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POLICY BRIEF

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MIND: a proposed strategic and collaborative platform for advancing chemical environmental risk assessment

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Abstract

Several scientific initiatives are underway to modernise and advance chemical environmental risk assessment (ERA), supporting the shift from conventional practices toward more mechanistic, integrated, and systems-based approaches. These developments aim to enhance ecological realism, improve predictive capacity, reduce reliance on animal testing, and foster greater alignment across sectors, ultimately contributing to better protection of biodiversity and the environment. Yet, translating these innovative approaches into regulatory practice remains challenging due to fragmented efforts and limited alignment between research and policy. To address this gap, the European Partnership for the Assessment of Risks from Chemicals (PARC) is fostering structured dialogue and stakeholder engagement to align research and innovation with regulatory needs. Within PARC, a proposed solution is the development of the MIND platform—*Map, Integrate, Network, Drive*—envisioned as a strategic and collaborative space that connects people, practices, and resources across disciplines and regulatory domains. MIND aims to encourage collaboration and knowledge sharing and integration, gradually connecting fragmented initiatives to build a more integrated and interoperable ERA knowledge ecosystem. By encouraging collaboration, improving data sharing, and enhancing policy relevance, MIND seeks to accelerate the uptake of advanced ERA approaches in regulatory practice, with a particular focus on safeguarding biodiversity. Over time, this may contribute to Europe's sustainability objectives and the ambitions of the European Green Deal.

Keywords Biodiversity, Chemicals, Ecotoxicology, Integrated environmental risk assessment, Knowledge exchange and management, Monitoring, New approach methodologies (NAMs), Next-generation environmental risk assessment, Partnership for the Assessment of Risks from Chemicals (PARC), Systems-based environmental risk assessment

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Environmental risk assessment in transition

Chemicals are essential to modern life, from protecting crops with pesticides to safeguarding livestock health with veterinary medicines. Yet, many of these chemicals also pose risks to human, animal, and environmental health [34, 49]. To address these risks, the European Union (EU) requires that numerous chemicals undergo a prospective risk assessment before they can be authorised for use. These assessments are governed by a suite of EU regulatory frameworks that collectively address a broad range of substances, including industrial chemicals, pesticides, pharmaceuticals, veterinary medicines, and—to a lesser extent—emerging contaminants and chemical mixtures. In addition to these forward-looking assessments, risk assessment is also applied retrospectively to monitor and manage chemical related risks.

In this context, environmental risk assessment (ERA) specifically focuses on evaluating the potential adverse effects of chemicals on the environment, including biodiversity, ecosystems, wildlife, and environmental compartments such as soil, water, and air. Its primary goal is to ensure that chemicals do not cause unacceptable harm to the environment by assessing chemical hazards, exposure, and resulting risks [20]. However, achieving this goal is inherently complex. Current ERA practices are often criticised for their narrow scope and lack of ecological realism [2, 9, 11, 35, 42, 47, 50]. As a result, ERAs may fail to capture the true impacts of chemicals on biodiversity and long-term ecosystem resilience [2, 42, 48]. This is particularly concerning given the EU's unprecedented biodiversity crisis, marked by alarming declines in insects including vital pollinators, as well as amphibians, birds, and keystone species [14]. These losses not only threaten ecosystems and their resilience, but also undermine food security and Europe's economic growth [14].

