

Article

A Questionnaire Survey on Contaminated Site Regulators' View of Implementing Green and Sustainable Remediation in China

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Abstract: Government contaminated site regulators, as policy executors and makers, have a profound impact on the development of green and sustainable remediation (GSR), but their cognitive level of GSR has not been well-studied. China has some experience in the management of contaminated sites and has the foundation to promote GSR. This study was conducted in the form of a questionnaire to investigate the understanding of GSR among Chinese site regulators at different levels. The study found that there was still a lot of resistance to promoting GSR in China. Firstly, even though the regulators thought GSR was necessary in China, most of them did not know GSR very well or lacked practical experience. Secondly, existing national and provincial policy standards did not have a good balance between the environmental, social and economic aspects, but gave priority to the environmental factors. Thirdly, the lack of standard and regulatory requirements was the most significant barrier to the implementation of GSR. The results of the survey can provide a reference for China or other developing countries to implement GSR. Practitioners should provide more knowledge and cases for regulators, supplement national policies or improve the provincial and municipal policy system.

Keywords: green and sustainable remediation; contaminated site; governmental regulator; questionnaire survey; environmental dimension; social dimension; economic dimension



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1. Introduction

Land contamination is a major environmental challenge in China, affecting both agricultural land and urban land [1]. China has been making substantial investments in the management of land contamination over the last decade, culminating in the “Soil Pollution Prevention and Control Action Plan (Soil Ten Provisions)” in 2016 [2] and the “Soil Pollution Prevention and Control Law of China (Soil Law)” in 2018 [3]. The implementation of Soil Ten Provisions has enabled China to improve the policies and standard system for soil pollution prevention and control, complete the construction of a national database of agricultural and contaminated land, and carry out a number of remediation demonstration projects. The Soil Law implemented a comprehensive risk-based system for the regulation and remediation of land contamination.

Under the Soil Law, contaminated site remediation is carried out to eliminate and/or control risks, primarily to human health, water and the wider environment [3]. Across the world, there is increasing interest in ensuring that site contamination management is carried out in a sustainable way [4]. Green and sustainable remediation (GSR) aims to reduce negative impacts and maximize the long-term benefits of remediation projects, and ensure an overall net benefit among social, economic, and biophysical conditions [5]. GSR

is an increasingly important part of the management of contaminated site and has attracted widespread attention [6,7].

A range of reports and white papers from across the world [8], policies [9,10] and frameworks [11,12] have laid the foundation for the concept and implementation of GSR. Moreover, a series of guidelines [13–15] and standards [16–18] have provided a feasible and flexible evaluation procedure; these helped to better integrate GSR into the full life-cycle of the remediation project. In addition, the Best Management Practices (BMPs) issued by the Environmental Protection Agency (EPA) of the United States (US) [19] and Sustainable Management Practices (SMPs) published by the Sustainable Remediation Forum of the United Kingdom (SuRF-UK) [20] helped stakeholders improve the sustainability of contaminated site management practices, without necessarily requiring in-depth sustainability analyses. Reviews [21–24] and status reports [5,25] showed the evolution of GSR, as well as providing a wider basis for the technical understanding of all aspects of GSR.

The development of GSR was the result of interactions between various factors, such as the development of the remediation industry, the progression of scientific research, and the improvement in practitioners' awareness. GSR evaluation and use is a multi-stakeholder activity including site managers, service providers, regulators planners among others [25–27]. Some researchers tried to investigate different stakeholders' perceptions of GSR [28–30], but their respondents were almost all researchers, and the sample size of the regulators was small. Where a regulator is also a policy-maker and possible implementer, they have the most far-reaching influence and can advocate for GSR [1,22]. The US and the United Kingdom (UK) are considered to have relatively high levels of GSR awareness; their regulatory agencies have taken some actions on GSR. In the US, the Department of Energy (DOE), Department of Defense (DOD), and EPA have collaborated in developing green remediation assessment tools, publishing green cleanup principles, sharing green remediation cases, organizing roundtable meetings, etc. The importance of sustainable remediation has been clearly recognized in the guidelines for the management of contaminated sites formulated by the UK government. For example, land contamination risk management (LCRM), established by the UK government in 2019 [31], clearly stated support for a sustainable approach to land contamination risk management. SuRF-UK's framework document price is also proposed in the document.

In recent years, China has carried out a range of actions related to the management of contaminated sites. Some of the critical milestones related to GSR are listed in Table 1.

Table 1. Key actions or regulations related to GSR in China.

No.	Action	Time	Main Target	GSR Considerations
1	Soil Pollution Prevention and Control Action Plan (Soil Ten Provisions) [2]	2016	Listed the actions that China should take to “strengthen soil pollution prevention and control, and gradually improve soil environmental quality” in the period of 2016–2021.	Consider the overall situation of economic and social development; promote the sustainable use of soil resources
2	China Sustainable Remediation Forum (SuRF-China)	2017	Promoted the implementation of GSR and the high-quality development of the environmental remediation industry in China	SuRF-China signed the proposal to promote GSR.
3	Soil Environmental Quality-Risk Control Standard for Soil Contamination of Development Land (GB36600-2018) [32]	2018	Set risk screening and control values for soil pollution on construction land for the protection of human health, as well as requirements for monitoring, implementation and supervision	Risk-based soil environmental quality standards

Table 1. Cont.

No.	Action	Time	Main Target	GSR Considerations
4	Soil Pollution Prevention and Control Law of China (Soil Law) [3]	2018	Protect and improve the ecological environment, prevent and control soil pollution, protect public health, promote the sustainable use of soil resources, advance the construction of ecological civilization, and promote sustainable economic and social development.	The concept of “sustainability” was also put forward in the principles.
5	The Principles of Green and Sustainable Remediation (T/CAE PI 26-2020) [33]	2020	Protect the ecological environment, ensure human health, and promote green and sustainable remediation of contaminated land	This standard specifies the principles, evaluation methods, implementation contents, and technical requirements of GSR for contaminated sites.

In 2021, China entered the 14th five-year plan; the central government advocated green development and put forward the goal of reaching a carbon peak by 2030 and a carbon-neutral target by 2060. In 2021, the Ministry of Ecology and Environment (MEE) also put forward the goal that “pollution reduction and carbon reduction should be coordinated” [34]. This goal directly influences the implementation of GSR on contaminated site. In China, there has been strong academic and research interest in GSR [35–37], but in specific practice, GSR is not actively implemented by regulatory departments at the regional and local authority levels. Braun, A.B. found that lack of awareness or acceptance of sustainable remediation principles by stakeholders hindered the effective incorporation of GSR in the remediation process [38]. Local regulators are the link between the central government, researchers and remediation practice; their level of awareness of GSR is particularly critical to the development of GSR in China.

From what has been discussed above, this study, for the first time, took local contaminated site regulators at all levels as research objects to: (i) understand the familiarity and cognitive level of regulators at all levels regarding GSR, as well as the resistance to the implementation of GSR in China; (ii) comprehensively analyze whether environmental, social and economic factors are reflected in the existing policy and standard system in a balanced way, and which factors should be strengthened; (iii) analyze the solutions to practical problems such as the prevention and control of secondary pollution and public participation. The results of this study can provide a reference for the following work: helping China or other developing countries promote GSR or develop appropriate GSR implementation strategies, help Chinese local governments improve the local policy and standard system, and help researchers clarify their research direction. Online questionnaires were selected, mainly because this method can quickly collect responses from a large number of people and reduce time, costs and geographical limitations.

