China Council for International Cooperation on Environment and Development (CCICED)

Special Policy Study Report

Eco-environmental Risk Management

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Chinese Co-chair and Study Members led report drafting; Chapter 3 describing international experiences was drafted by international members; Chinese and International Co-chair and Study Team Members contributed to and reviewed the report at each stage.

Background of the Study

Rapid socioeconomic development coupled with constraints on resources, pollution, and ecological degradation have already had significant impacts on public health, public safety, and social stability in China. During 2016-2020 and the implementation of the 13th Five-year Plan (FYP), China will be characterized by slowing economic growth, continued industrialization, increased use of natural resources, structural adjustment, urbanization, and social transformation. Environmental management will be more complicated and unpredictable, with pressures coming from rapid socioeconomic development and strong public demands for environmental quality.

During this period, environmental risks[1] will be more serious. China has already endured frequent environmental accidents and high levels of chronic exposure to pollution. Environmental risks affecting public safety, human health, and environmental and ecosystem quality continue to be evident. Meanwhile, public demand for a safe environment is intense and growing. Data from the *China Environmental Yearbook* show that the number of environmental petitions and complaints increased more than 20-30% annually in recent years. Public protests against environmental issues and events continue to occur.

In the face of serious environmental risks and the politically important task of constructing ecological civilization, the 2011 statement *Opinions on Strengthening Major Environmental Protection Tasks by the State Council* for the first time mentioned "risk prevention" in a national policy document. At the same time, China's Ministry for Environmental Protection (MEP) introduced a three-stage strategy called "reducing total amount of pollutants, improving environmental quality, and preventing environmental risk" in the 12th Five-year Environmental Planning Guideline. Risk prevention was also clearly included in China's environmental management strategy for the first time, indicating that the development of a risk prevention and management system had become an important part of building a new roadmap for the protection of China's environment and the construction of ecological civilization.

Opinions of the Central Committee of the Communist Party of China and the State Council on Further Promoting the Development of Ecological Civilization, issued in 2015, maintains the basic state policies of conserving resources and protecting the environment. It puts the development of ecological civilization in a prominent strategic place that is incorporated into the whole process of economic, political, cultural, and social development. In the same year, the Central Committee of the Communist Party of China and the State Council issued the *Integrated Reform Plan for Promoting Ecological Civilization System* to accelerate the establishment of a complete ecological civilization system and to promote the construction of ecological civilization. The *National Security Law of China*, implemented in 2015 has incorporated environmental safety into the national security system.

The Third Plenary Session of the 18th Communist Party of China Central Committee (Third Plenary) clearly pointed out that building ecological civilization requires:

1 The term "environmental risk" in this report includes ecological risks.

establishing a comprehensive ecological civilization system; implementing rigorous protection from the sources of environmental risk; compensating for damage; liability systems; and, improving the environmental governance system and the ecological restoration system. Compared with other environmental regulations and controls, China's environmental risk management system is seriously lacking in terms of effective strategy, institutions, policies, and technologies. Environmental risk issues have posed great challenges for the construction of ecological civilization in China. Studies are urgently needed to help build a series of effective and efficient environmental risk management policies and systems.

To explore the construction of an environmental risk management system and to provide policy recommendations for transforming environmental policy toward an environmental risk management mode, the China Council for International Cooperation on Environment and Development (CCICED) organized a team of domestic and foreign experts to conduct the special policy study (SPS) on "Eco-environmental Risk Management", with the School of the Environment at Nanjing University as the lead Chinese institution.

The project was launched in April 2015. The project team has studied the current situation and future prospects for environmental risks in China, reviewed China's environmental risk management system and analyzed its problems, and summarized international experiences on environmental risk management. This analysis underpins the policy recommendations for an environmental risk management system in China.

The team held three working meetings to integrate comments and suggestions from Chinese and international experts. This project report and its policy recommendations have been developed on the basis of joint efforts of these team members. We expect that this study will support the building of a robust environmental risk management system in China.

Summary of Key Findings

1. China's Environmental Risk Situation is Serious

The 2005 water pollution accident at the Songhua River, Jilin province, triggered initial efforts to construct an environmental risk management system in China. Since then China has paid more attention to environmental risk management. Although the frequency of accidental pollution events has decreased, they still occur often. MEP reported 712 and 471 environmental accidents for 2013 and 2014 respectively. Serious environmental accidents continue to happen, such as the Dalian oil pipeline explosion in 2010 and the Tianjin hazardous chemicals explosion in 2015.

Meanwhile, China is becoming more aware of long-term chronic risks such as $PM_{2.5}$ air pollution and contaminated sites. $PM_{2.5}$ has become the fourth highest mortality risk factor in China. According to Global Burden of Disease data, it caused approximately 1.23 million premature deaths in 2010.

At the same time, as public demand for environmental protection rises, the level of environmental risk that the public will accept is decreasing. The number of environmental petitions and complaints has grown at an annual rate of 20-30% in recent years. This is a new characteristic of environmental risk that is emerging in China. The gap between actual and publicly desired environmental risk levels is growing, which suggests that the current situation of environmental risk is serious and requires attention.

2. Current Environment Management System Cannot Meet the Demands for Environmental Risk Prevention and Control

The 18th National Congress of the Communist Party of China (CPC) introduced the goal of building a moderately prosperous society by 2020 and incorporating ecological civilization into the overall design of socialism with Chinese characteristics. During the critical period of completing the building of a moderately prosperous society, under current conditions many environmental risks remain that need to be reduced and controlled more effectively. The gap between current environmental risk levels and public risk perception has become a major restraining factor. The *National Security Law of China*, implemented in 2015, notes the need "to strengthen the early warning, prevention, and control of ecological risk, and to address accidental environmental incidents properly." Environmental safety thus is being recognized as part of the national security system.

Environmental risk management in China, however, is still in its early stages; that is, it is in an "event-driven, environmental response" mode. The environmental risk management system is incomplete, and it cannot yet meet the increasing public demands for eco-environmental safety and the needs of national security.

(1) The environmental risk governance system is incomplete. A comprehensive environmental risk-based decision-making system has not been well formed. Environmental risk assessment has not been comprehensively and substantially incorporated into major national strategies and plans (such as the Five-year Plans, new-

type urbanization, integrated development of the Jing-Jin-Ji area, the Belt and Road initiative, and the Yangtze River Delta economic zone), or into spatial planning decisions or project environmental impact assessments (EIA). Furthermore, China lacks a neutral institution to provide scientific environmental risk assessments for national decision making, and it lacks a high-level body to guide and oversee the environmental risk management system. Vertical and horizontal fragmentation across government departments and agencies in environmental management undermine efforts to address the many environmental risks facing China.

(2) The basis for environmental risk decision making is incomplete. Systematic environmental risk management goals and a national strategy and system for managing environmental risks have not been established. The current situation and prospects for control of environmental risks in China remain unclear. China lacks comprehensive and integrated national environmental risk analysis, assessment, and ranking to set priorities for risk management, and to shape environmental risk management goals and strategies. There are no clear or systematically derived management priorities for environmental risks or for selecting appropriate risk reduction strategies and measures. Meanwhile, China lacks research on the mechanisms through which environmental risks induce other risks, such as those related to social stability, economic security, and national and regional security. The analysis of comparative costs and benefits has not been well incorporated into actions and policies to reduce environmental risk.

(3) The set of enabling measures for environmental risk reduction is incomplete. For example, China lacks a unified environmental risk information database and data sharing system. The system of environmental laws and regulations to prevent and control risks is incomplete. The establishment of an environmental judiciary is still at the initial stage. Economic and financial instruments for environmental risk management are insufficient. The capacity for environmental risk emergency response is weak. Finally, responsibility on the part of industry and state enterprise for environmental risk control is seriously lacking. Environment, health, and safety (EHS) management systems have not been established in most of the enterprises.

(4) The environmental risk communication system is incomplete. While a preliminary environmental information disclosure and public engagement system has been established, there remains a lack of enabling and operating policies and regulations to guide information disclosure and public engagement in an orderly and sufficient manner. Both environmental information disclosure and public engagement are poorly implemented and ineffective. The environmental risk communication system is incomplete and incapable of meeting the needs for informing or eliciting public perception and understanding of environmental risks.

Driven by economic growth, industrialization, and other factors, environmental risk pressures in China will keep increasing in the immediate and long-term future, unless policies change these trends. Meanwhile, rising incomes and education will tend to promote greater public desire for protection against environmental risks. And, driven by the need to manage various environmental risk sources, risk management levels will improve over time with better policies and controls in place. It is expected that the increasing levels of environmental risk management combined with progress in the science and technology of environmental protection will offset the increments of environmental risk to some extent. But these risks may still not attain the levels needed to protect environmental quality, ecosystems, and human safety to the degree needed to

meet the public's willingness to accept these risks. The environmental risk situation therefore needs more attention to cope with present and future challenges. In other words, the environmental risk management system needs to be strengthened.

3. The Environmental Risk Management System in China Still Lags Behind Other Countries

Countries in Europe and North America and parts of Asia which have established relatively robust and efficient environmental risk management systems:

(1) These countries have established environmental risk governance systems at macro levels. They have incorporated environmental risk issues into national decision-making systems. A number of decision-making processes in these countries apply environmental risk assessment ─ with risk priority-setting ─ to maximize social well-being by adopting risk management measures that attain benefits justifying the costs. Institutions such as regulatory oversight bodies or environmental risk boards guide the work of ministries and agencies in these countries.

(2) A system of differentiated environmental risk management goals has been established for different types of risks and for different industries. Some of these risk goals are quantitative and some qualitative, using science-based risk assessment and incorporating levels of public concern and the cost-effectiveness of control measures.

(3) Environmental risk enabling systems which are relatively complete have been formed, including monitoring and data collection, effective laws and regulations, compliance enforcement, economic and financial instruments, and industry and enterprise responsibility systems.

(4) These countries have established institutionalized and effective environmental risk communication and orderly public engagement systems to inform the public and to elicit public preferences. These systems can help address the gaps between public perceptions and actual risk levels, which may affect confidence and trust among governments, citizens, and other stakeholders. Nonetheless, public perceptions can misjudge risks, sometimes overstating and sometimes understating them.

Compared with countries in Europe and North America, and increasingly in south-east Asia, environmental risk management systems in China still lag behind. International experiences can provide good benchmarks for building a successful environmental risk management system in China. Looking ahead, China could become a leader in creating new, state-of-the-art systems for environmental risk management, learning from and innovating beyond past approaches in other countries.

4. Building a Robust and Complete Environmental Risk Management System is Urgently Needed to Support the Transformation of Environmental Management

There is an urgent need to improve the environmental risk situation in China, to reduce environmental risk levels and improve the control of environmental risks more effectively, to reduce the gap between actual environmental risk levels and the public desire for greater protection at lower risk levels, and to protect national security. Hence, there is an urgent need to transform China's environmental risk management mode from pollution control and quality improvement to fully integrate risk prevention and

reduction. This environmental risk-based management system will form the foundation for the prevention and mitigation of environmental risks, and trigger effective responses to restore the consequences of environmental risks.

Based on analyses of the current status and future prospects of environmental risks in China, the status of and demands on its environmental risk management system, and inspired by international experience, this study proposes policy recommendations for building an effective environmental risk management system in China through a strategy comprising four areas: environmental risk governance; risk goals and strategies; enabling measures; and environmental risk communication and engagement. These recommendations are intended to provide a foundation for the transformation of the environmental risk management system in China.

Summary of Main Policy Recommendations

Recommendation 1. Establish a Risk-based Environmental Governance System

(1) Establish a high-level, permanent National Environmental Risk Board. The responsibilities of the Environmental Risk Board are to identify, assess, and prioritize current and potential future environmental risks ─ for the **three categories of risk: 1) sudden accidental risks, 2) cumulative threshold risk, and 3) long-term chronic risks**; to help resolve tradeoffs among multiple risks, and between economic development goals and environmental risk control; and, to coordinate and oversee environmental risk management issues across relevant government departments in an integrated way, ensuring environmental risk assessments for major national economic, legal, and environmental decision making.

(2) Establish a comprehensive environmental risk-based decision making system. Launch an environmental risk assessment and prevention system for the macro-strategies of China's national modernization process. Carry out short-term, middle-term and long-term environmental risk assessments for national macro-strategies such as new-type urbanization, integrated development of the Jing-Jin-Ji area, the Belt and Road initiative, and the Yangtze River Delta economic zone, and develop effective environmental risk prevention roadmaps for these strategies. Incorporate environmental risk assessment processes and risk management into government decisions at every level of policy, sector, regional, and urban planning, and major construction projects that have a potential to affect human heath, environmental quality, and ecosystem integrity, and for the development of environmental standards. Integrate multiple spatial plans, including economic and social development plans, urban and rural plans, land use plans, and ecological protection plans into one plan, incorporating environmental risk assessment. Integrate environmental risk assessment, environmental impact assessment, and social stability risk assessment to create synergy across multiple assessments.

(3) Rearrange environmental risk-based institutions and functions. Establish MEP departments for air, water, and soil to enable a coherent system of authority and responsibility for supervision of major environmental risks, and build in specific coordination mechanisms across the new departments to avoid problems of fragmentation; strengthen vertical authority and coordination of MEP with provincial environmental protection bureaus. Strengthen regional Environmental Supervision Centres with oversight by the National Environmental Risk Board. Reform the management system for dangerous chemicals which currently involves multiple departments. Clarify the main body of regulation. Incorporate chemicals management into the current environmental emergency response system.

Recommendation 2. Establish Environmental Risk Management Goals and Strategy

(1) Set environmental risk management targets. Set comprehensive national environmental risk reduction and minimization goals and targets incorporating the national development strategy, the results of a national environmental risk assessment,

the costs and benefits of risk control, and the public perception of risks. Require provinces, cities, and regions to prepare roadmaps setting out the pace and path to meet the targets, based on regional environmental risks, natural environmental conditions, economic and social conditions, and regional development strategies.

(2) Establish a comprehensive national environmental risk management strategy. Conduct a comprehensive, systematic national assessment to set national and regional risk priorities for the three categories of environmental risks. Based on the assessment results, develop and apply an environmental risk chain-based management approach emphasizing risk avoidance and prevention, and risk response, mitigation, compensation, and remediation where necessary, to reduce overall risks and yield health, environmental quality, and ecosystem benefits that justify the costs.

Recommendation 3. Establish Enabling Measures for Environmental Risk Management

(1) Complete legislation and a judiciary for environmental risk management. With the goal of establishing a whole-process approach for the prevention and reduction of environmental risks, improve laws and regulations for environmental protection. Put in place a soil environmental protection law, and establish supporting laws and regulations for legacy (historical) contaminated sites management. Develop a *Dangerous Chemicals Safety and Environmental Risk Law* that applies to all dangerous chemicals based on the existing *Hazardous Chemical Safety Management Regulation*. Implement life-cycle risk management for chemicals, and strengthen comprehensive supervision and regulation of priority pollutants in industrial production. Develop an *Environmental Liability Law*. Promote an environmental judiciary to support the control of environmental risks.

(2) Enable environmental risk information integration and sharing. Systematically integrate the environmental risk information that currently is distributed across multiple departments and levels of government by building on the new *Construction Plan for an Eco-environmental Monitoring Network* to incorporate environmental risk information into the national unified environmental information platform. Conduct research to fill information gaps (for example, exposure data and dose response functions for ecosystem and human health) and share these data via the Internet.

(3) Apply financial and economic instruments to prevent and reduce environmental risks. Develop and use financial and economic instruments for environmental risk control. Establish an environmental risk assessment-based enterprise financial security system for sudden and accumulative environmental risks. This should include mandatory liability insurance for industries and enterprises, an environmental risk deposit system for high-risk industries, and special funds for contaminated site remediation and environmental health compensation. Economic measures such as market based regulation also should be used to prevent and reduce environmental risks.

(4) Establish a collaborative multi-department environmental emergency response system with practical emergency response plans as a core requirement. Improve the effectiveness of all levels and all kinds of environmental emergency response plans. Establish joint emergency response mechanisms with clear authority, responsibility, and information sharing, involving government departments for safety

supervision, transportation, environmental protection, and public security. Optimize the allocation of regional environmental emergency resources.

(5) Clarify, support and enforce the primary responsibility for environmental risk prevention and control on the part of enterprises. Establish clear responsibilities for response and remediation by industries and state and other enterprises for accidental and legacy risks. Drive and support industry sectors and state and other enterprises to be responsible for adopting environmental risk management practices through government-enterprise cooperation, including punitive and incentive measures, and training. Require that enterprises establish environment, health, and safety (EHS) management systems. Put in place rules for mandatory environmental risk disclosure in financial reporting requirements of the China Securities Regulatory Commission, and gradually establish the green credit system with an emphasis on risk prevention.

Recommendation 4. Establish an Environmental Risk Communication and Engagement System

(1) Develop a transparent and effective environmental risk communication system. Launch data-sharing and disclosure mechanisms for multi-source environmental risk information (including risk sources and assessment, regular environmental monitoring, environmental emergency response, and public perception information) across national ministries and with local, regional, and provincial environmental protection bureaus. Using measures such as information transfer, round-table conferences, and community engagement, develop a multi-dimensional and transparent environmental risk communication and engagement system involving multiple stakeholders, including government departments, enterprises, the public, media, and social organizations. Establish mechanisms for risk knowledge transfer to and from the public.

(2) Establish an efficient environmental risk engagement programs. Develop and implement community and public engagement models for dialogue and feedback from affected communities. Promote public participation in strategic and environmental impact assessments of policies, spatial planning, and projects. Involve social organizations and community groups to help co-design or evaluate environmental risk management policies.

Contents

CHAPTER 1. CURRENT STATUS AND FUTURE PROSPECTS OF ENVIRONMENTAL RISKS IN CHINA

1.1 Definition of Environmental Risk

1.1.1 Concept of Environmental Risk

Environmental risk refers to the combination of the probability and consequence of adverse environmental outcomes from an event or activity which is induced by natural causes or human activities. It is determined by assessment of the probability of the event or activity occurring, the exposure of environmental receptors to the sources of risk, and the severity of the consequence or loss. It can be expressed as:

Environmental risk = extent of losses due to the event/activity × probability of it occurring

According to this definition, an event or activity can be defined as an environmental risk if it has a probability to cause environmental damage, no matter what the causes of the event or activity (natural or human). The losses include not only physical effects but also their social valuation.

1.1.2 Environmental Risk System and Environmental Risk Chain

In the reality of environmental risk management, the concept of environmental risk is often more in line with the common cognitions of stakeholders and with environmental risk management practices than the above formula. The environmental risk system is a complex entity which comprises environmental risk sources, environmental risk receptors, and control mechanisms (Figure 1-1).

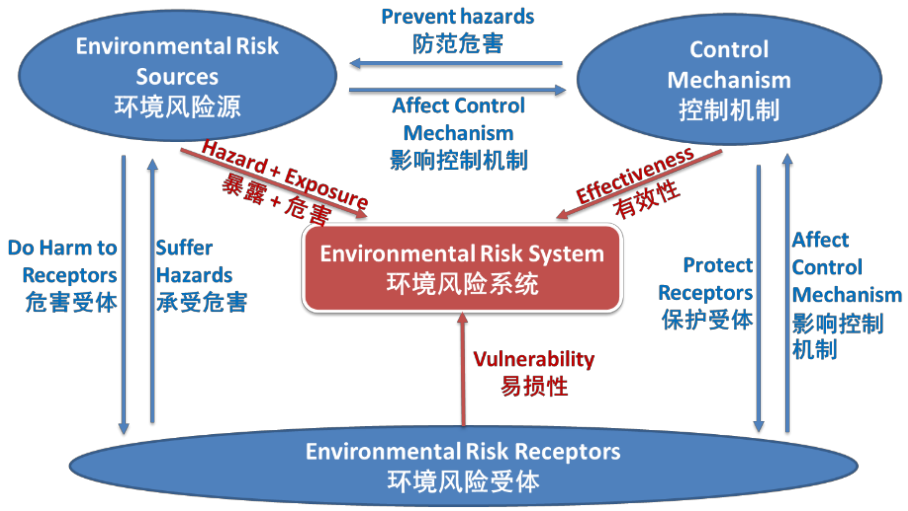

Figure 1-1. Environmental risk system

Environmental risk sources: the sources of possible environmental hazards include the precursors of environmental risk events or activities. Risk sources can be the production, transportation, utilization, and storage of flammable and explosive materials or toxic

chemicals and hazardous materials, treatment of the "three wastes" (waste water, waste gas, and solid waste), as well as long-existing polluted media such as emissions yielding chronic air pollution and soil and groundwater pollution at contaminated sites. Note that safety accidents inside industrial facilities, such as chemical explosions, may not automatically pose hazards to the external environment outside the facility, but the probabilities for environmental impacts do exist.

Environmental risk receptors: Entities such as humans, ecosystems, and socioeconomic structures that will suffer from risk consequences.

Environmental risk control mechanisms: Policies, measures, technologies and practices to reduce environmental risks. These include environmental risk source controls at industrial facilities, management mechanisms and practices at facilities, and the management of transport networks. Control mechanisms can be classed as primary or secondary. Primary mechanisms refer to control systems to avoid risk factors (such as energy and pollutants) being released from risk sources. The failure of primary control mechanisms includes the release of energy and pollutants in connection with natural disasters, and mechanical and human failures. Secondary control mechanisms refer to the systems for controlling the transport of released risk factors (e.g., blocking and reducing pollutants to avoid them entering into environmental media), and measures for reducing the exposure posed to receptors (e.g., evacuation of potentially exposed people). For environmental risks induced by natural disasters, secondary control mechanisms are more important for alleviating environmental damage.

Environmental risk events or activities can involve all components of the environmental risk system and they comprise the basic processes that constitute the environmental risk chain (Figure 1-2).

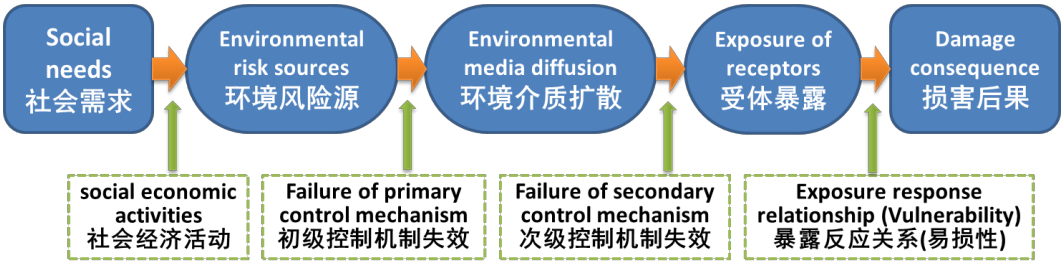

Figure 1-2. Environmental risk chain

In the whole process from social needs to risk damage, causes of environmental risks and their hazards may exist in any node of the risk chain. The purpose of environmental risk management is, first of all, to reduce the probabilities of environmental risk events happening. The purpose is also to reduce the damage if a risk event does happen at any node of the environmental risk chain. Damage can be minimized through laws, regulations, policy, and technical measures. These steps help reduce the environmental risks facing society and help secure regional and human health, environmental quality, and the functioning and integrity of ecosystems.

1.1.3 Determination of Categories and Scope of Environmental Risks

Based on the environmental risk chain, the characteristics of the process from environmental risk sources to damage are different for different types of risks. Since

there is no unified risk classification system in China, for the purposes of this report three categories of environmental risk have been defined along the spectrum from chronic to acute consequences (Figure 1-3):

Detailed descriptions of three categories of environmental risks are shown in Annex 1.

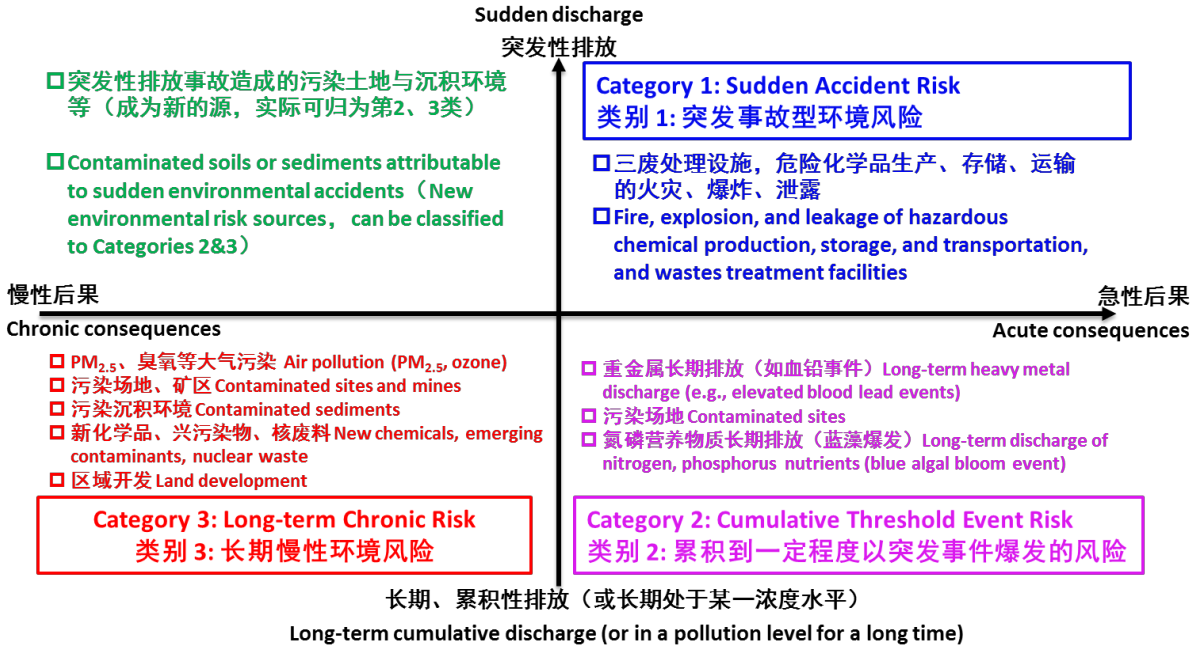

Figure 1-3. Categories of environmental risks

1.2 Current Status of Environmental Risks in China

1.2.1 Spatial and Temporal Characteristics of Environmental Risks in China

Accidental environmental pollution incidents.

A recent study[2] analysed accidental environmental incidents occurring during 1993-2014 on the basis of data provided in the *China Environmental Statistical Yearbook*, and as well collected 1065 detailed case studies during 2000-2010 through the *Safety and Environment Journal*, and from internet and media reports. These records include the first two categories of risk: accidental environmental events and activities where a threshold is reached. Since the data do not distinguish between Categories 1 and 2, we analysed the spatiotemporal characteristics of all these incidents considered together. As for Category 3 risks, this study provides analysis based on existing results from other researches.

The **frequency of environmental pollution incidents** has fluctuated with a declining trend (Figure 1-4). This is attributable to improvements in environmental risk

2 Bi, J et. al., 2012. Research report of China's 863 project of "Research on Integrated Technology System of Major Environmental Pollution Accident Emergency Response", with data updated to 2014. Unpublished.

management driven by environmental risk events. Environmental pollution incidents happened often during the early 1990s, with 2500 to 3000 cases. From 1994 to 2000 they fluctuated at high levels and then decreased and, after 2005, stabilized at around 500 per year. Little decrease has occurred in recent years.

Serious environmental accidents continue to happen, however, such as the Dalian oil pipeline explosion in 2010 and the Tianjin explosion in 2015. These show that accidental pollution event risks in China are still prominent. Although missing reports and concealment of pollution incidents produce some uncertainties in the data, the figures still reflect the overall trend of environmental pollution incident risks in China.

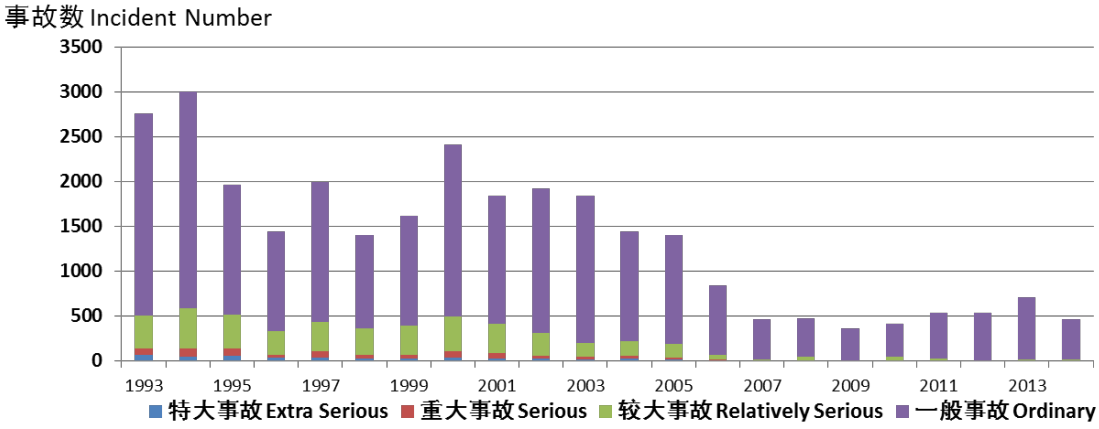

Figure 1-4 Environmental Pollution Incidents in China (1993-2014) [3]

Figure 1-5 shows the **spatial distribution** of the frequency of pollution incidents and the main risk sources. The graphic draws upon environmental classification results from approximately 46,000 enterprises in petrochemicals, chemical products, and pharmaceutical industries in the *Inspection of Environmental Risks and Chemicals in Key Sectors and Enterprises* conducted by MEP in 2009, and from the provincial pollution incident data in *China Environmental Statistical Yearbook*.

Unsurprisingly, the spatial distribution of environmental accidents is broadly consistent with the spatial distribution of major risk sources. Figure 1-5 shows that various types of pollution incidents happen where there are major risk sources. The areas with dense risk sources have more frequent pollution incidents, especially in eastern coastal regions and Hunan and Sichuan. Areas with fewer risk sources have fewer incidents, such as the northwest and northeast regions. Guangxi province has fewer major risk sources but it has a high frequency of incidents, an anomaly due to low environmental management capacity and a large industrial infrastructure. Other studies of spatial distribution of accidents reach broadly similar conclusions[4, 5].

3 Statistics on extra serious, serious, relatively serious, and ordinary pollution events in the *China Environmental Statistical Yearbook*.

4 Zhang, He-Da and Xiao-Ping Zheng, 2012. Characteristics of hazardous chemical accidents in China: A statistical investigation. *Journal of Loss Prevention in the Process Industries*, 25, 686-693.
5 Li, Yang, Hua Ping, Zhi-Hong Ma, and Li-Gang Pan, 2014. Statistical analysis of sudden chemical leakage accidents reported in China between 2006 and 2011. *Environ Sci Pollut Res* 21, 5547-5553.

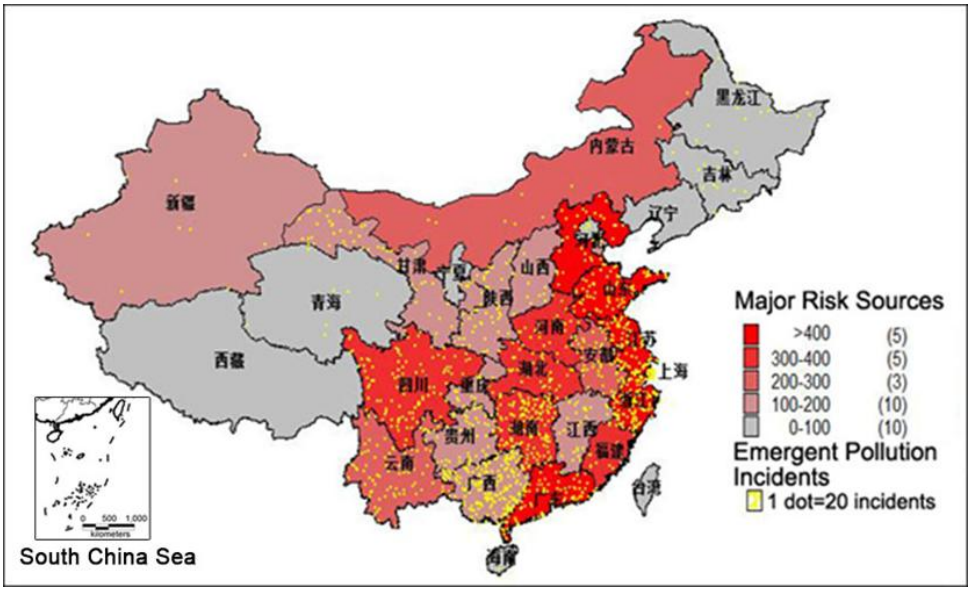

Figure 1-5 Distribution of accidental pollution incidents (1993-2014) [6]

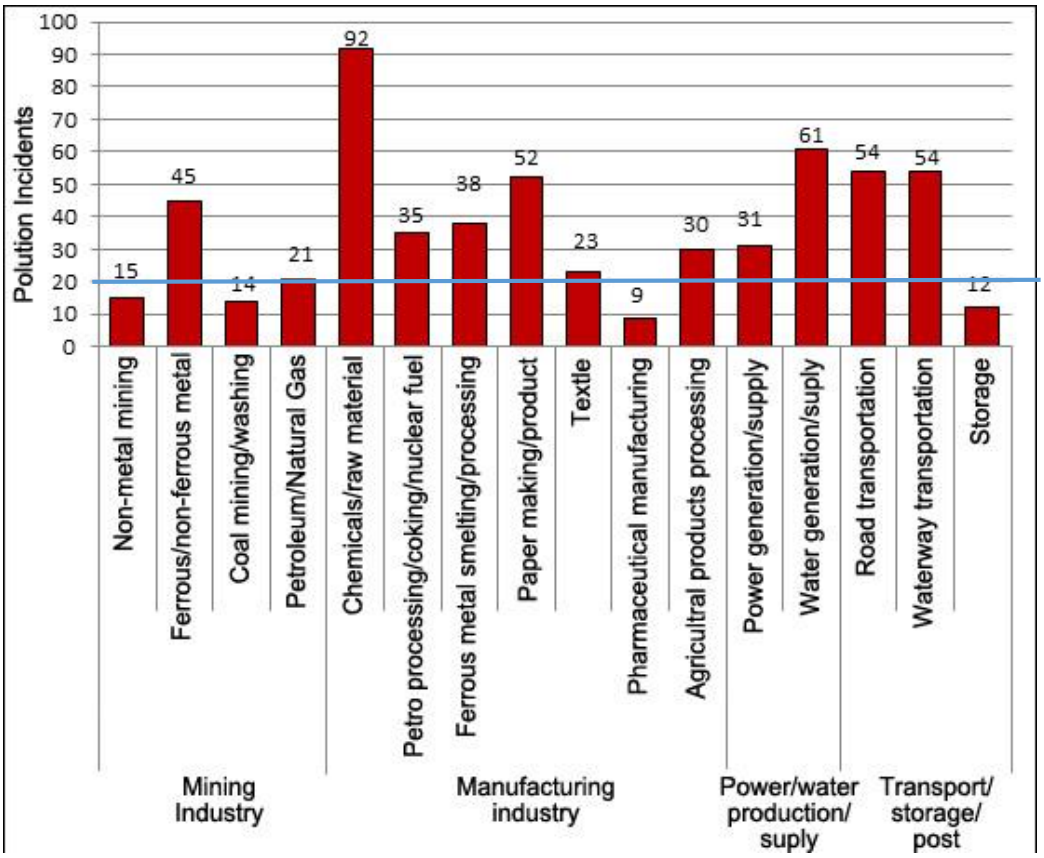

Figure 1-6. Sectoral Distribution of Main Incidents [7]

6 Based on analysis of provincial statistical data of pollution events from *China Environmental Statistical Yearbook* and data from *Inspection of Environmental Risks and Chemicals in Key Sectors and Enterprises* conducted by MEP in 2009.

7 Bi, J et. al., 2012. Research report of China's 863 project of "Research on Integrated Technology System of Major Environmental Pollution Accident Emergency Response". Unpublished.

This study also analysed **sectoral risk sources** (Figure 1-6) based on a survey of 1065 environmental pollution cases during 2000-2010. The results are broadly consistent with the literature cited above. Clearly, serious sector structural environmental risks exist in China. The order of the twelve sectors with most pollution incidents in China is: chemical raw material and products, water production and supply, road transportation, waterway transportation, paper making and paper products, ferrous/non-ferrous metal mining, ferrous/non-ferrous metal smelting/processing, petroleum processing/coking/nuclear fuel processing, power/heat generation and supply, agricultural products/food processing, textile manufacture and petroleum/natural gas exploration.

The study also looked at accidental environmental risks that are due to **industrial layout**. Many chemical production enterprises are located in densely populated areas, either on or near important water sources, rivers, lakes, wetlands, and ecological protection areas. These enterprises can become major environmental risks.

Results of the *Inspection of Environmental Risks and Chemicals in Key Sectors and Enterprises*, conducted by MEP in 2009, show that among 46,000 key sector and chemical enterprises, 12.2% are located within 1 kilometre of drinking water and ecological function protection areas; 10.1% are within 1 kilometre of densely populated residential areas; and 72% are along key rivers and basins such as the Yangtze, Yellow, and Pearl rivers, and Taihu Lake near Shanghai.

According to the *Report of Environmental Exposure Related Activity Patterns Research of Chinese Population* conducted by the Chinese Academy of Environmental Science, about 110 million people live within 1 kilometre of seven major polluting enterprises, and 140 million live within 50 metres of main roads. This report also examined the main causes for accidental environmental pollution incidents.

A recent study[8] of 1605 incidents divides the reasons for primary control mechanism failure into human factors and external factors such as equipment and weather conditions. Human factors are the main reason for incidents, accounting for 50% to 70%. Equipment failure such as wear, corrosion, aging, or extended use contributes to 10% to 20%. Poor institutional systems account for about 30%, with a rising trend.

Human factors can be divided into five types: violation of the law, non-compliance of operation, operational error, inadequate management, and weak capacity. Violation of the law accounts for 38.8% of total incidents and is the major reason. Inadequate management contributes to 36.2%. Other surveys of the causes of China's accidental pollution incidents point to similar causes, although the percentages differ among these studies[9].

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8 Bi, J et. al., 2012. Research report of China's 863 project of "Research on Integrated Technology System of Major Environmental Pollution Accident Emergency Response". Unpublished.

9 He, Guizhen; Lei Zhang, Arthur P.J. Mol, Tieyu Wang and Yonglong Lu, 2014. Why small and medium chemical companies continue to pose severe environmental risks in rural China. *Environmental Pollution*, 185, 158-167.

Li, Yang, Hua Ping, Zhi-Hong Ma and Li-Gang Pan, 2014. Statistical analysis of sudden chemical leakage accidents reported in China between 2006 and 2011. *Environ Sci Pollut Res* 21, 5547-5553.

Zhang, He-Da and Xiao-Ping Zheng, 2012. Characteristics of hazardous chemical accidents in China: A statistical investigation. *Journal of Loss Prevention in the Process Industries*, 25, 686-693.

Zhang, He-Da and Wei Liu, 2012. Causes of hazardous chemical accidents in China. *Journal of Industrial Safety and Environmental Protection*, 11, 10-11.

Finally, this study looked at the current status of **China's emergency response to environmental incidents**. It selected 50 cases from *Typical Environmental Accidents Cases (Part I)* (MEP Emergency Response Lead Group Office, 2011) to analyse the main reasons for the ineffectiveness of responses. The results (Annex 2) show that China's response capacity is weak. It lacks effective emergency response plans and scientific support, leading to improper response measures and poor control of environmental effects.

Long-term and chronic environmental risks in China

In addition to the above-mentioned types of environmental risks, there is a third type that has existed for a long time in China, but has been neglected because its effects are not sudden and acute. These are long-term or chronic environmental risks, and they include: soil contamination risk, health risk from accumulated air pollution, health and ecological risk from new emerging pollutants, and risk from regional development and large-scale infrastructure development on ecosystems.

Soil pollution

With increasing industrialization and urbanization, large areas of China's lands are gradually becoming contaminated, bringing significant environmental and health risks. The World Bank report *Current Status of Contaminated Site Remediation and Redevelopment* (2010) indicates that land contamination has become an increasingly serious environmental pollution problem in China. MEP and the Ministry of Land and Resources conducted the first national soil pollution investigation. The results show that the overall condition of soil pollution is problematic. Over 16.1% of the investigation sites exceed the soil quality standard. The degraded soil quality of cultivated land is worrying. Soil pollution problems in abandoned industrial and mining lands are prominent.

Soil quality is influenced by many factors. Soil pollution in China results from the long-term accumulation of economic and social development pressures. Industrial, mining, and agricultural activities and high natural background values are the major reasons for soil pollution in China. The pollution of cultivated soil can pose serious threats to agricultural product safety. The redevelopment of industrial and mining legacy contaminated sites may pose long-term and chronic health risks to the public, especially where there are heavy metals and persistent organic pollutants (POPs) present. For example, analysis of soil heavy-metal health risks from 62 mining areas in 19 provinces [10] shows that most of the areas have a carcinogenic risk[11] of between 1×10^{-4} and 1×10^{-5}, with a certain proportion of mining areas having a carcinogenic risk over 1×10^{-4}. Clearly, heavy-metal contamination in mining areas poses fairly high carcinogenic as well as non-carcinogenic risks to human health.

Although some practices in polluted soil management and remediation have been introduced, overall the number of contaminated sites remains unclear, and development

10 Li, Z., Ma, Z., van der Kuijp, T. J., Yuan, Z., & Huang, L. (2014). A review of soil heavy metal pollution from mines in China: pollution and health risk assessment. *Science of the total environment*, *468*, 843-853.

11 Based on risk assessment methodology defined in the *Technical Guidelines for Risk Assessment for Contaminated Sites* (HJ25.3-2014, MEP). The acceptable level for carcinogenic risk of a single pollutant is defined 1×10^{-6}..

of relevant laws and regulations still lags. A soil risk management system adapted to the China's situation has not yet been put in place.

Air pollution

In recent years, fine particulate matter ($PM_{2.5}$) air pollution has become a prominent environmental issue in China. Numerous epidemiological studies around the world have demonstrated that $PM_{2.5}$ is associated with negative health effects. The 2010 study by the Global Burden of Disease (GBD) showed that outdoor exposure to $PM_{2.5}$ was the fourth most serious mortality factor in China and was associated with 1.23 million deaths per year. The study calculated an average annual risk of dying from this cause when living in China of approximately 10^{-3} (Figure 1-7).

