



# Analysis on the Formation and Legislative Prevention and Control Measures of Groundwater Pollution: A Case Study from Xinjiang, China

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## ABSTRACT

The pollution of groundwater has worsened with rapid industrialization and economic development and its unreasonable exploitation. In addition, the absence of effective legislation that prevents pollution and effective measures that punish polluters significantly, contributes to groundwater pollution. To secure the sustainable use of groundwater resources, this study analyses the specific causes of groundwater pollution, highlights the lack and insufficiency of the legislation that prevents groundwater pollution, and proposes legal control measures to prevent groundwater pollution in Xinjiang, China. Results show that uncontrolled discharge of industrial wastewater and waste residue, unrestrained mining activities, and excessive fertilizer application are the specific causes of groundwater pollution. Four aspects of legal control measures are proposed to improve the effectiveness of current legislation that prevents groundwater pollution, that is; stringent groundwater pollution control laws and regulations systems, and pollution discharge registration systems; strengthened preventative measures; improved coordination systems; surveys on groundwater pollution conditions and improved systems for the environmental evaluation of groundwater; evaluation systems to optimize government performance and strengthened public education on the groundwater environment. The present results have research and reference value in the analysis of the characteristics and main sources of groundwater pollution, evaluation of groundwater quality, and control of groundwater pollution.

## INTRODUCTION

Groundwater is an important resource that restricts the development of the national economy and society. It also plays an important role in solving regional water shortages and adjusting the overall ecological environment. Unlike surface water, groundwater is concealed and stable. Once it is polluted, however, it is difficult to remediate and recover, given its weak self-cleaning ability even after the adoption of measures that prevent pollution. The global problems of groundwater pollution and exploitation have become more severe in recent years. To solve groundwater pollution, its current status must be understood. China has formulated and enforced several laws and regulations for the protection of water resources. The increasing severity of groundwater pollution, however, shows that the existing legislation remains defective and requires refinement.

Xinjiang is the main production base of grain, oil, sugar, and meat in China and thus has a crucial role in the national economy. This area receives abundant but uneven rainfall and experiences strong evaporation. Vertical and horizontal rivers, which are mostly seasonal streams, also run through Xinjiang. Groundwater remains the main water source for agricultural and industrial production and domestic con-

sumption in this region. Pollution from agriculture and animal husbandry is severe given the advanced stage of these industries in Xinjiang. Industrial three-waste discharge has also increased, given the rapid development of industrial and agricultural production, as well as the constant expansion of human population. The widespread pesticide and fertilizer application, domestic garbage and sewage discharge (Fig. 1), sewage irrigation, and nuclear power have increased the amount of daily waste. These contaminants penetrate the soil to severely contaminate groundwater.

To prevent and control groundwater pollution, this case study on Xinjiang, analyses the sources and legal control measures of groundwater pollution. The early prevention and elimination of possible groundwater pollution, the active governance of polluted groundwater, and the minimization of losses are important. To prevent and control groundwater pollution, regulations on liabilities should be strengthened. Reasonable legal punishments that correspond to harmful consequences should be implemented.

## EARLIER STUDIES AND COMMENTS

Many scholars have extensively researched the hazards and specific preventative measures of groundwater pollution.

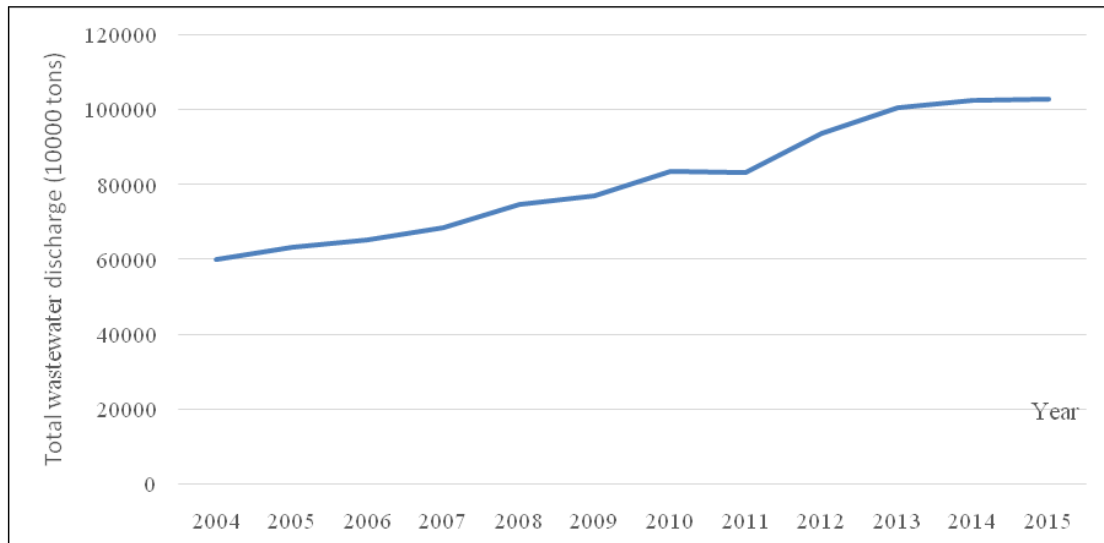


Fig. 1: Total amount of wastewater discharge in the Xinjiang autonomous region from 2004 to 2015. (Data from China's Environmental Statistics Yearbook 2005-2016).

To analyse the health hazards caused by groundwater pollution, Kim evaluated the health risks posed by uranium in the groundwater of 10 regions in Korea. This study showed that the radioactive cancer risk of uranium in groundwater is relatively high (Kim et al. 2004). Rapant also evaluated arsenic pollution in groundwater in Slovakia (Rapant et al. 2007). Emmanuel analysed the groundwater polluted by hospital waste discharge (Emmanuel et al. 2009). Lee utilized SAS software to analyse the hazards caused by the pollution of groundwater with chlorinated solvents (Lee et al. 2010). Phan implemented a monitoring analysis and health risk assessment for arsenic, manganese, iron, barium and other microelements in the shallow groundwater of Cambodia's Mekong River Basin (Phan et al. 2013). Wongsasuluk analysed the damage caused by heavy metal pollution in the shallow groundwater of an agricultural area in Thailand (Wongsasuluk et al. 2014). Li analysed the point source of groundwater pollution and health risks in a chemical industry park in Northwest China (Li et al. 2014). Previous studies that analysed the preventative measures for groundwater pollution include a study by Preene, their study analysed the various influences of underwater pollution control measures on urban development (Preene et al. 2015). Yu analysed the basic scenario of China's environmental legislation for groundwater pollution and pollution prevention (Yu et al. 2015). Dai analysed the preventative measures for groundwater pollution with agricultural irrigation in China and EU (Dai 2015). Wu analysed the status, problems, and control strategies of water pollution in China (Wu et al. 2015). Coulon analysed the challenges

of China's land and groundwater management, as well as introduced British experiences on groundwater pollution prevention (Coulon et al. 2016). Endo analysed the institutional arrangements and implemented measures for groundwater quality control in Kanagawa Prefecture, Japan (Endo 2016). Zhang evaluated the groundwater pollution risk of Beijing's formal landfills and proposed intervention measures and suggestions for groundwater pollution (Zhang et al. 2016). Liu analysed groundwater pollution control measures in semiarid areas (Liu et al. 2017). Existing literature shows that the damages caused by groundwater pollution are widespread. Given that groundwater is concealed and stable, preventative measures cannot easily and rapidly attain their desired effects on polluted groundwater. Thus, strengthening the statutory regulation of groundwater pollution is crucial to resolve groundwater pollution. Through the analysis of groundwater pollution status, pollution sources, and developmental trends, the present case study proposes relevant statutory regulations on pollution prevention and control. Important evidence is provided for the rational management and reasonable use of groundwater. Scientific bases for planning layout, infrastructure construction, urban environment recovery and control, and other aspects are also provided.

