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Review

Hazardous waste generation and management in China: A review

Huabo Duan [a,*], Qifei Huang [b,**], Qi Wang [b], Bingyan Zhou [b], Jinhui Li [a]

[a] *Department of Environmental Science and Engineering, Tsinghua University, China*
[b] *Chinese Research Academy of Environmental Sciences (CRAES), China*

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Abstract

Associated with the rapid economic growth and tremendous industrial prosperity, continues to be the accelerated increase of hazardous waste generation in China. The reported generation of industrial hazardous waste (IHW) was 11.62 million tons in 2005, which accounted for 1.1% of industrial solid waste (ISW) volume. An average of 43.4% of IHW was recycled, 33.0% was stored, 23.0% was securely disposed, and 0.6% was discharged without pollution controlling. By the end of 2004, there were 177 formal treatment and disposal centers for IHW management. The reported quantity of IHW disposed in these centers was only 416,000 tons, 65% of which was landfilled, 35% was incinerated. The quantity of waste alkali and acid ranked the first among IHW categories, which accounted for 30.9%. And 39.0% of IHW was generated from the raw chemical materials and chemical products industry sectors. South west China had the maximum generation of IHW, accounted for 40.0%. In addition, it was extrapolated that 740,000 tons of medical wastes were generated per year, of which only 10% was soundly managed. The generation of discarded household hazardous waste (HHW) is another important source of hazardous waste. A great proportion of HHW was managed as municipal solid waste (MSW). Hazardous waste pollution controlling has come into being a huge challenge faced to Chinese environmental management.

Keywords: Industrial hazardous waste; Medical waste; Household hazardous waste; Generation; China

Contents

1. Introduction

In recent years, both public health impact and transboundary movements of hazardous waste continue to be the hot topics through the world [1]. As one of the fastest developing countries with an average of 8% GDP increase, China is no exception for

* Corresponding author at: Tsinghua University, Sino-Italian Environmental & Energy Building, Room 805, Haidian District, Beijing 100084, China. Tel.: +86 10 6279 4351; fax: +86 10 6277 2048.
** Corresponding author. Tel.: +86 8491 5142; fax: +86 8491 3903.
E-mail addresses: dhb06@mails.tsinghua.edu.cn (H. Duan), huangqf@vip.sina.com (Q. Huang).

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facing the hazardous waste problems, especially toxic chemicals and heavy metal pollutants discharged from factories. Owing to the hazardous waste issue, China is not only suffering from huge pressure from domestic, but also arousing great concerns from abroad. Thus, how to control hazardous waste pollution is a key issue of environmental protection in China. According to Chinese law, hazardous waste is classified as three types: industrial hazardous waste (IHW), medical waste (MW), and household hazardous waste (HHW). Whereas, before managed as hazardous waste, IHW should be identified by one of the following methods: National Catalogue of Hazardous Wastes (NCHWs, hazardous waste list in China) or Identification Standards on Toxicity and Corrosivity Characteristic for Hazardous Wastes.

2. Generation and ultimate disposal of hazardous waste

2.1. Industrial hazardous waste

2.1.1. Generation

Based on effective NCHWs in 1998, IHW is classified into 46 categories, from HW-01 to HW-46, just conformed to Basel Convention (Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal). The quantity variation of IHW from 1999 to 2005 is shown in Fig. 1. The official statistic (National Bureau of Statistics of China, NBSC) quantity of IHW was about 11.62 million tons in 2005 [2], an average of which 43.4% was recycled, 33.0% was stored, 23.0% was securely disposed, and 0.6% was out of control, which means that 70,000 tons of IHW is discharged to the environment without any controlling measures annually. However, the actual generation of IHW was about 25.00 million tons according to a report from Nationwide General Investigation by Chinese Academy for Environmental Planning [3], which is as two times as the data from NBSC. Above difference has resulted from the unclear identification system of hazardous wastes and various sources of statistic data. In this paper, all the analyzed data is based on the statistic data from NBSC.

