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Implementation of a NaTech Vulnerability Index in a Seveso Establishment

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NaTech accidents are a class of cascading events that occur when natural and technological hazards collide. In the process industry, where multi-hazard substances are used in large quantities, failures due to natural events can bring simultaneously or sequentially events of acute toxicity, fire, and explosion, which might impact the population and the environment, also provoking economical losses.
The risk analysis methodology used by the Seveso industry often resulted in scenarios related to NaTech events being excluded due to their low probability. However, the increasing impacts of climate change may lead to variations in the recurrence of severe unexpected natural events that will greatly alter the projected frequency of NaTech events. For this reason, it is critical that decision-makers be adequately informed about potential NaTech risks and consider them not only in industrial safety reports but also in the provisions of emergency and city plans. In this paper, a planning tool is used to assess NaTech risk at a Seveso facility that manufactures lubricating oil additives.
A validated method was used to cross the information among the vulnerable industrial items, the typical damage modes triggered by the natural hazards, and the hazardous substances involved in the plant. The information was extracted from the public inventory of establishments at risk of major accidents connected with dangerous substances, and the safety report that the plant draws up.
The results provide an early warning system to the decision-makers about the NaTech vulnerabilities that threaten both, human health, and the environment, contributing to increasing their awareness and preparedness. Further research is required to integrate this kind of analysis with diverse current methodologies for characterizing NaTech events within territorial and multi-risk approaches.

1. Introduction

In the past, chemical plants were perceived as standalone facilities that produced chemicals and other products in isolation. However, with the development of technology and increased awareness of environmental and sustainability issues, the industry has evolved to a more integrated and holistic approach (Jain *et al*., 2017). Therefore, chemical industries are no longer perceived as isolated facilities, but as part of a larger, interconnected system that considers the entire production process and its impacts on human beings and the environment.
In this context, the Seveso III Directive (2012/18/EU) aims to prevent, prepare for, and respond to major industrial accidents involving hazardous substances, to protect human health and the environment. The directive sets out requirements for the classification and labelling of hazardous substances, where sites with more than a threshold quantity of chemical inventory, are classed as lower or upper-tier establishments. Then, operators of these establishments must identify, manage the risks associated with these hazardous substances, and submit a “safety report”, which contains the scenarios that the operator regards as credible. Subsequently, regulators must review all safety reports and verify their compatibility in the territories (European Commission, 2012).

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Although the Seveso safety reports are good practice and contribute to standardizing the information and the classification of hazardous substances and fostering the introduction of lessons learnt from past accidents; some shortcomings still arise from the directive application. For instance, it is important to remark that regulators without a reservoir of knowledge and multidisciplinary skills will not be able to effectively ensure safety measures (Pilone *et al*., 2022). On the other hand, a new challenge faced by people involved in disaster risk management is the so-called high-impact and low-probability (HILP) events, such as technological events triggered by natural hazards (NaTech). Even if it's kind of event presents a small likelihood (often neglected by operators), in case of occurrence, it may cause severe damage to individuals, infrastructure, environment, and society, being particularly complex because often they are the result of cascading events (Mesa-Gómez *et al*., 2020). Moreover, there is some evidence to suggest that the frequency of certain types of NaTech, may be increasing due to events linked to climate change (Ricci *et al*., 2021). Despite natural risks being an important consideration within the Seveso III Directive; nature and environment are often considered as target components, whereas the inverse complex interaction where the industrial facilities should be seen as vulnerable infrastructure targets of natural hazards, is typically not explored in sectorial risk plans, or overlooked due to its perceived low probability (Pilone *et al*., 2021).

Furthermore, the Sustainable Development Goals (SDGs) issued in 2015 for the United Nations Agenda, highlighted the necessity of developing holistic risk management approaches in all sectors, to strengthen the resilience and the adaptive capacity to the different natural hazards and disasters, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030 (United Nations, 2015a). At the same time, one of the key components of the Sendai Framework is the development and implementation of early warning systems as critical tools for disaster risk reduction and building more resilient communities (United Nations, 2015a).

In this line, the Italian National Adaptation Plan serves as a notable instance of a climate change adaptation strategy advanced by EU member states. It acknowledges the issue of NaTech events as one of the sectoral vulnerabilities related to climate change and recommends sector-specific measures and best practices to ensure effective adaptation to climate change in the industrial sector (Centro Euro-Mediterraneo sui Cambiamenti climatici, 2017). The adoption of an early warning system in areas interested in hazardous installations and infrastructures is a crucial element of this plan.

Considering everything described above, the goal of this research was to implement a NaTech indicator in a Seveso establishment. The purpose was to test the method providing the decision-makers, with an early warning system to rate objectively the implicit vulnerabilities in the interaction between industrial facilities and their surrounding area.

