ZDHC Quantis A BCG COMPANY

June 2025

A Decade of ZDHC

Assessing how ZDHC's Manufacturing Restricted Substances List, Wastewater Guidelines, and Air Emissions Guidelines reduce impact on nature

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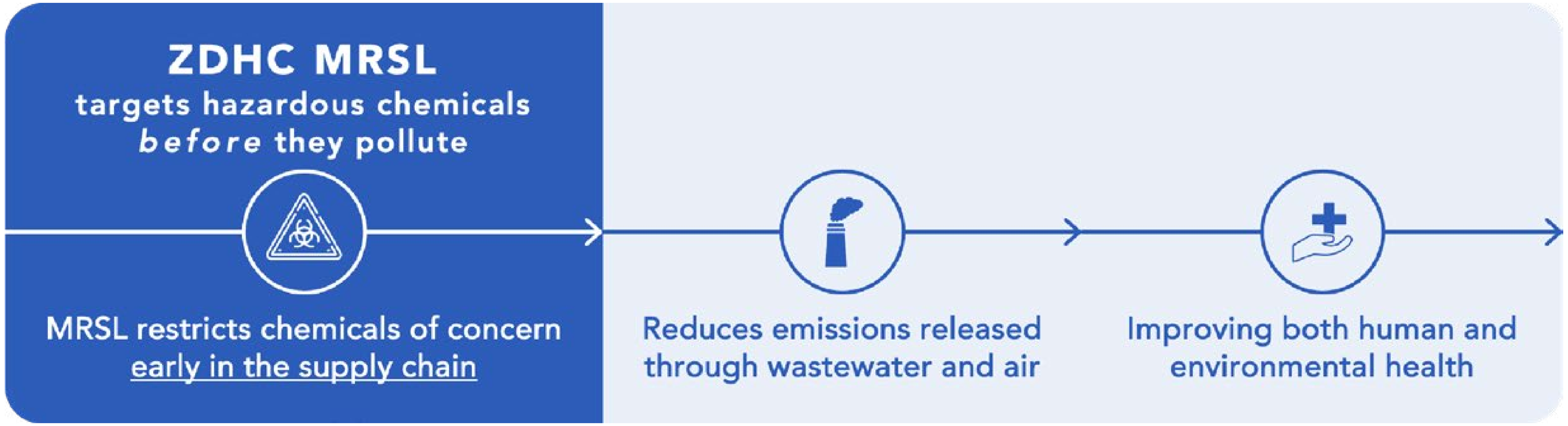
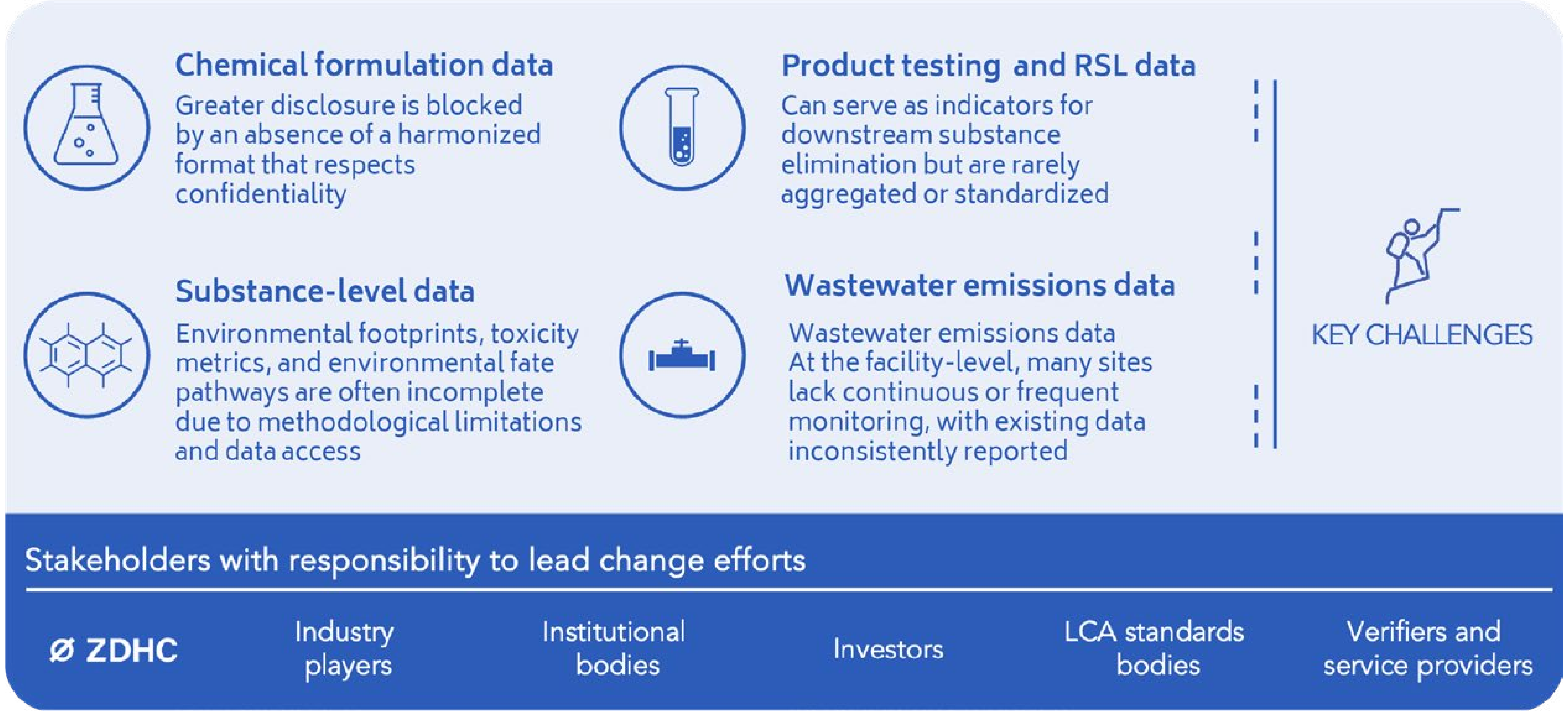
Bridging the Chemical Pollution Gap for Corporate Nature Strategies



APPROACH 1: Facility-specific case studies + APPROACH 2: Wastewater discharge assessment + APPROACH 3: Air emissions release assessment

ZDHC drives measurable reductions in Nature impact across its suite of tools and frameworks

Case Study	Human Toxicity	Freshwater Ecotoxicity	Water Use	Eutrophication	Climate Impact
NPEOs substitution in wet processing		51% ↓			21% ↑
DMFa substitution with water-based PU			95% ↓	27% ↓	45% ↓
ZDHC wastewater discharge scenarios (WALDB)	95% ↓	86% ↓		80-96% ↓	
Copper reduction via alkaline precipitation	1% ↓	13% ↓			
Chlorinated phenol dye substitution	74% ↓	8% ↓			
VOC emissions reduction at coating facility	90% ↓	91% ↓			
VOC emissions reduction at tannery facility	64% ↓	64% ↓			


Chemical formulation data
Greater disclosure is blocked by an absence of a harmonized format that respects confidentiality
Product testing and RSL data
Can serve as indicators for downstream substance elimination but are rarely aggregated or standardized
Substance-level data
Environmental footprints, toxicity metrics, and environmental fate pathways are often incomplete due to methodological limitations and data access
Wastewater emissions data
Wastewater emissions data At the facility-level, many sites lack continuous or frequent monitoring, with existing data inconsistently reported
KEY CHALLENGES
Stakeholders with responsibility to lead change efforts
ZDHC
Industry players
Institutional bodies
Investors
LCA standards bodies
Verifiers and service providers

Pollution from chemicals of concern is one of the least quantified drivers of nature loss. Hundreds of thousands of chemicals and mixtures are registered for commercial use globally, many of which lack toxicity or environmental fate data. Yet chemical releases are a leading cause of biodiversity degradation, freshwater contamination, and long-term ecosystem harm, especially in high-risk manufacturing regions. Over the past decade, **the Zero Discharge of Hazardous Chemicals (ZDHC) Foundation has emerged as a central convener to tackle this complexity** by eliminating chemicals of concern from global value chains through harmonized, science-based tools and industry-wide collaboration.

By rallying nearly 380 signatories across brands, chemical suppliers, manufacturers, and solution providers, ZDHC has moved the sector beyond fragmented compliance schemes toward a **coordinated and scalable implementation system**. The ZDHC Manufacturing Restricted Substances List (MRSL), alongside tools such as the ZDHC Gateway, Wastewater Guidelines, and Air Emission Guidelines, has formed the backbone of sustainable chemical management in the textile, apparel, leather, and footwear industries. Today, ZDHC's proven framework not only influences global environmental governance but also sets the benchmark for credible and measurable progress toward pollution prevention and the related impacts on nature.

This report explores the science-based potential of the ZDHC Foundation to deliver measurable reductions in nature-related impacts through eliminating chemicals of concern by **pioneering a first-in-class approach driven by real-world data.** Building on the demonstrated success of the MRSL in the textile, leather, and footwear sector, the analyses quantify how MRSL adoption can reduce pollution across air, water, and soil, whilst strengthening corporate nature strategies and enhancing business resilience in tandem.

Descriptions of the ZDHC tools assessed in this report

MRSL: a list of hazardous substances banned from intentional use in manufacturing processes to prevent pollution at the source.

Wastewater Guidelines: defines acceptable discharge limits for priority pollutants in treated effluent to reduce waterborne toxicity.

Air Emissions Guidelines:
tiered thresholds to limit harmful air pollutants like volatile organic compounds (VOCs) during production to protect human and environmental health.

Report findings

Proactive upstream chemical management through the ZDHC's tools can lead to substantial reductions of up to 80-96% in nature-related impacts and supports compliance with emerging frameworks.

Important Note

The nature-related impact reductions referenced in this report are based on case-specific data and modeled scenarios. These results are not intended to represent the entire textile, leather, and footwear industry, nor should they be used by individual brands to claim specific impact reductions without facility-level, process-specific, and transparently verified data. Misuse of these figures could result in misleading communication and risk allegations of greenwashing.

The ZDHC MRSL is a powerful and actionable tool that offers a harmonized global approach to chemical pollution reduction. Despite this, the report highlights significant data gaps, notably:

- **Chemical formulation data**
- **Substance-level environmental and toxicity data**
- **Product testing and RSL data**
- **Wastewater emissions data**

Addressing these data gaps offers significant potential to generate deep insights that can drive cross-sector change.

Extending the application of the MRSL beyond textile, leather, and footwear to adjacent sectors such as automotive, home furnishing, and electronics presents a **clear opportunity to unify chemical management standards and accelerate cross-industry unification and progress** towards delivering the Global Biodiversity Framework ambition. Immediate call to action has been proposed and lies with a prioritized group of stakeholders.

Immediate call to action

ZDHC Foundation

- Continue to be the **central convener**
- Continue to **evolve frameworks** and include more nature indicators
- Continue to develop existing **digital tools**

Industry Players

- Increase **proactive disclosure**
- Enhance **facility-level data** collection processes
- Champion the adoption of **ZDHC tools**

Institutional Bodies

- Integrate **ZDHC tools**
- Collaborate to develop chemical **risk reduction strategies**
- Champion a **coordinated roadmap** to reduce chemical footprints

Due to data availability challenges, a unique three-pronged approach was developed:

- **assessing facility-specific case studies**
- **wastewater discharge modeling**
- **air emissions assessments**

This was complemented, where possible, with the integration of the local state of nature where the pressures arise to evaluate the environmental outcomes of real-world chemical substitutions and subsequently their impact on nature.

By triangulating evidence from these cases, a credible and practical blueprint has been developed as the foundation for future chemical impact assessments across complex supply chains.

ZDHC

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Introduction

2.1. Objective of this report

The vision of the ZDHC Foundation is to create a world where better chemistry leads to the protection of life, land, air, and water. To do so, ZDHC has built precise guidelines, digital solutions, and a ZDHC Committed Community of Signatories to walk the talk. In the meantime, as there is an increasing demand for impact measurement driven by different stakeholders, from regulatory bodies to civil society to financial institutions, ZDHC is committed to play its part in supporting the industry to further strengthen its ability to measure and track the impact delivered. The primary intents of this report are to:

1. Explore the potential impact reductions on nature for a company that adopts the ZDHC MRSL

2. Map key data gaps to be filled to improve impact measurement

3. Propose stakeholder specific actions to kick-start the journey

This is investigated through key nature pressure areas such as pollution, water use, and ecotoxicity, complemented where possible with the integration of the local state of nature where the pressures arise. Building on the success of the ZDHC MRSL in the textile, leather, and footwear sector, the report seeks to quantify benefits using real-world substitution case studies and propose how the MRSL approach can be extended to other industries, such as automotive, home furnishing, and electronics, to drive harmonized and proactive chemical management. The ultimate objective is to demonstrate how ZDHC MRSL adoption not only reduces the use of chemicals of concern but supports a company in its broader nature strategy and goals, strengthens supply chain resilience, and prepares industries for evolving regulatory, and stakeholder expectations.

One of the main limitations of the methodology developed is data availability. This specifically relates to gaps in key chemical and emissions data including chemical formulation-level data (such as concentrations and environmental footprints), substance-specific release rates (to air and water) and measured concentrations in wastewater and sludge, among many others.
The approach formulated was therefore an adapted version of the Lifecycle Assessment (LCA) methodology defined by the 9 International Organization for Standardization (ISO) 14040 regulation and the European Commission.

This decision was taken prior to data collection with the understanding that data availability would be a key constraint to developing deeper insights. This proved to be the correct choice, evidenced through an inherent lack of data existence and, in some cases, a reluctance from key industry players to share inhouse data either from a confidentiality or reliability standpoint. Nonetheless, as a pioneering project, this report begins to showcase a reduced impact on nature when following the ZDHC MRSL to phase out chemicals of concern and reinforces the potential value that can be delivered following broader industry participation, data sharing, and iterative methodological refinement.

2.2. What is nature and why is chemical impact important?

From Climate to Nature

Climate has historically been a core focus of companies´ environmental sustainability. The focus on climate is now intertwined with nature, acknowledging that climate change significantly impacts ecosystems and biodiversity. The climate topic itself is well-understood, and companies are well-versed in reporting their greenhouse gas (GHG) emissions through well-established guidelines such as the Greenhouse Gas Protocol (GHGP) and Science-Based Targets Initiative (SBTi).

The nature topic refers to the interconnected web of living organisms and ecosystems (biodiversity), and natural resources (for example, water) that underpin all life and activity on Earth. Awareness on nature is not as widespread as for climate, but this is rapidly changing through the enforcement of nature-centric regulations such as the European Union Corporate Sustainability Reporting Directive (EU CSRD) or EU Deforestation Regulation (EUDR), and ever-growing public pressure from society and consumers to reduce impacts on nature. This momentum is reinforced globally by the Kunming-Montreal Global Biodiversity Framework (GBF), adopted in December 2022, which sets a landmark target to halt and reverse biodiversity loss by 2030. It includes targets such as protecting 30% of land and sea areas or integrating 10 biodiversity into corporate decision-making. A notable example is Target 7, which denotes "reducing pollution from hazardous chemicals by half".[1]

1 Convention on Biological Diversity

Climate and nature are highly interconnected, and companies benefit from having a comprehensive and intertwined climate & nature strategy. Disconnected approaches can undermine the ability of a company to reach its sustainability objectives. To illustrate an example: building a biomass-driven power unit to replace a fossil-based power unit will likely benefit the Climate target of a given company. However, if the origin of the biomass is not well managed, biomass-driven power could drive deforestation and generate detrimental soil and water impacts, harming local ecosystems. The decisions must therefore be informed considering both climate & nature perspectives through a holistic approach to ensure delivery on both agendas.

Leading fashion and luxury companies understand the value of a holistic nature strategy, incorporating climate to create much more informed strategic decisions, accelerate better business integration, and drive more targeted actions which yield higher impacts from their investments.

The role of chemicals

Chemicals are involved to some extent in every industry on the planet. Their presence is commonplace in everyday lives, be it through the rare-earth elements in televisions, the lithium-ion batteries that power most smart devices, the additives included in many foodstuffs, or the dyes that color clothes and furniture. Management of these chemicals, thus, plays a key role in environmental sustainability, as many chemicals have a detrimental impact on both climate and nature.

In the case of climate, the production and use of many chemicals involves high temperatures and therefore high energy consumption, releasing large volumes of carbon dioxide (CO_2). Use of some chemicals in certain industrial processes outside of textile manufacturing can also result in the emission of more powerful GHG emissions such as sulfur hexafluoride (SF6) or nitrous oxide (N2O), each having significantly higher global warming potential (GWP) than CO_2.

From a Nature perspective, chemicals of concern that are released into the environment (for example via waste) can have significant impacts. High concentrations of chemicals of concern (for example, benzene, formaldehyde) increase water ecotoxicity, soil degradation, and biodiversity loss due to their inherent chemical properties (for example, carcinogenicity, neurotoxicity). Some substances persist in the environment for long periods of time due to their high chemical stability, resulting in their accumulation in living organisms, known as bioaccumulation. A renowned example of this is per- and polyfluoroalkyl substances (PFAS), also known as "forever chemicals", which have been strongly linked to infertility and cancer in humans.[2] Beyond toxicity, some nitrogen- and phosphorous-containing compounds possess high eutrophication potential, whereby their run-off into bodies of water can radically alter aquatic ecosystems and cause oxygen-depleted "dead zones", killing marine and plant life alike.

Chemical pollution is a major driver of Nature loss but is often overlooked. Hundreds of thousands of chemicals are used globally, but many remain unassessed for their impact on Nature. The significant lack of data provides a major challenge for sustainability experts when tracking, assessing, and quantifying impact of specific substances, which exacerbates the challenge of developing potential solutions. Nonetheless, sustainable chemical stewardship is a fundamental part of corporate Nature strategies. In this report, the importance of optimizing the management of chemicals of concern to reduce the impact on Nature is highlighted, and how the ZDHC MRSL has demonstrated success in doing so in the textile, leather, and footwear sector is explored.

2 National Institute of Environmental Health Sciences
3 IPBES

2.3. How is the impact on nature assessed?

Measuring environmental impact is essential to driving credible sustainability strategies that reduce the impact on nature. Yet when it comes to nature, assessment is inherently more complex than climate. Unlike greenhouse gas emissions, which are globally standardized and measured in CO_2 equivalents (CO_2e), nature encompasses a wide set of pressures, dependencies, and outcomes that are location-specific, multidimensional, and interdependent. To provide a meaningful contribution toward halting nature loss, businesses must evaluate how their operations and supply chains interact with the natural world — both in terms of pressures they place on ecosystems and the benefits they can reap (for example, clean water or biodiversity). This is the core of what a Nature Assessment seeks to achieve.

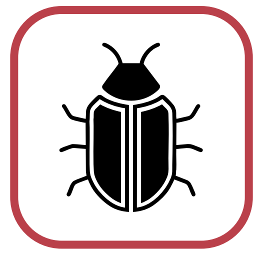
According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), there are five main pressures on nature:[3]

Land / sea-use change: (highest contributor): conversion of natural ecosystems for agriculture, industry, or urbanization, reducing habitat availability and ecosystem function.

Resource exploitation: over-harvesting of natural resources (for example, water, fish, timber) beyond replenishment rates, leading to ecosystem degradation.

Climate change: rising temperatures and extreme weather disrupting ecosystems, species distribution, and natural cycles.

Pollution: release of harmful substances such as pesticides, hazardous chemicals or plastics into air, water, and soil, causing toxicity and ecosystem degradation.



Invasive species and others: introduction of non-native species that outcompete or disrupt native biodiversity, alongside other indirect pressures such as disease.

Nature assessments can be done at product- and corporate-level and should align with global frameworks such as the Taskforce on Nature-related Financial Disclosures (TNFD) or methodologies such as Lifecycle Inventory Assessment (LCIA). The assessments are built around three core components:

- **Activity data: quantitative and qualitative data about a company value chain (for example, volumes of chemicals used, water withdrawn, energy consumed).**
- **Pressures on nature: the environmental pressures caused by activities — including water pollution, ecotoxicity, land use, and nutrient discharges.**
- **Local vulnerability: the ecological sensitivity of the landscapes where these pressures occur (for example, water-stressed regions, biodiversity hotspots).**

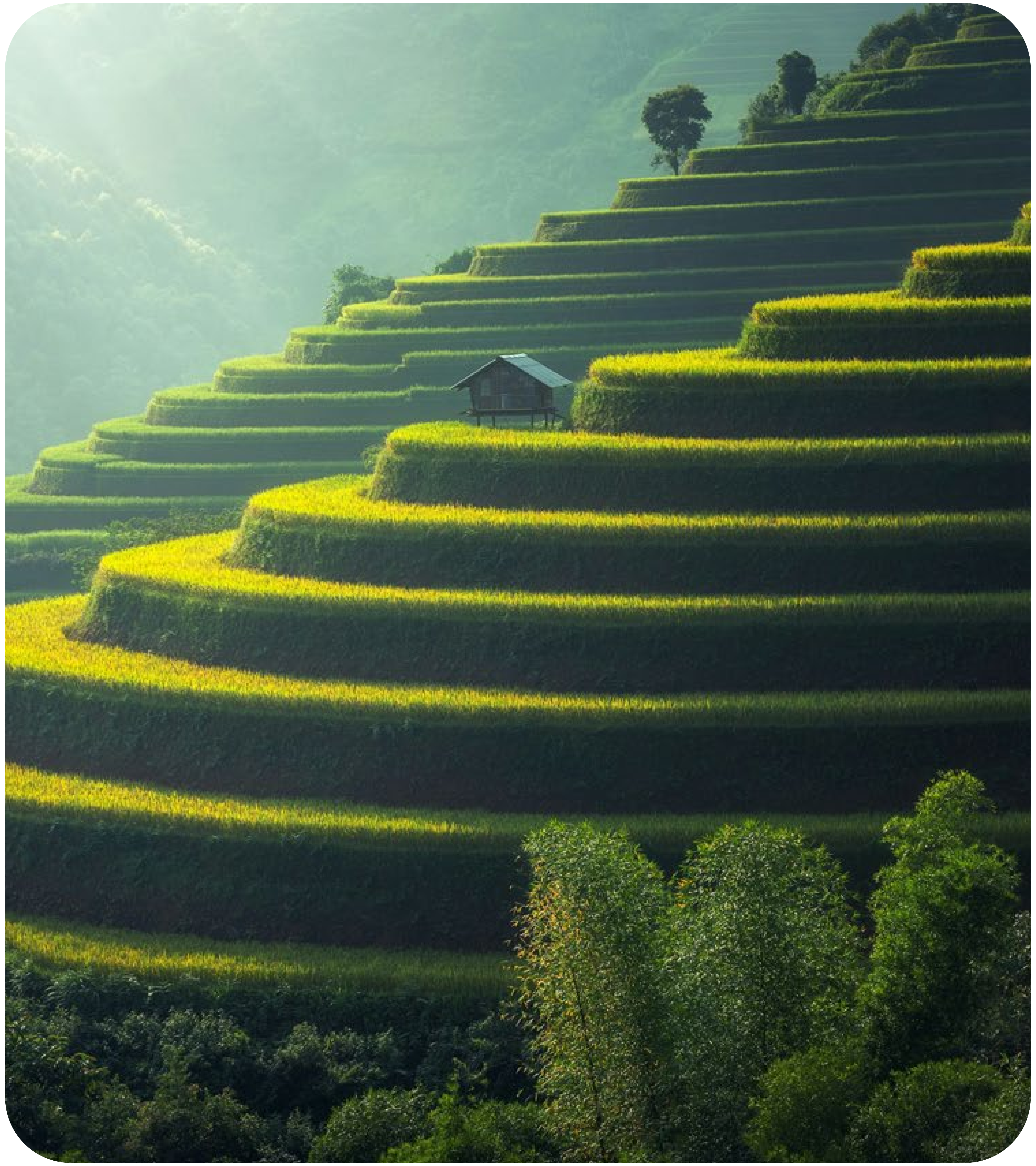
Together, these components enable the calculation of nature impact metrics – indicators that reflect the severity and significance of the contribution of a business to nature degradation. The methodology builds on existing corporate environmental data (for example, GHG inventories, water reporting) while extending it to location specific ecological data with the aim of delivering results that are actionable and site specific. Six main indicators are used for assessing the pressures on nature*:

- **Land use (m^2 occ. / y):** extent of land occupied and its impact on ecosystems
- **Ecotoxicity (CTUe):** impact of chemical emissions on ecosystems
- **Marine pollution (kg N eq.):** nitrogen-based pollution contributing to eutrophication
- **Water use (m^3):** freshwater consumption and potential depletion risks
- **Freshwater pollution (kg P eq.):** phosphorus-based pollution leading to freshwater eutrophication
- **Soil pollution (mol N eq.):** nitrogen deposition and contamination in soil

*Abbreviations for units can be found in the List of Abbreviations section.

Through a nature assessment, companies can identify their most material pressures and understand how these interact with vulnerable ecosystems. They can subsequently define targeted and informed actions that support both regulatory alignment and long-term environmental resilience.

Beyond environmental benefits, this approach delivers tangible business value from reduced operational risks (for example, through water scarcity, regulatory penalties), to enhanced supply chain stability and strengthened brand reputation. It can also improve investor confidence and provide access to emerging green finance mechanisms.



ZDHC

03

The role of ZDHC as an industry convener

3.1. The ZDHC MRSL and its success in Textile, Leather, and Footwear

The ZDHC MRSL is a globally harmonized list of chemicals of concern that are prohibited from intentional use in textile, leather and footwear manufacturing processes. It stands today as one of the most widely recognized frameworks for safer chemical use across the global fashion sector. Its purpose is to eliminate chemicals of concern at the source before they enter the supply chain and to significantly reduce both environmental and social impacts. Specifically, by targeting chemical substances early in the value chain, the ZDHC MRSL reduces emissions from chemicals of concern to air and water, thereby limiting the exposure of said substances to nature, local communities, and workers. This concept of prevention shifts the focus from controlling pollution after it occurs, to reducing it at the input stage, reflecting a commitment to safer chemistry with the ZDHC MRSL at its core as a strategic and visionary force for systemic change.

Since its inception in 2014, the ZDHC MRSL has reshaped the textile, leather, and footwear industry's approach to chemical management, following widespread adoption of nearly 380 signatories including leading brands, chemical formulators, approved solution providers and suppliers.

It provides a single source of truth for the industry by eliminating the need for individual MRSLs which often vary in levels of comprehensiveness and completion.

In tandem with ZDHC's other tools such as the Wastewater Guideline and ZDHC Gateway, the ZDHC MRSL has facilitated transparency and monitoring, thereby improving traceability and accountability for its members. The proactive approach of the ZDHC MRSL goes beyond regulatory compliance mechanisms such as the EU Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) law which itself regulates chemicals already on the market. Beyond proactivity, the ZDHC MRSL provides a foundation to pool industry expertise, refine methodologies for nature impact assessment, and facilitate comprehensive environmental data collection and transparency. Beyond a technical achievement, it represents an important milestone in collective environmental stewardship.

3.2. A solutions-oriented approach to strengthen corporate nature strategies.

The ZDHC MRSL offers a solutions-oriented tool that has enabled a decade of industry progress and represents a concrete solution for companies to strengthen their nature strategies on the topic of chemical related pollution. This is achieved by directly addressing one of the most challenging and underdeveloped areas in corporate environmental management–that of chemical pollution. The Science-based Targets for Nature (SBTN) framework is widely regarded as the most robust and science-aligned methodology for companies aiming to set credible, measurable targets to reduce their impact on nature.

Whilst initiatives such as the SBTN have brought structure to setting targets around land use, climate, and freshwater, their current guidance on chemical pollution is limited in scope, focusing exclusively on nitrogen (N) and phosphorus (P) compounds that contribute to eutrophication. While N and P are important for agriculture (for example, growing cotton), this presents a major gap in addressing the broader range of chemical impacts such as water and soil contamination, ecosystem degradation, long-term biodiversity loss, and potential human health impacts from the dyeing and finishing of fabrics.

The gap presents a significant barrier for companies seeking to act comprehensively across the five key IPBES pressure categories, particularly for pollution, which remains one of the least mature areas from a methodological standpoint. Specifically, the lack of methodologies in the current SBTN to assess the impact of chemical pollution beyond nitrogen and phosphorous severely hampers the ability of companies to evaluate and mitigate other chemical pollution. Most chemicals of concern that cause ecotoxicity, endocrine disruption, or bioaccumulation, for example, are not yet covered by current science-based target frameworks.

This includes substances such as dimethylformamide (DMFa), alkylphenol ethoxylates (APEOs), and short-chain chlorinated paraffins (SCCPs), among many others, that are utilized extensively not only in the textile, leather and footwear industry but also beyond in many other sectors including automotive, construction, and electronics.[4]

The lack of a structured methodology for setting reduction targets on these substances means that even companies with strong environmental ambitions struggle to take targeted and therefore prioritized action. As a result, chemical pollution, despite being an important driver of nature loss, often remains unquantified, unmanaged, and underprioritized in corporate nature strategies.

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Implementation of the ZDHC MRSL specifically helps to address this critical gap by providing an actionable, science-informed list of substances that should be eliminated from manufacturing processes non-regrettably. Unlike many regulatory lists which largely focus on compliance thresholds in final products, the ZDHC MRSL takes a preventive input-based approach, identifying harmful substances that must not be used or intentionally added at any stage of production, avoiding their release into the environment through

4 Science Based Targets Network.Corporate Manual for setting science-based targets for nature. s.l.: Science Based Targets Network, 2023.

wastewater, sludge, air emissions, or solid waste. In doing so, the ZDHC MRSL aligns with the precautionary principle and upstream pollution prevention, which are central to the “Avoid” and “Reduce” steps in the SBTN’s Avoid, Reduce, Restore and Regenerate, and Transform (ARRRT) action hierarchy.[5]

Whilst the SBTN continues to evolve its approach to broader chemical categories, the ZDHC MRSL enhances its ambition and enables companies to provide stewardship and accountability, reduce their chemical footprint, and contribute to reduced Nature impact goals globally. The ZDHC MRSL is not just a technical list; it is a strategic enabler for credible, measurable progress on one of the most urgent and overlooked dimensions of Nature loss – and part of a legacy that ZDHC has been instrumental in building for over 10 years.

3.3. How the ZDHC MRSL brings value beyond conformance.

Beyond facilitating industrial conformance, the ZDHC MRSL functions as a strategic tool for building business resilience in an ever-evolving regulatory and market landscape. In contrast to reactive approaches that wait for legislation to dictate substance bans, ZDHC MRSL adoption positions companies as proactive leaders rather than followers in the transition to safer chemistry, particularly in regions with less stringent regulations.

One of the clearest resilience benefits is anticipation of future regulation. Global policies are tightening around chemical pollution, with frameworks like the EU Chemicals Strategy for Sustainability, the EU Green Deal, and EU REACH expanding in scope and ambition. Outside of Europe, similar regulatory momentum is emerging, such as China’s priority management of new pollutants[6] or California’s Proposition 65 updates.[7]

The ZDHC MRSL approach enables businesses to anticipate and adapt to future regulations, thereby limiting potential disruptions such as reformulation costs, product recalls, or blocked market access. By providing practical guidance that aligns industry capability with safer alternatives, the ZDHC MRSL has potential to function as a forward-looking tool that identifies and manages high-risk substances effectively before they pose significant legal or commercial challenges.

Furthermore, the ZDHC MRSL may potentially support cost efficiency over time. By proactively phasing out chemicals of concern, companies can avoid future expenses related to pollution control technologies, wastewater treatment upgrades, or legal penalties.

For example, substituting a restricted solvent with a safer alternative might reduce energy demand in drying processes and eliminate the need for volatile organic compound (VOC) abatement systems.

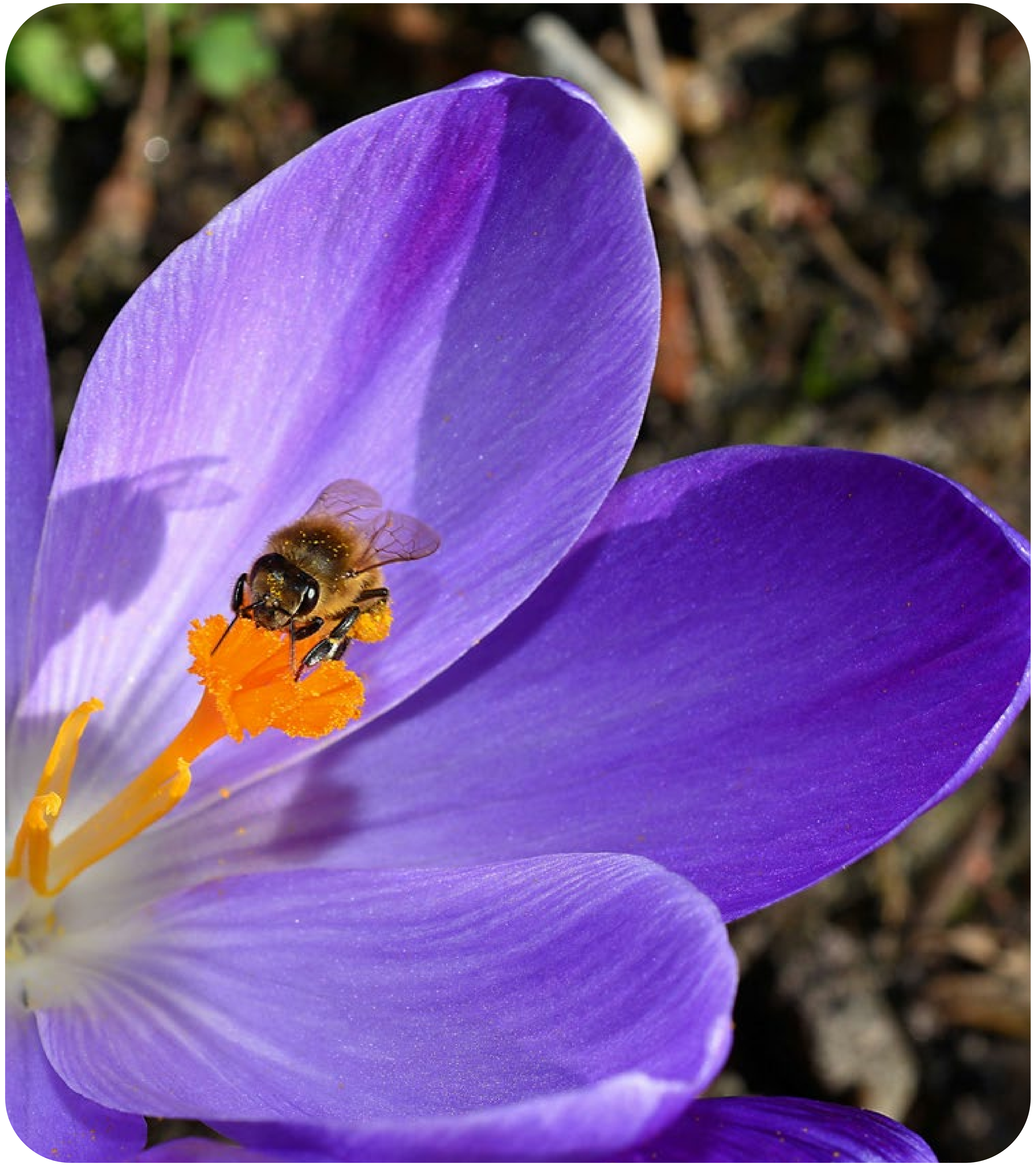
Beyond these potential savings, ZDHC MRSL implementation could also streamline supplier onboarding, auditing, and traceability, potentially enhancing operational efficiencies by standardizing expectations across the value chain. It might also help reduce reputational and liability risks associated with the use of chemicals of concern, particularly in sensitive markets or supply chains. However, quantifiable evidence and comprehensive business analyses would be required to validate these potential benefits.

5 ZDHC. ZDHC Manufacturing Restricted Substances List. s.l.: ZDHC, 2025.
6 The State Council the People’s Republic of China
7 California Office of Environmental Health Hazard Assessment

From an environmental footprint perspective, ZDHC MRSL adoption can enable companies to directly reduce pollution loads across air, water, and soil, not only at their own sites but across upstream suppliers. Because the ZDHC MRSL applies at the chemical formulation level, it drives systemic reductions in hazardous inputs, contributing to measurable reductions in toxic releases and occupational health hazards such as worker exposure. Unlike frameworks like REACH, which often require substance-level notification or downstream declaration, the ZDHC MRSL embeds upstream prevention into chemical formulation sourcing decisions. This is particularly valuable in global supply chains where enforcement of local environmental laws may be less robust or more inconsistent.

The ZDHC MRSL can significantly enhance market influence and brand differentiation, particularly as stakeholder expectations regarding transparency, circularity, and nature-related impacts continue to rise. Companies adopting the ZDHC MRSL are increasingly recognized as leaders in chemical stewardship, building greater credibility among consumers, investors, and regulators. While implementation of the ZDHC MRSL alone does not constitute a definitive “nature” claim, it strategically aligns with broader environmental objectives by systematically addressing pollution reduction, climate action, and water stewardship.

Furthermore, the ZDHC MRSL equips brands to communicate a robust, science-based sustainability narrative aligned with Environmental, Social, and Governance (ESG) frameworks, green procurement standards, and non-governmental organization (NGO) expectations. It also provides a structured approach to supplier engagement through clear guidelines for safer chemical practices, enhancing traceability and consistency. In this way, the ZDHC MRSL serves not merely as a technical standard, but as a strategic lever driving industry-wide transformation toward more sustainable chemical management.



04

Methodology and Results

This analysis considers three different methodological approaches to estimate the reduction of impacts on nature from textile, leather, and footwear production when adopting the ZDHC MRSL:

Approach 1 – Facility-specific case studies: facilities were explored that have substituted ZDHC MRSL-listed substances with conformant alternatives. A comparative LCA methodology was followed, including production and usage phases, clearly demonstrating environmental impacts before and after substitution.

Approach 2 – Wastewater discharge assessment: the reduction in nature-related impacts associated with wastewater discharges by using general textile industry datasets and specific facilities that transitioned from ZDHC Wastewater Non-Conformance to the various conformance levels (as defined by the protocol) was assessed.

Approach 3 – Air emissions release assessment: the reduction in nature-related impacts associated with VOC air emissions by leveraging data from facilities transitioning from Non-Conformance to Foundational conformance level under the ZDHC Air Emissions Guideline was assessed.

For these three approaches, impact reduction was assessed by considering the LCA indicators from the EU Commission Product Environmental Footprint (PEF) methodology for LCA. This methodology defines a standardized set of 16 environmental indicators that are used to assess the environmental performance of a subject (for example, a product) through a multi-dimensional approach. For this study, five of these indicators were determined to pertain most to the nature topic and were least likely to present data quality or volume challenges*:

Human toxicity (CTUh): assesses potential harm from chemical exposure to human health

Freshwater ecotoxicity (CTUe): measures the impact of chemical pollutants on freshwater ecosystems

Water use (m^3): measures the amount of freshwater extracted for industrial processes

Freshwater eutrophication (kg P equivalents): representing the fraction of nutrients reaching the freshwater end compartment (modeled based on the EUTREND model by Struijs et al. (2009) as implemented in ReCiPe 2008)

Marine eutrophication (kg N equivalents): representing the fraction of nutrients reaching the marine end compartment (modeled based on the EUTREND model (Struijs et al., 2009) via ReCiPe 2008)

*Human toxicity, non-cancer, is measured in Comparative Toxic Units for humans (CTUh). Freshwater ecotoxicity is measured in Comparative Toxic Units for ecosystems (CTUe). They are both calculated using the USEtox 2.1 model as described by Fantke et al. (2017),[8] Rosenbaum et al. (2008),[9] and further utilized in Saouter et al. (2017).[10]

8 Fankte, Peter, et al.
9 Rosenbaum, Ralph K., et al.
10 Saouter, Erwan, et al.

The freshwater eutrophication indicator primarily relates to nutrient pollution, particularly nitrogen and phosphorus compounds, which promote excessive algal growth and degrade aquatic ecosystems. ZDHC does not explicitly restrict nitrogen-containing substances through its MRSL, so the assessment of their impacts within this report focuses specifically on wastewater discharge, addressing these compounds through conventional wastewater parameters outlined in the ZDHC Wastewater Guidelines. Consequently, eutrophication impacts from nitrogen-containing compounds are explicitly evaluated within wastewater-related scenarios, adhering to established conventional discharge limits rather than ZDHC MRSL-based restrictions. However, it is important to recognize that an industry-wide shift toward bio-based commodity chemicals could increase reliance on agricultural inputs such as fertilizers and pesticides, altering the significance of nitrogen and phosphorus management and potentially increasing their contribution to eutrophication impacts in the future.

Other PEF impact indicators, notably land use change, have been deliberately excluded from this study as chemicals listed on the ZDHC MRSL and their selected substitutes predominantly originate from fossil-based feedstocks, with minimal to negligible reliance on bio-based materials. Consequently, potential impacts from land use transformation and related biogenic resource depletion are not deemed significant within the current scope. However, it should be acknowledged that this assumption might underestimate impacts if bio-based chemicals become more widely adopted in the future.

This methodological alignment was determined based on a data availability assessment conducted by experts in LCA, nature and chemicals from the sustainability consultancy Quantis, complemented by ZDHC and external experts' consultation, which revealed a distinct lack of appropriate primary data and secondary data required for a typical Nature assessment (see "Overview of Data Types" box).

Limitations of Use and Interpretation

All impact results are derived from modeled scenarios and specific case studies. These figures depend on local context, chemical substitutions, and treatment performance. They are not industry-wide averages or certifications of compliance. Use of these data for public claims must be grounded in critically verified, location-specific results.

Recognizing these limitations, a pragmatic approach was applied by extrapolating from available data points, representing a realistic solution given the current data constraints within the textile chemical supply chain. This ensured robust and meaningful results even when ideal data sets are currently not available and, in some cases, may never be available.

Overview of Data Types

Primary Data: Information collected directly from the source—for example, measurements taken directly from manufacturing plants or facilities. Primary data is highly specific, accurate, and detailed, but it can be difficult, time-consuming, and costly to gather.

Secondary Data: Information gathered from existing resources such as scientific literature, databases, industry reports or studies performed by other organizations. Secondary data is generally quicker and more cost-effective to obtain, making it useful when primary data collection is challenging or impractical.

4.1. Approach 1: Facility-specific case studies

In the initial approach, case studies were identified that could quantitatively demonstrate reductions in environmental impacts based on primary data. Initiatives from companies transitioning away from substances listed in the ZDHC MRSL were specifically considered, applying an LCA approach to evaluate the full lifecycle of these chemicals, from production to use phase, including textile wet processing.

This required gathering primary data through stakeholder interviews related to chemical production and detailed usage data from textile manufacturers. Essential information from manufacturers included the quantities of ZDHC MRSL substances and their substitutes used, their emissions to air and water, changes in additives consumption, water usage, and process alterations related to environmental outputs. However, significant challenges arose due to data gaps, as substituting one ZDHC MRSL substance for another often involves complex changes rather than a one-to-one switch, such as formulation variations at the textile facility level that are difficult to track and quantify. Additionally, many textile manufacturers collect emissions data aligned primarily with their local regulatory requirements, which can differ significantly in scope from the comprehensive data required for MRSL evaluations. As a result, available emissions data were, at times, incomplete, complicating accurate environmental impact estimation.

To address these limitations, secondary databases were extensively relied upon to accurately model the production processes of ZDHC MRSL substances and their alternatives. These secondary databases included WALDB, ecoinvent 3.10. and USEtox, which were chosen due to their ability to estimate the emissions for common textile emission processes and characterize the impact of chemicals of concern, thereby enabling estimation of environmental impacts using relevant impact indicators such as freshwater ecotoxicity and human toxicity.

By thoroughly reviewing existing research and leveraging similar or proxy data, expected emissions to air and water were estimated, integrating these findings into the modeling framework. This approach allowed comprehensive capture of life cycle impacts in a holistic manner. Although data limitations inherently introduce uncertainty, the observed reduction in freshwater ecotoxicity and human toxicity (non-cancer) when transitioning from original to ZDHC MRSL safer alternatives clearly highlights the substantial environmental advantages of adopting ZDHC MRSL conformant substitutes.

4.1.1. Case Study 1: Nonylphenol ethoxylates (NPEOs) alternative in wetting process at a facility in Jaipur, India

Context

Alkylphenol ethoxylates (APEOs), primarily NPEOs, have historically been widely used in textile wet processing operations such as scouring, dyeing, finishing, and washing due to their superior cleaning and emulsifying capabilities. However, their degradation into persistent and endocrine-disrupting compounds, particularly nonylphenol (NP), has raised significant environmental and human health concerns. Whilst EU REACH restricts the use of NP and its ethoxylates, many regions, including parts of Asia, Africa, and Latin America, lack such binding regulatory controls. This global inconsistency highlights the importance of using the ZDHC MRSL as a harmonized, international framework to proactively reduce the environmental and human health impacts of chemicals of concern, even in regions where regulation is limited or absent.[11] Consequently, the ZDHC initiative explicitly lists APEOs in its MRSL with the aim of eliminating their use throughout textile supply chains and promoting sustainable chemical management.

In this case study, alternatives to NPEO-based detergents used in textile wet processing were examined, focusing on formulations that eliminate NPEOs in favor of safer, more environmentally responsible ingredients.

Many of these alternative products are based on fatty alcohol ethoxylates (FAEs), a widely adopted class of non-ionic surfactants known for their effectiveness in low dosages and lower ecotoxicity profiles compared to NPEOs. This aligns with broader industry practices, where leading brands have successfully committed to phasing out NPEOs across their global supply chains. Effective substitution strategies have consistently prioritized the adoption of NPEO-free surfactants and involved close collaboration with suppliers to identify and implement viable replacements, reinforcing the practicality and effectiveness of this transition. Collectively, these examples demonstrate that safer alternatives are both technically achievable and commercially scalable across the textile sector.

In response to these concerns, safer alternatives such as FAEs (for example,AE7) have been developed and are increasingly adopted throughout the textile industry. These non-ionic surfactants effectively replace NPEO-based formulations across various textile wet-processing applications, including wetting, scouring, and emulsifying, without the environmental persistence and bioaccumulation risks associated with NPEOs. This specific case study demonstrates the successful substitution of NPEOs with AE7 in wetting applications, reinforcing the practicality and broader effectiveness of this safer alternative across multiple formulation scenarios.This study followed the direct discharge scenario in ZDHC's Wastewater Guidelines where wastewater that has been treated and generated by a supplier through its own and operated effluent treatment plant is discharged directly to the land, municipal sewers, or water bodies such as streams, lakes and oceans.