Fig. 2 shows a simple comparison on IHW generation between China and USA in 2005. The volume of IHW in USA was nearly four times more than in China [4]. However, a common characteristic between each other could be found that raw chemical material and manufacturing industry sector ranked the first contributor to the volume of IHW. While mining and processing of nonferrous metal ores was the second generator in China. USA is the petroleum and coal products industry.

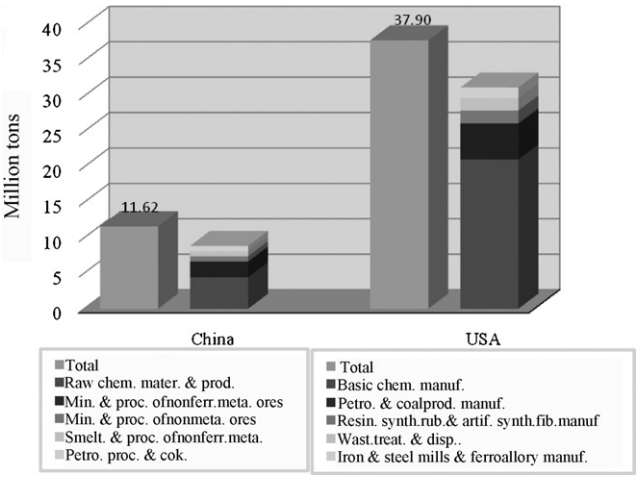

Fig. 2. A comparison on hazardous waste generation between China and USA (2005).

IHW was widely generated in China. The generation proportion of IHW in different regions is shown in Fig. 3. In 2005, almost above 40% of IHW was generated in South west China [5], which means that 4.65 million tons of IHW was from Sichuan, Guizhou, and Yunnan provinces which belong to undeveloped regions. The level of economic development and structure of the industry has resulted in the volume of IHW generation. The gross regional product among different regions is shown in Fig. 4. In South west China, the large quantity of IHW generation was due to the primitive and traditional production techniques, accompanied with mass but inappropriate mining and dressing activities for metals and other natural resource. Another 24% of IHW was from South east China, including Shanghai, Zhejiang, Jiangsu, and Shandong provinces. South east China belongs to developed regions. Accelerated development of economy, mass manufacturing and processing industry, and strict standard on environmental quality assessment, made the quantity of IHW increase continually.

IHW was almost generated in all industrial sectors (6 mining sectors and 41 manufacturing sectors defined by National Bureau of Statistics), but almost 90% of the IHW was from 9 main industrial sectors (Table 1). And 38% of IHW was gener-

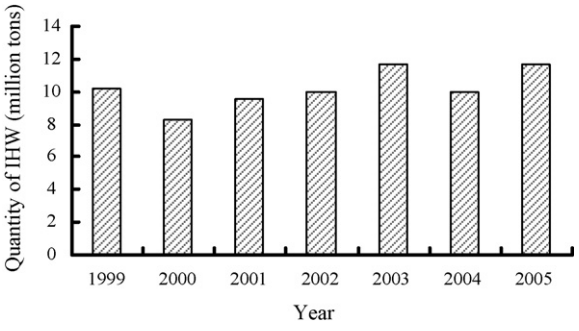

Fig. 1. Quantity of industrial hazardous waste in China from 1999 to 2005.

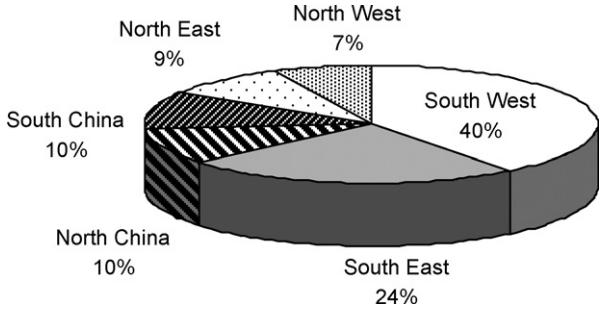

Fig. 3. Regional distribution and proportions for industrial hazardous waste in China (2005).