In response to these challenges, several initiatives are underway to modernise and advance ERA practices (Table 1), driven by scientific innovation, regulatory and policy developments, and societal demands for stringent environmental protection and biodiversity conservation. Among the approaches gaining prominence are new approach methodologies (NAMs), which form the foundation of next-generation ERA. NAMs encompass in vitro, in silico, and omics-based tools. These methods provide alternative test systems capable of measuring molecular and cellular responses at lower levels of biological organisation [32, 33]. NAMs may also enable extrapolation across species and biological scales, linking molecular and cellular effects to potential impacts at population and ecosystem levels [8, 12]). In addition, some NAMs can detect early signs of toxic stress before observable ecological harm occurs, providing opportunities for more proactive risk management [23]. Next-generation ERA could contribute to enhancing mechanistic understanding of toxic effects, and to developing more predictive and ecologically relevant assessments [27, 30, 33, 36, 46]. These advances align with EU policy goals, including the Chemicals Strategy for Sustainability and efforts to reduce reliance on animal testing. However, significant challenges remain before NAMs can be widely adopted in regulatory ERA. These challenges include uncertainties in extrapolation, the absence of harmonised protocols, and the lack of fit-for-purpose validation frameworks that go beyond traditional principles to clearly define reliability, relevance, and performance criteria for NAMs [25]. Current datasets often have limitations, making benchmarking difficult and raising questions about how validation should be interpreted and demonstrated in practice. Without robust approaches to confirm that NAMs can provide dependable indicators of real-world impacts, regulatory confidence will remain limited. Additional barriers include limited historical datasets, insufficient interpretive expertise within risk assessment bodies, and a lack of consensus on how NAMs should be integrated into ERA that currently relies on diverse regulatory data requirements. Moreover, enabling prospective assessment of chemical hazards will require agreement on protection goals and metrics that allow chemical effects on biodiversity to be estimated. Addressing these scientific and validation challenges is critical to avoid unrealistic expectations and to ensure that NAMs can make a meaningful contribution to future ERA that is more mechanistically informed, and ecologically relevant.

Traditionally, ERA has been conducted in silos—by substance, use, environmental compartment, taxonomic group, scientific field, or regulatory domain [2]. While this approach has contributed to environmental protection, it is insufficient to address the complexity of real-world conditions [42]. A new approach to ERA is therefore emerging that adopts a more holistic and context-specific perspective by integrating real-world ecological dynamics, landscape features, and agricultural practices [28, 37, 41, 52]. Integrated ERA seeks to combine multiple chemicals and environmental stressors—such as climate change, pollution, land use, and habitat fragmentation—and integrate multiple lines of evidence, including chemical and ecological data, into a unified assessment [5, 6]. It moves beyond single-substance assessments to consider cumulative and combined exposures, and the spatial and temporal variability of environmental conditions. However, the integration of these elements remains methodologically complex. Integrated ERA adopts a cross-disciplinary lens, fostering collaboration among scientific disciplines to ensure that diverse expertise informs decision-making. To support

Table 1 Comparative table of evolving approaches in environmental risk assessment (ERA), covering next-generation ERA, integrated ERA, and systems-based ERA

Dimension	Next-generation ERA	Integrated ERA	Systems-based ERA
Goal	Accelerate and enhance predictive assessment capabilities and mechanistic insights, while reducing animal testing by integrating new approach methodologies (NAMs)	Assess combined effects of multiple chemicals and stressors across scientific disciplines to gain a realistic view of ecosystem impacts	Apply systems thinking to understand how actions affect ecosystems over time, guiding sustainable strategies through assessments that integrate across disciplines and regulatory domains
Focus	Innovation: advances mechanistic understanding and improves extrapolation of effects across levels of biological organisation	Integration: bridges disciplines to assess both combined and cumulative chemical risks	Systems thinking: integrates systems dynamics, complexity, and feedback loops to support holistic and adaptive assessments
Tools	NAMs	Multi-disciplinary integration, multi-stressor analysis, expert judgement	Systems dynamics models, feedback loops, landscape-scale modeling, network analysis, engagement tools
Assessment scope	Molecular to ecosystem-level extrapolation	Multi-stressor and cross-disciplinary integration across chemical and ecological levels	Landscape-scale or whole-ecosystem level (e.g., farm systems)
Data considered	Large-scale biological and environmental datasets; machine learning	Multiple lines of evidence from ecology to toxicology, chemistry and geology; spatial and temporal scales	Interconnected ecological, biological and social data; feedback loops; emergent effects; adaptive processes; system resilience
Strengths	Efficient (i.e., rapid screening of many chemicals); mechanistically informed, reduces reliance on traditional animal testing	Comprehensive; supports cumulative and combined risk assessments	Realistic; long-term; captures complexity and interdependencies; supports sustainability and resilience goals; leverages coordination of existing resources
Limitations	Still developing for regulatory use; needs validation	Can be complex and resource-intensive (in terms of data needs)	Can be complex and resource-intensive (in terms of data and modelling needs); depends on further development of next-generation ERA and integrated ERA; need for simplification focusing on key parameters to support implementation; requires transdisciplinary collaboration

In practice, next-generation ERA, integrated ERA, and systems-based ERA are interconnected and build upon one another its implementation, the development of fit-for-purpose tools is increasingly important [41]. These tools must be capable of integrating diverse data sources, model complex ecological interactions, and guide decisions under uncertainty. Advancing such tools will be instrumental in realising the potential of integrated ERA to deliver ecologically realistic and policy-relevant assessments.

