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Mapping NaTech Research Gaps: A Systematic Review of Reviews

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NaTech events or risks, defined as technological accidents triggered by natural hazards, have become increasingly important in contemporary risk management. The growing frequency of disasters and intensification of natural hazards generate an urgent need for comprehensive understanding of this complex type of risk. The current literature on NaTech risks is fragmented across multiple fields and disciplines due to the transdisciplinary nature of these risks, as evidenced by the proliferation of existing literature reviews.
This first version paper presents an exploratory and original systematic review of the literature that identifies and categorizes the research gaps documented in existing NaTech reviews. Using a two-dimension coding method, we identify, categorize, map and then analyze the research gaps in these reviews. The first dimension draws on the research gap typology developed by Müller-Bloch and Kranz (2014) (deductive coding). The second dimension (inductive coding) proceeds by extracting themes from the gaps. Research progress documented in these reviews is also coded using the same epistemic categories, enabling a parallel analysis of both gaps and advances. The intersection of these coding dimensions produces a bidimensional matrix (epistemic nature of the gap; thematic content). This enables us to study the evolution of these gaps through parallel documentation of both identified gaps and research progress, determining which gaps have been addressed, which persist, and which are emerging.
Based on these results, we identify unidentified gaps: as a lack of ontological and epistemological questioning, a need to shift from site-centric to systemic conceptualizations, and a gap about warning and alert processes in multi-risk contexts. These gaps, complementing those already identified, may form a new research agenda for future cross-disciplinary research.

Keywords: NaTech, Research gap, Review, Natural hazards, Industrial hazards.

1. Introduction

Natural Hazard Triggering Technological Accidents, commonly referred to as NaTech events or risks, is generally used to designate the impact a natural disaster may have on all or part of an industrial facility capable of triggering an accident, the consequences of which may harm people, property, or the environment outside the industrial site's perimeter (cf. INERIS : National Institute for Industrial Environment and Risks). These complex events have become a critical concern in territorial risk management due to their potential to generate cascading effects. The urgency of addressing NaTech risks is further amplified by climate change, which is increasing the frequency, intensity, and unpredictability of the triggering natural hazards cumulate to the increasing human development (urbanization and industrialization). (Necci and Krausmann 2022)

In response to this growing threat, the scientific community has significantly increased its focus on NaTech research. This rising interest is evidenced by the proliferation of dedicated research projects at multiple scales. In France, the "PEPR-Risques" explicitly targets these issues through its sub-project "NaTech". At the European level, initiatives such as the REUNATECH project demonstrate a similar commitment to advancing knowledge and resilience strategies for these risks. This interest is also reflected in a growing literature. The annual publications increased from three per

year (in 2004) to 51 per year (in 2025). However, this growth does not guarantee structured progress. The field develops rapidly but remains underdeveloped and can still be considered to be in its infancy. Indeed, it has grown mainly from practical experience with accidents rather than from shared conceptual foundations. This approach meets urgent needs but also leads to fragmentation in NaTech research—a widespread challenge when new scientific or popular concepts emerge. As these ideas gain traction, the field can become fractured, which often slows the development of coherent knowledge. (Kuhn 1962)

This fragmentation can be also explained by the fact that NaTech are not typical risks as they acts as a "hyper-boundary-object" (Morton and Bury 2018; Trompette and Vinck 2009), in the way that it spans disciplines (climate science, engineering, social sciences, etc.), scales (from the scale of the territory to the industrial site equipment vulnerability), and temporalities (from the anticipation of changes in the territory and its infrastructure to the climate change evolutions).

These traits create difficulties for research and questions the validity and relevance of classic risk analysis approaches. For example, at a seminar within the actual French NaTech program, researchers from very different disciplines and engineers quite quickly diverged on the meaning of a risk scenario in the NaTech context and the relevance of old-fashioned bowtie type approaches in this context. Indeed, if NaTech does not mean the same thing for everyone, it becomes difficult to agree on what should be studied, with what methods and how results can be compared. In practice, this misalignment in epistemic references may slow down or even block innovation.

This seminar serves as a representative illustration of the fragmentation processes that are already apparent within the broader NaTech literature. Consequently, research on NaTech tends to accumulate without achieving substantive convergence. Even the secondary literature addressing NaTech exhibits significant fragmentation. Although a limited number of comprehensive reviews endeavor to address NaTech risks from interdisciplinary perspectives, the majority concentrate on specific dimensions—such as risk assessment methodologies, vulnerability models, distinct natural hazards, or the analysis of individual events—rather than integrating the field as a cohesive and unified domain of study.

In light of the aforementioned challenges, it is essential to articulate the epistemological foundations of the NaTech field and undertake a reflective examination of the processes by which knowledge is generated within this domain.

To initiate this work, we propose to carry out an original review specifically focused on research gaps. We define a research gap as an explicit statement where authors identify what remains lacking, uncertain, or insufficiently addressed in NaTech research (e.g. "There is a lack of methods for modeling cascading effects beyond industrial sites." or "Current models do not account for multi-hazard interactions.").

Indeed, we believe that, in a fragmented field, a classic narrative review is not always enough to build bridges across disciplines, as researchers typically focus primarily on the gaps relevant to their own discipline. Even the few generalist reviews rarely systematically extract or synthesize gaps in an interdisciplinary way, leaving researchers without a consolidated view of the global field's priorities Accordingly, conducting a systematic mapping of research gaps can provide scholars from diverse disciplines with a comprehensive and unified perspective on outstanding research needs guided by the core research subject itself rather than constrained by disciplinary boundaries. This synthesis level complements existing reviews and directly supports more cumulative knowledge production in NaTech research.

To tackle this challenge, we systematically examine a literature corpus composed of four existing interdisciplinary NaTech reviews. We then employ a novel methodology to extract, categorise, and map these gaps and progress statements (G/P). A research progress indicates a maturation in the field (e.g. "There is growing interest about participatory governance.").

This paper is a first version and should serve as a proof of concept before broadening the analysis to a larger corpus, including primary research

articles (see expected contributions).

The method follows three phases: (1) identifying, categorising, and mapping research gaps and progress from the selected reviews; (2) analysing G/P trends over time to distinguish gaps that have been addressed, persist, or are emerging; (3) conducting reflexive analysis to uncover "unidentified gaps".

2. Methodology

Most NaTech reviews structure the field through predefined dimensions (hazard types, modeling methods, or specific application domains). Our analysis follows a different approach: we identify research gaps from reviews and classify them by epistemic nature (Müller-Bloch and Kranz 2015), then derive NaTech themes inductively from these gap statements without imposing a predefined thematic grid. This produces a structured view of the field's knowledge needs and can reveal differences between established framings and what reviews actually problematize as missing priorities.

2.1. *Corpus constitution*

We conducted a comprehensive literature search in Scopus and Web of Science using the query "natech(s)" OR "na-tech(s)", filtered for review articles with no date restriction. After deduplication (Bibliometrix R-package), 28 unique publications remained. Manual screening excluded false positives (n=2), non-peer-reviewed documents (n=3), and non-English/French papers (n=2), leaving 21 reviews. We then selected articles providing comprehensive NaTech risk management overviews covering all hazard types and management phases, retaining only those with explicit sections on research gaps, future directions, or progress. This resulted in a final corpus of four articles (Steinberg et al. 2008; Cruz and Suarez-Paba 2019; Suarez-Paba et al. 2019; Mao et al. 2024).

The corpus is intentionally heterogeneous: while three articles are genuine systematic literature reviews, the 2008 article is a descriptive expert overview retained as a foundational baseline for NaTech research. The 2024 review (Mao et al. 2024) primarily addresses hydrometeorological hazards but was included given their centrality as NaTech triggers in the context of climate change.