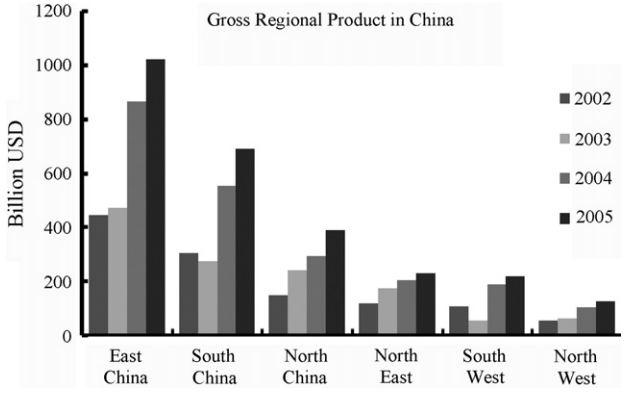

Fig. 4. Gross regional product in China from 2002 to 2005.

ated in raw chemical materials and chemical products industry. Top five industrial sectors with IHW volume were raw chemical materials and chemical products, nonferrous metals mining and dressing, smelting and pressing of nonferrous metals, petroleum processing and coking, and smelting and pressing of ferrous metals, accounted for 76% of total generated IHW. The generation of IHW is closely related to the industrial structure. The statistic data from USA and China (see Fig. 2) shows that raw chemical materials and chemical products industry, nonferrous metal mining and dressing are prone to generate IHW [4,5]. For one thing, amounts of toxic chemicals and heavy metals are used or extracted during the extraction, processing and manufacture phase; for another, above mentioned industrial sectors are the main contributors to national economy. The gross product of raw chemical materials and chemical products industry ranked the fourth among manufacture industry.

The characteristic of industrial structure has resulted in the categories of IHW. In China, the quantity of top five categories of IHW: waste alkali, waste acid, inorganic fluoride waste, copper wastes, and inorganic cyanide waste, accounted for 58.7% of total generated IHW [6]. The categories of IHW were listed in Table 2. Other categories with large quantity included zinc wastes, residues of refinery or distillation, wastes resulting from surface treatment of metals and plastics, arsenic wastes and lead wastes.

Table 2
Top 10 categories of industrial hazardous waste generated in China (classified as NCHWs)

Code of NCHWs	Wastes catalogues	Proportions (%)
35	Waste alkali	17.5
34	Waste acid	13.4
32	Inorganic fluoride wastes	12.5
22	Copper wastes	8.2
33	Inorganic cyanide wastes	7.0
23	Zinc wastes	4.2
24	Arsenic wastes	4.1
11	Residues of refinery or distillation	4.0
31	Lead wastes	3.8
17	Wastes resulting from surface treatment of metals and plastics	3.7
	Others	21.6

2.1.2. Treatment and disposal

The proportion of recycled IHW accounted for 43.4% of the total IHW volume in 2005. The qualified provinces with IHW recycling were Guangdong, Hunan, Shanghai, Liaoning, and Hebei, accounted for 85% of recycled IHW in total. But present technology and equipment used in recycling process was primitive and traditional for, e.g., some enterprises recycled lead acid battery, waste oil and electronic waste without any environmental protection facilities. Generally, precious substances were fully separated, but large proportion of residual waste water, waste gas and solid waste were discharged directly, which leaded to serious damage to environment. Moreover, local Environmental Protection Bureau (EPB) has not enough manpower and financial budget to supervise these problems.

