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Voluntary governance model for addressing heavy metal pollution in China: an analysis of the network governance approach

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ABSTRACT

China, as a developing nation, has undergone rapid industrial growth over the past three decades. However, due to inadequate environmental regulations and enforcement, many industrial enterprises have discharged untreated wastewater directly into water bodies, leading to heavy metal pollution. Prolonged exposure to these heavy metals has become a significant public health concern. In response, the Chinese government has implemented a top-down, centralized state-centric approach to address the issue. However, this model has faced challenges, particularly in terms of delayed response times. This paper introduces the voluntary governance model, which has the potential to be a supplement to the state-centric model. Such a complement aims to enhance the efficiency of environmental governance and provide citizens with a healthier, cleaner environment.

Key words: developing nation, environmental regulations, heavy metal pollution, industrial expansion, untreated wastewater

HIGHLIGHTS

- Heavy metal pollution affects human health.
- China suffers from heavy metal pollution.
- Voluntary governance provides a possible solution to heavy metal pollution.

1. INTRODUCTION

Over the past three decades, China has witnessed rapid industrial growth, particularly in the chemical industry, which stands as one of the nation's key sectors (Wang *et al.* 2015; Liu *et al.* 2018). Nevertheless, due to inadequate environmental legislation and enforcement, numerous chemical factories have been discharging untreated wastewater directly into water bodies, resulting in significant environmental issues, including heavy metal water pollution (Wang & Yang 2016). Prolonged exposure to heavy metal pollution has been linked to various adverse health effects in humans, such as cancer, pulmonary adenocarcinomas, and prostatic proliferative lesions (Żukowska & Biziuk 2008). To address this pressing concern of heavy metal pollution, the Chinese government had to urgently implement measures.

To address this environmental challenge, the Chinese government implemented a top-down, centralized state-centric governance approach known as the 'pollution first, treatment afterward' strategy (Zhang *et al.* 2016). However, this approach exhibited certain challenges, including prolonged response time to environmental issues. In this study, we employ the theory of network governance to analyze the current problem and propose a novel governance model called voluntary governance. By strategically incorporating voluntary governance as a supplement to the state-centric model, we aim to enhance environmental treatment efficiency. Finally, we discuss the constraints of voluntary governance and draw conclusions regarding its applicability.

2. THE CHALLENGE OF HEAVY METAL POLLUTION IN CHINA

Since 1991, China has witnessed an average annual gross domestic product (GDP) growth of approximately 10% (Wang *et al.* 2015). Among the significant developing industries in China over the past three decades, chemical engineering stands out,

encompassing the production and processing of petroleum, ore, food, fertilizers, plastics, and synthetic fibers (Liu *et al.* 2018). However, a notable environmental issue has emerged nationwide due to the direct discharge of untreated wastewater from many chemical factories into water bodies (see Figure 1). The discharged wastewater contains various heavy metals, including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), zinc (Zn), and mercury (Hg) (Wang & Yang 2016). Notably, previous research suggests that millions of people have been negatively impacted by heavy metal pollution (see Table 1), with many individuals suffering from cancer attributed to the consumption of water contaminated with high concentrations of heavy metals (Yang *et al.* 2018).

Heavy metal pollution has emerged as a nationwide problem, affecting various provinces. Among the 10 provinces most affected by heavy metal pollution, notable regions include Henan, Shandong, Sichuan, Hunan, Hubei, Jiangsu, Inner Mongolia, Yunnan, Guangxi, and Jiangxi (see Table 1). These provinces encompass a diverse range, from heavily populated areas like Shandong and Henan to sparsely populated regions like Inner Mongolia. Economic variations are also evident, from advanced economic provinces like Jiangsu to weaker economic provinces like Yunnan and Guangxi. Furthermore, the impacted areas span from northern regions, such as Shandong, to southern regions, such as Guangxi. Despite these differences, all provinces face significant threats from heavy metal pollution, necessitating a national-level approach to governance rather than regional solutions.

