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Special report

International Standardization Youth Star Competition 2025

2025国际标准化青年之星大赛

Global vision

Stakeholder partnership in the development of standardization activities

在标准化工作中与利益相关方建立合作关系的重要性

Exclusive interview

Rachel Miller Prada: Diversity, youth and future-oriented standardization

瑞秋·米勒·普拉达：标准化工作要着眼于多样化、年轻人和未来

Tom Heilandt: Confidence and continuous learning: Key for Chinese students to engage in international standardization work

汤姆·海伊兰特：增强自信和不断学习是中国大学生参与国际标准化工作的关键

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For more information

The voluntary national standard
GB/T 29772-2024, *General requirements of electric vehicle battery swap station,*
has taken effect since July 1, 2025.

The implementation of the standard is expected to help electric vehicle battery swap stations to adapt to diversified needs and vehicle models, promoting the industry's orderly and healthy development.

Bridging youth passion with global standards

To help university students know more about standards, and attract them to participate in standardization activities, the International Standardization Youth Star Competition was initiated by the International Standardization Outstanding Contribution Award Foundation (ISOCAF) in 2023, and has been held since then for three consecutive years in China. The 2025 Competition attracted 236 teams nationwide who demonstrated great enthusiasm for engaging in the standardization undertaking. The SPECIAL REPORT column presents the series reports on the competition, which is expected to inspire more young minds to step forward, innovate with purpose, and shape a future where standards unite ambition with impact.

Zhang Xiaogang, former President of ISO and Founder of ISOCAF, said in the address, “For students on this stage today, no matter what awards you have won, you have already achieved success. Standing out among over 230 teams nationwide is a success and an excellent learning opportunity. The nation’s development needs the younger generation to cultivate the consciousness and mindset of standardization, and genuinely contribute to China’s high-quality development, so as to realize your own life value.”

During the event, we conducted interviews with two international standardization experts–Rachel Miller Prada, ISO Capacity Building Project Manager, and Tom Heilandt, Former Secretary of the Codex Alimentarius Commission. The EXCLUSIVE INTERVIEW column presents two interview articles.

Rachel Miller Prada said, in ISO’s strategy, one goal is to ensure all voices are heard. ISO has realized that the participation rate of women aged 25-30 drops sharply, and is exploring solutions to keep women engaged in the standardization work, or to encourage their return after their childbearing and family-focused years. As part of the education program, ISO has also developed a game called Standard Quest to engage young audiences.

Tom Heilandt also gives invaluable advice to Chinese college students, “Chinese students receive excellent technical education and are known for their strong work ethic... they should be confident in their abilities. Their education is strong, and there is no reason to step back in international environments.”

In the GLOBAL VISION column, Dr. Zaki Al-Rubaei, Head of International Cooperation at the GCC Standardization Organization (GSO) shared his insightful views about modern organizations, standardization and stakeholder rations, as well as GSO’s initiatives for stakeholder partnership.

The article in the SPOTLIGHT column elaborates on why carbon standards begin to play a critical role. As green transition rises from a moral obligation to a core economic competitiveness, standards have emerged as the strategic pacesetter of global climate governance.

Enjoy your reading! May this issue of the magazine spark inspirations and insights.

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RESEARCH & EXPLORATION
研究与探索

Supplement 最新标准公告

(free of charge)

A batch of important national standards for CCUS released

Recently, State Administration for Market Regulation (SAMR) and National Standardization Administration of China (SAC) released 12 national standards for carbon capture, utilization and storage (CCUS), which will come into effect on July 1, 2026.

CCUS is a globally recognized key technological means for achieving the goal of carbon neutrality. The standards released this time cover important processes such as carbon capture, transportation, and storage, as well as basic links such as terminology and emission reduction assessment.

As for carbon dioxide capture, standards such as GB/T 46877-2025, *Carbon dioxide capture—General requirements for post-combustion CO_2 capture system*, stipulate the classification, composition, and technical requirements of post-combustion carbon capture systems, as well as evaluation methods for key performance indicators, operation evaluation, and management requirements.

As for carbon dioxide transportation, GB/T 46875-2025, *Quality requirements for carbon dioxide medium entering long-distance transportation pipeline*, determines the quality indicators, sampling, testing methods, and inspection rules for the medium entering long-distance transportation pipelines.

As for carbon dioxide storage, standards such as GB/T 46878-2025, *Carbon dioxide capture, transportation and geological storage—Geological storage*, specify the screening, selection, and evaluation methods for the storage sites, and clarify the evaluation methods for storage volume, the design of injection operation plans and risk management, as well as the requirements for storage engineering management.

As for commonalities and general requirements, standards such as GB/T 46872-2025, *Carbon dioxide capture, transportation and geological storage—Vocabulary—Cross cutting terms*, systematically define key terms and delineate the accounting boundaries, processes and methods for the greenhouse gas emission reduction of CCUS projects.

These standards will effectively unify basic concepts, provide unified technical specifications, testing methods and evaluation standards for key CCUS processes. They will promote technological innovation and industrial application along the CCUS chain, and contribute to carbon reduction and high-quality development.

China launches the global AI standards library and terminology library

The AI standardization technical committee of Ministry of Industry and Information Technology (MIIT/TC 1) held its plenary meeting recently in Beijing, where a series of achievements were released, marking China's efforts to build an open, collaborative, intelligent and efficient new standardization ecosystem.

Xie Shaofeng, Chief Engineer of MIIT, addressed the event. He pointed out that the technical committee should clarify the new tasks under the new circumstances, drive technological progress through standards, accelerate the evolution of products, enhance the intelligence level of enterprises, and accelerate the establishment of an industrial ecosystem. Future work will focus on promoting the processes of standards research, proposal, development, release, promotion, implementation, and evaluation. It is expected to become an advanced technical committee to lead technological innovation, regulates industry development, serve the national strategy, and have international influence, transforming standards achievements into a powerful driving force for the high-quality development of China's AI industry.

The two fundamental public service platforms, namely the global AI standards library and the global AI terminology library, debuted at the event. The standards library has included over 220 relevant Chinese AI standards at national and sectoral levels, with over 840 relevant standards approval information of international standardization organizations such as ITU, ISO, IEC, and IEEE. The terminology database collects over 1,200 AI-related terms, and comprehensively presents the core definition and application scope of AI, providing authoritative basis for standards drafting.

Fruitful results including the first AI agent for standards review, a sectoral standard for the assessment of embodied AI, and the report on AI standardization development were released at the event. Also, the China Artificial Intelligence Standardization Organization Ecosystem was established to break down organizational barriers and promote the harmonization among national, sectoral and association standards.

Six departments issue the plan for key tasks of modern logistics standardization

The State Administration for Market Regulation (SAMR), the National Development and Reform Commission, the Ministry of Transport, the Ministry of Commerce, the National Data Administration, and the State Post Bureau have jointly issued a plan for key tasks of modern logistics standardization for the period of 2025-2027. The plan delineates the development of 101 national standards in five aspects to support and advance the development of a unified national market.

In terms of enhancing the function of logistics infrastructure, efforts will be made for key facilities such as national logistics hubs, logistics parks, as well as warehousing and distribution centers. The development of standards for infrastructure design, service capabilities, and digital evaluation will be accelerated to improve the connectivity of logistics infrastructure and strengthen the modern logistics operation system.

In terms of innovation in logistics equipment and tools, the standards system for specific logistics facilities will be improved, advocating the recycling and shared use of logistics tools, and facilitating efficient connection of different transportation modes.

In terms of open and interconnected logistics data, key tasks include the basic framework for logistics data, interaction and sharing of logistics data, and the standards for data management of logistics enterprises. The efforts will further support the digital transformation and intelligent upgrading of logistics.

In terms of efficiency and quality improvement of logistics services, the focus is on accelerating the development of standards for digital and intelligent logistics, and mandatory national standards for the transportation of hazardous goods, better leveraging the role of logistics in enhancing the resilience and security level of the industrial chain and supply chain.

In terms of strengthening and improving the foundation of the logistics industry, more standards for contracts, enterprise capacity evaluation, and statistical monitoring will be perfected. Also, the training of logistics standardization talent will be strengthened, to enhance the level of logistics standardization in China.

SAMR has continuously strengthened logistics standardization work. During the 14th Five-Year Plan period (2021-2025), it has released 207 national standards in the logistics field, covering key aspects such as logistics parks, multimodal transport, green packaging for express delivery, traceability of imported cold-chain food, electronic data exchange of containers, and freight drones.

China Association for Standardization establishes the professional committee on low-altitude economy

The launching ceremony of the Professional Committee on Low-altitude Economy of China Association for Standardization (CAS) was held in Beijing on December 20, 2025. More than 200 representatives from government departments, scientific research institutions, and enterprises gathered to chart a new blueprint for the standardization development of China's low-altitude economy.

Yu Xinli, President of CAS, delivered an opening speech. She noted that the establishment of the committee represents a significant step by CAS to serve national strategies and respond to industry demands. She further outlined the five expectations of the committee in the future: adhering to systematic thinking in building the standards system; focusing on high-quality standards to address urgent industry needs; strengthening collaboration and synergy to promote standards implementation; deepening openness and cooperation to enhance international influence; and emphasizing mechanism innovation to improve service effectiveness. On behalf of the CAS, she expressed full support for the committee's work.

Tao Lan, Secretary-General of the committee, introduced that the members of the committee have covered key links in the upstream and downstream of the low-altitude economy chain. It will adhere to the principle of "prioritizing urgent needs, combining points and surfaces, and promoting construction through application", and steadily advance the construction of the standards system for low-altitude economy.

Xiang Jinwu, Academician of Chinese Academy of Engineering, and other 7 experts made keynote speeches at the ceremony, and shared their understanding of topics such as breakthroughs in equipment technology, establishment of safety management systems, and pathways for industrial application. The experts offered forward-thinking insights and practical approaches for the standardization and industry development of the low-altitude economy.

The committee will bring together industry stakeholders, leverage standards to drive technological innovation, and use regulations to ensure safe development, contributing standardization expertise and strength to foster new quality productive forces in the low-altitude economy.

ISO releases two standards for textiles

Recently, two international standards, ISO 8159:2025, *Textiles—Morphology of fibres and yarns—Vocabulary*, and ISO 17971:2025, *Textiles—Smart textiles—Test method for determining the screen-touch properties of fabrics*, were officially released. They are of positive significance for eliminating technical ambiguities in exchanges on textile products and filling the gaps in international standards.

ISO 8159:2025 defines the principal terms used to describe the various forms into which textile fibres can be assembled, up to and including cabled yarns. It contains terms of general application and a morphological scheme which illustrates the relationship among various terms from a production point of view. ISO's terminology standards serve as an important support for academic discussions, design and production, as well as trade and circulation. ISO 8159:2025 can effectively reduce communication barriers in product exchanges due to differences in expression and eliminate technical ambiguities.

ISO 17971:2025 specifies a test method for determining the screen-touch properties of fabrics. The method is applicable to all types of fabrics intended for use in products that serve as an interface when handling touchscreens. The applications of smart textiles have deeply integrated into daily life. The touchscreen property of fabrics affects the interaction experience between people and screens. This standard can objectively characterize the touchscreen performance of fabrics, providing unified technical support for the development, quality control, testing, and supervision of touchscreen textiles.

Chinatesta Textile Testing & Certification Services has contributed to the development of ISO 8159:2025 with leading efforts, and participated in the development of ISO 17971:2025. It offers Chinese wisdom and solutions to the global textile sector, and promotes its steady development.

ODCCN/PAS 1:2025 for humane entrepreneurship released in Seoul

Jointly promoted by China Council for the Promotion of International Trade Commercial Sub-Council (CCPIT CSC) and the Organization for Trade Development and Standards Cooperation (ODCCN), the release ceremony of the international standard ODCCN/PAS 1:2025 on guidance for humane entrepreneurship was held in Seoul, South Korea.

Experts from renowned universities shared their understanding of people-oriented entrepreneurial practices and local experiences. Representatives from 14 countries including China, South Korea, Malaysia, Indonesia, Myanmar, Tajikistan, the United Kingdom, Germany, Hungary, Slovenia, Latvia, Belarus, Ukraine and Argentina attended the event in hybrid forms.

The standard proposes the 10E model for humane entrepreneurship to build broad global consensus in the field of humane entrepreneurship and lay the foundation for the development of subsequent series of international standards.

ODCCN/PAS 1:2025 emphasizes the synergy between entrepreneurial orientation and people orientation, and promotes the formation of a virtuous cycle where “employee engagement promotes innovation, and innovation achievements nourish engagement”. The standard is applicable to organizations of different types and sizes, and is tailored to the trends of increasing global economic uncertainty, accelerated technological iteration, and continuous changes in the labor force structure. It can help entrepreneurs and managers to enhance organizational vitality and sustainable competitiveness.

The CCPIT CSC will continue to deepen international standardization cooperation and exchanges, standards publicity and training, and case promotion. Leveraging the achievements of the Northeast Asia standards cooperation project and the technical framework of ODCCN/PAS 1:2025, it will promote the humane entrepreneurship concept to be applied globally, and contribute standardization efforts to promoting inclusiveness, resilience and high-quality growth.

Standards:
The strategic pacesetter of global climate governance
标准成为全球气候治理的战略高地

Two international conferences in November 2025 jointly outlined a profound transformation of climate governance. The Committee on Trade and Environment (CTE) of the World Trade Organization (WTO) held a conference in Geneva, Switzerland, on November 4, where the topic of cooperation on trade-related carbon standards aroused heated discussions. The Leaders' Summit of the 30th Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) was held in Belém, Brazil, on November 7. At the meeting, the Open Coalition on Compliance Carbon Markets was officially launched with the initial membership of 11 economies including Brazil, China, and the EU. As the world's first transnational alliance on compliant carbon markets, the coalition aims to coordinate carbon pricing mechanisms, emission trading systems and related policies in various countries, and realize the interconnection of global compliance carbon market networks.

The two events show a global focus on carbon standards. As green transition rises from a moral obligation to a core economic competitiveness, standards have emerged as the strategic pacesetter of global climate governance. Standards not only define "green", but also shape the future ecosystem and trade orientation of the green and low-carbon industry. Developed countries are setting rules by virtue of their first-mover advantage, while emerging economies are seeking to make breakthroughs by relying on their development potential.

Standards become the core pillar of climate governance

The COP30 Action Agenda released by Brazil, the COP30 presidency, defines that international standards are a core tool for eliminating obstacles to climate actions. In addition, the Plans to Accelerate Solutions compiled by Brazil lays out 117 key global actions to address climate change, 63% of which treat standards as a critical measure for implementation. A climate action policy paper jointly released by standards organizations such as ISO and IEC, systematically expounds the pivotal role that standards can play in enhancing the comparability, credibility and accountability of climate actions. All these fully demonstrate the core position of standards in global climate governance.

The Paris Agreement sets the ambitious goal to hold global temperature increase to well below 2°C. However, this goal will ultimately become an empty slogan if it cannot be translated into actionable, verifiable and accountable concrete measures. Standards are exactly the key medium to achieve this transformation. They break down abstract emission reduction targets into specific emission factors, accounting boundaries, and monitoring frequencies, and define vague green concepts into clear energy efficiency grades, carbon footprint thresholds, and supply chain requirements.

Market-based mechanisms such as carbon markets, green finance and ecological compensation are important engines for achieving low-cost emission reduction. Their effective operation is highly dependent on a standards system that is sophisticated, stable and credible. Every step in the national carbon emissions trading market, from quota allocation, data verification to transaction settlement, is defined by standards. Similarly, the use of funds raised through green bonds and the assessment of environmental benefits must be supported by a sound standards system for green industry.