The proportion of stored IHW accounted for 33.0% of the total IHW volume in 2005. The storage proportion of selected hazardous waste, including waste alkali, copper wastes and inorganic fluoride waste, has reached to 33, 42 and 50% of their respective generation. While the time restriction of storage is only 1 year through to Chinese Law "Standard for Pollution Control on Hazardous Waste Storage" (GB 18597–001), the period of storage was quite long. From 1996 to 2004, it was estimated that the accumulative quantity of storage IHW had reached to 33,943,000 tons, which was three times as much as

Table 1
Nine largest sources of industrial hazardous waste generation, by industrial sectors categories

Categories of industrial sectors	Million tons				
	2001	2002	2003	2004	2005
Raw chemical materials and chemical products	5.13	5.72	6.26	3.89	4.44
Mining and processing of nonferrous metals ores	1.84	1.58	1.58	2.64	2.22
Mining and processing of nonmetal ores	–	–	0.71	0.62	0.76
Smelting and pressing of nonferrous metals	0.61	0.80	0.99	0.52	0.70
Petroleum processing and coking	0.39	0.42	0.54	0.59	0.75
Smelting and pressing of ferrous metals	0.47	0.30	0.29	0.25	0.32
Manufacturing of machine, electric and electron equipment	0.17	0.25	0.44	0.45	0.18
Medical and pharmaceutical products	0.23	0.17	0.20	0.20	0.21
Manufacturing of chemical fiber	0.12	0.13	0.16	0.14	0.28
Other industrial sectors	0.54	0.63	0.79	1.26	1.77
Total	9.52	10.00	11.70	9.95	11.62

Table 3
Formal disposal centers' facilities and capacity in recent years

Year	Numbers of formal disposal centers	Actual disposal capacity (tons)		Operation budget (million US$)
		Incineration	Landfill	
2001	92	99,000	37,000	2.63
2002	152	153,000	46,000	1.99
2003	154	331,000	90,000	3.92
2004	177	271,000	142,000	5.21

the generation of IHW in 2005. Moreover, quite few pollution prevention measures were constructed for IHW storage management. For example, a vast amount of IHW was stored without leakage prevention facilities, which inevitably leaded to serious pollution.

In this paper, disposal means incineration, landfilling and related ultimate treatment activities. The proportion of disposed IHW accounted for 23.0% of the total IHW volume in 2005. Generally, formal disposal center is the first option for hazardous waste treatment and disposal. By far, formal centers are far from to satisfy the disposal requirement. The amount of disposed IHW was 2.67 million tons, of which only 16.0% was managed by formal disposal centers with incineration facilities and secure landfilling sites. The current situation of formal disposal centers was listed in Table 3. The qualified provinces with IHW incineration facilities were Zhejiang, Jiangsu, Heilongjiang, and Shanghai, whose disposal capability accounted for 68.1% of incinerated IHW. And the qualified provinces with IHW landfilling were Guangdong, Liaoning, and Shanghai.

Except for the formal disposal centers, most of IHW was disposed by individual enterprise, but generally mixed with ISW, even with MSW. For instance, as a disposal method, hazardous waste chemicals, reagent and paint are often mixed with coal ash, boiler slag, or even MSW. Contaminated sites from hazardous waste and inappropriate disposal practices were shown in Fig. 5. These pictures are from several cities along Yangtze river in South west China.

By the end of 2004, the number of formal disposal centers for IHW was 177, of which 23 centers were newly constructed. A majority of provinces have established disposal centers for IHW management, except for Jiangxi, Henan, Hunan, Yunnan, Tibet, and Ningxia provinces. And the largest number of centers belonged to Jiangsu province, 34 in total. In 2004, National operation budget for IHW disposal centers was US$ 5.21 million, which increased 33% than in last year. Actual disposal capacity was 4,006 tons per day. Annual disposal quantity was only 416,000 tons (which decreased 1.2% than in 2003), of which 271,000 tons were incinerated, and 142,000 tons were securely landfilled. Actually, a great proportion of operated centers have not fully played the roles in disposing IHW. Effective capacity was much lower than designed volume. For example, effective capacity of incineration only accounted for 40%. In addition, incineration technology and equipment was primitive, which must be difficult to reach to national standards for IHW incineration.