The prevalence of heavy metal pollution in China can be attributed, in large part, to the inadequacy of proper environmental governance. This issue varies across different regions, each facing distinct environmental governance challenges. For instance, in certain provinces like Yunnan, the absence of a well-established environmental legislation system allowed chemical factories to freely discharge wastewater directly into water bodies. On the other hand, provinces such as Hebei,

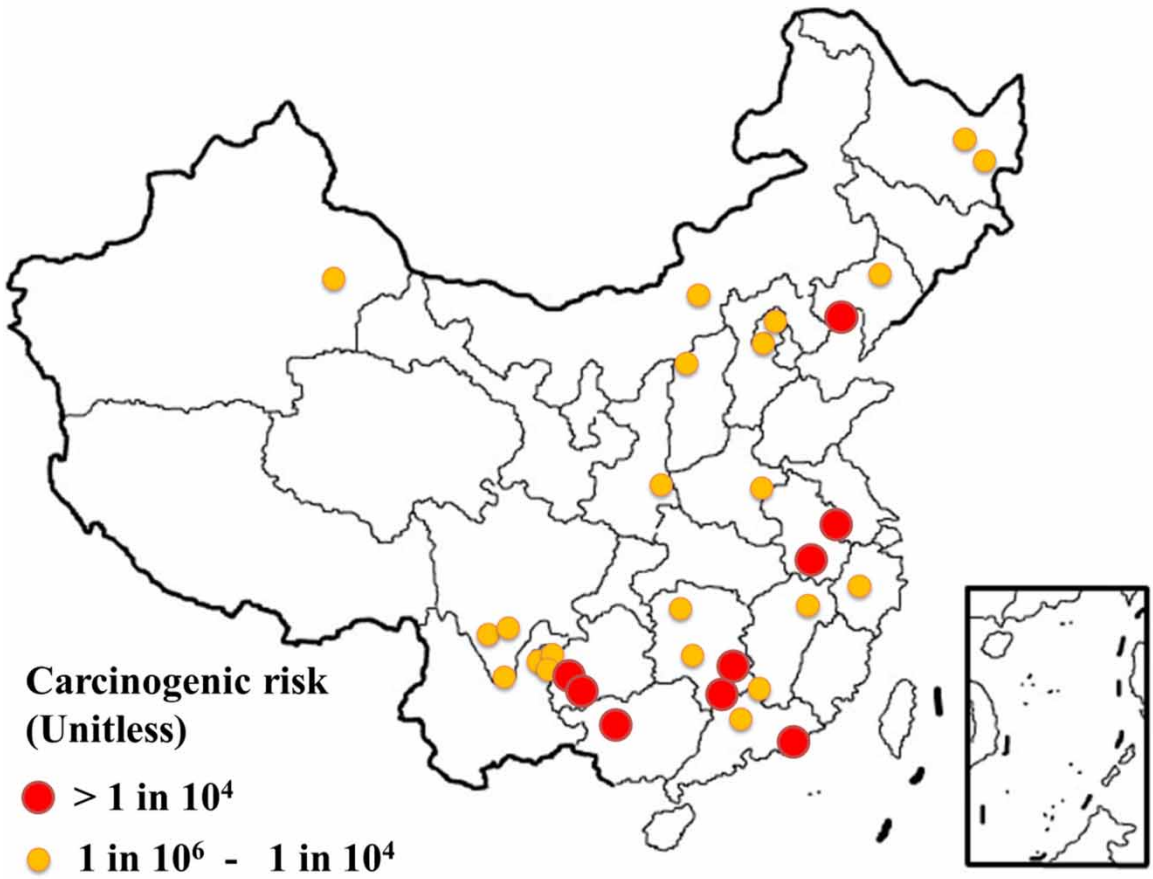

Figure 1 | Schematic illustration showing the distribution of carcinogenic risks caused by heavy metal pollution. Yellow dots represent medium carcinogenic risk, while red dots indicate high carcinogenic risk. The data sources for this illustration are Li *et al.* (2014); Zhang (2016).

