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Views & Comments

Promoting Environmental Risk Assessment and Control of Emerging Contaminants in China

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1. Introduction

In recent years, China has carried out an extensive preventative battle against air, water, and soil pollution, and the nation's environmental quality—as reflected by conventional pollutant indicators—has significantly improved. At the same time, the issue of emerging contaminants (ECs) is beginning to receive increasing attention. ECs generally refer to newly discovered or noticeable pollutants that pose risks to the ecological environment or human health. Either they have not been included in environmental management, or existing management measures are insufficient to effectively prevent and control their risks. The ECs of greatest concern generally include persistent organic pollutants (POPs), endocrine-disrupting chemicals (EDCs), pharmaceuticals and personal care products (PPCPs), and microplastics. These four categories of ECs are not entirely separate, as they interrelate with each other (Fig. 1). Chemical production and product usage are the main sources of ECs. China is the world's largest producer and consumer of bulk chemicals, and the production value of China's chemical industry is predicted to reach 50% of the global total by 2030 [1]. Scientific control of ECs based on their environmental risk assessment is a necessary way to support the prevention and legal governance of ECs.

2. Progress in environmental risk assessment and control of ECs

2.1. Research progress on environmental risk assessment and control of ECs

Since the publication of the book *Silent Spring* first called public attention to persistent organochlorine pesticide use in 1962, environmental risks of POPs have garnered increasing attention around the world. The concept of ECs first appeared in the late 1990s [2]; since then, global research on ECs has developed rapidly on topics including EC occurrence in the environment, EC pollution characteristics, and EC exposure and effects, promoting a better understanding of ECs and revealing the harm they do to both ecology and human health [3]. Important achievements have also been accomplished, such as an analysis system for ECs, migration and transformation laws, and ecological and health risk assessment and control technologies. Research on ECs has gone through three stages over time: identification and detection, traceability and risk, and process and control. According to a quantitative trend analysis, antibiotics, microplastics, EDCs, per- and polyfluoroalkyl substances (PFASs), pesticides, and nanoparticles have received increasing attention [4].

2.2. Global action on the environmental risk assessment and control of ECs

Scientific research outcomes have made the risk of ECs an international consensus, promoting global action toward EC control. Developed regions such as Europe and North America are highly concerned about the issue of ECs. In 1999, Dr. Daughton from the US Environmental Protection Agency (EPA) first proposed the concept of PPCPs [5]. From 1999 to 2000, the US Geological Survey conducted surveys in 139 rivers in 30 states across the United States, revealing the widespread presence of PPCPs in water environments [6]. In 2021, Dr. Richardson from the US EPA emphasized the role of elegant analytical chemistry solutions in a study of ECs [7]. Among ECs, PFASs have attracted the most global attention in recent years. In October 2021, the US EPA released the PFAS Strategic Roadmap, announcing its four-year (2021–2024) action plan for PFAS control, including research, limitation, and remediation. In March 2023, the US EPA proposed National Primary Drinking Water Regulation for six PFASs. The proposed mandatory maximum pollutant level (MCL) for both perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) is 4 $ng\cdot L^{-1}$, and the non-mandatory MCL target for both is 0 $ng\cdot L^{-1}$. In October 2020, the European Union implemented the Chemical Strategy for Sustainability, aimed at addressing chemical pollution and creating a nontoxic environment. In February 2023, the European Chemicals Agency (ECHA) published a restriction proposal to completely ban PFASs in the European Union. According to incomplete statistics, more than 10 000 PFASs will be restricted by this restriction proposal. If the proposal is approved, it will be implemented as early as 2026, becoming one of the largest chemical bans in European history

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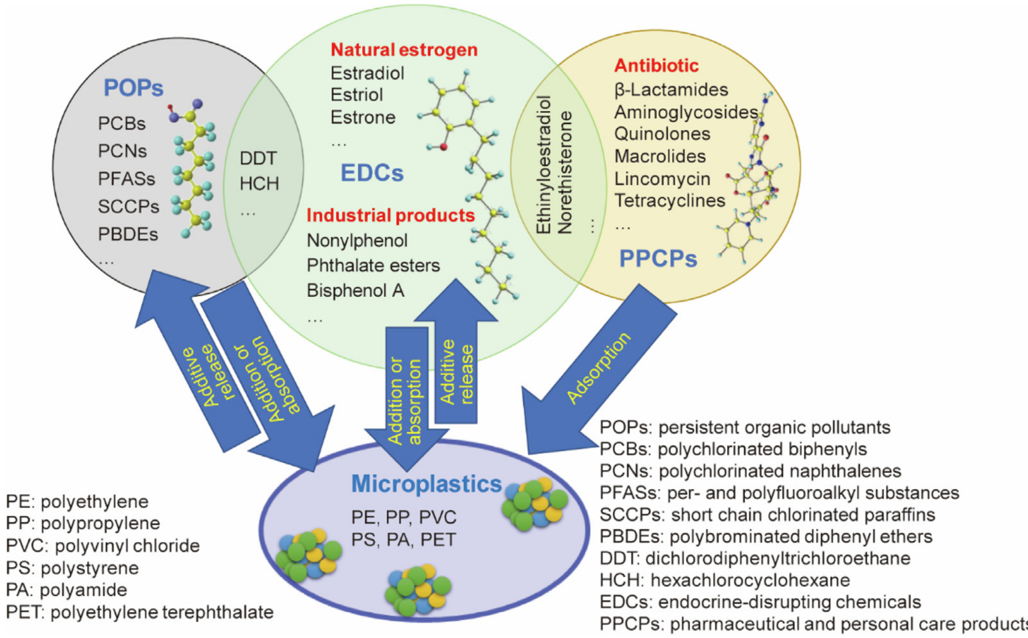

Fig. 1. The interrelationships among the four categories of ECs of greatest concern.

and the most extensive regulation of the chemical industry by the European Union. However, this proposal is highly controversial; some industries currently lack suitable alternatives, so its implementation would have a fatal impact on these industries.

Microplastics are a large class of ECs. Although the health risks caused by microplastics themselves are still under debate, the widespread use of toxic and harmful chemical additives—many of which are POPs or EDCs—in plastic requires attention [8]. These additives may pose sustained risks during plastic recycling and reuse. In September 2023, the zero draft of the Plastic Convention proposed eliminating or reducing chemicals and polymers of concern in plastic production. In November 2023, the ECHA released a report focusing on 63 priority chemical additives in polyvinyl chloride (PVC) and suggested regulatory actions on them [9].

2.3. China's action on environmental risk assessment and control of ECs

In the last 20 years, for the implementation of the Stockholm Convention, China has made positive progress in the prevention and control of POP pollution and has completely banned the production, use, import, and export of more than 20 types of POPs. Over 100 000 tonnes of POP waste from hundreds of historical sites have been cleared and disposed of [10]. The Chinese government also attaches great importance to the issue of ECs. In May 2022, the General Office of the State Council of the People's Republic of China issued the Action Plan for EC Control, which clarifies the overall framework of EC control in China—that is, "screening, assessment, and control" and "restriction, reduction, and treatment" (Fig. 2). Subsequently, by May 17, 2023, all 31 provincial-level administrative regions in the mainland of China successively issued their EC control work plans, in which some key industries and specific types of ECs are identified as key targets in individual provinces. The multi-departmental and cross-sectoral collaboration of different governmental departments is essential and needs to be well addressed. The List of ECs for Key Control (2023 edition) released by the Ministry of Ecology and Environment of the People's Republic of China has been put into effect since March 1, 2023. Since January 2023, EC control plans in prefecture-level cities have been released one after another, and action to control ECs is being fully deployed from top to bottom. However, EC control action in China still faces numerous problems. The issue we proposed—namely, "What are the problems and challenges faced by EC control?"—was selected as one of the top 10 cutting-edge scientific issues by the China Association for Science and Technology in 2022 [11]. Here, we analyze these problems and propose ways to further promote the environmental risk assessment and control of ECs.

3. Problems in the environmental risk assessment and control of ECs in China

Four main problems must be addressed for the environmental risk assessment and control of ECs in China:

(1) **The EC inventory is unclear, and the prioritization of ECs needs further clarification.** The production, sales, use, and emission inventory of most ECs in China are unclear, making it difficult to achieve precise traceability and effective control. There is an urgent need to establish inventories of newly proposed POPs that are being evaluated, as well as those that have been recently added to the Stockholm Convention or are awaiting approval from the National People's Congress of the People's Republic of China to take effect. Given the numerous different types of ECs, it is necessary to screen out high-priority ECs based on information such as properties, toxicity, and environmental exposure [12]. However, ECs lacking sufficient environmental exposure and toxicological data are easily excluded by priority screening schemes.

(2) **There is a lack of environmental monitoring data on ECs to fully support their environmental risk assessment.** At present, only controlled POPs listed in the Stockholm Convention are included in the monitoring to meet the minimum requirements of the Stockholm Convention implementation in China. Few other ECs have been included within the monitoring indicators related to ecological environment quality or pollutant emissions in China. EC monitoring in China is mainly aimed at completing short-term scientific research projects conducted by scientific institutions, and the studied areas have mainly been limited to the eastern regions in China. Furthermore, there is a lack of data to reflect long-term regional trends in EC pollution. Due to the lack of systematic and comprehensive data support, it is impossible thus far to accurately

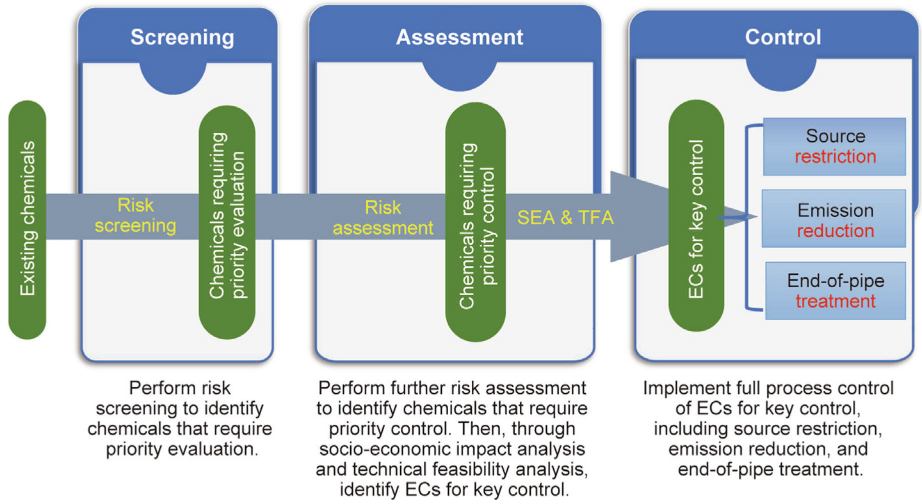

Fig. 2. The overall framework for EC control in China. SEA: socio-economic analysis; TFA: technical feasibility analysis.

identify the pollution characteristics, sources, and ecological and health risks of ECs in China. The joint effects and action mechanisms of the multiple coexisting ECs in the environment are incomprehensible, and it is difficult to identify their contributions to the total effects.

(3) **The lack of environmental criteria and standards for ECs makes it difficult to accurately assess their risks and effectively regulate them.** There is still a lack of unified evaluation criteria for human health or ecological protection in EC risk assessment. The differences in calculation methods for predicted non-effective concentrations and the selection of species toxicity data may lead to different risk assessment criteria, resulting in significant uncertainties in the EC risk assessment results, which is not conducive to the effective control and management of ECs. At present, environmental quality and emission control standards for ECs are also lacking, making it difficult to effectively control these pollutants in accordance with the law and regulations. In particular, if there are no mandatory EC control standards, few enterprises will be willing to actively spend human resources, material resources, and financial resources on EC control.

(4) **EC risk assessment and control presents long-term challenges, and technical difficulties exist in implementing the Stockholm Convention.** China is currently facing the problem of the coexistence and superposition of conventional pollutants and ECs. However, EC research and control capabilities are insufficient in many areas in China. With the development of environmental monitoring technology and risk assessment, the number of newly identified ECs will increase, and EC control will continue to present long-term challenges in proposing and solving new problems. In the past 20 years, China has established a relatively comprehensive POP convention implementation system and has achieved significant accomplishments in POP elimination and reduction [13]. However, we are still facing technical difficulties in the substitution of some currently controlled POPs and new POPs are continuously added, which may hinder China's implementation of the Stockholm Convention to some extent.

4. Promoting the environmental risk assessment and control of ECs in China

The environmental risk assessment and control of ECs in China should be promoted by focusing efforts on the multiple components (Fig. 3) in the following four aspects:

(1) **The first aspect is to strengthen the inventory investigation and priority screening of toxic and harmful chemicals related to ECs**. A database of EC production, sales, use, and disposal inventories should be developed. By utilizing computational chemistry and computational toxicology methods, as well as artificial intelligence technologies, reliable models for predicting EC characteristics, toxicity, and exposure should be developed. An information platform for priority screening based on the environmental risks of ECs should be established. The pollution level, persistence, harmful effects, and ecological and health risks of ECs in specific environments, as well as economic and technological factors, should be comprehensively considered in order to determine and dynamically update a list of high-priority ECs.

(2) **The second aspect is to strengthen EC monitoring and evaluation capabilities and to establish a database and information platform**. We should develop and standardize both precise quantification and rapid screening analysis technologies for multiple ECs and promote the application of EC identification methods based on targeted/non-targeted analysis and effect-directed analysis. We suggest the establishment of an EC monitoring alliance in China that can fully coordinate current EC monitoring resources. Unified EC monitoring technology specifications should be adopted to carry out EC monitoring, thereby solving the problem of poor systematicity and comparability of EC monitoring data. Focusing on key regions and industries, a nationally unified, data-sharing, and dynamically updated database and evaluation information platform for the pollution status of ECs should be established to provide scientific support for accurately assessing the environmental risks of ECs.

(3) **The third aspect is to establish environmental criteria and standards for the environmental risk assessment and control of ECs**. Technical specifications for environmental criteria for ECs should be developed based on species sensitivity distribution, including typical local species in ecosystems in China. Environmental EC exposure models and technical specifications should also be established, based on localized exposure scenarios and parameters, to achieve the precise assessment of human and biological exposure. Ecological and human health risk assessment criteria for ECs should be gradually established, and the regular performance of EC risk assessments in key regions and industries should be promoted. Environmental control standards for high-risk ECs should be gradually developed and implemented, and full life-cycle management and best available technologies (BAT)/best environmental practices (BEP) should be implemented to prevent the release of ECs from sources. Green substitutes for high-risk

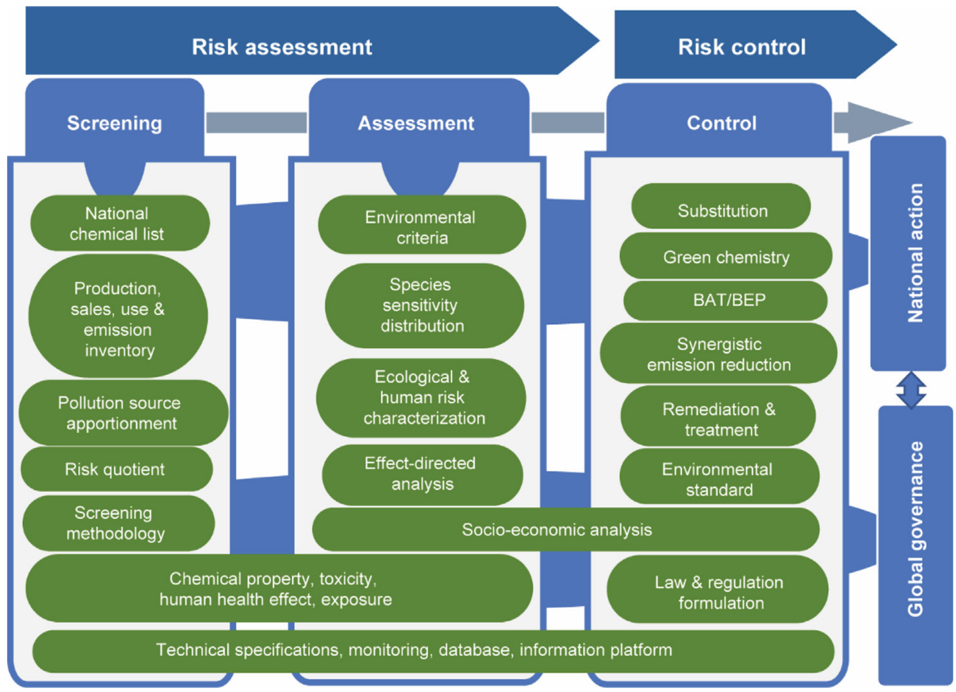

Fig. 3. The main components that promote the environmental risk assessment and control of ECs. BAT: best available technologies; BEP: best environmental practices.

chemicals should be invented and fully evaluated as safe and effective. Green and low-carbon technologies and processes that simultaneously reduce the emissions of both conventional pollutants and ECs should be developed to achieve the resource recovery of waste chemicals and to reduce both pollution and carbon emissions.

(4) **The fourth aspect is to strengthen the synergistic control and promote the global governance of ECs**. The synergistic control of conventional pollutants and ECs should be coordinated at the national level, improving the cross-regional and cross-departmental EC control working mechanism [1]. Taking the Yangtze River and Yellow River conservation strategies as an opportunity, we suggest that an innovative platform for EC risk assessment and control be established and that the combined prevention and control of ECs at the basin scale be promoted. Efforts should be made to bridge the gap between scientific research, engineering technology, policy management, and public participation in order to jointly promote EC governance, thereby supporting a thriving natural environment and establishing high quality of life in China. In the implementation of international chemical conventions, China should take the responsibility of a major country, extensively participate in global environmental governance, and enhance the power and influence of our discourse. Hence, China should deepen international exchange and cooperation in ecological environment protection, jointly seek solutions to the bottleneck of EC control, and work together with other nations to build a clean and beautiful world.

5. Conclusions and perspective

At the 2023 National Conference on Ecological and Environmental Protection, EC control was proposed by President Xi Jinping as a key area of national basic research and technological innovation in China. As this great task presents various problems and challenges, comprehensive scientific and technical support is urgently required for the environmental risk assessment and control of ECs in China. We propose the initiation of a National Major Science and Technology Special Project for EC Control to provide scientific and technological support for EC control in China. With progress in scientific and technological innovation, EC control will undoubtedly push forward the development of green chemistry and the upgrading of China's chemical industry [14], which will contribute to EC source elimination or reduction. Finally, we are convinced that the environmental risk assessment and control of ECs will promote the construction of a beautiful and healthy China.

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