Current Trends in Biotechnology and Pharmacy
Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

Assessing the Toxicity of Triethanolamine (TEA) in Consumer and Industrial Products: A Bibliometric Analysis of Research Trends and Health Implications

Keerthana Chezhian, Kiruthika Jevanantham Senthamarai, and Suresh Babu Palanisamy*

Department of Biotechnology, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha Nagar, Thandalam, Chennai - 602 105, Tamil Nadu, India.
*Corresponding author: sureshbabup.sse@saveetha.com

Abstract

The wide use of triethanolamine (TEA) in consumer and industrial products, especially in cosmetics, personal care items, pharmaceuticals, and surfactants, has raised serious scientific concerns. This is mainly due to its potential toxicity with long-term and repeated exposure. TEA serves as a pH balancer, emulsifier, and surfactant. However, studies increasingly point out the risks of skin and eye irritation, allergic reactions, organ toxicity, and possible cancer risk when its levels or usage duration go beyond recommended safety limits. This research offers a bibliometric and scientometric evaluation of the global research landscape concerning TEA's toxicity, focusing on health-related effects for consumer safety and regulatory standards. A dataset of 176 documents from Scopus, 83 from Web of Science, and 79 from PubMed (2001–2025) was analyzed using VOSviewer and RStudio (Biblioshiny) to reveal research trends, key contributors, thematic Co-occurrence mapping reveals frequent connections between TEA, oxidative stress, cancer pathways, and skin toxicity.This study provides the first comprehensive overview of TEA toxicity research, offering important insights into current knowledge gaps, policy implications, and future avenues for interdisciplinary research aimed at balancing industrial use with health protection.

Keywords: Triethanolamine, Cosmetic Toxicity, Safety, Long-Term Exposure, Carcinogenicity

Introduction

Triethanolamine (TEA) is an organic compound that acts as a surfactant, emulsifier, and pH adjuster in many consumer and industrial products. TEA belongs to the ethanolamine family, which has both amine and alcohol groups. This structure gives it useful properties in formulation chemistry (1-3). TEA stabilizes oil-water mixtures and manages alkalinity, making it an essential ingredient in cosmetics like lotions, creams, shampoos, and shaving foams. It is also used in industrial processes such as textile finishing, cement production, lubricants, and corrosion inhibitors. TEA has been part of the global chemical market for over fifty years due to presence in everyday products shows its economic and functional value, but it also raises serious concerns about the long-term health risks associated with repeated exposure. Unlike many specialty chemicals that people encounter primarily at work, TEA is often found by the public through skin contact with cosmetics, inhaling aerosols from personal care sprays, or ingesting small amounts in pharmaceuticals and food products. This widespread exposure increases the need for research on its safety, especially regarding skin irritation, allergic reactions, and potential systemic effects from long-term use (4). Interest in researching TEA has evolved over time. Initially, studies focused on its physical and chemical properties and benefits for formulations. This has expanded to include toxicology, skin safety, and regulatory assessments. TEA's structural similarity to diethanolamine (DEA)

Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

has garnered attention because the International Agency for Research on Cancer (IARC) has classified DEA as “possibly carcinogenic to humans” in some instances. Additionally, in certain cosmetic formulations, TEA can react with nitrosating agents to form N-nitrosodiethanolamine (NDELA), a potent carcinogen, which raises further safety concerns regarding its use in personal care products (5). The debate over TEA’s toxicity highlights a conflict between industrial use and consumer safety. Regulatory bodies like the U.S. Food and Drug Administration (FDA), the European Union (EU) Cosmetic Regulation, and the Cosmetic Ingredient Review (CIR) have established limits and guidelines for its application. However, research around the world continues to examine the long-term health impacts of low-dose exposure (6). These ongoing inquiries provide a foundation for studies aiming to connect fragmented data, monitor global research advancements, and evaluate the evolving discussion about TEA’s toxicity in both consumer and industrial contexts.

Applications of Triethanolamine in Consumer and Industrial Products

The widespread use of triethanolamine (TEA) across various industrial and consumer sectors highlights its versatility as a chemical intermediate. In the cosmetic industry, TEA is mainly used as an emulsifying agent and pH stabilizer (7). It helps create stable oil and water mixtures in products like facial creams, lotions, shampoos, shaving foams, and sunscreens (8). Its ability to neutralize fatty acids and form clear, uniform formulations makes it essential in personal care products. Beyond looks, it improves product texture, thickness, and shelf life, which has led to its broad use by cosmetic manufacturers worldwide. TEA also has important pharmaceutical applications. It is used in topical treatments, ointments, and oral products. Its ability to balance water and oil improves the solubility of active ingredients and, in turn, boosts absorption. TEA derivatives, like triethanolamine salicylate, are known for their anti-inflammatory benefits and are included in creams designed to ease arthritis and muscle pain (9). However, the use of these derivatives has raised concerns about toxicity levels and the risk of irritation or allergic reactions with long-term use. TEA's industrial applications further expand its importance (10). In textiles, it acts as a softening and dyeing aid. In construction, it serves as a grinding aid for cement, improving the milling process efficiency. TEA is also key in lubricants, corrosion inhibitors, metalworking fluids, and surfactants used in paints and coatings. Its ability to function as both a weak base and a surfactant offers flexibility across various fields, making it a popular option in chemical engineering. The widespread presence of TEA in both consumer and industrial areas shows a crucial link between usefulness and safety. Its many functions offer real advantages in product performance and manufacturing processes. However, its common use also raises significant questions about exposure levels in workplaces and everyday life (11). The following sections will explore these complexities and examine the growing research on the safety of TEA's extensive applications in relation to long-term human health and environmental sustainability.