Results and Interpretation

A comparative LCA was conducted, incorporating production phases of both NPEOs and FAEs. The LCA system boundary includes synthesis and chemical production, considering emissions linked to manufacturing inputs. NPEO9 was modeled through NP ethoxylation processes, whereas the alternative tridecyl alcohol ethoxylate 7 utilized alcohol ethoxylation production. The analysis specifically quantifies freshwater ecotoxicity (CTUe) and climate change impacts based on a formulation input ratio representative of typical industrial practices.

The results demonstrate clear environmental benefits when substituting NPEO9 with tridecyl alcohol ethoxylate 7 across both the production and usage phases. In thestudy, a conservative scenario was adopted, assuming the use of 4 kg of tridecyl alcohol ethoxylate 7 per 1 ton of fabric, compared to 3 kg of NPEO9 per 1 ton of fabric. This assumption is based on technical documentation of formulation practices and process expert input regarding the dosage requirements for achieving similar wetting and cleaning performance. Under this scenario, a **51% reduction** in freshwater ecotoxicity was observed. This is notably important as surfactants mainly enter wastewater systems during textile wet processing. However, this freshwater ecotoxicity credit is supplemented with a **21% increase** in climate change impact, driven mainly by the greater production footprint of tridecyl alcohol ethoxylate 7 and the higher usage dosage. Despite this trade-off, transitioning away from NPEOs still offers a substantial environmental advantage, particularly in reducing long-term aquatic toxicity.

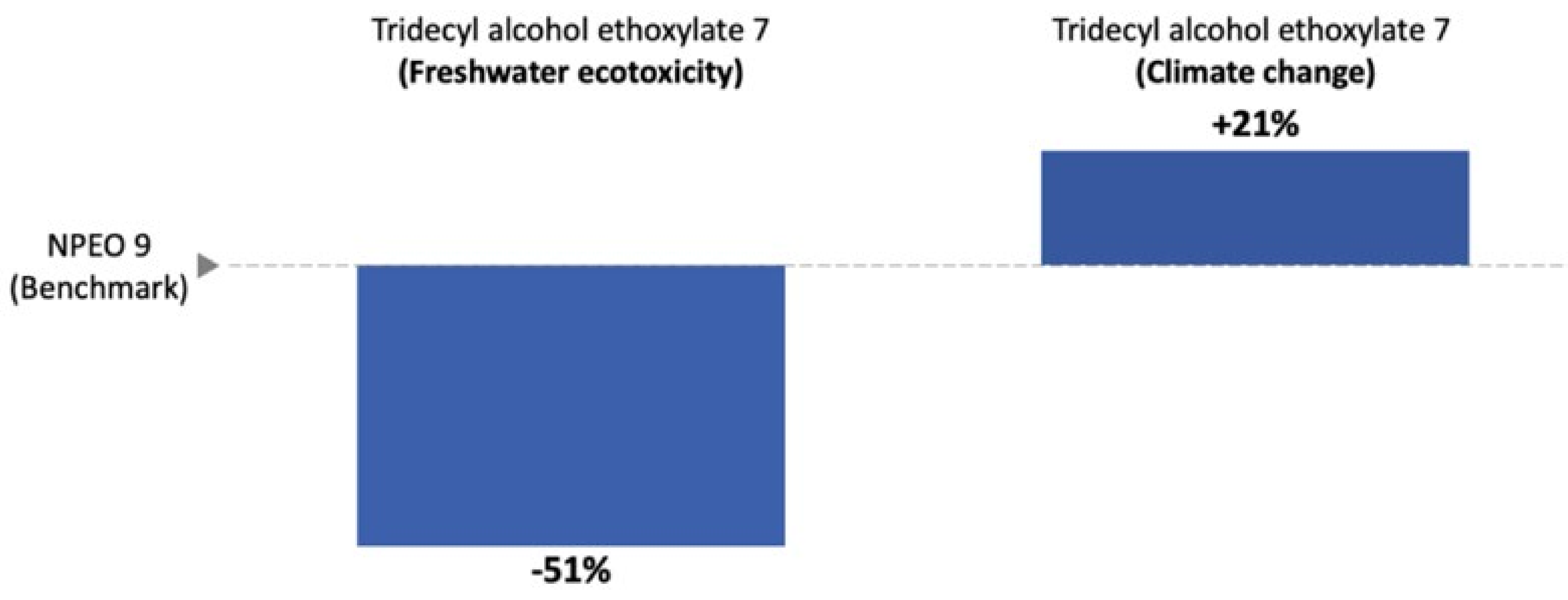


Figure 1. Comparative LCA results showing a 51% reduction in freshwater ecotoxicity and a 21% increase in climate change impact when substituting NPEO9 with tridecyl alcohol ethoxylate 7 in textile wet processing. Results reflect trade-offs between improved aquatic toxicity outcomes and higher production-related emissions. These results are based on specific scenarios and do not represent average or guaranteed outcomes across all suppliers or facilities.

In the analysis, the transformation of NPEO9 into NP, a compound highly persistent, toxic to aquatic life and prone to bio accumulation, was accounted for during wastewater treatment. NP itself is hydrophobic, meaning it strongly partitions into sludge, whereas NPEO9, particularly those with longer ethoxylate chains, tend to remain largely dissolved in wastewater due to their higher water solubility. This distribution is significant because even after wastewater treatment, the presence of NP in sludge poses a potential risk of environmental contamination if the sludge is landfilled, as NP can leach into soils and waters, contributing to long-term ecological impacts. This case study not only validates the efficacy and environmental benefit of Alcohol ethoxylates as substitutes for NPEOs in textile applications but also highlights broader market and regulatory implications.

It supports industry-wide efforts guided by ZDHC's chemical management objectives to eliminate harmful substances and embrace safer alternatives, ultimately helping to protect both human health and freshwater ecosystems.

Substituting NPEOs with FAEs not only brings freshwater ecotoxicity and therefore conformance benefits but also offers notable cost advantages. FAEs are generally less expensive per unit and can achieve equivalent performance at similar dosages across a range of textile processes. By lowering both regulatory risk and material costs, FAEs present a sustainable and economically viable solution for brands and manufacturers aiming to improve their environmental footprint while maintaining efficiency in production.

4.1.2. Case Study 2: Covestro LCA Study comparing dimethyl formamide (DMFa) and water-based processes for polyurethane (PU) textile-coated materials production

Context

Following a strategic decision to phase out DMFa, several stakeholders in the textile and textile-coated materials industry have collaborated to accelerate the transition toward safer, more sustainable alternatives. This transition has been supported through participation in ZDHC technical workshops, bringing together brands, vendors, PU manufacturers, and chemical suppliers to facilitate cross-industry dialogue and solutions for eliminating DMFa from production processes.

In collaboration with Covestro AG and its INSQIN® water-based PU technology, the focus was placed on advancing DMFa-free textile coated materials applications, particularly bags and wallets. Partner mills in China that are already fitted with Covestro's water-based PU systems underwent targeted audits beyond standard tier 2 sustainability assessments. These audits evaluated key capabilities such as readiness for water-based PU production, infrastructure for chemical separation, and controls to prevent DMFa cross-contamination. Mills were rated based on audit performance, and those with the highest scores were selected for trial and bulk production phases.
This initiative demonstrates industry capacity to address both technical and commercial challenges while fostering the broader adoption of DMF-free, waterbased PU technologies in textile-coated materials production.

Results and Interpretation

Covestro conducted an LCA to compare the environmental performance of two PU textile-coated material production technologies: a solvent borne process based on DMFa and conventional wet and dry coating, and a waterborne process using INSQIN® technology, which eliminates organic solvents from the coating phase. The functional unit of the study was defined as the production of 1,000 m^2 of coated fabric, and the system boundary covered the full process from raw material acquisition to the coated fabric leaving the factory gate — a "cradle-to-gate" approach. The LCA assessed multiple impact categories, including climate change, water use, and eutrophication potential. The results showed that switching from the solvent-borne to the waterborne process resulted in a **45% decrease** in climate change impacts, a substantial **95% reduction** in water use, and a **27% decline** in eutrophication potential—an indicator closely linked to nutrient pollution in aquatic ecosystems.

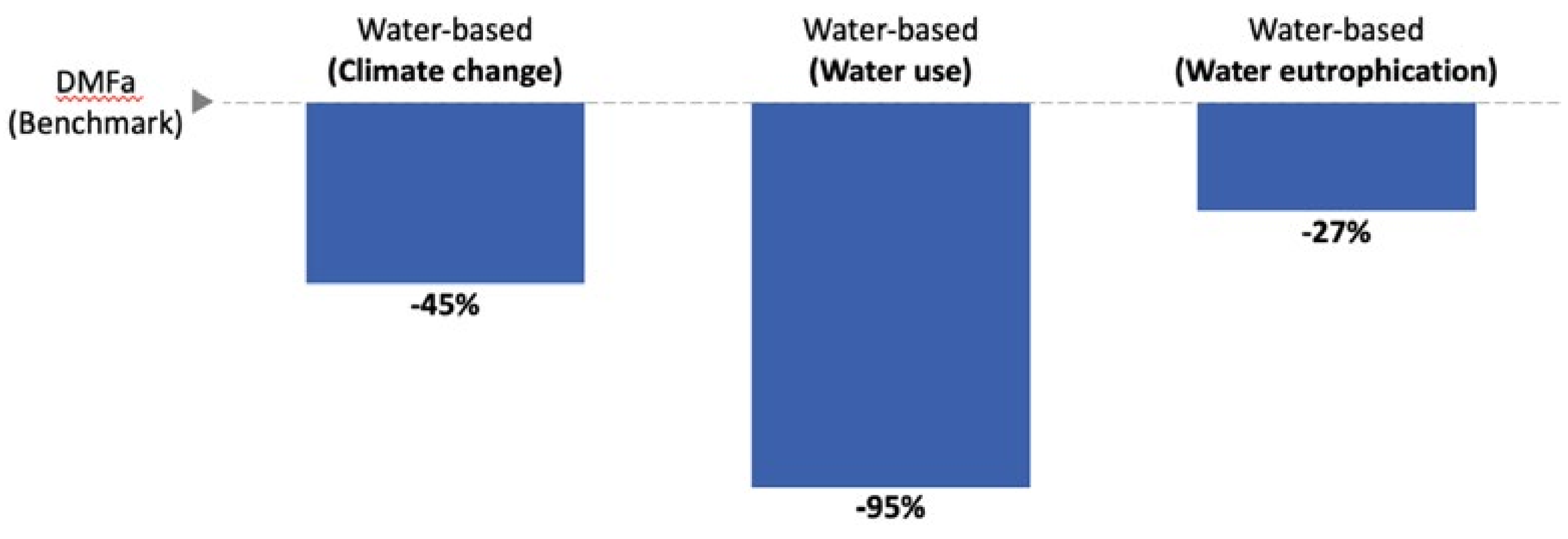


Figure 2. Comparative LCA results showing a 45% reduction in climate change impact, a 95% reduction in water use, and a 27% reduction in water eutrophication potential when substituting DMFa with water-based PU technology. Results highlight substantial environmental benefits across multiple impact categories in textile processing. These results are based on specific scenarios and do not represent average or guaranteed outcomes across all suppliers or facilities.

DMFa is a widely used solvent in conventional PU textile-coated materials manufacturing, but it presents serious occupational health and safety risks. Chronic exposure to DMFa has been linked to hepatotoxicity and reproductive toxicity, with documented cases of workers developing gastrointestinal symptoms, enlarged liver (hepatomegaly), and reduced sperm mobility.[12] Limited evidence also suggests a higher risk of miscarriage among pregnancies affected by workplace exposure to DMFa.[13] Despite its known hazards, DMFa is still not globally regulated under all occupational safety frameworks, although some regions have imposed limits. In the United States, OSHA enforces a permissible exposure limit (PEL) of 10 ppm (30 mg / m^3) over an 8-hour workday,[14] while the European Union classifies DMFa as a Substance of Very High Concern (SVHC) under REACH, capping exposure at 2 ppm (6 mg / m^3) for PU processing.[15] Some studies indicate that even short-term exposure to airborne DMFa can lead to detectable blood concentrations in workers, especially when protective controls are lacking or inconsistent.[16] These risks underscore the need for a proactive substitution strategy.

This case study demonstrates that transitioning from DMFa based solvent-borne PU to waterborne PU technologies can significantly reduce worker exposure to hazardous solvents whilst simultaneously delivering broader environmental benefits across the product life cycle. Waterborne systems eliminate DMFa use entirely, thus removing the source of exposure rather than managing it through downstream controls. These findings directly support ZDHC's decision to list DMFa on its Candidate List for Substitution, based on both scientific literature and precautionary principles. Although not currently regulated under the ZDHC MRSL, the health and environmental profile of DMFa strongly justifies efforts to replace it. This case also highlights preliminary economic benefits, particularly through energy and water savings, though a dedicated economic analysis would be required to fully substantiate these gains. Overall, this reinforces the value of safer-chemistry innovation as a dual win for workplace safety, sustainability, and cost efficiency in the textile and textile-coated materials sectors

12 U.S. Environmental Protection Agency (EPA)
13 Lai, David Y., et al.
14 Occupational Safety and Health Administration
15 IRIS Biotech
16 Zhang, Qingyu, et al.

4.2. Approach 2: Wastewater discharge assessment

Textile manufacturing processes, particularly wet processing stages such as dyeing and finishing, generate wastewater often contaminated with a complex mixture of chemicals of concern, including dyes, chemical additives, and heavy metals like cadmium and lead. The ZDHC MRSL plays a critical role in preventing the discharge of these chemicals of concern by eliminating harmful substances at the source, but chemical input controls alone are not enough in this case. Without proper wastewater treatment, conventional pollutants can still cause significant environmental damage. Both input management and effective effluent treatment are essential to safeguard ecosystems and communities.

These discharges, when untreated or poorly managed, pose severe threats to aquatic ecosystems, harming biodiversity and contributing to water pollution. In response to this, large parts of the textile industry have adopted the ZDHC Wastewater Guidelines, which defines a three-tier level of achievement framework (Foundational, Progressive, and Aspirational) specifically for conventional wastewater parameters. For ZDHC MRSL-listed substances, however, these guidelines apply strict detection limits, focusing on elimination rather than tiered reductions.

This study applies a comparative LCA methodology to evaluate the toxicity impacts of textile wastewater under four ZDHC conformance scenarios: Non-Conformant, Foundational, Progressive, and Aspirational. For each scenario, potential reductions in toxicity impacts were assessed through improved treatment and chemical management. The World Apparel and Footwear Lifecycle Assessment Database (WALDB), developed by Quantis was used as the main inventory source.

WALDB provides textile-specific emission factors for heavy metals (for example, mercury, chromium VI, cadmium, lead) and conventional parameters (AOX, nitrates, phenols), aligned with real industrial conditions (see box below).

Overview of Relevant Chemical Substances

AOX (Adsorbable Organic Halogens): Primarily derived from bleaching processes using chlorine-containing chemicals and the use of chlorinated solvents in textile processing.

Nitrates: Mainly originate from the use of nitrogen-containing dyes, fixing agents, and residual compounds in dye baths and finishing formulations.

Phenols: Often released from dyeing operations using phenolic compounds, as well as from certain finishes, detergents, and textile auxiliaries.

Heavy Metals: (e.g., Mercury, Chromium VI, Cadmium, Lead) Typically associated with specific dyes and pigments, tanning agents, and metal-based dye fixation processes used during textile manufacturing.

Sampling protocols outlined by the ZDHC Wastewater Guidelines were followed, which include monitoring influent, effluent, and sludge. For modeling environmental and health impacts, LCA data bases such as ecoinvent 3.10. database were leveraged to assess human toxicity (CTUh), freshwater ecotoxicity (CTUe), and eutrophication impacts(kg P / N eq)

4.2.1. Case Study 1: ZDHC scenarios based on secondary database

Context

This case evaluates toxicity impacts based on a representative WALDB dataset for textile wastewater, using three ZDHC-aligned scenarios: Progressive and Aspirational, compared to a Foundational baseline. Only pollutants covered in WALDB and aligned with ZDHC (primarily heavy metals and conventional parameters) were included. ZDHC MRSL-listed parameters were excluded due to limitations, specifically in the scope and granularity, in the WALDB dataset relating to the average concentration of these specific ZDHC MRSL substances concentration in the average textile wastewater, rather than limitationsin primary data collection or ZDHC's monitoring practices. The functional unit was set as 1 m^3 of discharged wastewater. This study followed the direct discharge scenario of ZDHC's Wastewater Guidelines where wastewater that was treated and generated by a supplier through its own and operated effluent treatment plant is discharged directly to the land, municipal sewers, or water bodies such as streams, lakes and oceans. The scope of this study includes reduction related to wastewater discharge only, excluding, for example, upstream production. It does not consider the impact of the presence of other chemicals that can have high ecotoxicity value and assumes that wastewater is characterized only by heavy metals and conventional parameters.

Results and Interpretation

The differences in treatment level and parameters threshold translate directly into differences in environmental impacts, as quantified by the approach. **Table 1** below summarizes the calculated human toxicity (CTU_h), freshwater ecotoxicity (CTU_e), freshwater eutrophication (kg P), and marine eutrophication (kg N) results for each scenario, using the heavy metal and conventional parameters-based approach described in section 8.1.2. As the conventional parameter values improve from Foundational through Aspirational, the values for human toxicity, freshwater ecotoxicity, and eutrophication decline significantly, indicating reduced environmental impact and potential harm.

Scenario	Human toxicity (non-cancer) (CTU_h)	Freshwater ecotoxicity (CTU_e)	Freshwater eutrophication (kg P)	Marine eutrophication (kg N)
Foundational	2.4 E-07	256	3.4 E-3	3.2 E-2
Progressive	5.9 E-08	88	5.7 E-4	1.2 E-2
Aspirational	1.3 E-08	36	1.2 E-4	6.5 E-3

Table 1. Human toxicity (CTU_h) per 1 m^3 of wastewater and freshwater ecotoxicity (CTU_e) per 1 m^3 of wastewater, for textile industry under heavy metal and conventional parameter thresholds.

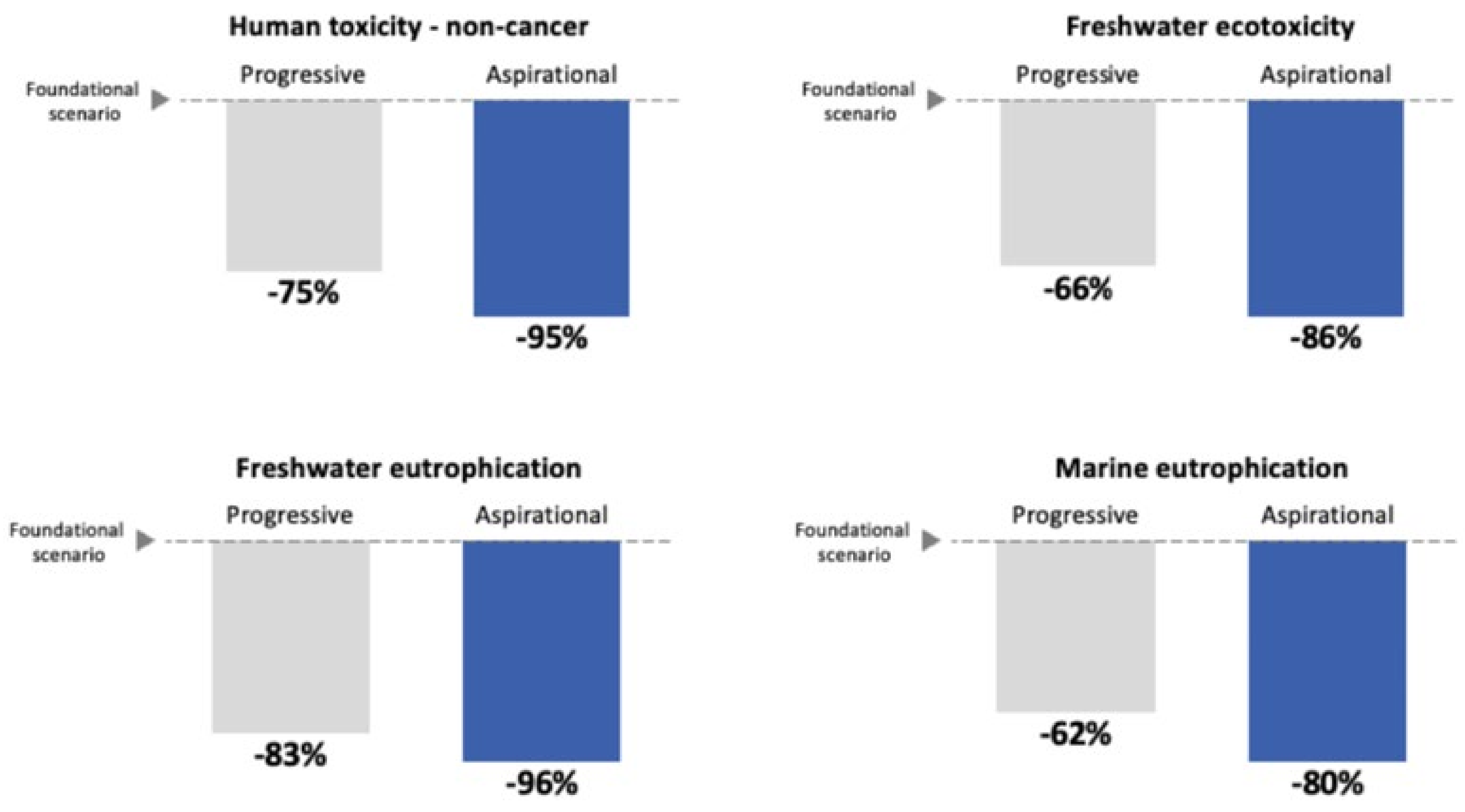


Figure 3. Reductions in environmental and human health impacts achieved by progressing from ZDHC Foundationalto Progressive and Aspirational wastewater conformance levels. The analysis shows significant improvements across freshwater ecotoxicity, human toxicity, and both freshwater and marine eutrophication, demonstrating the value of ZDHC wastewater thresholds in driving measurable nature-related outcomes.These results are based on specific scenarios and do not represent average or guaranteed outcomes across all suppliers or facilities.

The results of the modeling provide compelling evidence that higher levels of ZDHC wastewater conformance can drive substantial reductions in nature-related impacts. Transitioning from a Foundational to a Progressive discharge profile already delivers meaningful gains, including a **53% reduction** in human toxicity (non-cancer), a **51% reduction** in freshwater ecotoxicity, a **78% reduction** in freshwater eutrophication, and a **59% drop** in marine eutrophication potential. These improvements are further amplified at the Aspirational level, where reductions reach **95% for human toxicity, 86% for ecotoxicity, 96% for freshwater eutrophication, and 80% for marine eutrophication potential.**

Notably, these benefits are achieved through improved management of conventional wastewater parameters–particularly heavy metals, AOX, and nitrogen compounds–without requiring advanced technological overhauls. This demonstrates the practical and scalable value of the ZDHC Wastewater Guidelines as a tool for environmental risk reduction. Beyond compliance, this framework enables facilities to tangibly reduce pollution and protect ecosystems, especially in regions with heightened biodiversity or freshwater stress. Taken together, the findings highlight wastewater discharge quality as one of the most accessible and high-leverage points for intervention in the supply chain. Even incremental improvement toward Progressive conformance delivers measurable impact, making ZDHC's tiered approach not only scientifically sound, but operationally strategic in the path to nature-positive manufacturing.

4.2.2. Case Study 2: Copper Reduction in wastewater via Alkaline Precipitation in Panipat, India

Context

In this case, a textile facility in India was found to have 1800ppm of copper in its wastewater, vastly exceeding the ZDHC limit of 1ppm. In this scenario, copper originated from a copper-complex dye intentionally used at the facility, aligning with ZDHC MRSL requirements, as heavy metal limits do not apply to colorants inherently containing listed metals in their compositional structure. Although the dye itself complies with MRSL guidelines, the resulting elevated copper concentrations observed in the wastewater indicating that current processing or wastewater treatment practices are insufficient. To address this, the facility applied alkaline precipitation to reduce copper levels, followed by sludge incineration. Only copper varied between scenarios; all other parameters were within compliant ranges. Data from ecoinvent 3.10. was used to estimate the fraction of copper retained in ash versus emitted to the environment. The LCA model was based on $1m^3$ of wastewater discharge.

This study followed the direct discharge scenario of ZDHC's Wastewater Guidelines where wastewater that was treated and generated by a supplier through its own and operated effluent treatment plant is discharged directly to the land, municipal sewers, or water bodies such as streams, lakes and oceans.

The scope of this study includes reduction related to wastewater discharge only, excluding, for example, upstream production. The wastewater discharge composition base scenario is limited to conventional parameters and heavy metals. It does not consider the impact of the presence of other chemicals that can have high ecotoxicity value and assumes that wastewater is characterized only by heavy metals and conventional parameters.

This has been complemented by an analysis of the local nature sensitivity to toxicity. The most advanced nature impact assessments integrate not only the pressure exerted by the company on nature (m^3 of water withdrawn from river, or pollution released in the environment) but also evaluate the local status of nature and its sensitivity to this particular pressure. As stated by SBTN, "equivalent pressures occurring in different geographic locations will have different significance, depending on factors such as the sensitivity of the local ecosystem to additional changes, presence of threatened species, or reliance of local communities on an impacted resource. Therefore, to understand the contextual significance of a company's pressure footprint, spatial State of Nature (SoN) indicators are required."[17]

To do so, the local State of Nature has been assessed considering 2 dimensions:

- **Pressure-sensitive State of Nature indicator (SoNP)**
- **Biodiversity related state of nature indicators (SoNB) which includes:**
  1. Freshwater biodiversity richness
  2. Freshwater endemism

17 SBTN(B)

SoNP is used to assess the local sensitivity of nature to the pressure, in this case toxicity, assessed through a mapping of Toxicity Stress provided by WWF Water Risk Filter.[18] This is a measure of the negative effects experienced by the aquatic system due to chemicals and mixtures of chemicals that are transported through and accumulate in freshwater ecosystems and negatively affect the aquatic ecosystem.

This indicator is based on the "best case" effect curve linking scenario between the "Human Impact and Water Availability Indicator" (HIWAI) proxy for pressure to the ecological impact expressed by the msPAF metric (Posthuma et al., 2019)[19] using predicted environmental concentrations of 1,785 chemicals as modelled by van Gils et al. (2020).[20]

Toxicity

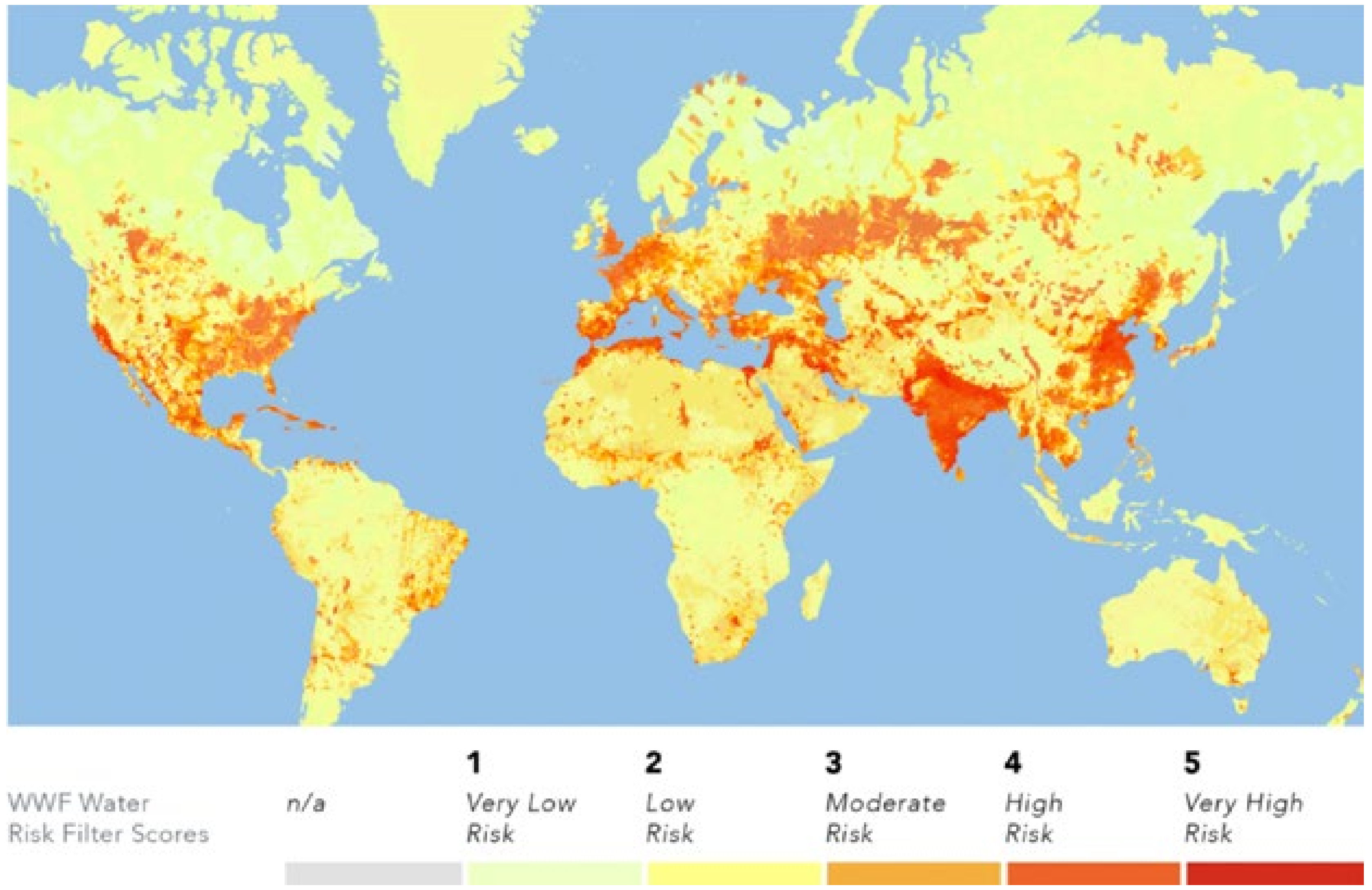


Figure 4. Global map of freshwater toxicity stress based on WWF Water Risk Filter data, used to assess local ecological vulnerability to chemical pollution. Regions in red indicate higher risk of ecosystem harm from accumulated chemical mixtures.

18 WWF
19 Posthuma, Leo, et al.
20 Van Gilds, Jos, et al.

SoNB is used to estimate the local status of biodiversity by evaluating the richness and uniqueness of freshwater ecosystems. This is assessed through spatial mapping of freshwater biodiversity richness (number of species) and freshwater endemism (species foundonly in that location), helping to identify areas of heightened conservation value and reputational sensitivity. Freshwater biodiversity richness is based on the Freshwater Ecoregions of the World (FEOW) 2015 data developed by World Wildlife Fund (WWF) and The Nature Conservancy (TNC), and the count of fish species is used as a representation of freshwater biodiversity richness. The rationale is that companies operating in river basins with higher number of fish species face higher reputational risks.[21]

Freshwater biodiversity richness

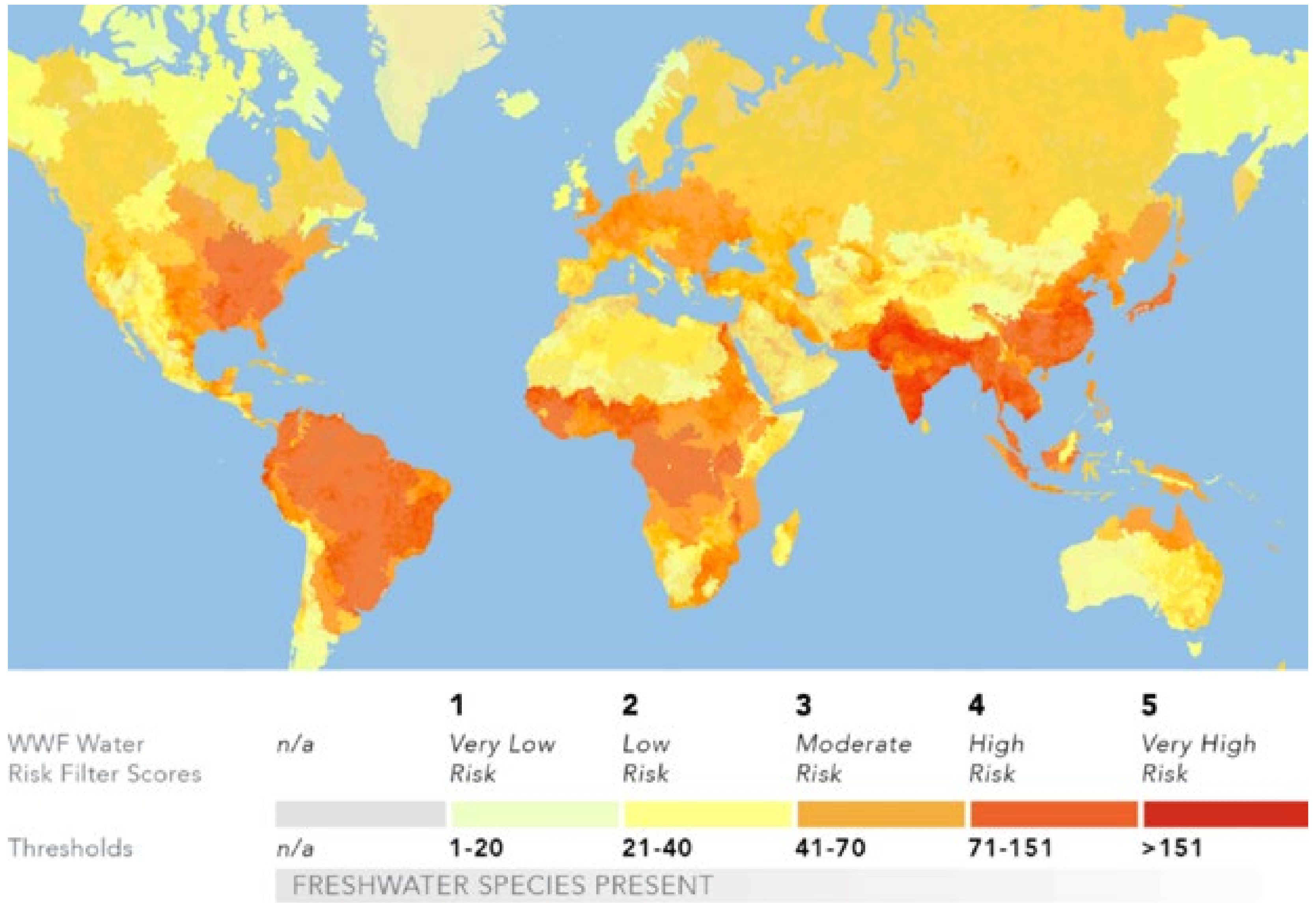


Figure 5. Global distribution of freshwater biodiversity richness based on WWF and TNC's FEOW dataset. Areas in red indicate regions with the highest number of freshwater fish species, representing locations of elevated biodiversity value and reputational risk

21 Abdel, R., et al.

Freshwater endemism is based on the FEOW 2015 data developed by WWF and TNC. The rationale is that companies operating in river basins with higher number of endemic fish species are facing higher reputational risks.

Freshwater endemism

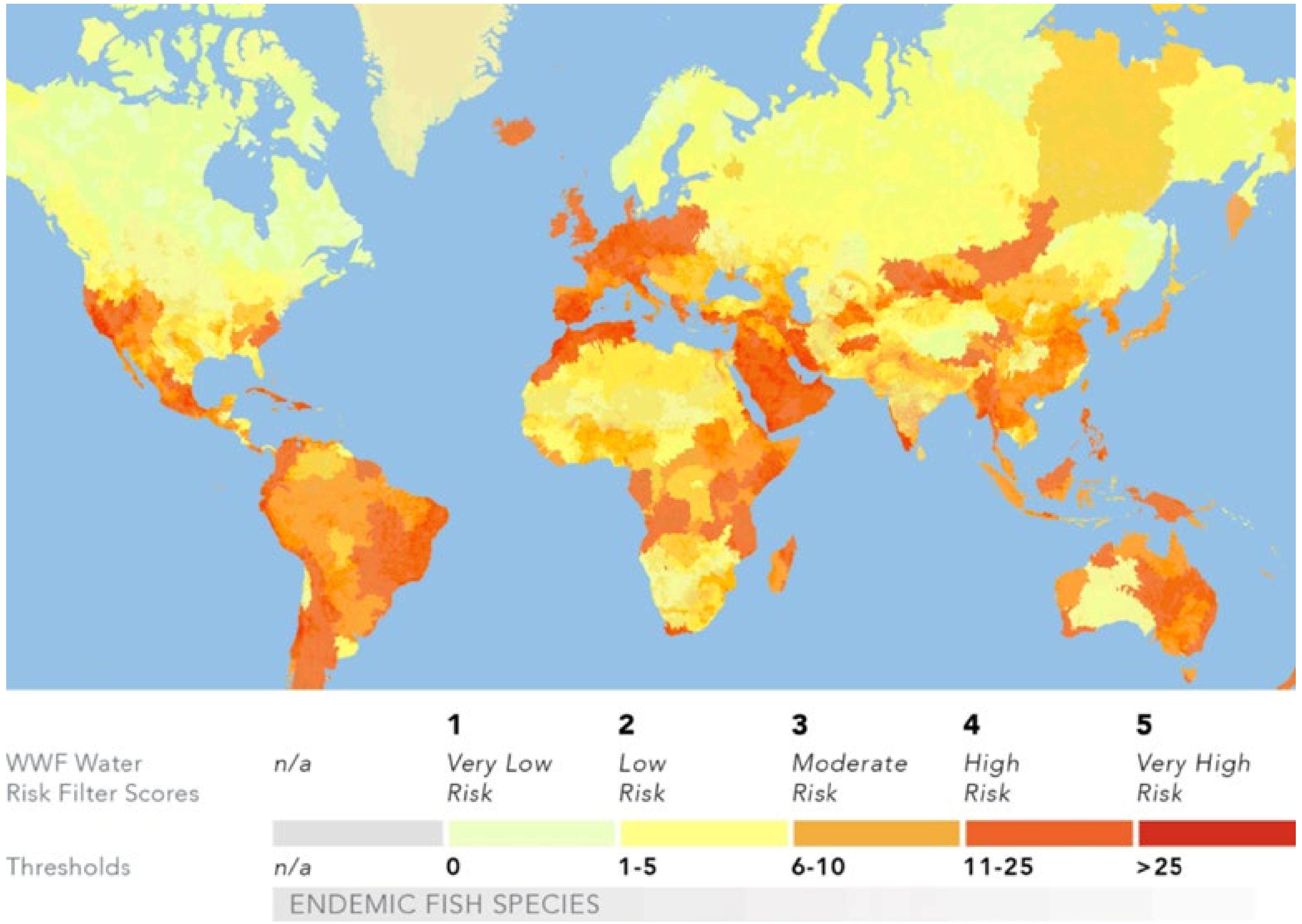


Figure 6. Global distribution of freshwater endemism based on FEOW data. Regions shown in dark orange and red indicate areas with a high number of endemic freshwater fish species, where chemical pollution may pose elevated risks to unique and irreplaceable biodiversity.

Results and Interpretation

After the enhancement in the wastewater treatment, freshwater ecotoxicity **dropped by 13%**, while human toxicity **decreased by 1%** compared to the non-conformant scenario. This reflects the greater toxic effect of copper on aquatic species compared to humans. Copper disrupts gill function and osmoregulation in fish, making it harmful even at trace levels. In contrast, humans regulate copper through homeostasis, and effects appear only under chronic exposure. This case illustrates the **value of targeted metal removal**, even if human health gains appear modest in this case.

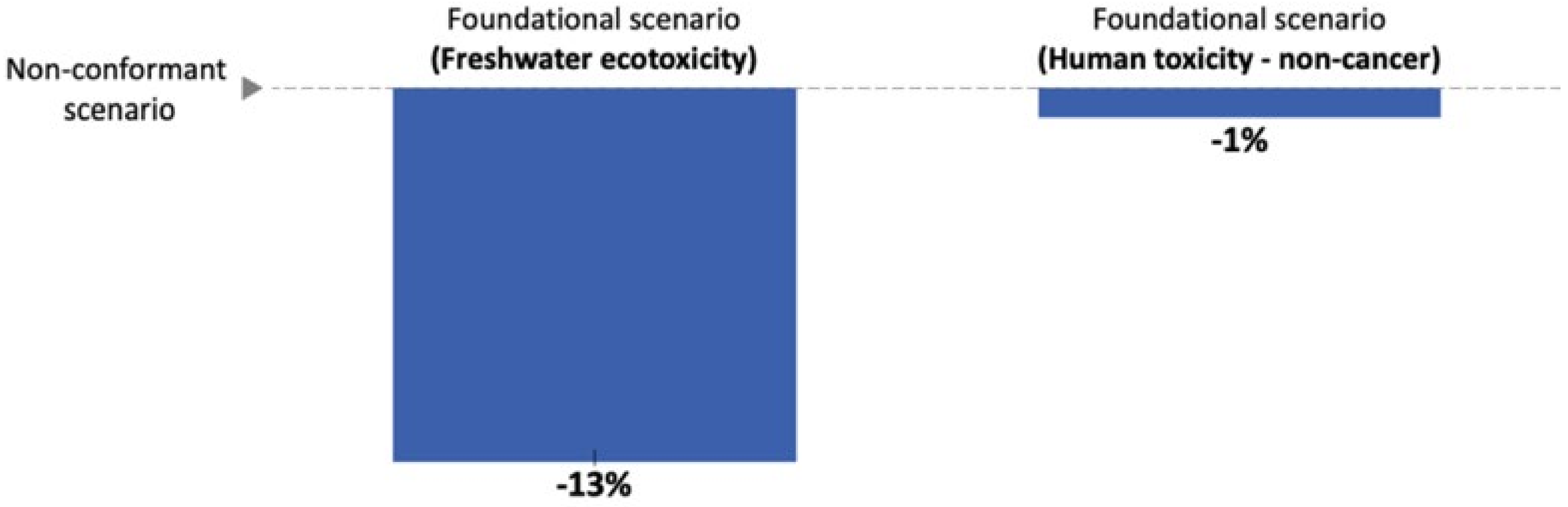


Figure 7. Impact reduction from copper removal via alkaline precipitation at a textile facility in India. A 13% reduction in freshwater ecotoxicity and 1% reduction in human toxicity (non-cancer) were achieved, illustrating the environmental value of targeted heavymetal mitigation. These results are based on specific scenarios and do not represent average or guaranteed outcomes across all suppliers or facilities.

In Panipat, India, the location of the assessed facility, the freshwater ecosystem demonstrates **very high toxicity stress,** indicating significant local sensitivity to the release of chemical pollutants. This heightened sensitivity suggests that any discharge of chemicals of concern poses substantial risks to aquatic species.

Toxicity

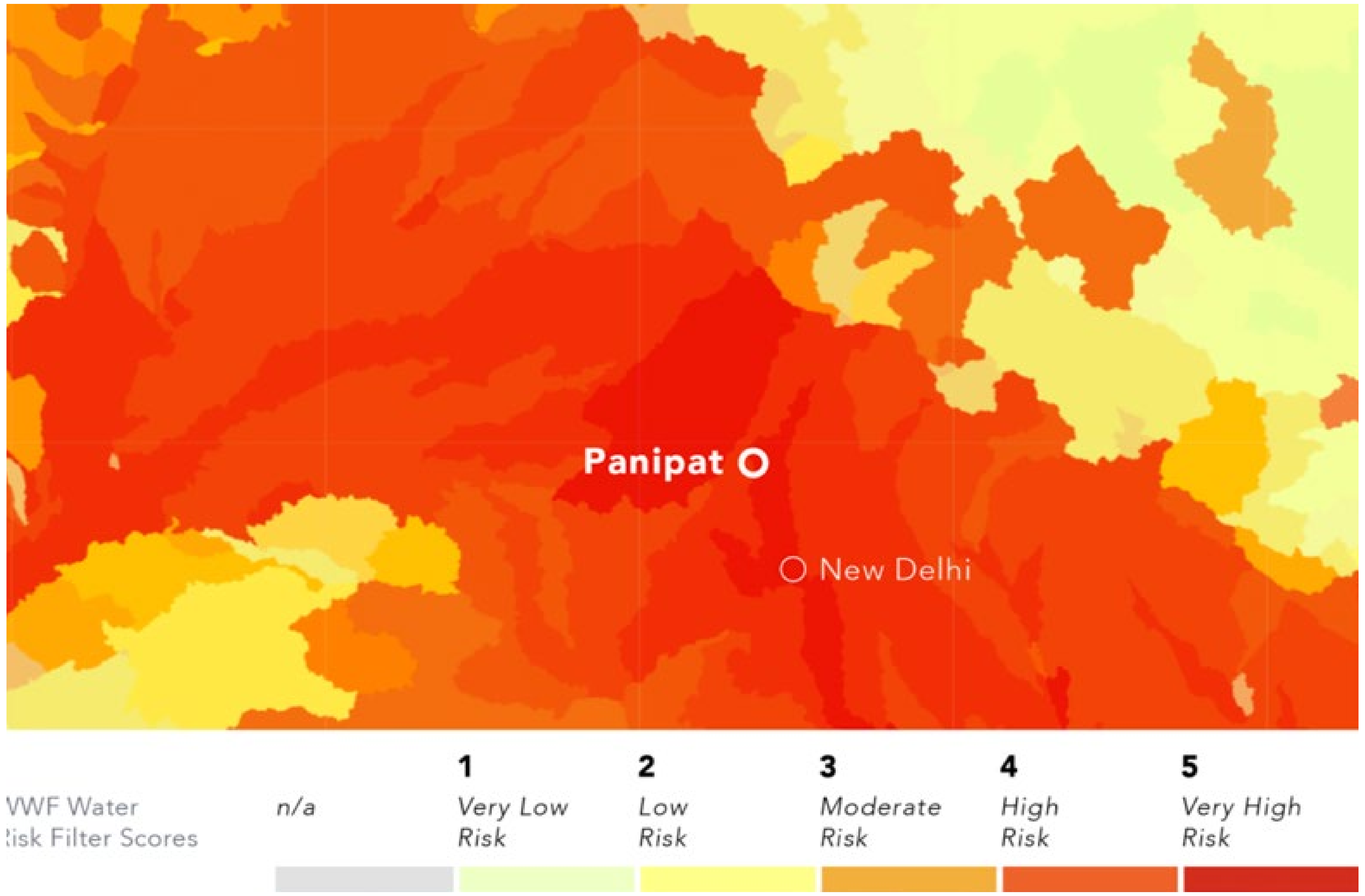


Figure 8. Toxicity stress map for the Panipat region in India, indicating a very high-risk freshwater zone based on WWF Water Risk Filter scores. The region's ecological sensitivity underscores the importance of wastewater treatment and chemical reduction measures in local manufacturing facilities.

Additionally, the region exhibits high **freshwater biodiversity richness,** even though the local endemism is relatively low. Consequently, chemical releases in this area have the potential to affect numerous freshwater species, amplifying the ecological significance of effective wastewater management.

Freshwater biodiversity richness

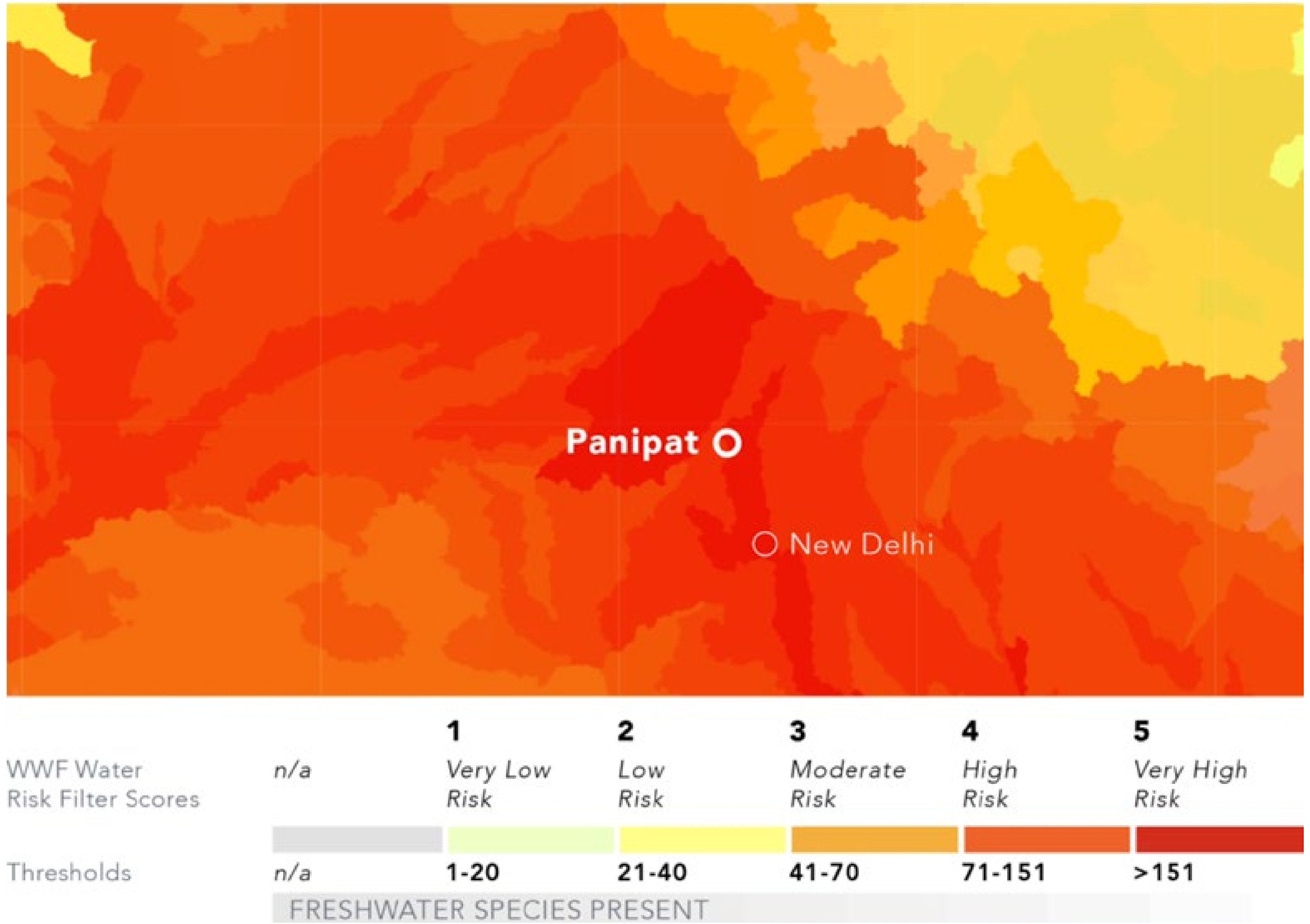


Figure 9. Freshwater biodiversity richness in the Panipat region, India, based on WWF Water Risk Filter data. The area is marked by a high density of freshwater species, highlighting its ecological importance and the heightened urgency for effective chemical pollution control.

Although endemism in the Panipat region is relatively low, the area still holds high ecological importance due to its high freshwater biodiversity richness and significant toxicity stress. This means that even without a concentration of unique species, pollution can impact a broad range of aquatic life. Consequently, reducing chemical emissions remains critical to safeguarding regional ecosystem health.

Freshwater endemism

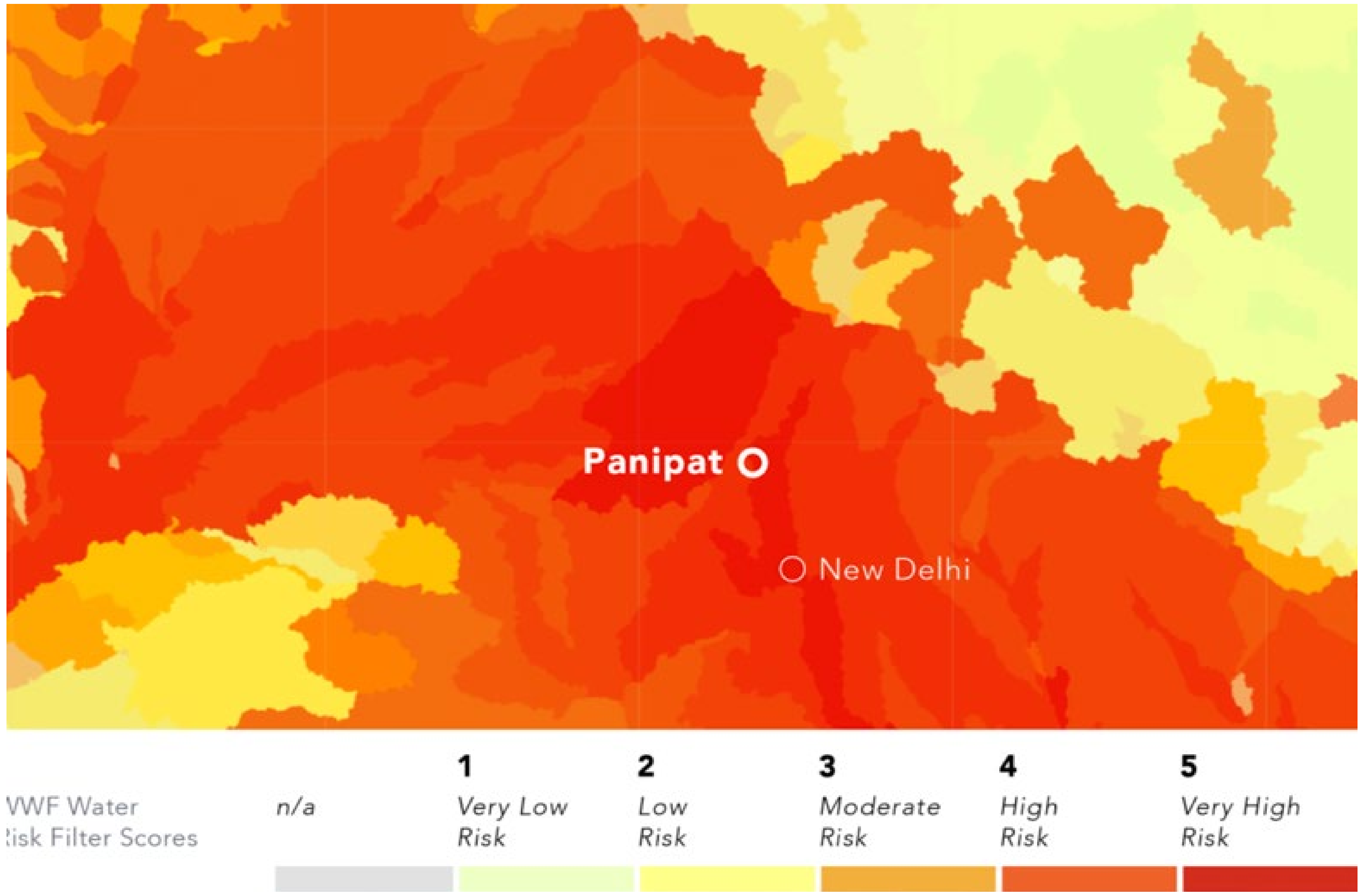


Figure 10. Freshwater endemism in the Panipat region, India, based on WWF Water Risk Filter data. The map indicates relatively low levels of species endemism in this area, with lighter shading corresponding to lower counts of species found only in that location.

By aligning with ZDHC's wastewater guidelines and achieving reductions in chemical of concern emissions, specifically through targeted copper removal, this facility reduces its impact in a critically sensitive environmental context. Progressing further toward the "Progressive" or "Aspirational" conformance levels of the ZDHC guidelines would enable the facility to further diminish its ecological footprint, yielding meaningful improvements in freshwater biodiversity conservation in this ecologically sensitive area.

4.2.3. Case Study 3: Chlorinated Phenol Dye Substitution in Suzhou, China

Context

A facility in China operating an effluent treatment plant with a capacity of 1300m^3/day detected elevated concentrations of pentachlorophenol (PCP, 3.5ppm) and tetrachlorophenol (TeCP, 6.1ppm) in its treated wastewater. These contaminants were traced back to the dye formulation initially used, which itself was conformant with the ZDHC MRSL. However, earlier testing had not identified these impurities due to limitations in testing scope, as analyses did not cover comprehensive sampling across multiple production lots. Subsequent wastewater analysis, complemented by powder analysis, confirmed these impurities originated from chlorobenzene solvents undergoing chlorination reactions during dye manufacturing.

Recognizing this contamination risk, the dye manufacturer implemented enhanced fractional distillation processes, prompting the facility to shift to a new, optimized dye formulation. This collaborative improvement demonstrates manufacturing excellence through corrective action and illustrates how targeted chemical purification can significantly enhance product safety and environmental outcomes, highlighting the complementary role of ZDHC wastewater guidelines alongside the ZDHC MRSL.

In this case study, the impact of this specific dye substitution was isolated to assess its contribution to total toxicity, whilst all other wastewater parameters, including heavy metals and conventional pollutants such as nitrates, remained unchanged and fully conformant with ZDHC thresholds. Although the facility later replaced all other dyes and sizing agents with ZDHC - conformant alternatives, the modeling focused solely on the substitution of the identified dye. This targeted approach enabled a clear assessment of the chlorophenol-related toxicity reduction associated with removing a single high-impact substance within an otherwise conformant system.

This study followed the direct discharge scenario of ZDHC's Wastewater Guidelines, where wastewater that was treated and generated by a supplier through its own and operated effluent treatment plant is discharged directly to the land, municipal sewers, or water bodies such as streams, lakes and oceans. The scope of this study includes reduction related to wastewater discharge only, excluding, for example, upstream production. The wastewater discharge composition scenario is limited to conventional parameters, heavy metals, and chemicals of concern denoted in this study. It does not consider the impact of the presence of other chemicals that can have high ecotoxicity value and assumes that wastewater is characterized only by heavy metals and conventional parameters.

The methodology applied previously in Case Study 2 to assess the local state of nature, considering both pressure-sensitive toxicity (SoNP) and biodiversity-related indicators (SoNB), has been replicated here in Case Study 3 to consistently evaluate local ecological impacts.

Results and Interpretation

Replacing a single high-impact dye containing pentachlorophenol (PCP) and tetrachlorophenol (TeCP) yielded a **74% reduction** in human toxicity (non-cancer) and an **8% reduction** in freshwater ecotoxicity. Despite being one variable amongst many, this dye accounted for a disproportionate share of environmental risk. The case confirms that targeted substitution of chemicals of concern, especially those persistent and bioaccumulative, can dramatically improve a facility's environmental footprint, even when all other parameters are compliant.

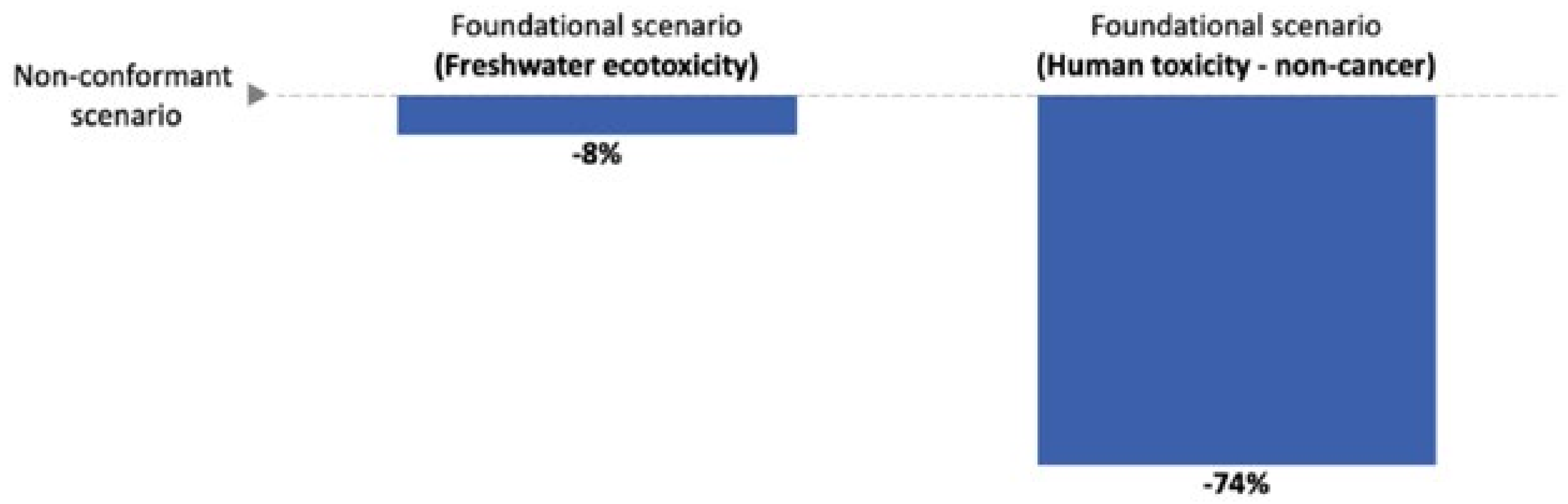


Figure 11.
Impact reductions from targeted dye substitution at a textile facility in Suzhou, China. Replacing a dye containing PCP and TeCP led to a 74% reduction in human toxicity (non-cancer) and an 8% reduction in freshwater ecotoxicity, highlighting the effect. These results are based on specific scenarios and do not represent average or guaranteed outcomes across all suppliers or facilities.

The significant reduction in human toxicity (non-cancer) is primarily due to the high toxic potency of PCP and TeCP, which were present in the original dye formulation. These chlorinated phenols possess extremely high non-cancer toxicity characterization factors, thus making even small emissions highly impactful and significantly elevating toxicity scores. While PCP and TeCP are classified as probable human carcinogens,[22] their carcinogenic potential is not reflected in this specific indicator, as it exclusively measures non-cancer impacts. Consequently, the reduction observed here pertains strictly to non-cancer toxicity effects.

22 U.S. Environmental Protection Agency (B)

While the freshwater ecotoxicity (CTUe) factors for PCP and TeCP are also high, the reduction was not as significant as other pollutants (such as halogenated organic compounds and heavy metals) likely dominated the ecotoxicity profile in the baseline scenario. This case illustrates how targeted chemical substitution can lead to dramatic human health benefits and significant ecological benefits. In Suzhou, China, freshwater ecosystems surrounding the facility exhibit **very high toxicity stress**, showing significant vulnerability of local aquatic life to chemical contamination.

Suzhou lies within a region of very high freshwater biodiversity richness, indicating a dense concentration of aquatic species. This richness reflects the ecological complexity and productivity of the local river systems, where even moderate disturbances can have cascading effects on ecosystem health. Such biodiversity hotspots are particularly sensitive to pollution, reinforcing the importance of chemical substitution and wastewater management in preserving species integrity.

Toxicity

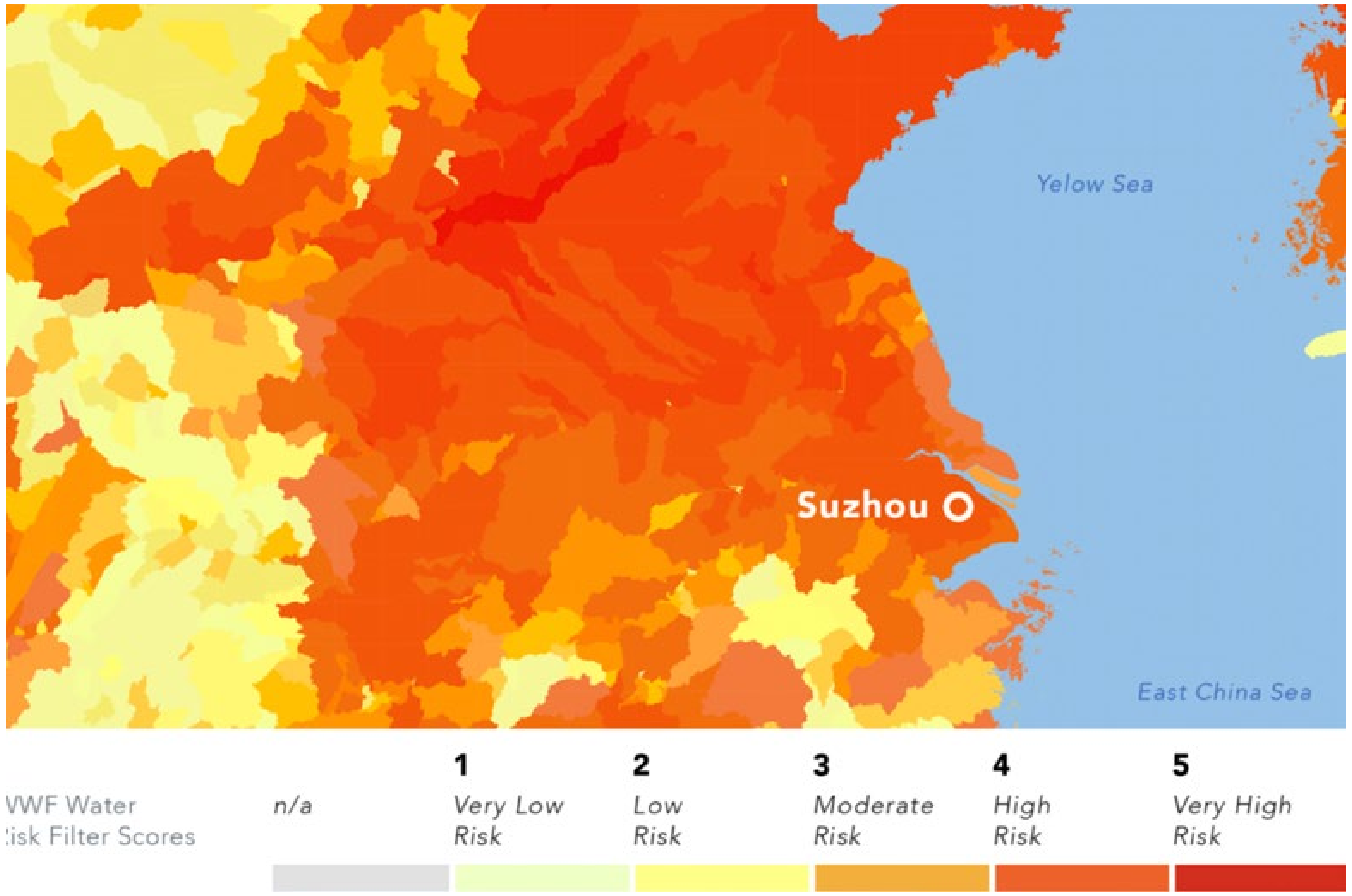


Figure 12.
Toxicity stress map of the Suzhou region, China, based on WWF Water Risk Filter scores. The area is classified as high to very high risk, reinforcing the ecological significance of targeted chemical substitutions in local manufacturing and their role in protecting sensitive freshwater ecosystems.

Freshwater biodiversity richness

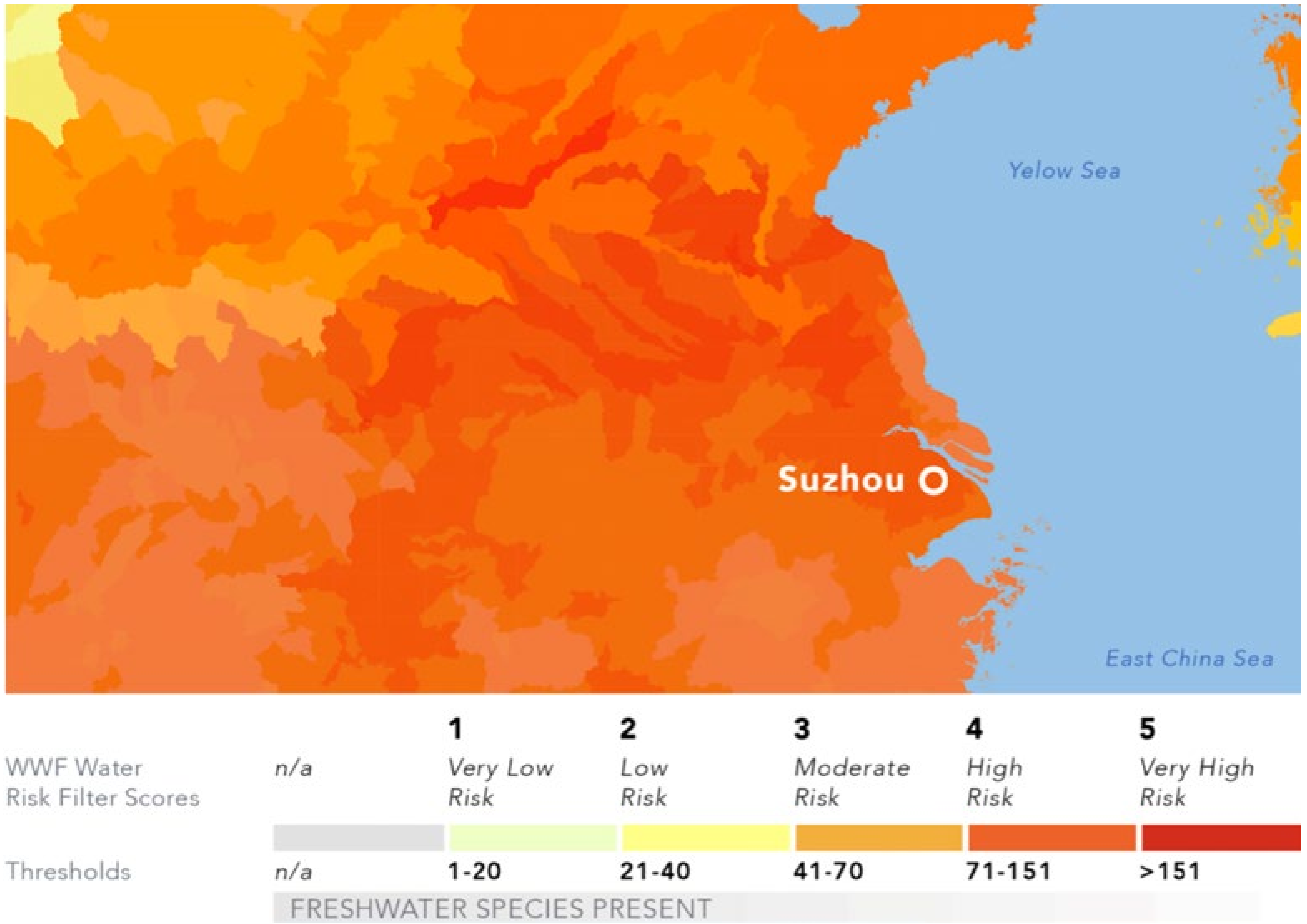


Figure 13.
Freshwater biodiversity richness in the Suzhou region, China, based on WWF Water Risk Filter data. Areas in darker red represent a higher number of freshwater species, highlighting regions of elevated ecological complexity and conservation priority.