2.2. Medical waste

Medical wastes were those wastes from health-care-related facilities such as hospitals: waste of animals intentionally exposed to pathogens; bulk human blood and blood products; pathological waste; microbiological waste; medical sharps [7,8]. At present, there is no detailed statistical data for MW management in China [9]. But the quantity of total MW could be extrapolated as following.

The number of health institutions in 2005 were 298,997, including hospital, health center, outpatient department and clinic, sanatorium, specialized disease prevention and treatment institute, center for disease control and prevention and medical research institute. The number of beds in health institutions was 3,367,502. An average utilization rate of beds was 75.1% [10]. The current situation of health institutions, beds and their utilization proportion were listed in Table 4.

Fig. 5. Contaminated sites from hazardous waste and impropriate disposal practices.

Table 4
Number of health institutions, beds and their utilization rate

	Year						
	1950	1980	1990	2000	2003[a]	2004	2005
Number of health institutions	8,915	180,553	208,734	324,771	291,323	296,492	298,997
Number of beds in health institutions	119,119	2,184,423	2,925,390	3,177,000	3,164,022	3,268,374	3,367,502
Utilization rate of beds in hospitals and health centers (%)	87.9	85.6	70.2	64.5	69.3	73.1	75.3

[a] Institutes of medicine and drug clinical experimentation and confirmation institutions have been excluded from the official statistic number since 2003.

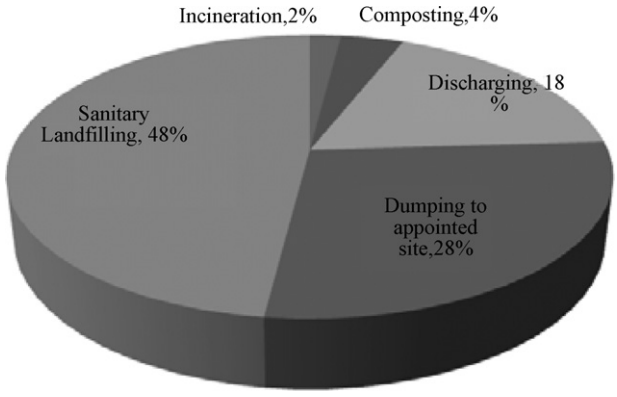

Fig. 6. Disposal scenarios and respective proportions for MSW management.

Provided total daily production of MW for one bed was 0.8 kg [11] (conservative parameter, estimated from survey in several cites), following these calculations, the volume of MW was around 740,000 tons in 2005.

However, the study showed that the secure disposal proportion for MW was quite lower after cases investigation on several cites. Almost above 90% of the total MW was deposed as MSW or discharged without controlling; only 10% was incinerated in a formal way [12]. In addition, a majority of incineration facilities were not fully operated and used primitive technology and simple equipment, which consequentially caused serious pollution.

2.3. Household hazardous waste

Some jobs around the home require the use of products containing hazardous substances. Such products may include paints, cleaners, stains and varnishes, car batteries, motor oil, and pesticides. The used of leftover contents of such consumer products are known as "household hazardous waste" [13–15]. At present, quite few national and local regulations are drafted for HHW management in China. There was also no detailed reported data for HHW. Due to the unprompted participation of private collectors and informal companies, recycling rates for a few valuable hazardous wastes with great amounts were comparatively higher, such as waste lead batteries, waste mineral oils, photographic chemical wastes, waste mercury lamp and certain electronic waste contained heavy metal and PCBs. But other HHWs were almost managed as MSW. Fig. 6 shows the present situation of MSW management in China. The proportion of safe disposal for MSW management, including incineration, sanitary landfilling, and composting, only accounted for 54% of the MSW volume. That inevitably accelerated the pollution of HHW.

3. