollution because of chemicals in tanks mixing with flood waters	Protections against flood water should be constructed. Safety measures should be established before the disaster.
D2		Spontaneous ignition and explosion because of mixing of chemicals in tanks with flood waters	Flood disasters should be included in planning.
D3		Loss of life and property due to fire because of transporting the storage tank with flood waters	Strengthening work should be done for storage tanks. Fixing should be done.
D4		Loss of life and property due to explosion because of transporting the storage tank with flood waters	
D5		Loss of life and property due to fire because of the overturning of the storage tank	Dikes should be built around storage tanks.
D6		Loss of life and property due to explosion due to overturning of storage tank	
D7		Loss of life and property due to toxic spread because of the overturning of the storage tank	
D8	Wastewater tank	Waste overflow because of flood water passing through the wastewater tank enclosures	Waste water tanks must be flooding-resistant .
D9		Disruption of water treatment and disposal systems because of flood waters passing through wastewater tank enclosures, toxic release	In preparation for heavy rain, the wastewater tank level should be kept low and disposed of immediately if possible.
D10		Toxic release because of flood waters passing through the wastewater tank enclosures	

***Table 7** (continued)*

#	Source of Hazard	Effects of Hazard	Recommendations
D11	Electrical connections	Loss of life and property due to fire that may occur because of electric current/spark	The electrical installations should be enclosed by protected mechanisms.
D12		Loss of life and property due to an explosion that may occur because of an electric current/spark	
D13	Connection equipment	Explosions because of leakage that may occur due to possible deformation in connection equipment	Periodic checks of connection equipment such as , valve, safety valve, inlet-outlet line should be made.
D14		Environmental pollution because of leakage that may occur due to possible deformation in connection equipment	
D15	Fuel transfer pump	Environmental pollution because of fuel spillage through the pump due to the gasket failure of the fuel transfer pump.	Periodic maintenance of the pumps should be done. It can be positioned so that it is higher than the flood water level.
D16	Safety barriers	Property damage to the facility due to the failure of the emergency shutdown system in case of flood	Periodic maintenance of safety barriers should be monitored and controlled by running them during exercises.
D17		Loss of life because of the conductivity of the electric current in the flood water due to the failure of the electric current	
D18	Pipelines	Fires due to rupture in pipelines connected to flood waters	Improved barrier should be designed around the piping.
D19		Environmental pollution because of rupture in pipelines connected to flood waters	
D20		Toxic release due to rupture of pipelines due to flood waters	
D21	Lack of disaster training among employees	Loss of life and property because of unconscious actions of employees during floods	Disaster training should be given to the employees in a way that gives priority to the disasters they may be exposed to in terms of their region.
D23	Vehicles and construction machinery	Loss of life of workers in the field due to flood waters dragging vehicles and work machines	A sheltered area away from employees should be determined for the working areas of vehicles and work machines.
D24		Property damage because of flood waters dragging vehicles and construction equipment	
D25	Tanker loading terminal	Damage to the terminal due to the strength of the flood water	Necessary reinforcements should be made at the terminal and material selection can be made according to the danger during the construction phase.
D26	Tanker	Environmental pollution because of overturning of the tanker due to the force of the flood water	Tanks should be fixed in a flood-resistant manner.
D27	Heavy snowmelt in the spring in the facility area	Loss of life and property because of flood waters due to heavy snowmelt transporting unfixed equipment	The equipment should be fixed and the equipment to be used should be selected in accordance with the flood risk.
D28		Damage to equipment such as valves, reactors and sensors by flood waters due to heavy snowmelt	

Table 7 *(continued)*

#	Source of Hazard	Effects of Hazard	Recommendations
D29	Pressure relief valve	Property damage because of failure to control the pressure due to the loss of function of the pressure relief valve because of flood waters	Periodic maintenance of the pressure relief valve should be performed.
D30		Rupture in tanks because of failure to control the pressure due to the loss of function of the pressure relief valve because of flood waters	
D31		Explosion in tanks because of failure to control the pressure due to the loss of function of the pressure relief valve because of flood waters.	
D32	Drainage system	Property damage because of failure to control flood waters due to the drainage system's failure to drain the flood water	A drainage system should be provided for the facility and its controls should be implemented.
D33	LPG contains hydrocarbon compounds	Fire because of deformation in the tank because LPG contains hydrocarbon compounds.	The structure of the tanks should be strengthened to prevent the release of hydrocarbon, which is a flammable substance, from the tanks.
D34		Explosion because of deformation that may occur in the tank because LPG contains hydrocarbon compounds.	