2. Materials and Methods

2.1. Questionnaire Design

This questionnaire consisted of three parts (see Appendix A). The first part was pertained to demographic information, such as the region, the department, and their title. The second part investigated provincial and local government regulators’ perception of GSR, and the extent of the practical implementation of GSR in China. The third part focused on asking regulators which dominant environmental, social and economic factors were being considered in GSR decisions using a checklist developed on this basis.

In the questionnaire design stage, the factors related to GSR released by SuRF-UK, the Interstate Technology & Regulatory Council (ITRC) and EPA [11,13,15] were collected, and a series of communications with some soil regulators was carried out. Based on their suggestions and practical experience in China, this questionnaire was designed, and a total of 21 GSR factors were selected for the checklist (Table 2). Additional questions were asked about secondary pollution prevention and public involvement in decision-making, and open questions about perceived barriers to the implementation of GSR in China.

Table 2. Green and sustainable remediation factors included in the questionnaire.

No.	Environment	Society	Economy
1	Prevention and control of secondary pollution caused by waste, exhaust gas, solid waste, dust, noise, etc.	Protect the health and safety of construction workers	Effectively control the construction period, remediation cost and long-term operating costs
2	Reduce greenhouse gas emissions	Impact on the public and surrounding population	Encourage indirect benefits to the local area
3	Maintain soil physical and chemical properties and ecological functions of soil	Marked buildings and cultural relics protection	Encourage the creation of local jobs
4	Save resources and energy during the remediation process	Public involvement	Encourage engineering and technological innovation
5	Use clean energy	Follow the “polluter pays” principle	Improving professional remediation skills
6	Impact on the ecological environment	Consider ethical issues	
7	Impact on regional natural environment	Encourage the purchase of local labor and products	
8	Encourage in-situ remediation	Bring prosperity to disadvantaged groups	
9		Improve the regional social sustainability index	

2.2. Respondents' Profile

In China, the MEE is responsible for the supervision and administration of the prevention and control of soil pollution throughout the country, and they prepare or issue national policy standards. Provincial, municipal and county, or district ecology and environment departments (EED) are responsible for the supervision and administration of soil pollution prevention and control within their respective areas. Provincial EED can also formulate more detailed, localized, or innovative/supplementary policy standards according to its actual conditions, but it must follow national policy standards, and cannot greatly differ to or deviate from national policy standards. At the time of the issuance of this questionnaire, some of the developed provinces had established policy standard systems related to site management, while others were considering doing so. As the municipal and county or district EEDs had little experience, they all followed national or provincial policy standards. Almost all provincial and municipal EEDs have one subordinate agency to provide technical support; they help draft policies and standards, assist in reviewing reports, and provide technical support in decision-making. Their level of knowledge plays a particularly decisive role in the implementation of GSR. However, the district or county EED is directly subordinate to the municipal EED; they generally do not have a technical support agency.

Therefore, the objects of the questionnaire distribution were the staff of soil-management divisions of EED at all levels in 32 provincial municipalities, directly under control of the central government or autonomous regions (hereinafter collectively referred to as provinces) in mainland China, as well as the staff providing technical support for provincial or mu-

municipal EED. The survey questionnaire was set up online (<https://www.wenjuan.com/>, accessed on 10 November 2019) and the link to the questionnaire was sent to 180 targeted respondents. All the targeted respondents were all engaged in the prevention and control of soil pollution, and they could understand the questions listed in the questionnaire. The questionnaire was not distributed to other institutions, to ensure the reliability of the collected information. A total of 125 respondents from 30 provinces filled out the questionnaire; only Fujian and Ningxia did not provide effective feedback.

The composition of the responses received is shown in Figure 1. Of these responses, 17% were from provincial EEDs, 24% from technical support agencies of provincial EEDs, 32% responses from the municipal EEDs, 12% from technical support agencies of municipal EEDs, and 15% from county- or district-level EEDs. A total of 13% of responses were the division director or above, 33% were the section chief and 54% were section members.

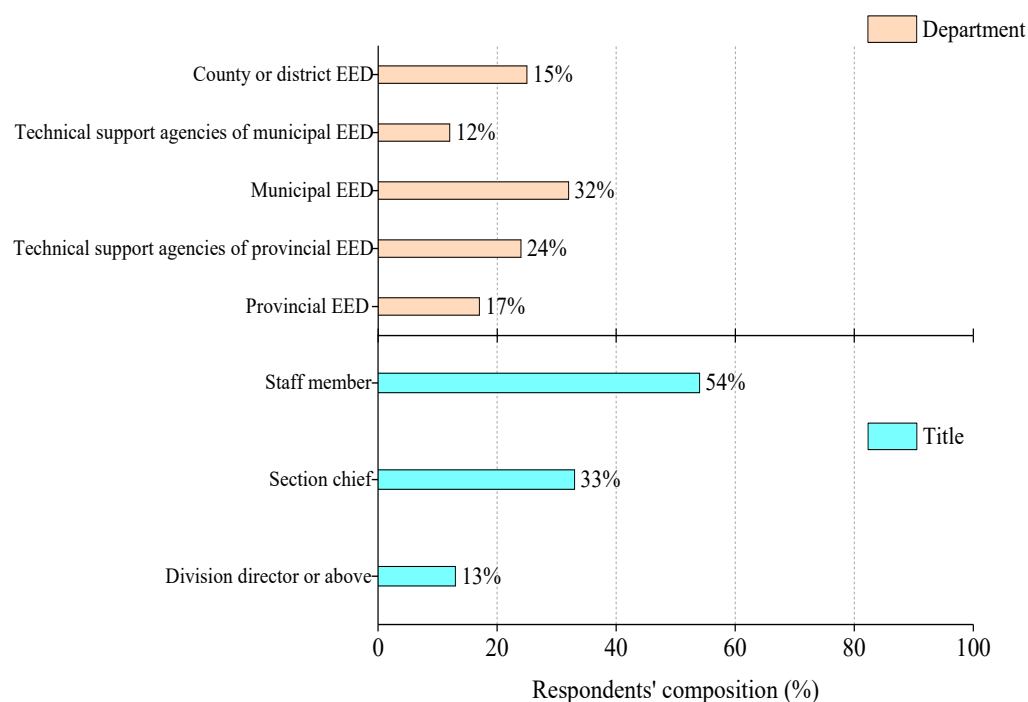


Figure 1. Respondents' composition.

2.3. Data Analysis

A statistical analysis of the questionnaire data was performed using the software "Origin 9.0" (OriginLab). In order to address "design effects" in the questionnaire survey, standard error estimators were adjusted by the bootstrapping methods described by Hou D. et al. [29].

2.4. Limitation of the Method

Most of China's soil regulators do not have rich GSR experience; their main job is to complete the tasks listed in the Ten Soil Provisions [2]. To attract regulators to carefully fill in the questionnaire and improve the validity of the provided information, the questionnaire design followed the following three principles: 1. Referee the sustainable remediation indicators published by SuRF-UK [11]; 2. Choose topics that all the regulators can understand and be interested in; 3. The questionnaire should not be too long, and the time needed to fill in the questionnaire should be under 10 min. Therefore, this questionnaire only selected some indicators for investigation, and did not cover all indicators. In addition, in the municipal- and county-level surveys, the questionnaire was only sent to the areas with prominent soil-pollution problems, instead of covering all the cities and counties, and only represented the views of some soil regulators.

