



Research on the Pollution Hazard of Municipal Solid Waste in China and its Prevention and Control Legal Countermeasures

Rui Cao*(**)[†] and Hao Wang***

*Collage of History and Ethnic Culture, Guizhou University, Guiyang, Guizhou 550025, China

**Yunnan Normal University, Kunming, Yunnan 650500, China

***Collage of Economics and Management, Yunnan Normal University, Kunming, Yunnan 650500, China

[†]Corresponding author: Rui Cao

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ABSTRACT

In order to further analyse the hazards of environmental pollution caused by municipal solid waste pollution in China, and put forward the legal countermeasures of preventing and controlling solid pollution, this paper reviews the specific causes of urban solid waste pollution in China, and analyses the harm of four aspects, such as air, water, soil and landscape, caused by the pollution of municipal solid waste. The results show that the main causes of municipal solid waste pollution are, a large population, imperfect laws and regulation system, single disposal of solid wastes and poor public understanding of recycling of solid wastes. Municipal solid waste, mainly pollutes the atmospheric environment, water environment, soil environment and surface landscape. Specific legal countermeasures are proposed based on four aspects: strengthening industrial solid waste control and formulating specific control measures, perfecting the legal system for municipal solid waste control and encouraging classification recycling of garbage, enhancing the construction of a legal liability system for medical wastes and perfecting regulations for the management of electric and electronic wastes, strengthening government supervision and administrative enforcement of solid wastes. The conclusions can provide positive references to strengthen municipal solid waste disposal, relieve municipal solid waste pollution, explore control laws, and achieve an urban ecological balance.

INTRODUCTION

Solid waste pollution in cities has become one of the main threats to the environment with urbanization, industrialization and the increase in people's living standard. The economic development model will be terminated at the cost of high resource consumption and the environment. The conflict among economic and social development, sustainable resource utilization, and environmental protection has become more prominent in recent years because of the increasing population, relative resource shortage and rapid economic growth in China. The solid waste output in cities is higher than that in rural areas. Solid wastes have a complicated composition, which proposes high requirements on disposal technology. In particular, the disposal quantities of industrial solid wastes in major cities are considerably large (Table 1), which will intensify environmental pollution day by day. In fact, although China has enlisted solid waste control into the legislation procedure, several practical problems still exist. For example, related laws and regulations are underused in practice, and no exclusive laws and regulations for industrial solid waste management have been formulated. Industrial solid wastes are thrown and dis-

posed randomly, and recycling of industrial solid wastes has attracted inadequate attention. Pollution control means are relatively weak. No laws and regulations on classification recycling of garbage have been established, making classification recycling difficult. No special laws on recycling of domestic garbage have been formulated, resulting in the low recycling rate of useful materials. The division of labour in laws and regulations of hazardous waste management is ambiguous, accompanied with immature supporting regulations and corresponding measures. The range of hazardous waste does not cover all hazardous wastes, and no laws on recycling of hazardous wastes have been implemented. Moreover, the supervision and management means of hazardous waste manufacturers and operators are relatively ineffective. Therefore, perfecting China's legal system for municipal solid waste control can guide management of municipal solid wastes, can facilitate solid waste control in rural areas, can improve the living environment for residents, can promote the harmonious economic and social development, has important theoretical value to the concept of circular economy, can accelerate perfection of China's environmental law system, and can provide references to practical production activities.