Because of the preliminary hazard list in Organization 1, 34 hazard effects caused by the flood disaster were determined. Multiple hazard effects were obtained for the storage tank, waste water tank, pipeline and pressure relief valve.

For the identified hazard effects, the risk value was obtained by multiplying the probability of occurrence of the risks, the frequency of exposure to the hazard and the numerical values of the effect it creates. Erzurum province becomes prone to floods due to heavy snow melt in the spring months. The facilities are located in the altitude range of 1600–1750 m (HGM, 2022). Considering snowmelt and altitude factors, the frequency of exposure to the hazard was evaluated according to the frequency of the flood disaster. The obtained risk value determines the priority of the measures to be taken. Flooding has direct and indirect consequences in industrial facilities such as buckling, buoyancy up to 30 meters, tipping, hard friction, slippage, displacement, hydraulic pressure, failure of flanges and connections (Olivar, 2018). Fine Kinney evaluation report for Organization 1 is presented in Table 8.

Twenty-two hazard effects were rated in the Fine Kinney method. The main parameters affecting the probability of storage tank failure are water height, water velocity and tank filling level (Landucci et al., 2014). Because of the risk rating, it was observed that there were four significant risks and two high risks in Organization 1. LPG contains hydrocarbon compounds and that electric current becoming more conductive with flood water posed a high risk. Periodic maintenance of safety barriers should be monitored and controlled to reduce the electric current conductivity with flood water. The structure of the tanks should be strengthened to prevent the release of hydrocarbon, which is a flammable substance, from the tanks. Other recommendations for each hazard effects and risk are presented in Table 8.

Table 8. *Fine Kinney evaluation report for Organization 1*

#	Hazard	Risk	Those affected	Risk Grading				Actions to be Taken
				Possibility	Frequency	Severity	Risk Value	
1	Mixing of chemicals into flood water because of a storage tank rupture	Environmental pollution, self-ignition, explosion	Employees, living creatures (plants, animals), third parties	3	1	15	45 Possible Risk	Protections against flood waters should be built. Flood disasters should be included in planning. Safety measures should be established before the disaster.
2	Fire because of transporting the storage tank with flood waters	Loss of life and property	Employees and third parties	1	1	7	7 Acceptable Risk	Strengthening work should be done for storage tanks. Fixing should be done.
3	Explosions because of transporting the storage tank with flood waters	Loss of life and property	Employees and third parties	1	0.5	40	20 Possible Risk	
4	Fire due to overturning of storage tanks	Loss of life and property	Employees and third parties	3	0.5	7	10.5 Acceptable Risk	Dikes should be built around storage tanks.
5	Explosion due to overturning of storage tanks	Loss of life and property	Employees and third parties	3	0.5	15	22.5 Possible Risk	
6	Toxic release from overturning a storage tank	Loss of life and property	Employees, living creatures (plants, animals), third parties	3	0.5	15	22.5 Possible Risk	
7	Flood waters passing through wastewater tank enclosures	Disruption of water treatment and disposal systems, waste overflow, toxic release, skin and eye diseases	Employees, living creatures (plants, animals), third parties	6	1	15	90 Significant Risk	Waste water tanks must be flooding-resistant . In preparation for heavy rain, the wastewater tank level should be kept low and disposed of immediately if possible.
8	Fire due to electric current/spark	Loss of life and property	Employees	6	1	15	90 Significant Risk	The electrical installations should be enclosed by protected mechanisms.

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***Table 8** (continued)*

#	Hazard	Risk	Those affected	Risk Grading				Actions to be Taken
				Possibility	Frequency	Severity	Risk Value	
9	Explosion by electric current/spark	Loss of life and property	Employees and third parties	3	0.5	40	60 Possible Risk	
10	Leakage due to deformation in connecting equipment	Explosion, environmental pollution	Employees, living creatures (plants, animals)	3	0.5	15	22.5 Possible Risk	Periodic checks of connection equipment such as , valve, safety valve, inlet-outlet line should be made.
11	Fuel spillage due to fuel transfer pump seal failure	Environmental pollution	Living creatures (plants, animals)	1	0.5	7	3.5 Acceptable Risk	Periodic maintenance of the pumps should be done. It should be positioned so that it is higher than the flood water level.
12	Failure of the emergency shutdown system in case of flood	Property damage	Employees	1	1	1	1 Acceptable Risk	Periodic maintenance of safety barriers should be monitored and controlled by running them during exercises.
13	Electric current becoming more conductive with flood water	Injury, death	Employees and third parties	6	1	40	240 High Risk	
14	Rupture in pipelines connected to flood waters	Fire, environmental pollution	Employees, living creatures (plants, animals), third parties	3	1	40	120 Significant Risk	Improved barrier should be designed around the piping.
15	Rupture of pipelines because of flood waters	Toxic spread	Employees, living creatures (plants, animals), third parties	3	1	40	120 Significant Risk	
16	Lack of disaster training among employees	Loss of life and property	Employees and third parties	6	1	7	42 Possible Risk	Disaster training should be given to the employees in a way that gives priority to the disasters they may be exposed to in terms of their region.
17	Dragging of vehicles and construction equipment by flood waters	Loss of life and property	Employees	3	0.5	1	1.5 Acceptable Risk	A sheltered area away from employees should be determined for the working areas of vehicles and work machines.

***Table 8** (continued)*

#	Hazard	Risk	Those affected	Risk Grading				Actions to be Taken
				Possibility	Frequency	Severity	Risk Value	
18	Overturning of the tanker due to the force of the flood water	Environmental pollution	Employees, driver	3	0.5	7	10.5 Acceptable Risk	These tanks can be fixed.
19	Carrying unfixed equipment from flood waters due to heavy snow melt	Loss of life and property	Employees and third parties	3	1	7	21 Possible Risk	Equipment should be fixed, equipment to be used should be selected in accordance with the risk of flooding..
20	Loss of function of the pressure relief valve because of flood waters	Property damage, rupture, and explosions in tanks	Employees	1	0.5	15	7.5 Acceptable Risk	Periodic maintenance of the pressure relief valve should be performed.
21	Failure of the drainage system to drain the flood waters	Property damage	Employees	3	0.5	3	4.5 Acceptable Risk	A drainage system should be provided for the facility and its controls should be implemented.
22	LPG contains hydrocarbon compounds	Fire, explosion	Employees and third parties	6	0.5	40	240 High Risk	The structure of the tanks should be strengthened to prevent the release of hydrocarbon, which is a flammable substance, from the tanks.

Organization 2

There are 4 pipelines: a tank filling line with a diameter of 77.9 mm, a tank emptying line, an LPG cylinder filling line and an LPG compressor line with a diameter of 52.5 mm in 2. The pipeline has a pressure of 16 bar. Organization 2, unlike Organization 1, is located within the organized industrial zone. In line with these data, Organization 2 was analyzed specifically for the trigger mechanism of flood disaster, and the preliminary hazard list analysis applied is presented in Table 9.

In Organization 2, 37 hazard effects were determined because of the preliminary hazard list. Multiple hazard effects were obtained for the storage tank, the waste water tank, the pipeline, the organization's location within the organized industrial zone, and the pressure relief valve.

The risks were graded because the organization was located within the organized industrial zone. The Fine Kinney evaluation report for Organization 2 is presented in Table 10.

***Table 9.** Preliminary hazard list for Organization 2*

#	Source of Hazard	Effects of Hazard	Recommendations
D1	Storage tank	Environmental pollution because of mixing of chemicals in tanks with flood water	Enclosures should be constructed against flood waters. Flood disasters should be included in planning.
D2		Spontaneous ignition and explosion because of mixing of chemicals in tanks with flood waters	Safety measures should be established before the disaster.
D3		Loss of life and property due to fire because of transporting the storage tank with flood waters	Strengthening work should be done for storage tanks. Fixing should be done.
D4		Loss of life and property due to explosion because of transporting the storage tank with flood waters	
D5		Loss of life and property due to fire because of the overturning of the storage tank	Dikes should be built around storage tanks.
D6		Loss of life and property due to explosion due to overturning of storage tank	
D7		Loss of life and property due to toxic spread because of the overturning of the storage tank	
D8	Wastewater tank	Deterioration of water treatment and disposal systems because of flood waters passing through the wastewater tank enclosures	Waste water tanks must be flooding-resistant .
D9		Waste overflow because of flood water passing through the wastewater tank enclosures	In preparation for heavy rain, the wastewater tank level should be kept low and disposed of immediately if possible.
D10		Toxic release because of flood waters passing through the wastewater tank enclosures	
D11	Electrical connections	Loss of life and property due to fire that may occur because of electric current/spark	The electrical installations should be enclosed by protected mechanisms.
D12		Loss of life and property due to explosion due to electric shock, electric current/spark	
D13	Connection equipment	Explosions because of leakage that may occur due to deformation that may occur in connection equipment.	Periodic checks of connection equipment such as , valve, safety valve, inlet-outlet line should be made.
D14		Environmental pollution because of leakage that may occur due to deformation in connection equipment	
D15	Fuel transfer pump	Environmental pollution because of fuel spillage from the pump due to the gasket failure of the fuel transfer pump.	Periodic maintenance of the pumps should be done. It can be positioned so that it is higher than the flood water level.
D16	Safety barriers	Property damage to the facility due to the failure of the emergency shutdown system in case of flood	Periodic maintenance of safety barriers should be monitored and controlled by running them during exercises.
D17		Loss of life because of the conductivity of the electric current in the flood water due to the failure of the electric current	

***Table 9** (continued)*

#	Source of Hazard	Effects of Hazard	Recommendations
D18	Pipelines	Fires due to rupture in pipelines connected to flood waters	Improved barrier should be designed around the piping.
D19		Environmental pollution because of rupture in pipelines connected to flood waters	
D20		Toxic release because of rupture of pipelines connected to flood waters	
D21	Lack of disaster training among employees	Loss of life and property because of unconscious actions of employees during floods	Disaster training should be given to the employees in a way that gives priority to the disasters they may be exposed to in terms of their region.
D22	Vehicles and construction machinery	Loss of life of workers in the field due to flood waters dragging vehicles and work machines	A sheltered area away from employees should be determined for the working areas of vehicles and work machines.
D23		Property damage because of flood waters dragging vehicles and construction equipment	
D24	Tanker loading terminal	Damage to the terminal due to the strength of the flood water	Necessary reinforcements should be made at the terminal and material selection can be made according to the danger during the construction phase.
D25	The organization is located within the organized industrial zone.	Illness, loss of life because of chemicals carried by flood water	Public awareness should be raised. Safety measures can also be improved. Flood disaster should definitely be considered in emergency plans.
D26		Injury, loss of life and property because of fires and explosions	
D27		Affecting the surrounding structures from possible environmental pollution because of storage tanks rupture	
D28		The domino effect of institutions and organizations around the organization	It should be ensured that institutions and organizations take safety measures against chemicals in the environment. Employees in environmental institutions and organizations should be made aware.
D29	Tanker	Soil and water pollution because of the tanker overturning due to the force of the flood water	Tanks should be fixed in a flood-resistant manner. Dikes should be added around tanks at a certain height and area, impermeable.
D30	Heavy snowmelt in the spring in the facility area	Loss of life and property because of flood waters due to heavy snowmelt transporting unfixed equipment	The equipment should be fixed and the equipment to be used should be selected in accordance with the flood risk.
D31		Damage to equipment such as valves, reactors and sensors by flood waters due to heavy snowmelt	
D32	Pressure relief valve	Property damage because of failure to control the pressure due to the loss of function of the pressure relief valve because of flood waters	Periodic maintenance of the pressure relief valve should be performed.
D33		Rupture in tanks because of failure to control the pressure due to the loss of function of the pressure relief valve because of flood waters	
D34		Explosion in tanks because of failure to control the pressure due to the loss of function of the pressure relief valve because of flood waters.	
D35	Drainage system	Property damage because of failure to control flood waters due to the drainage system's failure to drain the flood water	A drainage system should be provided for the facility and its controls should be implemented.
D36	LPG contains hydrocarbon compounds	Fire because of deformation in the tank because LPG contains hydrocarbon compounds.	The structure of the tanks should be strengthened to prevent the release of hydrocarbon, which is a flammable substance, from the tanks.
D37		Explosion because of deformation that may occur in the tank because LPG contains hydrocarbon compounds.	