Table 1 | The 10 provinces exhibiting the largest estimated heavy metal pollution areas

Province	Population (Million)	GDP per capita (nominal, United States Dollars)	Estimated heavy metal pollution area (Hectares)	Percentage of China's polluted area
Henan	94.0	6,980	14.0	8.5%
Shandong	95.8	10,790	10.6	6.4%
Sichuan	80.4	6,613	9.5	5.8%
Hunan	65.7	7,489	8.3	5.1%
Hubei	71.9	9,179	7.9	4.8%
Jiangsu	78.7	17,176	7.5	4.6%
Neimenggu	24.7	12,156	7.0	4.3%
Yunnan	46.0	5,117	6.8	4.1%
Guangxi	46.0	6,214	6.0	3.6%
Jiangxi	44.6	6,693	5.4	3.3%
Total	647.8	—	83.0	50.5%

Note. Economic data were derived from the source: International Monetary Fund of the World Economic Outlook of April 2018 with permission (Del Rio Lopez & Gordo Mora 2019). The estimation of heavy metal pollution areas originated from the source: Ministry of Environmental Protection, China (Chen *et al.* 2018; Li *et al.* 2022).

Henan, and Shandong had established and published environmental laws, yet their monitoring systems proved insufficient. Consequently, chemical factories in these regions continued to release wastewater into waterways, confident that they would not face punitive consequences.

Moreover, in some rural areas, the lack of awareness and education about environmental laws led people to unknowingly release heavy metal-polluted water without realizing its illegality. In contrast, some urban centers possessed a higher level of awareness regarding the illegal nature of wastewater release. However, driven by economic interests, some individuals still chose to flout the environmental laws and release polluted water despite being fully aware of the consequences.

The combination of these factors resulted in a significant burden of heavy metal pollution across China, exacerbating the complexity of addressing the problem of unregulated wastewater release. The multifaceted nature of the issue calls for a comprehensive and targeted approach to environmental governance, incorporating measures to educate the public, enforce legislation, and incentivize responsible industrial practices. Only through such concerted efforts can China effectively combat the challenges posed by heavy metal pollution and achieve a healthier and more sustainable environment for its populace.

3. CHALLENGES AND OPPORTUNITIES IN THE HEAVY METAL POLLUTION GOVERNANCE MODEL

To address the issue of heavy metal pollution, China's government currently employs a top-down, centralized state-centric governance approach, characterized by the 'pollution first, treatment afterward' strategy. This governance model involves a sequential process when dealing with heavy metal pollution incidents. Initially, local communities report contamination cases to their respective local governments (Step 1). Subsequently, the local governments escalate the matter to the central government (Step 2), which then formulates comprehensive plans and policies to resolve the pollution problem. The central government may seek support from external entities, such as research institutes for technology expertise, non-governmental organizations (NGOs) for human resources, or business associations for financial investment (Step 3). Ultimately, the identified solutions are implemented at the affected locations to achieve remediation (Step 4) (refer to Figure 2).

However, the current state-centric governance system exhibits several limitations that necessitate critical consideration:

(1) *Long response time*: The sequential nature of the governance process leads to significant delays in addressing heavy metal contamination issues. By the time the problem is reported, local communities may have already experienced adverse consequences, sometimes manifesting within a week. In contrast, the reporting, decision-making, and implementation phases may require a minimum of 2–4 months.
(2) *Low governance efficiency*: The existing reporting system may not provide the central government with sufficient information to make well-informed decisions. Additionally, the implementation of remediation plans and environmental law

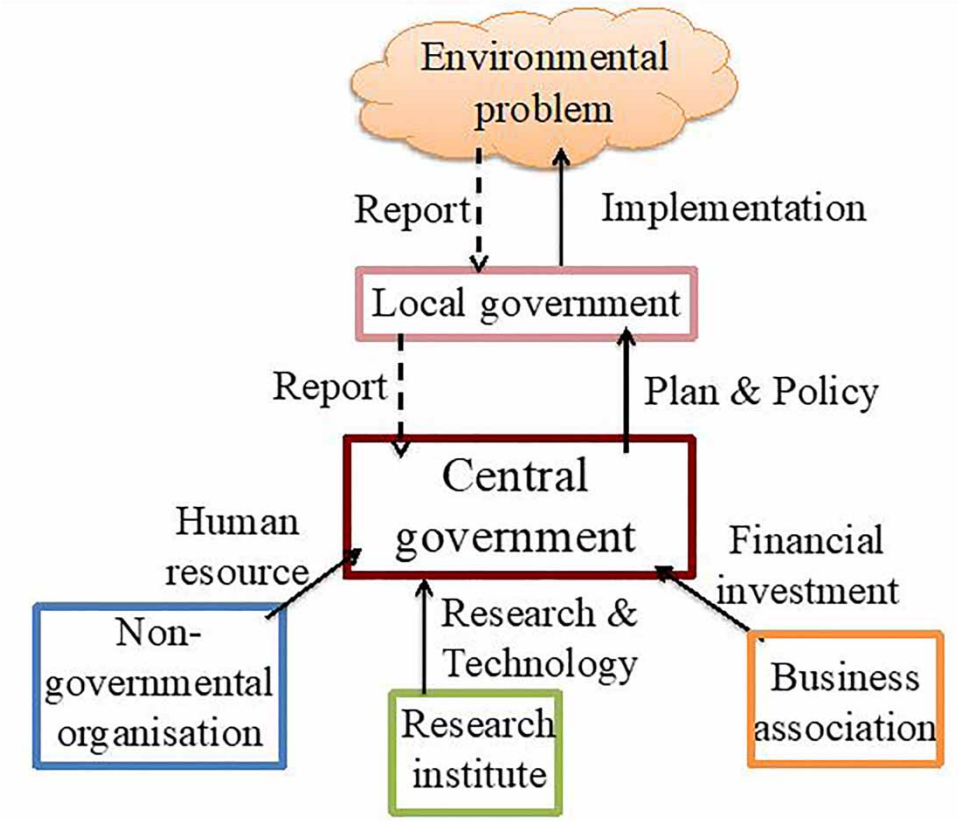

Figure 2 | A schematic illustration of China's existing state-centric governance system employed for environmental remediation.

enforcement may encounter resistance, such as protests from local chemical industries, which significantly hampers governance efficiency.

(3) *Inaccurate remediation plans and policies*: Immaturity in the information system restricts the central government's understanding of the situation, leading to potential inaccuracies in the formulation of remediation plans and environmental policies. Insufficient funding allocation or the adoption of inappropriate remediation technologies may result from this lack of accurate information, leading to resource wastage during the governance process.

(4) *Restriction of scientific research and technological development*: The concentration of decision-making power within the state-centric governance model may impede academic freedom and dampen the enthusiasm of researchers. Furthermore, the central government's limited expertise in environmental matters might hinder its ability to provide insightful recommendations to researchers, consequently limiting the scope of environmental research.

Addressing these limitations calls for a reassessment of the governance model, exploring potential adjustments to foster more efficient and timely responses to heavy metal pollution incidents. Emphasizing improved data collection, enhanced communication channels, and greater collaboration between government institutions, research bodies, NGOs, and businesses could pave the way for a more agile and effective governance system in tackling heavy metal pollution in China. Moreover, striking a balance between centralized authority and academic freedom can stimulate innovation, thus accelerating advancements in environmental technologies and research endeavors.

4. THE ROLE OF VOLUNTARY GOVERNANCE IN COMBATING HEAVY METAL POLLUTION

To address the limitations inherent in the current centralized top-down state-centric governance model, this paper adopts the theory of network governance for analysis. This theory revolves around fostering synergy among various entities (Jones *et al.* 1997) and has proven valuable in studying ecological and environmental challenges, aiding researchers in understanding

distinct roles within a governance model and offering innovative policy design recommendations (Bixler *et al.* 2016). A prior study utilized the theory of network governance to enhance efficiency and streamline decision-making processes by distributing knowledge (Poole 2014).

Within the framework of network governance, four typical governance models exist: state-centric (hierarchical) governance, multi-partner governance, market governance, and voluntary governance (self-governance) (Lowndes & Skelcher 1998). At present, China primarily adheres to the state-centric governance model when addressing heavy metal pollution issues. However, this paper delves into the concept of voluntary governance as a novel approach to complement the existing state-centric governance system, aiming to achieve more efficient remediation efforts.

The voluntary governance model grants increased autonomy to local governments and organizations. Within this model, in the event of heavy metal pollution, local governments and organizations gain the ability to directly address environmental challenges without the traditional process of reporting the issue to the central government and awaiting policy and remediation plans. Moreover, a higher proportion of funding required for heavy metal pollution treatment and technological advancements is allocated to local governments and organizations, as opposed to the central government (see Figure 3). This shift in allocation aims to empower local entities and enhance their capability to respond promptly and effectively to environmental crises, fostering a more agile and adaptable approach to addressing heavy metal pollution issues in China.

In comparison to the state-centric governance model, voluntary governance emerges as a highly effective approach for addressing pollution issues in China, particularly in underdeveloped villages and towns (for a comprehensive comparison, refer to Table 2). Notably, the voluntary governance model possesses several key characteristics that contribute to its efficacy:

(1) *Rapid pollution treatment*: One of the primary advantages of voluntary governance lies in its ability to achieve swift pollution treatment. In contrast, the state-centric governance approach entails a lengthier response time due to the sequential reporting process from local to central government. This delay often arises from the central government's limited understanding of specific heavy metal pollution situations, necessitating further investigation before devising a treatment plan. Conversely, voluntary governance largely relies on the knowledge and understanding of local governments and organizations, enabling quicker responses and more expedited processing times.

(2) *Efficiency through codes of conduct and local involvement*: Voluntary governance operates on the basis of codes of conduct and actively involves local communities in solving their environmental problems. The realization that they are actively contributing to pollution treatment enhances the commitment and participation of local people, resulting in improved pollution treatment efficiency.

(3) *Accurate treatment plans and environmental policies*: A significant advantage of voluntary governance stems from its ability to foster more accurate treatment plans and environmental policies. Heavy metal pollution tends to be a regional problem, characterized by specific locations, areas, and contaminants. In such cases, local governments and organizations possess a deeper understanding of the local environmental issues, making them better suited to collaborate on developing targeted treatment plans and environmental policies.

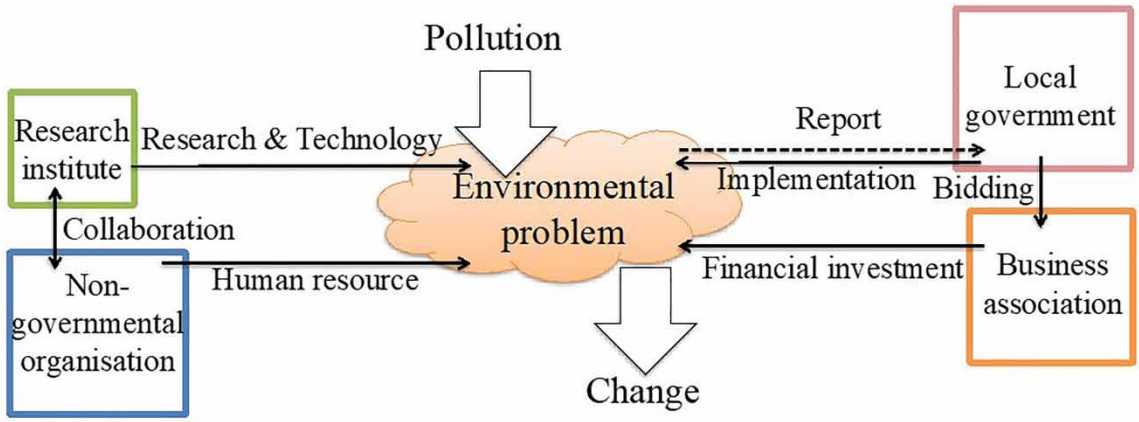

Figure 3 | A schematic illustration of the voluntary governance model applied in environmental remediation.