EARLIER STUDIES

Countries in the world are dedicated to implementing control measures of municipal solid waste pollution. In particular, developing countries are facing serious municipal solid waste pollution problems because of rapid economic development. Many studies on the current status and control measures of municipal solid waste pollution have been reported. Alba analyzed air pollution caused by combustion residues of municipal solid wastes and proposed the corresponding control measures (Alba et al. 2000). Wang analyzed China's solid waste control measures (Wang et al. 2001). Huang believed that solid waste pollution has become a significant challenge for environmental management in China and analyzed the current situation of solid waste management in China (Huang et al. 2006). Rapti-Caputo evaluated the pollution risks caused by refuse landfill based on hydrogeological data and solid waste landfill management (Rapti-Caputo et al. 2006). Mor analyzed the groundwater pollution close to municipal solid waste landfill in Delhi, the capital of India, and proposed related waste management measures (Mor et al. 2006). Henry investigated the challenges of municipal solid waste management (MSWM) in developing countries based on Kenya (Henry et al. 2006). Beyer introduced China's specific legal measures and policies on solid waste pollution (Beyer 2006). Schiopu analyzed the management experiences and pollution control measures of Romania in solid wastes (Schiopu et al. 2007). Quina analyzed air pollution caused by combustion of municipal solid wastes (garbage) (Quina et al. 2008). Sharholy indicated that MSWM is one of main environmental problems in cities in India and approximately 90% of garbage is treated in open dump and garbage landfills, which will cause harm to public health and results in environmental issues (Sharholy et al. 2008). Al Sabahi argued that Yemen, a developing country, is suffering from serious water pollution and its garbage landfill is one of the pollution sources. Al Sabahi proposed that the government should expand the sanitary landfill and prevent further pollution to surface water, underground water, and soil (Al Sabahi et al. 2009). Firdaus analyzed the quantity of municipal solid wastes in Delhi, India and believed that solid waste management is a significant challenge that will encourage the participation of nongovernmental and community-based organizations (Firdaus et al. 2010). Cheng deemed that China's rapid economic development and large-scale urbanization have resulted in large amounts of municipal solid wastes and that waste combustion can improve the environmental quality effectively (Cheng et al. 2010). Tian analyzed the collection, separation and disposal flow-chart of solid wastes in China, and proposed several sugges-

Table 1: Top 10 cities in the list of general industrial solid waste outputs (2015).

City	Unit (10,000 tons)
Liaoyang City, Liaoning Province	7,349.5
Erdos City of Inner Mongolia	7,302.1
Hulunbeir of Inner Mongolia	4,856.3
Panzhuhua City, Sichuan Province	4,559.4
Xinzhou City, Shanxi Province	4,190.2
Shuozhou City, Shanxi Province	4,004.4
Datong City, Shanxi Province	3,614.6
Baotou City of Inner Mongolia	3,105.8
Luoyang City, Henan Province	3,039.8
Baise City, Guangxi Autonomous Region	2,917.7

(Annual Report of Solid Waste Pollutions in Big and Middle-sized Cities in China (2016))

tions on comprehensive management to prevent air pollution and improve garbage management (Tian et al. 2013). Han collected 20 soil samples in different cities in China and evaluated the environmental pollution level caused by municipal solid waste combustion (Han et al. 2016). Liu believed that general industrial solid waste is an important component of solid wastes and generally causes serious soil, underground water, and air pollution every year in China and proposed the corresponding management measures (Liu et al. 2016). These studies reveal that many developing countries focused considerable attention to solid waste pollution control and controlled solid waste pollution mainly through comprehensive economic and governmental regulations. Therefore, further perfecting China's laws and regulations on municipal solid wastes and strengthening law enforcement could coordinate the relationship among the economy, society, humans and nature, improve human settlements directly, and provide a good environment for people's survival and development.

MAIN CAUSES OF MUNICIPAL SOLID WASTE POLLUTION IN CHINA

China is still at the low level of the comprehensive utilization of municipal solid wastes. However, environmental pollution in China tends to be intensifying gradually, which is caused by the following four aspects:

Social Reasons

The large population in China is an important cause of the annual growth of solid wastes in China. The urban population increased in recent decades because of the urbanization process (Fig. 1). The nonagricultural population increased rapidly, resulting in the annual growth of the resident consumption level and measure of consumption. The considerable number of consumers, measure of consumption, and life activities will surely result in con-

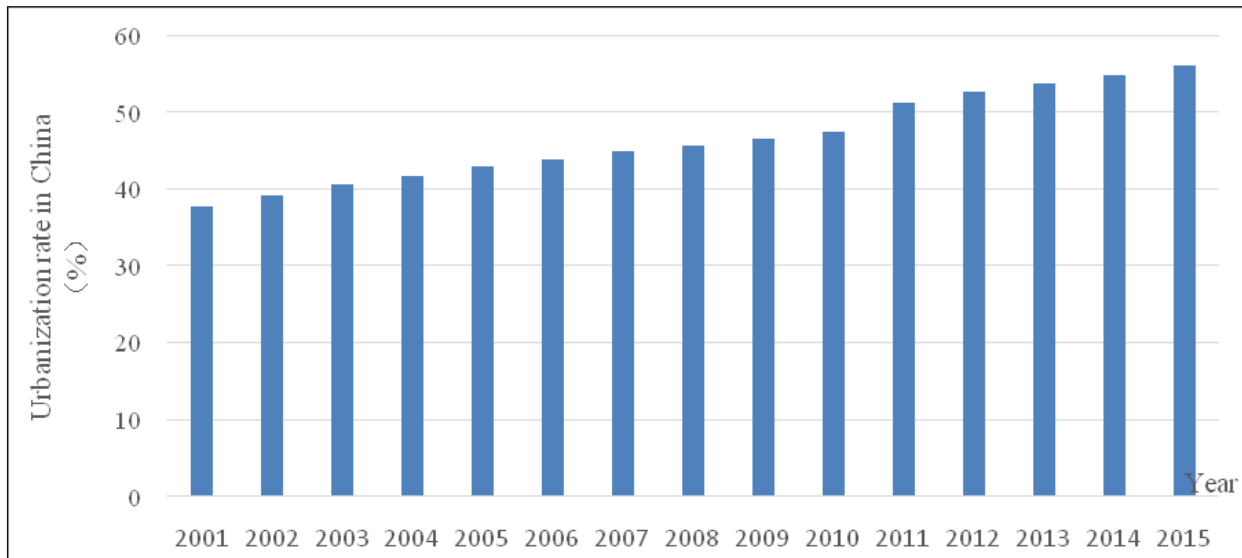


Fig. 1: Urbanization rate in China from 2001 to 2015.

tinuous growth of solid wastes. At the same time, China is struggling with production resource shortage and serious resource wastes. The economic boom will drive the continuous growth of resource demands. China exploits resources from nature and produces abundant wastes simultaneously. Limited by technologies and productivity, many wastes are underused and could not be converted reasonably, thus causing abundant resource wastes and intensifying resource shortage directly.

Legislation Reasons

First, no perfect laws and regulation systems have been formulated. China's legal concept of solid waste management is immature and is basically at the stage of "pollution first and control second," which fails to adapt to the demands of the current economic development level. Waste management neglects the control of pollution sources. Laws and regulations on solid waste recycling are imperfect and lack legal mandatory and punitive measures. Most legal measures on solid waste management and pollution control in China are instructional laws and regulations, which have weak legal effects and could not inhibit violation behaviour effectively.

Technical Reasons

Single disposal of solid wastes is currently implemented. With the annual growth of industrial waste emissions (Table 2), resource wastes are intensifying gradually. Thus far, more than 70% of domestic solid wastes in China are dumped, leaving a relatively low proportion of garbage disposal by combustion, incineration-based energy extraction, compost, and recycling. Waste disposal has a low technical

level and an ineffective management system, resulting in the low comprehensive utilization of industrial solid wastes and causing serious environmental pollution. Without sound supporting infrastructure, solid wastes could not be treated timely and effectively in China, thus easily causing secondary pollution.

Ideological Reasons

The public has only limited knowledge on solid wastes and has not realized the recycling value of solid wastes. Under the poor government propagation, Chinese residents are rarely aware of recycling of consumer goods and often throw solid wastes directly, which causes resource wastes. Chinese people have low consciousness of environmental protection and public participation. Thus, enhancing public education on recycling and controlling solid waste pollution from the source is proposed and is the most effective and economic pollution control method.

MAIN HAZARDS OF MUNICIPAL SOLID WASTE POLLUTION IN CHINA

Compared with the rapid growth of solid waste output, the comprehensive utilization volume of solid waste in China is small, accompanied with a small growth rate and comprehensive utilization. China's disposal capacity and utilization speed of solid wastes lag behind the rapid growth of solid waste output. Municipal solid waste is one of the primary sources of solid wastes and has become a chronic problem with the change of lifestyle. Solid wastes are not environmental media, but are the final form of various environmental pollutants. Direct piling or open storage of solid

Table 2: Handling capacity of industrial solid wastes in China.

Year	Industrial solid waste output (10,000 tons)	Industrial solid waste emission (10,000 tons)	Comprehensive utilization volume of industrial solid wastes (10,000 tons)	Storage capacity of industrial solid wastes (10,000 tons)	Disposal capacity of industrial solid wastes (10,000 tons)	Comprehensive utilization of industrial solid wastes
2000	81,608	3,186.2	37,451	28,921	9,152	45.9
2001	88,840	2,893.8	47,290	30,183	14,491	52.1
2002	94,509	2,635.2	50,061	30,040	16,618	51.9
2003	100,428	1,940.9	56,040	27,667	17,751	54.8
2004	120,030	1,762.0	67,796	26,012	26,635	55.7
2005	134,449	1,654.7	76,993	27,876	31,259	56.1
2006	151,541	1,302.1	92,601	22,399	42,883	60.2
2007	175,632	1,196.7	110,311	24,119	41,350	62.1
2008	190,127	781.8	123,482	21,883	48,291	64.3
2009	203,943	710.5	138,186	20,929	47,488	67.0
2010	240,944	498.2	161,772	23,918	57,264	66.7
2011	326,204	433.3	196,988	61,248	71,382	59.8
2012	332,509	144.2	204,467	60,633	71,443	60.9
2013	330,859	129.3	207,616	43,445	83,671	62.2
2014	329,254	59.4	206,392	45,724	81,317	62.1

wastes (particularly harmful wastes) without treatment will result in the entry of harmful substances into the human body indirectly through air, soil, and water or directly, thereby threatening human health. These harmful substances will cause potential short-term and/or long-term damages to human beings.

Atmospheric Pollution

Solid wastes generally pollute the atmospheric environment through the following ways: some organic solid wastes will be decomposed by microorganisms under the appropriate temperature and humidity, producing smelling or toxic gases that cause regional air pollution; fine particles and powders can intensify dust pollution in the air after being exposed to the weather, which will influence air quality directly; some gangue piles with relatively high sulphur content will ensure spontaneous combustion and produce abundant SO₂. Combustion of solid wastes also pollutes the atmospheric environment. Dry or light substances in municipal solid wastes fly with the wind, causing atmospheric pollution. In solid waste piles, some organic matters will be decomposed under the appropriate temperature and humidity to produce harmful gases. Some putrefaction emits smell that will cause atmospheric pollution. Wastes in landfills will produce abundant marsh gases under the influence of microorganisms. More than 90% of marsh gases produced in the active period in landfills are methane and CO₂. Methane is easily concentrated at low-lying regions or in buildings when dissipating to the air, which easily causes combustion and explosion. In most cities in China, wastes are simply dumped or piled up in open fields. Many waste landfills have no

marsh gas discharge system and gases are emitted randomly, which pollute the surrounding atmospheric environment and brings potential risks of explosion and fire accidents. In addition, other smelling and volatile gases (e.g., ammonia and hydrogen sulfide) are generated in waste landfills.

Water Pollution

In China, many enterprises dump solid wastes into rivers, lakes and oceans directly. In this process, solid wastes will enter rivers and lakes with natural rainfall or surface runoff, polluting the surface water and generating percolate into soil and underground water. Direct emission of hazardous wastes, such as residues, into rivers, lakes or oceans will cause serious pollution. The invasion of percolate generated by solid waste piles into water will affect the survival of the aquatic environment and aquatic animals and plants, deteriorate water quality and gradually reduce the population of aquatic animals and plants. Furthermore, the invasion of percolate generated by solid waste piles into water will influence the survival of other animals and plants related to water through the food chain. Municipal wastes not only contain many pathogenic microorganisms, but will also produce abundant acid and alkali organics during piling and dissolution of heavy metals. Municipal wastes are the pollution source integrating organics, heavy metals and pathogenic microorganisms. Municipal wastes will enter rivers and lakes with natural rainfall or surface runoff and will be deposited for a long time, thus decreasing the water area. The harmful components cause considerable water pollution. Direct dumping of wastes into water will cause serious damages and large-scale toxic deaths of aquatic

Table 3: Top 10 cities with the highest municipal waste outputs in 2015.