Guided by the ongoing contributions of next-generation ERA and integrated ERA, a further strategic development is gradually taking shape in the form of systems-based ERA [2, 4, 9, 17–19, 38, 51]. Systems-based ERA applies systems-thinking to understand how ecological, chemical, and societal factors interact and change over time [2]. It moves beyond individual risks to capture feedback loops, cascading effects, long-term ecological consequences, and landscape-level processes. As a result, systems-based ERA would enable assessments that not only evaluate current impacts but also anticipate future system responses. It recognises that environmental risks are rarely linear or isolated, but embedded within interconnected systems that evolve over time and space. Crucially, systems-based ERA relies on collaboration: not only among scientific disciplines, but also through active engagement with regulators, stakeholders, communities, and knowledge holders. By integrating previously disconnected data, knowledge, and stakeholder needs, it would foster a more unified and adaptive approach to risk assessment [2, 38, 51]. Although still in its conceptual phase, systems-based ERA is emerging as an area of research with potential to inform sustainability transitions, adaptive management, and strategic policy planning [2, 9, 11, 17–19]. Its value lies in fostering systemic, transdisciplinary, and stakeholder-inclusive approaches that could, over time, complement existing regulatory paradigms [9, 43, 44].

From innovation to implementation: strengthening the science-to-policy interface

Next-generation ERA, integrated ERA, and systems-based ERA are emerging as scientifically promising and potentially complementary approaches that could, over time, contribute to advancing ERA practices. However, their uptake within regulatory contexts remains challenging. While fragmented and uncoordinated efforts hinder integration into coherent policy frameworks and regulatory practice [40], this is only part of the challenges. Additional barriers include the rapid pace of scientific innovation, which often exceeds the ability of regulatory systems to adapt; the lack of standardisation across tools, models, and methodologies; and regulatory prerequisites that limit the adoption of novel approaches that fall outside established guidelines. Furthermore, gaps in technical know-how, institutional capacity, and training can prevent the effective implementation of such advancements. These challenges reflect a broader systemic issue: the difficulty of translating research and innovation (R&I) outputs into actionable, policy-relevant frameworks that meet regulatory standards, timelines, and operational realities, while remaining sufficiently streamlined for practical use by risk assessors across diverse sectors and regulatory domains. Bridging this gap will require strategic alignment, stakeholder engagement, and targeted efforts to validate and operationalise these approaches within existing regulatory structures.

Recognising the persistent challenges of integrating new risk assessment practices into regulatory frameworks, the EU Partnership for the Assessment of Risks from Chemicals (PARC) [29] seeks to reshape how chemical risks are assessed by aligning R&I with regulatory needs and fostering collaboration [21, 24]. Unlike traditional top-down research programs, PARC is built on a regulatory challenge-driven framework that actively connects scientific research with societal needs for health and environmental protection. A central objective is to strengthen the science-to-policy interface through structured dialogue among researchers, risk assessors, regulators, and policymakers. This ensures that scientific knowledge generated within PARC is not only robust and policy-relevant, but also has the potential to be translated into regulatory practice across the EU. By bridging the gap between R&I and regulatory implementation, PARC helps ensure that scientific outputs address regulatory needs, and remain actionable and impactful, thereby amplifying PARC's long-term contribution to the EU regulatory landscape. PARC's efforts include exploring the integration of NAMs [21] and new ERA practices, including systems thinking [2, 9], to help advance chemical risk assessment, while contributing to the EU's long-term ambition of reducing reliance on and ultimately phasing out animal testing.