3. Results and Discussion

3.1. Regulators' Awareness on Green and Sustainable Remediation

The respondents' understanding and view of the importance (namely, the necessity) of GSR was evaluated by two questions: ① Before taking part in this questionnaire, what did you know about GSR? Four answers were set: Be familiar with GSR and try to implement it in practice; Be familiar part of GSR, but not clear how to implement; Only heard of it, but don't know what it is; Never heard. ② Is it necessary to implement GSR? Respondents' views are described by four levels: Strongly necessary; Be necessary; Ordinary; Not necessary.

As shown in Figure 2, 44.0% of respondents knew some of the content of GSR but were unsure how to implement it, 34.4% of respondents had only heard of GSR, but were not sure what it was. Only 11.2% of respondents were familiar with GSR and tried to implement it in practice. The familiarity of the five surveyed groups with GSR was also compared. It was found that the technical support departments of provincial and municipal EEDs were more familiar with GSR and were trying to implement it. Provincial, municipal-, county- or district-level EED's familiarity with GSR was similar, but at a lower level than that of the technical support departments. Part of the reason for the low level of reports of a good familiarity (especially at all levels of EED) may be related to workload issues, given the recent introduction of the Soil Law [3] and the Soil Ten Provisions in China [2]. These two documents were published in 2019 and 2016, respectively. Since 2016, local EEDs have established soil environment management divisions with full-time soil supervision personnel, sometimes from a very limited starting point. However, the local EED should complete the work listed in the Soil Law and the Soil Ten Provisions, such as building a management framework, improving policies and standards, increasing site management capacity, conducting investigations and remediation demonstration, and building a national site database. Therefore, only a few administrations have had sufficient resources to explore GSR.

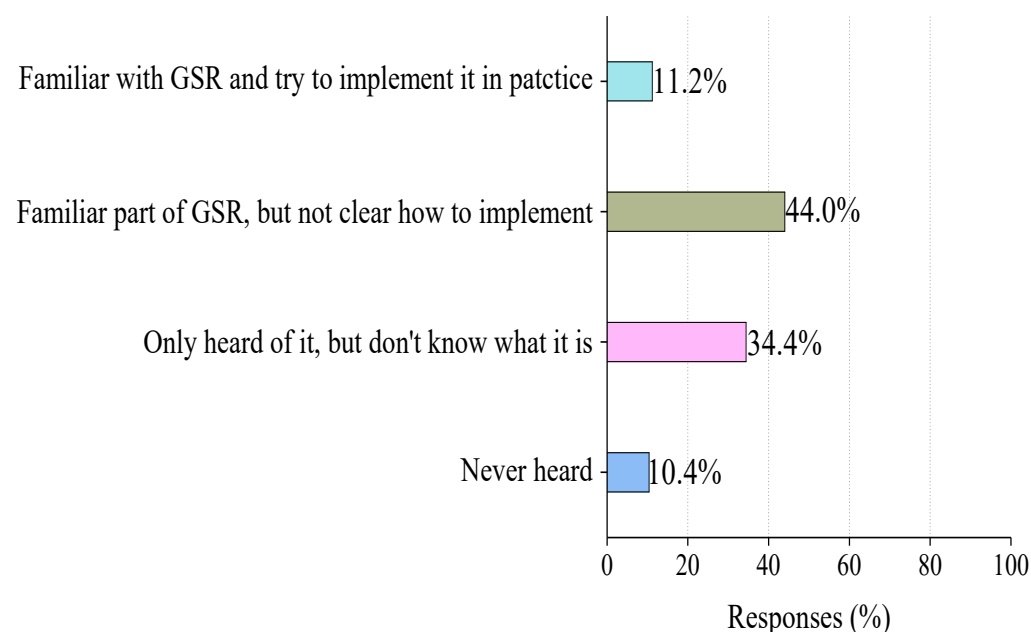


Figure 2. The familiarity of the respondents with GSR.

The survey found that, despite the low level of reported knowledge, nearly all respondents considered GSR to be necessary, with 70.4% of respondents considering it strongly necessary to implement GSR (as shown in Figure 3). In the five surveyed groups, the staff from district or county EEDs expressed a stronger desire for GSR than the other four groups. With the 2019 Soil Law, China set out its programme and regulations for

soil contamination. China has actively engaged with the international community in the development of land contamination management approaches and processes, and achieving sustainability in contaminated site management has become increasingly prominent [39]. Meanwhile, China also adopted the United Nations Sustainable Development Goals into its policy [40]. Because climate change is regarded as an important environmental issue, which can have a wide range of impacts on a global scale [41,42] and is also widely studied by researchers [43,44]. These strong levels of interest created a powerful impetus for the development of GSR to optimize the existing risk-based Chinese approach.

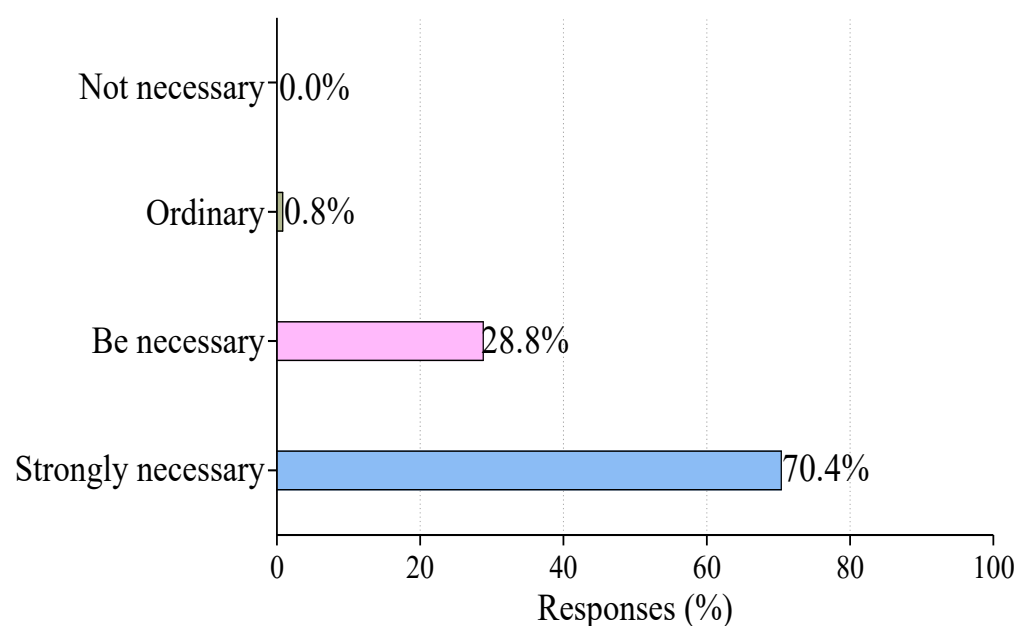


Figure 3. The necessity to implement GSR.

3.2. Regulators' Perception of How Well the Scope of GSR Is Reflected in Policy

The respondents were all engaged in the prevention and control of soil pollution, and were familiar with the details of the policy standards related to the prevention and control of soil pollution. This study used the details of GSR to analyze the details of these policies and regulations. Respondents' perceptions of how well the scope of GSR is reflected in policy were surveyed by a multiple-choice question: "Which elements of sustainability (environment, society and economics) reflected in the national/provincial policy system for contaminated site?"

As shown in Figure 4, from the regulators' perspective, the environmental factor was well-adopted in both national and provincial policy systems, but society and economic factors were not well-adopted. A few respondents believed that national and provincial policies did not incorporate the three elements of sustainability. The reason for this may be that the Soil Law of China only mentioned sustainable development as the purpose of the law; in comparison with the environmental aspect, the economic and social aspects were not fully described in the specific provisions.

Regulators were also asked to rank the importance of the three elements. The average ranking was: environmental factor > social factor > economic factor. The results of the two questions revealed that both makers and implementers of policy paid more attention to environmental factors and lacked an awareness of how to balance the three factors.

The policy makers and implementers related to contaminated sites were all from EEDs; their expertise and main concerns was the environment, not the social or economic aspects. The green remediation proposed by the EPA also aimed to decrease the carbon footprint and maximize the environmental outcome of cleanup projects, with the environment as the main concern. Sustainable remediation accounts for environmental, social and

economic factors, but is mainly advocated by non-governmental organizations, such as the sustainable remediation forums of various countries. Policy imbalances also lead to environmental bias in some technology assessment tools [45].

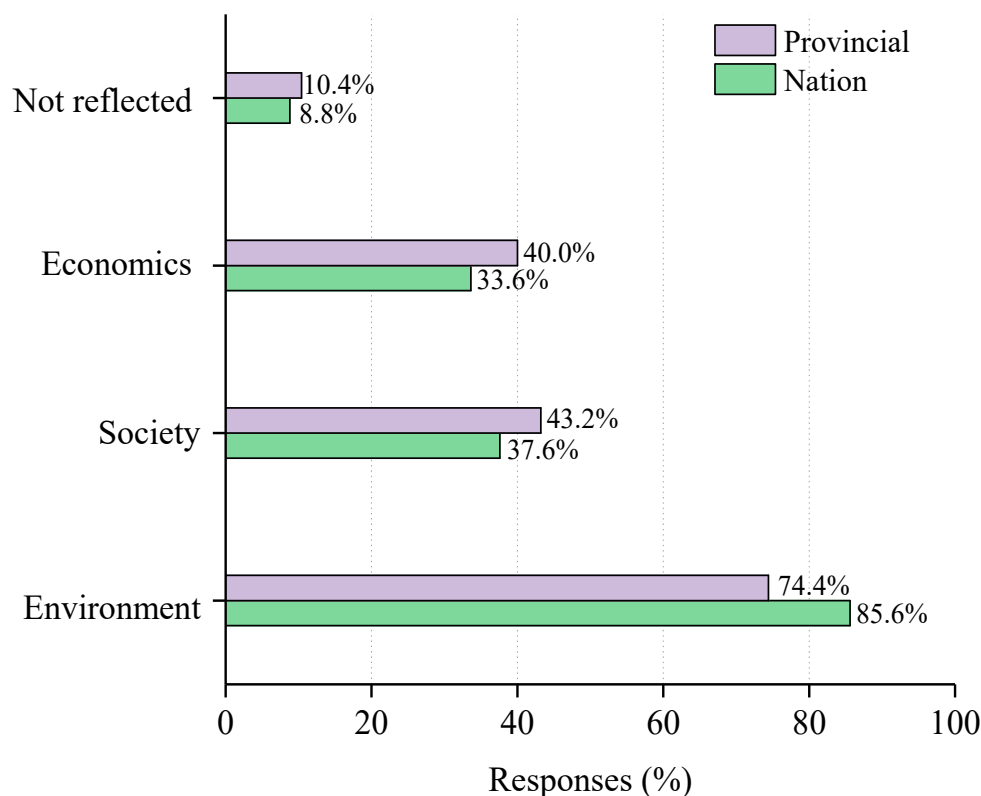


Figure 4. The reflection of three elements in the national and provincial policy.

3.3. Green and Sustainable Remediation Considerations in National Policies

As mentioned in Section 2.1, this paper investigates not only the situation regarding the environment, society, and economy, but also some practical problems related to these three elements in China.

3.3.1. Environmental Dimension

Eight environmental factors (listed in Figure 5) were selected to investigate whether they were reflected in national policies and which two factors should be most strengthened in the future. Figure 5 reveals that “preventing and control secondary pollution” had the highest adoption rate, with the second and the third highest rates being for “impact on the ecological environment” and “maintaining soil physical and chemical properties and ecological functions”. Although these three factors had a high adoption rate, the regulator still thought they should be strengthened further. The three factors related to reducing carbon footprint, “reducing greenhouse gas emissions”, “using clean energy” and “saving resources and energy during the remediation process”, had a lower adoption rate and were not considered to be strengthened.

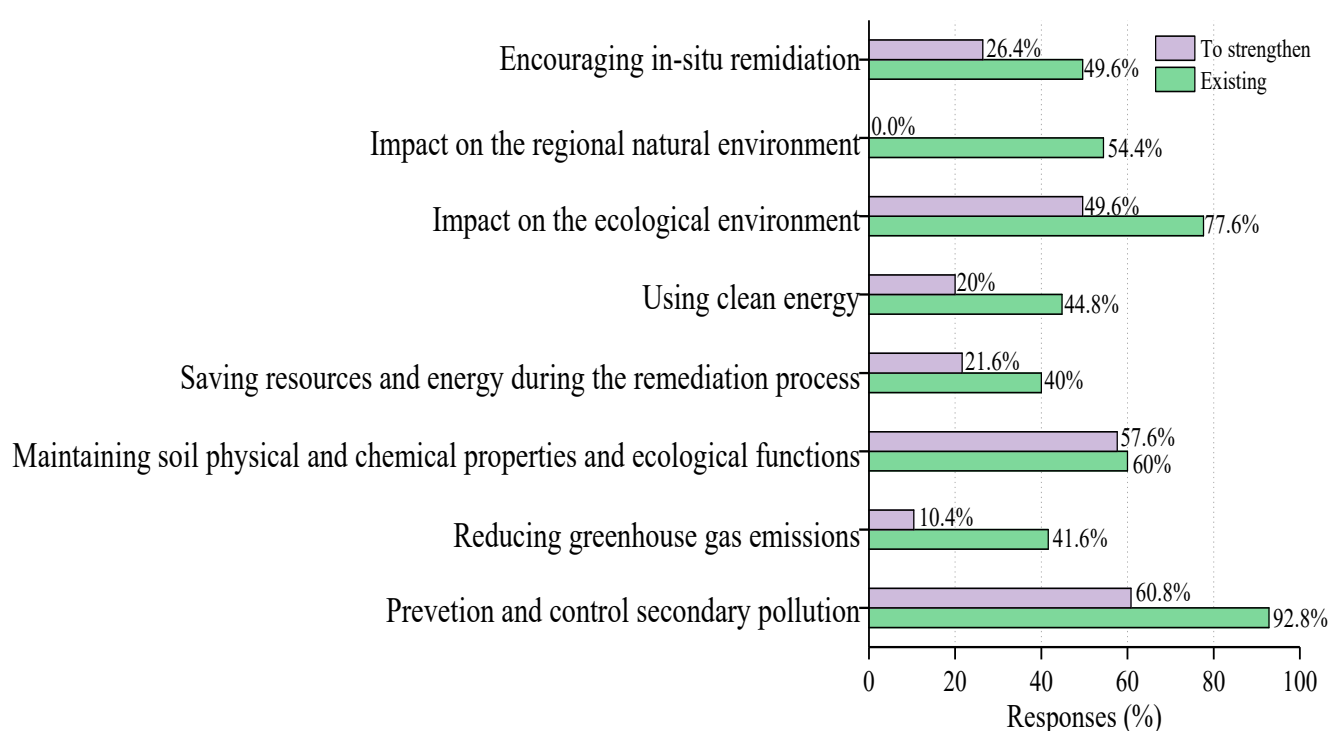


Figure 5. Detailed environmental factors reflected in national policies.

These results showed that Chinese regulators are very concerned about the secondary effects of the remediation process, and they had little incentive to deal with the elements of the policy that did not require much enforcement. Greenhouse gas (GHG) emissions and energy-saving have always been hot topics in various fields [46], but the degree of adoption for these factors was low and was not thought to be strengthened. This situation is similar to some previous studies, mainly focusing on the researchers [28–30,47]. O'Connor D. et al. indicated that this may be caused by the limited experience and abilities regarding GHG in the remediation industry [30]. For example, the remediation industry had much greater experience in and ability to handle hazardous waste than to reduce greenhouse gas emissions. The Chinese central government placed green development at a high level in the 14th five-year plan and MEE put forward the goal of “synergizing pollution reduction and carbon dioxide emission” from 2021 [48]. Therefore, factors related to reducing carbon emission and carbon footprint can be strengthened in future policies.

In recent years, secondary pollution prevention and control has become a hot topic in the field of contaminated site remediation in China; both policies and case studies have been discussed in the research [35,49,50]. Therefore, two more questions were set up to survey regulators' views on how to solve the problem of secondary pollution prevention: ① Regarding the prevention and control of secondary pollution in the remediation process, please select two issues that should be solved mostly. There were five choices: Other, strengthening the professional talent team, strengthening the implementation of control measures, developing monitoring equipment and technology, issuing technical guideline. ② Please choose the most suitable measure for the implementation of secondary pollution prevention and control in China. Five answers were offered: other, permit system, environmental impact assessment system, periodic reporting system, environmental supervision system.

Figure 6 shows that “issuing technical guideline” and “strengthening the implementation of secondary pollution control measures in the process of remediation” were identified as the most critical issues to be solved. However, “developing monitoring equipment and technology” was considered less important. In China, several policy documents already referred to the prevention and control of secondary pollution in the site-remediation process. However, there was still no technical guidance or capacity building on the prevention and control of secondary pollution at this stage, which made it difficult for regulators to supervise the prevention and control of secondary pollution during site remediation. However, for regulators, if environmental supervision is not in place, this may directly affect their career development. Therefore, in regulators’ opinion, policy and capability were important means of solving these problems.

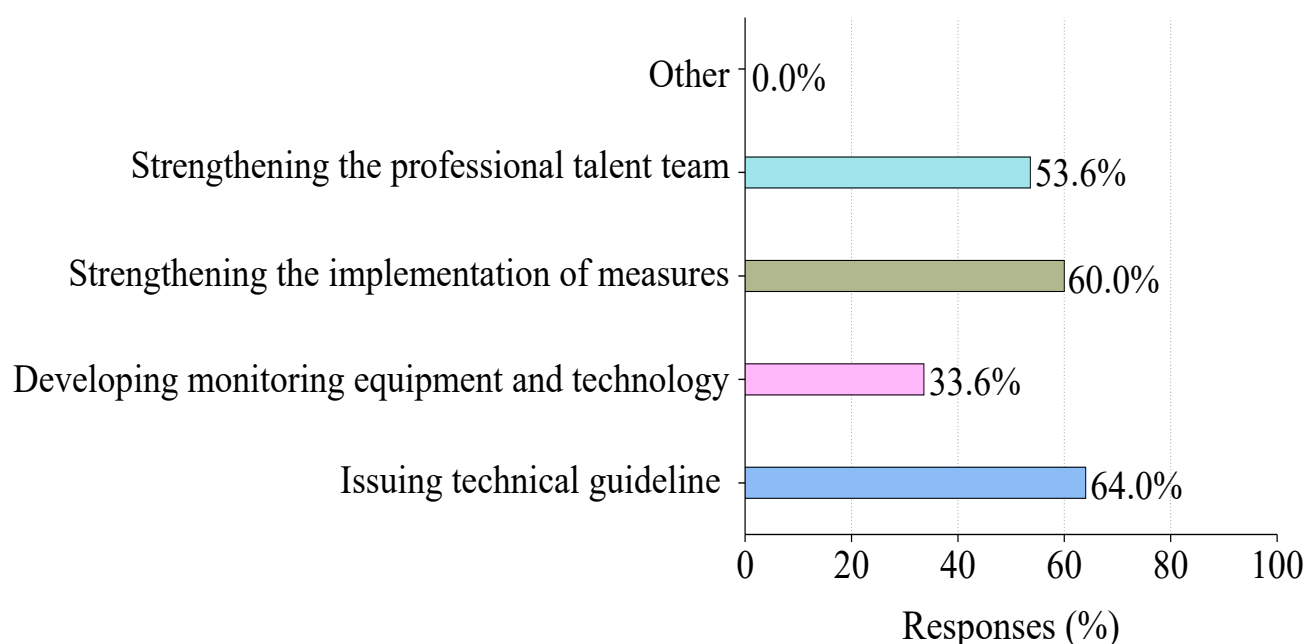


Figure 6. The most critical problems to be solved in secondary pollution prevention and control.

Finally, Figure 7 revealed that the environmental supervision system was considered the most effective way of supervising the prevention and control of secondary pollution. Although an environmental supervision system is not required by law, almost all site owners employed a third party as the environmental supervision unit when carrying out site remediation in China, to provide technical services such as tracking guidance, supervision and management for environmental protection in the process of site remediation, and to guide the remediation unit in the implementation of various environmental protection measures and requirements in the remediation project. Beijing EED also issued technical guidelines for environmental supervision in the process of contaminated sites’ remediation (DB11/T 1279-2015, in China Beijing) [51]. Some developed countries use environmental permits [52], but China has just begun to do this, mainly in the pollution discharge of production enterprises. However, this is rarely used in the remediation of contaminated sites. China also tried to use the environmental impact assessment system in recent years; however, because practitioners did not think this was a good system, it was cancelled in 2021 [53].

Prior J. indicated that the public near the contaminated site had a very low understanding and acceptance of remediation technology [54]. Soil remediation in China is risk-based; after site remediation, there still is an acceptable residual risk left on the site. If the public cannot understand “acceptable risk”, and it may cause a certain amount of panic to the public, or even generate malignant mass events. Therefore, enhancing and checking public awareness of risks should be taken seriously. With the implementation of the Soil

Law and the Soil Ten Provisions, regulators have realized the importance of effective risk communication. A double-choice question was surveyed: “To increasing the public trust or support, which measure do you think is the most effective?” Seven choices were set up, as shown in Figure 9.

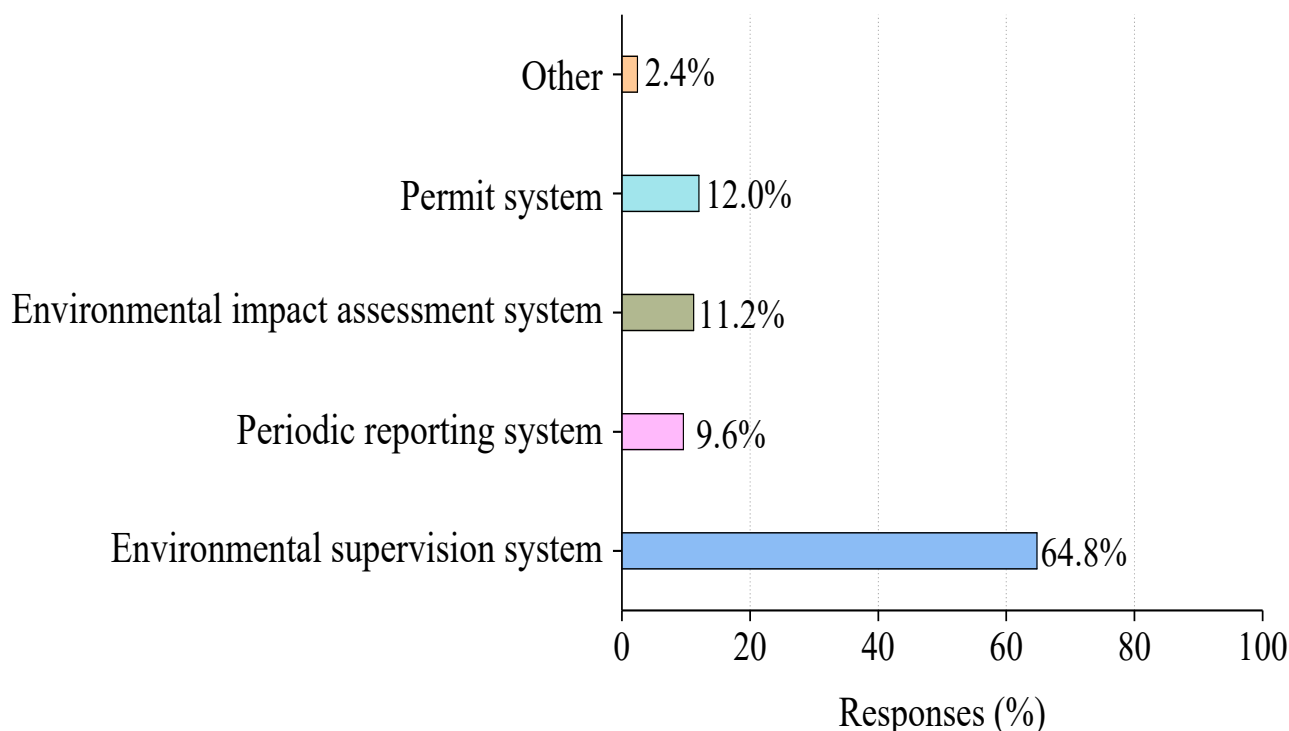


Figure 7. The most suitable measure to the pollution prevention and control of secondary pollution.

3.3.2. Social Dimension

Nine social factors (listed in Figure 7) were selected, to investigate whether they were reflected in national policies and which two factors should be most strengthened in future. As shown in Figure 8, “impact on the public and surrounding people”, “public involvement” and “following the polluter pay principle” had a high adoption rate. “Protecting human health and workers safety”, “impact on the public and surrounding people”, and “public involvement” were three factors that need to be strengthened. This result shows that regulators gave priority to the factors mentioned in the exiting policy system and did not pay the same amount of attention to factors not mentioned in this policy. Public involvement, reducing the impact of nearby residents and polluter paying, were all basic principles of the Soil Law, but there was still a lack of documents guiding practice, which may be why regulators thought that this needed to be strengthened in the future. Hou, D. et al. [29] surveyed the adoption of sustainable remediation practices in US and found that “encouraging the purchase of local labor and products” and “bringing prosperity for disadvantaged groups” was generally lower than other GSR considerations. The main reason for this was that green restoration in the US focused more on the environmental benefits than the social benefits.

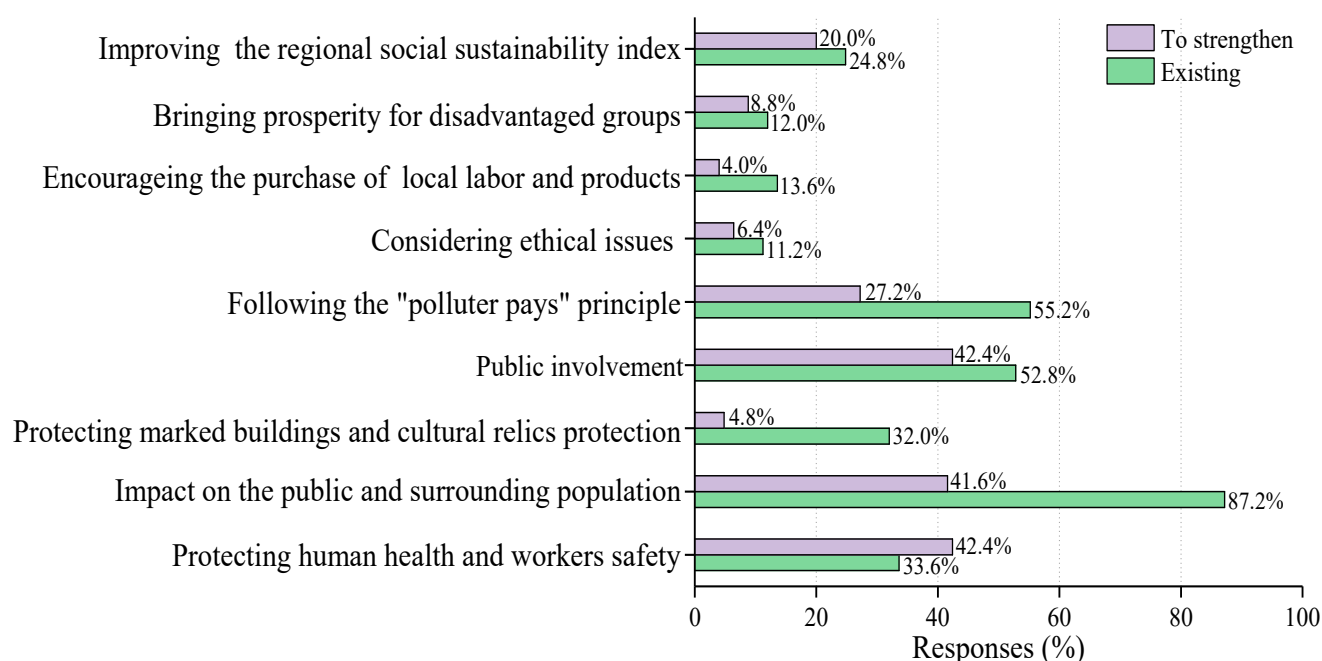


Figure 8. Detailed social factors reflected in national policies.

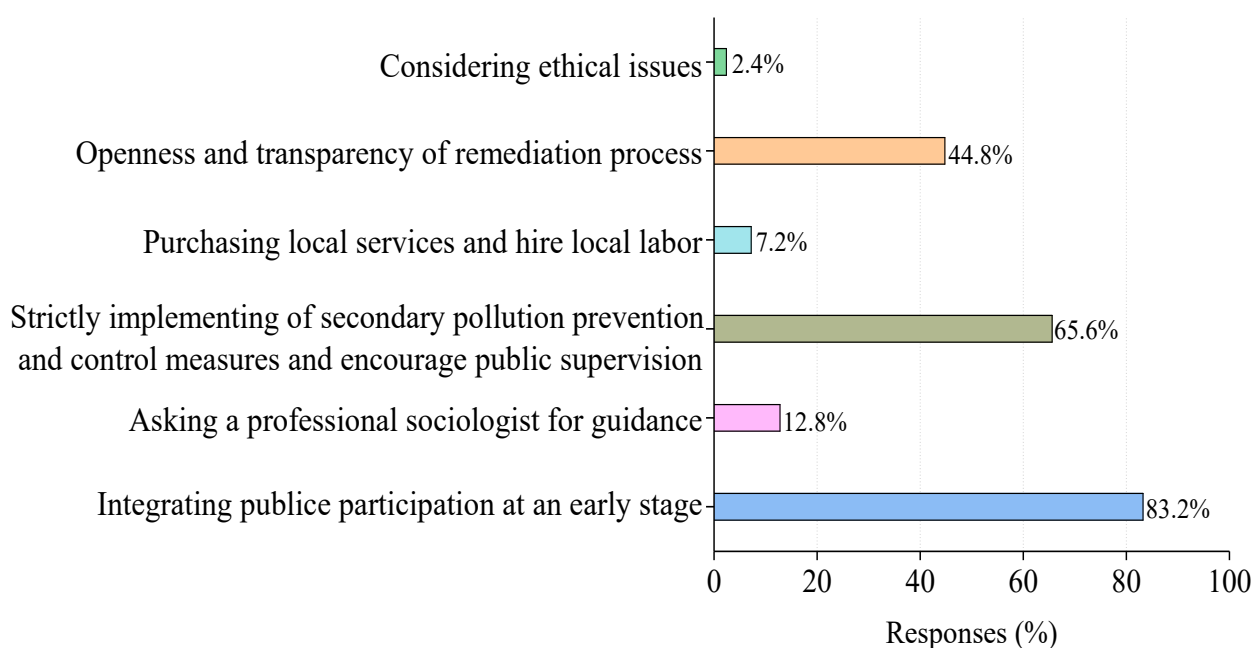


Figure 9. The measures to increase the public trust or support in remediation process.

As shown in Figure 9, “integrating public participation at an early stage” was considered the most effective measure. “Strictly implementing measures to prevent and control secondary pollution and encourage the public to supervise their implementation”, and “openness and transparency of remediation process” also had a high response rate. It can be seen that regulators expected the public to participate in the decision-making and implementation process of remediation projects, and remediation units could manage remediation projects scientifically, and protect the safety of surrounding residents. The results are different from the former study, carried by Li, X. et al.; they found that, compared with developed countries, the incidence of public participation indicators adopted by China was relatively low [55].

3.3.3. Economic Dimension

Five economic factors (listed in Figure 10) were selected to investigate whether they were reflected in national policies and which two factors should be most strengthened in the future. As shown in Figure 10, “effectively controlling the remediation period, remediation project cost and long-term operation cost” had high adoption rate, which was followed by “encouraging indirect benefits to the local area” and “improving professional remediation skills”. Additionally, “effectively controlling the remediation period, remediation project cost and long-term operation cost” and the factors related to technological capacity improvement were also considered to be strengthened in the national policy. In addition, “encouraging the creation of local jobs” had a very low adoption rate and was not considered strengthened, which was also evident in Figures 8 and 9. Hou, D. et al. also found that the consideration of “enhancing local employment” was not effectively adopted by remediation practitioners [28].

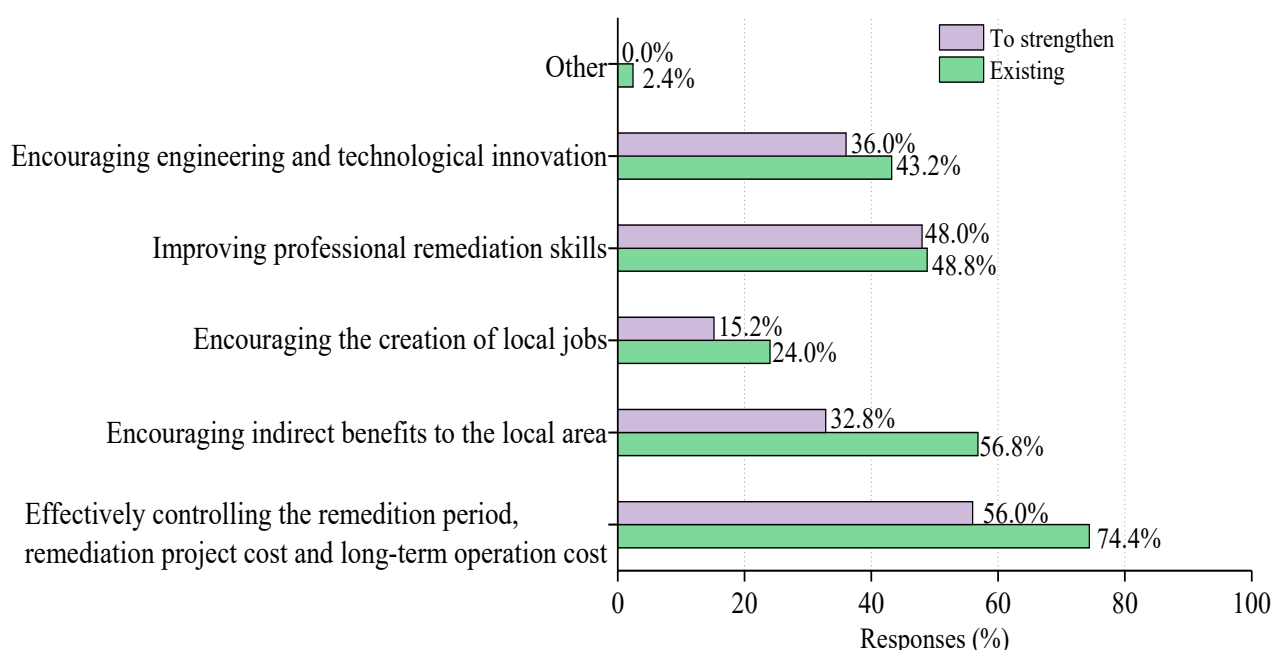


Figure 10. The measures to increasing public trust in or support for the remediation process.

3.4. Barriers to GSR Implementation in China

After a detailed review of the previous literature on barriers to GSR implementation [22,38], five barriers were selected for ranking by the regulators; the results are shown in Table 3.

Table 3. Mean ranking of five barriers to GSR implementation in China.

Barriers	Mean Ranking
GSR standard system is incomplete	2.35
No relevant terms in the national policy system	2.65
Lack of expert team, professional knowledge	3.05
Insufficient understanding of the concept of GSR	3.40
Pressure of remediation cost and time	3.54

The two most influential barriers were “GSR standard system is incomplete” and “no relevant terms in the national policy system”. “Insufficient understanding of the concept of GSR” and “pressure of remediation cost and time” were not considered the major barriers. The questionnaire conducted in the US by Ellis R. [8], and in many countries

worldwide by Hou, D. et al. [28,29], also showed that lack of regulatory mandate was the most influential barrier.