2. Materials and Methods

A method previously validated by Pilone *et al*. (2021b) and Pilone *et al*. (2022) were used to calculate the "NaTech indicator". In a nutshell, this method rate objectively the NaTech vulnerabilities associated with industrial establishments, crossing information among the natural hazards that threaten the area where the plant is located, and their interaction with the industrial vulnerable items (Factor A), and the hazardous substances involved in the plant (Factor B). The information used in the present case was collected from the safety report.

For the verification of Factor A, the presence (or not) and the position of vulnerable equipment must be identified. Regarding this, the chapter "Establishment description" in the safety report results in the cornerstone, where the technology, the process, and the operating conditions are described. On the other hand, for the identification of natural hazards may be consulted the presentation of the establishment site in the safety reports. From this, it was possible to identify important elements such as the establishment description and its territorial location, its geographical position, as well as meteorological, geological, seismic, and hydrographic information, which could be further investigated. Then, the interaction between Vulnerable Items and Natural Hazards was evaluated following the binary criteria proposed by Pilone *et al*., (2021b) and Pilone *et al*. (2022).

Moreover, Factor B is divided into two sub-factors related to the Type (B1) and Quantity (B2) of each hazardous substances detained by the plant. For instance, B1 depend on the section within Annex I of the III Seveso Directive that substance correspond (such as section H, P, E, O), while B2 depends on the substance trespass de different thresholds established in the government document applicable (Official Gazette, 2015; DGR, 2010). Furthermore, B1 was split in two sub-categories, according to the potential damage to human health (B1HH) and environment (B1Env). Consequently, B1HH associate ranks for substances in the sections human health (H) and physical hazards (P) from the above-mentioned Annex, while different ranks are assigned to B1Env which includes substances in the section hazardous to the environment (E), and other substances (O). The ranks assigned to each factor or subfactor match with the values proposed in (Pilone et al., 2021; Pilone et al., 2022).

Summarizing, the NaTech Indicator (NI) is estimated according to the following Eq. (1).

$$NI = Factor\ A + \frac{1}{n_m}\sum_{i=1}^{n}(\text{Factor B}1_i \cdot \text{Factor B}2_i) \tag{1}$$

Where,
m: corresponds with each section within Annex I of the III Seveso Directive (H, P, E, O, and other substances).
n: corresponds to the number of different substances detained inside the same m-section (i.e., in the section hazards to the environment "E" if two substances are dangerous to the aquatic environment, category of chronic toxicity- "E2", then n=2).

3. Results and Discussion

3.1 Factor A determination

The study case corresponded with an upper-tier Seveso establishment with a typical typology clustered in the category "chemical and petrochemical industry" according to the description given by Casson Moreno et al. (2018). Its specific activity is the production of lubricants and oil additives, where both, the principal raw materials used, and the final products, are mostly chemicals. The unitary operations that are carried out in the plant are both chemical (neutralization, carbonation, polymerization) and physical (distillation, filtration, blending). The activities also include auxiliary technical systems necessary for the production plant's operation, such as compressed air, treated wastewater, steam production, and nitrogen (ISPRA, 2015).
Within all the processes and functions of the pant were identified the following items: atmospheric storage tanks, pressurized tanks, thermal power stations, tall structures such as chimneys and flares, heat exchangers, process columns, complex systems of pipelines (even pressurized), reactors, water treatments organs. These items were clustered using the categories established in the present methodology, while all the categories of hazards proposed in the current methodology were found significant with greater or lesser intensity, to the territory under analysis. In the table could be seen the results for the determination of Factor A.

Table 1: calculation of Factor A: Vulnerable Items.

NaTech → Vulnerable Items		Water treatment basins	Atmospheric/ pressurized tanks	Underground deposits	Tall structures	Basins others equipment	Hazardous storage
Position of the Items →	Inside (I) Outside (O)	(O)	(O)	-	(O)	(O)	(O)
Hazards ↓	Ratings	1	1	0	1	1	1
Earthquake	1	1	1	0	1	1	1
Flood	1	1	1	0	0	1	1
Storm	1	1	1	0	1	1	1
Fire	1	0	1	0	1	1	1
Obsolescence	1	1	1	0	1	1	1
	Total ratings	4	5	0	4	5	5
			Factor A = 23				

As can be appreciated, the presence of almost all the elements in the columns and row of Table 1, results in a high factor A with represent around 85 % of the highest Factor A (Pilone et al., 2022). Moreover, the outside position (O) of the items *increases* their vulnerability. From this alarm, is evident that further research is required about the assessment of the multi-risk vulnerabilities in the territory where the plant is located. The territorial multi-risk index proposed by Beltramino et al. (2022) could be useful to better individualize vulnerabilities at the local scale, combining all the relationships and elements examined in the area where the plant is located and its surrounding territory. The latter association of vulnerabilities with the industrial critical infrastructure should use the typical damage modes triggered by the natural hazards defined in the "guidance for operators of hazardous industrial sites and national authorities" (European Commission, 2022).