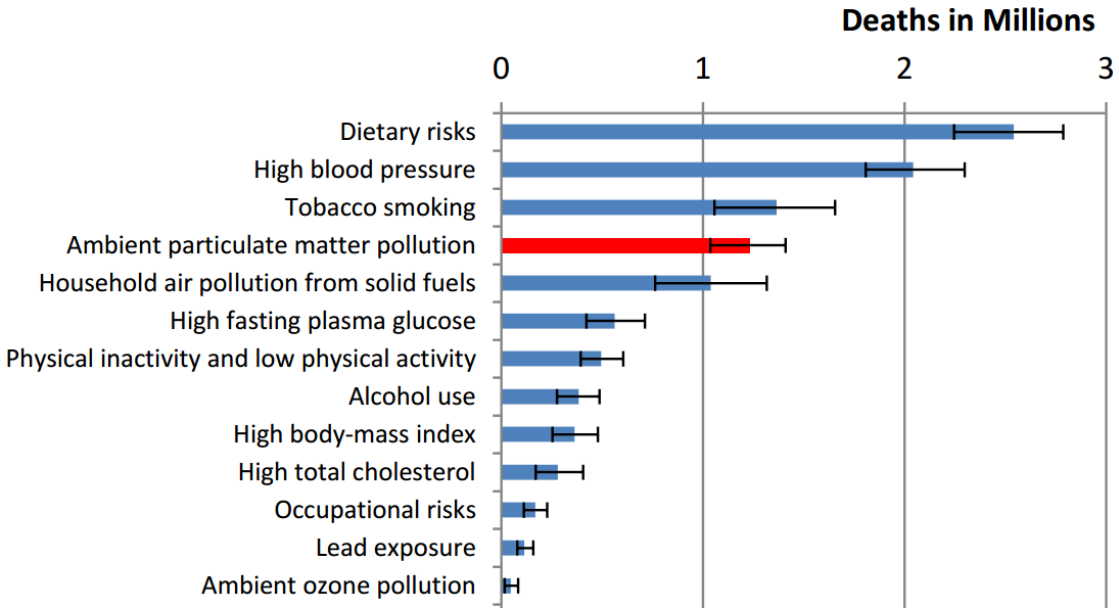


Figure 1-7 Distribution of premature death risks of China from Global Burden of Disease study 2010 [12]

Similarly, Lelieveld et al. (2015) estimated 1.36 million deaths per year in China in the year 2010 due to outdoor exposure to $PM_{2.5}$ and ozone.[13] Rohde and Muller (2015), using new monitoring data from China's several hundred ground-level air reporting stations (showing $PM_{2.5}$ levels in China around 50 $\mu g/m^3$ or higher, above the ambient regulatory limits set in China at 35 $\mu g/m^3$, in the European Union (EU) at 25 $\mu g/m^3$ and in the US at 12 $\mu g/m^3$), estimate that there were 1.6 million deaths per year in China

12 Yang G, Wang Y, Zeng Y, Gao GF, Liang X, Zhou M, et al. (2013). Rapid health transition in China, 1990–2010: findings from the Global Burden of Disease Study 2010. *The Lancet* 381:1987-2015.

13 Lelieveld, J., J. S. Evans, M. Fnais, D. Giannadaki & A. Pozzer (2015). The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature* 525: 367-371 (17 September 2015).

in the year 2014 due to $PM_{2.5}$ or more than 4,000 deaths per day.[14] In addition to these heavy health burdens caused by outdoor air pollution, almost as many lives are lost in China due to indoor air pollution, primarily from burning solid fuels for cooking and heating (Figure 1-7).

The long-term health harm of PM pollution cannot be ignored any more. The public has gradually recognized the health risk of $PM_{2.5}$ along with a more general increase in environmental awareness. As a result, China's new *Ambient Air Quality Standards* (GB3095-2012) included $PM_{2.5}$ and marked a shift in the environmental management model from an orientation on pollution control toward an orientation on improving environmental quality.

Currently, the public has high concern about $PM_{2.5}$. Meanwhile there is insufficient concern about other pollutants that also bring health and ecological risks and that will gradually become a bigger problem. These include short-lived climate pollutants or SLCPs (that is, black carbon and tropospheric ozone) as well as carbon dioxide and methane emissions acting as greenhouse gases.

Water pollution

The situation of water pollution in China is serious. According to the *Environmental Quality Bulletin* released by MEP, the proportion of water inferior to class V ('inferior V water') [15] is 9.2% for state-controlled monitoring sections in seven river systems in 2014. Inferior V water sections are mainly located in the Haihe, Yellow, Yangtze, Pearl, and Huaihe rivers. In 2013, the Chinese Center for Disease Control and Prevention (CCDC) issued a report titled *Water Environment and Gastrointestinal Cancer Death Atlas in Huaihe River Basin*, which shows consistency between heavily polluted waters and high gastrointestinal cancer rates in the Huaihe River Basin. The long-term environmental health risk due to water pollution cannot be neglected.

New chemicals and emerging pollutants

Emerging pollutants are chemical pollutants that are newly identified or were not confirmed in the past ─ and therefore are not listed in relevant regulations ─ and that pose risks to human health and the environment. These pollutants are normally generated from human activities, and will not easily decompose in the environment. Many newly introduced materials and chemicals have shown obvious health hazards and an environmental presence, for example, nanomaterial pollution, fluorinated organic compounds, environmental endocrine disruptors, antibiotics, and flame retardants. In recent years, more studies show that emerging pollutants have been detected in environmental media at many places in China, and so the risk of these pollutants to the environment and human health deserves attention.

14 Robert A. Rohde and Richard A. Muller (2015). Air Pollution in China: Mapping of Concentrations and Sources. Univ. of California at Berkeley, http://berkeleyearth.org/wp-content/uploads/2015/08/China-Air-Quality-Paper-July-2015.pdf .

15 China's *Environmental Quality Standards for Surface Water (GB3838-2002)*. Surface water quality is classified into five classes with different functions. Class I is the highest quality and applicable for river sources and nature reserves, while Class V is the lowest and applicable for general agriculture and landscape use. http://kjs.mep.gov.cn/hjbhbz/bzwb/shjbh/shjzlbz/200206/t20020601_66497.htm

Taking antibiotics as an example, research conducted in Jiangsu and Zhejiang by Fudan University on exposure of children to multiple antibiotics shows that among 1000 children tested, at least 58% were detected with one type of antibiotic in urine samples and 25% were detected with two types of antibiotics [16]. Furthermore, the *Ten Years Investigation Report of Antibiotics in China* issued by CAS Guangzhou Geochemistry Institute in 2015 concluded that the resistance of bacteria to antibiotics can be partly attributed to antibiotics found in the environment.

Thus, the environmental and health risks of emerging pollutants need to be addressed in environmental risk management to avoid a repetition of the way that pollution from heavy metals, organochlorine pesticides, and PCBs has become a major environmental risk.

Solid waste

Along with rapid industrialization and urbanization, environmental pollution due to industrial solid waste (especially hazardous waste) and municipal solid waste are becoming more prominent. For example, it is estimated that up to 5 million square meters of soil have been contaminated by chromium slag[17]. Improper disposal of solid waste risks damage to environmental quality and to ecosystem and human health. Solid waste issues may cause social conflict, such as the public protest events against waste incineration projects in recent years. Environmental risks of solid waste warrant review.

Ecological impact of regional development

With rapid industrialization and urbanization, China's long-term and chronic ecosystem changes caused by regional development are a part of the environmental risk management challenge. The *Ecological Footprint Report of China 2012* indicates that since the 1970s the consumption of renewable resources in China has exceeded their capacity to regenerate. Ecosystems face ever increasing pressure from population and development. The long period of overdevelopment has resulted in serious degradation of ecosystems. Regional development has led to the continuous decrease of natural ecosystems such as forest, bush, grassland, and wetland, as well as the decrease of natural habitat quality and biodiversity.

Ecological risks brought on by regional development have major implications on national ecological security. In 2015, the State Council issued the *Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road*, signalling that the "Belt and Road" is in the process of moving from concept to reality. The Silk Road Economic Belt will pass though sensitive ecosystems in Western China. Large-scale infrastructure construction and regional development may pose further threats to regional ecosystems.

Radiation sources and nuclear wastes

Radiation sources have been widely used in different sectors including medical and health care, scientific research, and industrial production. Radiation sources may affect the environment and public health if there is improper management. The radiation

16 http://www.chinadaily.com.cn/hqgj/jryw/2015-04-13/content_13536869.html
17 From the *12th Five-year Plan for Hazardous Solid Waste Pollution Control of China*.

sources census conducted by the former Environmental Protection Administration, Ministry of Health, and the Ministry of Public Security in 2004 shows that there were more than 10 thousand units with more than 140 thousand radiation sources in China. Radiation source accidents have occurred in recent years, including the radiation source lost incident in Nanjing in 2014[18]. Clearly, China's radiation source management levels need to be improved.

Meanwhile, China's nuclear power industry is developing rapidly. As of March 2015 23 nuclear power units were operating while 26 were under construction. Furthermore, 45 units are "under preparation" and 177 are planned[19]. With more use of nuclear power in China, the environmental risks of nuclear waste disposal will become a prominent issue. The inherent hazards of used nuclear fuel are primarily its radiotoxicity and its chemical toxicity. Due to radioactivity and cumulative characteristics, the long-term presence of even small amounts of radiation sources and nuclear wastes may cause long-term and cumulative health damage to humans and the environment.

1.2.2 Current Situation of Public Perceptions of Environmental Risks in China

Although the frequency of environmental pollution incidents has shown a decreasing trend since the 1990s, the level that the public is likely to regard as acceptable or tolerable is also decreasing. This leads to a new characteristic of environmental risk in China: increasing public demand for environmental protection (Figure 1-8).

This demand is seen with the increase in environment-related mass protests every year. The adverse effects of numerous pollution incidents have resulted in growing resentment, panic, and public resistance to industries posing potential risks, and the "not in my backyard" effect. Mounting public demands and their dissemination through various media are having more influence on infrastructure construction projects and policy development, such as the many protests against the PX (para-xylene) chemical and waste incineration projects which have occurred in recent years[20]. Environmental complaints and demands have become one of the main challenges in China's socioeconomic development.

Therefore, environmental risk management cannot be isolated from the public's perceptions of risk and acceptable risk levels. On the one hand, as long as actual environmental risk levels are higher than what the public will tolerate, conflict will be inevitable. On the other hand, the large gap between actual risk levels and the public's risk perception may be caused by lack of knowledge, not by policy choice. Information dissemination through news media may result in amplification or exaggeration of risk information, which may magnify perceptions beyond the actual risks, especially regarding sudden highly visible incidents.

At the same time, there are also many instances of the public being unaware of the risks surrounding them, especially chronic long-term exposures. The public's

18 http://news.xinhuanet.com/politics/2014-05/11/c_126484963.htm

19 Park Duri (PIAO, Douli), Study on China's nuclear power development in coastal regions and environmental issues, undergraduate thesis of Peking University, 2015. Park Duri obtained these data from World Nuclear Association, *Medium and Long-term Development Plan for Nuclear Power (2005-2020)*, and *Action Plan of Energy Development Strategy (2014-2020)*.

20 http://www.mzyfz.com/cms/minzhuyufazhizazhi/jujiaoyuzhuanti/html/696/2012-11-30/content-591810.html

misunderstanding about actual risk levels (either overstating or understating them) could make it difficult to achieve the objectives of risk management.

One should keep in mind that public risk perception is not uniform: there is a wide distribution of preferred risk levels that individuals find acceptable or tolerable. Public estimates of acceptable risk levels are also not uniform among risk sources. Data about public perceptions are important to understand public concern and to design better communications about risks and more socially acceptable risk management strategies.

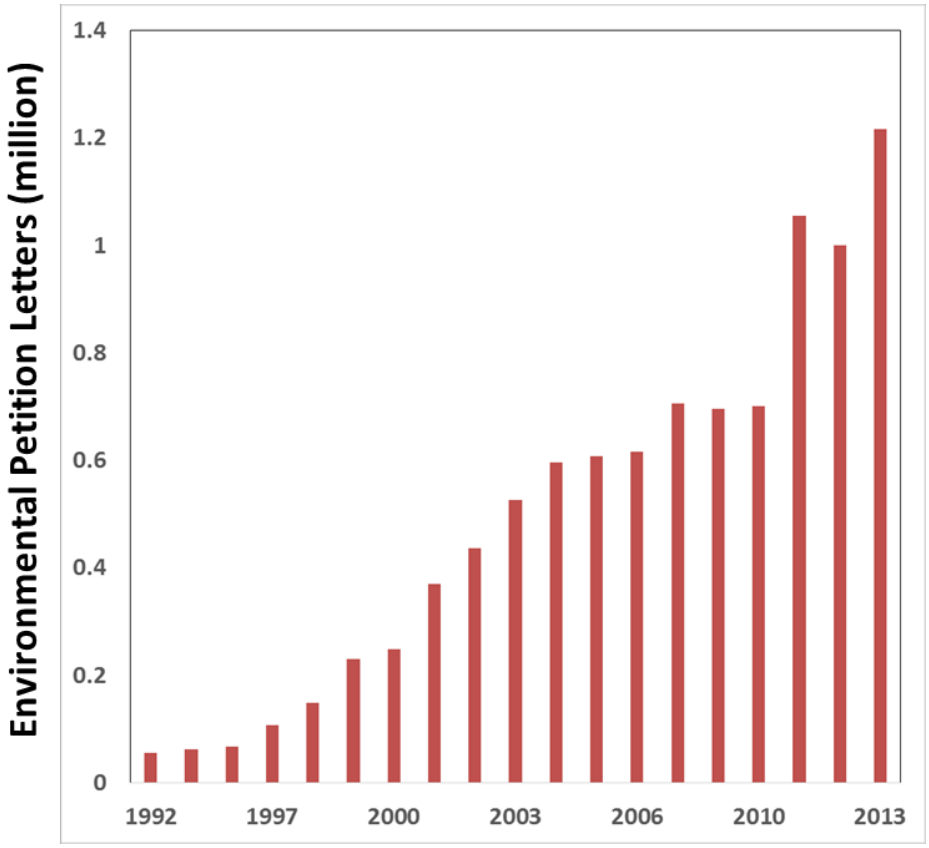


Figure 1-8. National Environmental Complaints Letters[21] (Note: Environmental complaints though internet and telephones were counted separately. Data after 2011 include complaints from letters, internet, and telephones.)

1.2.3 Current Environmental Risk Levels in China

According to the above analysis, types of environmental risk are complicated and so it is inappropriate to use a single indicator to characterize environmental risk levels. For this study, seven representative indicators from seven environmental risks were selected to characterize current environmental risk levels in China: accidental pollution events,

21 Data from *China Environmental Yearbook*.

soil, air, and water pollution, climate change, economic loss, and public complaints. Together, these indicators can form an "environmental risk rose" (Figure 1-9).

Overall, environmental risk levels in China remain high. Note that this figure presents the result of only a preliminary and semi-quantitative analysis and that the distances between circles are not to scale — the points around a given circle do not necessarily represent equal levels of risk or seriousness. Specific and systematic environmental risk assessment is needed in China to add more indicators to complete the risk rose and obtain more accurate risk level assessments. Detailed descriptions of the environmental risk rose are shown in Annex 3.

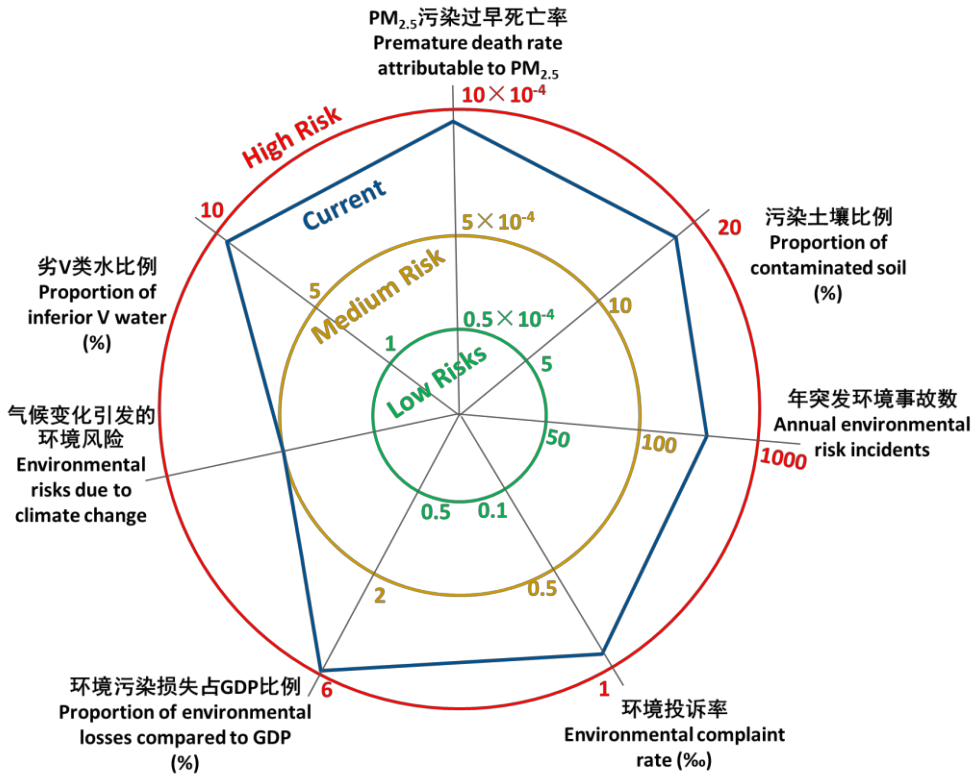


Figure 1-9. Environmental risk rose of China (Based on Annex Table 3-1; the blue solid line represents current risk levels)

1.3 Prospects for Environmental Risks in China

1.3.1 Overall Prospects for Environmental Risk Levels in China

Based on the analyses of prospects for driving forces of environmental risk levels and public risk perceptions (Annex 4), this study puts forward three management scenarios to discuss the future prospects for environmental risk levels.

Scenario 1: Environmental management will be maintained in the current mode, that is, event-driven, focused on environmental quality without systematic risk management (Business as Usual scenario).

Scenario 2: A systematic environmental risk management system is established.

For Scenario 1 and Scenario 2, the study does not consider the effects of environmental risk communication and engagement.

Scenario 3: Based on Scenario 2, the effects of environmental risk communication and engagement are also incorporated.

Figure 1-10 shows the historical and future prospects for environmental risk levels and public environmental risk acceptance levels. It should be noted that the lines are illustrative. Levels of actual risks, and of public acceptance of risk, are more complex and multifaceted than can be depicted in simple lines. The scientific basis for claiming that environmental risk was much higher in the past is based on the historical trend of accidental pollution events, but there is a lack of information about other risks, particularly long-term chronic risks.

The ability of a new risk-based environmental management system to reduce overall risk is anticipated, but the line shown here (Scenario 2) is a qualitative and intuitive perspective and is not based on a forecasting model. Is it clear in some cases that the public risk acceptance level will be higher following risk communication and engagement (Scenario 3, blue area with black boarder) than the cases without communication (grey line), because communication and engagement will reduce rumours and fears. In other cases communication and engagement may increase the awareness level of previously neglected risks and hence decrease the acceptance level. The overall trend of risk acceptance level is expected to decrease, with early involvement of risk communication and engagement, which can reduce unnecessary public concerns.

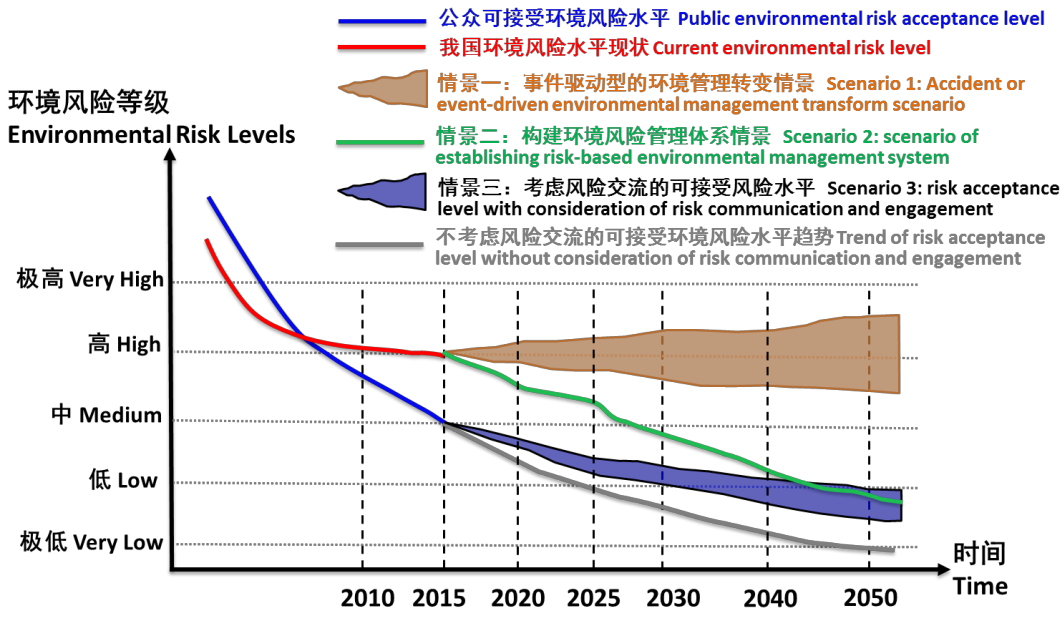


Figure 1-10. Prospects for environmental risk levels and public environmental risk acceptance levels in China

Historical trends:

An underlying premise in Figure 1-10, indicated in the red line for current risks, is that, driven by environmental events, environmental risk management levels have been improving in recent years, that is, current risks have declined in response to new policies. For example, since the Songhua River water pollution accident in 2005, China has implemented a series of measures to address sudden pollution accidents. After a series of heavy metal pollution incidents, China issued the *12th Five-year Plan of Comprehensive Heavy Metal Pollution Prevention*. The overall accidental environmental risk level has kept decreasing since the 1990s (red line) which is attributed to improvement in environmental risk management levels. This may depict the trend for acute accident events (as indicated above in Figure 1-4), but it may not represent the trend for long-term chronic risks which appears to have been increasing through this period (see Section 1.2.1 above). The large increase in risk sources, for example, for heavy chemical industrial capacity and combustion of coal, and a generally higher ecosystem vulnerability may thus point in the direction of higher risk levels over time. Latent risks from years of chronic air, water, and soil pollution are beginning to materialise over time.

Meanwhile, along with increases in national income and education levels, the public acceptance levels for environmental risk are decreasing more rapidly than the actual environmental risk level (blue line). In recent years (especially the last 10 years), public risk acceptance levels have been lower than the actual environmental risk levels. The gap between them keeps growing, which contributes to continuing social conflicts.

Future prospects:

Figure 1-10 offers three possible scenarios. These are "educated perspectives" and are not based on data or forecasting models.

Scenario 1: Driven by economic growth and industrialization (especially the growth of heavy chemical industries and coal combustion), the pressure on environmental risks will keep growing. However, based on historical experience ─ where environmental management responses were driven by accidents or by acute environmental risk events ─ the increasing ambition of environmental risk management policies and the progress of environmental protection science and technology will limit the increase in environmental risk to some extent. Environmental risks which have been known for some time will stabilize or decrease slowly. Meanwhile, emerging risks will complicate the environmental risk situation. The environmental risk prospect in this scenario includes uncertainties (orange area). Risk levels, however, will not meet public acceptance levels. The gap between them will also keep growing, and the risk situation will remain problematic.

Scenario 2: Establishing and completing the risk-based environmental management system will comprehensively elevate the level of ambition of environmental risk management in China. Thus, environmental risk levels will keep decreasing and the gap between actual risk levels and public perceptions will shrink. The environmental risk gap could be significantly alleviated under this scenario.

Public risk acceptance level (without consideration of environmental risk communication and engagement)： With socioeconomic development, national

income and education levels will keep rising, which will lead to a continual decrease in public risk acceptance levels (grey line). At the same time, other risks may be underestimated or neglected by the public. As the public gains knowledge about the underestimated or neglected risks, however, the acceptance levels for these risks are expected to decrease. If there is no risk communication and engagement, the public would probably conclude that these risks are too high to be tolerated.

Scenario 3: Establishing and implementing a reasonable environmental risk communication and engagement system, along with the expected actual risk reduction achieved by Scenario 2, will help change the risk perception levels in line with socioeconomic development levels (that is, bringing the grey line up to the blue area). This will lead the actual environmental risk levels to meet the increasing public demands on environmental safety. At the same time, risk communication may increase awareness of some previously neglected risks. This resolution of the gap between actual risk levels and public preferences could be a major overall goal of environmental risk management in China. However, it is hard to determine when China will achieve this goal. The goal should take account of the benefits and costs of actual policy options to reduce risks.

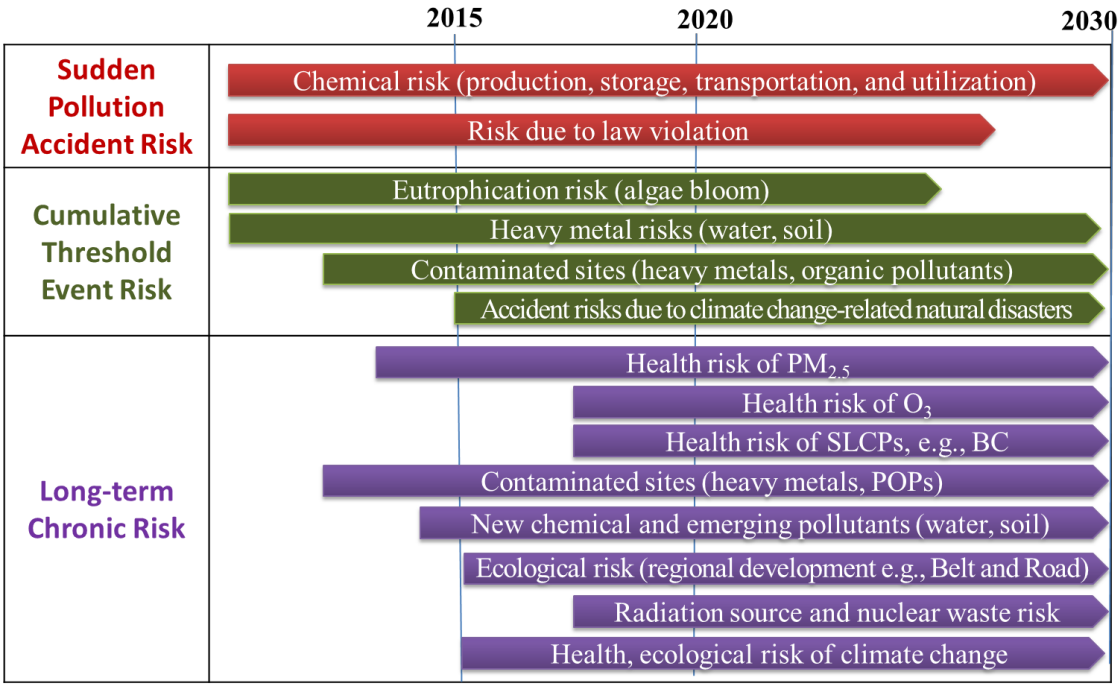
1.3.2 A Preliminary Scan of Environmental Risks in the Short and Medium Term Future

Based on the analysis of the current status and future prospects of environmental risks in China, this report provides a preliminary identification of environmental risks of high concern in the near future for the three categories of risks (Figure 1-11).

During the 13th FYP period and beyond, China should continue to take measures to address those environmental risks to which attention is already being paid in the current stage to the year 2015 (for example, chemicals, eutrophication, heavy metals, $PM_{2.5}$ and so on). Soon after 2015, China should start paying attention to those risks which are overlooked currently (for example, ozone, black carbon, greenhouse gases, nuclear wastes and radiation, and so on) and also to the risks that may occur in the future (for example, ecological risks associated with the Belt and Road construction). Note that this is a preliminary analysis. Further in-depth research and assessment is needed to identify and prioritize the future environmental risks in China.

Climate change presents an ongoing risk. In November 2014 China committed to have its greenhouse gas (GHG) emissions peak by 2030 and decline after that. Major policy measures are being put in place, including for a national GHG emissions cap-and-trade program, and targets to increase the use of renewable energy sources.[22]

22 http://www.nytimes.com/2015/09/25/world/asia/xi-jinping-china-president-obama-summit.html



Note：SLCPs: Short lived climate pollutants; BC: Black carbon; POPs: Persistent organic pollutants.

Figure 1-11 Preliminary scanning of environmental risks of concern in the short and medium term future

1.4 Principles of Environmental Risk Management

Based on the analysis of the current status and future prospects for environmental risks in China, this report summarizes the principles for environmental risk management that will provide a basis for policy recommendations.

(1) **Cost-effective/cost-beneficial management.** Since environmental risk management resources are limited, it is important to manage environmental risks in a cost-effective way. Cost-effective management of environmental risk is obtained when a given objective is attained at least cost; a cost-benefit approach seeks to optimize objectives where the marginal value or benefit of environmental risk reduction action is equal to the marginal cost of the action. Across the elements of environmental risk assessment and management, these approaches can play a role, for example in target setting based on cost-benefit analysis, modelling to forecast environmental risk outcomes, and the valuation and selection of environmental risk reduction measures including legal and economic measures.

(2) **Synergistic management and tradeoffs.** Different environmental risks are interrelated, and are related to other risks such as food safety, workplace safety risks or social risks. Reduction of a risk may increase or decrease another risk. Thus the synergistic effects among risks, and tradeoffs among them, should be considered in environmental risk management — with the objective of reducing overall risk.

(3) **Differentiated management for different risk types**. Different environmental risk management schemes and measures are needed for different risk types, which require the clarification of the characteristics of different risks based on a comprehensive environmental risk analysis and assessment in China.

(4) **Dynamic and adaptive management over time.** Environmental risk management measures need to be in line with the characteristics of the particular stage of social and economic development. Further, risk management policies need to learn from and respond to changes over time in knowledge, technology, and public values. This requires dynamic evaluation and adaptation through monitoring, analysis, and the adjustment or revision of environmental risk management policies.

(5) **Differentiated management across regions**. Environmental risk management measures need to be in line with the social and economic characteristics of different regions. This requires regional environmental risk analysis and assessment, and targeted risk management strategies.

(6) **Environmental risk communication and engagement.** The development and implementation of any environmental risk management measure needs to communicate information to the public, and as well, elicit and consider the preferences of the public and relevant citizens groups and communities. This requires that sufficient and effective risk communication and engagement be carried out.

CHAPTER 2. CURRENT STATUS AND DEMANDS OF ENVIRONMENTAL RISK MANAGEMENT SYSTEMS IN CHINA

2.1 Urgency of Environmental Risk Management System Construction in China

The 18th National Congress of the CPC introduced the goal of building a moderately prosperous society by 2020 and incorporating ecological civilization into the overall design of socialism with Chinese characteristics (that is, promoting economic, political, cultural, social, and ecological progress). *Opinions of the Central Committee of the Communist Party of China and the State Council on Further Promoting the Development of Ecological Civilization*, issued in 2015, maintains the basic state policies of conserving resources and protecting the environment. It puts the development of ecological civilization in a prominent strategic place that is incorporated into the whole process of economic, political, cultural, and social development. In the same year, the Central Committee of the Communist Party of China and the State Council issued the *Integrated Reform Plan for Promoting Ecological Civilization System* to accelerate the establishment of a complete ecological civilization system and to promote the construction of ecological civilization.

Now with China at the critical point of completing the building of a moderately prosperous society and accelerating the construction of ecological civilization, a serious environmental risk situation and gaps between risk levels and public perceptions have become major factors restraining development. Furthermore, environmental problems have grown to become a major issue affecting national security.

The *National Security Law of China*, implemented in 2015, notes the need "to strengthen the early warning, prevention, and control of ecological risk, and to address accidental environmental incidents properly." Environmental safety thus is being recognized as part of the national security system.

In the face of increasing public demands for environmental protection and the needs of national security, it is urgent to transform environmental management policy into an environmental risk management system that focuses on risk prevention and reduction and thus supports the achievement of ecological civilization.

To improve the environmental risk situation in China, to eliminate the gap between environmental risk levels and public acceptance levels, and to protect national security, an effective and efficient environmental risk management system is needed. The release of *Ambient Air Quality Standards (GB 3095-2012)* showed that environmental policy has begun to transition from an approach focused on pollution control to a more proactive approach focused on improving environmental quality.

The environmental risk management system, however, remains incomplete. It cannot support the ultimate transformation to the environmental risk management mode with the objective of risk prevention and reduction, and it cannot meet the increasing public demands for eco-environmental safety.

To support policy recommendations on an environmental risk management system for China, this chapter analyses the current status and deficiencies of the environmental

risk management system from four perspectives: environmental risk governance, goals and strategies, enabling measures, and environmental risk communication and engagement.

2.2 Incomplete Environmental Risk Governance System in China

During the past 30 years, to address the environmental problems accompanying rapid socioeconomic development, industrialization, and urbanization, environmental governance has been improving. However, during the past 10 years, frequent accidental environmental incidents have attracted more public attention ─ and environmental risk management has attracted the government's attention.

The Songhua River water pollution accident in 2005 led to improvements in prevention and emergency response capacity. Conditions such as elevated levels of lead in children's blood and $PM_{2.5}$ air pollution pose environmental risks due to cumulative pollution levels have attracted more attention from government. Environmental risk issues have been gradually incorporated into national decision- making system.

The 18th National Congress of the CPC proposed to incorporate ecological civilization into the overall layout of socialism with Chinese characteristics. Environmental risk prevention was introduced into the *Twelfth Five-year Plan for National Economic and Social Development*. The *Opinions on Strengthening Major Environmental Protection Tasks by the State Council* in 2011 proposed to establish more efficient environmental risk management and emergency response systems. The *National Security Law of China*, implemented in 2015, formally incorporated environmental safety into the national security system and notes the need "to strengthen the early warning, prevention, and control of ecological risk, and to address accidental environmental incidents properly."

Overall, the environmental management system in China is still at an early stage. It is still event-driven in many cases, and still focuses on short-term pollution control. A risk prevention and reduction environmental management mode has not been formed. From the macro perspective, the environmental governance system remains incomplete.

(1) A comprehensive environmental risk-based decision making system has not been established

At the national strategic level, the current environmental management system has not considered sufficiently the risks posed by economic development or regional development, or the risks due to industrial layout from the perspectives of environmental risk in decision-making. Environmental risk assessment has not been comprehensively and substantially incorporated into major national strategies and plans (such as the Five-year Plans, new-type urbanization, the Belt and Road initiative, integrated development of Jing-Jin-Ji area, and the Yangtze River Delta economic zone).

Although environmental risk prevention has been incorporated into the *Twelfth Five-year Plan for National Economic and Social Development*, environmental risk management is still in a relatively weak position compared to economic development. The 12th FYP only requires the prevention of environmental risks during the implementation of the plan; it does not require a decision on whether and how to implement the plan based on environmental risk assessment results. In any event,

consideration of environmental risks in the process of developing policies and plans is lacking for governments at all levels.

(2) A neutral and scientific institution to oversee and support environmental risk assessment and management is missing

Environmental risk assessment and management are professional tasks requiring objectivity and impartiality during environmental risk assessment and supervision. Thus, government should value the results produced by science-based environmental risk institutions that provide a neutral and credible source of information and risk assessments. However, China lacks a neutral institute to provide scientific risk assessments for national decision making to guide, coordinate, and oversee environmental risk management practices.

(3) The institutional structure of environmental departments cannot meet the needs of environmental risk management

The environmental management system in China is vertically and horizontally fragmented. Technically, local environmental departments receive guidance from higher-level environmental departments, but administratively they are subject to management from local governments. The routine environmental supervision of local environmental departments is restricted by local governments, which results in weak enforcement.

Within MEP, due to the lack of an integrated, top-down design, various departments have overlapping responsibilities. This has caused difficulties in the coordinated management of environmental risks. For instance, the departments of Pollution Control, EIA, Laws and Regulations, and the Emergency Response Center have individually developed their own environmental risk assessment methods. Some departments have too broad functions. For example, the Department of Pollution Control is known as "mini MEP" because it has responsibilities in multiple fields including water, air, solid waste, chemicals, vehicles, and oceans.

According to analysis of risk sources of accidental environmental pollution incidents, the production, storage, and transportation of hazardous chemicals are the major sources of these accidents in China. The 2015 hazardous chemicals warehouse explosion in Tianjin again shows the need to strengthen the integrated management of these chemicals and environmental risk control. Currently, several government agencies, including those responsible for safety supervision, public security, environmental protection, and health are involved in chemicals management. Within MEP, chemicals management involves departments such as Department of Pollution Control and the Emergency Response Center. The power and responsibilities for chemicals management overall are unclear, which has led to ineffective control of environmental risks of chemicals.

2.3 Lack of Environmental Risk Management Goals and Strategies

According to the *China Environmental Statistical Yearbook*, the frequency of environmental pollution accidents is down to about 500 every year after 2005, which indicates some effectiveness in environmental risk management work. However, public perception of acceptable risk levels keeps lowering while social and economic

development levels rise. Meanwhile, long-term chronic exposures, such as to air pollution, continue at high levels. The conflict between acceptable environmental risk levels for risk control and the public's acceptable levels will be become more prominent in the future.

It is necessary therefore to control environmental risks within levels acceptable to the public. To achieve this objective, environmental policy must be changed from pollution control and quality improvement approaches to a more proactive risk prevention and reduction approach. There is still a long way to go, however, to advance the risk management system. It requires the development of relevant objectives and strategies to facilitate the transformation of the environmental management mode.

A more robust overall objective is to maximize social well-being through the management of environmental risks. Public perceptions can be highly varied (no single risk acceptance level is possible), so the net benefits of different risk management policies and measures will depend on the type of risk and the costs of control. While public valuations need to be incorporated into those benefit estimates, public perceptions can sometimes misjudge risks, overstating or understating them.

To date, a complete set of environmental risk management goals, and the strategies to meet them, have not been developed in China. The State Ministry of Work Safety issued the *Personal and Social Acceptable Risk Criteria for Hazardous Chemical Production and Storage Enterprises (trial)* in 2014, which proposes management criteria for new and existing facilities in different types of areas. Although this standard is for safety risk management of hazardous chemicals, it offers a reference for criteria for the management of accident environmental risks, since safety accidents involving hazardous chemicals are closely related to pollution accidents. In addition, the *Technical Guideline for Risk Assessment of Contaminated Sites*, released in 2014, recommends the methodology and sets acceptable levels for non-carcinogenic and carcinogenic risks. These recommended criteria, however, mainly rely on US criteria for reference. Further studies are needed to determine whether these criteria are suitable for China.

Already there have been preliminary attempts to set environmental risk management goals in China, but there are no goals in national strategies or laws to support the overall goal of controlling environmental risk levels due to socioeconomic development at levels acceptable to the public. Environmental risk types are complicated, and environmental risk levels are different for different socioeconomic development levels in different regions and periods. Further studies are needed to explore environmental risk management goals and criteria for different regions, periods, and types of risks.

An environmental risk management strategy and system has not yet been established in China. The current situation and prospects for environmental risks are unclear. There is a lack of a comprehensive and integrated national environmental risk assessment and ranking of priority risks. Furthermore, there is a lack of research on the mechanisms through which environmental risks induce other risks, such as social stability, economic security, and national and regional security. The management priorities for environmental risks are unclear, and cannot support the development of environmental risk management strategies.

2.4 Insufficient Enabling Measures System for Environmental Risk Management

In recent years, to meet the needs of environmental risk management in the context of frequent environmental pollution events, environmental protection departments have been constantly improving the enabling measures system for environmental risk management. Overall, however, the system of enabling measures remains incomplete, and cannot yet meet the requirements for effective and comprehensive environmental risk management.

(1) Environmental laws and regulations are incomplete, and the environmental judiciary is still at an early stage

After several major environmental incidents, China has started to develop relevant laws. Both the *Emergency Response Law* and the newly revised *Environmental Protection Law* put forward the principle of "Prevention as priority with combination of prevention and emergency response." It clarified the environmental risk management responsibilities on the part of governments at all levels, departments, and enterprises.

Individual laws such as the *Water Pollution Control Law* and the *Solid Waste Pollution Control Law* have special provisions for "environmental pollution accidents response." They state the requirements for site selection and layout of pollution emission enterprises, prevention and emergency response preparedness, response and restoration. Preliminary revisions to the *Air Pollution Prevention and Control Law*, which will be implemented in 2016, incorporate risk management issues.

Overall, however, the system of environmental risk management law and regulation is incomplete. First, legal gaps still exist. For example, the lack of an *environmental liability law* prevents the determination of liability and compensation for damage following environmental pollution events. And there is a lack of relevant laws and regulations related to soil environment protection, contaminated sites remediation, and re-use management. Existing environment-related laws and regulations address environmental risk issues to some extent, but relevant provisions are not specific or clear enough, and their operability is low.

The environmental judiciary is an important guarantor that environmental protection laws and regulations can play their roles and be enforced. China's first environmental protection court was established in Qingzhen City in Guizhou province, in 2007. By the end of 2014 there had been more than 300 environment resource trials, collegial panels, and circuit courts. The Environment Resource Trial Court under the Supreme People's Court was established in July 2014.

So, an initial environmental judiciary system has been established in China; however, it cannot yet play its role well. There is a lack of professional judiciary human resources, and environmental judiciary capacity needs to be improved.

(2) There is no unified environmental risk information database and data sharing system

Providing and sharing information is essential for the improvement of environmental management. Currently, there is no overall coordinated approach to the management and sharing of environmental risk and management information. Each government

department involved with environmental issues ─ environmental protection, water conservancy, ocean, meteorology, land and resources, agriculture, and so on ─ has one or more sets of data but no unified data interface, data sharing mechanism, or basic database. Data redundancy and conflicts exist.

Even inside environmental protection departments, data sharing is weak. This means that the information requirements for environmental risk assessment and management cannot be met. During an emergency response, weak data sharing may affect the implementation of the response measures. Thus it is necessary to integrate the data from different departments and develop a unified environmental risk information system that can be shared across departments.

In addition, basic data about environmental risks are still lacking. First, there is no exposure information for environmental risks such as numbers, distribution, and location of contaminated and high hazard sites, concentration data for emerging pollutants, and so on. Second, research on exposure-response relationships between environmental risk factors and receptors is still weak with a consequent lack of exposure response information, for example, environmental baselines relating to human and ecological health.

In 2015 the State Council issued the *Construction Plan for Eco-environmental Monitoring Network* to address these issues: the incompleteness of the scope and elements covered by the current eco-environmental monitoring network; the lack of unified data construction plans, standards, and information disclosure; gaps in information sharing; and the low quality of monitoring data. This new plan proposes to establish an eco-environmental monitoring "big data" platform, and to establish mechanisms for eco-environmental monitoring data integration, sharing, and unified disclosure. The plan provides a good opportunity for environmental risk data to be incorporated and integrated into this system.

(3) A system of financial instruments for environmental risk management has not been developed

China is still at an early stage of using financial instruments in environmental management, although it has seen certain achievements. For instance, in 2007 MEP and the China Insurance Regulatory Commission (CIRC) jointly issued the *Guidance on Environmental Pollution Insurance* and in 2013 conducted a series of pilots, and then issued a follow-up *Guidance on Pilots of Mandatory Environmental Pollution Insurance*.

The current financial instruments for environmental risk management still have many problems, however, and the system is incomplete. First, there is no mandatory legal requirement for financial assurance at a national level. The new *Environmental Protection Law* will only "encourage enterprises to buy environmental pollution liability insurance," although some provinces have adopted some form of insurance pilots. Such mandatory requirements need to be specific to ensure that they respond to the risks to be managed. Second, the value of the environment and natural resources has not been commonly recognized in the current economic system. Environmental financial instruments cannot be well integrated with current financial systems, a fact that has hindered the development of financial instruments for environmental risk management.

In addition, there is a lack of technical directives and guidelines to support pollution liability financial assurance. For instance, even though MEP and CIRC jointly issued *Technical Guidelines of Environmental Risk Assessment – Environmental Risk Classification for Chlor-alkali Sector* and *Technical Guidelines of Environmental Risk Assessment – Environmental Risk Classification for Sulfuric Acid Enterprises (trial)*, there are large gaps in sectoral coverage, and a lack of appropriate provisions to assist in determining premium rates, liability limits, damage verification, or compensation.

(4) Environmental risk emergency response capacity is weak

China has established an initial emergency response preparedness plan network including national, special, and departmental plans, plans for local institutes and enterprises, and temporary preparedness plans. These constitute an overall environmental emergency response plan management system. Nonetheless, the overall levels and operability of emergency response plans in China are relatively low. Most of the responses to environmental emergencies have shown that joint emergency response across regions and departments is insufficient, information collaboration is inadequate, equipment and technologies for emergency monitoring, early warning, and disposal remain weak, and the operability of emergency response plans is poor. It is necessary to increase the capacity for environmental emergency response to the same high level of capacity exist for natural disaster response in China.

MEP released the *Measures of Accidental Environmental Event Emergency Management* in 2015, which requires that enterprises, public institutions, and environmental departments at all levels conduct regular emergency response exercises based on the emergency response plans, write exercise evaluation reports, analyse existing problems, improve their emergency plans based on the exercises, and publicize their response plans and exercises. The implementation of this regulation will improve the operability and overall level of emergency response plans in China. However, there remains a lack of relevant guidelines and effective punitive and incentive measures that will drive and facilitate emergency response exercises and revisions to plans.

(5) Weak industry and enterprise responsibility

Analysis of the main causes for environmental pollution incidents in chapter 1 shows that low awareness of environmental responsibilities and violations of laws and regulations by industries and enterprises are the main reasons. From the perspective of environmental management, increasing the compliance level of China's enterprises is a long-term challenge. Therefore, building a corporate environmental risk responsibility system, adjusting relationships between government and enterprises, creating economic incentive instruments such as taxes, fees, and tradable quotas, and stimulating the inherent vigour of enterprises to lower environmental risks, are important pathways for a new model of environmental management.

Since the adoption of the ISO14001 international environmental management system standard, many international enterprises have improved their internal environment, health, and safety (EHS) systems, thus lowering corporate environmental risk and social cost. With the more recent ISO26000 corporate social responsibility (CSR) guidelines, many enterprises are considering the implementation of CSR practices as being important for their business. Many enterprises in China have established their EHS

systems and have also gradually implemented a CSR strategy, for example, SINOPEC and the Shenhua Group.

Most enterprises, however, do not have a strong motivation to establish an internal EHS management system. This gap has been reflected in the 2015 Tianjin explosion accident, where insufficient information disclosure for hazardous chemicals contributed to improper emergency response. Regulations like the Seveso Directives in the EU could provide a possible model for China.

2.5 Weak Environmental Risk Communication and Engagement System

China is in a stage of transformation in which the traditional environmental risk management approach is no longer compatible with modern risk management requirements. First, environmental risks are becoming more widespread, diverse, and complex. More than ever, environmental risk management requires more cooperation among departments, across governments at all levels, and with the public at large. It also requires more flexibility to adapt to local natural and socioeconomic situations, and more modern information technologies. It is essential to establish an environmental risk communication system with the participation of government, enterprises, and public organizations through information sharing, disclosure, and public participation in risk management. This is an inevitable choice for the rule of law in China.

In 2006, China's State Environmental Protection Administration (now MEP) released the *Temporary Measures of Public Participation of Environmental Impact Assessment* which facilitated and normalized public participation in EIA. *Measures of Environmental Information Disclosure (trial)* released in 2007 facilitated and normalized the environmental information disclosures of environmental protection departments and enterprises. The 2015 *Environmental Protection Law* has a chapter on "information disclosure and public engagement" which explicitly stipulates that citizens, corporations, and other organizations have the right to obtain environmental information and to participate in and oversee environmental protection issues. Furthermore, it stipulates that environmental protection departments at all levels, other departments which have environmental protection duties, and major pollutant discharging units should disclose relevant environmental information. MEP released the *Measures of Public Engagement in Environmental Protection* as the supplemental regulation to the *Environmental Protection Law* in the same year, which stipulates the rights and ways for public participation in environmental protection.

Thus, preliminary environmental information disclosure and public engagement systems have been established. However, some problems still exist:

(1) Current laws and regulations are mainly for environmental protection departments. They lack provisions for information integration, sharing, and disclosure across ministries. Although the *Measures of Environmental Information Disclosure for Enterprises and Public Institutions* was released in 2014, there remains a lack of supporting and operable punitive and incentive policies and regulations for information disclosure by enterprises. This has led to poor implementation of environmental information disclosure and public engagement by enterprises.

(2) An effective and responsive environmental risk communication and negotiation system has not been established. There are few provisions or specific plans to ensure

that environmental risk levels remain within those that the affected populations regard as acceptable. Communication and engagement can help inform the public and elicit public preferences that will bring official policies on acceptable risk levels in line with what social groups and the public at large expect. Communication can also help adjust risk perceptions to the local economic situation and political standards. Meanwhile, education and training in the field of emergency management is lacking, including for self-rescue, evacuation, and damage avoidance by members of the public, especially vulnerable people. Communication is an integral part of emergency response education. It can inform people how to behave in emergencies and crisis situations. This is particularly important for vulnerable people such as the elderly.

(3) The *Measures of Public Engagement in Environmental Protection* offers citizens, corporations, and other organizations the right to engage in policy making and to oversee illegal behaviour by corporations and other organizations. However, concrete ways, measures, and procedures for public engagement are still lacking. Public engagement is a mere formality. A discussion is needed to specify what type of policy should be open for public debate and engagement. China also lacks provisions on how to incorporate stakeholders into policy making procedures.

CHAPTER 3. INTERNATIONAL EXPERIENCES OF ENVIRONMENTAL RISK MANAGEMENT

3.1 The history of environmental risk management systems in developed countries

A number of countries have established robust and systematic environmental risk management systems. For example the Netherlands, the United Kingdom, the United States, Canada, Australia, New Zealand, Singapore, and South Korea all have strong risk assessment systems and risk-based policy regimes. Their history shows however that these risk control systems were only gradually developed, driven by a series of major pollution accidents or events, and or by longer-term chronic pollution during their process of industrialization.

In the US, for example, there were several photochemical smog incidents in the 1940s and 1950s in the Northeast and in Southern California. The smog spurred the development and implementation of the US *Clean Air Act*. By the 1970s, after several amendments of the *Clean Air Act*, the laws and regulations governing air pollution control and risk prevention were established. The *Act* requires US Environmental Protection Agency (EPA) to set national ambient air quality standards (NAAQS) and other policies to protect public health and welfare.

Similarly, the *Clean Water Act* (1972) was enacted after crises at Lake Erie and the Cuyahoga River. Another example is the Love Canal crisis (1978), which spurred the enactment of the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA, also called the *Superfund Act*) in 1980. A series of technical guidelines were developed under the superfund system. A national priority list of contaminated sites that threaten harm to human health and the environment was also developed. While much remediation was achieved and risk management systems for contaminated sites established, studies have shown that CERCLA has required clean-up of low-risk sites at a very high cost.

In Europe the development of these systems has also been event driven following the great smog of London in 1952, the Seveso disaster of 1976, and the Sandoz chemical spill of 1986. All these events led to more stringent regulation.

Risk prevention is an important principle of environmental legislation in European Union (EU) countries. Environmental risk assessment is considered one of the bases for applying environmental risk prevention. Relevant legislation mainly focused on worker safety and health protection, then gradually shifted to environmental pollution prevention and response. The EU's Maastricht Treaty, promulgated in 1992, and raised risk prevention to the level of constitutional principle. The Bulletin on Environmental Risk Prevention Principles passed by the EU in 2000 provided a clear and effective guideline for environmental risk prevention, especially risk assessment. Meanwhile, the EU has developed a series of specific laws and directives to provide further regulation on the risk management of industrial activities, corporate environmental risk, and water environment, human health, and ecosystem maintenance.

Driven by a series of environmental pollution events, the US gradually established a robust environmental risk management system – though it continues to debate about

and reform its system. During the process, the US Environmental Protection Agency (EPA) and US National Academy of Sciences (NAS) continually worked to rethink and research environmental risk assessment tools, all of which advanced environmental risk assessment and management approaches. For example, in 1994, NAS published *Science and Judgment in Risk Assessment* (the *Blue Book*) which evaluated the deficiencies of environmental risk management tools (including environmental risk assessment methods and procedures, priority setting methods, data acquisition, and risk communication). This tool was used by the EPA for toxic air contaminants management. In 2009 NAS published *Science and Decisions: Advancing Risk Assessment* (the *Silver Book*). The report conducted a review and evaluation of risk analysis and assessment approaches used by the EPA, and offered recommendations for practical improvements that the EPA could make.

Overall, the robust environmental risk management systems in European countries and the United States and Canada provide useful lessons for China. It should be noted however that the establishment of these systems was driven by a combination of pollution accidents, the demonstration of chronic health and ecosystem effects of chemicals, air and water pollution, and soil and water pollution from contaminated sites. Thus the establishment and improvement of such systems should not be event-driven but instead should be guided by a strategy which incorporates accidental, acute threshold, and chronic environmental risks from a range of sources. Further, the development of environmental risk assessment systems suggests that there needs to be ongoing re-evaluation and improvement of the risk management system to adapt to changes in risk conditions.

3.2 International Experiences of Environmental Risk Governance

(1) Vertical risk responsibilities and integration

In the US, several agencies are responsible for risk assessment and management, including the EPA, the Department of Energy, the National Oceanic and Atmospheric Administration (NOAA), the Department of Agriculture, the Food and Drug Administration, the Occupational Safety and Health Administration, the Department of Transportation, the Nuclear Regulatory Commission, and the Department of Homeland Security. In each of the 50 states, state-level environmental protection agencies, agriculture agencies, food and drug management agencies, and commodity inspection agencies are responsible for state-level environmental risk assessment and management. The state-level environmental bodies receive supervision from EPA regional offices, and often are delegated authority by the EPA to implement federal laws ─ subject to national oversight and enforcement by the EPA ─ in a system of "cooperative federalism."

In the EU, EU-level institutions adopt policies that need to be "transposed" into member state law. Within almost all EU member countries the national environmental ministry supervises environmental protection at the local level through regional offices.

(2) Horizontal risk responsibilities and integration across ministries

Fragmentation across agencies is a challenge even in the most developed regulatory systems. As just noted, in the US multiple federal agencies manage multiple risk domains. This horizontal proliferation of agencies and missions can make priority-

setting difficult, and can lead to tradeoffs in which reductions in one risk by one agency unintentionally yield increases in other risks under the domain of another agency (or failure to attain the co-benefits of reducing multiple risks in concert). The EPA has special authority over many environmental laws, and working relationships with other national departments with environmental risk responsibilities. For instance, relevant federal departments must provide environmental impact statements on new projects, and the EPA has the authority to review these statements and recommend improvements. But the major mechanism for horizontal coordination across US agencies occurs at the White House (centre of government).

In other countries, the use of environmental risk in decision making has also been growing. The system in Norway is noteworthy for its integration of macroeconomic planning models and environmental scenarios. The Norwegian model informs policy makers and advisers in the ministries of finance, industry, energy, and environment about the consequences for environmental risk of macro- and sometimes micro-economic policies in the country.

In the EU, there are also agreements to share environmental data, and institutions are legally bound to submit data to central institutions such as the National Statistics Bureaus. The European Environmental Agency provides recommendations to member countries on policy development and decision making on environmental protection, and promotes environmental information communication among member countries, as well as environmental monitoring. The Environment Department of the European Commission (DG XI) is responsible for coordinating development of environmental quality standards, developing and revising environmental laws and regulations, and ensuring enforcement and implementation of relevant environmental policies. The science and technology department (DG XII) is responsible for providing support to policy making on environment, health, education, and energy. The Minister of the Environment is part of the cabinet in most EU member countries. Environmental ministries in several countries have set up internal departments based on environmental elements or media (air, water, soil, biodiversity).

(3) Environmental risk boards

To reinforce the importance of building environmental risk into decision making ─ and to ensure national oversight of risk management ─ the establishment of "national risk boards" is emerging, and a few countries have taken this step. The World Bank, in its annual World Development Report (2014) [23] , included as its first policy recommendation that every country should establish a National Risk Board. The World Bank report citing earlier reports [24,25] argued that countries often face numerous risks but have fragmented institutional structures for responding to those risks. One result of such fragmentation is that different risks are addressed separately, with little coordination, leading to skewed priority-setting and to poor risk tradeoff decisions (where efforts to reduce one risk unintentionally induce other risks, or shift risks to

23 The World Bank (2014). "Managing Risk for Development." (pp.278-279). World Development Report 2014

24 John D. Graham & Jonathan B. Wiener (1995), Risk vs. Risk, Harvard University Press (chapter 11, "Resolving Risk Tradeoffs," pp.257-260).

25 World Economic Forum (2007). Global Risks Report.

other populations, or fail to attain co-benefits). Fragmented agencies also may lack mechanisms for longer-term foresight of emerging risks outside their domains.

A national risk board can help address these problems of fragmentation and provision of foresight by coordinating across the complex institutional structure and varying challenges of risk assessment and management. Its role can be advisory to official government policy makers, or it can have a more influential or even official role in shaping policy itself. Its membership can consist of experts outside of government, or government officials, or a mix of these and other types of participants.

Several countries have established versions of a national risk board. The US has created a White House Office of Information and Regulatory Affairs (OIRA), which oversees and coordinates across federal risk regulation and reviews cost-benefit analyses of federal regulation. The EU has created an Impact Assessment Board (IAB) located in the Secretariat General, and recently renamed it the Regulatory Scrutiny Board, to oversee and coordinate regulatory policies. Singapore has the strongest example of a fully national risk board, including risk assessment, horizon-scanning foresight, and priority-setting functions. The country takes a "whole-of-government integrated risk management" approach, advised by a Centre for Strategic Futures (now called the Strategy Group in the Prime Minister's Office) and a Risk Assessment Horizon Scanning (RAHS) office located in the National Security Coordination Secretariat.

In addition, the US and several countries in Europe have established post-crisis or post-disaster investigation bodies or "safety boards." In many cases, such post-crisis investigations are conducted by one-time, *ad hoc* commissions of inquiry, which can focus high-level attention on a major event (such as the US 9/11 Commission, and the US Deepwater Horizon Oil Spill Inquiry Commission), but these bodies lack the permanent expert staff, the historical perspective, and the credibility that come with repeated investigations over many incidents over time. Thus, some countries have gone further to establish permanent, independent post-crisis/disaster investigation bodies. A new study examines these national safety boards[26]. Strong examples include the single-sector US National Transportation Safety Board (NTSB), and the multi-sector Dutch Safety Board (DSB).

(4) Roles of scientific institutions

Scientific institutions play a critical role in determining the facts behind the assessment and management of environmental risks. They can provide valuable input to the work of environmental risk boards and government policy makers. The EU has designated and tasked science-based institutions with bringing forward the factual basis for the regulation of environmental risks and advising on the environmental benefits (lower risk) of regulation. An example is the International Institute of Applied Systems Analysis (IIASA), based in Austria, which provides the scientific basis for air quality management in Europe.

Similar organizations providing the scientific basis for risk assessment and management exist in the US states, such as NAS, the Centre for Disease Control and

26 Edward Balleisen, Lori Bennear, David Cheang, Jonathon Free, Megan Hayes, Emily Pechar, and A. Catherine Preston (2015), "Institutional Mechanisms for Investigating Crises and Regulation Reassessment: The Commission of Inquiry and the Safety Board" (in E. Balleisen et al., eds, Policy Shock, Cambridge Univ. Press,) forthcoming.

Prevention CDC), the National Institute of Environmental Health Sciences (NIEHS), the National Oceanic and Atmospheric Administration (NOAA), the research office of the EPA, and the national labs of the Department of Energy. By means of transparency in operation, inclusiveness in participation, and scientific integrity, these institutions have earned the respect of policy makers as advisors on the factual basis of regulation of environmental risk.

3.3 International Experiences of Environmental Risk Goals and Strategy

(1) Setting goals, targets, and acceptable risk levels

The US *Clean Air Act* (CAA) as amended in 1990 incorporates 10^{-6} risk frequency into Section 112 as the residual risk level for hazardous air pollutants (air toxics) in Section 112. But this quantitative probability level is unusual among US laws. And it is not the main regulatory requirement in Section 112 under which maximum available control technology, or MACT must be applied first. Besides Section 112, in other areas of the CAA, such as those addressing national ambient air quality standards (NAAQS) and other US laws, do not generally define a quantitative risk level. Instead, US laws often instruct EPA to "protect public health" or "prevent unreasonable risk," and leave it to EPA to determine the quantitative risk level in specific policies.

The most elaborate approach to assessing and determining environmental risk in the EU is found in the case of classical air pollutants. Air quality guidelines for these pollutants are based on the impact pathway approach. This approach allows an estimate of risk of environmental damage associated with exposure and also expected reduced damage (that is, benefits) from reduced exposure. The actual emission levels are the results of negotiations that take costs as well as benefits into account. For hazardous chemicals the approach is cruder. In Europe the REACH directive specifies "substances of high concern."

An influential study[27] found a wide variety of quantitative risk levels espoused in different US laws with many different levels or standards. A more recent study surveyed the actual regulation of many risks in the US and Europe and found no consistent principled approach to precaution. Rather, it found a complex pattern of different degrees of precaution addressed to different risks[28].

Annex Table 5-1 provides the risk goals under various laws and regulations in the US and the EU. These are variously expressed in quantitative, qualitative, or technology terms.

In the US and Europe, consideration of cost-benefit and cost-effectiveness also guide the determination of targets for environmental risk reduction. Cost-benefit means that the optimal level of risk reduction is selected by weighing the marginal benefit of environmental risk reduction against the marginal cost of risk reduction. Cost-effectiveness means that a given level of risk reduction is achieved at least cost. These principles are often presented in legal language such as the benefits should justify the costs, or seek to maximize net benefits, or aim for environmental risk to be as low as

27 Alon Rosenthal, George Gray and John Graham, "Legislating Acceptable Cancer Risk from Exposure to Toxic Chemicals," 19 *Ecology Law Quarterly* 269-362 (1992)
28 J.B. Wiener, M.D. Rogers, J.K. Hammitt & P.H. Sand, eds., The Reality of Precaution: Comparing Risk Regulation in the US and Europe (RFF Press/Earthscan/Routledge, 2011)

reasonably practicable, prevent unreasonable risk, protect public health using the least burdensome alternative, minimize risk given due consideration of cost, or best available technology given due consideration of cost.

(2) National assessment and strategy

The main goal of national risk assessments is to identify current and emerging risks, estimate their seriousness, and contribute to setting priorities. Risk assessments provide a numerical or at least a qualitative basis for judging the likelihood, seriousness, and distribution of expected damages over time. A risk assessment seeks to measure the product of probability and outcomes, and helps estimate the benefits of reducing risks and the distribution of these expected benefits across target groups (for example children, elderly people, poor people, and so on).

