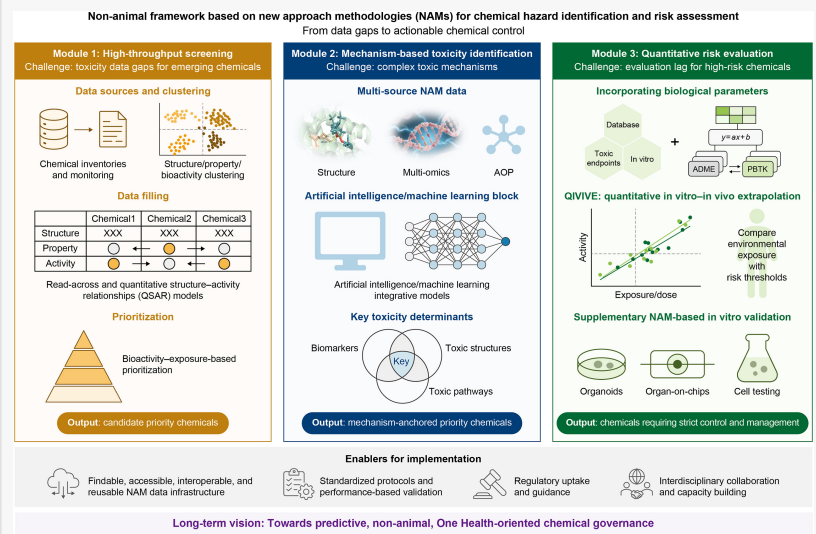
A new era beyond animal testing: Ai-driven framework reinvents chemical risk assessment

GA, UNITED STATES, December 16, 2025 /EINPresswire.com/ -- As the world faces a surge of new synthetic chemicals and increasingly complex toxicity patterns, traditional animal testing can no longer keep pace with modern environmental and health risks. This study presents a forward-looking, non-animal assessment framework designed to detect hazardous chemicals faster and more precisely than ever before. By merging high-throughput screening, AI-enabled toxicity mapping, and quantitative in vitro–to–in vivo risk modeling, the framework uncovers priority pollutants, reveals their toxicity mechanism, and predicts risk thresholds. Together, these tools lay the foundation for a predictive, prevention-oriented chemical governance system fit for the challenges of the 21st century.



Non-animal framework based on new approach methodologies (NAMs) for chemical hazard identification and risk assessment.

The number of chemicals released into global supply chains has skyrocketed to hundreds of millions, yet only a tiny fraction has undergone rigorous toxicity evaluation. Animal testing—long considered the backbone of chemical safety—are now strained by a prolonged testing period, exorbitant costs, and low throughput. At the same time, modern contaminants increasingly display nontraditional toxicity behaviors, from non-monotonic dose responses to complex multi-target biological interactions. These scientific hurdles collide with ethical debates and regulatory momentum to reduce reliance on animals. Due to these challenges, there is an urgent need to develop new, integrative approaches for chemical hazard identification and risk assessment.

In a new study published on 4 December 2025 in Environmental Science and Ecotechnology, researchers from the Chinese Research Academy of Environmental Sciences and Beijing Normal University unveil a unified, non-animal framework that reimagines how chemical risks are

evaluated. The system brings together high-throughput computational screening, multi-omics toxicity insights, and advanced in vitro models powered by AI. By bridging mechanistic understanding with quantitative exposure predictions, the framework offers regulators and scientists a cohesive roadmap for rapidly identifying harmful chemicals and determining safe environmental thresholds.

The authors construct a three-part framework that transforms chemical assessment from isolated tests into a predictive, mechanism-driven pipeline. The first module tackles the global toxicity data gap by cross-referencing chemical inventories from multiple databases with quantitative structure–activity relationship (QSAR) models, read-across methods, and bioactivity clustering. This high-throughput process rapidly flags chemicals lacking safety data and nominates candidates requiring urgent evaluation. The second module applies artificial intelligence to multi-source toxicological evidence—including genomics, transcriptomics, proteomics, and adverse outcome pathways. Machine learning models uncover patterns too complex for traditional methods, pinpointing toxic structural features, molecular biomarkers, and mechanistic pathways. Advanced models such as ToxACoL demonstrate the ability to predict toxicity across species and experimental conditions, even when datasets are limited or imbalanced. The final module bridges laboratory findings with real-world exposure. By integrating ADME factors, physiologically based toxicokinetic models, and organoid or organ-on-chip validation, the system translates in vitro responses into in vivo-equivalent doses. Environmental concentrations can then be compared against these predicted thresholds to quantify ecological and human risks with unprecedented speed.

Together, these modules move toxicology toward a scalable, anticipatory model that replaces slow, reactive testing with proactive chemical management.

A lead expert involved in the study emphasizes that this integrated framework represents a critical turning point for global chemical governance. They note that high-quality, multimodal NAM datasets—when standardized, validated, and shared transparently—can deliver predictions that rival or surpass traditional animal studies. Yet, they also highlight key challenges, including data harmonization, model interpretability, and the need for interdisciplinary talent trained in toxicology, AI, and regulatory science. With sustained investment and clear policy guidance, the expert believes this framework could become a cornerstone of next-generation chemical safety evaluation.

The study's framework opens a pathway toward chemical safety assessments that are faster, more humane, and more scientifically robust. It can help regulators swiftly pinpoint high-risk pollutants, guide safer chemical design in industry, and provide early warnings for emerging contaminants before they become widespread hazards. By linking predictive toxicology with the principles of One Health, the framework supports integrated protection of human health, ecosystems, and biodiversity. Its successful implementation could strengthen climate resilience, reduce pollutant-driven ecosystem damage, and accelerate global sustainability efforts aimed at managing chemical risks in a rapidly changing world.

References

DOI
10.1016/j.ese.2025.100638

Original Source URL
https://doi.org/10.1016/j.ese.2025.100638

Funding information
This work was funded by the National Natural Science Foundation of China (Grant Nos. 42277274 and 42394154).

Lucy Wang
BioDesign Research
email us here