4. Conclusions

This study is the first comprehensive investigation of the GSR perception of Chinese site regulators in the provincial, municipal, county or district EED. The survey results indicated that government regulators related to site management thought that GSR was necessary in China, although most of them did not know GSR very well or lacked practical experience. Existing national and provincial policy standards do not have a good balance between environmental, social and economic aspects, but give priority to environmental factors. Additionally, regulators at all levels did not always regard social and economic factors as being as important as environmental factors. The existing policy system does not fully reflect the details of the three elements; only factors related to secondary pollution prevention and control, public participation and remediation cost and life-cycle control are mentioned in the policy. There is still a lack of technical documents to support their implementation, which has caused some troubles for the regulators. Therefore, regulators focus less on factors that are not mentioned in the policy, such as the factors related to reducing greenhouse gas emissions, purchasing local labor and creating local jobs, although these factors are often discussed by researchers. The formulation of technical guidelines and implementation of an environmental supervision system are considered to be the most important problems and the best supervision means to prevent and control secondary pollution, respectively. Differing from previous studies, regulators advocated early public participation and transparency of restoration projects to gain public support for remediation projects. Meanwhile, the lack of standard and regulatory requirements was the most significant barrier to the implementation of GSR.

This is also the first comprehensive and in-depth examination of China's policy standard system using environmental, social and economic elements and their more detailed indicators. At the national level, China's contaminated site management system has been established, but from the perspective of GSR, there is still a big gap. The existing policy and standard system for polluted sites is not enough to support the realization of "synergizing pollution reduction and carbon dioxide emission". Therefore, future studies need to consider how the existing defects in policies can be supplemented, such as by issuing supplementary policy documents or providing further detail in provincial and municipal policy documents. The results of this study also show that, in order to promote the implementation of GSR, practitioners should provide more knowledge and cases of GSR for regulators to better understand GSR. Although this research is carried out in China, it can also provide a reference for other developing countries.

Due to the limitation of the survey time and the interviewees' insufficient understanding of GSR, the questionnaire was only sent to the regulators with certain a foundation of soil pollution prevention and control, which could not represent all the regulators in China. In future, the research scope can be expanded, and different questions can be set for people of different levels to obtain more detailed conclusions

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Appendix A. Details of the Survey Questionnaire in This Article

1. Please fill in your province (fill in the blanks)
2. Which level of Ecology and Environment Department (EED) do you come from. (Single choice)
 - (a) Provincial EED
 - (b) Technical support agencies of provincial EED
 - (c) Municipal EED
 - (d) Technical support agencies of municipal EED
 - (e) County or district EED
3. Please fill in your title (fill in the blanks)
4. Before taking part in this questionnaire, what did you know about GSR? (Single choice)
 - (a) Familiar with GSR and try to implement it in practice
 - (b) Familiar part of GSR, but not clear how to implement
 - (c) Only heard of it, but don't know what it is
 - (d) Never heard
5. Is it necessary to implement GSR? (Single choice)
 - (a) Strongly necessary
 - (b) Be necessary
 - (c) Ordinary
 - (d) Not necessary
6. Which elements of sustainability (environment, society and economics) reflected in the national policy system for contaminated site? (Multiple choice)
 - (a) Not reflected
 - (b) Economic
 - (c) Society
 - (d) Environment
7. Which elements of sustainability (environment, society and economics) reflected in the provincial policy system for contaminated site? (Multiple choice)
 - (a) Not reflected
 - (b) Economic
 - (c) Society
 - (d) Environment
8. Please rank the importance of the three elements of environmental, social and economic in the existing national policy standard system. (Ranking)
 - (a) Economic
 - (b) Society
 - (c) Environment
9. Which environmental factor is reflected in the existing policy standard system? (Multiple choice)
 - (a) Encouraging in-situ remediation
 - (b) Impact on the regional natural environment
 - (c) Impact on the ecological environment
 - (d) Using clean energy
 - (e) Saving resources and energy during the remediation process
 - (f) Maintaining soil physical and chemical properties and ecological functions
 - (g) Reducing greenhouse gas emissions
 - (h) Prevention and control secondary pollution
10. Please choose the two environmental factors that should be strengthened most in the existing policy standard system. (Double choice)
 - (a) Encouraging in-situ remediation

- (b) Impact on the regional natural environment
 - (c) Impact on the ecological environment
 - (d) Using clean energy
 - (e) Saving resources and energy during the remediation process
 - (f) Maintaining soil physical and chemical properties and ecological functions
 - (g) Reducing greenhouse gas emissions
 - (h) Prevention and control secondary pollution
11. Regarding the prevention and control of secondary pollution in the remediation process, please select two issues that should be solved mostly. (Double choice)
- (a) Other
 - (b) Strengthening the professional talent team
 - (c) Strengthening the implementation of control measures
 - (d) Developing monitoring equipment and technology
 - (e) Issuing technical guideline
12. Please choose the most suitable measure for the implementation of secondary pollution prevention and control in China. (Double choice)
- (a) Other
 - (b) Permit system
 - (c) Environmental impact assessment system
 - (d) Periodic reporting system
 - (e) Environmental supervision system
13. What social factors are reflected in the current policy standard system? (Multiple choice)
- (a) Improving the regional social sustainability index
 - (b) Binging prosperity for disadvantaged groups
 - (c) Encouraging the purchase of local labor and products
 - (d) Considering ethical issues
 - (e) Following the “polluter pays” principle
 - (f) Public participation
 - (g) Protecting marked buildings and cultural relics protection
 - (h) Impact on the public and surrounding people
 - (i) Protecting human health and workers safety
14. Please choose the two social factors that should be strengthened most in the existing policy standard system. (Double choice)
- (a) Improving the regional social sustainability index
 - (b) Binging prosperity for disadvantaged groups
 - (c) Encouraging the purchase of local labor and products
 - (d) Considering ethical issues
 - (e) Following the “polluter pays” principle
 - (f) Public participation
 - (g) Protecting marked buildings and cultural relics protection
 - (h) Impact on the public and surrounding people
 - (i) Protecting human health and workers safety
15. To increasing the public trust or support, which measure do you think is the most effective? (Double choice)
- (a) Considering ethical issues
 - (b) Openness and transparency of remediation process
 - (c) Purchasing local services and hire local labor
 - (d) Strictly implementing of secondary pollution prevention and control measures and encourage public supervision
 - (e) Asking a professional sociologist for guidance
 - (f) Integrating public participation at an early stage

16. Which economic factors are reflected in the existing policy system? (Multiple choice)
 - (a) Other
 - (b) Encouraging engineering and technological innovation
 - (c) Developing a team of professionals
 - (d) Encouraging the creation of local jobs
 - (e) Encouraging indirect benefits to the local area
 - (f) Effective control the construction period, construction cost and long term operation cost of the remediation project.
17. Please choose the two economic factors that should be strengthened most in the existing policy standard system. (Double choice)
 - (a) Other
 - (b) Encouraging engineering and technological innovation
 - (c) Developing a team of professionals
 - (d) Encouraging the creation of local jobs
 - (e) Encouraging indirect benefits to the local area
 - (f) Effective control the construction period, construction cost and long term operation cost of the remediation project.
18. What do you think is the resistance to GSR in our country at this stage? (Ranking)
 - (a) GSR standard system is incomplete
 - (b) No relevant terms in the national policy system
 - (c) Lack of expert team, professional knowledge
 - (d) Insufficient understanding of the concept of GSR
 - (e) Pressure of remediation cost and time

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