As a complement to the science-based risk assessment, it is prudent to conduct a concern assessment among major stakeholders (industry, citizens, social organizations) to explore their risk perceptions and concerns. Public concerns may differ from expert risk assessments, potentially due to heuristic strategies of public perception. Depending on the outcome of the concern assessment, different management and communication strategies should be designed and aligned to the risk management options that are derived from the priority setting exercise of the responsible decision making agency.

When setting goals and formulating strategies for risk reduction, international experience has shown that it is essential to involve the public — as per the guidelines of the International Risk Governance Council (IRGC)[29] — to gain an understanding of perceptions.

Risk perceptions include four major triggers:

a) Intuitive biases and heuristics that make a risk appear more (or less) serious than it actually is

b) Specific areas such as food or drinking water quality that lead to heightened public concern. These very sensitive topics vary from culture to culture and often from social group to social group

c) High concerns may come from distrust of or lack of confidence in any of the crucial actors involved (for example, industry or regulators)

d) High concerns can be used to develop a strategy to promote specific policies or to get public attention for an issue or a group (strategic motivation).

It is essential to address these four elements of perceptions in risk management and risk communication. Being sensitive to public concerns helps to gain acceptance of official policies and to build up trust in management institutions.

29 International Risk Governance Council (IRGC). 2005. White Paper on Risk Governance: Towards an Integrative Approach. Geneva: IRGC

3.4 International Experiences of Environmental Risk Enabling Measures

(1) Risk data and monitoring

The European Environmental Agency (EEA) in Copenhagen is developing a European Environment Information and Observation Network (Eionet) with the aim of providing quality data, information, and expertise for assessing the state of the environment and stress factors. This information will support information dissemination and the development of policies and measures, and enable them to be monitored for their effectiveness. Eionet will provide systematic, nationally validated, high-quality environmental data.

The US EPA, and the US government generally, collects extensive data on overall environmental quality indicators (for example, e.g. ambient air and water pollution), as well as on the environmental impacts of each source of pollution (e.g. such as emissions and discharges from private firms, and environmental impacts of government programs). EPA also operates several information disclosure requirement programs, such as the Toxics Release Inventory and the Greenhouse Gas Reporting Rule.

(2) Economic instruments

Environmental taxes and fees are used in Europe and the US mainly in energy management and air pollution risk control. Risks from water pollution are mainly regulated by permit. Risk of losing biological diversity is regulated in Europe by zoning (similarly to ecological red lines), but there are some financial instruments and incentives towards farmers and to a lesser extent fishermen.

Europe in particular regulates consumption of fossil fuels ─ an important precursor to risk from air pollution ─ and CO_2 by economic instruments. In the context of environmental risk, the lowering of fossil energy consumption and CO_2 emissions implies lower emissions of particulate matter, mercury, SO_2, NO_X and other air pollutants.

The US has long used tradable emission permits for air pollution control, including for lead, chlorofluorocarbons (CFCs), and SO_2 emissions control. The SO_2 tradable permits system, adopted in the 1990s, is considered a success story that has been cost-effective and has achieved considerable emissions reduction, hence lowering environmental risk to health and ecosystems. The low cost made possible by the trading system enabled the ambition for emissions reductions to be tightened in several rounds over time. The EU then adopted after 2001 a tradable permit system to reduce greenhouse gases, ─ the EU Emissions Trading System (ETS).

(3) Financial security instruments for environmental risks

Financial security instruments (FSI) include secured funds, on-demand performance bonds, company guarantees, and insurance. These financial solutions are available to industrial operators and to government agencies. Financial security requirements may be applied on a sectoral basis, to industrial activities with the highest level of risk, for example, or on a regional or national level. They may incorporate risks associated with normal or abnormal operations, such as during accidental or natural hazard events.

A range of American, European, and Asian countries have adopted FSIs) for environmental risk management. These are used to fund the prevention of environmental risks and remediation of damage to the environment. Some FSI's, such as insurance, have the added benefits of encouraging loss-reduction and risk prevention behaviour. Environmental pollution liability insurance was first adopted in the US in 1966, and now has become a relatively complete system. Special environmental protection insurance companies were also established in 1988. The entire EU has adopted environmental liability systems supported by encouraging the use of financial security instruments since the Environmental Liability Directive came into force, some on a voluntary basis, some mandatory. In 2016 South Korea will introduce a compulsory environmental insurance program for industrial companies that handle hazardous chemicals.

Some common themes and developments that arise from countries' financial security systems are: mandatory or voluntary financial provisions; instrument choice including insurance, bonds, and funds; default options for insolvency; establishing minimum limits for insurance or bonds; evolution of legislation from pollution-centred to broader environmental damage; and, evolution of financial markets to incorporate risks.

(4) Emergency response

In the US, the Federal Emergency Management Agency is responsible for leading and supporting nationwide environmental risk emergency response. The country has established a national emergency management information system and a National Incident Management System (NIMS). It has issued a national response plan, and established a comprehensive warning and emergency management system with the four key elements of prevention, response, remediation, and mitigation. It also has special emergency response systems for oil spills, nuclear accidents, and other specific types of accidents. And it has post-accident investigation bodies, notably the NTSB and the Chemical Safety Board, to assess the cause and to recommend improved prevention policies.

In the EU, emergency response is guided by the REACH chemical registration requirements, the Seveso II and III directives, the EU civil prevention mechanism, and the 112 emergency response mode. The Seveso directives that regulate production facilities distinguish between upper tier (high risk) and lower tier (low risk) facilities. Upper tier facilities are regulated much more strictly.

More generally, there are two main characteristics of the EU environmental risk management system related to accidents. First, close attention is paid to land use planning, in order to prevent environmental accidents. Strategic environmental assessment is carried out for land use plans. Second, public participation is given priority and is a formal prerequisite in the planning process.

In terms of emergency response, the International Commission for the Protection of the Rhine launched the Warning and Alarm Plan (WAP) in 1985. Within the framework of WAP, countries in the Rhine basin all established environmental warning centres. The EU put the Major Accidents Reporting System (MARS 4.0) into operation in 2001 to help member countries make reasonable decisions in addressing major environmental pollution accidents.

Environmental risk management in Japan covers various kinds of natural environmental incidents and man-made environmental incidents. Japan established a national crisis management system based on comprehensive disaster management, and formed a risk management system of "risk prevention and reduction, crisis management, and national security." The country established a disaster prevention information system and emergency response system at central and local levels, and formed a horizontally and vertically integrated disaster relief and emergency response information network.

(5) Industrial responsibility

In Europe and elsewhere, governments and regulatory authorities have put in place incentives for environmental risk practices by enterprises. They emphasize to companies the necessity and benefits of environmental risk assessment processes and management as an integral part of an enterprise's progress and success. These processes incorporate avoidance and management of hazards, opportunities for cost management, positive influences on internal culture, marketability of green products, and tools to communicate with stakeholders.

These government measures may include recommending to companies the adoption of international and national standards such as International Environmental Management Standards ISO 14000 series, Europe's Eco-Management and Audit Scheme (EMAS), and Risk Management Standards ISO 31000 series. Other standards for environmental risk management include the Global Environmental Management Initiative (GEMI) and the International Finance Corporation's Environmental and Social Performance Standards. Incentives for environmental risk planning by enterprises are also built into the Seveso and REACH directives in Europe, and US laws such as the *Clean Air Act* 112. Some countries have put in place codes of practice and standards such as Spain's UNE Standard 150008, Australia's Sectoral Standards and Government Agency Environmental Network (GAEN), and the UK's Pollution Prevention Guidelines (PPGs).

Industrial sectors in Canada, the US, Europe and elsewhere have implemented voluntary industry-developed performance standards to manage environmental risks and drive performance improvement. This has produced benefits which provide incentives to industrial sectors to reduce and manage environmental risks, with benefits including public safety, improved environmental performance, reduced management costs, increased community confidence, and reduced regulatory requirements.

Industry standards can be recognized in government regulations, providing further incentive to the industry to adopt and achieve the standard. Examples of voluntary standards programs include the Chemistry Industry Association of Canada's *Responsible Care* ® program[30]; and, the Mining Association of Canada's *Toward Sustainable Mining*™ initiative[31]. The Responsible Care ® program started in the late 1980s in Canada and is now is a global, voluntary initiative developed autonomously by the chemical industry in 52 countries. Combined, these chemical industries account for nearly 90% of global chemical production, including in Hong Kong SAR and China. In China, Responsible Care® is a program of the Association of International Chemical

30 http://www.canadianchemistry.ca/responsible_care/index.php/en/index
31 http://mining.ca/towards-sustainable-mining/how-tsm-works/tsm-verification

Manufacturers (AICM) registered in Hong Kong, which consists of 50 international chemical company members. State owned enterprises do not participate[32].

For European and American enterprises, the setup of EHS (Environment, Health, and Safety) departments and improvement of management systems has become a major part of these companies' sustainable development strategies.

(6) Environmental risks reporting in financial reporting requirements

A number of countries in North America and Europe have put in place rules for environmental risk disclosure through their securities exchange regulators, , integrating environmental risk into financial reporting requirements. In Canada this is done through securities regulators' rules for public disclosure[33]. The US Securities and Exchange Commission (SEC) also administers guidelines on disclosure of environmental risks. A new European Union directive on non-financial (environmental and social) disclosure by corporations has a similar purpose[34].

All this has built on the mandatory financial reporting of environmental risks in the UK, France, Germany and other countries[35]. The Buenos Aires Stock Exchange has added to its information disclosure requirements regulations requiring public companies to include information about their environmental insurance[36]. Disclosure is also a key element of environmental measures in Europe, for example in the Seveso and REACH directives.

3.5 International Experiences of Environmental Risk Communication and Engagement

(1) Communication

A major challenge for environmental risk management is that risk perception often differs from statistically or experimentally derived numerical risk assessments. Addressing this gap between public perception and expert assessment is one of the most challenging tasks for inclusive risk governance. This can partly be addressed by effective risk communication[37]. Risk communication needs to address the physical properties of a risk, the rationale for risk management options, the tradeoffs between risks and benefits as well as the agency's responses to people's perceptions and concerns. To accomplish all these goals is difficult, and meeting the various demands simultaneously often leads to value conflicts and communication contradictions.

It is important to use targeted, two-way public communications and engagement to build public understanding of environmental risks. Transparent and effective

32 http://www.icca-chem.org/en/Home/Responsible-care/Responsible-Care-Members/

33 https://www.osc.gov.on.ca/en/SecuritiesLaw_sn_20091218_51-717_corp-gov-enviro-disclosure.htm

34 http://ec.europa.eu/finance/accounting/non-financial_reporting/index_en.htm

35 https://halshs.archives-ouvertes.fr/halshs-00658734/document

36 http://www.iclg.co.uk/practice-areas/environment-and-climate-change-law/environment-and-climate-change-law-2015/argentina

37 US-National Research Council (1989), Improving Risk Communication. Washington, D.C.: National Academy Press. And: Fischhoff, B., N.T. Brewer and J.S. Downs. 2011. Communicating Risks and Benefits: An Evidence-Based User's Guide. Report. Washington: US Department of Health and Human Services, Food and Drug Administration (FDA) (www.fda.gov/ScienceResearch/SpecialTopics/RiskCommunication/ default.htm).

communication of environmental risks between the policy maker and the public is necessary to: elicit the preferences and meet the demands of citizens affected by development; and, build understanding of risks, including the differences between perceived risks and assessed risk.

Effective communication of risk will also build public and community confidence in government ─ if this is supported by sensible regulation or other demonstration of actions to reduce risks to citizens. Many international studies on risk management emphasize the need for intensive risk communication between different agencies and decision-making bodies. Even within an agency it is important to facilitate the dialogue among risk experts such as toxicologists, cost-benefit analysts, and legal staff [38].

International best practice guidelines for communication and cooperation among and between agencies have been proposed [39]. These guidelines should address the transparency requirements of data and action plans, a protocol of who has to be consulted or informed prior to going public with a specific policy, and a documentation plan that requires a structured approach to set up a data bank and a workable archive for all agencies involved. Respective agencies can establish a risk information sharing board that monitors the risk sharing practices and also determines what information is shared with a wider public.

(2) Engagement

One of the major tasks in policy making is the need to ascertain support by major stakeholders. Many of these stakeholders not only have a special interest in risk reduction, they also have knowledge in risk reduction methods and practices. It is essential to include these groups in risk governance. Key stakeholders include: scientists and experts; affected citizens; the private sector; and social organizations. In addition, one needs to take account of the public media as mediators between the policy level and the wider public.

Public involvement can pursue the following functions [40]:

- *Enhancing transparency:* Publish exposure data. Inform people ahead of time of new developments or plans. Provide all public bodies with the necessary information so that they can act upon this information.
- *Collecting feedback and preferences:* Conduct surveys, set up focus groups, and conduct dialogue sessions with social groups and representatives of the affected public about their priorities, preferences, concerns, and anxieties. Use this information for both more effective risk communication programs, inputs to benefits valuation, and more sensitive risk management plans.
- *Exercising and preparing people for emergencies*: Conduct regular exercises and information programs for making people familiar with appropriate

38 Löfstedt, R. (2001): Risk Communication and Management in the Twenty-First Century. *International Public Management Journal* 73: 335–346

39 BfR (German Federal Institute for Risk Assessment) (2007). ERiK - Development of a Multi-Stage Risk Communication Process, edited by R.F. Hertel and G. Henseler.. BfR-Wissenschaft 04/2007. BFR: Berlin 2007.

40 OECD (2002). Guidance Document on Risk Communication for Chemical Risk Management. Series on Risk management, No 16. Paris: OECD Press. And. Renn, O.: Risk Governance. London: Earthscan, p. 203

behaviour in emergency situations.

- *Co-designing policies:* Include representatives of industry, social organizations, and citizens in monitoring or measuring exposure. Provide telephone or mobile phone hotlines for reporting events. Use formats of citizen participation for urban and industrial planning. Consult stakeholder groups when preparing new or revised policies.

It is important to design public engagement policies in accordance with one or more of the four major purposes. Each purpose requires a different approach, different formats and moderation techniques. In the US and the EU, dedicated private and public institutions have specialized in designing the most appropriate risk communication and engagement programs depending on purpose and risk.

CHAPTER 4. POLICY RECOMMENDATIONS TO ESTABLISH AN ENVIRONMENTAL RISK MANAGEMENT SYSTEM IN CHINA

This study proposes policy recommendations for building a proactive environmental management system based on environmental risk prevention and reduction. Such a system will meet the basic needs of social and economic development and the eco-environment, and will support the intrinsic requirements for construction and implementation of China's *Integrated Reform Plan for Promoting Ecological Civilization System*. It comprises four strategic elements: environmental risk governance, risk goals and strategies, risk enabling measures, and environmental risk communication and engagement. Establishing and completing the environmental risk management system will focus on the prevention and reduction of the three categories of environmental risks presented in chapter 1. The basic framework for the system is shown in Figure 4-1.

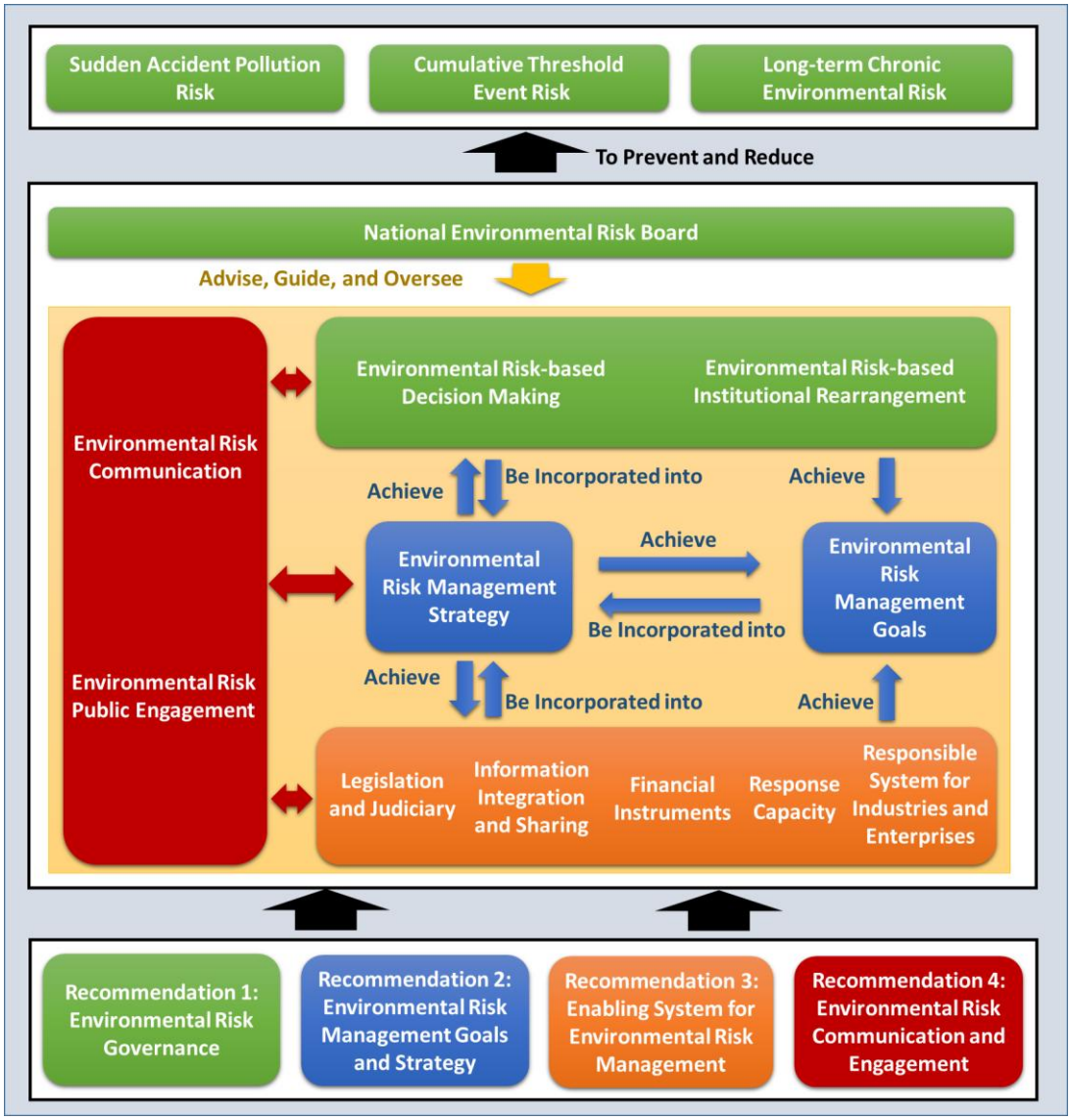


Figure 4-1 Framework for the Environmental Risk Management System Based on Policy Recommendations

4.1 ESTABLISH THE RISK-BASED ENVIRONMENTAL GOVERNANCE SYSTEM

The recommendations in this study are founded on the urgent need to fully integrate environmental risk assessment and management into the environmental governance system of China at all levels. This will enable a proactive environmental management approach focused on prevention and reduction of environmental risks to replace the current reactive approach of environmental management with its focus on pollution control. By implementing these recommendations China has the opportunity to achieve major improvements in environmental quality, human health, and security.

4.1.1 Establish a High-level, Permanent National Environmental Risk Board

China needs a high-level, permanent National Environmental Risk Board at the centre of national government. The responsibilities of this board would be to: identify, assess, and prioritize current and potential environmental risks (sudden accidental, cumulative threshold, and long-term chronic risks); help identify opportunities to reduce multiple risks, and resolve tradeoffs among multiple risks and between economic development goals and environmental risk control; coordinate and oversee environmental risk management in an integrated way; ensure evaluation of ongoing policies with a view to learning and improvement over time; and, ensure that environmental risk assessments are undertaken to inform major national economic, legal, and environmental decisions. The board would provide the cornerstone for the national environmental risk management system.

The National Environmental Risk Board would mainly focus on environmental risk, but its work would be linked to other kinds of risks with strong environmental interactions, for example: natural disasters, food safety, workplace safety, and climate change. Its responsibilities and functions would include:

a) Lead the development of national environmental risk management goals and a national environmental risk strategy. Guide their implementation.

b) Undertake national and regional environmental risk assessments and horizon scanning to identify emerging risks, drawing on a wide network of researchers in many domains of environmental quality, ecosystem integrity, and public health.

c) Analyze risks and decide on priority environmental risks at the national and regional levels related to policies, planning, and major investments. Assess benefits and costs of policy options, identify opportunities to reduce multiple risks, and help resolve tradeoffs among risks and between socioeconomic development goals and environmental risks.

d) Assess the adequacy of government risk management policies at every level, with a view to learning and improvement over time.

e) Identify responsibilities for risk management and oversee actions taken to manage risks by responsible government agencies. Provide support to science-based decision making for environmental risk management, and oversee policy impact assessments.

f) Initiate and monitor effective risk communication and engagement processes and ensure that the results of risk perception studies are integrated into risk management and communication programs.

4.1.2 Establish a Comprehensive Environmental Risk-based Decision-making System

(1) Establish an environmental risk assessment and prevention system for national macro-strategies for China's national modernization process

Carry out short-term, medium-term and long-term environmental risk assessments for national macro-strategies such as the building of an overall well-off society, new-type urbanization, integrated development of the Jing-Jin-Ji area, the Belt and Road initiative, and the Yangtze River Delta economic zone, and develop effective environmental risk prevention roadmaps for each macro-strategy.

(2) Incorporate environmental risk assessment and management into the decision-making systems of governments at all levels

Incorporate environmental risk assessment and risk management requirements into government decisions ─ at every level of policy, planning, and implementation ─ that have a potential impact on environmental quality, ecosystem integrity, or human health, and for the development of environmental standards. Establish a comprehensive planning system and assessment system for decision making of major policies and plans. This will contribute to the government's efforts to deepen reform and streamline regulatory measures. Specifically:

a) Apply strategic environmental assessment (SEA) to incorporate environmental risks into policies, plans, and major infrastructure projects at all levels. Apply risk-based SEA strategic environmental assessment, incorporating cost effectiveness and benefits considerations, during the formulation of all national and sectoral policies and plans, including for energy, industry, agriculture, transportation, and regional development, and during feasibility assessment of major infrastructure projects. Pay close attention to vulnerable people who may be affected by the implementation of such policies and plans. Incorporate environmental risk assessment and philosophy of environmental risk management into the development of environmental standards.

b) Promote Multiple-in-One spatial plans, integrating economic and social development plans, urban and rural plans, land use plans, and ecological protection plans into one plan. Apply environmental risk assessment to evaluate environmental risks, including costs and benefits comprehensively in Multiple-in-One spatial plans to identify priority zones and risks, and draw ecological protection red lines. Establish a system to ensure synergies across multiple assessment processes including environmental risk assessment, environmental impact assessment, and social stability risk assessment.

(3) Incorporate Climate Change into Environmental Risk Decision Making

Conduct periodic assessments of climate change-related environmental risks, undertaken by third-party organizations under the guidance of the National Environmental Risk Board in cooperation with the National Climate Strategy Centre

(NCSC), and involving extensive social participation. These assessments will inform decisions on environmental risk management.

4.1.3 Rearrange Environmental Risk-based Institutions

(1) Establish a management structure based on environmental elements

Support the transformation of the department structure of MEP to produce a coherent system for environmental risk management, with clear powers and responsibilities. Therefore, replace the current Departments of Pollution Control and Total Emission Control with new Departments of Air Pollution Control, Water Pollution Control, and Soil Pollution Control. Adjust the functions of the Department of Ecological Protection to include protection of ecosystem functions, nature reserve management, and biodiversity protection. It will be necessary to build in specific coordination mechanisms across the new departments to avoid previous problems of fragmentation and to ensure that cross-media shifts in environmental risks do not occur.

In addition, it must be recognized that much of the work for effective environmental risk management must still be done by other ministries, other levels of government, and enterprises. The role of MEP thus includes ensuring that a robust regulatory and policy framework is in place which fully integrates environmental risk management, and applies strong enforcement to ensure the prevention and reduction of environmental risks.

(2) Establish Chemical and Environmental Emergency Response Centres

Reform the management system for dangerous chemicals which currently involves multiple departments. Clarify the main body of regulations. Incorporate chemicals management into environmental emergency response systems and strengthen their management of hazardous chemicals.

(3) Strengthen vertical connections of environmental departments

Build strong vertical connections from MEP to provincial and local environmental departments that will incorporate a consistent approach to environmental risk assessment and management. Increase the decision-making power of higher level environmental departments for cadre management, including appointment and dismissal. Boost the performance management of officials in lower level environmental departments. Ensure the relative independence between local environmental protection departments and local governments to avoid interference in environmental supervision and decision making by local governments.

(4) Strengthen regional Environmental Supervision Centres

Clarify the role of regional Environmental Supervision Centres through legislation, and clarify their mandate for supervision as well as their responsibilities and obligations. This effort should be undertaken with oversight by the National Environmental Risk Board. Increase investment in staffing and equipment. Convert public institutes to government units when appropriate.

4.2 ESTABLISH ENVIRONMENTAL RISK MANAGEMENT GOALS AND STRATEGY

4.2.1 Set Environmental Risk Management Targets

The overall goal of environmental risk management is to prevent or reduce environmental risks in order to secure human health, environmental quality, the functioning and integrity of ecosystems and national security, increase social well-being, and make risk levels compatible with public perception of acceptable levels.

(1) ***Set comprehensive national environmental risk reduction targets for priority environmental risks***. These targets should be developed by the National Environmental Risk Board, based on the results of a national environmental risk assessment and the setting of priorities it undertakes. Risk targets need to factor in the costs and benefits of risk control, the feasibility of applying risk control technologies, and public perception of risks.

(2) ***Require each province, region and city to set environmental risk targets***. These are to be set according to regional socioeconomic development conditions and risk types relevant to each region, based on the national risk targets and using methods developed by the National Environmental Risk Board. Acceptable environmental risk levels differ for different types of risks and for different socioeconomic development levels in regions and for different periods. International experience shows there is no one universally acceptable risk level. Examples of risk targets are shown in Annex 5.

(3) ***Require provinces, cities, and regions to prepare a roadmap to determine the pace and path to meet the environmental risk targets***. These are to be based on priority regional environmental risks, environmental conditions, economic and social conditions, regional development strategy, and the need to maintain public confidence.

4.2.2 Establish and Implement a Comprehensive National Environmental Risk Management Strategy

Apply the principles of "whole process management" and "priority management" to establish and implement a comprehensive environmental risk management system in China. The goal is to transform the current reactive approach of environmental management, with its focus on pollution control, to a proactive environmental risk prevention and reduction mode.

It is necessary to establish priorities for environmental risks and identify the management urgency for different risks, so as to achieve the greatest environmental and social benefits with limited management resources.

(1) ***Conduct a full, comprehensive national risk assessment and ranking exercise to set national priorities.*** Priorities are to be set for each of the three categories of environmental risks — sudden accident risks, cumulative threshold event risks, and long-term chronic risks. Since environmental risk priorities and goals will change with the progress of socioeconomic development, this national risk assessment needs to be conducted periodically.

(2) ***Establish and apply a risk chain-based environmental risk management system.*** (Figure 1-1 shows the risk chain). This is to be based on the assessment results, emphasizing risk avoidance and prevention, and risk response, mitigation, compensation, and remediation where necessary, to reduce overall risks and yield public health, environmental quality, and ecosystem benefits that justify the costs.

Based on the results of this study, we propose a preliminary environmental risk management strategy roadmap (Table 4-1). Further in-depth research and assessment is required to identify and establish the detailed roadmap for future environmental risk management in China.

Table 4-1 Preliminary roadmap for environmental risk management strategy in China

Year	Strategic Roadmap	
	Management System	**Risk Level**
2020	■ Environmental risk prevention and reduction is incorporated into the national macro strategy and into sector policies, spatial plans, and infrastructure development decision making ■ "Whole process management" and "priority management" based environmental risk management system is partially established	■ A number of priority risks are in progress to be reduced, for example $PM_{2.5}$
2025-2030	■ Environmental risk management system is transformed to the proactive mode to prevent and reduce all categories of environmental risks ■ Environmental risk management system is fully implemented based on “whole process management” and “priority management”	■ A number of risks (e.g., environmental risks due to law violations, eutrophication, heavy metals in water and soil) are successfully controlled ■ Overall environmental risk is reduced with improved ecological and public health, and is increasingly aligned with public risk perception
2040-2050	■ Evaluate and adjust the environmental risk management system to fit evolving conditions and needs	■ Some environmental risks will take longer into this stage to be managed successfully, such as those related to climate change ■ Overall environmental risk is controlled at low levels and in line with public risk perception, and secures high levels of environmental quality, and ecological and public health

4.3 ESTABLISH AND IMPROVE THE SYSTEM OF ENABLING MEASURES FOR ENVIRONMENTAL MANAGEMENT

4.3.1 Strengthen and Complete Legislation and Strengthen the Judiciary for Environmental Risk Management

(1) Complete the system of environmental risk management laws and regulations

With the goal of transforming the current reactive environmental management approach to a proactive environmental risk prevention and reduction mode, and applying whole process management, it is necessary to improve laws and regulations for environmental protection.

First, fill the gaps in law for environmental risk management.

a) **Develop a new *Environmental Liability Law*.** This law would have provisions for ecological damage compensation and restoration, causality identification, public interest litigation, environmental damage evaluation, liability insurance and broader financial assurance, as well as systems for funding and dispute resolution.

b) **Develop environmental management laws for soils and contaminated sites**. Issue the *Soil Environmental Protection Law* as soon as possible and develop supporting laws and regulations for contaminated sites management. Soil environmental legislation should pay more attention to the protection of clean soil, especially farmland, and the management and control of contaminated sites.

Second, environmental risk-related provisions in existing laws and regulations are not specific and clear enough and their operability is low. Thus there is a need to revise existing laws and regulations to incorporate and make environmental risk control provisions more concrete.

c) **Develop a *Dangerous Chemicals Safety and Environmental Risk Law* that applies to all dangerous chemicals**. This law would be based on the existing *Hazardous Chemical Safety Management Regulation* and focused on implementing life-cycle risk management for chemicals, including comprehensive risk assessment of new chemicals, provisions for chemicals production, handling, transport, storage, use, and waste management, as well as disclosure of chemicals use, transportation, and storage by industry and government ministries and agencies at all levels. Strengthen comprehensive supervision and regulation of priority pollutants in the process of industrial production.

d) **Revise Civil Law or Tort Liability Act**. Expand the scope of compensation for personal injury caused by environmental pollution, clearly incorporate potential health damage into compensation, clarify standards for direct and indirect loss identification, and incorporate pure economic loss into property damage compensation, as appropriate.

Third, conduct retrospective assessments for all relevant laws on a periodic (5 or 10 year) basis and revise or amend relevant laws according to results of these assessments and changing social, economic, and environmental risk conditions.

(2) Promote and strengthen the environmental judiciary

Although the environmental judiciary system in China is still in its early stages, the system is important to ensure that environmental protection laws and regulations are enforced. Put in place measures to promote the environmental judiciary in China, including the training of professional judiciary human resources and promoting public consciousness about environmental rights.

4.3.2 Enable Environmental Risk Information Integration and Sharing

Vertical and horizontal fragmentation of environmental risk information, including its storage and management, has resulted in data redundancy and conflicts. Taking the lead from the State Council's 2015 *Construction Plan for an Eco-environmental Monitoring Network*, integrate environmental risk information which is distributed across multiple government departments into a national unified environmental information platform, or data centre, and establish a specific subdivision for environmental risk information.

This subdivision will include information on risk attributes and spatial information on environmental risk sources and surrounding sensitive receptors, monitoring and management information on risk sources, and relevant policies, laws, and regulations. Develop specific agreements and protocols for sharing environmental risk information, both horizontally and vertically across environmental protection departments and between MEP and other government ministries.

Support extensive research on environmental exposure and dose response functions based on ecotoxicology, human health risk, and environmental epidemiology to fill data gaps. These data can be incorporated into the unified environmental risk information database.

4.3.3 Apply Financial and Economic Instruments to Prevent and Manage Environmental Risks

Higher quality environmental financial instruments are required for environmental risk management. Establish an enterprise financial security system, based on environmental risk, for sudden accident, cumulative event, and chronic environmental risks, including liability insurance for industries and enterprises, an environmental risk deposit system for high-risk industries, and special funds for legacy contaminated site clean-up and remediation. Economic measures such as market based regulation also should be used to prevent and reduce environmental risks.

(1) Improve the environmental liability and financial assurance system

Clarify the role of environmental liability insurance and other financial assurance instruments from the legal perspective, and apply mandatory liability insurance and/or other financial assurance for high-risk industrial sectors. Based on sector characteristics, develop guidelines for enterprise environmental risk assessment, damage verification, and determination of compensation methodology. This will provide technical support for improvement and implementation of an environmental risk liability insurance system and assist in the determination of premium rates.

(2) Establish and optimize special funds for environmental risk control

Establish an environmental risk deposit system for high-risk industries. Enterprises with high environmental risks would pay corresponding deposits to environmental ministries and bureaus, according to their risk classifications. This will enable environmental agencies to pay damage compensation and remediation costs using the deposits when environmental risk events happen. These ministries and bureaus can hold accountable the responsible enterprises after the events, so as to protect the environmental rights of the people surrounding the enterprises.

Establish special funds for contaminated site clean-up and remediation. With the progress of urbanization, some contaminated sites in urban areas may be re-developed. Remediation management of contaminated sites is urgently required. However, remediation costs are high, which is a major barrier for the redevelopment of contaminated sites. Further, for some contaminated sites, the responsible enterprises cannot be found or have become bankrupt, so that funds for site remediation cannot be guaranteed.

4.3.4 Establish a collaborative multi-department environmental emergency response system with practical emergency response plans as a core requirement

(1) ***Develop relevant policies and measures to improve the effectiveness of environmental emergency response plans at all levels***. The National Environmental Risk Board, in collaboration with professional organizations, should be responsible for developing guidelines for these plans and for supporting policies to ensure effective response plan development and training exercises.

(2) ***Establish strong environmental emergency response capacities.*** Establish joint emergency response mechanisms with clear powers and responsibilities and requirements for information sharing, with emergency response plans as the core. This would involve government departments responsible for safety supervision, transportation, environmental protection, and public security, as well as enterprises. Optimize the allocation of regional environmental emergency resources.

4.3.5 Establish a Responsibility System for Industries and Enterprises

Establishing corporate environmental risk responsibility needs to start from the relationship among government, the public, and enterprises, to motivate enterprises under internal and external pressure to establish and improve their acceptance of responsibilities for environmental risks. Government has a role in creating the right conditions, through a combination of law and regulation, with enforcement and incentives to industry to act responsibly.

(1) ***Drive and support industry sectors to be responsible for adopting environmental risk management practices***. Clarify the response and remediation responsibilities of industries and enterprises for accidental and legacy risks, specify in law and regulation environmental risk information disclosure obligations, and provide regulatory recognition for adoption of leading practices by enterprises.

Apply a series of incentive measures in the fields of investment, green credit, taxes and fees, land, market access, government procurement, and tradable quotas to create an

environment that encourages leading enterprises to establish their environmental risk responsibility system. Provide training in EHS practice for enterprises, and develop measures to spur enterprises to establish their EHS systems.

Focus on sectors with critical environmental risks. These would include the chemical industries. Through their industry groups such as the Association of International Chemical Manufacturers (AICM), encourage them to broaden in China the application of the successful international Responsible Care® Program. Similarly, engage the China Mining Association to address environmental risks.

(2) ***Develop and implement a program for environmental risk management improvement in state enterprises***. Require state enterprises to raise the level of environmental risk management to the international standards applied by foreign companies, and provide incentives and support for them to become national leaders. Led by MEP and working with each sector ministry, develop environmental risk assessment and EHS training for state enterprises, based on priority risks identified by the National Environmental Risk Board. Promote a third-party service market making full use of professional organizations in corporate environmental risk management, and provide professional services to small and medium enterprises in this field.

(3) ***Put in place rules for mandatory environmental risk disclosure in the financial reporting requirements of the China Securities Regulatory Commission***. Through mandatory information disclosure, environmental risk management becomes a major factor that can affect enterprise financing and stimulate stock exchange listed enterprises to consciously and actively implement environmental risk management practices.

4.4 ESTABLISH AN ENVIRONMENTAL RISK COMMUNICATION AND ENGAGEMENT SYSTEM

4.4.1 Develop a transparent and effective environmental risk communication system

The diversity and complexity of environmental risks requires more effective and responsive communication, cooperation, and negotiation among government agencies and multiple stakeholders. Poorly informed public risk perceptions may result in the exaggeration or the attenuation of the actual risks, or the neglect of other risks. It may also result in inappropriate emergency response to risk events.

(1) ***Establish an environmental risk data sharing mechanism across ministries, and with provincial and local environmental bureaus***. This can be based on the *Plan for an Eco-environmental Monitoring Network*. Establish an accessible mechanism for public disclosure of risk information, to be implemented by government ministries and provincial and local environmental bureaus. The mechanism will include requirements for disclosure of multi-source risk information, including risk sources and location, regular environmental monitoring results for the sources, risk assessments, environmental emergency response plans, and information on public perception of risk. Such information provides a basis for the building of an efficient and orderly environment risk communication and public engagement system.

(2) ***Develop a multi-dimensional, transparent environmental risk communication and engagement system***. This should involve multiple stakeholders including

government ministries, enterprises, representatives of citizens and communities, media, and social organizations. The system should use various measures such as information transfer, round-table conferences, and community engagement.

Establish mechanisms for risk knowledge transfer to and from the public, including on specific risk reduction strategies and hazard chain information, so that government ministries and bureaus better understand public preferences and the public has a better perception of environmental risks.

It is also essential to familiarize citizens and communities with risks that they will face in everyday life. They need to know how to behave in emergencies and gain knowledge about self-rescue, evacuation, and strategies for avoiding damage after an environmental risk incident. Effective communication lowers public vulnerability to risk events, especially for vulnerable people and the most exposed segments of the population.

4.4.2 Establish Effective Environmental Risk Engagement Programs

Environmental risk management is not only a matter for government departments and enterprises, but also an opportunity to involve the relevant stakeholders such as affected communities, social organizations, scientific research institutions, and the broader public. Establish an environmental risk management and emergency response system involving all relevant stakeholders and specify their roles in environmental risk management including emergency response. It is important to value their contribution to environmental risk management, including emergency response, with their special knowledge, their familiarity with the region or locale, and the specific mitigation or adaptation skills they possess.

Develop community and public engagement models for dialogue and feedback from affected communities. Involve relevant stakeholders to co-design environmental risk management policies and include the feedback from stakeholders in policy and planning design. Promote public participation in policy and regional plan development, and in the conduct of policy and plan-level SEA and project EIAs.

China Council for International Cooperation on Environment and Development (CCICED)

Special Policy Study Report

Eco-environmental Risk Management

Annex

CCICED 2014 Annual General Meeting
November 9-11, 2015

ANNEX 1. Description of Three Categories of Environmental Risks

Category 1: Sudden pollution accident risk. This type of environmental risk event occurs mainly due to the natural or human-caused fire, explosion, or leakage of hazardous chemicals from production, storage, transportation, and waste treatment facilities. A quantity of pollutants is released suddenly and poses acute effects on ecosystems, environmental quality, and human health.

Category 2: Cumulative threshold event risk. This type of risk event happens mainly due to human-caused long-term and chronic discharge of pollutants. The acute consequence occurs when exposure accumulates to certain levels exceeding a threshold or tipping point. For example, the Taihu Lake blue algal bloom event in 2007 was the result of long-term discharge of nitrogen and phosphorus together with the appropriate weather conditions suitable for algae growth. Many episodes of elevated blood lead levels in children that have occurred in recent years were the result of long-term discharge of heavy metals which accumulated to toxic levels. Acute air pollution episodes are another example.

Category 3: Long-term chronic environmental risk. This type of risk poses chronic adverse effects due to human-caused long-term discharge of pollutants or persistent pollution in environmental media, for example: chronic ecosystem effects, human health effects from $PM_{2.5}$ pollution, contaminated sites, new chemicals and emerging pollutants, radiation sources and nuclear wastes, as well as long-term ecological degradation due to infrastructure or regional development. Some pollutants with climate change effects, such as short lived climate pollutants (short-lived climate-forcing pollutants, that is, black carbon and tropospheric ozone), have both adverse health effects and a greenhouse effect.

It should be noted that Categories 2 and 3 may share the same risk sources. For example, exposure to contaminated sites may not only cause unnoticed chronic health effects, but also may cause visible and acute events when contamination reaches a threshold. Another example is that $PM_{2.5}$ pollution not only causes chronic health risks, but also may cause heavy pollution episodes when weather conditions limit its diffusion.

In Figure 1-3, Category 1 sudden pollution accidents may involve persistent pollutants. After the emergency response to the accident, persistent pollutant residues may remain in environmental media for a long time and thus form contaminated sites or sediments. In that case, environmental risk before pollution accidents can be classified to Category 1. After emergency disposal, contaminated sites or sediments would become new risk sources and thus can be classified as Category 2 or 3. For example, nitrobenzene in the 2005 Songhua River pollution accident, crude oil in the 2010 Dalian oil pipeline explosion, and cadmium in the 2012 Longjiang River cadmium pollution accident, all may lead to residues in sediments and would pose long-term ecological and health risks.

ANNEX 2. Problems of Current Environmental Emergency Responses

This study selected the 50 typical pollution incident cases from *Typical Environmental Accident Cases (Part I)* (MEP Emergency Response Lead Group Office, 2011) to analyse the main reasons for the ineffectiveness of environmental emergency response, as shown in Annex Table 2-1.

Annex Table 2-1

The main reasons for ineffectiveness of environmental emergency response from 50 cases

Reasons	Proportion
Emergency response monitoring was not reasonable with incomplete or unreasonable monitoring indicators and lack of post supervisory monitoring.	**48%**
Insufficient cross-department and cross-region coordination, with information sharing and joint action to be strengthened.	**40%**
Lack of emergency response and protection equipment, resulting in ineffective pollution reduction and health threat to emergency response staff.	**28%**
Did not disclose relevant information at the early stage of incidents, causing public panic and influencing social stability.	**28%**
Lack of effective emergency response plan and scientific decision making, improper emergency response measures at the early stage of incidents which contributed to inadequate pollution control and even caused secondary pollution.	**26%**
Did not have scientific and timely warning on air and water environment, a circumstance which was unable to provide support to decision making.	**22%**
Limited emergency response monitoring capacity and shortage of staff.	**20%**

ANNEX 3. Current Environmental Risk Levels in China

For this study seven representative indicators from seven environmental risks were selected to characterize the current environmental risk levels in China, including accidental pollution events; soil, air, and water pollution; climate change; economic loss; and public demands (Annex Table 3-1). Meanwhile, based on the consideration of current levels of the indicators, Annex Table 3-1 suggests a preliminary comparison of each current indicator level with three risk levels - low, medium, and high - sketching a rough range of possibilities. For example, for the indicator of "annual environmental risk accidents," considering that the pollution accident frequency in China before 2005 was relatively high (over 1000 events each year), 1000 is identified as the high level and reflects the effectiveness of environmental risk control since 2005.

According to Global Burden of Death (GBD) 2010 study data[41], the premature death rate attributable to $PM_{2.5}$ is 0.6×10^{-4} in Australia, which is one of the least $PM_{2.5}$ polluted countries in the world (where the population weighted annual $PM_{2.5}$ concentration is 2.3 $\mu g/m^3$). Thus 0.5×10^{-4} is set as the low risk level. And 10×10^{-4} is set as the high risk level, which is near the current level of China.

For the environmental complaint rate, considering that it continues to increase since the 1990s, this study suggests that levels in the early 1990s were at a low level and 1‰ is the high public demand level, which is near the current situation. Risk levels of other indicators are set based on their current status and relevant demands for environmental management in China.

Annex Table 3-1 Current environmental risk levels in China

Indicators	Low	Medium	High	Current
Annual environmental risk accidents [a]	50	100	1000	452
Proportion of contaminated soils (%) [b]	5	10	20	16.1
Premature death rate attributable to $PM_{2.5}$ [c]	0.5×10^{-4}	5×10^{-4}	10×10^{-4}	9×10^{-4}
Proportion of inferior V water [d]	1	5	10	9.2
Environmental risks due to climate change [e]	NA	NA	NA	Medium
Proportion of environmental losses compared to GDP % [f]	0.5	2	6	6
Environmental complaint rate (‰) [g]	0.1	0.5	1	0.89

a Current level: From *China Environmental Statistical Yearbook (2014)*.
b Current level: From the first national soil pollution investigation results released by MEP and Ministry of Land and Resources in 2014.
c Current level: Calculated from GBD 2010 and Chinese population.
d Current level: From *Environment Quality Bulletin (2014)*.
e Including health risks of complex air pollution and biodiversity losses due to climate change, secondary environmental pollution accidents due to climate change-related natural

[41] http://vizhub.healthdata.org/irank/heat.php

disasters such as coastal and river flooding and extreme weather events, etc. Based on the current trends of global warming, environmental risks due to climate change will be more serious in the future. Thus the current risk level is set to medium. A quantitative analysis has not yet been undertaken by this study.

f Current level: From the report of *Impacts of Environmental Protection on Economic under New Normal Situation* issued by MEP in 2015. http://news.xinhuanet.com/fortune/2015-09/09/c_1116513933.htm。

g Current level: Calculated using data from *China Environmental Yearbook (2014)* and China population.

The "environmental risk rose" (Figure 1-9) is based on Annex Table 3-1. The figure intuitively demonstrates examples of multiple environmental risks and the associated levels. The environmental risk rose can be applied to demonstrate the risk management goals in the future. Note that this figure presents the result of only a preliminary analysis, which cannot completely characterize risk levels for all kinds of environmental risks. The risk examples are preliminary and the risk levels represent semi-quantitative results. The distances between circles in the rose diagram are not to scale. The points around a given circle do not necessarily represent equal levels of risk or seriousness. For example, around the outer-most circle, 10×10^{-4} risk from $PM_{2.5}$ air pollution corresponds to roughly 1.3 million deaths per year in China, whereas 10% inferior V water or 1000 environmental incidents may not be associated with such high mortality levels. And movements along the radius lines of the rose, from the outer circle toward the center, do not necessarily represent equal or proportionate reductions in risk.

ANNEX 4. Prospects for Driving Forces of Environmental Risks in China

4.1 Driving Forces of Environmental Risk

Driving Forces of Environmental Risk Levels

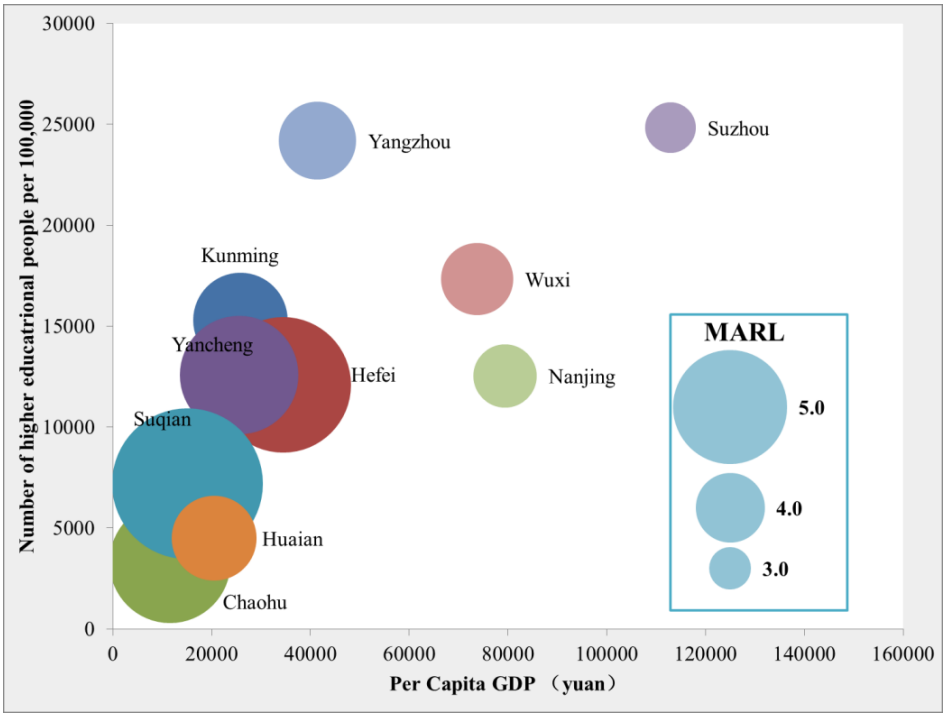
Based on the model of the environmental risk chain (Figure 1-2), social needs are the origins of the formation and existence of environmental risk sources. Environmental risk sources are formed during the process of socioeconomic activities. Thus environmental risk pressure factors can be characterized by indicators which can reflect socioeconomic activities, such as GDP and industrialization. And along the whole process of the environmental risk chain, causes of environmental risk events may exist in any risk chain node with poor management. Thus the level of environmental risk management applied is also an important factor which can influence risk levels. In addition, technological progress can also benefit environmental risk reduction.

Driving Forces of Public Environmental Risk Perceptions

The public response to environmental risk based on people's own subjective perceptions may vary significantly with differing socioeconomic status and education levels, which will influence judgement and acceptable risk level. A total of 3550 samples from 16 cities in Jiangsu, Anhui, and Yunnan provinces were surveyed for determining the desired level of acceptable risk [42]. The analysis concluded that economic development level and education level are the two most important factors influencing acceptable risk level (Annex Figure 4-1). Acceptable risk level decreases with the increase of per capita GDP (or national income) and education levels.

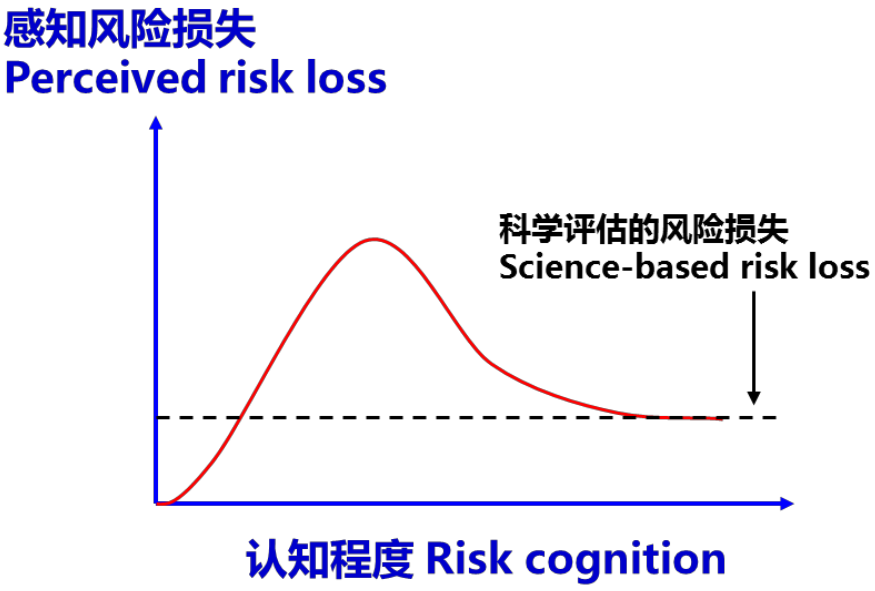
In addition, the emergence of new media such as the internet facilitates faster dissemination of information. Information dissemination through new media may result in exaggeration of risk information which may magnify the actual risks and lead to larger gaps between public perception levels and objective risk levels. For example, several para-xylene (PX) projects have had mass protest incidents in recent years. In some cases, rumours may be disseminated. For example, the rumour of explosions of chemical plants in Xiangshui county, Jiangsu, in 2011 caused panic and the relocation of tens of thousands people in nearby communities. In other cases risks are underestimated or poorly communicated, such as when smog was once dismissed as "fog" or people in some cancer villages are unaware of the risk they are exposed to. Thus appropriate risk communication to bridge the gap between environmental risk levels and public acceptance levels needs to be considered.

42 Bi, J et al, 2012. Research report of China's 863 project of "Research on Integrated Technology System of Major Environmental Pollution Accident Emergency Response". Unpublished.



Annex Figure 4-1. Relationship between acceptable risk and per capita GDP and education (The area size of the circle represents the public Maximum Acceptable Risk Level, i.e., MARL)

Studies have shown that risk cognition and public perceived risk loss have the relationship shown in Annex Figure 4-2. In recent years, with the increase in public education levels and development of information dissemination technology, the public has gained more knowledge about environmental risks than ever before. However the public is still at a stage with insufficient knowledge (left side of the curve peak). The increase in risk cognition results in increasing perceived risk loss, which lowers the risk acceptance level. Without proper risk communications, the risk level will be exaggerated when public risk acceptance level decreases to a certain level. This explains why there are so many “not in my backyard” events in China in recent years. Thus proper environmental risk communication and engagement are needed to continually increase public risk cognition to ensure that the public perceived risk loss is in line with the science-based risk loss (right side of the curve peak).



Annex Figure 4-2. Relationship between risk cognition and public perceived risk loss[43]

4.2 Prospects for Driving Forces of Environmental Risk Levels and Public Risk Perceptions

Prospects for Driving Forces of Environmental Risk Levels

GDP growth and industrialization. Using data from the *China Statistical Yearbook*, Annex Figure 4-3 shows GDP growth and its composition in China from 1978 to 2014. It can be seen that China's economy has had a high rate of growth since the 1990s. With the World Wide Fund for Nature and China's Policy Research Center for Environment and Economy, MEP issued a report on *Indicator Instrument and Empirical Study for Green Economic Decision Making* in 2015. The results show that China's economic growth is still driven by heavy chemical industries, which account for more than 70% of the industrial gross output since 2005. The gross output of heavy chemical industries keeps increasing and its energy consumption has increased from about 1.5 billion tons of standard coal equivalent in 2001 to 3.75 billion in 2013, with significant increase in air pollution risk including $PM_{2.5}$.

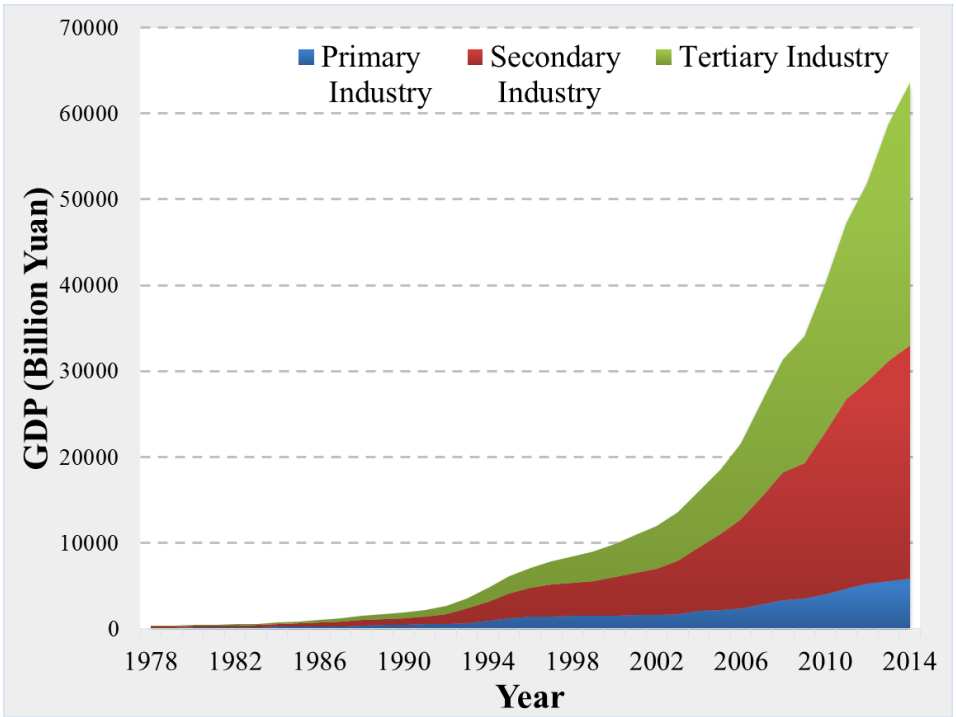
In recent years, China's economic growth rate has been slowing and it is going through structural adjustment. The GDP growth rate in 2014 was 7.3% - down from about 10% in preceding years, but still at a high level. The Economic Research Institute of the National Development and Reform Commission issued the interim report *Research on Development Environment, Trend, and Strategy of China during 13th Five-year Plan*,

[43] Bi, J et al, 2006. Regional Environmental Risk Analysis and Management, China Environmental Science Press.

showing that the GDP growth rate during the 13th FYP period will remain at about 7% and gross output of heavy chemical industry will also keep increasing.

In addition, to promote economic development, China will implement a series of national development strategies such as the Belt and Road initiative, integrated development of the Jing-Jin-Ji area (the Beijing-Tianjin-Hebei "supercity"), and the Yangtze River Delta economic zone. These will become new economic growth points. The construction and operation of infrastructure and industrial projects during the implementation of these strategies will pose great pressures on regional environmental quality and ecosystems, especially fragile ecosystems.

Climate change. In addition to growth and industrialization, global warming and climate change may also add stresses to China's public health and ecological challenges. Climate change can create both direct and indirect environmental risks for humans and ecosystems. For example, higher temperatures may exacerbate air pollution that may pose more long-term and chronic health risks. Higher temperatures may also reduce ecosystem resilience to environmental risks; for example, extended droughts may undermine fragile eco-systems. Sea level rise, storm surges and flooding may damage coastal eco-environments along waterways. Meanwhile, the increased probability of natural disasters induced by climate change may also increase the probability of secondary sudden pollution accidents. Global warming has been a universally accepted fact. Climate change in the future will increase the environmental risk levels.



Annex Figure 4-3. GDP growth and its composition in China (1978-2014)

Prospects for Driving Forces of Public Risk Perceptions

During the 13th FYP period and in the years following - although China will see a in a slowing of economic growth and structural adjustment - the growth rates are still at relatively high levels, and per capita GDP and average income level will keep rising. According to the *China Statistical Yearbook*, China's per capita GDP in 2014 was around 7500 US dollars. The report of *Research on Development Environment, Trend, and Strategy of China during 13th Five Year Plan* shows that China's per capita GDP in 2020 will be over 10,000 US dollars and reach the levels of moderately developed countries.

For the education trend, according to *National Middle and Long-term Education Reform and Development Plan (2010-2020)*, the population with a level of education will reach 145 million in 2015 and 195 million in 2020. It can be expected that public demands for education and the national education level will keep rising after 2020. Thus the public environmental risk acceptance levels will keep decreasing as educational level and individual income continue to grow in the future.

Overall Prospects for Environmental Risk Driving Forces in China

Based on the above analysis, the prospects for driving forces of environmental risk levels and public perceptions are summarized in Annex Table 4-1.

Annex Table 4-1 Prospects for Environmental Risk Driving Forces in China

Driving forces		Short and Middle Term 2015-2030	Long Term 2030-2050 [e]
Driving forces of environmental risk levels	**GDP**	increase rapidly [a]	keep increasing but more slowly
	Gross output of heavy chemical industry	increase rapidly [b]	keep increasing but more slowly
	Climate change	become more serious	become more serious
	Environmental risk management level	keep improving but driven by environmental risk events or activities	keep improving but driven by environmental risk events or activities
	Environmental science and technology level	keep increasing	keep increasing
Driving forces of public environmental risk acceptance levels	**Education**	increase [c]	increase
	National income	increase [d]	increase

a According to *China Statistical Yearbook*, the GDP growth rate in 2014 was 7.4%. The interim report of *Research on Development Environment, Trend, and Strategy of China during 13th Five Year Plan* by the Economic Research Institute of the National Development and Reform Commission shows that the GDP growth rate during the years of the 13th Five Year Plan will remain about 7%.

b According to the report of *Indicator Instrument and Empirical Study for Green Economic Decision Making* issued by the World Wide Fund for Nature and China's Policy Research Center for Environment and Economic, MEP, heavy chemical industries account for more than 70% of the industrial gross output - a figure that keeps increasing.

c According to *National Middle and Long-term Education Reform and Development Plan (2010-2020)*, the population with high education level will reach 195 million in 2020 - which is 50 million more than 2015.

d According to *China Statistical Yearbook*, China's per capita GDP in 2014 was around 7500 US dollars. The report of *Research on Development Environment, Trend, and Strategy of China during 13th Five Year Plan* shows that China's per capita GDP in 2020 will be over 10000 US dollars.

e Preliminary analysis based on short and middle term prospects.

ANNEX 5. The Risk Goals under Various Laws and Regulations in the United States and the European Union

Annex Table 5-1 provides the risk goals of various laws and regulations in the United States and the European Union. These are variously expressed in quantitative, qualitative, or technology terms.

Annex Table 5-1 Risk Goals in Risk-Based Laws and Regulations

United States			
Risk Goal/Target	**Domain**	**Scope/Objective**	**Law/Regulation**
Apply Maximum Available Control Technology (MACT). If residual risk of most exposed individual remains greater than 10^{-6}, then more stringent measures must be adopted.	Environment	Air toxics: Develop air pollutant-based air quality standards according to protection target. MACT is set to equal the best 12% of industry performance in each source category.	US *Clean Air Act*, section 112
Protect public health and welfare with an adequate margin of safety	Environment	National ambient air quality standards (NAAQS)	US *Clean Air Act*, sections 108-109
"Best technology" requirements, which explicitly or implicitly may include cost-benefit considerations	Environment	Integrity of chemical, physical and biological contents of national waters	US *Clean Water Act*, sections 304, 316
Maximum contaminant levels (MCLs) that approach the level of "no observed adverse effect"	Environment	Drinking water standards; 1996 amendments authorized EPA to set "alternative MCLs" using cost-benefit and risk-risk tradeoff analysis	US *Safe Drinking Water Act*
Prevent unreasonable risk	Environment	Manage the production and circulation of industrial chemical products	US *Toxic Substance Control Act*
Food additives allowed only if reasonable certainty of no harm	Food safety	Manage consumer health risks from food additives in processed food	US *Food, Drug and Cosmetic Act; Food Quality Protection Act*
Set standards that ensure a **"reasonably safe and healthful workplace**". **Regulate workplace toxic substances "to the extent feasible"**	Workplace health and safety	OSHA must **demonstrate some "significant" risk before regulating** (as clarified by 1980 Supreme Court decision). "Feasible" interpreted by 1981 Supreme Court decision as the maximum degree the industry could afford without shutting down.	US *Occupational Safety and Health Act*
European Union			
Risk Goal/Target	**Domain**	**Scope/Objective**	**Law/Regulation**
Best available technology (BAT) in different industries	Environment – air	Prevent, reduce and mitigate to the extent possible industrial pollution through establishing a framework to control industrial activities**.**	Industrial Emissions Directive

Quality goals for Good Ecological Status and Good Chemical Status	Environment – chemicals + water	Standards and measures through enforcing basin environmental quality and integrated management; Based on available scientific and technical data, environmental conditions in the various regions, and the economic and social development of the EU as a whole	Water Framework Directive
Burden of proof on companies - to demonstrate how the substance they manufacture and market can be safely used.	Environment - chemicals	Protect human health and eco-environment from risk of chemical products, and enhance competitiveness of EU chemical industry; ECHA has marked a number of Substances of Very High Concern (SVHC) as having particularly high environmental risk	REACH Directive - Registration, Evaluation, Authorization, and Restriction of Chemicals
Promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements and making a contribution to sustainable development	Environment - ecosystems	Reduce and manage regional ecological risk	Habitats Directive