Toxicological Concerns and Health Implications

The toxic profile of triethanolamine (TEA) has sparked ongoing debate in toxicology, dermatology, and regulatory science. Its ability to perform in various roles has secured its place in cosmetics, pharmaceuticals, and industrial products; however, increasing evidence indicates that long-term or repeated exposure to TEA may lead to several negative health effects. These include short-term issues like skin and eye irritation, and long-term concerns such as sensitization, toxicity to organs, and possible cancer risk (12). The range of risks associated with TEA highlights the challenge of balancing its industrial use with consumer safety. One of the most frequently reported effects of TEA exposure is irritation of the skin

Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

and eyes. Cosmetic products with higher concentrations of TEA can damage the stratum corneum barrier, causing dryness, redness, or allergic contact dermatitis. Workers in industries that use TEA-based surfactants and metalworking fluids have also experienced irritant contact dermatitis, especially those with extended hand exposure or inhalation of aerosols. These findings raise serious concerns, given how often the general public comes into contact with TEA through personal care products. Another important toxicological issue is the risk of forming nitrosamines. When TEA interacts with nitrosating agents, it may produce N-nitroso diethanolamine (NDELA), a known potent carcinogen in animal studies (13, 14). Animal studies have shown further support for TEA's potential for systemic toxicity. High doses applied to the skin of rodents have resulted in liver and kidney changes, altered organ weights, and tissue damage (15, 16). Laboratory studies have indicated that TEA can disrupt cell membrane integrity and mitochondrial function, raising concerns about its toxicity at the cellular level. Additionally, recent research into nanotoxicology has found that TEA, when mixed with nanoparticles or engineered materials, may increase oxidative stress responses, complicating the toxicological picture further. Although human epidemiological data is limited, available evidence suggests that chronic low-level exposure might not be harmless (17). Reports of occupational asthma, allergic reactions, and respiratory irritation related to aerosolized TEA underscore the necessity for more comprehensive long-term monitoring (18). In summary, these toxicological findings emphasize the conflict between TEA's benefits for industries and consumers and its potential health risks. While most regulatory evaluations assert that TEA is safe within specific concentration limits, the absence of standardized testing across countries, coupled with a lack of long-term studies on humans, has created significant knowledge gaps. This ongoing uncertainty has led to a growing body of research focused on clarifying TEA's toxicological effects. Mapping this literature through bibliometric analysis offers a chance to assess current knowledge and identify research priorities to ensure safer use of TEA in the future.

Regulatory Perspectives and Safety Assessments

The global regulation of triethanolamine (TEA) shows an ongoing effort to balance its usefulness in consumer and industrial applications with worries about its potential toxicity (19). Unlike many chemical ingredients that are banned outright when toxicity is suspected, TEA exists in a more unclear regulatory area. Its widespread use in cosmetics, pharmaceuticals, and manufacturing has led to detailed policies that allow its application under specific concentration limits and safety conditions (20). Consequently, the regulatory landscape for TEA features both harmonization efforts and regional differences, revealing the complexities of managing chemical safety risks (21). In the United States, the Cosmetic Ingredient Review (CIR) Expert Panel has evaluated TEA's safety several times. They concluded, in multiple reports, that TEA is safe for use in cosmetics and personal care products when concentrations do not exceed 5% in leave-on products and 10% in rinse-off products, as long as formulations do not include nitrosating agents that could create N-nitrosodiethanolamine (NDELA). The U.S. Food and Drug Administration (FDA) does not impose a complete ban on TEA but closely watches compliance with these concentration limits, especially regarding nitrosamine contamination (22). Another significant issue is the lack of long-term, standardized toxicology studies that can clearly determine TEA's long-term health risks. While short-term irritation and sensitization studies are plentiful, data on carcinogenicity (23), systemic absorption, and reproductive toxicity in humans remain scattered. This lack of solid evidence puts regulators in a reactive position, adjusting policies as new data

Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

appear instead of anticipating long-term risks. In this situation, bibliometric analysis is a helpful method for consolidating the fragmented regulatory and toxicological literature. By mapping the development of TEA research across scientific communities, one can identify not only the scientific agreement but also the gaps that impede effective regulation. Understanding how different regions handle TEA safety may ultimately lead to more consistent policies, ensuring both the continued usefulness of the compound and the protection of public health.