City	Municipal waste outputs (10,000 tons)
Beijing	790.3
Shanghai	789.9
Chongqing	626
Shenzhen	574.8
Chengdu	467.5
Guangzhou	455.8
Hangzhou	365.5
Nanjing	348.5
Xi'an	332.3
Foshan	328

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organisms. Harmful components in wastes, such as mercury from red plastics, neon light tube and battery, cadmium from printing, ink, fibre, enamel, glass, cadmium dyes, paints and dyeing ceramics, and lead from yellow polyethylene, lead water pipe, and antirust paints, will permeate into soils with percolate if treated improperly, thus polluting underground water. Moreover, these harmful microelements can infiltrate into the water network (including wells, rivers, and surrounding sea areas) with rainwater, intake by plants, and enter the human body through the food chain, thereby threatening human health.

Soil Pollution

Solid waste piling and dumping occupy large land resources, and harmful components pollute the soils, change the original soil structure and deteriorate the soil quality. The rapid increase in domestic garbage and limited disposal capacity will form large waste piles and occupy large land resources. Industrial solid wastes, particularly harmful wastes, can kill microorganisms and animals in soil through high temperature, toxic water or other reactions after weathering and rain washing, thus decreasing microorganism activity in soils and changing the soil composition.

Landscape Pollution

The large gangue dumps and garbage piles in suburbs change the local surface landscape and destroy the beautiful natural environment. Scattered garbage in rivers and lakes in cities, scenic areas and tourist attractions could be seen everywhere, causing visual pollution, and affecting the integral beauty of the city and scenic area. The top 10 cities with the highest municipal waste output in China in 2015 are listed in Table 3. Beijing ranked the first in terms of municipal waste output (7,903,000 tons), followed by Shanghai (7,899,000 tons), Chongqing (6,260,000 tons), Shenzhen (5,748,000 tons) and Chengdu (4,675,000 tons). The total municipal waste outputs of the top 10 cities

reached 50,786,000 tons, accounting for 27.4% of the total municipal waste outputs of cities that have information. These domestic garbage piles in suburbs easily ferment and corrode, which will produce strong smells, induce large-scale reproduction of mosquitoes, flies and rats, and cause diseases and infections.

LAWS AND REGULATIONS ON MUNICIPAL SOLID WASTE POLLUTION CONTROL

Enhance Industrial Solid Waste Pollution Control and Formulate Specific Control Measures

The formulation and development of special laws on industrial solid waste pollution control will focus on the concept of circular economy. Special regulations that supplement the Circular Economy Promotion Law will be established and perfected as soon as possible. Related regulations and laws will be used to restrict the behaviour of industrial production enterprises and encourage them to manage industrial solid wastes based on the concept of circular economy. The environmental protection and profit maximization of industrial solid waste production enterprises will be connected tightly under price leverage and benefit driving, such as giving tax preferences to economic agents using renewable materials, particularly heavy metal and chemical industrial enterprises. The environmental protection and profit maximization of industrial solid waste production enterprises can reduce industrial waste emission from the production source, increase resource recycling, and achieve a win-win situation for industrial enterprises in profits earning and waste disposal. Considerable efforts will be exerted to avoid the production of industrial solid wastes and implement waste recycling. Given that product design and production are the stages that can mostly reduce waste usage, the prevention law of industrial solid waste will be reflected by the liability of industrial product designers and production enterprises, requiring them to reduce waste output to the maximum extent by implementing effective measures. Industrial waste producers will be held responsible for waste collection, classification, reuse, and disposal. Enterprises that produce industrial solid waste, consumers of industrial products, and disposal operators will all assume certain environmental expenditures within their duty scopes for environmental protection and relief for victims.

Perfect Legal System of Municipal Solid Waste Pollution Control and Encourage Classification Recycling

With the progress of urbanization, municipal solid waste increases dramatically and some new characteristics occur. The existing legal system of municipal solid waste pollution control could not adapt to the new situation completely. How to establish a government-dominated development