2.2. *Coding*

The coding process consists of breaking down text into units of analysis and integrating them into categories selected according to the research objective. We code epistemic nature deductively and G/P thematics inductively.

2.2.1. *Extraction of units of analysis*

We systematically identified units of analysis explicitly referring to G/P within dedicated sections (e.g., "Future research directions"). Gaps were extracted from sentences expressing deficiency ("There is a need for..."), scarcity ("lack of sufficient research"), or recommendations ("should be more vigilant"). Progress was identified via accumulation markers ("heightened interest"), achievements ("have been developed"), or evolutionary steps ("researchers have started to"). Extracted units were then randomized to minimize contextual biases.

2.2.2. *Epistemic deductive coding*

Each unit was assigned a single epistemic category using the taxonomy proposed by Müller-Bloch and Kranz (2015) with revised labels from Adu and Miles (2023), excluding the "population gap" as irrelevant here. We broadened "practical-knowledge gap" into "practical gap" to capture operational shortfalls without assuming underlying knowledge is established, and applied the same categories to progress statements.

2.2.3. *Thematic inductive coding*

Categories emerged directly from the data using a descriptive coding strategy (Gavart-Perret et al. 2018), akin to open coding in grounded theory (Strauss and Corbin 1990). The resulting taxonomy is detailed in the results. Unlike epistemic coding, thematic coding is non-exclusive: a single unit can be tagged with multiple categories to reflect the multi-dimensional nature of certain G/P.

Table 1. Original taxonomy and proportion (adapted from Müller-Bloch and Kranz).

Category	Retained definition (with example)
Knowledge (84%)	The desired research findings do not exist. Example: "Conducting longitudinal studies on long-term psychological and physical health effects by Natech events is also important."
Methodological (6%)	A variation of research methods is necessary to generate new insights. Example: "Methodologies that provide useful information for a complete analysis without the need for specific probabilistic data and robust mathematical models are lacking."
Theoretical (6%)	Theory should be applied to certain research issues to generate new insights. Example: "New proactive approaches with a broader scope will support better Natech risk management."
Empirical (2%)	Research findings or propositions that need to be evaluated or empirically verified.
Evidence (1%)	Results from studies allow for conclusions in their own right but these are contradictory when examined from a more abstract point of view.
Practical (1%)	Professional behavior or practices deviate from the research findings or are not covered by the research. Example: "There is a need for centralized reporting of natechs."

2.3. *Data analysis strategy*

The two coding dimensions were first examined separately to describe the overall distribution of epistemic natures and thematic areas. They were then combined in a matrix (see figure 1) where each cell represents a specific (epistemic × thematic) pair, readable through three lenses: cells with a high number of gaps (research priorities); cells with few or no gaps despite theoretical relevance (potential blind spots); and a reflexive interpretation to identify "unidentified gaps" and determine whether they signal a mature area or a gap in the global research program.

3. Results

The findings of this preliminary study are synthesized in the matrix provided in the figure 1. A total of 84 units were extracted and coded, comprising 55 research gaps and 29 research progress statements. The quantitative data presented in the matrix reflects the frequency of thematic occurrences rather and not directly the number of gaps itself. Consequently, the total aggregation in the matrix (n=102) exceeds the number of original units (n=84), as a single complex statement could be assigned to multiple thematic categories to fully capture its multi-dimensional nature.

3.1. *Epistemic and thematic landscape's gap*

3.1.1. *Epistemic profile*

The epistemic distribution of gaps highlights a specific profile for NaTech research compared to the theoretical baseline of Müller-Bloch and Kranz (2015) (see table 1). While "knowledge gaps" remain dominant (45%), their share is notably lower than the theoretical standard (84%). In contrast, "methodological" (31%) and "practical" (18%) gaps are significantly over-represented compared to the expected 6% for each. This shift confirms a field heavily oriented towards tool development and operational application rather than purely abstract knowledge accumulation. The "theoretical" category (5%) aligns closely with the baseline (2%), while the absence of "evidence" and "empirical gaps" (0%) confirms their marginal role in literature reviews, consistent with the original application.

3.1.2. *Thematic profile*

An analysis of thematic frequencies across the entire corpus identifies several priorities within the NaTech research agenda (see the first column of the appendix). The most recurrent themes include risk communication and perception, reflecting a strong focus on the societal perception of NaTech risks. Additionally, issues related to data

Thematic	Sub-thematic	Total (G)	Total (P)	Total (G + P)	(Steinberg & al., 2008)								(Cruz & Suarez-Paba, 2019) (Suarez-Paba & al., 2019)								(Mao & al., 2024)							
					13 units				0 unit				23 units				15 units				19 units				14 units			
					08 G (Kn)	08 G (Me)	08 G (Pr)	08 G (Th)	08 P (Kn)	08 P (Me)	08 P (Pr)	08 P (Th)	19 G (Kn)	19 G (Me)	19 G (Pr)	19 G (Th)	19 P (Kn)	19 P (Me)	19 P (Pr)	19 P (Th)	24 G (Kn)	24 G (Me)	24 G (Pr)	24 G (Th)	24 P (Kn)	24 P (Me)	24 P (Pr)	24 P (Th)
Data and information management	Data sharing / accessibility	5	1	6			4															1			1			
	Data collection / capitalization	2	2	4			1																1		2			
	Quality / standardization	2	0	2																	1	1						
	Empirical observations	1	0	1																	1							
Effects and impacts	Consideration of NaTech	4	3	7			4												2							1		
	Safety equipment	1	4	5	1												1							3				
	Population health	4	0	4									1								3							
	Cascading / systemic effects	2	0	2																	2							
	Nuclear facilities	1	0	1																	1							
Governance	Participatory governance	4	0	4			1						1	1	1													
	Interdisciplinary research	3	1	4												3				1								
	International community	0	3	3															3									
	Regulation	0	1	1																				1				
Methods	Mixed methods	3	0	3										2								1						
	New methodologies	0	3	3														1							2			
	Framework	2	0	2																		2						
	Quantitative methods	1	1	2	1													1										
	Qualitative methods	1	0	1										1														
	Real-time analysis	1	0	1										1														
	Semi-quantitative methods	0	1	1																					1			
Natural hazard	Hydrometeorological hazards	1	6	7									1				2							4				
	Extreme temperatures	3	0	3									3															
	Climate change integration	2	1	3																	1	1			1			
	Lightning	1	2	3									1				1							1				
	Multi-hazards	0	3	3													1	1						1				
	Landslides	2	0	2									2															
	Tsunamis	2	0	2									2															
	Volcanic eruptions	1	0	1									1															
Risk management cycle	Communication / perception	5	3	8									4				2				1			1				
	Prevention / risk reduction	3	3	6			1						1		1		2								1			
	Crisis management	1	3	4													1		1		1			1				
	Education / training	3	0	3																			3					
	Total	61	41	102	2	0	11	0	0	0	0	0	17	5	2	3	10	3	6	1	11	6	4	0	15	6	0	0

Fig. 1. Research gaps and progress matrix

sharing and accessibility, as well as the explicit consideration of NaTech in existing frameworks, appear as central concerns. Finally, participatory governance emerges as a new trend, highlighting the community's growing interest in participative decision-making processes.

3.2. *Evolution over time*

In 2008, the reviewed article (Steinberg et al. 2008) reports only research gaps and no progress statements, reflecting a field still in its formative stage. These gaps concentrate on two core issues: the lack of explicit consideration of NaTech in industrial and territorial risk management, and the absence of adequate data sharing and accessibility mechanisms. From an epistemic standpoint, the gaps are overwhelmingly coded as "practical gaps", with only a small share classified as "knowledge gaps", which suggests that concern for NaTech risk emerged primarily from operational needs rather than from prior theoretical debates. Thematically, the "lack of NaTech consideration" appears as a central deficiency in 2008 but disappears as a gap in later reviews, where only progress is reported on this front, indicating that NaTech has since been recognized and integrated as a distinct risk category. Similarly, the early concern about data sharing and accessibility does not reappear as a gap in subsequent periods, hinting at partial resolution or at least reduced salience of this issue in later syntheses.

In 2019, the two reviews (Cruz and Suarez-Paba 2019; Suarez-Paba et al. 2019) place much stronger emphasis on communication and risk perception, which emerge as well-defined gaps in the NaTech literature. At the same time, the governance dimension becomes visible for the first time, with explicit calls to broaden the field towards interdisciplinary research and participatory approaches. Epistemically, this period is marked by the appearance of "theoretical gaps" (3 units), where authors argue that existing conceptual frameworks are insufficient and that new theories or adaptations from adjacent disciplines are required to adequately frame NaTech governance and decision-making.

By 2024 (Mao et al. 2024), the center of gravity has shifted towards the effects and impacts of

NaTech events, especially on physical and mental health outcomes for affected populations. The most recent review highlights both the need to better understand these health impacts and the importance of education and training for stakeholders, as well as the explicit consideration of cascading and systemic effects that characterize complex NaTech scenarios. Interestingly, gaps related to participatory governance and transdisciplinary collaboration, which were prominent in 2019, are less visible in the 2024 review. However, this absence should not be interpreted as a resolution of these issues; governance and trans-disciplinarity remain critical and active research frontiers, as evidenced by major contemporary initiatives such as the French PEPR, which explicitly prioritize the co-construction of risk strategies and cross-disciplinary integration.

Overall, the mapping of thematic frequencies in our matrix reveals multiples levels of research deficits. At the first level, we observe well-identified gaps (e.g., Participatory governance, Communication and perception) to which the community already devotes sustained attention. At a second level, hapax recent themes (appearing only once or twice) potentially act as weak signals, indicating emerging gaps that have yet to gain collective traction. At the third level, we have ”unidentified gaps” or ”unknown-gaps”.

3.3. *Unidentified gaps*

Our preliminary mapping of G/P statements also enables the identification of unidentified gaps—blind spots that do not emerge explicitly from the reviewed “future research” sections but become visible through cross-synthesis. By providing a consolidated view of explicitly stated research needs, this mapping allows us to deduce these latent gaps, provided we verify these are genuine research voids by consulting the broader literature to ensure the subject has not already been addressed. Indeed, In line with our initial assumptions, no gap is directly formulated in the reviews regarding the need for an ontological and epistemological framework for NaTech risk. Other missing priorities could also be questioned (e.g., the warning/alert phase, specific hazard types), but in this preliminary version we deliberately focus on the ontological and epistemological axis, which we consider a necessary starting point for clarifying the research object before addressing more operational gaps. These additional unidentified gaps will be examined more fully in the final expanded version of the paper.

3.3.1. *Lack of a stabilized definition and need to conceptual expansion*

Despite substantial research, NaTech lacks a stabilized definition and an integrated conceptual framework. Historically, NaTech has been framed primarily through the lens of a natural hazard impacting a specific industrial facility (a site-centric perspective). This concept should be taken further by integrating it into a more territorial approach. For example, NaTech should be conceptualized as an integral component of multi-risk (Curt 2021) and characterized by cascading propagation across multiple interconnected vulnerabilities (Pescaroli and Alexander 2018; Castro Rodriguez et al. 2025). In other words, the field requires a shift towards a truly systemic and integrative approach (Gill et al. 2022).

3.3.2. *Absence of ontological and epistemological inquiry*

Our analysis shows that NaTech risk research has always prioritized operational issues, focusing mainly on how to manage this risk. While practical solutions are important, this focus on ”doing” has left little room for ”thinking” about what NaTech risk actually is. We believe it is time to go back to the base and study NaTech risk as a concept and explore its ontological status (Aven et al. 2011). Because its increasing entanglement with climate change, industrial densification, and network complexity, we may constitute NaTech risk as a ”hyper-boundary-object” (Morton and Bury 2018; Trompette and Vinck 2009): entities that span disciplines, scales, and temporalities. This shift could finally provide the common language and shared framework that the community currently lacks.

Furthermore, given the urgency and irreversibility of climate change, future research could also

productively situate NaTech within the epistemological framework of post-normal science (Funtowicz and Ravetz 1993; Rosa 1998), which is tailored for contexts where facts are uncertain, values are disputed, stakes are high, and decisions are urgent.

Finally, recognizing NaTech risks as emerging risks—defined by the IRGC as risks that are highly uncertain, under development, and with potentially severe impacts that existing frameworks struggle to address—helps reassess whether conventional risk-management approaches remain appropriate, or whether frameworks specifically designed for emerging risks should be prioritized. In that perspective, determining the stage of emergence of NaTech risk (Mazri 2017) can provide actionable insights for governance and regulation by clarifying the level of uncertainty and the type of institutional response required. In this specific case, analyzing the temporal evolution of the G/P ratio may serve as an empirical indicator to support this staging over time.

4. Discussion

This first version primarily aimed to provide an initial overview of G/P by starting, as is often recommended, with an analysis of secondary literature (review articles), while also reporting a set of preliminary findings. It also lays the groundwork for an innovative, systematic methodology to assess research trends.

However, two sets of limitations must be acknowledged. First, the proposed method has intrinsic constraints, which are detailed below, notably those associated with relying on review-level evidence and with the choices made in the extraction, coding, and synthesis procedures. Second, the study is constrained by a relatively small sample of articles; this was a necessary and explicit design decision at this stage, consistent with the rationale presented above, to refine the scope and analytical categories before scaling up.

These limitations will be addressed in the forthcoming developments of this work, which will expand the corpus and integrate primary studies to strengthen the robustness and transferability of the findings.

Concerning the methodological limitations and the sample-related constraints and then introduces the planned extensions for the final version.

Quantifying qualitative data inevitably involves reductionism, risking the loss of context and nuance. By translating complex arguments into discrete counts, we treat these frequencies as indicative trends rather than absolute measurements. Despite this limitation, this heuristic approach remains valuable for systematizing heterogeneous sources.

Beyond general epistemological constraints, our study design presents specific limitations. First, the nature of manual extraction limited our sample size. Second, the dominance of the "knowledge" category (covering over 80% of gaps) obscures finer distinctions; future research should fragment this category into more granular sub-types as suggested by Müller-Bloch and Kranz (2015).

5. Conclusion

This systematic mapping of research gaps and progress in NaTech literature lays the foundational building block for advancing transdisciplinary research in the field. By providing a comprehensive synthesis that tracks gap evolution alongside documented advances, our work wants to create a shared framework to bridge disciplinary silos.

As a preliminary scoping exercise based on review articles, this version offers an initial mapping of the research landscape. The full-length study will extend this analysis to primary literature and deliver three hierarchical contributions.

First and foremost, we will establish a rigorous ontology of NaTech risk through systemic conceptual expansion and boundary-object conceptualization. This ontological clarification is prerequisite to any epistemological development, as it defines what constitutes a NaTech event and delineates the boundaries of the field.

Second, we will systematically map research gaps by grouping gap statements into thematic clusters and tracking their evolution over time. This temporal analysis will distinguish persistent gaps, emerging concerns, and apparently resolved issues.

Third, we will refine existing epistemic gap categories (ontological, epistemological, axiological) to enhance their practical applicability, enabling more consistent gap identification across studies.

Finally, synthesizing these contributions, we will propose a consolidated research agenda that identifies priority research directions.

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