The development process of the national carbon market in China fully reflects how standards

underpin market-based mechanisms. Launched in July 2021, the national carbon emissions trading market covers 2,162 key emission units in the power generation sector, with annual carbon dioxide emissions of approximately 4.5 billion tons, which becomes the world's largest carbon market. To ensure the stable operation of this complex system, China has established a multi-level institutional system composed of laws and regulations, technical specifications and administrative measures.

In a world of deeply intertwined value chains, standards in a country are increasingly spilling over into international rules. Through the Corporate Sustainability Reporting Directive (CSRD) and the Carbon Border Adjustment Mechanism (CBAM), the EU has imposed its environmental standards on global supply chains. The European Parliament adopted a bill to revise the ESG information disclosure rules in the EU on November 13, 2025, significantly raising the threshold for enterprises to comply with sustainability requirements, while granting exemptions to about 80% of the enterprises originally within the scope. This adjustment has been interpreted as a signal that EU policies are shifting toward deregulation, reflecting the complexity and sensitivity of standards as a tool for making international rules.

The story of carbon-related standards in China began in the 1980s. Efforts on explorations and practices of energy conservation standards were made to alleviate the imbalance between energy supply and demand. These efforts laid the technical and regulatory foundation for energy conservation and emission reduction, cultivated standardization professionals, and accumulated management experience.

Such practices not only directly drove the leapfrog increase in the energy efficiency of products such as refrigerators and air conditioners. For instance, the standard for energy efficiency of refrigerators underwent four revisions in 16 years, driving the popularization of technologies including variable frequency control and high-efficiency thermal insulation. More importantly, such practices fostered a policy thinking that prioritizes standards.

When China announced its goals of "striving to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060" in September 2020, the standards system and technical capabilities forged through decades of efforts became an important institutional cornerstone for realizing such ambitious goals.

The global arena of climate-related standards

At present, the global arena of climate-related standards is showing a pattern of competition and cooperation. Developed economies represented by the EU tend to promote their standards system through unilateral legislation (such as CBAM), which brought about the Brussels Effect. Emerging economies including China advocate strengthening dialogue and coordination on standards under multilateral frameworks such as ISO, WTO and UNFCCC.

Taking their advantages in technology, capital and talent, developed countries occupy a dominant position in ISO and other international standards organizations. Their standards usually feature high costs and high complexity, posing a capacity threshold for developing countries.

Most developing countries emphasize the principle of common but differentiated responsibilities, asserting that standards should be inclusive and accessible, and provide developing countries with alternative solutions that balance scientificity and feasibility. Released in 2022, the Implementation Plan for Establishing and Improving the Systems of Standards and Measurement for Carbon Peak and Neutrality further clarifies the goal of completing the development and revision of standards in key fields by 2025, offering a useful reference for developing countries in building their own carbon standards system.

The existing carbon border adjustment mechanisms and carbon emission trading systems in the globe have not harmonized their standards and rules, resulting in huge value differences of the equal emission reduction volume in different markets. Independent measurement, reporting and verification (MRV) systems in various countries lead to fragmentation, which seriously hinders the coordinated development of carbon markets.

Launched at the COP30, the Open Coalition on Compliance Carbon Markets serves as a direct response to coordinated development. Covering approximately 40% of the global carbon emissions, the alliance aims to smooth cross-border carbon credit circulation channels by coordinating MRV systems, accounting methodologies and trading rules, which has unfolded a new chapter for global carbon governance.

During the COP30, National Climate Change Secretariat of Singapore, together with Gold Standard and Verra, jointly launched the Article 6.2 Crediting Protocol of the Paris Agreement on November 12, 2025, which adds an independent carbon standards system to the Paris Agreement for the first time, breaking the long-standing disconnect between the voluntary carbon market and the compliance carbon market. The interconnection between the two kinds of markets will inject new vitality into the global carbon market.

In addition, China Certified Emission Reduction (CCER) mechanism is expected to integrate with the global market through this protocol, attracting international capital to support domestic green projects.

Opportunities for emerging economies

In China, the development of green and low-carbon standards is an evolutionary journey from passive adaptation to active shaping. Especially after the dual carbon goals were put forward in 2020, carbon standards development in China has entered a period of full-scale acceleration.

Faced with the complex landscape of profound changes in the global carbon governance system and the intensifying game over international rules, China adheres to the philosophy of advancing practices while improving standards. It has made breakthroughs in carbon market construction, accounting methodologies, international coordination and other fields, forming a practical path for carbon standards with Chinese characteristics.

The Opinions on Promoting the Green and Low-carbon Transition and Strengthening the Development of the National Carbon Market was officially released by the CPC Central Committee and the State Council in August 2025. As the first national-level document in the field of carbon market in China, it clearly proposes that a national carbon emission trading market based on total quota control will be basically established by 2030, which combines free and paid quota allocation. It indicates that China's carbon market has entered the comprehensive deepening phase.

This document draws on the valuable experience gained from years of operation of the domestic carbon market: by the end of August 2025, the cumulative trading volume of national carbon market quotas had reached 696 million tons, with a total turnover of 47.826 billion yuan. The compliance rate in 2024 hit 99.98%, maintaining a leading position among major carbon markets in the globe.

More importantly, the guiding role of market mechanisms in industrial transformation has become increasingly prominent. In recent years, 564 key emission units in the power generation sector have turned their quota deficits into surpluses through technological transformation, with a total surplus quota of 58.25 million tons, forming a market incentive mechanism in which carbon emissions incur costs and carbon reduction brings benefits.

In the global climate governance, China, on the one hand, actively communicates with developed economies such as the EU and the U.S. to promote the mutual recognition and convergence of accounting methodologies, MRV systems and trading rules. On the other hand, China supports Africa, Southeast Asia and other regions in enhancing their capacity for standards development and implementation through South-South cooperation, technical assistance, training on standards and other means.

At the recent meeting of the WTO CTE, China noted that it is willing to explore multilateral cooperation paths for the coordination of carbon-related standards with other parties to address the common concerns of WTO members as developing countries.

In China, the efforts on carbon standards in the new era show three distinct characteristics: firstly, adhering to a problem-oriented approach and constantly improving the standards system for the priorities of the dual carbon work; secondly, focusing on technological innovation and promoting the application of technologies such as blockchain and artificial intelligence to facilitate standards implementation; thirdly, emphasizing multi-stakeholder governance and forming a pattern of collaborative advancement by the government, enterprises and research institutions.

The standards implementation model developed by China features government guidance, market-driven forces, social participation, scientific research collaboration and service extension, and provides an effective path for the implementation of carbon standards across the globe.

Building an inclusive new order for global standards

As global climate change intensifies, the international community is paying growing attention to carbon emission reduction. Carbon standards, as a vital tool for climate governance, have made their development a focal point among countries.

At the COP30, trade-related topics were officially included into the discussions of the conference. The outcome document explicitly opposes the setting of unilateral trade barriers in the name of climate action, emphasizing that international trade rules should serve the popularization of clean energy technologies and sustainable development. In the final resolution, all countries reached a consensus to establish the Integrated Forum on Climate and Trade (IFCCT) for dialogues on issues such as carbon border measures and low-carbon product standards. This mechanism is mainly designed to provide a communication channel rather than formulate unified rules.

The path to building an open, fair and inclusive rule system of international standards for climate change is fraught with challenges. Driven by considerations such as protecting domestic industries and maintaining technological advantages, countries have introduced differentiated standards.

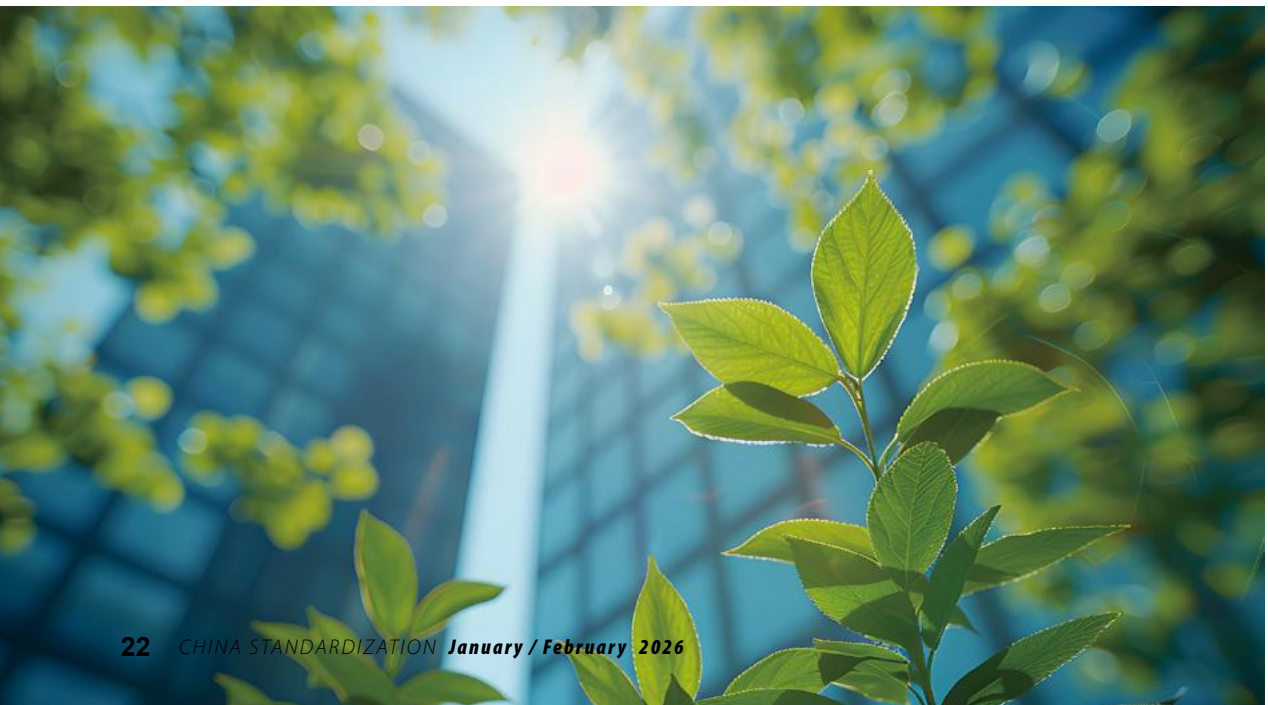
For example, the EU's CBAM has imposed multiple compliance burdens on enterprises. Under such background, both the political will and technical feasibility are facing tests to promote the harmonization of global standards. Even in developing countries, there are significant disparities in standards development capabilities. How to design a hierarchical standards path tailored to the national conditions of various countries and avoid exacerbating inequality is an issue that global climate standards must address.

The COP30 witnessed a historic turning point in the global carbon standards system. China is both an active participant and an important leader in the process. Through various forms such as standards mutual recognition, capacity building and South-South cooperation, China is advancing the development of a global carbon standards governance system that is more equitable, reasonable, inclusive, and orderly, and facilitates win-win cooperation.

On December 5, 2025, at the 5th Carbon Neutrality and Green Development Conference held in Beijing, Daniel Shechtman, Nobel Laureate in Chemistry, called for joint efforts and consensus across industries and communities, as well as international cooperation, to achieve carbon neutrality.

Looking ahead, China will continue to promote international coordination and mutual recognition of carbon-related standards, contributing to the interconnection of the global carbon market. It will also continue to actively share its experience in carbon market development and carbon-related standardization to support developing countries in enhancing their capacity building. As the world's largest developing country, China is fully aware of the challenges faced by developing countries in addressing climate change and participating in carbon standards development.

In a signed article published on December 5, 2025, Ma Weihua, former President of China Merchants Bank and member of the UNDP SDG Impact Steering Group, pointed out that as the country with the largest-scale low-carbon transition in the world, China should leverage its practical experience to drive the upgrading and improvement of the global green and low-carbon standards system.



At the specific design level of the standards system, it is necessary to build an authoritative database system that is measurable, verifiable and comparable, centering on core indicators such as carbon footprint, carbon intensity and supply chain carbon data. The standards system covers the entire life cycle from raw material extraction, production, and transportation to end-use and recycling, ensuring the comparability of data from enterprises or institutions across different industries, countries and regions.

China's practice in carbon-related standards has revealed three core principles. Firstly, the development of standards must align with the level of productive forces, which means that they should not only guide technological progress but also be grounded in reality. Secondly, the coordination of global standards must uphold the principle of fairness, fully taking into account the differences and needs of developing countries. Thirdly, the vitality of standards lies in their application. Only by integrating with market mechanisms, policies and measures can they exert their maximum effectiveness.

Looking forward, China's carbon standards development has entered a new historical stage. Nevertheless, it should take into account that the global landscape of carbon governance is still confronted with challenges such as the impact of unilateralism, the intensification of standards fragmentation and the widening North-South gap. China will adopt an open and inclusive stance, demonstrate Chinese wisdom and responsibility in the field of carbon-related standardization, and work together with countries around the world to march toward a green and sustainable future.

In the days to come, the story will continue to unfold. Each chapter of it will embody the commitment to green development, the pursuit of fairness and justice, and the responsibility for the common future of humanity. This is precisely the most touching core of China's story about carbon standards.

翻译/靳吉丽

(Translated by Jin Jili based on the article published in the Chinese magazine *China Stanardization* in December 2025)

Stakeholder partnership in the development of standardization activities

在标准化工作中与利益相关方建立合作关系的重要性

By Dr. Zaki Al-Rubaei
文/扎基·阿尔–鲁贝伊

Introduction: The choice is no longer whether—but when and how!

Today, organizations can no longer choose whether or not to engage with stakeholders; the only real decision is when and how to do it successfully.

Engaging stakeholders is essential for any type of organization, public, private, or civil society. In fact, it is a fundamental part of effective governance, continuous improvement, and social responsibility. The principle behind stakeholder engagement is simple yet powerful: those who can influence or be affected by an organization's mission must be given the opportunity to express their views and contribute to shaping the decisions that impact them.

Organizations that fail to engage stakeholders proactively will eventually be forced to do so reactively, often under pressure from economic actors, rising public awareness, or fast-changing technologies and crises. Such defensive engagement tends to be costly and reputation-damaging, eroding trust among all parties involved.

Meaningful engagement, on the other hand, reflects a willingness to listen, communicate, and adapt. It allows organizations to reconsider their strategies, realign decisions, and find balanced solutions that generate value for everyone, businesses, society, and stakeholders alike.

Modern organizations and stakeholder relations

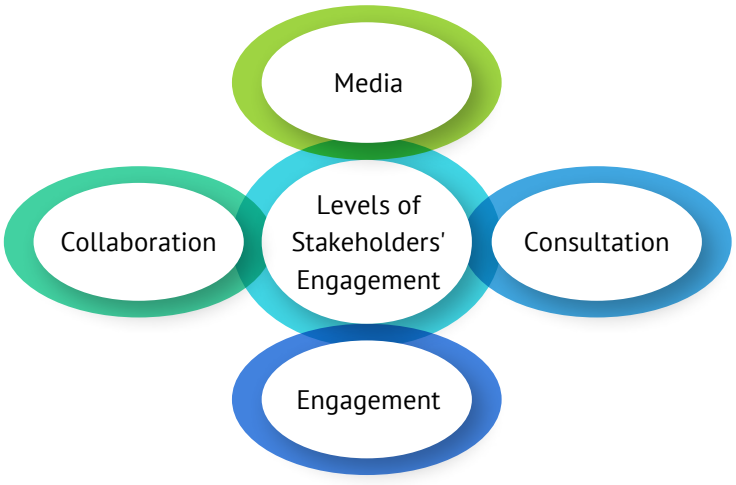
Forward-looking organizations that understand the dynamics of modern business recognize that stakeholder relations are not optional; they are a strategic necessity. By building trust-based partnerships, organizations can better manage risks, anticipate change, and turn challenges into new opportunities for sustainable collaboration.

Like any other strategic process, stakeholder engagement must be structured and systematic, spanning from early planning and goal setting to monitoring, evaluation, and continuous learning. It is not a one-time consultation for public display, but a recurring institutional process that strengthens relationships, mutual understanding, and accountability over time.

Standardization and stakeholders

In ISO terminology, a *stakeholder* is any individual or group that has an interest in an organization's decisions or activities. This includes customers, employees, suppliers, investors, regulators, and society at large.

Within standardization, engaging stakeholders has become a cornerstone of modern practice. National, regional, and international standardization bodies recognize that effective consultation and participation are essential to widening awareness, understanding expectations, and aligning technical work with real market and social needs.



Stakeholder engagement in standardization ensures that standards and technical regulations serve the public interest by focusing on the needs of users, businesses, and civil society. It strengthens both public and private sectors and enhances the overall quality infrastructure, creating coherence across national, regional, and global standardization systems.

Through their expertise, research findings, and feedback, stakeholders help improve the relevance, quality, and inclusiveness of standards and regulations, fostering ownership, trust, and compliance. The earlier stakeholders are involved in developing or commenting on standards, the more effective and credible the outcomes become.

Transparency and notification: a global obligation

Many countries and standardization bodies now publish their draft standards and regulations systematically through official channels, inviting public consultation. This practice promotes transparency, widens participation, and enhances awareness.

At the international level, organizations such as the ISO and the World Trade Organization (WTO) treat stakeholder consultation and public notification as fundamental principles of standard and regulation development.

For example, under the WTO's Technical Barriers to Trade (TBT) and Sanitary and Phytosanitary (SPS) Agreements, member states are required to notify and consult both domestically and internationally—via the e-Ping notification system—allowing at least 30 to 60 days for comments on draft mandatory regulations. Neglecting to consider such feedback may be treated as an unjustified technical barrier to trade.

GSO initiatives for stakeholder partnership

The GCC Standardization Organization (GSO) is deeply committed to enhancing stakeholder partnerships. It encourages all sectors:

- profit-based entities such as manufacturers, traders, and importers;
- non-profit institutions such as laboratories, universities, research centers, regulators, and consumer protection groups, to actively participate in standardization activities.

GSO views these partnerships as complementary and integrative roles that strengthen cooperation, knowledge exchange, and capacity building. Examples of key GSO initiatives include:

- The Stakeholder Participation Initiative for developing Gulf standards and technical regulations;

- The Gulf Cooperation Groups of Notified Bodies;
- The Economic Operators Forum;
- The Open Day for Economic Operators;
- The Gulf Regulatory Coordination Network (GRC-Net);
- The Unified Gulf Notification System aligned with WTO procedures.

Meetings of the Gulf Cooperation Groups for Notified Bodies in May 2024

Meetings of the Notified Bodies - Working Groups (2025) on December 7, 2025

Standardization Ambassadors Forum in May 2024

Sixth Gulf Open Day for Economic Operators in Dubai in May 2024

Benefits and added value: engagement, enrichment, compliance

Building meaningful relationships with stakeholders generates value across multiple dimensions:

- Consumer and environmental protection, improved public health, and reduced technical barriers to trade;
- Lower costs for manufacturers through early alignment with standard requirements;
- Higher quality outcomes, ensuring standards better reflect real market and consumer needs;
- Easier implementation of standards and regulations supporting sustainability, climate action, food security, and innovation;
- Knowledge exchange among technical committees, experts, and stakeholders;
- Enhanced innovation, as diverse perspectives lead to creative, practical solutions;
- Broader professional networks that foster future partnerships and trust;

• Richer discussions and inclusive decision-making, reflecting the diversity of stakeholders affected by standards;

• Greater credibility and transparency, reinforcing public trust in the standardization process;

• Expanded opportunities for cooperation, such as joint training, events, and research.

These benefits demonstrate that stakeholder engagement is not a procedural formality, but a strategic investment in relevance, trust, and sustainable growth.

Core principles for effective engagement

For stakeholder participation to be truly effective and dynamic, standardization bodies should:

• Facilitate and simplify participation for all interested or affected parties;

• Seek input from stakeholders on how they prefer to be engaged;

• Provide clear, timely information enabling meaningful involvement;

• Encourage dialogue and acknowledge all viewpoints, including those of decision-makers;

• Ensure that stakeholder voices are heard in decisions that affect people, markets, and the planet;

• Provide transparent feedback showing how contributions influenced the final decisions.

Governance: The foundation of trust

Engagement must not be spontaneous or symbolic—it requires good governance. Standardization organizations must ensure fair representation, balanced participation, and avoidance of dominance by any single group. Properly governed engagement processes guarantee that the priorities, expectations, and needs of all stakeholders are met transparently and equitably.

Partnership in standardization and quality is not merely an option—it is a necessity for excellence and global relevance. Building strong relationships leads to exceptional results and better serves end-users and society.

To achieve this, standardization organizations should develop and implement a structured roadmap that enhances and institutionalizes stakeholder participation—from identifying and analyzing stakeholder groups to understand their expectations and aligning activities with shared benefits.

This strategic perspective sets the stage for the next article entitled How to Design a Roadmap for Stakeholder Engagement in Standardization Development, which will explore in detail the methods and tools to build such an effective roadmap for the future of smart, participatory standardization.

About the GCC Standardization Organization (GSO)

The GCC Standardization Organization (GSO) is the official regional standardization body of the Gulf Cooperation Council, established pursuant to a resolution of the GCC Supreme Council in 2001 and operational since 2004. Its membership comprises the GCC Member States and the Republic of Yemen.

GSO is mandated to develop and harmonize standards, technical regulations, metrology systems, and conformity assessment schemes across the GCC region. It supports regulatory convergence, product safety, consumer protection, and the facilitation of intra-regional and international trade.

GSO has developed more than 29,000 Gulf standards, with approximately 94% aligned with international standards, and administers unified conformity assessment systems, including the Gulf Conformity Mark (G-Mark). Through international cooperation, digital regulatory tools, and capacity-building initiatives, GSO contributes to reducing technical barriers to trade and strengthening the region's integration into the global standardization and trading system.

About the author:

Dr. Zaki Al-Rubaei serves as Head of International Cooperation at the GCC Standardization Organization (GSO) in Riyadh, Saudi Arabia. He holds a PhD in Management Sciences, with specialization in Leadership and Organizational Development, and has more than 27 years of professional experience, including over 18 years dedicated to regional and international standardization.

Throughout his career, Dr. Al-Rubaei has played a key role in strengthening the Gulf standardization system and expanding its global engagement. He has led and coordinated international cooperation with more than 80 regional and international organizations, including ISO, IEC, WTO, ITU, CODEX, and UNIDO, and has represented GSO in numerous high-level international forums and negotiations.

His professional focus lies at the intersection of standardization, trade facilitation, institutional development, and sustainable development. In parallel with his executive responsibilities, he is an author, writer, and certified trainer and consultant. He has directed several training and capacity-building units and has delivered numerous professional programs in leadership, management, and standardization at regional and international levels.

Diversity, youth and future-oriented standardization

Interview with **Rachel Miller Prada,** ISO Capacity Building Project Manager

标准化工作要着眼于多样化、年轻人和未来

—专访ISO能力培养项目经理 **瑞秋·米勒·普拉达**

China Standardization: **Can you please briefly introduce ISO, its international standards as well as your scope of work?**

Rachel Miller Prada: ISO is an independent non-governmental organization dedicated to developing international standards. Currently, ISO has 175 member bodies, representing 175 countries that participate in its standard development work. We have a portfolio of over 24,000 international standards, with around 100 new standards issued or existing ones revised every month.

The ultimate goal of our standardization work is to support the achievement of the United Nations Sustainable Development Goals (SDGs). Every standard we develop and every task I undertake in my role contributes to these global objectives.

ISO international standards are designed to advance clean energy access, safe drinking water supply, quality of life improvement, gender equality, food security and more—all of which are pivotal to realizing the SDGs.

ISO's strategic framework is built around three core pillars, one of which is ensuring all voices are heard. To this end, we prioritize the participation of women, young professionals and representatives from developing countries in standardization processes. We have compiled data on the age distribution of technical experts involved in ISO's work worldwide, as shown in Figure 1-2.

Unsurprisingly, the majority of ISO technical committee members are 45 years old or above. What I would like to draw your attention to, however, are two age groups: professionals under 25, and those aged 35-44. At ISO, a "young professional" is defined as someone 35 years old or younger and there is a striking underrepresentation of young talent in our standardization work.

Notably, among younger technical experts, women account for a larger share of participants. But as the age of experts increases, this trend reverses, with men becoming the majority in ISO technical committees. The participation rate of women aged 25-30 drops sharply, and many women exit the field of standardization altogether at this stage.

Figure 1-2: The age distribution of technical experts involved in ISO's work worldwide

While we cannot pinpoint the exact reasons, we can make reasonable assumptions about the life changes women experience around this age—marriage, child-rearing and shifting life priorities, all of which are completely understandable. The critical issue is that once women leave the technical domain, they rarely return. This raises key questions for us: How can we retain women in standardization work? What barriers can we remove to facilitate their participation? And how can we attract them back to the field after stepping away?

It is also interesting to look at the data from China. Chinese technical experts participate in ISO's work at the international level, and we observe the same trend: a large number of young women engage in technical standard development initially, but their participation rate declines significantly over time, with most not returning to the field after leaving.

This is a challenge ISO is actively addressing. We recognize the problem and are exploring solutions to keep women engaging in standardization work, or to encourage their return after their childbearing and family-focused years.

In terms of supporting our members to attract and engage young professionals in standardization, we have launched an education program that serves as a platform for knowledge and experience sharing. Many ISO members are already making substantial efforts to involve young professionals and students in standardization activities—but we need to enable collective learning and peer-to-peer knowledge exchange across the global network.

I am pleased to note that the International Standardization Outstanding Contribution Award Foundation and SAC in China are doing excellent work in this regard as part of the network.

As part of the education program, we have developed a game called **Standard Quest** to engage young audiences. It is a fun, dynamic and completely free tool that helps users understand ISO international standards and their impact on daily life. You can download and play the game via this link: **https://standardquest.iso.org/app/**. A Chinese version of the game is also available—feel free to play it with your friends, colleagues and family members.

Why is it so important to attract young people to engage in standardization work?

Rachel Miller Prada: Standardization is a never-ending endeavor. As technology advances and new social and technological needs emerge, we require technical expertise from every sector, because standards touch nearly every aspect of our lives. We must continuously cultivate and engage the next generation of talent, as they are the future of this field.

Young people bring fresh perspectives, innovative ideas and insights into emerging standardization needs. Engaging them at an early stage allows them to contribute to standardization throughout their entire professional careers.

Rachel Miller Prada delivers a speech at the International Standardization Youth Star Competition 2025 in Qingdao, China.

For young people, what benefits can they gain from learning more about standards and participating in standardization activities?

Rachel Miller Prada: First, from ISO's perspective and that of our members, young people inject new experiences and ideas into the standardization community. This helps us stay attuned to evolving trends, emerging technologies and shifting societal interactions.

Second, for young professionals themselves, expertise in standardization is a highly marketable skill that sets them apart from their peers. Standardization is a specialized field, and many companies participate in ISO's standard development work at the international level. Having the experience of sitting at the technical table with these companies equips young professionals with in-depth knowledge of standard development—knowledge that becomes a valuable asset when applying for jobs or attending interviews, opening doors to more career opportunities.

What is your opinion of this year's International Standardization Youth Star Competition?

Rachel Miller Prada: I have been fortunate enough to be involved in this competition since its very inception. I have witnessed its growth year after year: more student participants, new thematic tracks and growing pride and satisfaction among the organizing foundation and team. The competition has enormous potential and continues to expand, even its venue rotates among different cities each year. I am very much looking forward to watching its continued growth in the years to come.

From left to right: Erik Vladimir Simić, SIST Young Standardization Ambassador, Rachel Miller Prada, Xu Shanshan, Secretary-General of International Standardization Outstanding Contribution Award Foundation, Tom Heilandt

What advice would you give to university students who aspire to work at international organizations like ISO? What skills are the most important?

Rachel Miller Prada: When it comes to working at international organizations, English proficiency is a fundamental skill. Standardization work at ISO is conducted primarily in English, so you need to be able to articulate your experiences and ideas clearly and concisely in the language.

Given the international nature of the sector, you will interact with people from all over the world—individuals with different ways of thinking and expressing themselves. It is crucial to be comfortable in such diverse environments, respect these differences and view them as opportunities to broaden your horizons and enrich your own experiences, rather than seeing them as barriers.

I have noticed that some Chinese university students are relatively shy and struggle with public speaking. I think this is a common issue among the younger generation globally, as people are increasingly reliant on mobile phones and computers for communication, leading to a decline in face-to-face interactions. This is not unique to China, it is a phenomenon we see across Europe, the United States, Australia and beyond.

It is important to remember that standardization work is about engaging with people, not machines. When you sit around the table with other experts, the goal is to reach a consensus. This requires the ability to adapt to different cultures and languages—a key skill in standardization work. Unfortunately, there is no shortcut to developing this skill; it takes time and practice to become comfortable. Public speaking, for example, is a skill that improves only with deliberate practice. There are no secrets to mastering it. You just need to keep practicing until you feel confident. CS

Confidence and continuous learning:

Key for Chinese students to engage in international standardization work

Interview with **Tom Heilandt**, Secretary-General of the International Federation for Sustainability and Justice, former Secretary of the Codex Alimentarius Commission

增强自信和不断学习是中国大学生参与国际标准化工作的关键

—专访国际可持续性和公正联合会秘书长、国际食品法典委员会前秘书长 **汤姆·海伊兰特**

China Standardization: **What is your view on this year's International Standardization Youth Star Competition?**

Tom Heilandt: This is the first time I have attended this event, which was founded by my good friend Dr. Zhang Xiaogang, whom I first met in 2016 when he was President of ISO. It is an excellent initiative. I strongly believe that it is essential for young people to become involved in standardization.

Standards are the building blocks of civilization. Without standards, progress would slow dramatically, and each generation would have to reinvent what already exists. At the same time, standards must continuously evolve to respond to new requirements, new thinking, new technologies, and new energy. The competition plays an important role in stimulating young people's interest in standards.

I have worked in standard setting for more than 30 years and have never lost interest in it. One reason is that standardization demonstrates what people can achieve through cooperation. No one can develop standards alone. Bringing experts together, supporting constructive discussion, and reaching agreement on a final text is both challenging and deeply rewarding.

Tom Heilandt with the editorial team of *China Standardization* magazine

Three students delivered speeches in English today. How would you assess their performance?

Tom Heilandt: All three students were very well prepared and demonstrated a strong command of English. The student who was selected distinguished herself by telling a story with a strong human dimension, clearly explaining why standardization matters. This approach showed creativity, confidence, and effective communication, which I found particularly impressive.

What advice would you give to university students who wish to work in international organizations such as the United Nations? What skills are most important?

Tom Heilandt: First and foremost, language skills are essential. Chinese students already possess a very powerful language—Chinese—but they need at least one additional working language, such as English, French, Spanish, Arabic, or Russian. English remains the main working language in most UN organizations and is therefore indispensable. The higher the level of proficiency is, the better the opportunities are. Knowledge of a third language can further distinguish a candidate.

It is also important to continue learning throughout one's career. This includes languages, information technology—especially artificial intelligence—as well as personal skills such as presentation, negotiation, and intercultural communication.

Chinese students receive excellent technical education and are known for their strong work ethic. In international meetings, I have sometimes observed that Chinese experts are hesitant to speak. When asked, some explained that they felt it was not polite to speak up. I experienced similar feelings when I was younger and initially found public speaking challenging. Over time, I realized that a discussion is simply a conversation—whether with two people or with one thousand—and I gradually came to enjoy it.

I would also encourage students to take calculated risks when applying for international positions. When I had my first interview with the United Nations, I already had a job I enjoyed in the private sector. I was told that I might need to perform support tasks for several years before taking on independent responsibilities. I replied honestly that this would not be acceptable to me. It was a risk, but it helped clarify expectations and ultimately worked in my favor.

Chinese students should be confident in their abilities. Their education is strong, and there is no reason to step back in international environments. International careers are not for everyone, and opportunities are limited, but this should not discourage those who genuinely wish to contribute to global cooperation and to making the world a better place. CS

About Tom Heilandt:

Tom Heilandt is a senior international expert in food safety and standardization, with more than 30 years of experience in the development, governance, and implementation of international standards. From 2014 to 2023, he served as Secretary of the FAO/WHO Codex Alimentarius Commission, the principal international body responsible for food standards, guidelines, and codes of practice. In this role, he supported consensus-based decision-making among more than 180 member countries, including China, and observer organizations from government, industry, and academia.

Mr. Heilandt has longstanding experience in supporting China's engagement in international standardization. He has worked closely with Chinese competent authorities, scientific institutions, and experts to facilitate effective participation in international standard-setting processes and to promote consistency between national systems and international food safety standards. He has also contributed to advisory activities related to food safety risk assessment and science-based regulatory cooperation.

Earlier in his career, Mr. Heilandt held senior positions at the United Nations Economic Commission for Europe (UNECE), where he was responsible for international agricultural quality standards, and at FAO in Geneva, where he led engagement with private sector stakeholders. In addition to serving as Secretary General of the International Federation for Sustainability and Justice, a newly established Vienna based think tank, he currently advises international organizations, industry platforms, and policy initiatives on food safety, sustainability, and standards governance, working from Hong Kong and Europe.

In 2024, he received the Chinese Government Friendship Award in recognition of his contribution to China–international cooperation in food safety and standardization.

International Standardization Youth Star Competition 2025 inspires young students

2025国际标准化青年之星大赛激励学子投身标准化事业

By Fang Luofan
文/方洛凡

The final and award ceremony of the International Standardization Youth Star Competition 2025 were held in Qingdao on November 22-23. The competition attracted 236 teams nationwide who demonstrated great enthusiasm for participating in the standardization undertaking.

The competition followed the mode of "the industry puts forward questions, and the academia provides solutions". Shandong Port Group Co., Ltd., Contemporary Amperex Technology Co., Ltd. (CATL), Huawei Technologies Co., Ltd., and Beijing Zhongbiaolvjian Engineering Design and Research Institute Co., Ltd. set up themed tracks respectively, and competitors developed standard proposals for the corresponding themes.

The International Standardization Youth Star Competition was initiated by the International Standardization Outstanding Contribution Award Foundation (ISOCAF) in 2023 for the sake of public welfare, and was held annually since then. The event builds a platform to bring together enterprises, institutions and universities, which brings opportunities for young students to showcase their capabilities, and provides outstanding young talent for enterprises. A total of 14 teams entered the final. After on-site presentations and defenses, the judges evaluated the teams, and determined the medalists of the four tracks.

The Special Contribution Award was given to Fudan University, the Institute of Standardization of China Academy Machinery Science and Technology Group Co., Ltd., and Qingdao Harbor Vocational & Technical College for their support for the competition.

The 2025' ISOCAF Youth Ambassador Final was held during the award ceremony, where students competed on the spot by giving English speeches. After on-site voting, Qiu Yunyi from China Jiliang University was honored as the Youth Ambassador, and Zhang Ziyang from Qingdao University and Huang Jiahui from Civil Aviation Flight University of China won the title of Youth Star.

Zhang Xiaogang, former President of ISO and Founder of ISOCAF, made a welcome speech to the event. The award ceremony was addressed by Li Zhiping, Vice President of China National Institute of Standardization (CNIS), Zhang Yongyan, Director of Qingdao Administration for Market Regulation, and Xu Guowang, Senior Executive Manager at Shandong Port Group/Party Secretary and Chairman of the Shandong Port Vocational Education Group/Party Secretary of Qingdao Harbor Vocational & Technical College.

A salon entitled "Cross-Domain Talks on Standardization" was held during the event. Focusing on standardization talent cultivation in universities, the experts introduced and discussed demands of different industries for standardization talent. A more closely-connected collaborative platform was established through dialogue and exchange, empowering more youth to thrive in the field of standardization. It has created new opportunities for the cooperation between schools and enterprises in the field of standardization, and injected long-lasting vitality into the development of standardization in China.

The salon brought together experts from the industry and academia, including Zhang Hongbo, Director for Standards and Regulations at CATL, Wang Tao, Director of Enterprise Management Department at Qingdao Port Co., Ltd. of Shandong Port Group Co., Ltd., Cai Chengjun, Vice President and Deputy Secretary-General of China Association for Engineering Construction Standardization, Zhou Wei, Director of Automotive Transport Research Center at the Research Institute of Highway of Ministry of Transport, and Ru Peng, Vice President of the Research Institute of Intelligent Social Governence and Professor at School of Public Policy & Management of Tsinghua University.

A flag-handover ceremony was held to announce that the International Standardization Youth Star Competition 2026 is set to take place in Guangzhou, Guangdong Province. Witnessed by Xu Shanshan, Secretary-General of ISOCAF, Long Jian, Deputy Director-General of Qingdao Administration for Market Regulation, passed the competition flag to Ding Li, Deputy Director-General of Guangzhou Administration for Market Regulation. The Guangdong-Hong Kong-Macao Greater Bay Area (GBA) has abundant technological innovation industries and educational resources. The GBA standards, jointly implemented by Guangdong, Hong Kong, and Macao, have become a vital tool to align rules within the region, serving as a valuable exploration of China's institutional opening up.

Xu Shanshan delivered the closing address, noting that "though silent, standards regulate all things; though invisible, they shape the order of all". She promised that the ISOCAF will continue to leverage public welfare to better empower the cause of standardization. "Let us join hands to ignite a spark through standardization, lighting the way forward for more young scholars," she emphasized.

Directed by ISO Central Secretariat and the Standardization Working Committee of the All-China Federation of Industry and Commerce, the event was jointly hosted by ISOCAF, CNIS, Qingdao Administration for Market Regulation, and Shandong Port Group Co., Ltd. It was co-organized by the Institute of Standardization of China Academy Machinery Science and Technology Group Co., Ltd., China Automotive Standardization Research Institute, China Association for Engineering Construction Standardization, and Qingdao Institute of Standardization.

Winners of the International Standardization Youth Star Competition 2025

Smart and Green Port——Shandong Port Track

Civil Aviation Flight University of China — Gold Medalist

Suzhou Chien-Shiung Institute of Technology — Silver Medalist

Fudan University — Bronze Medalist

New Energy Battery——CATL Track

Research Institute of Highway of Ministry of Transport — Gold Medalist

Qingdao University — Silver Medalist

Tsinghua University / China Jiliang University — Bronze Medalist

Short Range Communications——Huawei Track

Southwest Jiaotong University — Gold Medalist

China Jiliang University — Silver Medalist

Two teams from Sichuan University of Science and Engineering — Bronze Medalist

Engineering Construction——Zhongbiaolvjian Track

Guangxi University — Gold Medalist

Qingdao University — Silver Medalist

Beijing University of Technology — Bronze Medalist

National development requires the younger generation to cultivate the standardization consciousness and mindset

The International Standardization Youth Star Competition is held for three consecutive years. We have witnessed continuous improvement in the competition each year, which is a result of our collective efforts.

On October 15, the State Council held a study session under the theme of "Strengthening the leading and safeguarding role of standards, and promoting high-quality economic development through standards upgrading". Why is standardization receiving such significant attention in China today? It is because China is transforming toward high-quality development. To achieve high quality, high standards must come first. Our competition is precisely an activity that promotes China's transition to high-quality development.

For students on this stage today, no matter what awards you have won, you have already achieved success. Standing out among over 230 teams nationwide is a success and an excellent learning opportunity. The nation's development needs the younger generation to cultivate the consciousness and mindset of standardization, and genuinely contribute to China's high-quality development, so as to realize your own life value.

I would like to extend special thanks to several enterprises for their strong support of this competition, to the market regulatory authorities at all levels for their support and assistance, to all the distinguished guests and experts for their active participation, to the mentors and students of various teams supporting this competition behind the scenes, and to all the staff.

We hope to develop this competition into an international standardization contest for university students. I am very pleased to see us moving step by step toward this goal. Thank you for your joint efforts to leverage standardization to help the world sing the same tune.

Zhang Xiaogang,
former President of ISO and Founder of the International Standardization Outstanding Contribution Award Foundation

Guiding the younger generation to explore new scenarios for participating in standards development and application

Li Zhiping,
Vice President of China National Institute of Standardization (CNIS)

Standards are the common language that consolidates global consensus and builds the most solid foundation for international partnerships. They are the cornerstone for global sustainable and high-quality development. Young students, with their active and vibrant minds, represent the future and hope of standardization.

The ISO Strategy 2030 proposed to encourage the next generation of experts to extensively participate in international standards development. China's National Standardization Development Outline also emphasizes strengthening the development of the standardization talent pool, piloting the integration of professional and standardization education, and promoting the integration of industry and education in standardization through encouraging higher education institutions to collaborate with standardization research institutes, enterprises, and public institutions. In this regard, as a professional institution engaged in standardization research, CNIS is committed to exploring the construction of the standardization discipline, the establishment of a standardization knowledge system, and the cultivation of the standardization talent pool.

We are also delighted to see that this competition has conducted creative explorations and beneficial attempts in areas such as standardization talent cultivation.

First, it starts from learning, guiding the younger generation to actively explore new scenarios for participating in standards development and application. True knowledge comes from practice, and participation is the best way to learn. During this competition, the participating students, centered on the topic of each track, independently determined technical routes, proposed standardized solutions, and drafted standards proposals under the guidance of experts. This process greatly facilitates their understanding of standards and standardization work, and promotes new explorations in the application scenarios of standards development.

Second, it is driven by innovation, directly addressing new topics in cutting-edge and hot fields of standards both domestically and internationally. Focusing on the frontiers of technology and industrial development, this

competition has established four tracks: new energy batteries, short-range communications, smart and green ports, and engineering construction. These are all cutting-edge hotspots and development directions in technological advancement and industrial upgrading globally, reflecting the sensitivity and insight of all participants toward standards for key emerging technologies. It also effectively responds to the concerns of international standardization organizations regarding strategic issues such as sustainable development, helping to promote a new vision where standards lead industrial development.

Third, it takes practice as the stage, showcasing new pathways for standardization development in the new era. Having industries pose the questions and academia provide the answers is the biggest highlight of this competition. It allows young students to simulate the real-world scenarios of research work around specific themes. The competition continuously cultivates young people's observation skills and innovative thinking, demonstrates the rigorous, standardized, and meticulous spirit of the participating teachers, students, and review experts, and enables all participants to appreciate the productivity created by combining standardization concepts and methods with practice, thus provoking the vitality of standardization in the new eras.

Looking ahead, we have entered the era of artificial intelligence. Standards digitalization and intelligence are flourishing, and AI empowerment is profoundly influencing and changing the patterns and ecosystem of standardization. We look forward to an "AI-empowered standardization" track in the future competition, to encourage young students to boldly explore and innovate in the paths, methods, and tools of "AI + standardization".

CNIS is also very willing to leverage its own advantages and platform to provide necessary support for the competition, working with all parties to jointly advance the pace of "AI + standardization" and inject new momentum into standardization development.

Qingdao helps promote the innovative integration of standardization education and youth talent cultivation

Zhang Yongyan,
Director of Qingdao Administration for Market Regulation

The third International Standardization Youth Star Competition is held in Qingdao. We are very pleased to see that 236 teams from renowned domestic universities are actively participating in the competition. ISO has also sent a representative to Qingdao, demonstrating its high level of attention and support for the competition.

This competition focuses on standardization and innovation. It aims to inspire the enthusiasm of young people to learn, use, and write standards, converging into a continuous stream of youthful energy for the standardization cause in China and globally. Qingdao has always attached great importance to standardization work, actively organizing and implementing the "Standardization +" strategic action, becoming one of the first seven Standard Internationalization Innovative Cities in China to pass acceptance. Qingdao has consecutively hosted five Qingdao Forums on International Standardization, creating a high-level international dialogue platform globally where standard managers, developers, and users jointly participate, build consensus, and cooperate closely.

The International Standardization Talent Training and Exchange Base (Qingdao) is the only international standardization training base established by ISO in China. It has already hosted 8 sessions of ISO regional training courses, covering 42 countries across East Asia, South Asia, Southeast Asia, West Asia, Eastern Europe, Oceania, and other regions, cultivating a total of 233 international standardization experts. It has also conducted 40 sessions of offline and online public welfare training globally, training over 5,300 participants cumulatively, establishing a full-chain talent cultivation system covering general education, professional training, practical exercises, and international exchange.

Young contestants are the rising stars of the standardization cause and future participants, promoters, and even leaders in international rule-making. This competition promotes the integration of industrial upgrading and talent cultivation through standardization. The professional competence, innovative thinking, and international perspective demonstrated by the contestants in this competition are admirable and fill us with confidence in the future of the standardization cause.

SPG contributes wisdom and strength to cultivating international standardization talent

Established in 2019, the Shandong Port Group (SPG) comprises four port groups (Qingdao Port, Rizhao Port, Yantai Port, and Bohaiwan Port) and 12 business segments. SPG connects 3,345 kilometers of coastline within Shandong Province. Its cargo throughput has consistently ranked first globally for many years, and its container volume growth ranks second globally, forming a port cluster covering the entire industrial chain. It is also a world-class port cluster that bears the major mission of serving national strategies and promoting Shandong's high-quality development.

SPG has always stood at the forefront of opening up, vigorously implementing a standardization innovation strategy and treating standardization as a core tool for modern enterprise governance. With the guidance and support of government departments at all levels and the concern and assistance from all sectors of society, we have built a new "1+5+N" standards system framework. We have established 8 national and provincial-level standardization platforms, including the national pilot for smart green port service standardization, one of the first batch of standard validation stations in the transportation industry, and the working group on green port under SAC/TC 530. We have led or participated in the development of approximately 200 international, national, sectoral, and association standards, and developed and applied about 3,600 enterprise standards. SPG has hosted events such as the Qingdao Forum on International Standardization, using standardization innovation to empower high-quality development. As the organizer of this competition, the Shandong Port Vocational Education Group focuses on the needs of the port and shipping industry, and integrates vocational education and training resources, to build a comprehensive, integrated skill talent cultivation system.

As the flagship of the Shandong Port Vocational Education Group, Qingdao Harbor Vocational & Technical College, since its founding in 1975. It has innovated an integrated and standardized educational model, offering 42 port and shipping characteristic majors. The graduate employment rate has remained above 98% for many years. The college has cumulatively supplied over 80,000 high-quality graduates to the national port and shipping industry and trained more than 100,000 trainees. It has been successively approved as one of the National Backbone Higher Vocational Colleges, and the Demonstration College for Vocational Education under the Ministry of Transport.

Xu Guowang,
Senior Executive Manager at Shandong Port Group; Party Secretary and Chairman of the Shandong Port Vocational Education Group; Party Secretary of Qingdao Harbor Vocational & Technical College

The intelligent leap of wireless short-range connection

Wan Lei,
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Founded in September 2020, the International SparkLink Alliance (iSLA) now has approximately 1,200 members in diverse sectors including terminals, homes, vehicles, manufacturing, transportation, finance and healthcare. The iSLA has established a technical standards system for wireless short-range communication covering full-stack standards such as the end-to-end protocol system. It is composed of three layers, the access layer, the basic service layer, and the basic application layer, which achieves constant iteration with standards upgrade.

The SparkLink 1.0 series standards, released in 2022, have included two communication technologies at the NearLink Access Layer: the Synchronous Low Latency Broadband (SLB) technology and Synchronous Low Energy (SLE) technology. With high-quality service assurance as its core goal, it has achieved mature capabilities in audio, video and basic control.

The SparkLink 2.0 series standards, released in 2024, focus on the Synchronous Link Positioning (SLP) technology, enabling hierarchical positioning of sub-meter, decimeter and centimeter levels. Meanwhile, it has introduced an integrated communication and sensing design. In terms of protocol architecture, it has optimized the core functions of the basic service layer and initially established cross-scenario business interaction channels within the basic application layer.

The SparkLink 3.0 series standards with project approval in August 2025 will further enhance the capabilities of the basic application layer to better support multi-scenario service collaboration and AI applications. Additionally, it will expand passive IoT scenarios at the access layer through SLZ.

With the adoption of the NearLink wireless communication system, the members of iSLA have successively launched products including smartphones, tablets, styluses, mice, speakers, headphones, and televisions, which cover comprehensive application scenarios for humans, vehicles, homes and industrial parks, and gradually enable a complete industrial ecosystem.

The continuous evolution of SparkLink technical standards is essentially driven by the coordinated effect of market demands and technological innovation. In terms of technological innovation, based on the three core modes of SLB, SLE and SLP, the SparkLink 3.0 will incorporate the SLZ mode, which will be completed next year.

SPG achieves remarkable results in standardization work

Shandong Port Group (SPG), which was established in August 2019, regards standardization as the cornerstone of modern enterprise management, and vigorously implements the standardization innovation strategy. Its standardization work mainly focuses on the following four aspects.

Firstly, establishing a new pattern of standardization system through strategic guidance. SPG has built a "1+5+N" standards system framework, and established a standardization working mechanism. At present, 8 standardization platforms at national, ministerial and provincial levels have been settled at SPG.

Secondly, demonstrating new achievements in standardization development with practice empowerment. SPG has formulated and implemented the first "Q (quality) + HSSE (health, safety, security and environment)" management system in China's port industry. It has constructed and operated Asia's first fully automated container terminal, and built the world's first intelligent aerial transportation collection and distribution system and "hydrogen power + 5G" terminal. In addition, it has developed more than 200 international, national, sectoral, local and association standards, as well as over 3,600 enterprise standards, covering management standards, work standards and technical standards.

Thirdly, achieving new breakthroughs in international standards via deepened opening up and cooperation. SPG has taken the lead in developing the first international standard for sustainable development and supply chain services of port cities. It has contributed to the publication of two international standards, with another three under development. SPG has connected more than 700 ports in over 180 countries, and actively invited Hamburg Port of Germany, Port Klang of Malaysia, London Port of the U.K. and other ports to participate in international standards development.

Fourthly, drawing a new blueprint for standardization development with concerted efforts. SPG invests over 5 million yuan annually in the development of standards at provincial and national levels, and organizes training courses to cultivate international standardization professionals. At present, three employees are selected as the international standardization professionals of SAMR and the Ministry of Transport. By promoting international exchanges and cooperation with high standards, SPG has actively collaborated with international standardization platforms such as ISO and the Global Shipping Business Network (GSBN), helping Chinese port standards to go global.

Luo Jian,
Director of Enterprise Management Department, Shandong Port Group

Standards lead the high-quality development of intelligent construction in China

Cheng Zhijun,
Secretary-General of the Working Committee on Intelligent Construction, China Association for Engineering Construction Standardization

To advance intelligent construction, standards must come first. The Ministry of Housing and Urban-Rural Development has issued the List for Replicable Experience and Practices for Developing Intelligent Construction four times successively and the Technical Guidelines for Intelligent Construction (Trial). A number of pilot cities have evaluated intelligent construction projects and enterprise intelligent construction capabilities, and released the list of application scenarios for intelligent construction. In addition, relevant industry associations have developed management standards in the field.

Established in January 2024, the Working Committee on Intelligent Construction of China Association for Engineering Construction Standardization (CECS) aims to build a professional standardization platform to support the industrial transformation and boost the construction industry in China. Its key tasks include standards system building, standards development, and standards implementation.

In terms of standards system building, based on an intelligent construction system architecture, the working committee has built a standards system. This year, it has developed a new standards system consisting of six modules: new industrialization construction, intelligent construction, green construction, collaboration and integration, foundation and synthesis, as well as support and guarantee.

In terms of standards development, the committee has developed standards for intelligent construction in architectural projects, and established an element system and an evaluation indicator system in this field for the first time. It has released standards for evaluating intelligent construction capabilities of enterprises and modular integrated intelligent construction. At present, over 30 standards are under the committee's centralized management, which cover areas such as intelligent construction technologies, intelligent equipment, and engineering application of intelligent construction.

In terms of standards implementation, evaluation and certification are important approaches to promote the application of standards. The scope of evaluation and certification for intelligent construction includes projects, enterprises, personnel, equipment, and software. The committee aims to promote standards implementation through the "standards + evaluation and certification" model, giving play to the role of evaluation in driving construction development.

编译/曹欣欣 靳吉丽

(Edited and translated by Cao Xinxin and Jin Jili based on the speeches)

Standards help shape the future responsibly

标准以负责任的方式塑造未来

By Erik Vladimir Simić 文/埃里克·弗拉迪米尔·西米奇
SIST Young Standardization Ambassador

I come from Slovenia, a small but ambitious country from Central Europe. I study at the Faculty of Electrical Engineering at the University of Ljublgana. I have the privilege of being one of the first young ambassadors of standardization not only in Slovenia but of this generation across the entire world.

As the famous Chinese philosopher Lao Zi once said, a journey of 1,000 miles begins with a single step. For me, the young ambassador of standardization project was exactly that first step. The initiative grew out of the Autumn School of Standardization, a short practice-oriented program that introduces students to the importance of standards in modern society.

The Autumn School combines theory and practice, where participants learned about the role of Slovenian Institute for Standardization (SIST) in the community and its cooperation with CEN, CENELEC, ISO and IEC. They discovered how companies drive to innovate more standards. This year, for the first time, we conclude with a competition during which students propose new national standards based on actual challenges faced by companies.

Erik Vladimir Simić accepts interview during the International Standardization Youth Star Competition 2025 in Qingdao, China.

From this program, the young ambassadors of standardization are born. Our mission is simple as young ambassadors. It is to connect young people with the world of standardization to share its importance and to bring fresh perspectives. Through this role, I have attended numerous events and technical committee meetings, learning how standards strengthen industries, economies, friendships, and cooperation across borders.

One of my proudest moments of this year was helping to bring together numerous student teams to show a true case of how creativity and standardization can go hand in hand. But what I also value most is how these projects spread beyond Slovenia. By presenting here in China, the U.K., Ireland, Croatia, Austria and many more countries, we are building an international network of young people who see standardization not as limitation, but as a platform for innovation and collaboration.

Beyond the technical aspects, this experience has taught me about people, communication, and persistence. Public speaking, which once terrified me, is now something I really enjoy. Each challenge from studies, project deadlines to keeping step with the sheer standardization has been a step for me to become a better and professional person.

I truly believe that standardization is not about documents or regulations, but about people working together for a common goal. It is the foundation upon which innovation safely grows. This is why young people should engage with it, because our creativity, energy, and just a different point of view can bring new life into this global process.

Together, we are proving that the language of standards is the language of progress, cooperation and shared vision. Today, each of you has joined me on this great journey. As world renowned life coach and motivational speaker Anthony Robbins reminds us, “the only impossible journey is the one you never begin”. I encourage you to take that first step, explore this world, attend a seminar, join a working group, or simply learn how standards shape our everyday lives.

By understanding standards, we don’t just learn rules. We learn how to shape the future responsibly. It may seem small now, but it will open doors you have never known existed. This is what happened to me and I truly believe it can happen to anyone of you too.

The youth sail for their future career through joining the competition

在标准的坐标系里寻找青春的答案

By Fang Luofan
文/方洛凡

During the final of the International Standardization Youth Star Competition 2025, *China Standardization* interviewed several teams. In these young students, we see stories of their exploration, perseverance and dreams. The competition has come to an end, but the real journey has just begun: How will this experience change their future pursuit?

China Standardization: **Why do you participate in the International Standardization Youth Star Competition 2025?**

Team from Qingdao University (New Energy Battery Track): We major in standardization engineering, which is quite relevant to the theme of the competition. The competition can help us know the latest trends of international standards. Also, the preparation and presentation process can enhance our logical thinking and expression skills, and improve our English proficiency level. This competition has broadened our international perspective, and enabled us to have a deeper understanding of standards, which is very helpful for our future learning and growth.

Team from China Jiliang University (Short Range Communications Track): China Jiliang University features metrology, standards, quality, market regulation, as well as inspection and quarantine. Our school attaches great importance to standardization talent cultivation. It has set up the Standardization Engineering major and also founded a club named the Standard Study Group. Therefore, we have a strong desire to participate in standards development. Under the guidance of our teachers, we participate in this competition and we sincerely hope to take part in the development of international standards and various types of standards in the future.

Team from Qingdao University (Engineering Construction Track): We all major in standardization engineering, so we are quite interested in this competition. The competition is an innovative event where the industry puts forward the questions and the academia provides the solutions. It is a rare opportunity for us to consolidate our professional knowledge and gain some experience related to enterprises.

Team from Fudan University (Smart and Green Port Track): Our university has launched a standardization course this year. We enrolled in this course and learned from very authoritative and experienced teachers in the field of standardization. The teachers led us to learn standardization knowledge and also recommended this competition to us. We want to seize this opportunity to apply the knowledge we have learned and broaden our horizons.

What is the greatest benefit you have gained from participating in this competition?

Team from Qingdao University (Engineering Construction Track): Throughout the entire process, from the preliminary round to the final, the ability to collaborate is the most important aspect of our team. All of us and our instructor worked together, and the division of tasks was very clear. Additionally, the judges provided some professional suggestions, which gave us a deeper understanding of standardization.

Team from Beijing University of Technology (Engineering Construction Track): Our greatest gain is being able to communicate with the experts. They pointed out the shortcomings of our standard draft, which is very helpful for our future work.

Team from China Jiliang University (Short Range Communications Track): We have gained a deeper understanding of specific standards for communications, the definition of standardization, and the process of standards development. Through a comprehensive review of relevant materials, we found that Huawei's short range communication technology currently holds a leading position globally.

Team from Fudan University (Smart and Green Port Track): What we mainly learned from our courses was theoretical knowledge. By participating in this competition, we learned a lot during the practical process.

Do you think the competition has given you any influence regarding your future career planning?

Team from Beijing University of Technology (Engineering Construction Track): The competition has expanded our career paths. In the future, when we are looking for jobs, we no longer have to limit ourselves to careers that are directly related to our major. We can also consider jobs that are related to technical standards.

Team from China Jiliang University (Short Range Communications Track): To be honest, our majors have little connection with standardization. However, all majors can be combined with standardization, in particular standards development. Therefore, an additional option has been created for our career planning. On the basis of our major, we can also engage in work related to standardization in the future.

Study on the development, applications, and standardization status of environmental DNA (eDNA) technology in China

浅析环境DNA技术发展、应用及我国标准化情况

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Abstract: Environmental DNA (eDNA) technology has revolutionized biodiversity monitoring with its non-invasive, sensitive, and cost-efficient approach. This paper systematically reviews eDNA advancements, examining its applications in aquatic and terrestrial ecosystems and assessing China's standardization progress. It delineates four developmental phases from single-species detection to high-throughput sequencing, and highlights China's contribution to the development of technical standards. While significant progress has been made, challenges persist in quantitative accuracy, methodological consistency, and large-scale implementation. Future efforts should prioritize enhanced standardization, improved quantification techniques, broader applications, and international collaboration to drive innovation in eDNA technology.
Keywords: environmental DNA, development, application, standardization status

1. Introduction

Environmental DNA (eDNA) technology represents a paradigm shift in ecological monitoring, enabling species detection through genetic materials collected from environmental samples rather than direct organism observation. This approach has gained global recognition for its ability to detect rare and elusive species, monitor invasive organisms, and assess biodiversity with unprecedented efficiency[1].

In China, the adoption of eDNA technology has accelerated in recent years, driven by the country's growing emphasis on ecological civilization construction and biodiversity conservation. Recent policy frameworks such as China's Ecological Civilization Construction initiative and the 14th Five-Year Plan for Biodiversity Conservation have explicitly prioritized the development and application of new environmental technologies. The 2025 National Ecological Quality Monitoring Station tender (GPCGD251115FG146F) specifically allocates 470,000 yuan for air eDNA technology protocol and standardization, demonstrating institutional commitment to technological integration.

The technology has been successfully applied in diverse ecosystems, from the Yangtze River basin for endangered species monitoring to coastal regions for invasive species detection. Notably, Chinese researchers have made significant contributions to methodological innovations, particularly in adapting eDNA approaches to local biodiversity challenges.

The standardization of eDNA technology in China has progressed through a multi-level, bottom-up approach, with technical specifications evolving from institutional and regional standards to potential national adoption. This framework has yielded comprehensive protocols across diverse applications, including species-specific identification[2], ecosystem monitoring[3-5], and specialized methodologies[6,7]. Notable milestones include Beijing's DB11/T 2358-2024, which establishes full workflow specifications for benthic macroinvertebrates, and T/CSES 81-2023, which standardizes metabarcoding approaches[8]. These standards, ranging from field collection protocols to laboratory construction requirements[9,10], demonstrate China's systematic effort to create an integrated eDNA standardization framework tailored to its complex aquatic ecosystems.

This paper aims to trace the historical development of eDNA technology and its adaptation, evaluate current applications across different ecosystem types in China, assess the China's status of standardization efforts and identify gaps, and propose future directions for technological advancement and standardization.

2. Development of eDNA technology

2.1 Global technological evolution

The evolution of eDNA technology can be categorized into four distinct generations, each marked by significant methodological breakthroughs[11]. The earliest applications in the 2000s relied on conventional PCR techniques targeting single species, primarily for detecting rare or endangered aquatic organisms. This first-generation technology demonstrated the fundamental viability of eDNA approaches but was limited in scope and throughput.

The advent of next-generation sequencing catalyzed the second generation of eDNA technology, enabling simultaneous detection of multiple species through metabarcoding approaches. This period (2011-2015) saw exponential growth in eDNA applications, particularly in aquatic biodiversity surveys. Researchers developed universal primer sets targeting specific taxonomic groups, allowing comprehensive community assessments from single water samples.

The third-generation innovations (2016-2020) focused on field applicability and targeted detection. Techniques like multiplex PCR and recombinase polymerase amplification (RPA) enabled rapid, specific identification of priority species, particularly valuable for invasive species monitoring and biosecurity applications. These methods reduced reliance on sophisticated laboratory infrastructure, expanding eDNA's potential for routine monitoring.

The current fourth-generation eDNA technology integrates high-throughput sequencing with automated sampling and advanced bioinformatics. The development of metagenomic approaches that bypass PCR amplification has reduced taxonomic bias, while real-time monitoring systems have enabled near-instantaneous biodiversity assessment.

2.2 Technological adaptation in China

Chinese researchers have made distinctive contributions to eDNA technology development, particularly in adapting methods to local biodiversity monitoring needs. The Pearl River Delta eDNA monitoring program represents one of the most comprehensive applications of metabarcoding technology in estuarine environments globally. By employing customized primer sets and locally validated reference databases, the project has achieved remarkable detection sensitivity for both native and invasive fish species.

In the Yangtze River basin, researchers have pioneered eDNA approaches for monitoring critically endangered species like the Chinese sturgeon (*Acipenser sinensis*). These efforts have overcome challenges posed by the river's turbid waters and extensive seasonal flow variations, developing specialized sampling protocols and preservation methods.

Recent technological innovations from Chinese institutions include: High-sensitivity RPA assays for field detection of invasive species; Integrated eDNA sampling systems for deep-water environments; Machine learning approaches for processing complex eDNA datasets from diverse ecosystems.

These technological innovations reflect China's rapid advancements in adapting eDNA methods to its unique ecological challenges, from turbid river systems to complex estuarine habitats. To contextualize these developments, Table 1 traces key milestones in China's eDNA technology progression from early proof-of-concept studies (e.g., amphibian detection in 2012) to standardized protocols (e.g., DB11/T 2023-2022) and cutting-edge applications like airborne eDNA monitoring. Together, these milestones underscore how China's research has evolved from foundational validation to large-scale implementation, shaping both local practices and global methodologies.

Year	Milestone	Significance
2012	First eDNA detection of rare amphibians	Demonstrate feasibility in Chinese ecosystems
2015	Yangtze finless porpoise eDNA monitoring	Establish protocols for large river systems
2018	Pearl River fish metabarcoding study	Largest estuarine eDNA survey to date
2020	Development of portable eDNA detection kit	Enable field applications
2022	Airborne eDNA monitoring in Guangdong	Expand beyond aquatic systems
2023	Beijing's standard for fish and shellfish identification (DB11/T 2023-2022)	The first eDNA technical local standard
2025	*Technical guidelines for distribution assessment of invasive alien aquatic animals based on environmental DNA* for soliciting opinions	The first eDNA national ecological environment sectoral standard

Table 1: Milestones in eDNA technology development in China

3. Applications in Chinese ecosystems

3.1 Aquatic biodiversity monitoring

China's extensive freshwater and marine ecosystems have served as important testing grounds for eDNA technology. Coastal and marine applications have focused on monitoring fish community recovery in protected areas, detecting range expansions of tropical species under climate change, and assessing the effectiveness of artificial reef deployments.

In the Yangtze River system, eDNA monitoring has become an essential tool for tracking populations of endangered species following the implementation of fishing bans and habitat restoration projects. The technology's ability to detect species at extremely low population densities has provided crucial data for conservation planning.

Longitudinal research on detecting the Chinese sturgeon within the Yangtze River basin has shed light on the methodological effectiveness of eDNA techniques in comparison to traditional survey methods for spotting rare and endangered species. The findings indicate that eDNA detection exhibits relatively higher or at least comparable detectability when juxtaposed with traditional survey approaches, such as net-based surveys[12]. Metabarcoding analysis of Dongting Lake water samples achieved 92% species detection accuracy compared to 68% for visual surveys[13].

The South China Sea eDNA monitoring program has established baseline biodiversity data across the region's coral reef systems, employing standardized sampling protocols across multiple research institutions.

3.2 Terrestrial and special ecosystem applications

While aquatic systems dominate eDNA applications, Chinese researchers have made significant advances in terrestrial monitoring. Soil eDNA studies have revealed unprecedented microbial diversity in ecologically sensitive regions like the Qinghai-Xizang Plateau. These investigations have provided new insights into ecosystem responses to climate change and human disturbance.

Specialized applications include: Cave ecosystem monitoring in karst regions; Forest canopy biodiversity assessment; Urban ecosystem studies integrating air, soil, and water eDNA.

The Guangdong air eDNA monitoring project represents one of the first systematic attempts to apply eDNA technology to atmospheric biodiversity assessment, with potential applications in allergen monitoring and airborne pathogen detection.

3.3 Conservation and management applications

The eDNA technology has become integrated into several national conservation programs: national park monitoring networks, invasive species early warning systems, wetland restoration effectiveness assessment, and wildlife trade monitoring and enforcement.

These applications leverage eDNA's advantages in sensitivity, scalability, and cost-effectiveness compared to traditional monitoring approaches. The technology has been particularly valuable in monitoring species that are difficult to detect through conventional means, such as cryptic amphibians and small-bodied fish species.

4. Standardization progress and challenges

4.1 Current standardization framework

China's eDNA standardization efforts have progressed through a multi-level approach, with technical specifications first developed at institutional and regional levels before potential elevation to national standards.

For instance, the Shanghai Environmental Science Society's standards (T/SSESB) for invasive species detection represent pioneering efforts to establish consensus protocols for specific applications.

The Beijing local standard for benthic macroinvertebrate (DB11/T 2358-2024) provides a more comprehensive framework, detailing sampling design principles, field collection protocols, laboratory processing methods, data analysis and interpretation guidelines, and quality control measures.

These standards reflect China's strategy of developing application-specific protocols before attempting broader methodological standardization, and demonstrate China's incremental approach to eDNA standardization, with protocols tailored to specific taxa, methodologies, and applications.

To systematically compare the scope, key features, and timelines of these efforts, Table 2 summarizes the major eDNA standards currently implemented across China, highlighting their technical focus and progression from foundational workflows (e.g., species identification) to advanced applications (e.g., invasive species detection and bioassessment).

4.2 Key standardization challenges

Despite progress, several significant challenges remain in eDNA standardization:

1) Methodological variability: Different research groups and monitoring programs often employ substantially different protocols for sample collection, processing, and analysis, compromising data comparability.

2) Quantification uncertainty: The relationship between eDNA detection signals and actual organism abundance remains poorly understood for most species, limiting the technology's utility in population assessment.

Standard	Type	Scope	Key features	Release date	Implementation date
DB11/T 2023-2022, *Technical regulations for fish and shellfish identification using environmental DNA*[2]	Local standard	Fish and shellfish identification	Full workflow specification for eDNA recognition of fish and shellfish	2022-09-29	2023-01-01
DB32/T 4539-2023, *Technical method for environmental DNA monitoring of fresh water organisms*[4]	Local standard	Technical method standardization	Full workflow specification for eDNA recognition of fresh water organisms	2023-09-22	2023-10-22
DB11/T 2358-2024, *Technical specification for environmental DNA monitoring of fresh water benthic macroinvertebrates*[3]	Local standard	Technical method standardization	Full workflow specification for eDNA recognition of fresh water benthic macroinvertebrates	2024-12-25	2025-04-01
T/SSESB 14-2025, *Multiplex PCR detection method for aquatic invasive species based on environmental DNA technology*[6]	Association standard	Aquatic invasive species	Detection of 12 aquatic animals using environmental DNA combined with multiplex PCR technology	2025-04-25	2025-04-25
T/SSESB 13-2025, *RPA rapid detection method for aquatic invasive species based on environmental DNA technology*[7]	Association standard	Aquatic invasive species	Rapid detection of 4 aquatic animals using environmental DNA combined with RPA technology	2025-04-25	2025-04-25
T/SEEPLA 08-2024, *Water ecological monitoring-environmental DNA quantitative real-time PCR method*[5]	Association standard	Technical method standardization	Monitoring of freshwater biota groups or species in aquatic ecological monitoring with quantitative real-time PCR method	2024-11-26	2024-11-26
T/CSES 148-2024, *Technical requirements for the construction of aquatic environmental DNA laboratory*[9]	Association standard	Laboratory construction requirements	General principles and requirements for the construction of environmental DNA laboratories	2024-07-10	2024-07-10
T/CSES 82-2023, *Technical guidelines for environmental DNA-based freshwater bioassessment*[10]	Association standard	Evaluation	Standardize the evaluation index and analysis method of freshwater organisms based on environmental DNA technology	2023-01-04	2023-01-04
T/CSES 81-2023, *Freshwater biomonitoring—Environmental DNA metabarcoding method*[8]	Association standard	Technical method standardization	Multi group monitoring of freshwater organisms based on DNA sequence similarity	2023-01-04	2023-01-04

Table 2: Comparison of the current major eDNA standards in China

3) Reference database gaps: Many Chinese species lack reference sequences in public databases, complicating taxonomic assignment of eDNA sequences.

4) Quality control implementation: While quality control principles are widely recognized, practical implementation varies significantly across studies and monitoring programs.

4.3 Emerging standardization initiatives

Recent developments suggest progress toward more comprehensive standardization:

The Ministry of Ecology and Environment has initiated working groups to develop national technical guidelines; Cross-institutional collaborations are working to develop unified laboratory protocols; Quality assurance/quality control (QA/QC) frameworks are being tested in major monitoring programs; And efforts are underway to expand and validate reference sequence databases for Chinese biodiversity.

5. Future perspectives and recommendations

5.1 Technological development priorities

Future advancements in eDNA technology should focus on:

1) Quantification methods: Developing reliable approaches for estimating species abundance from eDNA data

2) Persistency modeling: Better understanding how environmental factors affect eDNA degradation rates

3) Automation: Integrating robotic sampling and real-time analysis capabilities

4) Data integration: Developing frameworks for combining eDNA data with other monitoring approaches

5.2 Standardization roadmap

A phased approach to national standardization should:

1) Consolidate existing regional and application-specific standards;

2) Develop core methodological standards for key workflow steps;

3) Establish certification programs for eDNA service providers;

4) Create mechanisms for regular standards updates reflecting technological advances.

5.3 Implementation strategies

Effective large-scale implementation requires:

1) Capacity building programs for monitoring agencies;

2) Development of shared laboratory infrastructure;

3) Establishment of national eDNA data standards and repositories;

4) Integration with existing environmental monitoring networks.

5.4 International collaboration opportunities

China should actively participate in global eDNA initiatives through:

1) Contribution to international standards development;

2) Joint methodology validation studies;

3) Data sharing agreements;

4) Collaborative technology development projects.

6. Conclusion

China's eDNA technology development has progressed rapidly from initial research applications to operational monitoring use. The country has made distinctive contributions to methodological innovation, particularly in adapting eDNA approaches to its diverse ecosystems and conservation challenges. While standardization efforts have advanced through regional and application-specific standards, comprehensive national standards remains in progress.

The coming years present critical opportunities to consolidate China's leadership in eDNA technology through focused investments in methodological research, standardization, and capacity building. By addressing current challenges in quantification, quality control, and reference data, eDNA technology can fulfill its potential as a transformative tool for biodiversity conservation and ecosystem management in China's ecological civilization construction.

Realizing this potential will require sustained collaboration between research institutions, government departments, and industry partners, as well as active participation in the development of global eDNA technology. With coordinated effort, China is well-positioned to emerge as a global innovator in both eDNA technology development and large-scale implementation.

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The mechanism of international law empowering international standardization and China's response

国际法赋能国际标准化的作用机理与中国因应

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Abstract: As a crucial aspect of international governance, international standardization requires legitimacy grounded in the principles and frameworks established by international law. Building upon an understanding of the commonalities between international law and international standardization, this paper explores the mechanism through which international law centered on treaties empowers international standardization.
Keywords: international law, international standardization, mechanism

In a society governed by the rule of law, the establishment and maintenance of any social order necessitates the protective role of law. Similarly, international standardization activities require international law as a legal safeguard. Therefore, building upon the common ground between international law and international standardization, this paper systematically explores the mechanism through which international law centered on international treaties empowers international standardization.

1. Analysis of common ground between international law and international standardization

Standards and laws share fundamental characteristics[1], forming the basis for international law's role in empowering international standardization.

1.1 International nature

Both international law and international standardization possess an international dimension, a defining feature of both. International law constitutes a vital branch of jurisprudence, primarily regulating the rights and obligations among subjects of the international community. International standardization represents a vital component within standards, encompassing global standardization activities. Both serve as crucial rules for maintaining international order.

Within the international law-based international order, international law provides the legal framework for global governance. As a key element of international governance, international standardization likewise requires legitimacy grounded in the principles and frameworks established by international law.

1.2 Normativity

Both international law and international standardization exhibit normativity, a prominent characteristic of both. This is primarily manifested in their adherence to strict procedural and certainty requirements throughout the entire process of rule formulation, and implementation.

At the rule-making level, both are presented in written form. International law primarily takes the form of international treaties and international conventions, defining the boundaries of rights and obligations. International standardization is mainly presented as standards, specifying standardized content such as technical parameters and evaluation criteria.

At the level of rule enforcement and application, both are implemented by relevant authorities. Generally, international law is enforced and applied by international legal organizations such as the International Court of Justice, while international standards are managed and implemented by international standards organizations such as ISO.

1.3 Binding nature

Both international law and international standardization possess binding force, an implicit characteristic of both. They are codified rules primarily aimed at constraining behavior, stipulating "what it should be" or "what one should do".

Compared to standards as soft law, international law as hard law exerts stronger efficacy in constraining the behavior of subjects. Leveraging oversight mechanisms and dispute resolution procedures, international law can impose sanctions on rule-breakers, endowing its binding force with a more explicit coercive attribute[2]. While standards lack the coercive power of international law, they emerge from the interactions and negotiations among diverse stakeholders, incorporating their collective will. This flexibility makes standards more readily accepted and adhered to by actors within the international community.

2. The mechanism of international law empowering international standardization

2.1 International law promotes the development of standards and specifications

As the legal foundation of international governance, international law provides codified legal basis for international standardization, thereby guiding the development of international standards. For example, Article 6.1 of Chapter 6 of the Regional Comprehensive Economic Partnership (RCEP) Agreement stipulates that contracting parties shall ensure that one or more of their standards developing bodies, which are responsible for the development, adoption, and implementation of national standards, accept and comply with the provisions of Annex 3 of the Agreement on Technical Barriers to Trade (TBT).

This provision regulates the development of standards and specifications among RCEP member states, maintains order in standards development, and provides a more unified and coordinated standard specification system for international standardization activities.

2.2 International law regulates international standardization activities

International law regulates international standardization activities by clarifying substantive and procedural matters, thereby maintaining the order of such activities. For instance, Annex 3 of the TBT Agreement, "Code of Good Practice for the Preparation, Adoption and Application of Standards", specifically outlines the content of standards openness for WTO members and the operational rules for international standardization activities. It covers core principles such as non-discriminatory treatment in the standardization field, avoidance of unnecessary trade barriers, and prioritizing the adoption of international standards.

These rules provide concrete, actionable guidance for members conducting standardization work, significantly reducing trade costs stemming from standards fragmentation and offering critical institutional support for the coordinated advancement of international standardization activities.

2.3 International law facilitates international standardization cooperation

International law advances international standardization cooperation by mitigating conflicts between national standards and guiding collaborative standardization efforts among nations.

On one hand, international law effectively reduces conflicts in national standards and specifications. For instance, Article 2.4 of the TBT Agreement stipulates that when developing technical regulations, members shall base them on relevant existing or forthcoming international standards, unless these are ineffective or inappropriate due to climatic, geographical, or technical reasons. This provision requires members to incorporate relevant international standards into their domestic technical regulations, effectively coordinating regulatory conflicts arising from differences in adopted standards.

On the other hand, international law guides standardization cooperation among nations. For instance, under Article 5(3) of Chapter 6 of the RCEP Agreement, contracting parties shall, where appropriate, enhance communication and coordination at the international level regarding international standards. This provision mandates, from an international law perspective, that contracting parties actively engage in international standardization cooperation.

3. China's response to international law empowering international standardization

3.1 Improving the synergistic safeguards mechanism between Chinese standards and laws

Strictly adhering to the fundamental principle of national legal unity enshrined in the *Constitution of the People's Republic of China* and the statutory framework for standardization work outlined in the *Standardization Law of the People's Republic of China*, the State Administration for Market Regulation (SAMR), as the administrative apartment for standardization in China, should fully leverage its coordinating functions. It should lead collaborative efforts with the National Standardization Administration of China (SAC), the comprehensive management body for standardization work, and the China National Institute of Standardization (CNIS), the national-level specialized research and technical support institution for standardization.

Together, they ought to advance legislative research and formulation of the *Regulations on the Coordinated*

Implementation of Laws and Standards. The regulations must systematically standardize core elements of coordinated implementation at the institutional level: 1) Establish a joint supervisory body comprising SAMR and relevant departments, defining its oversight, guidance, and dispute resolution responsibilities during coordination; 2) Specify detailed supervision procedures covering the entire process—from pre-standardization legal compliance reviews and dynamic tracking evaluations during implementation to adjustments and corrections following conflicts between standards and laws; 3) Establish specific requirements for coordinated implementation, particularly mandating that standards developing bodies conduct compatibility studies between standards and existing laws, administrative regulations, and relevant international treaties during the drafting stage.

3.2 Advancing modern standards governance toward building a community of shared future for mankind

Centered on the concept of building a community of shared future for mankind, international legal principles have emerged, including the priority protection of common interests of all humanity and the principle of consultation, cooperation, and shared benefits[3]. From an international perspective and guided by the goal of building a community of shared future for mankind, China should make more efforts to the modernization of international standards governance.

On one hand, based on the principle of prioritizing the common interests for all humanity, China should unswervingly uphold the law-based international order. Unlike the rules-based international order, the law-based international order is founded on international law centered around the *Charter of the United Nations*, and the very foundation empowering international standardization is international law.

On the other hand, guided by the principle of consultation, cooperation, and shared benefits, China should actively engage in international standardization dialogue and exchange through platforms provided by international organizations such as WTO and international standards bodies such as ISO. First, China should actively promote the internationalization of its standards, contributing more high-level, high-quality standards to global standardization efforts. Second, China should prioritize talent cultivation for international standardization, particularly developing professionals with expertise in both international law and international standardization, thereby providing human resources support to international standardization organizations.

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The application of China's standards on AI screening for diabetic retinopathy in Cambodia

中国的糖尿病视网膜病变人工智能筛查规范在柬埔寨的实践应用

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Abstract: Diabetic retinopathy (DR) is a leading cause of vision loss among working-age populations, with early screening significantly reducing the risk of blindness. However, resource-limited regions often face challenges in DR screening due to a shortage of ophthalmologists. This study reports the implementation and outcomes of the Chinese local standard DB52/T 1726-2023, *Regulations for the application of diabetic retinopathy screening artificial intelligence*, in Cambodian healthcare institutions. A pilot DR screening program with independent operational capability is established by providing a non-mydriatic fundus camera and deploying a localized diabetic retinopathy artificial intelligence (DR-AI) screening platform at the Cambodia-Kingdom Friendship Hospital in Phnom Penh, along with comprehensive training. From January to August 2025, a total of 565 patients with type 2 diabetes were screened, yielding a DR detection rate of 26.0% (147 cases). Research findings demonstrate that applying mature Chinese DR-AI screening standards and technological solutions through international collaboration in regions with a scarcity of ophthalmic professionals is both feasible and effective. This project serves as a reference for promoting DR-AI in resource-constrained countries and regions, highlighting its significant potential to leverage AI in addressing the global burden of chronic diseases and advancing the modernization of health systems.
Keywords: international collaboration, overseas application of standards, diabetic retinopathy, AI screening

1. The impact of diabetic retinopathy and its global burden

Diabetes is one of the leading chronic diseases worldwide, with its prevalence and associated diseases increasing annually. Between 1990 and 2022, the number of global diabetes patients surged from approximately 200 million to 828 million, with the highest growth observed in China and regions such as Southeast Asia, South Asia, and the Middle East[1]. Currently, China has approximately 110 million diabetic patients[2]. Diabetic retinopathy (DR) is the most common and severe ocular complication of diabetes[3] and remains the primary cause of visual impairment and blindness in working-age populations worldwide[4]. The global prevalence of DR among diabetic patients stands at 22.27%, and in 2020, there were 103.1 million people globally suffering from severe vision impairment due to DR, with projections indicating this number will rise to 106.5 million by 2045[5]. DR often develops insidiously, and its early stages are typically difficult to detect. Once it progresses to advanced stages, irreversible vision loss, even blindness, occurs. The vision impairment caused by DR not only limits the patients' mobility but also leads to depression, which severely affects quality of life, and places a heavy burden on individuals, families, and the society[6].

Early detection and management of DR can prevent more than 90% of blindness in affected patients[7]. Both national and international guidelines recommend annual retinal screening for patients with type 2 diabetes mellitus (T2DM)[8,9]. However, the shortage of ophthalmologists capable of conducting DR screening and diagnosis has long hindered the implementation of large-scale screening programs. This issue is particularly pronounced in developing countries. For instance, Cambodia has only 3.2 ophthalmologists per million people, well below the World Health Organization's recommended ratio of 25 per million[10]. However, technological advances have brought significant breakthroughs in artificial intelligence (AI), and diabetic retinopathy artificial intelligence (DR-AI) screening has become one of the most mature applications of AI in medicine. Multiple studies have demonstrated that DR-AI systems exhibit high sensitivity and specificity in diagnosing DR[11,12]. AI technologies inherently possess the characteristics of low cost and strong scalability, and, through international collaborations, have the potential to address DR screening challenges in resource-limited regions[13].

2. Main content of the standard for diabetic retinopathy AI screening and its application in Guizhou

DB52/T 1726-2023, *Regulations for the application of diabetic retinopathy screening artificial intelligence*, proposed and developed by the Guizhou Center for Disease Control and Prevention, was officially issued by the Market Regulation Administration of Guizhou Province on April 12, 2023. This standard outlines comprehensive guidelines for the evaluation criteria of DR-AI screening systems, including the requirements for operators and the screening environment, target populations, screening timing, frequency, and procedural protocols, see Table 1. Since its implementation, DB52/T 1726-2023 has been applied in multiple demonstration bases across Guizhou Province, covering Guiyang City, Liupanshui City, Qiannan Autonomous Prefecture, and Qiandongnan Autonomous Prefecture. In these regions, nearly 8,000 adult T2DM patients have undergone DR-AI screening. This initiative represents a significant step toward the widespread adoption of AI-driven diagnostic tools for DR within regional healthcare systems.

	Specific provisions	Technical/management requirements	Scientific rationale/objective
System performance standards	Scope of application	Primary and secondary healthcare institutions, DR outpatient clinics	
	Screening capability evaluation	Sensitivity/specificity/accuracy: ≥90% Test sample: At least 1,000 cases of both DR and non-DR retinal images	To ensure the diagnostic reliability of the AI system in detecting diabetic retinopathy with high precision
	Identification speed	Time per image: <20 seconds	To meet the efficiency demands for screening in primary healthcare settings
	Data security	Security measures: Use of digital signatures and mainstream encryption algorithms (for storage and transmission)	To comply with medical data privacy regulations and ensure the protection of sensitive patient information
Operational standards	Personnel qualifications	Required: Medical licensure + certification in DR-AI operation training	To ensure professional competency in screening operations
	Facility requirements	Area: ≥10m², Temperature: 18-24°C, Humidity: 45%-65%, RHLight control: Adequate shading facilities, Standardized furniture: Chair and table height alignment	To guarantee optimal imaging quality and a safe, controlled environment for screening
	Equipment requirements	Certified non-mydriatic fundus camera, Imaging range: ≥45°, Pixel resolution: ≥5 megapixels	To comply with international retinal imaging standards (e.g. ETDRS) for accurate diagnostic performance
Screening population management	Target population	Diabetic patients and high-risk groups (as defined by WS397-2012)	To ensure the inclusion of key at-risk populations for early disease detection
Screening timing and frequency	Screening timing	Type 1 diabetes mellitus (T1DM): First screening for DR within 5 years after diagnosis, typically following puberty T2DM: Initial comprehensive ophthalmic examination upon diagnosis	To implement risk-based, progressive screening strategies aligned with disease progression
	Screening frequency	T1DM: Annually T2DM: Every 1-2 years DR Patients: Mild NPDR: Annually Moderate NPDR: Every 3-6 months Severe NPDR/PDR: Every 3 months Gestational diabetes: At each trimester and postpartum for 1 year	

	Specific provisions	Technical/management requirements	Scientific rationale/objective
Screening process	Imaging acquisition standards	Inform of the precautions Patient information entry Retinal imaging and quality assessment Upload of images to the DR-AI platform for analysis Communication of DR-AI results to the patient Referral or follow-up recommendations based on the results	Coverage of core areas of DR lesions
	Quality assessment	Imaging position: Compliant, marginal, non-compliant Clarity: Compliant, marginal, non-compliant Readable range: Compliant, marginal, non-compliant Overall quality confidence: Good, acceptable, poor	To ensure stringent control over the quality of input data from the outset, thereby optimizing diagnostic accuracy and reliability
	DR-AI result interpretation	Diagnosis: Presence or absence of DR Grading: Severity classification of DR Management recommendations: Blood glucose targets, lifestyle modifications, and referral guidance	To integrate screening results with clinical interventions, facilitating evidence-based decision-making and personalized patient management
Referral mechanism	Stratified management	Low risk: Annual screening (≤ Grade 2 lesions), no referral required Moderate risk: Biannual screening (Grade 3 lesions) High risk: Immediate referral (≥ Grade 4/PDR/DME involving the macula)	To align healthcare resource allocation with disease severity, ensuring timely and appropriate patient management through a risk-based referral system
Support system	Appendices A/B	Utilizes the international DR/DME grading standards (Table A.1/A.2) in conjunction with China's diabetes diagnostic criteria (Table B.1) and high-risk population definitions (Table B.2)	To integrate internationally recognized standards with localized protocols, ensuring the practical application of global best practices within the context of Chinese healthcare settings

Table 1: Summary of the requirements for artificial intelligence screening in DR in the standard

3. Cooperation with Cambodian healthcare institutions on DR-AI screening based on the standard

In October 2024, the Guizhou Provincial Center for Disease Control and Prevention and the Guizhou Provincial Preventive Medicine Association jointly organized the Guizhou-ASEAN public health cooperation meeting in Guiyang, Guizhou Province, as shown in Figure 1. During the event, we engaged in extensive discussions with Dr. Touch Kun, Vice President of the Cambodia-China Friendship Preah Kossamak Hospital, and invited him to experience the DR-AI screening personally. This interaction led to the establishment of a collaborative partnership between the two parties.

In January 2025, we visited the Cambodia-China Friendship Preah Kossamak Hospital to conduct an on-site investigation and discuss the details of our collaboration. During this process, we gained a comprehensive understanding of the challenges faced by Cambodia in DR screening, particularly issues related to screening standards, the lack of retinal imaging equipment, and the absence of AI-

Figure 1: Group photo of the cooperation meeting

assisted technologies. Through multiple rounds of technical discussions, the Cambodian side expressed significant interest in the DR-AI screening technology and recognized its value in early diagnosis and DR prevention. Ultimately, both parties reached an agreement on collaboration and signed a detailed contract, as shown in Figure 2-3.

As part of this collaboration, we provided the Cambodian team with a non-mydriatic retinal camera as aid and deployed a localized DR-AI screening platform. To facilitate the use of DR-AI technology by Cambodian medical personnel, our team developed an English version of the platform. In addition to technical deployment, we adopted a hybrid training model to offer systematic training for Cambodian doctors, ensuring their capacity for long-term, sustainable operation. The training included AI screening standards for DR, DR-AI platform operational skills, DR prevention and treatment theories, international grading standards (ICDR), retinal camera operation, and community-based DR-AI screening processes. This comprehensive training successfully enabled the implementation of international standards in Cambodia.

According to 2012 data from the World Health Organization (WHO), the diabetes prevalence rate among adults in Cambodia stands at 5.1%. However, the country faces a severe shortage of medical resources, with only 3.2 ophthalmologists per one million people, significantly lower than the WHO's recommended standard of 25 per million[10]. The number of T2DM patients in Cambodia is steadily increasing, projected to rise from 145,000 in 2008 to 264,000 by 2028[14]. In Battambang Province, the blindness prevalence rate is 3.4%, while the low vision rate reaches 21.1%[15], yet only one private medical facility is equipped with a mydriatic retinal examination service[16]. In rural areas, the coverage rate for DR screening is under 12%, and 60% of county-level hospitals lack retinal cameras[13]. Currently, Cambodia is facing a critical shortage of DR screening services. However, with the rapid increase in diabetes cases, the burden of vision loss due to DR is expected to escalate dramatically. There is an urgent need to address this crisis through DR technology and international collaboration[13].

From January to August 2025, since the implementation of the collaborative project, the Cambodia-China Friendship Preah Kossamak Hospital has conducted screenings for 565 type 2 diabetes patients, with an average age of 49.89 ± 14.36 years. Among these, 304 (53.8%) were male and 261 (46.2%) were female. Of the patients, 147 were diagnosed with DR, resulting in a DR prevalence rate of 26.0%. The distribution of DR severity was as follows: 47 cases (32.0%) of mild DR, 74 cases (50.3%) of moderate DR, and 24 cases (16.3%) of severe DR.

Figure 2: Dr. Hu Yuandong introduces DR-AI technology to Cambodian medical personnel

Figure 3: Inauguration ceremony of the China (Guizhou)-Cambodia DR-AI collaborative project

4. Conclusion

In summary, through the implementation of this project at the Cambodia-China Friendship Preah Kossamak Hospital, the standardized DR screening approach has been successfully introduced and applied in Cambodia. This initiative has also established an independent DR-AI screening pilot capable of operating autonomously. The project has not only enhanced the technological capabilities of Cambodian healthcare institutions in DR screening and prevention but also laid the groundwork for the future expansion of DR-AI screening technology to other regions. In the future, the development of a national standard for DR-AI screening in Cambodia is anticipated, thereby facilitating the modernization of the country's healthcare system.

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Preliminary study on a quantification method and standardization for aquatic microbial loads based on microbial diversity absolute quantitative sequencing

基于微生物多样性绝对定量测序技术的水体微生物负荷计量方法及标准化初探

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Abstract: This study establishes and validates a method for the precise quantification of aquatic microbial loads using microbial diversity absolute quantitative sequencing. By adding synthetic spike-in DNA to water samples from the Dahei River prior to DNA extraction and 16S rRNA gene sequencing, it generates standard curves to convert sequencing data into absolute microbial copy numbers. The method, which is proved highly accurate ($R^2 > 0.99$), reveals a clear contrast between the river sites: the upstream community has not only a significantly higher total microbial load but also a completely different makeup of species compared to the downstream site. This approach effectively overcomes the limitations of relative abundance analysis, providing a powerful tool for environmental monitoring, and proposes key steps for future standardization to ensure data comparability and integration.

Keywords: absolute quantification, microbial load, 16S rRNA sequencing, spike-in, standardization, aquatic microbes

1. Introduction

Aquatic microbial communities are fundamental drivers of global biogeochemical cycles. Their composition and load are critical indicators of water ecosystem health, stability, and safety risks, such as pathogen transmission[1]. Therefore, the precise qualitative and quantitative analysis of aquatic microbes is a central task in environmental microbiology.

The current monitoring of aquatic microbes primarily relies on traditional culture methods, qPCR, and high-throughput sequencing. Culture methods are time-consuming and fail to capture the vast majority of unculturable environmental microbes. While qPCR allows for quantification, its throughput is limited, making it unsuitable for depicting complete community profiles. High-throughput sequencing-based microbial diversity analysis (relative quantification) provides a comprehensive view of community structure but is constrained by the "compositional closure" problem, where species abundances are presented as relative proportions, obscuring their true absolute quantities per unit volume/mass of sample[2]. This limitation hinders direct comparisons of total microbial load or specific population sizes across different samples.

Absolute quantitative microbiome sequencing has emerged to address this gap. This technique involves adding known quantities of exogenous spike-in sequences to samples before DNA extraction[3]. A standard curve is constructed to convert sequencing data from relative proportions to absolute abundances, simultaneously providing information on "who is there" and "how many are there". Although the principle is proposed, its systematic application, validation for quantification efficacy in water monitoring, and discussion

toward standardized protocols remain insufficient.

This study employs a complete absolute quantification workflow—from sample processing and spike-in addition to sequencing and bioinformatic analysis—on water samples from the upstream and downstream sections of the Dahei River. The objectives are to: 1) validate the accuracy and feasibility of this method for quantifying aquatic microbial loads; 2) demonstrate the unique advantages of absolute quantitative data in deciphering environmental differences; and 3) systematically explore the key steps and future pathways for standardizing this technology for the first time in China, thereby laying a methodological foundation for building a comparable and integrable baseline database for aquatic microbial loads.

2. Materials and methods

2.1 Sample collection and processing

The study area was located within the Dahei River basin in Hohhot City, Inner Mongolia. Sampling sites were established at upstream (Site A, 111.75373429°N, 40.74965081°E), and downstream (Site B, 111.79378021°N, 40.76841437°E) locations, as shown in Figure 1, with three biological replicates collected per site (A1, A2, A3; B1, B2, B3). Water samples were collected by sterile containers and immediately filtered through 0.45 μm polycarbonate membranes to concentrate microbial biomass. The filters were stored at -80°C until DNA extraction.

2.2 Absolute quantitative microbiome sequencing workflow

Spike-in addition and DNA extraction: Prior to cell lysis, a precise amount of synthetic spike-in DNA (with known copy numbers and no homology to environmental microbes) was added to each sample, following the principle outlined of the study of Stämmler et al.[3] Genomic DNA was then extracted with a standard commercial DNA extraction kit.

PCR amplification and library preparation: The V3-V4 hypervariable region of the 16S rRNA gene was amplified by primers (F: ACTCCTACGGGAGGCAGCA; R: GGACTACHVGGGTWTCTAAT) tailed with Illumina adapter sequences.

Sequencing: Sequencing was performed on the Illumina Novaseq platform using a PE250 strategy.

2.3 Bioinformatic analysis

Data preprocessing and standard curve generation: The raw sequencing data were first processed to remove technical sequences, such as adapters and primers, that were added during the laboratory preparation steps, using the software tools Trimmomatic[4] and cutadapt[5]. Subsequently, all spike-in sequences were identified and filtered out using BLASTN[6]. A standard curve was independently generated for each sample by plotting the log of the theoretical spike-in copy numbers against the log of the empirically observed read counts, followed by linear regression analysis.

Absolute abundance transformation: Based on the standard curve, the read counts for all amplicon sequence variants (ASVs) in each sample were converted into absolute copy numbers with the fitting formula, resulting in a species abundance table with units of "copies/g".

Community analysis: Denoising and ASV generation were performed using the QIIME2 (2020.6) platform[7] and the DADA2 algorithm[8]. Taxonomic assignment was conducted against the SILVA 138 database. Based on the absolute abundance table, subsequent analyses included Alpha diversity (Chao1, Shannon, Simpson), Beta diversity (PCoA, NMDS based on Bray-Curtis and Unifrac distances[9]), inter-group differential species analysis Metastats[10, 11].

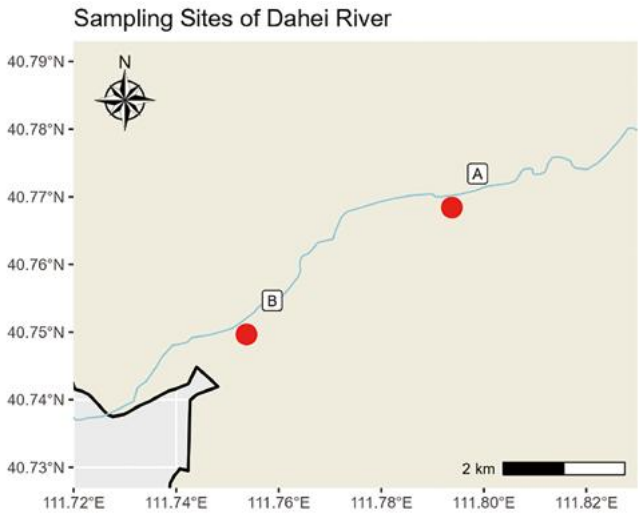

Figure 1: The locations of sampling sites of the Dahei River

3. Results

3.1 Sequencing data quality and standard curve validation

Sequencing yielded 1,444,640 paired-end raw reads. After stringent quality control, splicing, and spike-in sequence filtration, 566,505 high-quality clean reads were obtained. All samples had sufficient sequencing depth (59,705~108,986 reads), providing a solid foundation for subsequent analysis.

The core evidence for the validity of the quantification method comes from the spike-in standard curves for all six samples. As shown in the representative data, all standard curves demonstrated an excellent linear fit (R^2 values all close to 1), as shown in Figure 2. This indicates stable amplification efficiency of the spike-in sequences and a high consistency between their theoretical and empirically detected copy numbers, thereby proving that the use of this curve to calculate absolute microbial copy numbers from sequencing

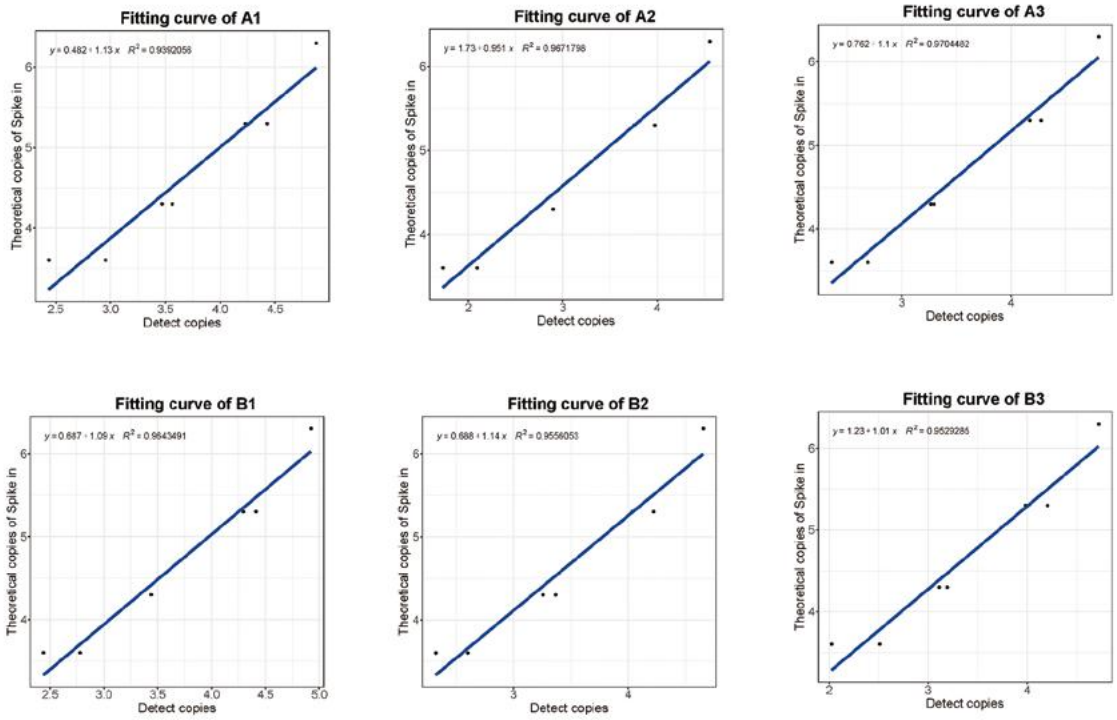

Figure 2: Standard curves for absolute quantification based on spike-in sequences

reads is highly reliable and accurate.

3.2 Absolute quantification of microbial loads and comparative advantage

The transformation of taxonomic annotation results into absolute abundances provided the absolute copy numbers for each sample at various taxonomic levels. The data revealed that the total microbial load in the upstream Site A samples was generally higher than in the downstream Site B samples, as shown in Table 1. For instance, the average total species copy number in Site A was 2.53×10^7 copies/g, compared to 1.88×10^7 copies/g in Site B—a difference of 1.35-fold.

This finding highlights the fundamental advantage of absolute over relative quantification. With relative abundance analysis alone, one can only discern differences in the "proportion" of bacterial types between Site A and B, unable to determine if these differences are due to the actual increase/decrease of specific bacteria or fluctuations in total microbial load. Absolute quantification definitively shows that the upstream water has not only a different community structure but also a significantly higher total microbial mass per unit weight. This has more direct implications for assessing the degree of eutrophication, self-purification capacity, or potential health risks of the water body.

3.3 Community structure and diversity within an absolute quantification framework

Under the absolute quantification framework, alpha

Sample	Kingdom	Phylum	Class	Order	Family	Genus	Species
A1	12,879,517	12,143,177	12,117,474	10,872,952	10,144,150	9,535,462	9,265,142
A2	67,436,733	64,324,303	64,172,282	59,508,906	55,611,061	51,822,164	50,455,107
A3	22,513,805	21,156,779	21,102,618	19,010,433	17,709,604	16,578,252	16,147,074
B1	16,918,958	16,159,251	16,143,530	15,359,537	14,217,042	13,549,541	13,329,803
B2	11,842,327	11,449,938	11,443,067	10,897,114	10,539,761	10,083,458	9,955,394
B3	40,307,213	39,033,093	38,991,326	37,154,125	35,541,728	33,731,787	32,997,975

Table 1: Total microbial load across sampling sites

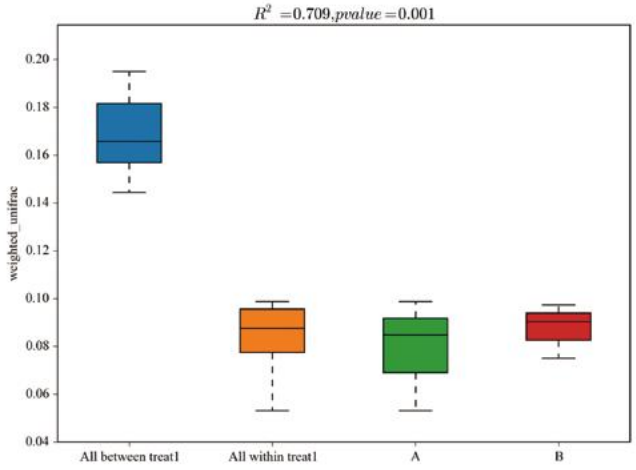

Figure 3: Comparative analysis of microbial community structure between Site A and B

diversity analysis showed that Site A samples had higher ASV numbers (e.g., A1: 2900, A3: 2987) and Shannon indices compared to Site B (e.g., B2: 1686). Beta diversity analysis (PCoA, NMDS) indicated a significant separation in community structure between Group A and B (Figure 3), analysis of similarities, treat1 mean different position like upstream and downstream, P<0.05).

Traditionally, this would be interpreted as "Site A has higher microbial diversity than Site B". Combined with absolute quantification data, this conclusion can be deepened: Site A possesses a richer variety of species (high richness), and the absolute quantities of these species in the environment are also higher (high load). This combination of "quality" and "quantity" provides a more comprehensive perspective for understanding the comprehensive impact of environmental factors on microbial communities.

3.4 Analyzing the absolute contribution of differential species

Metastats[11] analysis identified several taxa (biomarkers) that were significantly different between Site A and B. For example, at the class level, Campylobacteria and Parcubacteria were significantly enriched in Site A, as shown in Table 2.

Absolute quantification allows us to move beyond "which species are different" to assess "how much these differential species contribute to the total load difference". By examining the absolute copy numbers of these biomarkers, their specific impact on the observed total load disparity can be quantified. For instance, if a bacterial class enriched in Site A has a very high absolute copy number, it may be a key driver of the higher total load in Site A. This analysis enables a more precise assessment of the ecological role of key species.

4. Discussion on standardization—opportunities and challenges

This study successfully applies absolute quantitative microbiome sequencing to aquatic environmental monitoring, validating its potential as a powerful quantification tool. However, it is essential to transition this from an advanced technique to a standard methodology, a push for standardization.

4.1 Summary of methodological advantages

The method simultaneously obtains microbial community composition, diversity indices, and differential species, and achieves absolute quantification of the targets. The data richness and quantification accuracy are unmatched by traditional methods.

4.2 Key considerations for standardization

1) Development of standard reference materials for aquatic eDNA: A pivotal step toward robust standardization is the development and commercialization of certified standard reference materials. These should consist of synthetic or cell-based mock communities with precisely defined genomic DNA copy numbers, ideally encompassing a diverse range of taxa relevant to aquatic environments (e.g., bacteria, archaea). These standardized materials can serve as universal positive controls and calibrators. They can be used to (a) spike into samples to generate standard curves as demonstrated in this study, and (b) be processed as stand-alone controls in every batch to monitor the entire workflow's accuracy and reproducibility, from DNA extraction to sequencing and

Class	Mean (A)	Variance (A)	Std.err (A)	Mean (B)	Variance (B)	Std.err (B)	P value	Q value
Campylobacteria	1.62e-02	5.91e-07	4.44e-04	3.71e-03	8.20e-07	5.23e-04	0.00e+00	0.00e+00
Unclassified Patescibacteria	1.49e-03	2.26e-08	8.68e-05	5.32e-05	3.46e-10	1.07e-05	9.91e-04	5.55e-02
Parcubacteria	6.00e-02	2.28e-06	8.73e-04	1.46e-02	2.30e-05	2.77e-03	1.98e-03	7.40e-02
Fusobacteriia	6.74e-03	3.98e-07	3.64e-04	1.61e-03	2.32e-08	8.80e-05	2.97e-03	8.33e-02
Gracilibacteria	6.42e-03	1.19e-06	6.29e-04	8.80e-04	1.58e-07	2.30e-04	6.58e-03	1.41e-01

Table 2: Biomarkers significantly differing between Site A and B

bioinformatic quantification.

2) Standardization of spike-ins: In parallel with the development of complex reference materials, it is recommended that authoritative bodies lead the establishment of a universal spike-in sequence library suitable for different water types (freshwater, seawater, wastewater), with clear specifications for their sequences, purity, storage, and addition amounts, building on principles upon the foundational work of Stämmler et al.[3]

3) Standardization of experimental protocols: Key steps such as DNA extraction methods (especially for waters with varying suspended solid content) and PCR amplification conditions (cycle number, polymerase) need to be unified and validated to minimize batch effects and ensure data comparability.

4) Standardization of bioinformatic pipelines: The use of widely validated analysis pipelines (e.g., QIIME2[7] + DADA2[8]) and unified reference databases (e.g., SILVA) is recommended, along with the establishment of standardized analysis parameters and scripts.

5) Standardization of reporting: It is advised that final reports must include core quality control metrics (e.g., standard curves with R^2 values, data from the processing of standard reference materials), absolute copy number summary tables, and diversity analyses based on absolute abundance, to facilitate data integration and comparison across different research institutions.

4.3 Limitations and future perspectives

This method still faces challenges, such as the variation in 16S rRNA gene copy numbers among different species, which may introduce quantification bias. The influence of DNA extraction efficiency on absolute quantification also requires further evaluation. Future research could explore multi-spike-in systems to correct for extraction biases and attempt cross-validation with other absolute counting methods like flow cytometry. Looking ahead, the standardization and promotion of this technology will strongly support the construction of the National Baseline Database for Aquatic Microbial Loads, providing indispensable data support for water environment health assessment, pollution warning and source tracking, and global change research.

5. Conclusion

Using the Dahei River as a case study, this study has successfully established and systematically validated a method for absolute quantitative microbiome sequencing based on spike-in internal standards. This method enables the precise quantification of microbial loads in water while simultaneously resolving community structure, effectively overcoming the inherent limitations of relative quantification techniques[2]. It proposes the suggestion that academia, sectoral standards organizations, and regulatory bodies jointly focus on and promote the standardization process of this technology, enabling its early adoption as a routine tool for aquatic microbial monitoring and providing more robust technical support for safeguarding water ecological security and public health.

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