Table 2 | The comparison between state-centric governance and voluntary governance

	State-centric (hierarchical) governance	Voluntary governance (self-governance)
Basis of governing	Authority and regulation	Peer pressure
Policy instruments	Tax incentives	Codes of conduct
Advantages	Traditional governance, formal process	Efficient governance, fast reactions,
Limitations	Slow reactions, low flexibility and efficiency, little communication, inaccurate plans and policy	Difficult implementation, internal resistance, limited resources and funding
References	(Lowndes & Skelcher 1998; Fujita & Phanvilay 2008; Yayoi & Kaisone 2008; Chen & Ding 2023)	(Jones *et al.* 1997; Lowndes & Skelcher 1998; Chen & Ding 2023)

(4) *Stimulating technological development*: The decentralization process intrinsic to voluntary governance provides local research institutes with greater freedom to conduct essential research. This academic freedom is paramount for scientific exploration and technological development. Furthermore, voluntary governance promotes enhanced communication and collaboration between different research institutes and organizations, creating an environment conducive to the development of novel environmental technologies and the advancement of quality environmental education (refer to Figure 4).

In light of these strengths, the voluntary governance model emerges as a promising alternative to bolster pollution treatment efforts. Its emphasis on local involvement, accurate regional focus, and fostering technological advancements positions it as a valuable complement to the existing state-centric governance system. By leveraging the unique advantages