Table 10. *Fine Kinney evaluation report for Organization 2*

#	Hazard	Risk	Those affected	Risk Grading				Actions to be Taken
				Possibility	Frequency	Severity	Risk Value	
1	Mixing of chemicals into flood water because of a storage tank rupture	Environmental pollution, spontaneous combustion, explosion	Employees, living creatures (plants, animals), third parties	3	1	15	45 Possible Risk	Protections against flood waters can be constructed. Flood disasters should be included in planning. Safety measures should be established before the disaster.
2	Fire because of transporting the storage tank with flood waters	Loss of life and property	Employees, third parties	1	1	7	7 Acceptable Risk	Strengthening work can be done for storage tanks. Fixing should be done.
3	Explosions because of transporting the storage tank with flood waters	Loss of life and property	Employees, third parties	1	0.5	40	20 Possible Risk	Enclosures should be built around storage tanks.
4	Fire due to overturning of storage tanks	Loss of life and property	Employees, third parties	3	0.5	7	10.5 Acceptable Risk	Bundles and enclosures should be built around the storage tanks so that they are not affected by possible sparks.
5	Explosion due to overturning of storage tanks	Loss of life and property	Employees, third parties	3	0.5	15	22.5 Possible Risk	By taking the storage tank into the pool, it can be ensured that the fire does not spill out from the pool.
6	Toxic release from overturning a storage tank	Loss of life and property	Employees, living creatures (plants, animals), third parties	3	0.5	15	22.5 Possible Risk	The potential toxic spread should be prevented by constructing bunds and enclosures around storage tanks.
7	Flood waters passing through wastewater tank enclosures	Disruption of water treatment and disposal systems, waste overflow, toxic release, skin and eye diseases	Employees, living creatures (plants, animals), third parties	6	1	15	90 Significant Risk	Waste water tanks must be flooding-resistant . In preparation for heavy rain, the wastewater tank level should be kept low and disposed of immediately if possible.
8	Fire due to electric current/spark	Loss of life and property	Employees	6	1	15	90 Significant Risk	Electric installations should be enclosed by sheltered mechanisms.
9	Explosion by electric current/spark	Loss of life and property	Employees, third parties	3	0.5	40	60 Possible Risk	Periodic checks should be made. All electrical panels must have an insulation material in front of them.

Table 10 *(continued)*

#	Hazard	Risk	Those affected	Risk Grading				Actions to be Taken
				Possibility	Frequency	Severity	Risk Value	
10	Leakage due to deformation in connecting equipment	Explosion, environmental pollution	Employees, living creatures (plants, animals)	3	0.5	15	22.5 Possible Risk	Periodic checks of connection equipment such as , valve, safety valve, inlet-outlet line should be made.
11	Fuel spillage due to fuel transfer pump seal failure	Environmental pollution	Living creatures (plants, animals)	1	0.5	7	3.5 Acceptable Risk	Periodic maintenance of the pumps should be done. It can be positioned so that it is higher than the flood water level.
12	Failure of the emergency shutdown system in case of flood	Property damage	Employees	1	1	1	1 Acceptable Risk	Periodic maintenance of safety barriers should be monitored and controlled by running them during exercises.
13	Electric current becoming more conductive with flood water	Injury, death	Employees, third parties	6	1	40	240 High Risk	To cut off the contact of electricity with the flood water, electricity should be installed inside the covered areas or insulation materials should be used to completely cut the contact of the electricity with the flood water. Personnel must be prevented from entering the electrical risky areas.
14	Rupture in pipelines connected to flood waters	Fire, environmental pollution	Employees, living creatures (plants, animals), third parties	3	1	40	120 Significant Risk	Improved barrier can be designed around the piping.
15	Rupture of pipelines connected to flood waters	Toxic spread	Employees, living creatures (plants, animals), third parties	3	1	40	120 Significant Risk	
16	Lack of disaster training among employees	Loss of life and property	Employees, third parties	6	1	7	42 Possible Risk	Disaster training should be given to the employees in a way that gives priority to the disasters they may be exposed to in terms of their region.
17	Dragging of vehicles and construction equipment by flood waters	Loss of life and property	Employees	3	0.5	1	1.5 Acceptable Risk	A sheltered area away from employees can be determined for the working areas of vehicles and work machines.

Table 10 *(continued)*

#	Hazard	Risk	Those affected	Risk Grading				Actions to be Taken
				Possibility	Frequency	Severity	Risk Value	
18	Transport of chemicals to the settlement area by flood water	Illness and loss of life	Employees, living creatures (plants, animals), third parties	6	1	100	600 Very High Risk	Enclosures should be built around an organization. Improvements should be made to the drainage systems.
19	The spread of the fire within the organization to the surrounding organizations	Loss of life and property	Employees, third parties	6	1	40	240 High Risk	Environmental awareness should be raised. Necessary precautions for fire and fire response systems should be developed within the organization.
20	The explosion experienced within the organization has effects on the environmental organizations	Loss of life and property	Employees, third parties	6	1	100	600 Very High Risk	Structures should be established around the establishment boundary to eliminate the effects of explosion immediately. The immediate evacuation of personnel and the public in the relevant areas should be ensured.
21	Overturning of the tanker due to the force of the flood water	Environmental pollution	Employees, driver	3	0.5	7	10.5 Acceptable Risk	Tanks should be designed to withstand flood water severity. Strong fixation of the tanks must be ensured.
22	Carrying unfixed equipment from flood waters due to heavy snow melt	Loss of life and property	Employees, third parties	3	1	7	21 Possible Risk	Equipment must be fixed. The equipment to be used should be selected in accordance with the flood risk.
23	Loss of function of the pressure relief valve because of flood waters	Property damage, rupture, and explosions in tanks	Employees	1	0.5	15	7.5 Acceptable Risk	Periodic maintenance of the pressure relief valve should be performed.
24	Failure of the drainage system to drain the flood waters	Property damage	Employees	3	0.5	3	4.5 Acceptable Risk	A drainage system should be provided for the facility and its controls should be implemented. The drainage system should be improved.
25	LPG contains hydrocarbon compounds	Fire, explosion	Employees, third parties	6	0.5	40	240 High Risk	The structure of the tanks can be strengthened to prevent the release of hydrocarbon, which is a flammable substance, from the tanks.

***Table 10** (continued)*

#	Hazard	Risk	Those affected	Risk Grading				Actions to be Taken
				Possibility	Frequency	Severity	Risk Value	
26	Chemical spillage in the residential area because of the storage tank rupture	Environmental pollution, skin and eye diseases	Living creatures (plants, animals), third parties	3	0.5	15	22.5 Possible Risk	Dikes should be built around the storage tanks, so that the settlement area is not affected or affected with the least damage in case of a possible flood disaster.
27	The people living in the residential area are unconscious and vulnerable to dangers.	Injury, loss of life, property damage	Public	6	1	15	90 Significant Risk	The public should be made aware. Safety measures should be selected according to the residential area.
28	The institutions and organizations around the organization are vulnerable to possible domino effects.	Injury, loss of life, property damage	Employees	6	1	100	600 Very High Risk	It should be ensured that institutions and organizations take safety measures against chemicals in the environment. Employees in environmental institutions and organizations should be made aware.

Twenty eight hazard effects were graded in the Fine Kinney method. Because of the risk rating, it was observed that there were three very high risks and three high risks in Organization 2. It was indicated that the institutions and organizations around the organization are vulnerable to possible domino effects, the explosion experienced within the organization has affects on the environmental organizations and the transport of chemicals to the settlement area by flood water had very high risks. To eliminate the hazard on the transport of chemicals to the settlement area by flood water, enclosures should be built around the organization and improvements should be made to the drainage system. Other recommendations for each hazard effects and risk are presented in Table 10. It can be said that Organization 2 is more risky than Organization 1. Increasing the severity of the flood increases either the water height or the water velocity and increases the vulnerability of the equipment (Caratozzolo et al., 2022). The degree of damage caused by the flood is determined by the characteristics of the flood, the location of the settlement and the characteristics of the population. Building standards, system design, the presence of warning systems, the presence of toxic and reactive substances, structural strength, drainage capacity, and anchoring to the ground are among the factors that affect damage due to flood-triggered Natech accidents (Rota et al., 2008).

4. CONCLUSION

Analysis of past Natech accident data showed that meteorological disasters were more dominant. Therefore, risk management of Natech accidents triggered by meteorological disasters is particularly important. It was determined that Erzurum was among the most risky provinces in terms of landslides (19%) and floods (19) from meteorological disasters. It was assumed that lightning was compatible with flood and landslide data. It was shown that various storage tanks can be affected by Natech accidents, and within the scope of the relevant To conduct Natech risk analysis studies, high-level organizations within the scope of the Regulation containing the relevant equipment were selected. Natech accidents triggered by lightning were analyzed by YILKOMER and RADSAN. The environmental condition, occupancy, structural features, usage parameters of the building as well as the height and width information of the building were processed into the analysis program. Protection levels were obtained for Organization 1 and Organization 2 as 3 and 4, respectively. Although a similar risk level was determined for the organizations in the analyses carried out, the damage risk of Organization 2 was found to be higher. Natech accidents triggered by the flood were examined with the preliminary hazard list and Fine-Kinney methods. In Organization 2, more hazard effects were determined with both methods, and it was determined that Organization 2 could create possible domino effects on the surrounding structures/buildings. Considering Türkiye's disaster nature, the study will constitute an important resource in the risk analysis of technological accidents triggered by natural disasters and it is foreseen that it will make significant contributions to both legislation and scientific studies.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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