3.2. Factor B determination

Table 2 summarizes all the information related to the hazardous substances involved in the plant, also with the ratings assigned for the factors Type ($B1_{HH}$ and $B1_{ENV}$) and Quantity (B2).
From the simple observation of the table, it can be appreciated not only the substance's hazardousness but also how the threshold is surpassed for more than one category, typical of the upper-tier Seveso establishment. With the information obtained in 3.1 and 3.2, the NaTech Indicator determination is the next step.

Table 2: hazardous substances involved in the Seveso establishment.

2012/18/EU Annex I section	Hazardous substance	Hazard Statements	Upper tier threshold (t)	20 % (lower tier) (t)	Quantity (t)	$B1_{HH}$	$B1_{Env}$	B2
Health hazards (H2)	Methanol	H301, H311 H331, H370	200	10	339	3	-	1
Physical Hazards (P5c)	Toluene	H225	50 000	1000	171	2	-	0.2
	Methyl Methacrylate	H225, H335 H319, H315			25.4	2	-	0.2
	Automotive Diesel	H225, H315			3.5	2	-	0.2
Physical Hazards (P6b)	Azobis-methylbutyronitrile (AMBN)	H242, H302 H225, H315 H319, H312	200	10	1	2	-	0.2
Hazards on the environment (E1)	Sodium hypochlorite	H400	200	20	10	-	3	0.2
Hazards on the environment (E2)	Raws materials and products (Irgamet 39, methacrylic ester, Zinc dialkyldithiophosphate, Alkyldiphenylamine, phenol derivative, blending mixtures)	H411, H412 H400, H315 H317, H301 H311, H331	500	40	708	-	3	1
	Hazardous waste (API tank foam, sludge, waste oil from maintenance, reclamation sludge, dirty mixed materials)	H411, H304 H315, H318 H335,			150	-	3	1

3.3. NaTech Indicator determination

This section presents separate the final determinations of NI for both, human health (HH) and for the environment (Env). In Eq. (2) and Eq. (3) can be realized the rating substitution from data in Table 2. Furthermore, could be appreciated the development of each equation and the final solutions for NI(HH) and NI(Env).

$$NI(HH) = FactorA \cdot [\left(\frac{B1_{H2} \cdot B2_{H2}}{1}\right) + \frac{(B1_{P5c1} \cdot B2_{P5c1}) + (B1_{P5c2} \cdot B2_{P5c2}) + (B1_{P5c3} \cdot B2_{P5c3}) + (B1_{P6b1} \cdot B2_{P6b1})}{4}] \quad (2)$$

$$NI(HH) = 23 \cdot [\left(\frac{3 \cdot 1}{1}\right) + \left(\frac{(2 \cdot 0.2) + (2 \cdot 0.2) + (2 \cdot 0.2) + (2 \cdot 0.2)}{4}\right)]$$

$$NI(HH) = 23 \cdot (3 + 0.4) = 78.2$$

$$NI(Env) = FactorA \cdot \left[\left(\frac{B1_{E1} \cdot B2_{E1}}{1}\right) + \frac{(B1_{E21} \cdot B2_{E21}) + (B1_{E22} \cdot B2_{E22})}{2}\right] \quad (3)$$

$$NI(Env) = 23 \cdot [\frac{(3 \cdot 0.2) + (3 \cdot 1) + (3 \cdot 1)}{3}]$$

$$NI(Env) = 23 \cdot (2.2) = 50.6$$

In the case of NI(HH), the value obtained is greater than 45 % highest NI(HH) value, while it's important to remark that NI(Env) represents approximately the 50 % of the potentially highest value. The results generated from the available information in the safety reports of this Seveso establishment, constitute an early alarm for the decision-makers about the susceptibility of the plant, to suffer disruptions able to generate cascading events, which may considerably harm the environment, the population, and the infrastructure.

4. Conclusions

A semiquantitative NaTech indicator was implemented in an upper-tier Seveso establishment that produces lubricants and oil additives. Factor A resulted in 23, which joined to the upper tier characteristic of the establishment and the hazardousness of the substance detained, were turned into high values of NaTech Indicator for both, human health (78.2), and environment (50.6).

The results of the NaTech indicator implementation in this study case, acted as an early warning system, offering a first glance from the categorical available data, about the vulnerability interaction between the establishment and its surrounding area. From the implication of the results, further research can be planned to characterize and contextualize the territorial multi-hazards intensity, which threatens the plant as a vulnerable infrastructure. In addition, the quantitative, spatial, and resilient analysis should be performed complementary to the present research. It would enable us to weigh the association between natural and technological elements, increasing the awareness and contributing to improving the preparedness against NaTech events.