MINDing ERA: advancing ERA via a strategic and collaborative platform

To build on PARC's momentum and address persistent fragmentation in efforts to advance chemical ERA practices, the development of MIND—*Map, Integrate, Network, and Drive*—is proposed within PARC as a strategic and collaborative platform. MIND is not an information technology system, but a knowledge-driven, community-oriented initiative designed to connect people (actors and expertise), practices (methodologies, processes, and initiatives), and resources (data, tools, and projects) across disciplines and regulatory domains. Acting as a strategic integrator, its core objective is to protect biodiversity from chemicals by bridging R&I, regulatory ERA science, policy development, and real-world implementation.

By transforming scattered efforts into a connected and interoperable ERA knowledge ecosystem, MIND aims to enhance relevance, foster coherence, and enable and accelerate regulatory uptake in support of EU sustainability goals and the European Green Deal.

MIND consists of four interconnected components that work together to strengthen the ERA knowledge ecosystem: *Map* identifies what exists; *Integrate* combines knowledge; *Network* activates collaboration; and *Drive* provides the strategic backbone by defining direction, priorities, and governance.

- ***Map*** will systematically identify and map people, practices, and resources across disciplines and regulatory domains to uncover synergies, avoid duplication, and reveal knowledge gaps. This process will enable cross-domain collaboration and ensure that scientific insights and stakeholder contributions are captured, organised, and shared for research, regulatory decision-making, and policy. By capturing both documented knowledge and tacit knowledge (i.e., expert experience and stakeholder insights), *Map* will create a dynamic framework for collaboration, ensuring decisions are informed by formal evidence and practical know-how.
- ***Integrate*** will link explicit and tacit knowledge to address key ERA challenges. It will combine diverse data sources, scientific approaches, and stakeholder perspectives, while establishing structures for reliable integration and knowledge generation. By identifying gaps, outdated assumptions, and opportunities for improvement, *Integrate* will generate new insights. This structured approach may simplify complexity, focus on key risk factors and enhance clarity and policy relevance. Ultimately, *Integrate* will support coherence across disciplines and enable informed, efficient, and actionable decision-making.
- ***Network*** aims to build and sustain a dynamic community of practice that connects academia, regulators, policy makers, and practitioners to accelerate knowledge exchange and co-create solutions. It will serve as a collaborative space where tacit knowledge is shared, debated, and tested through joint problem-solving and teamwork. By leveraging existing networks and engaging stakeholders, *Network* will promote inclusive collaboration, trust, and adaptability, and ensuring ERA advancements reflect shared priorities and real-world needs.
- ***Drive*** serves as MIND's catalytic governance function, ensuring alignment, adaptability, and impact across all components. It guides decisions on which questions to prioritise, which methods to adopt or phase out, and how collaboration evolves. Crucially, *Drive* enables phasing out outdated practices and embracing new approaches to stay adaptable to emerging insights.

By bridging R&I with governance frameworks, MIND intends to reinforce connections between environmental management, biodiversity conservation, and sustainable chemical use. This approach will equip risk managers with robust tools and actionable, scientifically grounded insights for timely and transparent decisions. Ultimately, MIND will ensure that actions align with broader environmental and societal goals, making it an essential driver of evidence-based governance in a rapidly evolving context.

Experience gained in PARC through Activity 6.4.4 "*Risk assessment to support and promote efficient overall protection of biodiversity*" [9], highlights the value of establishing and engaging a community of practice. This approach has proven instrumental in fostering shared understanding on concepts like systems-based ERA and accelerating knowledge exchange and regulatory uptake of ERA advancements. In collaboration with the EU-funded projects PollinERA (Understanding Pesticide-Pollinator Interactions to support EU Environmental Risk Assessment and Policy) [31] and SYBERAC (Towards a Systems-Based, holistic Environmental Risk Assessment of Chemicals) [39], PARC conducted a regulatory needs analysis involving regulators, scientists, and stakeholders across the EU [9]. Through surveys, webinars, workshops, and meetings, the process revealed a pressing need for stronger collaboration between research and regulatory communities to better align R&I with regulatory priorities. Building on these insights, MIND is proposed as a strategic initiative to foster exchange and alignment at a broader scale.