Bibliometric Approach in TEA Toxicity Research:

The growing research on triethanolamine (TEA) reflects an increasing concern about its potential health effects. However, even after decades of toxicological studies(24), the knowledge remains scattered across different fields, such as dermatology, pharmacology, industrial hygiene, and chemical engineering. Individual studies often focus on narrow aspects of TEA, like skin irritation, nitrosamine formation, or workplace exposure, without combining these findings into a complete view of its overall risks. This fragmentation poses challenges for regulators, manufacturers, and healthcare professionals who need clear evidence for decision-making. Bibliometric and scientometric methods provide a systematic way to address this issue. By examining publication trends, author networks, thematic clusters, and keyword co-occurrences across global databases like Scopus, Web of Science, and PubMed, bibliometric analysis offers a broad view of the research field. Unlike traditional narrative reviews, this method highlights macro-level patterns, such as which countries and institutions are leading TEA research, how international collaborations are changing, and what themes dominate scientific inquiry. Additionally, tools like VOSviewer and Biblioshiny (RStudio) allow visualization of keyword networks, factorial clusters, and country-level scientific output. This capability helps trace the intellectual, conceptual, and social framework that shapes the discussion on TEA toxicity. These analyses are particularly useful for revealing research gaps. For instance, while studies on skin irritation are common, long-term epidemiological research on chronic low-level exposure is rare. Similarly, even though regulations stress nitrosamine contamination, few studies specifically look at solutions in real-world consumer products. Bibliometric mapping can highlight these overlooked areas, guiding future research toward topics with significant public health importance. Moreover, bibliometric insights can help with policy harmonization. By comparing publication trends across regions, we can see how different countries prioritize aspects of TEA research—like industrial exposure in North America, cosmetic safety in Europe, or pharmaceutical uses in Asia. Making these differences visible can lay the groundwork for international discussions and the creation of more consistent global regulatory standards. In short, bibliometric analysis does more than just count publications; it reconstructs the intellectual path of TEA research, identifies key contributors, and uncovers its changing thematic focuses. For a compound that is widely used and often debated, this level of detailed mapping is essential. It helps scientists and regulators make informed choices and ensures that consumer safety keeps pace with industrial advancement. By placing toxicological issues in a broader scientometric context, this study aims to provide a thorough evaluation of TEA research, bridging the gap between scientific evidence and policy action.

Bibliometric Analysis

Bibliometric analysis is a systematic and quantitative way to evaluate scientific literature. It helps identify research trends, thematic clusters, collaboration networks, and intellectual structures in a specific field (25). This study used bibliometric methods to review the research landscape on the toxicity of triethanolamine (TEA), focusing on its health effects and regulatory significance(26). This approach allows us to look beyond

Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

individual toxicological studies and build a complete picture of the field, showing both strengths and knowledge gaps.

Data Collection and Sources

A thorough literature search was conducted across three major scholarly databases: Scopus, Web of Science (WoS), and PubMed. These platforms were chosen for their broad coverage of peer-reviewed journals in toxicology, pharmacology, industrial hygiene, and cosmetic sciences (15). The search included the keywords “triethanolamine” AND “toxicity” along with related terms like “dermal absorption,” “carcinogenicity,” “cosmetic safety,” and “occupational exposure.” The search resulted in 176 documents from Scopus, 83 documents from WoS, and 79 documents from PubMed, covering the years 2001 to 2025. To ensure accuracy and prevent duplication, we screened the records for relevance and cleaned them using bibliographic management tools. The publications included original research articles, reviews, book chapters, and conference papers, reflecting the diversity of the TEA research landscape.

Data Processing and Tools

The data were standardized and exported in the formats needed for bibliometric software: CSV for Scopus, plain text for WoS, and PubMed format for PubMed. We performed the analysis using two complementary platforms: VOSviewer (version 1.6.20) was used to create visualizations of co-authorship networks, keyword co-occurrence maps, and international collaboration structures. This tool offered insights into the intellectual and conceptual links within TEA toxicity research. Biblioshiny (RStudio interface of the Bibliometrix package) was used for deeper analyses, including mapping thematic evolution, conducting factorial analysis, and assessing document type distributions and country-level productivity. Biblioshiny allowed for interactive visualization of trends and facilitated comparisons between databases.

Scope of Analysis

The bibliometric workflow provided a multidimensional view of triethanolamine (TEA) toxicity research by examining diverse indicators of scholarly activity. Annual scientific production illustrated how publication output has evolved over time, while document type distribution distinguished between original research articles, reviews, and other categories of work. Together, these measures highlight not only the increasing scientific interest in TEA but also the balance between empirical investigations and broader syntheses of knowledge. Keyword co-occurrence highlighted dominant themes, conceptual clusters, and research gaps, while factorial analysis offered a higher-level perspective by charting the intellectual structure and thematic evolution of the field. This structured approach therefore generates a comprehensive map of TEA research, enabling an evidence-based evaluation of how the scientific community has addressed the compound’s toxicological effects over time.

Results

Document Type- The distribution of publication types on triethanolamine (TEA) toxicity shows the nature of scientific contributions across the three databases we analyzed (Fig. 1). The vast majority of documents are original research articles, making up more than 90% of the total output. This dominance highlights the experimental and data-driven focus of TEA studies, especially in toxicology, dermatology, and occupational health. The prevalence of primary research shows the ongoing need to produce new evidence about TEA’s toxic profile, including in vitro cell culture models, in vivo animal testing, and limited human case studies. Review articles are fewer in number, around 6 to 7%, but they still play an important role in bringing together scattered findings and providing a broader view of TEA’s health risks. The relatively small but increasing number of reviews indicates a developing research area, where efforts are

Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

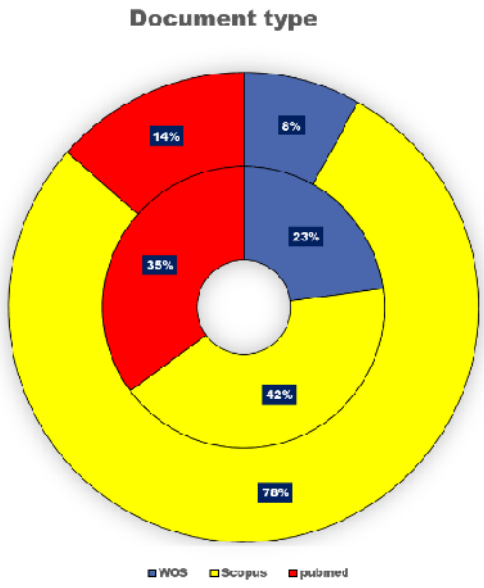

Fig 1: Document type depicts inner circle representing the number of research articles and outer ring of review articles from all the three databases (WOS, Scopus and PubMed)

The dominance of original research emphasizes the scientific community's focus on examining TEA's toxic mechanisms and exposure pathways through empirical study. At the same time, the relatively smaller share of reviews points to the need for more thorough evaluations that could guide regulatory frameworks and consumer safety standards.

Annual Scientific Production:

The annual scientific output on triethanolamine (TEA) toxicity research shows a clear upward trend over the past two decades, with notable fluctuations due to changes in regulatory focus, industry practices, and toxicological discussions (27). Between 2001 and 2010, publication activity was modest, with fewer than 10 documents each year across all databases (Fig. 2). This early research mostly focused on chemical characterization and initial toxicological assessments, especially concerning TEA's role as a surfactant and emulsifier in cosmetics and industrial formulations. From 2011 onward, there was a steady increase in

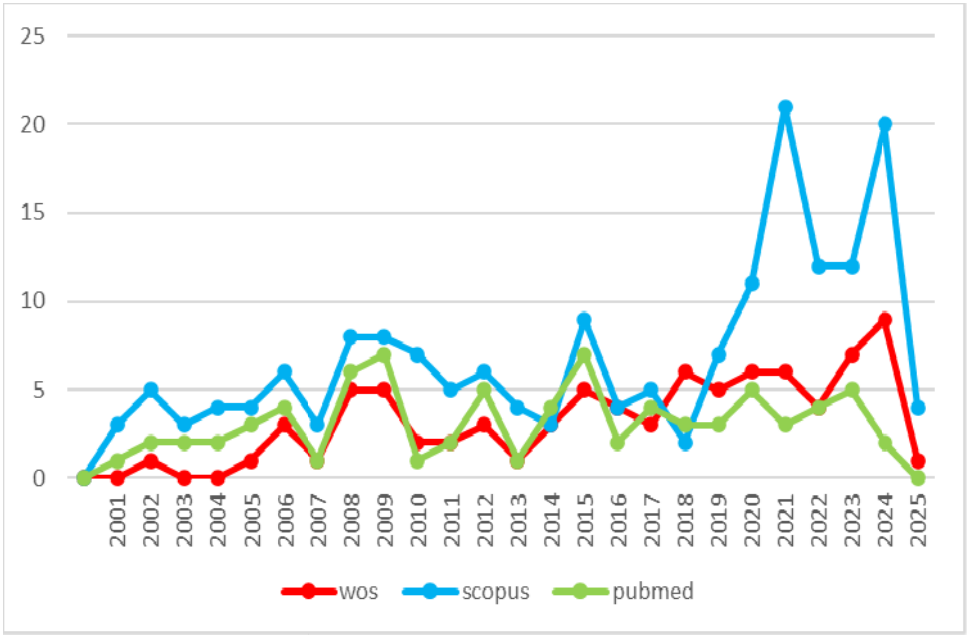

Fig 2: Annual scientific production

Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

publications, particularly in Scopus, which consistently reported more than Web of Science and PubMed. This growth aligned with increased regulatory scrutiny in Europe and North America regarding nitrosamine contamination and skin safety (28). This prompted a rise in toxicological and dermatological studies. By 2018 to 2020, publication activity intensified, with Scopus exceeding 25 annual publications, reflecting greater interest in consumer safety and occupational exposure. The most notable increase occurred between 2020 and 2023, when global research output on TEA toxicity accelerated sharply. This surge likely stems from renewed focus on the safety of cosmetic ingredients, progress in nanotoxicology (where TEA is increasingly studied alongside engineered nanoparticles), and ongoing regulatory discussions about ethanolamine derivatives.

A decline is apparent in 2025, but this is likely due to incomplete data collection for the current year rather than an actual drop-in research activity. Overall, the upward trend highlights a sustained and growing global concern about TEA toxicity, showing that the compound remains central to discussions in cosmetic chemistry, industrial uses, and public health (29, 30).This temporal growth pattern not only reflects the expanding scientific curiosity around TEA but also highlights the compound's transition from a routine formulation agent to a priority subject of toxicological evaluation. The rise in publications following regulatory alerts demonstrates how policy discussions and safety reviews can directly influence academic output. The consistent upward trajectory indicates that TEA has become a recurring focus of interdisciplinary inquiry, reinforcing its relevance as both a chemical of industrial value and a substance of toxicological concern requiring ongoing monitoring.

Country Scientific Production:

The geographical distribution of scientific output on triethanolamine (TEA) toxicity shows clear regional patterns in research productivity (Fig. 3a, 3b, 3c). Scopus data indicate that China, India, and the United States are among the top contributors, reflecting active research in both industrial toxicology and cosmetic safety. China has particularly high publication counts, which matches its role as one of the consumers of cosmetic and industrial chemicals. India's significance comes from its growing pharmaceutical and cosmetic sector. The United States makes substantial contributions through studies on occupational health, dermatological research, and regulatory science. In contrast, the Web of Science (WoS) data show a more selective distribution, with China again in the lead,

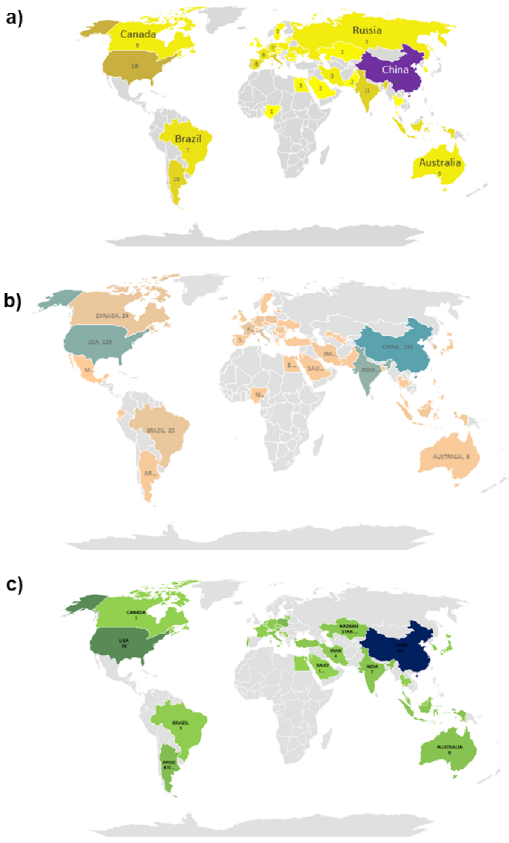

Fig 3: Countries scientific production (a) WoS (b) Scopus (c) PubMed

Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

Table 1: Top 10 publishing country from all three database

Rank	Country	WOS	Country	Scopus	Country	PubMed
1	China	19	India	30	China	17
2	Usa	10	China	23	Usa	14
3	India	8	Usa	19	Germany	4
4	Italy	5	Italy	7	Italy	4
5	Argentina	4	France	6	Argentina	2
6	Germany	3	Canada	5	Australia	2
7	Portugal	3	Germany	4	France	2
8	Russia	3	Korea	4	India	2
9	Canada	2	Poland	4	Iran	2
10	Poland	2	UK	4	Poland	2

followed by the United States, Brazil, Russia, Canada, and Australia (Table 1). The inclusion of Latin American and European countries in WoS highlights a growing global interest in chemical safety, occupational exposure and environmental toxicology. Although overall counts in WoS are lower compared to Scopus, the overlap in leading nations shows a consistent international effort to explore the health implications of TEA.

Notably, contributions from countries like Brazil, South Korea, and Australia indicate the compound's global relevance, extending beyond major industrial powers. The rising presence of nations in Asia and South America suggests a more decentralized research landscape, where TEA toxicity is investigated not just in traditional research centers but also in regions with rapidly growing chemical industries. This shift reflects both the globalization of consumer products and the increasing importance of local regulatory frameworks in shaping scientific agenda (31). The maps reveal that while research on TEA toxicity is concentrated in a few high-output countries, international contributions are steadily increasing. This diversification shows a growing recognition of TEA as a global public health issue, deserving of collaborative scientific and regulatory attention across multiple regions.

Keyword Co-occurrence Network

The structure of triethanolamine (TEA) toxicity research can be understood by analyzing keyword co-occurrence networks. These networks show how often terms appear together in scientific literature and how they group into themes (Fig. 4). The visualization reveals several distinct clusters, each representing a major research area in the field. At the center of the network, the terms "triethanolamine" and "toxicity" stand. Red cluster focuses on carcinogenicity, amines, diethanolamine, and absorption, highlighting concerns about nitrosamine formation and similar compounds. The yellow cluster addresses skin, occupational exposure, and metalworking fluids, emphasizing TEA's significance in consumer safety and workplace health. Other clusters expand TEA research beyond traditional toxicology. The blue cluster, which includes cytotoxicity, hydrogel, and optimization, indicates a growing connection between TEA and biomedical or materials science

The green cluster links TEA with nanoparticles, quantum dots, and carbon nanotubes, showing its role in nanotoxicology where TEA-modified materials are assessed for safety. The purple and orange clusters feature terms like solubility, chromium, cells, and stability, reflecting interest in physicochemical interactions and combined

Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

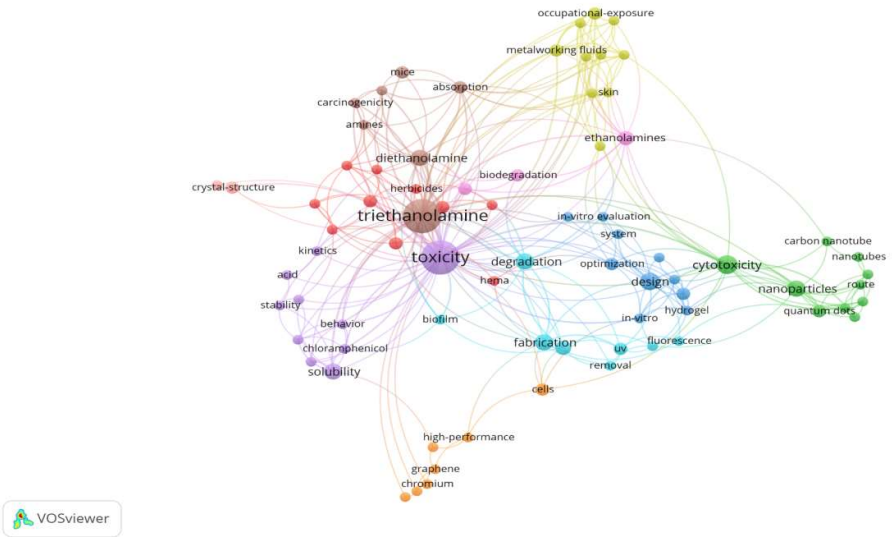

Fig 4: Network visualization of Keywords

exposure. This clustering shows that TEA toxicity research is not limited to cosmetic safety but also includes industrial toxicology(32), nanomaterial safety, occupational health, and pharmaceutical formulation. Additionally, the frequency of keywords related to occupational and dermal exposure points to the risks TEA poses to both consumers and industrial workers. Overall, the keyword co-occurrence analysis shows how TEA has become a topic of interdisciplinary study, connecting toxicology, chemistry, materials science, and regulatory science. The clustering of keywords not only illustrates the depth of the field but also offers guidance for setting research priorities, such as long-term human exposure, strategies to reduce nitrosamines, and the safety of TEA-modified nanomaterial.

Factorial analysis

The factorial analysis of triethanolamine (TEA) organizes related keywords and themes into clusters that represent different aspects of scientific inquiry (Fig. 5). Each cluster highlights a specific research focus, reflecting the various approaches used to assess TEA's safety. The upper-right cluster emphasizes the clinical and medical context, represented by keywords like clinical trial, radiation dermatitis, triethanolamine salicylate, and human studies. This cluster shows that researchers have examined TEA not only as a cosmetic ingredient but also as part of pharmaceutical formulations. Its use in topical anti-inflammatory creams and dermatological products has gained attention. Studies in this group often evaluate short-term efficacy while raising questions about long-term safety, particularly concerning skin irritation and cumulative exposure. Research here highlights TEA's role as a formulation aid, contributing to product stability and solubility. However, the frequent appearance of toxicological markers such as histopathology emphasizes the dual focus of this cluster—addressing both product performance and the potential biological effects of exposure. The lower-left cluster represents material and physicochemical investigations, characterized by terms such as zeta potential, particle size, drug delivery systems, and transmission electron microscopy. This cluster indicates how TEA has found applications in nanotoxicology and advanced material sciences, particularly in modifying nanoparticles and polymeric drug carriers. The use of these terms reflects a growing

Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

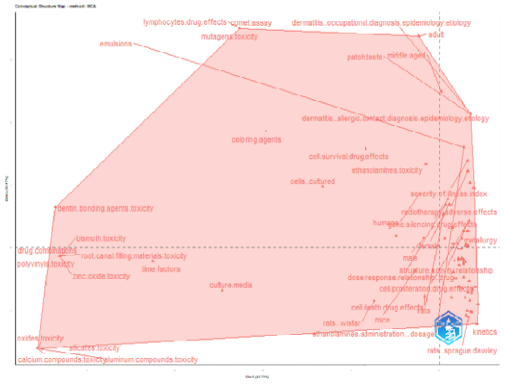

Fig 5: Factorial analysis

research area where TEA's chemical properties are applied in biomedical engineering while raising questions about its compatibility with living cells and its toxic effects. The lower-right cluster captures the essential toxicological and chemical studies, with terms like ethanolamines, toxicity, chemistry, and triethanolamine. This foundational cluster includes general safety assessments of TEA and related compounds, often serving as the basis for regulatory evaluations.

Research in this area tends to focus on mechanistic studies, including pathways of irritation, potential carcinogenicity, and chemical stability in consumer products. Together, these clusters show how TEA research spans multiple domains—ranging from cosmetic and pharmaceutical safety to nanomaterial applications and mechanistic toxicology. The factorial structure demonstrates that TEA is not studied in isolation but as part of broader scientific discussions on chemical safety, formulation science, and human health. This thematic diversity highlights both the complexity and significance of TEA toxicity research in influencing regulatory decisions and promoting safer practices in industry.

Discussion

The scientometric analysis of triethanolamine (TEA) toxicity research shows a field that has changed a lot over the past two decades. This reflects a growing global concern about the safety of this commonly used chemical. The steady rise in publications, especially after 2010, indicates that TEA has shifted from being seen mainly as a formulation agent to becoming significant in toxicology and regulation. The growth across Scopus, Web of Science, and PubMed demonstrates that TEA research is not limited to one discipline; it involves chemistry, toxicology, dermatology, pharmacology, and occupational health, highlighting its multidisciplinary nature. The scientometric evidence therefore paints a picture of a field that is scientifically advanced yet fragmented in terms of regulation. TEA toxicity research has produced valuable mechanistic insights and expanded into new areas, but the lack of standard methods and unified global policies continues to slow progress toward clear safety evaluations. Ultimately, current report suggests that future TEA research should take a more unified, interdisciplinary, and policy-oriented approach. By addressing knowledge gaps, aligning regulatory standards, and looking ahead to emerging applications, the global scientific community can ensure that the benefits of TEA in industrial and consumer products do not compromise long-term human health.

Future Scope

The bibliometric analysis shows the increasing attention on triethanolamine (TEA) toxicity and highlights several research gaps that need further investigation. Future studies should focus on long-term human exposure assessments because most current findings are limited to animal models and short-term clinical observations. Expanding into epidemiological studies will be essential for understanding the health risks linked to daily consumer and occupational exposure. Also, the role of TEA in nanomaterial applications and drug delivery systems is a new area of inquiry. Its interactions with nanoparticles and cellular systems must be carefully evaluated. It is also important to tackle the ongoing issue of nitrosamine formation, which raises regulatory concerns but remains underexplored in real-world consumer product conditions. Finally, research should

extend beyond skin studies to include inhalation and occupational exposure pathways. This will ensure a thorough evaluation of TEA's risks. Alongside these scientific efforts, there is a strong need for global regulatory consistency which would offer guidance for manufacturers and better protection for consumers. In summary, future TEA research should adopt a broad, long-term approach. It should combine various fields and align globally, balancing the benefits of the compound's industrial use with strong protections for human health.

Conclusion

This bibliometric analysis offers an overview of the research landscape on triethanolamine (TEA) toxicity. It shows how TEA has changed from a common ingredient in cosmetics and industrial products to a compound with serious toxic and regulatory concerns. By analyzing data from Scopus, Web of Science, and PubMed and using tools like VOSviewer and Biblioshiny, the study mapped publication trends, country contributions, keyword networks, and thematic clusters in the field (33). The findings indicate that research on TEA has grown significantly in recent decades, with a notable increase in publications after 2010 and peaks in the last five years. Major contributors include China, India, and the United States, along with emerging research from regions like South America and Australia. This reflects TEA's global importance. Thematic analyses show that while traditional issues such as skin irritation, nitrosamine contamination, and occupational safety remain critical, new research areas have developed, especially in nanotoxicology and pharmaceutical formulations. These include a lack of long-term human exposure studies, inconsistent regulations across regions, underexplored exposure pathways like inhalation, and weaknesses in strategies to reduce nitrosamine formation. These limitations stress the need for continued interdisciplinary research and stronger collaboration among scientists, regulators, and industry professionals. In conclusion, TEA toxicity research represents the evolving connection between scientific progress, public health, and policy development. The use of bibliometric methods has clarified the field's trajectory, key contributors, and thematic focuses while revealing important gaps that need to be filled.

References

1. Libralato G, Volpi Ghirardini A, Avezzù F (2010) Seawater ecotoxicity of monoethanolamine, diethanolamine and triethanolamine. J Hazard Mater 176:535–539
2. Sen U, Gurol MD (2022) Carbon dioxide delivery and resulting biomass separation in microalgae cultivation using triethanolamine. Sep Sci Technol 57:1279–1289
3. Allolinggi GS, Setyani W (2025) Factorial Design Optimization of Antioxidant Cream from Kepok Banana Peel Extract: Formulation, Characterization, and Stability Evaluation. Natural Sciences Engineering and Technology Journal 5:445–457
4. Lim DS, Lim SK, Kim MK, Kwon YC, Roh TH, Choi SM, Yoon S, Kim HS, Lee B-M (2018) Formation and inhibition of N-nitrosodiethanolamine in cosmetics under pH, temperature, and fluorescent, ultraviolet, and visual light. J Toxicol Environ Health Part A 81:241–253
5. Valipanah Z, Rahmani A, Gill P, Rafati A (2024) Detection and measurement of N-nitrosodiethanolamine: old challenges and advanced approaches. Discov Chem. https://doi.org/10.1007/s44371-024-00016-8
6. Balwierz R, Biernat P, Jasińska-Balwierz A, Siodłak D, Kusakiewicz-Dawid A, Kurek-Górecka A, Olczyk P, Ochędzan-Siodłak W (2023) Potential carcinogens in makeup cosmetics. Int J Environ Res Public Health. https://doi.org/10.3390/ijerph20064780
7. Lim S, Jeon S, Choi J, Lee K (2018) Formation of N-nitrosodiethanolamine (NDELA) from cosmetic ingredients containing triethanolamine. Korean Journal of Environmental Health 44:681–690
8. Nwose EF, Victor OT, Ojodomo AI, Juliet OI (2022) A Review On The Toxicological

Vol. 20 (Supplementry Issue 1A), March 2026, ISSN 0973-8916 (Print)., 2230-7303 (Online)
10.5530/ctbp.2026.1s.13

Implication Of Cosmetic, Hair Dyes And Relaxers. GSJ 10:266–291
9. Cioc RC, Joyce C, Mayr M, Bream RN (2023) Formation of N-nitrosamine drug substance related impurities in medicines: a regulatory perspective on risk factors and mitigation strategies. Organic Process Research & Development 27:1736–1750
10. Manchuri KM, Shaik MA, Gopireddy VSR, Naziya Sultana, Gogineni S (2024) Analytical methodologies to detect N-nitrosamine impurities in active pharmaceutical ingredients, drug products and other matrices. Chem Res Toxicol 37:1456–1483
11. Kumar Y, Uke SJ, Kumar A, Merdikar SP, Gupta M, Thakur AK, Bocchetta P, Gupta A, Kumar V, Kumar Y (2021) Triethanolamine–ethoxylate (TEA-EO) assisted hydrothermal synthesis of hierarchical β-MnO2 nanorods: effect of surface morphology on capacitive performance. Nano Ex 2:040008
12. Nudelman R, Kocks G, Mouton B, Ponting DJ, Schlingemann J, Simon S, Smith GF, Teasdale A, Werner A-L (2023) The nitrosamine “saga”: Lessons learned from five years of scrutiny. Org Process Res Dev 27:1719–1735
13. Almeida FT, Caldas R, Pereira T (2020) Allergic contact dermatitis caused by triethanolamine in an ultrasound gel. Contact Dermatitis 82:64–65
14. Janmeda P, Jain D, Chaudhary P, Meena M, Singh D (2024) A systematic review on multipotent carcinogenic agent, N-nitrosodiethylamine (NDEA), its major risk assessment, and precautions. J Appl Toxicol 44:1108–1128
15. Stott WT, Radtke BJ, Linscombe VA, Mar M-H, Zeisel SH (2004) Evaluation of the potential of triethanolamine to alter hepatic choline levels in female B6C3F1 mice. Toxicol Sci 79:242–247
16. Stout MD, Kissling GE, Suárez FA, Malarkey DE, Herbert RA, Bucher JR (2008) Influence of Helicobacter hepaticus infection on the chronic toxicity and carcinogenicity of triethanolamine in B6C3F1 mice. Toxicol Pathol 36:783–794
17. Lessmann H, Uter W, Schnuch A, Geier J (2009) Skin sensitizing properties of the ethanolamines mono-, di-, and triethanolamine. Data analysis of a multicentre surveillance network (IVDK*) and review of the literature. Contact dermatitis 60:243–255
18. Fiume MM, Heldreth B, Bergfeld WF, et al (2013) Safety assessment of triethanolamine and triethanolamine-containing ingredients as used in cosmetics. Int J Toxicol 32:59S-83S
19. Gamer AO, Rossbacher R, Kaufmann W, van Ravenzwaay B (2008) The inhalation toxicity of di- and triethanolamine upon repeated exposure. Food Chem Toxicol 46:2173–2183
20. Shin K-O, Lee Y-M (2016) Simultaneous analysis of mono-, di-, and tri-ethanolamine in cosmetic products using liquid chromatography coupled tandem mass spectrometry. Arch Pharm Res 39:66–72
21. Zhao D (2025) Export Control of Triethanolamine and Related Items: Policies and Difficulties. J. WTO & China 15:
22. Lim DS, Roh TH, Kim MK, Kwon YC, Choi SM, Kwack SJ, Kim KB, Yoon S, Kim HS, Lee B-M (2018) Risk assessment of N-nitrosodiethylamine (NDEA) and N-nitrosodiethanolamine (NDELA) in cosmetics. J Toxicol Environ Health Part A 81:465–480
23. Wu K, Wei G-W (2018) Quantitative toxicity prediction using topology based multitask deep neural networks. J Chem Inf Model 58:520–531
24. Karim A, Mishra A, Newton MAH, Sattar A (2019) Efficient toxicity prediction via simple features using shallow neural networks and decision trees. ACS Omega 4:1874–1888
25. Kamaraj M, Kiruthika N, Naganathan T, Saranya T, Aravind J (2025) Bibliometric analysis and impact of heavy metals contamination in soils. Global Journal of Environmental Science and Management 11:321–342
26. Klambauer G, Unterthiner T, Mayr A, Hochreiter S (2017) DeepTox: Toxicity prediction using deep learning. Toxicol Lett 280:S69

27. Nanda KK, Tignor S, Clancy J, Marota MJ, Allain LR, D'Addio SM (2021) Inhibition of N-nitrosamine formation in drug products: A model study. J Pharm Sci 110:3773–3775
28. (2001) Opinion concerning Dialkyl- and Dialkanolamines and their salts in cosmetic products (SCCNFP/0609/01). Scientific Committee on Cosmetic Products (SCCNFP)
29. (2013) Ethanol, 2,2′,2″-nitrilotris-: Human Health Tier II Assessment. Canberra: Department of Health. Australian Government (NICNAS/ICSR)
30. Shyamalagowri S, Shanmugasundaram HA, Bhavithra HA, Akila N, Nallusamy SG, Jeyaraj S, Gladstone J, Aravind J, Kamaraj M (2024) Saravanan, Pandiaraj. Carbon-based adsorbents for the mitigation of polycyclic aromatic hydrocarbon: a review of recent research. Environmental Geochemistry and Health 46:
31. Qin X, Dong Y, Wang M, Zhu Z, Li M, Yang D, Shao Y (2019) In situ growing triethanolamine-functionalized metal-organic frameworks on two-dimensional carbon nanosheets for electrochemiluminescent immunoassay. ACS Sens 4:2351–2357
32. Knaak JB, Leung HW, Stott WT, Busch J, Bilsky J (1997) Toxicology of mono-, di-, and triethanolamine. Rev Environ Contam Toxicol 149:1–86
33. Kemeç A, Altınay AT (2023) Sustainable energy research trend: A bibliometric analysis using VOSviewer, RStudio bibliometrix, and CiteSpace software tools. Sustainability 15:3618