While biodiversity richness captures the number of species present, freshwater endemism highlights how many of those species are found nowhere else. Suzhou exhibits notable levels of endemism, underscoring its global conservation importance. These conditions mean that chemical emissions in the region risk impacting species with no safe refuge elsewhere, increasing the stakes for robust chemical management.

Freshwater endemism

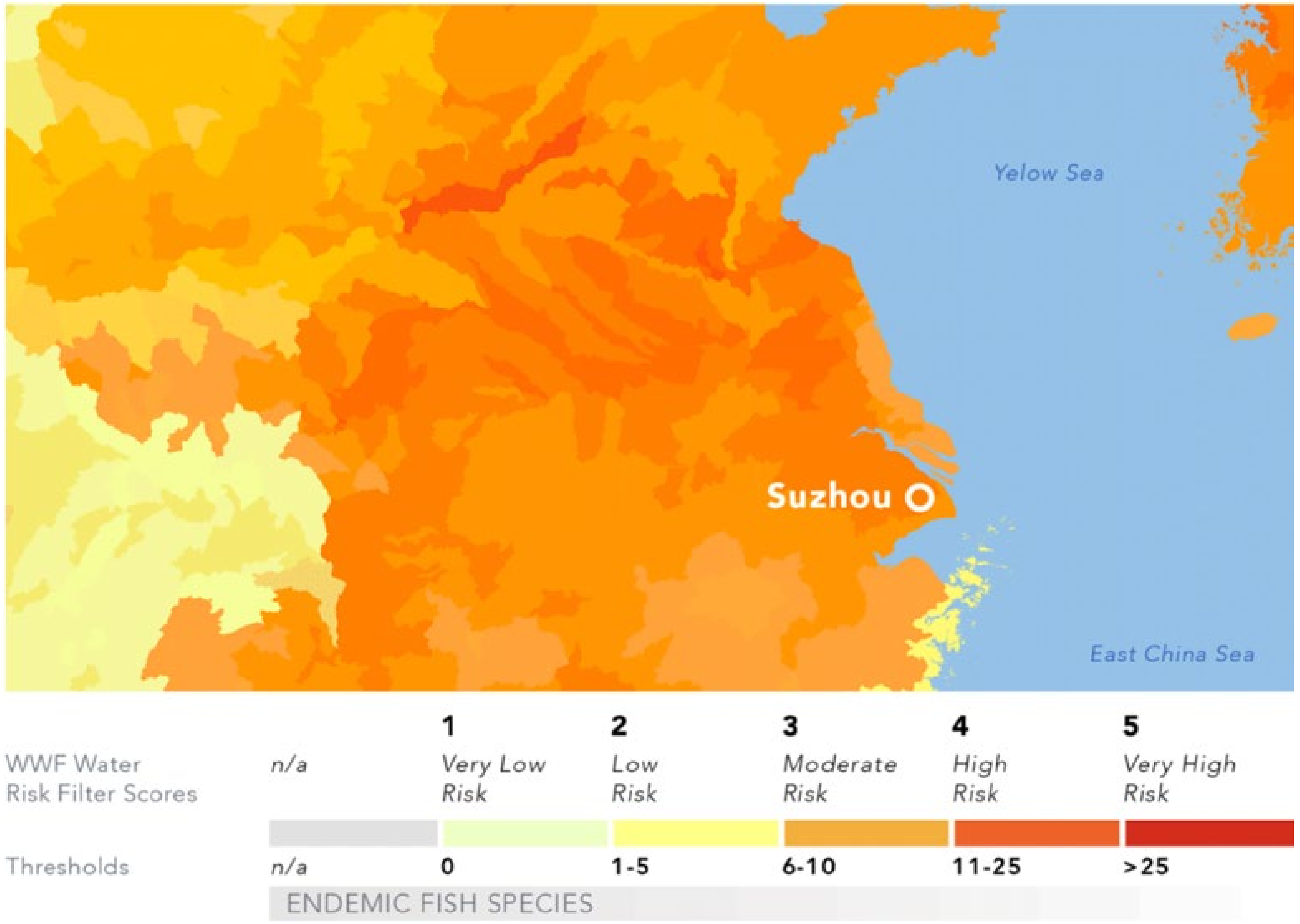


Figure 14.
Freshwater endemism in the Suzhou region, China, showing the distribution of species found exclusively in this location. High endemism zones signal increased vulnerability, where pollution impacts could affect globally irreplaceable species.

Given the high ecological value and sensitivity of this region, continuous efforts in chemical substitution and adherence to strict sustainability practices are crucial for preserving its irreplaceable biodiversity. This case study clearly demonstrates how adherence to ZDHC guidelines and proactive chemical management significantly reduces hazardous emissions, effectively lowering the ecological risks in sensitive ecosystems and thus validating ZDHC's critical role in protecting nature.

4.3. Approach 3: Air emissions release assessment

The ZDHC Air Emission Guidelines V1.0 provide standardized protocols for textile manufacturing facilities to quantify and reduce potential to emit (PTE) VOC emissions to air. Emissions are calculated using the TE method, which is based on the quantities and compositions of chemical formulations used during production. The PTE represents the theoretical maximum volume of VOC emissions a facility could release, assuming no emissions control measures or abatement technologies are in place, thus reflecting a worst-case emissions scenario.Facilities are classified into three tiers based on their total annual PTE VOC emissions, designed to incentivize continuous improvement in emissions reduction:

- **Foundational: 25 tons/year**
- **Progressive: 15 tons/year**
- **Aspirational: 5 tons/year**

VOC emissions in textile processing primarily result from solvent-based applications, including coating, printing, finishing, and drying operations. Common VOCs emitted include aromatic hydrocarbons (for example, benzene, toluene), carbonyl compounds (for example, formaldehyde), and widely used industrial solvents such as DMFa, methyl ethyl ketone (MEK), 2-propanol, and ethyl acetate.

4.3.1. Case Study 1: VOC emission abatement at a Coating Facility in Ho Chi Minh, Vietnam

Context

A textile coating facility in Vietnam was assessed by reviewing its complete chemical inventory and calculating its total VOC PTE using the methodology outlined in the ZDHC Air Emissions Guidelines. The calculated PTE exceeded ZDHC conformance thresholds, prompting the modeling of a scenario in which the facility meets the foundational level by installing a regenerative thermal oxidizer, a proven abatement technology that thermally oxidizes VOCs at 800–1000°C into carbon dioxide and water, achieving typical destruction efficiencies of 95–99%.[23]

The analysis incorporated compound-specific VOC removal efficiencies, as not all VOCs degrade equally. DMFa, for example, requires higher temperature and residence time for effective removal compared to more volatile solvents like MEK or ethyl acetate.The scope of the study is limited to reductions related to air emissions only, excluding, for example, upstream production. The air emissions composition of the base case scenario is limited to the VOCs in this study.

23 U.S. Environmental Protection Agency (C)

VOC	CAS number
DMFa	68-12-2
Methyl ethyl ketone (2-butanone)	78-93-3
Isopropanol (2-propanol)	67-63-0
Ethyl acetate	141-78-6

Table 1. VOCs analyzed in this case study

When evaluating the impact of this emission reduction, both human toxicity (non-cancer) and freshwater ecotoxicity was assessedin line with USEtox characterization.[24] While human health is the primary concern due to the direct inhalation risks of many VOCs, it is important to note that the type of VOC matters as much as the quantity emitted. Some VOCs, like DMFa, have significantly higher human health toxicity factors than others, and thus their presence can disproportionately affect the overall toxicity impact. Therefore, the modeling does not only reflect total VOC mass reductions, but also the specific health and environmental hazard profiles of each substance, providing a more accurate assessment of the benefits achieved by moving toward ZDHC conformance.

24 Rosenbaum, Ralph K., et al.

Results and Interpretation

The facility was found to emit **320.8 tons / year of VOCs** which significantly exceeds all ZDHC thresholds. This high value reflects the typical characteristics of coating operations, which often rely heavily on solvent-rich formulations to dissolve and apply functional polymers and binders. Assuming the facility implements a regenerative thermal oxidizer system that brings total VOC emissions down to the **ZDHC Foundational limit of 25 tons / year**, the modeling showed significant reductions in environmental and health impacts. Specifically, the results showed a: **90% reduction in human toxicity** (non-cancer) and **91% reduction in freshwater ecotoxicity.**

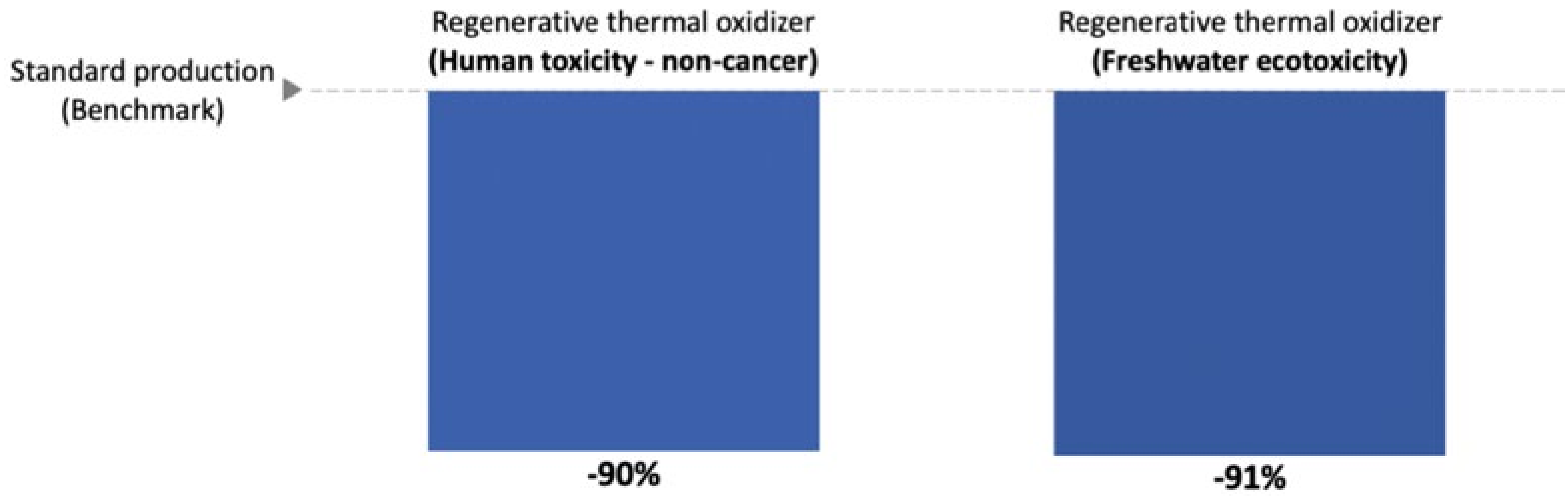


Figure 15. Results showing a 90% reduction in human toxicity (non-cancer) and a 91% reduction in freshwater ecotoxicity when implementing a regenerative thermal oxidizer to reduce VOC emissions. These results are based on specific scenarios and do not represent average or guaranteed outcomes across all suppliers or facilities.

Although VOCs are emitted to air, they can also impact water systems through **indirect pathways.** These include **wet deposition** (where VOCs dissolve into rainwater and enter surface waters) and **dry deposition** (where particle-bound VOCs settle onto land or water bodies).

Such pathways are particularly relevant for **semi-volatile and water-soluble VOCs**, which can migrate across environmental compartments. This case demonstrates how targeted emission abatement, aligned with ZDHC conformance thresholds and adapted to the specific VOC profile of a facility, can result in substantial improvements in both human health protection and ecosystem preservation. It further underscores the cross-media benefits of cleaner air strategies in textile manufacturing.

4.3.2. Case Study 2: VOC emission abatement at a Tannery Facility in Tamilnadu, India

Context

The VOC emissions at the tannery facility were evaluated by analyzing the complete chemical formulation inventory and calculating the total VOC PTE following the methodology outlined in the ZDHC Air Emissions Guidelines. The assessment identified significant quantities of VOCs relevant to leather tanning processes, notably formic acid, acetic acid, and ethylene glycol butyl ether. Given the chemical properties of these compounds, particularly their moderate volatility and higher resistance to thermal oxidation, a scenario was modeled in which the facility conforms to the foundational level by employing a regenerative thermal oxidizer, considering compound specific destruction efficiencies.

VOC	CAS number
Formic acid	64-18-6
Acetic acid	64-19-7
Ethanol	64-17-5
Isopropanol (2-propanol)	67-63-0
Acetone (2-propanone)	67-64-1
1-butanol	71-36-3
Ethylene glycol butyl ether (2-butoxyethanol)	111-76-2

Table 2. VOCs analyzed in this case study

Using USEtox characterization factors, the analysis quantified reductions in human toxicity (non-cancer) and freshwater ecotoxicity, emphasizing the specific toxicological profiles of each VOC rather than aggregate mass alone. This approach ensured an accurate representation of the environmental and human health benefits achieved by implementing tailored VOC abatement measures within the tanning facility. The scope of the study is limited to reductions related to air emissions only, excluding, for example, upstream production. The air emissions composition of the base case scenario is limited to the VOCs in this study.

Results and Interpretation

The facility was found to emit **102.2 tons/year of VOCs**, also significantly exceeding the **ZDHC threshold of 25 tons/year**. The value reflects the solvent-intensive processes typical of tanning operations, particularly during fat liquoring, re-tanning, and finishing, where solvent-based formulations are commonly used. To address this, the implementation of a regenerative thermal oxidizer system capable of reducing total VOC emissions to the ZDHC Foundational limit of 25 tons/year was modeled. The LCA results demonstrated clear improvements in environmental and human health impacts through a **64% reduction** in freshwater ecotoxicity and a **64% reduction** in human toxicity (non-cancer).

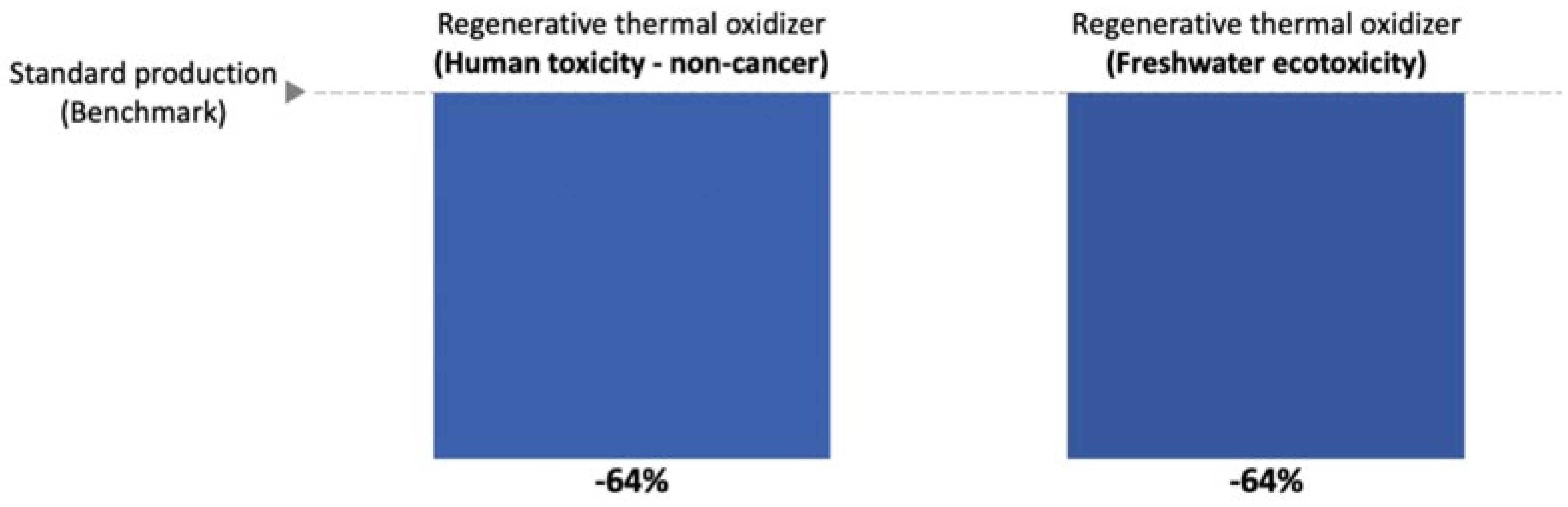


Figure 16. Results showing a 64% reduction in human toxicity (non-cancer) and a 64% reduction in freshwater ecotoxicity when applying a regenerative thermal oxidizer to lower VOC emissions.These results are based on specific scenarios and do not represent average or guaranteed outcomes across all suppliers or facilities.

While the regenerative thermal oxidizer system effectively removes most volatile compounds (for example, ethanol, acetone, and 2-propanol), some VOCs such as **formic and acetic acid**, due to their semi-volatile and water-soluble properties, are **less efficiently abated** and contribute disproportionately to the remaining impact. This case additionally illustrates how targeted VOC emission reduction, aligned with ZDHC thresholds and customized to the VOC profile of a tanning facility, can yield substantial benefits for both human health and the environment, supporting the broader transition to more sustainable leather production.

4.4.Summary table: key findings from ZDHC-related case studies

Case no.	Case Studies	Key Impact Metrics	Main Conclusions
1	NPEOs substitution in wet processing	↓ **51% freshwater ecotoxicity** ↑ **21% climate change impact**	Substitution of NPEOs, a substance restricted by ZDHC MRSL, significantly reduces ecotoxicity; climate impacts slightly rise due to production emissions.
2	DMFa substitution with water-based PU	↓ **45% climate change impact** ↓ **95% water use** ↓ **27% eutrophicationpotential1**	Substitution of NPEOs, a substance restricted by ZDHC MRSL, significantly reduces ecotoxicity; climate impacts slightly rise due to production emissions.
3	ZDHC wastewater discharge scenarios (WALDB)	↓ **95% human toxicity** ↓ **86% freshwater ecotoxicity** ↓ **96% freshwater eutrophication** ↓ **80% marine eutrophication**	Upgrading wastewater treatment from Foundational to Aspirational ZDHC levels dramatically reduces ecological and public health impacts.
4	Copper reduction via alkaline precipitation	↓ **1% human toxicity** ↓ **13% freshwater ecotoxicity**	Applying ZDHC wastewater guidance helps mitigate heavy metal pollutants like copper, with modest benefits to freshwater systems.
5	Chlorinated phenol dye substitution	↓ **74% human toxicity** ↓ **8% freshwater ecotoxicity**	Substituting chlorinated phenols (ZDHC MRSL substances of concern) effectively lowers toxicity and supports ecological health.
6	VOC emissions reduction at coating facility	↓ **90% human toxicity** ↓ **91% freshwater ecotoxicity**	VOC reductions aligned with ZDHC thresholds greatly enhance both human and ecological health.
7	VOC emissions reduction at tannery facility	↓ **64% human toxicity** ↓ **64% freshwater ecotoxicity**	VOC reductions aligned with ZDHC thresholds greatly enhance both human and ecological health.

Table 3.
Summary of key data points calculated throughout this report for each case study, highlighting the overall reduced impact on nature metrics when following the ZDHC MRSL, Wastewater Guidelines and Air Emission Guidelines. Note the importance of a holistic Climate and nature strategy, shown in **Case 1** where an increase in climate change impact is observed through the modeling.
Case 2 denotes average eutrophication potential across marine and freshwater, as these could not be distinguished in this case. These results are based on specific scenarios and do not represent average or guaranteed outcomes across all suppliers or facilities

The table summarizes the key findings from the case studies, emphasizing the key impact reductions achieved by implementing ZDHC- aligned practices to reduce the impact on nature. These different cases illustrate how the long-standing efforts of ZDHC, through the MRSL, Wastewater Guidelines and Air Emissions Guidelines, can enable real-world implementation and measurable reduction of environmental impacts.

Across all case studies, one insight stands out: **the facility level is where impact happens.** Mills and tanneries play a central role in the adoption of safer chemistry, wastewater management, and air emissions reduction. Strengthening ZDHC implementation at these nodes in the supply chain offers one of the most direct and scalable ways to reduceenvironmental pressures and demonstrate quantifiable progress.

05

Key data gaps and future potential

While the ZDHC MRSL provides a globally aligned framework, the ability to comprehensively quantify its environmental and human health benefits, especially regarding the nature topic, is still hindered by data gaps. These limitations affect how effectively the industry can evaluate progress, assess chemical substitution outcomes, and make informed decisions grounded in environmental evidence.

A major challenge is the **limited transparency in chemical formulations**, which remains one of the most persistent obstacles to meaningful environmental impact tracking. Full compositions are frequently withheld by chemical suppliers due to intellectual property concerns, proprietary formulations, or the absence of commercial incentives for disclosure. Even when safety data sheets (SDS) are available, they often omit critical information such as the exact percentage composition or the presence of minor but hazardous co-formulants. Additionally, the absence of Chemical Abstracts Service (CAS) numbers, or the inclusion of only generic chemical categories (for example, “surfactant blend”), prevents proper identification, assessment, and traceability of substances across the value chain. This lack of clarity impedes hazard assessment, weakens supplier accountability, and severely limits the ability of downstream users to link chemical inputs to nature-related impacts.

Second to chemical formulation data is the **widespread lack of substance-level information**, including toxicity profiles, GHG footprints, and water footprints. These gaps prevent stakeholders from evaluating the full environmental and health impacts of individual chemical ingredients within a formulation. Without standardized and complete datasets at the substance level, even disclosed formulations become difficult to interpret meaningfully. This exacerbates the transparency issue; when a chemical name is available, but its hazard characteristics, emissions factors, or degradation behavior are missing or outdated, its environmental relevance cannot be properly assessed. The inability to trace both what is used and how it behaves severely limits the industry’s capacity to quantify trade-offs, prioritize substitutions, and credibly link formulation changes to nature-related outcomes.

Zoom on Ecotoxicity

Ecotoxicity is an indicator used in LCA to assess the impact of chemical emissions on ecosystems. Used in best-in-class environmental impact assessment frameworks and models, 3 keymethodological shortcomings hinder the robustness of current ecotoxicity impact results and must be clearly acknowledged.

1. **Ecotoxicity characterization factors can have a high level of uncertainty, often due to limited or inconsistent ecotoxicological data, extrapolation across species and ecosystems, and varying modeling assumptions. This makes the quantification of impacts on ecosystems less reliable.**

2. **No methodology effectively accounts for the “cocktail effect”, where mixtures of substances (for example, formulations) may amplify toxicity beyond the sum of individual substance impacts. This means that the effects of chemical mixtures are overlooked, even though organisms in real-world environments are exposed to complex pollutant combinations.**

3. **Ecotoxicity modeling in LCA is typically limited to freshwater ecosystems, excluding potential important environmental pressure categories (for example, terrestrial, marine and atmospheric ecotoxicity, bioaccumulation, etc.) significantly narrowing the scope of assessment and limiting the ability to capture broader nature-related impacts.**

These methodological shortcomings are not insurmountable; with targeted data generation, continued model refinement, and broader inclusion of relevant pressure categories, current frameworks can evolve to more holistically capture the full spectrum of chemical-related nature impacts.

A third challenge is the **limited use of Restricted Substances List (RSL) or product testing data as a verification indicator for chemical phase-out.** While such testing does not capture upstream formulation use, it can serve as a practical proxy to demonstrate whether hazardous substances have been effectively eliminated from final products. However, these datasets are rarely aggregated, standardized or shared across brands and suppliers, limiting their utility in broader chemical phase-out tracking and nature impact assessments.

Another barrier is the **lack of reliable wastewater emissions data at the facility-level.** Many production sites do not have continuous or high-frequency monitoring systems in place, which limits the ability to capture fluctuations in chemical loads over time. Even when data is available, it is often reported inconsistently across facilities or using non-standardized formats, with key variables such as sampling method, frequency, or detection limits left undocumented. This inconsistency creates uncertainty in emission estimations and makes it difficult to compare performance across sites or assess progress over time. Without harmonized, high-quality discharge data, it becomes very challenging to quantify the actual environmental pressure exerted by wastewater and link it to upstream chemical management practices or nature impact indicators.

The chemicals industry struggles with low data granularity on emissions due to the complexity and variability of chemical processes, inconsistent reporting practices, and limited standardized monitoring protocols. These make it difficult to link specific chemical usage to their actual release into wastewater or air. Many ZDHC MRSL substances lack detailed emission profiles, and their behavior in industrial conditions remains under-characterized.

In addition, there is a lack of historical data and documentation, not only from fashion brands but also from chemical suppliers and formulators. Past substitutions are often undocumented, and formulation changes are rarely captured in a way that allows for comparison or evaluation of environmental trade-offs over time. These challenges are compounded by gaps in LCA databases, where many commonly used chemicals and processes in textile manufacturing are not represented adequately. As a result, it is currently not possible to quantify the impact of several restricted substances or their substitutes on indicators such as ecotoxicity, human toxicity, or nature-related outcomes using standard LCA tools.

Efforts are underway to address the limitations of data gaps in LCA databases and improve data quality and availability. For example, the WALDB database developed by Quantis in partnership with a consortium of textile, leather and footwear stakeholders had begun to fill critical inventory and emissions data gaps. It provides robust, sector-specific LCA data that improves the accuracy of environmental modeling within textile supply chains. However, comprehensive work is still needed to ensure broader coverage of substances and processes relevant to ZDHC MRSL implementation and nature-related impact assessment.

An increase in data availability and transparency would make it possible to scale local state of nature analyses for a pool of factories to drive prioritization and therefore solution implementation. For example, conducting a comprehensive assessment for the different production facilities of a single supplier, or for the different factories a single company is sourcing from.

This analysis would allow companies to have a more complete understanding of their current nature footprint and to prioritize interventions where it would have the most impact.

It is already understood that the distribution of wet processing in the world matches with areas of high toxicity stress, in most cases. It can therefore already be considered, from a nature strategy perspective, that implementing the ZDHC MRSL in the textile, leather and footwear sector is a no regret action that contributes to the reduction of nature impact in areas where it can have real impact. But refining the analysis and finetuning impact measurement requires continually enhanced data quality and availability.

In Asia, many textile wet processing facilities are located in regions with some of the highest global toxicity stress levels. This geographic overlap presents both a challenge and an opportunity, where by targeting these high-risk zones with ZDHC-aligned chemical management could deliver significant nature impact reductions at scale.

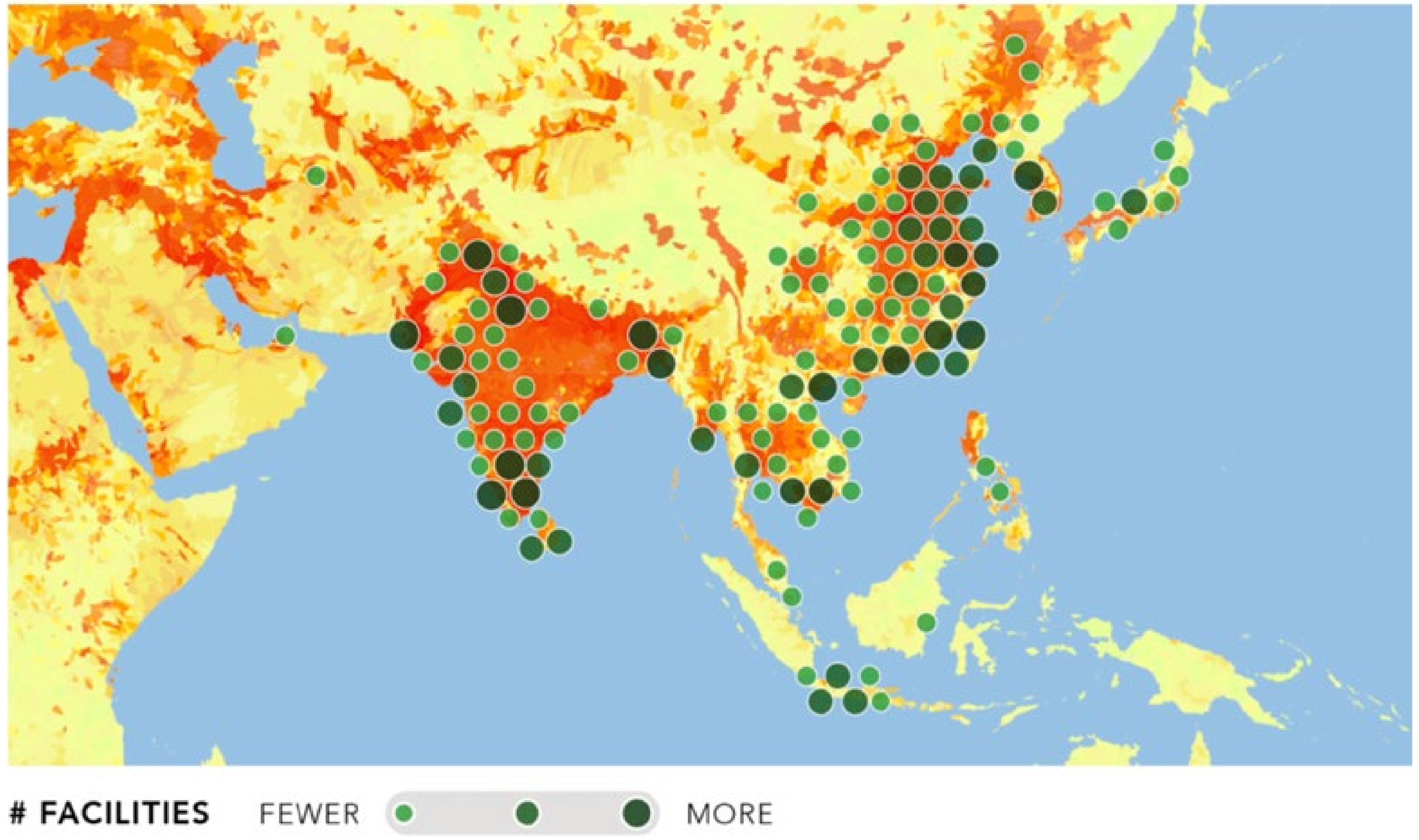


Figure 17. Distribution of apparel and footwear manufacturing facilities across Asia overlaid with freshwater toxicity stress levels. High facility density is concentrated in areas marked by very high environmental sensitivity, highlighting the importance of targeted action in the region.

European production sites also intersect with several toxicity stress hotspots, particularly in Southern and Eastern Europe. While data systems may be more mature in this region, refined emissions tracking and harmonized MRSL adoption remain essential to drive measurable progress.

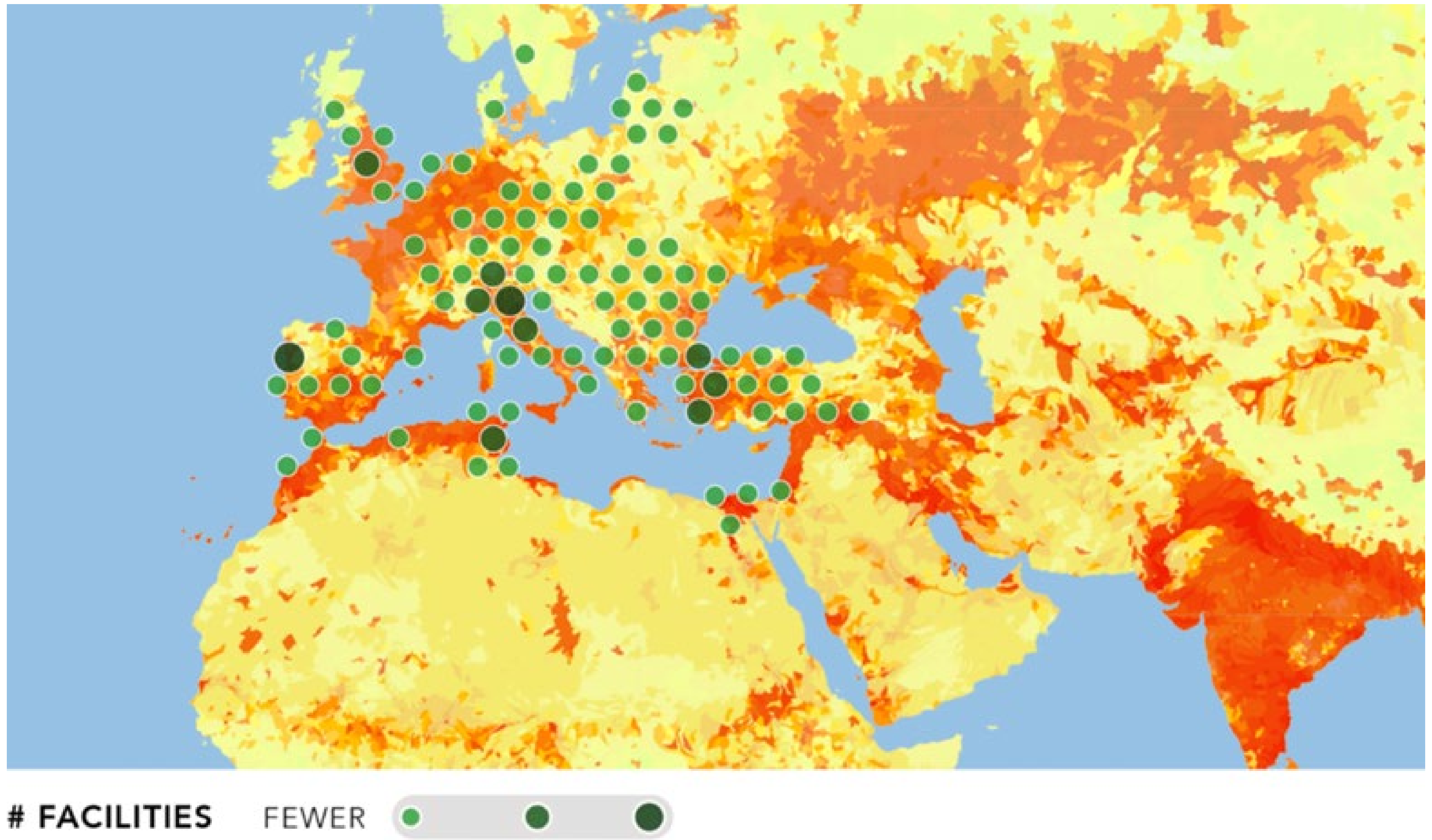


Figure 18. Facility locations in Europe mapped against toxicity stress data. Several clusters are located within high-risk ecological zones, underlining the continued relevance of standardized chemical management in regulated regions.

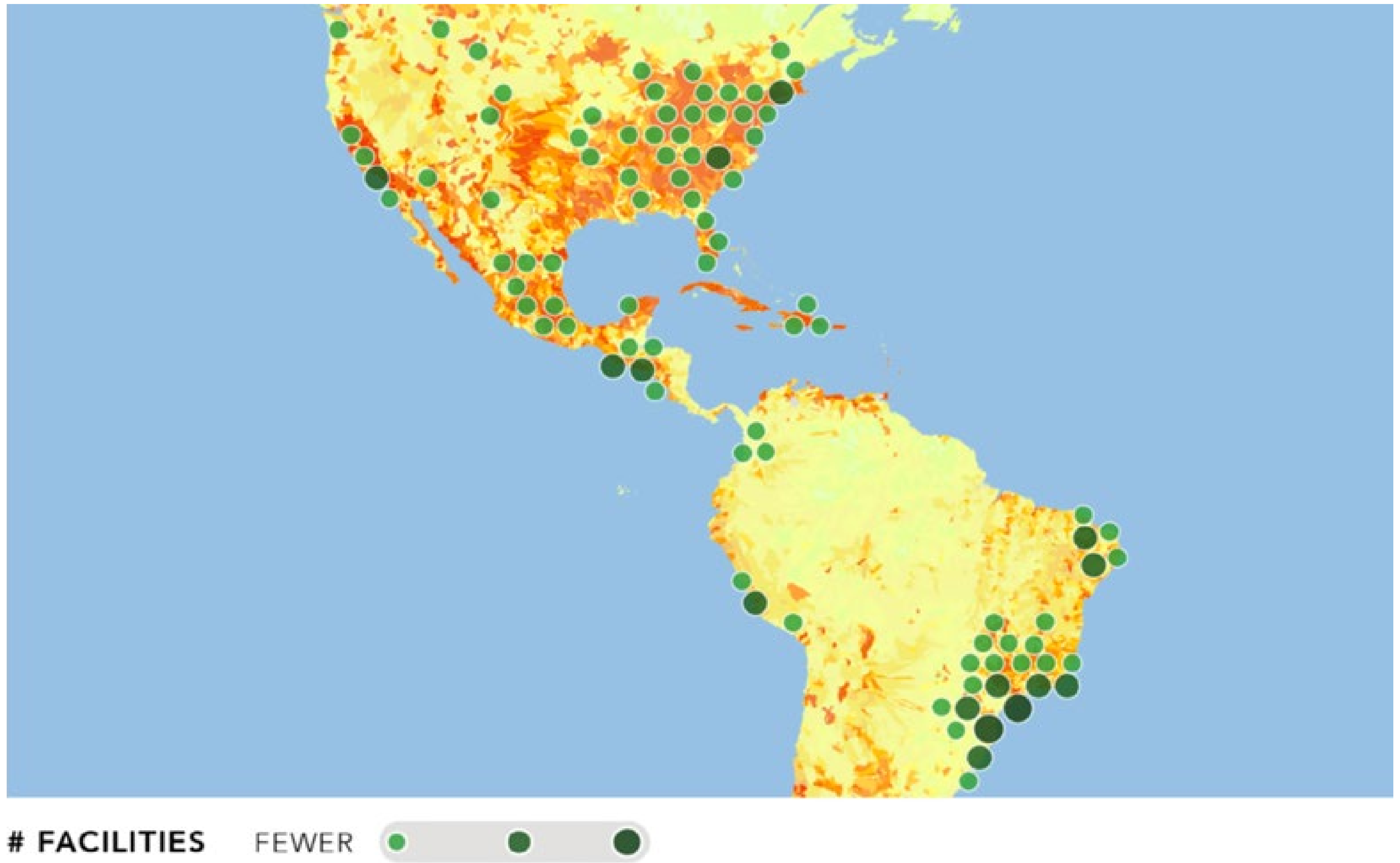


Figure 19. Manufacturing facility distribution across the Americas shown with corresponding freshwater toxicity stress levels. The diversity of risk across regions illustrates the importance of geographically contextualized Nature impact assessments.

In the Americas, facility clusters span a range of toxicity zones, from moderate to very high stress. This variation reinforces the need for localized data to support prioritization and tailor interventions to each environmental context.

Looking ahead, as data quality and accessibility improves, particularly for more complete chemical formulations, substance-specific emissions, and documentation, it will be possible to move from hazard-based substitution to more precise risk-and impact-based decision-making. This will allow the industry to prioritize chemical phase-outs based on their quantified contributions to human and ecological harm, model more accurate trade-offs in substitution, and align ZDHC MRSL implementation with science-based environmental targets. With enhanced datasets, ZDHC and its partners will be better equipped to measure progress, strengthen accountability, and make more informed choices that maximize impact reduction on nature.

06

Beyond Textile, Apparel, Leather and Footwear

6.1. Potential in industries beyond Textile, Apparel, Leather and Footwear.

Textiles and leather are used across many industries beyond the fashion sector. This report explores a few key sectors, namely automotive, home furnishings, and electronics, where an extension of ZDHC tools could naturally be considered due to material, chemical, and supplier similarities. Beyond the sectoral similarities, these sectors hold significant chemical footprints, with clear opportunities to reduce pollution through upstream substitutions. The core value-add of extrapolating the ZDHC MRSL cross-industry lies in the global harmonization of such an initiative, providing a reliable and proven single source of truth for global markets and industries.

6.1.1. Automotive industry

Background

The automotive sector has established a well-known global framework: the Global Automotive Declarable Substance List (GADSL). GADSL is maintained by the Global Automotive Stakeholders Group and serves as a harmonized list of chemicals that must be declared or prohibited in automotive parts and and materials. It covers substances expected to be present in vehicles at the point of sale.

In practice, automakers and suppliers use GADSL via tools like the International Material Data System (IMDS) to track and report chemical content in components, aligning with regulations such as the EU End-of-Life Vehicle (ELV) Directive and REACH. Individual automakers may also maintain internal restricted substance lists, but these typically build upon or mirror GADSL to ensure consistency across the global supply chain.[25]

GADSL's scope focuses exclusively on finished products, functioning primarily as a declarable substances list, not as a restricted substances list. It identifies substances that must be declared if present above certain thresholds in final automotive materials and components. These include heavy metals (such as lead or cadmium), certain brominated flame retardants, and other chemicals of concern flagged by international regulations. This differs from the MRSL approach, which phases out chemicals of concern. Similarly to the ZDHC MRSL, GADSL is industry-driven rather than a law. Automakers enforce it contractually, where suppliers must declare listed substances in the IMDS database and avoid prohibited ones. This reporting system supports regulatory conformance and sustainability goals by giving manufacturers visibility into their material chemistry. Adoption of GADSL is essentially universal among major original equipment manufacturersand their tier suppliers, making it a globally adopted standard. GADSL focuses on chemical content in the final product (the car) and thus addresses substances that could affect end-users, recyclers, or the environment upon disposal.

However, it does not cover the vast array of inputor process chemicals used during manufacturing if they do not remain in the finished part. This can include solvents, cleaners, or processing aids that evaporate or are washed off. This means that a chemical could be highly toxic to workers or ecosystems during production but go unmonitored by GADSL if it is not in the final product.

25 Global Automotive Stakeholder Group

This differs significantly from the ZDHC MRSL approach, which proactively phases out chemicals of concern from manufacturing altogether.

GADSL's inclusion criteria are driven largely by regulatory and human health concerns. It supports sustainability indirectly by identifying chemicals of concern through industry-wide awareness. Chemicals tend to appear on GADSL if they are globally regulated or recognized as hazards, not necessarily because an ecological risk assessment was performed. For instance, persistent bio-accumulative toxins (PBTs) are often regulated and thus on GADSL, but other chemicals that pose long-term ecosystem toxicity might not be listed until laws require it. Nature-related criteria are therefore not systematically or explicitly evaluated in GADSL unless they coincide with legislative restriction or hazard classification. The current system may overlook upstream pollution impacts (air emissions or wastewater contamination at factories).

Potential value of a ZDHC MRSL approach

The extension of the ZDHC MRSL to the automotive sector could happen immediately for the interior components of cars that consist of textiles or leather, or contain foams, or adhesives. By restricting or phasing out the most hazardous process substances (even those that leave no residue in the car), a ZDHC MRSL would reduce occupational exposures and environmental emissions from factories and their tier suppliers, making it a globally adopted standard. This would be a proactive step beyond GADSL's current final product scope. For instance, instead of simply controlling paint solvent emissions via local regulations, an industry MRSL might outright prohibit carcinogenic solvents in any production process, forcing safer alternatives. This shifts the focus to input chemistry, aligning chemical use with the principle of prevention at source.

Currently, management of manufacturing-stage chemicals is left to individual company policies or local environmental laws, leading to inconsistent oversight. An automotive MRSL, especially if developed collaboratively with major original equipment manufacturers, would create a unified governance tool. It could require suppliers to disclose and avoid certain harmful chemicals in production, improving data transparency, revealing how much of certain solvents or additives are used and prompt data collection on safer substitutes – data that is largely absent when focus is only on final parts.

By eliminating particularly toxic, persistent, or bio-accumulative chemicals from manufacturing, an MRSL directly reduces pollution released to air, water, and soil from automotive plants. This can support global nature impact reduction by lowering the chemical load on ecosystems. For example, phasing out PFAS-based mold release agents or chromium(VI) plating processes would reduce soil and water contamination around production sites, thereby reducing overall nature impact. Such an initiative would align the automotive industry with global calls to halve the risks from chemicals of concernby 2030, moving beyond conformance and contributing to broader environmental objectives.[26]

Overall, implementing the ZDHC MRSL, Wastewater Guidelines, and Air Emissions Guidelines in the automotive industry would begin bridging the gap between conformance-driven substance control and a holistic chemical management that strives to safeguard both human health and nature. It would likely build on the success of GADSL by extending the chemicals used throughout manufacturing, which is currently a major gap, enabling the industry to drive down its overall environmental footprint.

26 United Nations Environment Programme

6.1.2. Home furnishing industry

Background

Home furnishings refer to items such as rugs, curtains, upholstery and bedding that help make a house a home. Similarly to the automotive industry, extension of the ZDHC MRSL to the home furnishing sector would be relatively simple and swift for textile and leather pieces, as well as those materials used in furniture. Whilst some textile manufacturers who process fabrics, yarns, or leather are already engaged in the ZDHC Roadmap to Zero program, the home furnishing sector overall currently lacks a single unifying chemical list on the order of GADSL or an industry MRSL. Instead, chemical restrictions are fragmented, and driven by a patchwork of regulations, voluntary standards, or individual corporate initiatives. This presents an opportunity to scale across the sector beyond the level of current engagement.

Furnishing manufacturers must comply with general chemical regulations that apply to consumer products. For example, in the EU, REACH regulations apply to furnishing and furniture articles –for instance, if a sofa contains >0.1% of a Substance of Very High Concern (SVHC), it must be disclosed to customers and reported to the SCIP database.[27]

Additionally, persistent organic pollutants (POPs) like certain brominated flame retardants are globally banned by the Stockholm Convention, which impacts foam and textile use in furnishings worldwide.[28]

27 European Chemicals Agency
28 Stockholm Conventionon Persistent Organic Pollutants

In the absence of mandatory lists, the industry leans on voluntary frameworks to define "safe" chemistry such as the ANSI/BIFMA e3 Furniture Sustainability Standard, which is particularly used for office or contract furniture. This framework provides a list of "Chemicals of Concern" (Annex B) defined by hazard characteristics: PBT chemicals, carcinogens, reproductive toxicants, and endocrine disruptors.

Conformance is voluntary, but it incentivizes reducing or eliminating chemicals of concern in products and manufacturing.[29]

Programs like OEKO-TEX Standard 100 (for textiles including furniture upholstery) and GREENGUARD (which tests finished furniture for low chemical emissions) are third-party certifications that enforce specific chemical limits. For example, OEKO-TEX banned certain azo dyes, heavy metals, and flame retardants in textile components, and GREENGUARD limits total VOC emissions from furniture finishes and foams.

However, while these certifications indirectly influence manufacturers to avoid certain substances during production, they do not explicitly address or ensure the proactive elimination of chemicals of concern at the source, thus potentially allowing continued risks associated with these substances earlier in the supply chain.[30]

A few large furniture retailers have their own restricted substance policies. Notably, IKEA has a robust chemicals policy ("IKEA Chemical Restrictions") that goes beyond regulations. IKEA, for instance, phased out all brominated and chlorinated flame retardants in its furniture by 2000 and has banned PVC in its products since the 1990s.[31]

29 ANSI/BIFMA
30 OEKO-TEX Service GmbH
31 Inter Ikea Systems B.V.

Potential value of a ZDHC MRSL approach

An MRSL in the home furnishing industry would fill a current gap by establishing clear, preventative guidelines for chemical use. It would help move the sector from a reactive stance (complying with the latest ban or putting out the latest fire drill over a chemical of concern) to a proactive and strategic stance where harmful chemicals are systematically phased out in advance. This not only protects human health but also reduces the ecological footprint of furnishing manufacturing. By doing so, the home furnishing sector can contribute to the overall goal of chemical footprint reduction and make supply chains safer for nature.

An MRSL adopted by multiple furnishing players worldwide would set a global baseline for chemical safety in their manufacturing which is currently missing. Maintenance of said MRSL would create a platform for continuous improvement as new science emerges and provide a platform to pool sectoral expertise.

Suppliers would gain clarity on which chemicals are universally unacceptable, simplifying conformance and standardization.
For a global furnishing brand, it ensures the same high standards in all factories, whether in Asia, Europe, or the Americas, strengthening environmental governance and harmonization across borders. This would additionally drive retailer, consumer, and investor confidence in the sector as it actively manages its chemical impacts as part of nature impact strategy acceleration.

Building an MRSL program often involves creating tools for chemical inventory and disclosure as ZDHC has done through its MRSL, Wastewater Guidelines, and Air Emissions Guidelines. In home furnishings, this could encourage suppliers to report all the chemical formulations they use, giving manufacturers additional visibility into their supply chain chemistry. This new data can help identify hotspots of chemical of concern usage and track progress in reducing them.

6.1.3. Electronics industry

Background

The most prominent regulation in the electronics industry is the Restriction of Hazardous Substances (RoHS) directive, adopted in the EU and mirrored by many countries. RoHS (and its various national equivalents) bans or strictly limits certain chemicals of concern in electronic products (notably lead, mercury, cadmium, hexavalent chromium, and certain brominated flame retardants, with recent additions like some phthalates).[32] This acts as a de facto global standard because electronics companies design products to be RoHS-compliant worldwide. Additionally, REACH SVHC disclosure requirements apply to electronics hardware, for exampleif an appliance contains an SVHC above 0.1% in any component, that must be communicated. However, these frameworks only cover specific substances in the final electronic product. They are narrow in scope (RoHS began with six substances, now a few more) and ensure those chemicals are not present above tiny thresholds in any homogeneous material of the device. They do not govern what chemicals can be used in the manufacturing steps, except those that may carry through to the product.

A compilation by the Clean Electronics Production Network(CEPN), a multi-stakeholder initiative specifically targeting safer chemicals in electronics manufacturing, shows that many leading electronics companies have developed MRSLs to communicate restrictions on manufacturing process chemicals to their supply chains.

For example, Apple's Regulated Substances Specification includes not only product content limits but also bans certain chemicals in supplier factories (Apple banned benzene and n-hexane in final assembly processes in 2014). Similarly, Dell, HP, Intel, Microsoft, Samsung, and others have guidelines for manufacturing process chemicals –some of which are publicly available.[33] These lists vary in format and scope but commonly address solvents, cleaning agents, and other process substances that pose worker health or environmental risks. These lists typically ban certain chemicals outright from use in supplier factories or set conditions (for example, can only be used in closed systems with proper controls). The focus here is on protecting worker health and preventing environmental contamination at factories.

The CEPN has also identified a Priority Chemicals list, the first round of which in 2019 focused on nine high-hazard solvents used in electronics production.[34] These include chemicals like benzene, n-hexane, methylene chloride, toluene, and others that are known to be toxic to workers and the environment. The process of selecting these involved looking at chemicals present on member companies' MRSLs and screening them against hazard criteria (for example, classified carcinogens, reproductive toxins). The overall goal is to prioritize these for elimination or substitution across the industry. The CEPN does not impose regulations, but it provides tools and encouragement for companies to commit to phase them out. It is essentially a collective push towards an MRSL approach industry wide.

Electronics industry consortia additionally have guidelines that indirectly affect chemical use. For example, the Electronics Industry Citizenship Coalition (EICC, now RBA) has a code of conduct that includes occupational safety and environmental provisions,prompting member companies to address chemical exposure in factories.[35] Also, the Electronic Product Environmental Assessment Tool(EPEAT), a procurement eco-label, rewards product designs that eliminate certain chemicals of concernbeyond RoHS (like PVC or chlorinated flame retardants). These initiatives create incentives to reduce harmful chemicals but lack the explicit, comprehensive lists that an MRSL provides.

32 The European Parliament and the Council of the European Union

33 Clean Electronics Production Network
34 Clean Electronics Production Network (B)
35 Responsible Business Alliance

Potential value of a ZDHC MRSL approach

A unified MRSL approach in the electronics sector would bring consistency, transparency, and pre-emptive chemical management across an otherwise fragmented landscape. While several major electronics companies already maintain internal MRSLs and participate in initiatives like CEPN, there is currently no standardized, cross-industry list with aligned mechanisms.

A shared MRSL would eliminate this variability, reducing complexity for suppliers and setting up a clear, common baseline for safer chemistry across global production sites. It would also fill the current regulatory blind spot by addressing chemicals of concern used during manufacturing, many of which are not covered by product-focused frameworks like RoHS or REACH yet pose significant risks to human health and the environment.

By targeting chemicals of concern such as solvents, etchants, and cleaning agents used, for example, in semiconductor fabrication, an industry-wide MRSL would help electronics companies mitigate some of their material chemical risks.

These substances often never appear in the final device but contribute significantly to toxic emissions, worker exposure, and ecosystem contamination at manufacturing sites. Many of these facilities are in regions facing increasing scrutiny over air and water quality, such as Southeast Asia, making proactive substitution a reputational and operational imperative.

Beyond health benefits, phasing out high-hazard substances can simplify factory safety protocols, reduce the need for costly containment systems, and support compliance with evolving regulations on industrial waste and discharge. Strategically, a sector-wide MRSL would unify fragmented efforts and allow the industry to speak with a unified voice on safer chemistry.

It would enable consistent expectations and reduce compliance friction in multi-client facilities, helping brands meet upcoming disclosure requirements under frameworks like CSRD and TNFD. It can further support the future proofing of product portfolios considering expanding global restrictions on persistent chemicals such as PFAS.

For leading electronics brands, adopting and promoting a shared MRSL could reinforce market positioning as sustainability frontrunners, particularly in public procurement, green tech, and investor ESG assessments, where chemical footprint reduction is an emerging differentiator. These strategic tools can drive further benefits to the electronics sector through their coverage of materials such as polymers, metals, paper, and cardboard that are particularly significant in the sector.

07

Call to Action

7. Call to Action

This report demonstrates that implementing the ZDHC MRSL, guidelines, and tools reduces chemical of concern pollution, yielding tangible benefits for both human health and nature, even with existing methodological and data limitations. Real-world case studies confirm that proactive chemical management significantly reduces toxicity and environmental impacts associated with air emissions, wastewater discharge, and overall facility operations. In the Covestro case, preliminary economic benefits of chemical substitution are also seen through water savings, highlighting the potential for strategic maneuvers that can be made with relative ease with more informed economic analyses. However, fully and accurately capturing these environmental and economic benefits requires targeted action to overcome data gaps, broaden cross-industry MRSL adoption, and strengthen collective stakeholder collaboration across the chemical value chain.

7.1. Addressing data gaps to accelerate impact

By systematically addressing data gaps and improving the granularity, consistency, and transparency of chemical and emissions data, stakeholders across the industries will enable more precise and credible nature impact assessments. Enhanced data availability and accuracy will empower companies to prioritize high-impact interventions, optimize resource allocation, and tangible demonstrate progress against their sustainability goals.

This prioritized and targeted approach serves as a foundational guide for collective industry action, moving **beyond compliance towards proactive environmental stewardship and long-term, sustainable business resilience.** By aligning stakeholder efforts and clearly defining responsibilities, ZDHC and its partners can scale the environmental benefits of MRSL adoption, driving meaningful reductions in chemical pollution and protecting ecosystems and human health globally. To truly begin to quantify and optimize the environmental and social benefits of ZDHC MRSL implementation, the industry should focus on filling the following key data gaps:

More comprehensive formulation data (for example, comprehensive ingredient lists, % concentrations, co-formulants)

- **Key challenge:** greater disclosure is blocked by an absence of harmonized and confidential reporting format

More comprehensive substance-level environmental and toxicity data (for example, GHG footprints, water footprints, toxicity profiles, environmental fate pathways)

- **Key challenge:** currently limited data collection and tracking in real industrial settings

More standardized product testing and RSL data to verify phase-out of hazardous substances

- **Key challenge:** datasets can serve as practical downstream indicators that substances have been eliminated but are rarely aggregated, standardized, or shared across brands and suppliers

More reliable and standardized wastewater emissions data at facility level

- **Key challenge:** many sites lack continuous or high-frequency monitoring and existing data is often inconsistently reported

7.2. A shared responsibility – primary stakeholders

Addressing the critical data gaps identified in this report requires coordinated action and clear accountability across stakeholders. **Three key stakeholder groups can prioritize actionable next steps:** the ZDHC foundation, industry players (including manufacturers, brands, suppliers), and institutional bodies. The considerations below outline high-priority steps for each group with the united goal of facilitating more accurate nature impact assessments.

The ZDHC Foundation

- **"Be the convener" and facilitate data sharing and collaboration.** As the architect and steward of key frameworks for over a decade, ZDHC has earned a unique position amongst the industry as a mature and recognized convener on chemical management. With 10 years of cross-sector collaboration and implementation credibility, ZDHC is well-positioned to drive the next phase of impact measurement and nature strategy alignment as a centralized and standardized convener for industry players, experts, decision-makers, and certifiers. ZDHC should host cross-sector working groups, seminars, and conferences to align brands, suppliers, and chemical companies on shared impact measurement goals and define next steps.

- **Leverage ZDHC's proven leadership to continue to evolve frameworks** by collaborating with standard setters (such as SBTN, TNFD, ISO) to develop systematic and standardized emissions data monitoring, reporting, and verification at facility-level. Specifically aim to increase the frequency and scope of wastewater and air emissions reporting to enhance data comprehensiveness, accountability, a more transparent data-sharing culture, and data-driven strategic decision-making.

- **Continue to develop existing digital tools and platforms** to support improved input tracking, higher formulation-level transparency, and comprehensive chemical disclosure across supply chains, ensuring stakeholders have access to reliable and actionable data.

7.2.1. Industry players

- **Increase proactive disclosure** of detailed hazard, toxicity, and emissions data, closing significant transparency gaps, supporting better-informed LCAs, and promoting consistent reporting practices. Be open to collaborate closely with ZDHC and partners throughout the supply chain to develop certification schemes and clear reporting protocols, ensuring credible and standardized verification of environmental impacts.

- **Enhance data collection processes** at the facility level, specifically clearer tracking and management of chemical substance fate, ensuring more comprehensive, regular, and transparent reporting of emissions and chemical usage data. Disclose more comprehensive formulation information to support 72 nature-related industry goals whilst respecting intellectual property protection. Specifics to be co-defined with ZDHC and other standard setters concerning the key data gaps identified in this study.

- **Actively champion ZDHC tool adoption and advancement** by joining the ZDHC community as a new contributor or by becoming an ambassador as an existing member. Drive outreach to adjacent industries and geographies to scale MRSL impact beyond fashion and promote supplier engagement and internal alignment to embed safer chemistry into procurement, product development, and compliance systems. Take a leadership role in multistakeholder forums, support pilot projects, and share implementation experiences and data to accelerate collective learning. Prioritize investment of resources-technical, operational, and financial-into the next phase of MRSL driven environmental performance.

7.2.2. Institutional bodies

Recognize and integrate the ZDHC MRSL into global policy efforts on chemical pollution. UN bodies including the UNEP SAICM (Strategic Approach to International Chemicals Management) should engage with ZDHC to avoid duplication and build on proven methodologies for chemical of concern elimination at source.

Collaborate to co-develop harmonized chemical risk reduction strategies aligned with international biodiversity and pollution goals. Institutions like the Global Chemicals Outlook, OECD Working Party on Chemicals, and the Basel- Rotterdam-Stockholm Conventions Secretariat should work alongside ZDHC to align definitions, impact categories, and data requirements for chemical of concern tracking.

Champion a coordinated, science-aligned roadmap for chemical footprint reduction by scaling the adoption of input-based control mechanisms like the ZDHC MRSL across industries and regions. Institutional bodies should support alignment between ZDHC and emerging frameworks such as the Global Framework on Chemicals (GFC) and Kunming-Montreal Global Biodiversity Framework, particularly Target 7.

7.3. A shared responsibility – secondary stakeholders

7.3.1. Investors

- **Incentivize measurable chemical risk reduction** by integrating ZDHC-aligned chemical management criteria into ESG frameworks, due diligence checklists, and investment screening tools. Investors can drive market transformation by recognizing proactive substance phase-out and pollution prevention as indicators of long-term resilience and license to operate.

- **Support greater transparency and disclosure** by encouraging portfolio companies to report on MRSL adoption, wastewater and air emission conformance, and chemical footprint progress. ZDHC tools such as the Gateway and ClearStream offer trusted, verifiable datasets that can enhance sustainability-linked finance, impact metrics, and reporting obligations under evolving disclosure regimes (such as CSRD or TNFD).

- **Embed chemical risk into portfolio engagement strategies** by prioritizing companies that adopt proactive substance phase-out practices, such as those aligned with the ZDHC MRSL. Investors can use ZDHC participation and verified implementation as meaningful ESG signals of long-term chemicalrelated environmental accountability and regulatory preparedness.

7.3.2. LCA standards bodies and practitioners

- **Expand LCA methodologies and databases** by incorporating comprehensive inventories that cover production and syntheses of MRSL substances. These inventories should be detailed and both technology- and location-specific to maximize data granularity and accuracy for environmental assessments.
- **Include comprehensive datasets for textile processing activities,** such as dyeing, finishing, and coating, to enhance accuracy and relevance of environmental impact modeling specific to textile manufacturing.
- **Develop standardized protocols** to systematically assess chemical substitution trade-offs, enabling more informed and strategic decision-making for safer chemical alternatives.
- **Ensure close alignment** between global LCA standards and ZDHC MRSL criteria, reinforcing consistency, credibility, and comparability across assessments.

7.3.3. Verification and analytical service providers

- **Expand analytical capabilities to align with MRSL-listed substance detection requirements,** ensuring labs can accurately detect trace concentrations of chemicals of concern in wastewater, sludge, air emissions, and chemical formulations. This includes building capacity for emerging chemical classes such as PFAS, SCCPs, and siloxanes, which require specialized analytical methods (for example, gas / liquid chromatography-mass spectrometry).
- **Standardize verification and reporting protocols** across third-party testing bodies to enable consistent, credible tracking of MRSL implementation across global supply chains. By harmonizing test scopes, reporting formats, and detection limits, certification and lab partners can enhance comparability of data across geographies and reduce audit fatigue for suppliers.
- **Integrate nature-relevant metrics** into chemical certification schemes, linking compliance with MRSL conformance to broader environmental outcomes such as toxicity reduction, water quality improvement, and pollution prevention. Certification systems should begin referencing impact-based indicators (such as CTUe, kg N or P equivalents, VOC mass balance) alongside hazard-based thresholds to better reflect ecosystem-level benefits of safer chemistry adoption.

7.4. A practical path forward

Extending the ZDHC MRSL approach into industries beyond fashion, including those denoted previously, represents a strategic opportunity to standardize chemical management and pollution reduction across global supply chains. Cross-industry MRSL adoption will reinforce global environmental governance and establish a unified platform for proactive chemical stewardship.

As expectations around transparency rise, procurement strategies must increasingly reflect environmental accountability — not only at the product level, but across materials and chemicals used. Companies can embed nature and climate considerations into sourcing criteria and supplier evaluations, helping align buying decisions with environmental commitments. Upcoming policies like the EU Digital Product Passport will likely accelerate this shift by requiring consistent environmental data across product lifecycles. ZDHC-aligned suppliers and manufacturers will be well-positioned to meet these demands with verifiable data and impact metrics. Now is a critical moment for industry stakeholders, regulators, certifiers, financial institutions, and standard-setting bodies to collaboratively advance this agenda. By taking clear, coordinated, and immediate action, we can all collectively mitigate chemical pressures on nature, enable healthier social communities, and ensure more sustainable, resilient industrial operations for the future.

CALL TO ACTION	KEY STAKEHOLDERS	KEY NEXT STEPS
Chemical formulation data	• Industry players	• Develop confidential reporting format • Increase proactive disclosure
Substance-level data	• Industry players • Standard-setting bodies	• Standardize data collection • Increase data availability
Product testing and RSL data	• Industry players • Verifiers and service providers	• Standardize data sharing • Increase data availability
Wastewater emissions data	• Industry players • Verifiers and service providers	• Standardize data reporting • Increase facility-level monitoring

Play your part in populating data gaps and streamlining future reporting to reduce impact on Nature

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List of abbreviations

AOX	**Absorbable Organic Halogens:** organic halogen compounds adsorbed on activated carbon, indicative of water pollution.
APEOs	**Alkylphenol Ethoxylates:** Surfactants used in textile and cleaning applications, known for environmental persistence and toxicity.
ANSI / BIFMA	Standards from the American National Standards Institute and Business + Institutional Furniture Manufacturers Association.
ARRRT	**Avoid, Reduce, Restore and Regenerate, and Transform:** Hierarchy guiding nature-positive strategies in sustainability.
SoNB	**Biodiversity related state of nature:** Indicators tracking biodiversity condition in a given region.
CO_2	**Carbon dioxide:** Primary greenhouse gas emitted through fossil fuel combustion and industrial processes.
CAS	**Chemical Abstracts Service:** A registry number system to uniquely identify chemical substances.
CEPN	**Clean Electronics Production Network:** Collaborative initiative working to eliminate toxic exposures in electronics manufacturing.
CTUe	**Comparative Toxic Unit for aquatic ecosystem:** Used in LCA toxicity assessments.
CTUh	**Comparative Toxic Unit for human health:** Used in LCA for toxicity potential.
DMFa	**Dimethylformamide:** Solvent used in synthetic leather and plastics; classified as toxic.

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GWP	**Global Warming Potential:** Relative measure of how much heat a greenhouse gas traps over a time period.
GHG	**Greenhouse Gas:** Emissions that trap heat in the atmosphere, including CO2, CH4, N2O, and others.
GHGP	**Greenhouse Gas Protocol:** Standard for measuring and managing greenhouse gas emissions.
SF_6	**Sulfur Hexafluoride:** Potent greenhouse gas used in electrical insulation; extremely high GWP.
HIWAI	**Human Impact and Water Availability Indicator:** Metric reflecting human pressure on freshwater availability.
PEF methodology	**Indicators from the European Commission Product Environmental Footprint:** LCA-based indicators for assessing product environmental performance.
IPBES	**Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services:** UN body that provides knowledge on biodiversity and ecosystem services.
ISO (14040)	**International Organization for Standardization:** Standard outlining principles and framework for life cycle assessment.
Kg	Kilogram, a base unit of mass in the metric system.
GBF	**Kunming-Montreal Global Biodiversity Framework:** Global plan adopted to halt and reverse biodiversity loss by 2030.
Land use (m^2 occ. / y)	Land occupation measured in square meters per year, used in LCA.

LCA	**Lifecycle Assessment:** Method for evaluating environmental impacts of a product throughout its life cycle.
LCIA	**Lifecycle Inventory Assessment:** Phase of LCA involving the classification and characterization of environmental impacts.
MEK	**Methyl Ethyl Ketone:** Volatile organic solvent used in coatings and adhesives.
Mol	Mole, a unit for amount of substance in chemistry.
N	**Nitrogen:** Key nutrient element; contributes to eutrophication when released in excess.
N2O	**Nitrous Oxide:** Greenhouse gas emitted from agriculture and industry; high GWP.
NGO	**Non-governmental Organization:** Independent organizations not part of government, often focused on social or environmental issues.
NP	**Nonylphenol:** Toxic breakdown product of NPEOs; persistent and harmful to aquatic life.
NPEOs	**Nonylphenol Ethoxylates:** Surfactants phased out due to persistence and aquatic toxicity.
PCP	**Pentachlorophenol:** Toxic biocide and wood preservative; persistent organic pollutant.
PFAS	**Per- and Polyfluoroalkyl Substances;** Synthetic chemicals used for water- and grease-resistance; highly persistent.

PEL	**Permissible Exposure Limit** Legal limit in the U.S. for exposure to a chemical substance in workplace air.
POPs	**Persistent Organic Pollutants:** Toxic chemicals that persist in the environment and bioaccumulate through food chains.
P	**Phosphorus** Nutrient that contributes to eutrophication when overused in agriculture or industry.
PU	**Polyurethane:** A versatile polymer used in coatings, foams, and textiles, often replacing solvent-based alternatives.
PTE	**Potential to Emit** Estimate of the maximum capacity of a facility to emit pollutants.
PPM	**Parts Per Million:** Measurement of chemical concentration, often used in pollution metrics.
SoNP	**Pressure-sensitive State of Nature Indicator:** Metric reflecting sensitivity of ecosystems to pressure from pollution or land use.
RSL	**Restricted Substances List:** List of chemicals banned or restricted in manufacturing processes.
RoHS	**Restriction of Hazardous Substances:** EU directive restricting use of specific hazardous substances in electronics.
SDS	**Safety Data Sheet:** Documents providing safety and handling information for chemical products.
SBTi	**Science-Based Targets Initiative:** Partnership helping companies align emissions reductions with climate science.
SCCPs	**Short-chain Chlorinated Paraffins:** Toxic and bioaccumulative substances used in metalworking and plasticizers.
SoN	**State of Nature:** Snapshot of ecological state in a location, including biodiversity health.
SVHC	**Substance of Very High Concern:** Chemicals flagged by EU REACH for their hazardous properties.
TNFD	**Taskforce on Nature-related Financial Disclosures:** Framework for companies to report nature-related financial risks.
TNC	**The Nature Conservancy:** Nonprofit organization working to conserve lands and waters around the world for nature and people.
WALDB	**The World Apparel and Footwear Lifecycle Assessment Database:** LCA database specific to apparel and footwear impacts.
MRSL	**The ZDHC Manufacturing Restricted Substances List:** List of chemicals banned from intentional use in ZDHC-signatory facilities.
VOC	**Volatile Organic Compound:** Organic chemicals that easily become vapors; contributors to air pollution.
WWF	**World Wildlife Fund:** Global conservation organization focused on protecting biodiversity and reducing environmental degradation.
ZDHC	**Zero Discharge of Hazardous Chemicals Foundation:** Global initiative working to eliminate hazardous chemicals in textiles.

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