Shaping the MIND platform

The development of the MIND platform has now been accepted and will be actively pursued within PARC, in collaboration with representatives of EU agencies (such as the European Environment Agency (EEA) [15] and the European Food Safety Authority (EFSA) [16]), the European Commission's Joint Research Centre (JRC) [22], national regulatory bodies (such as the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) [1], the German Environment Agency (UBA) [45], and the Environment Agency Austria (EAA) [10]) and EU-funded projects. These actors bring extensive expertise and are well-placed to identify regulatory challenges that affect the quality of ERAs (e.g., [3, 13]). Their input would help ensure that research efforts are aligned with real-world regulatory needs and that scientific insights are translated into practical guidance for decision-makers.

In terms of structure and operations, strategic oversight will be provided by a high-level steering group, composed of risk assessors from regulatory risk assessment bodies. Meeting regularly, the high-level steering group will guide priorities and monitor progress using the Double Diamond approach—*Discover, Define, Develop, Deliver* [7]—to structure its work and ensure iterative refinement of strategic direction. To translate the platform's strategic vision into practice, the core facilitation team will lead operational delivery. This includes translating the platform's four strategic pillars—*Map*, *Integrate*, *Network*, and *Drive*—into a coherent and actionable project plan. The core facilitation team will coordinate activities, define milestones, and establish mechanisms for cross-sectoral engagement, ensuring that strategic objectives are systematically embedded into practice. Stakeholder contributions from linked projects and case studies would provide essential data, tools, and expertise to support implementation and validate collaborative approaches.

Aligning the MIND platform with regulatory ERA frameworks, integrating monitoring data, and avoiding duplication—particularly in relation to initiatives such as the One Substance–One Assessment framework and the Common Data Platform on Chemicals—remains essential. While the One Substance–One Assessment is not yet fully operational, MIND can play a supportive role in helping to realise and complement its objectives.

Securing sustainable commitment and funding is a critical priority for ensuring the long-term viability of the MIND platform. Achieving this will require positioning MIND within PARC and future EU programmes, demonstrating its value, and establishing a governance model that enables co-funding opportunities and sustained investment. Equally important is fostering broad-based engagement by bringing together a diverse range of stakeholders—including EU Member States, academia, industry, and the public sector—to openly discuss challenges, share perspectives, and co-develop solutions. Their active participation is essential to anchor MIND as a central coordination mechanism and ensure it reflects shared priorities and real-world needs.

While a broad definition of future ERA that integrates human and environmental health is conceptually aligned with the One Health framework [26], operational challenges persist. These include divergent endpoints, regulatory contexts, and stakeholder needs across human and environmental health domains. To ensure meaningful integration, the specific requirements of human health must be further elaborated and operationalised. PARC addresses these challenges by developing harmonised frameworks, interoperable tools, and pilot studies to turn integration from concept into practice.

Conclusion

The proposed MIND platform moves beyond earlier fragmented efforts, offering a strategic and unified approach to advancing chemical ERA, integrating biodiversity considerations, and enabling its regulatory uptake. Unlike previous initiatives that often operated in disciplinary or regulatory silos, MIND takes a transdisciplinary approach that fosters connections among people, practices, and resources across disciplines and regulatory domains. By establishing a community of practice, it will foster structured collaboration among EU agencies, national bodies, and research projects. While promising, its successful adoption faces practical challenges, including securing long-term funding, establishing institutional anchoring across regulatory bodies, and encouraging uptake of innovative ERA practices. Acknowledging these challenges while clearly demonstrating its added value would position MIND as a strategic and collaborative platform for advancing ERA practices and their regulatory uptake, and for protecting biodiversity.

Abbreviations

ANSES	French Agency for Food, Environmental and Occupational Health and Safety
EAA	Environment Agency Austria
EEA	European Environment Agency
EFSA	European Food Safety Authority
ERA	Environmental risk assessment
EU	European Union
JRC	Joint Research Centre
MIND	Map, integrate, network, and drive
NAMs	New approach methodologies
PARC	European Partnership for the Assessment of Risks from Chemicals
PollinERA	Understanding Pesticide-Pollinator Interactions to support EU Environmental Risk Assessment and Policy
R&I	Research and innovation
SYBERAC	Towards a Systems-Based, holistic Environmental Risk Assessment of Chemicals
UBA	German Environment Agency

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Not applicable.

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The authors declare no competing interests.

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