mechanism with diversified investment and how to form an integral municipal garbage disposal system based on advanced technologies and equipment to achieve the goal of waste reduction, harmless recycling must be considered when constructing a reasonable legal system of MSWM. Municipal solid waste disposal must obey the existing solid waste pollution control standards and technical specifications strictly. Newly constructed garbage incineration plants, landfills, and facilities must meet the legal standards to protect environmental benefits and bring solid waste disposal to legal system completely. The legislation shall determine managers and executors of municipal solid wastes as different levels of environmental protection departments to avoid excuses and rights disputes among related departments. A long-term MSWM mechanism and a reward and punishment system will be constructed to restrict the garbage dumping behaviour of residents through legal means, shift the attention of domestic garbage pollution management from reduction of domestic garbage output to recycling, encourage residents to buy and use renewable products, and formulate the garbage management legal system of reward first and punishment second. Moreover, this garbage management legal system proposes perfecting specific laws and regulations on classification recycling of domestic garbage and establishing the corresponding legal system, including formulating specific rules, perfecting supporting regulations and legislation systems, increasing the efficiency of classification recycling, implementing classification recycling at the source, and enforcing related laws and regulations throughout the garbage disposal process.

Strengthen the Construction of a Legal Liability System for Medical Waste Management and Perfect Electric and Electronic Waste Management Laws

In the legal liability system established and perfected for medical waste management, the legal representative is considered the first responsible person and implements the system of accountability strictly. The production, collection, transportation, temporary storage and disposal of medical wastes will have the corresponding regulations and corresponding responsible persons. The entire implementation system will be constructed. Finally, measures to prevent missing and dissipating medical wastes will be established and the corresponding reporting system will be constructed. Technical specifications on medical waste management will be perfected. Scientific and reasonable technical specifications are the prerequisites of effective medical waste management. Institutionalization of these technical specifications is the guarantee of scientific medical waste management, pollution reduction, disease prevention and health protection. The regulations on concentrated incineration of

medical wastes will be implemented strictly. With respect to the collection of medical wastes, the classification collection network will be expanded. The total production, categories, and disposal conditions of medical wastes will be recorded and managed by computer network technology. Regulations on electric and electronic waste management will be established to provide legal support to recycling of electric and electronic wastes. The supporting technical policies and industrial standards will be formulated, which will support the enforcement of laws and regulations and enhance the operability and feasibility of laws.

Strengthen Government Supervision and Reinforce Administration Enforcement of Laws on Solid Waste Pollution Control

Solid waste recycling is mainly a function of the government. The government will be responsible for the entire process and will play the most important role. The legality and order of solid waste recycling activities will be protected by formulating perfect laws and regulations. At present, China's legislation on solid waste recycling is still defective and has many blanks. Solid waste recycling activity has weak legal protection. The state should focus its attention to solid waste recycling, protect the smooth accomplishment of solid waste recycling through policies and other specific administrative behaviour, expand tax preferences, provide simple procedures for constructing nonprofit recycling organizations, or manage and issue solid waste recycling information, to promote the construction of a harmonious society. The government mainly plays the supervisory role in solid waste recycling activities.

CONCLUSIONS

With the continuous growth of resource and energy consumption in China, solid waste output increases year by year. The improper disposal of solid wastes (mainly dumping, piling and incineration) causes not only serious ecological environmental pollution but also abundant resource wastes. In this study, specific causes of municipal solid waste pollution in China and the corresponding atmospheric, water, soil and landscape pollution caused by municipal solid wastes are analyzed. The solid waste pollution control laws are proposed. This study concludes that a large population, imperfect laws and regulation systems, single disposal of solid wastes, and poor public understanding of recycling of solid wastes are the main causes of municipal solid waste pollution. Municipal solid waste pollution is mainly reflected by atmospheric, water, soil and surface landscape pollution. Specific control laws were proposed in this study based on four aspects, i.e., strengthening industrial solid waste control, perfecting the legal system

for municipal solid waste control, enhancing the construction of a legal liability system for medical wastes and electric and electronic wastes and reinforcing government supervision and administrative enforcement of solid wastes, to relieve municipal solid waste pollution, and achieve effective control of municipal solid waste pollution in China. The results are important in establishing and perfecting the related municipal waste management system and perfecting the legal system for solid waste pollution control in China under the legislative concept of sustainable development circular economy. In this study, specific attention should be focused on the environmental damages brought about by municipal solid waste pollution and the establishment and implementation of specific laws and regulations. In-depth research on establishing a legal system of comprehensive resource utilization, learning the solid waste pollution control measures of foreign countries, exploring market-oriented solid waste recycling management organizations, and constructing nongovernmental solid waste recycling management organizations to strengthen government supervision should be conducted in the future.

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