#### ANALYSIS OF GROUNDWATER POLLUTION DEVELOPMENT IN THE XINJIANG AUTONOMOUS REGION

**Excessive discharge of industrial wastewater and waste residue:** In Xinjiang, human population is concentrated in

urban areas and around industrial and mining enterprises. As industries develop, the long-term excessive discharge of industrial wastewater and waste residue, insufficient treatment of industrial wastewater during production, and integrated production of domestic waste all adversely impact the environmental quality of local groundwater. Several large and medium enterprises in Xinjiang cannot discharge industrial wastewater in accordance with standards. Small enterprises discharge industrial wastewater in situ. During groundwater usage in industrial production, large amounts of waste gas, wastewater, and waste residue are directly or indirectly discharged, thus degrading groundwater quality. Industrial production pollutes large areas with a strong impact on the groundwater. A large amount of poisonous gases must be eliminated in many industrial production processes. For example, the acid industry mainly discharges sulphur dioxide, nitrogen oxides, and other acid gases. Iron/steel metallurgy and non-ferrous smelting enterprises discharge sulphur dioxide, hydrogen chloride, lead, manganese, and other metal compounds. The oil industry mainly discharges hydrogen sulfide, carbon dioxide, and sulphur dioxide. Discharging waste gases into the air not only causes air pollution, but also affects the living conditions of residents and endangers public health. Moreover, contaminants leach through the soil with the action of rainfall and snowfall, thus polluting groundwater. When unprocessed industrial wastewater is discharged into the watercourse or other surface water, the surface water is first polluted, followed by groundwater. Pollution with industrial wastewater is the most direct and severe type of groundwater pollution.

**Consumption of groundwater resources by mining activities:** Mining industries are highly active in Xinjiang because of the abundant mineral resources in the area. The construction of a surface water conservation project changes the conditions of surface water flow, which can significantly affect the balance and hidden state of groundwater. Groundwater pollution easily occurs when piled tailings are leached by rainfall. Abandoned tunnels and drilling holes in the mine lot can channel groundwater pollution under the influence of rainfall and surface water. The pit water discharged by mining (e.g., coal mining drainage) has a low pH value. By contributing to the dissolution of calcite and dolomite, this type of acidic water can cause calcium and magnesium salts to enter aquifers after penetrating the ground, thus increasing the total hardness of groundwater.

**Excessive application of chemical fertilizers during agricultural production:** Xinjiang, as a crop production province, utilizes a large amount of groundwater for agricultural production, thus highly affecting groundwater resources. Given that chemical fertilizers contain nitrogen, phosphate and potassium, irrigation water can pollute shal-

low groundwater. Pesticides contain large amounts of harmful ingredients that remain in the soil, water, and organisms. These ingredients gradually concentrate in animals and humans as the food chain flows, eventually exerting adverse effects. The discharge of domestic pollutants directly pollutes shallow groundwater via penetration and lixiviation, thus increasing the total hardness of groundwater and degrading the groundwater environment. Given that municipal sewage often contains nitrogen, phosphorus, potassium, and organic carbon, sewage is extensively used to irrigate crops to reduce fertilizer costs and improve soil fertility. However, the long-term use of sewage can easily cause groundwater pollution and decrease crop production.

**Production and domestic waste:** Environmental pollution that is contributed by industrial and domestic waste is in the process of storage or retting. Organic nitrogen is transformed into  $\text{NH}_4^+$  or  $\text{NO}_3^-$  after a complex mineralization process and penetrates the groundwater after lixiviation by rainfall.  $\text{NO}_3^-$ ,  $\text{NO}_2^-$ , and  $\text{NH}_4^+$  pollute shallow water tables. During the rapid economic development of the Xinjiang Autonomous region, its urban geological environment constantly suffered from anthropogenic perturbation. The original evolutionary trend of the geological environment is broken, and the deterioration of the urban geological environment is becoming more prominent, especially in groundwater. Considerable amounts of discharged domestic sewage also cause groundwater pollution. Domestic sewage, detergents, domestic garbage, and excreta constitute the main components of urban sewage. Toxic chemicals, sewage, bacteria, and viruses are discharged from medical and health units and laboratories, thus threatening groundwater quality. Urban traffic has also become more developed. Massive emissions of automobile exhausts cause atmospheric pollution, which reaches the ground by lixiviation. Recalcitrant pollutants penetrate the groundwater and cause ground-water pollution.

## PRELIMINARY SITUATIONAL ANALYSIS OF PREVENTATIVE LEGISLATION FOR GROUNDWATER POLLUTION IN THE XINJIANG AUTONOMOUS REGION

**Lack of independent preventative laws for groundwater pollution:** Accomplishing comprehensive groundwater protection and groundwater pollution prevention by merely relying on local administrative regulations is difficult. The effect of local administrative laws and regulations on law enforcement should also be considered. Although methods are primarily based on groundwater protection, comprehensive protection for the groundwater still cannot be attained. Neglecting groundwater resources outside the city to accomplish several objectives results in a broken legislative

system for groundwater pollution prevention. Although, partial protection for groundwater resources has been attained, the absence of separate legislation that prevents groundwater pollution results in the lack of stringent groundwater standards and regulations and supervisory systems. Furthermore, local governments will adopt different standards to undertake environmental liabilities during practical operations. In addition, the adopted pollution prevention measures become inconsistent with the characteristics of polluted groundwater, which can further affect the effective governance of pollution.

**Absence of groundwater pollution prevention measures in rural regions:** Drinking water is derived from the direct mining of groundwater and easily be influenced by the external environment during mining. Traditional methods for agricultural production have been transformed by the input of science and technology. The direct action of novel production materials change the physical and chemical properties of soil and water. The residents of rural regions have a poor understanding of groundwater and their scope of groundwater use is limited. Groundwater pollution in rural areas is difficult to control because groundwater pollution spreads widely once it occurs. Furthermore, no effective preventative legislation for groundwater pollution exists in rural regions, thus leading to more problems in preventing environmental pollution. No advanced sewage treatment facility can prevent pollution, and most financial expenditures invested in pollution governance attempt to solve environmental problems only in urban areas. Rural areas require financial investments and attention that correspond to those provided for the protection and prevention of pollution in the entire environment.

**Insufficient penalties make deterring polluters difficult:** Existing laws specify that groundwater polluters should face administrative, civil, and criminal liabilities. However, the practical enforcement of these liabilities is deficient given complex realities. Health damages caused by groundwater pollution have a long incubation period. Therefore, financial compensation cannot completely cover personal losses in lawsuits. Groundwater is an important component of the suitable ecological environment that is the basis for the development of human beings. Once it becomes polluted, its ecological function cannot easily recover within a short period. Population in polluted areas also face harm from the environment over the long term. Furthermore, the victims cannot apply for compensation through legal approaches, which not only obstructs the implementation of justice but also hinders the self-conscious obedience of enterprises to environmental protection laws. Therefore, ecological losses should be placed under civil compensation in future revisions of the law. Enterprises or individuals will have to face

civil and criminal penalties once they consciously or unconsciously cause groundwater pollution. These rules will regulate the behaviour of economic subjects.

## LEGAL CONTROL MEASURES FOR GROUNDWATER POLLUTION PREVENTION

**Comprehensive regulatory system for groundwater pollution and effective registration system for pollution discharge:** The government should widely consider suggestions from the public and pass a law for the protection of water resources as soon as possible. The government should also focus on managing and protecting China's groundwater resources in their entirety, as well as combine the development and use of groundwater resources and pollution prevention. Different countries have strengthened their rules on legal liabilities to ensure the effective implementation of laws and strengthen the enforcement of protective legislation for water resources. Unlike those in foreign countries, the penalties for groundwater pollution in China cannot sufficiently prevent pollution events. Therefore, China's new legislation should improve civil compensation amounts; force violators to minimize damages; organically integrate civil, administrative, and criminal liabilities; and force polluters or destroyers to pay for their violations based on the principle of "polluters bear and beneficiaries compensate". The pollution discharge license and system of reporting and registration must also be improved. The reporting and registration system should utilize legal norms to regulate reported and registered pollution discharge. The competent department of the environmental protection agency should supervise and manage the pollution discharge and prevention behaviour of a specific actor based on a series of legal norms.

**Strengthen the prevention and control of groundwater pollution, as well as develop the coordination mechanism of prevention and control:** Based on existing laws, groundwater resource management in China involves two departments: the Ministry of Water Resources and the Ministry of Environmental Protection. Although the functions of these two ministries always overlap, these departments often have disputes because of arrogance and private interests. Long-term noncooperation results in lost time for the regulation of China's groundwater environment and decreases the administrative efficiency of competent environmental departments. Therefore, government departments should absorb the domestic and overseas experiences of environmental regulation and set an independent department for the regulation of groundwater resources. The relevant administrative departments of water resources in China should combine the features of different drainage basins, as well as formulate laws and regulations that build a juridical

status of basin management sectors. Their primary task is to build a management system with China as the basic premise and to refine the market-orientated coordination mechanism. If the coordination result is not consistent with local benefits, then the coordination measure generally cannot be effectively implemented, which finally leads to failure in coordination.

**Conduct research on the pollution status of groundwater and develop the evaluation system of the groundwater environment:** Unlike surface water, groundwater is deeply buried in the ground. Given the complexity of the geological framework and fragility of the groundwater environment, a comprehensive understanding of the pollution status of China's groundwater is important. To secure drinking water, an evaluation system should be developed to evaluate groundwater quality, mining technology condition, environmental benefit, and protective measures for the groundwater environment. The supervisory and evaluation system of the groundwater environment should be completed; a groundwater supervision network should be established at the national level; the automation and informatization supervision ability of the national groundwater supervisory body should be further improved; and groundwater dynamics should be effectively supervised. Thus, the development and utilization of groundwater resources, as well as the prevention and control of surface subsidence, are dependent on the scientific data that are provided by a nationwide groundwater monitoring project. Therefore, decision support should be provided to control the departments that formulate relevant policies.

**Optimize the evaluation system of government performance and strengthen public education on the groundwater environment:** The traditional evaluation system of governmental performance should be modified by increasing the contribution of environmental protection to government performance or by establishing a performance evaluation system that is centered on green GDP. The public has no clear understanding of the importance of groundwater and is unaware of the need to protect groundwater resources. Therefore, government control departments should utilize numerous measures to popularize groundwater knowledge and to equip the public with self-knowledge on groundwater protection.

The government and the public can comprehensively utilize the internet through social media, newspapers, and other public media to organize relevant environmental protection activities that are based on China's groundwater pollution problems. Information on the prevention and control of groundwater pollution should be disseminated. The public should be made aware of the damage of groundwater

pollution, as well as the urgency and social importance of pollution prevention. All citizens should focus on the groundwater pollution problem and build a suitable atmosphere to protect the groundwater environment.

## CONCLUSION

Groundwater is a concealed, stable, and complex system that is affected by diverse factors. Although groundwater pollution is far less direct than surface water pollution, it is difficult to remediate. Therefore, its ecological damage and human health effects are profound. The strategic resource characteristics of groundwater highlight the severity of groundwater pollution. This study presents the deficiency of groundwater prevention and control legislation. Legal regulatory measures for groundwater pollution prevention and control are also proposed based on the causes of groundwater pollution. Research results show that the specific causes of groundwater pollution in Xinjiang Autonomous Region include the excessive discharge of industrial wastewater and waste residue, unrestrained mining activities, the overuse of chemical fertilizers in agricultural production, and the excessive disposal of industrial and domestic waste. Preventative and control legislative measures for groundwater pollution can be established by developing a regulatory system, strengthening existing prevention and control measures, studying pollution conditions, and optimizing an evaluation system for government performance. Groundwater prevention and control are comprehensive. Therefore, future studies should be conducted on the quality evaluation of the groundwater environment and pollution status of groundwater, as well as the construction of a comprehensive governance measure system that includes the environment, economy and society.

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