References

Beltramino, S., Scalas, M., Castro Rodriguez D.J.,Brunetta G., Pellerey F., Demichela M., Voghera A., Longhi A., Mutani G., Caldarice O., Miraglia G., Lenticchia E., La Riccia L., 2022, Assessing territorial vulnerability: Testing a multidisciplinary tool in Moncalieri, Italy, TeMA, Journal of Land Use, Mobility and Environment, 15 (3), 355-375.

Casson Moreno V., Reniers G., Salzano E., Cozzani V., 2018, Analysis of physical and cyber security-related events in the chemical and process industry, Process Safety and Environmental Protection, 116, 621-631.

Castro Rodriguez D.J., Beltramino, S., Scalas, M., Pilone E., Demichela M. Territorial Representation of a Vulnerability Associated with the Seveso Installations in a Nord Italian Case Study. Proceedings of the 32nd European Safety and Reliability Conference (ESREL 2022) Edited by Maria Chiara Leva, Edoardo Patelli, Luca Podofillini, and Simon Wilson ©2022 ESREL2022 Organizers. Published by Research Publishing, Singapore.

Centro Euro-Mediterraneo sui Cambiamenti Climatici, 2017. Piano Nazionale di Adattamento ai Cambiamenti Climatici (PNACC) - Prima stesura per la consultazione pubblica. <https://www.minambiente.it/sites/default/files/archivio_immagini/adattamenti_climatici/documento_pnacc_luglio_2017 .pdf>, accessed 30.11.2020.

DGR, 2010, Regional Council Resolution No. 17-377-Guidelines for the assessment of industrial risk in land use planning: Strategic Environmental Assessment and Technical Report on Major Industrial Risks". DGR (Deliberazione della Giunta Regionale-Regional Council Resolution), July 26, 2010. In: Official Bulletin of the Piedmont Region under art. 61 of the Statute and art. 14 of D.P.G.R. n. 8/R/2002. (In the Italian language).

European Commission, 2012. Directive 2012/18/EU of the European parliament and of the council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing council directive 96/82/EC text with EEA relevance. Off J Eur Union L197, 1–37.

European Commission, 2022, Joint Research Centre, Necci, A., Krausmann, E., NaTech risk management: guidance for operators of hazardous industrial sites and for national authorities, Publications Office of the European Union.

ISPRA, 2015, Inventory of establishments at risk of major accidents connected with dangerous substances. Istituto Superiore per la Protezione e la Ricerca ambientale (ISPRA). <rischioindustriale.isprambiente.gov.it/seveso-query-105/Default.php> accessed 12.11.2022.

Jain P., Pasman H. J., Waldram S. P., Rogers W. J., Sam Mannan M., 2017, Did we learn about risk control since Seveso? Yes, we surely did, but is it enough? An historical brief and problem analysis, Journal of Loss Prevention in the Process Industries, 49, Part A, 5-17.

Mesa-Gómez A., Casal J., Muñoz F., 2020, Risk analysis in NaTech events: State of the art, Journal of Loss Prevention in the Process Industries, 64, 1-16.

Official Gazette, 2015, Legislative Decree No. 105/June 26/ 2015-Implementation of Directive 2012/18/EU on the control of major accident hazards involving dangerous substances, In: Official Gazette, July 14, 2015, No. 38, S.O. (In Italian language).

Pilone E., Casson Moreno V., Cozzani V., Demichela M., 2021, Climate change and NaTech events: A step towards local-scale awareness and preparedness, Safety Science, 139, 105264, 1-20.

Pilone E., Demichela M., Camuncoli G., 2021b, A NaTech Vulnerability Indicator for Local Planners, In Proceedings of the 31st European Safety and Reliability Conference, (ESREL 2021), Published by Research Publishing, Singapore, ISBN: 978-981-18-2016-8 Edited by Bruno Castanier, Marko Cepin, David Bigaud and Christophe Berenguer.

Pilone E., Demichela M., Camuncoli G., 2022, Na-Tech Risk: a New Challenge for Local Planners, Chemical Engineering Transactions, 90, 223-228.

Ricci F., Casson Moreno V., Cozzani V., 2021, A comprehensive analysis of the occurrence of NaTech events in the process industry, Process Safety and Environmental Protection, 147, 703-713.

United Nations, 2015a, Transforming our world: the 2030 Agenda for Sustainable Development (A/RES/70/01),<un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf> accessed 25.08.2022.

United Nations, 2015b, Office for Disaster Risk Reduction (UNISDR), Sendai Framework for Disaster Risk Reduction 2015-2030, UNISDR/GE/2015 - ICLUX EN5000 1st Ed. Switzerland, <preventionweb.net/files/43291_sendaiframeworkfordrren.pdf> accessed 25.08.2022.