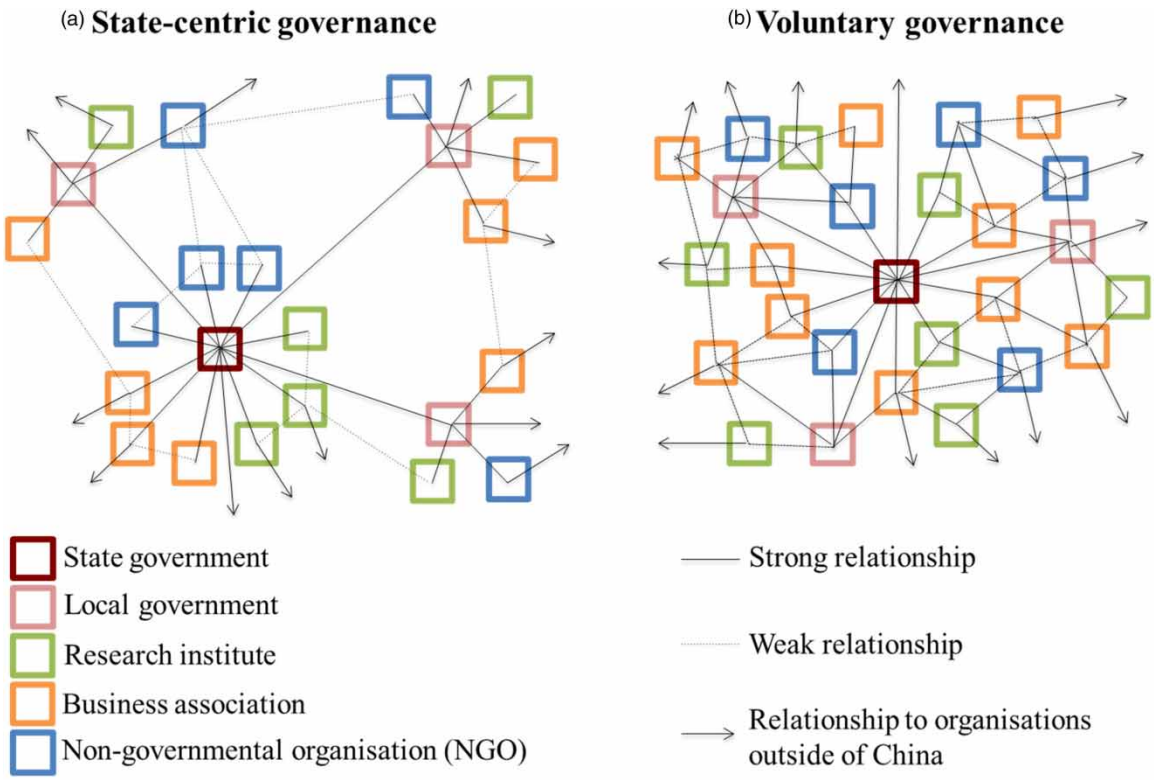

Figure 4 | A schematic illustration of the network in (a) state-centric governance and (b) voluntary governance.

of voluntary governance, China stands to enhance its capacity to tackle pollution challenges effectively and achieve a more sustainable environmental landscape.

5. THE PATH TO IMPLEMENTATION OF VOLUNTARY GOVERNANCE IN ENVIRONMENTAL REMEDIATION

In examining the potential benefits of the voluntary governance model for addressing heavy metal pollution, it is crucial to acknowledge the inherent limitations that may impede its smooth implementation. Despite its promising features, voluntary governance faces certain challenges, which warrant careful consideration. The following points outline the key limitations of the voluntary governance model:

(1) *Cultural challenges*: The adoption of the voluntary governance model may encounter cultural obstacles rooted in a long-standing tradition of employing a top-down state-centric governance approach. Traditional Chinese culture emphasizes reporting problems to higher authorities and adhering to their guidance in solving issues. Transitioning away from such deeply ingrained cultural practices necessitates a concerted, long-term effort from various organizations to ensure successful implementation. In areas where the local populace is unfamiliar with the voluntary governance system, confusion and resistance may arise during the remediation process.

(2) *Resistance to novel policy and governance systems*: The shift to voluntary governance involves both policy innovation and decentralization of decision-making. However, this change may encounter resistance from those who maintain that centralized decision-making is the most efficient. To overcome this, it is essential to confront these traditional beliefs and demonstrate how decentralization can lead to more effective outcomes. This mindset shift is gradual and requires strategic communication and evidence-based arguments.

(3) *Challenges in gathering funding*: The successful application of the voluntary governance system demands substantial financial investment. Adequate funding is crucial to support various aspects of the voluntary governance model, such as employing environmental experts, advocacy, and advertisement. While China's government currently enjoys a sound financial position, persuading the government to allocate considerable resources to environmental reform remains a challenge.

In light of the above analysis, it is clear that directly replacing the current state-centric governance system with the voluntary governance model is not realistic. However, this paper suggests that the voluntary governance system could be selectively applied in specific areas to address heavy metal pollution more efficiently. By strategically targeting regions where the cultural landscape and willingness to embrace change align with the principles of voluntary governance, its implementation can be optimized. The gradual integration of voluntary governance in these contexts can pave the way for enhanced pollution remediation efforts and serve as a step toward adopting a more diversified governance approach in China's environmental management. As shown in Table 2, state-centric (hierarchical) governance excels in traditional governance and formal processes, while voluntary governance (self-governance) offers advantages in efficiency and rapid response. Furthermore, voluntary governance holds the potential to complement state-centric governance, creating a synergistic approach to tackling environmental challenges.

6. CONCLUSION

In conclusion, heavy metal pollution remains a critical challenge, affecting millions of people over the past three decades. Although the state-centric governance model has made progress in addressing this issue, it faces limitations such as delayed response times, inefficiency, imprecise treatments, and a lack of technological innovation. To address these challenges, this study introduces network governance as an analytical framework and advocates for the adoption of voluntary governance as a complementary approach. Voluntary governance has the potential to revitalize local enthusiasm and enhance environmental management practices. However, successful implementation requires overcoming cultural barriers and securing adequate funding. By strategically incorporating voluntary governance as a supplement to the state-centric model, China can harness its unique strengths to achieve more sustainable and efficient pollution control.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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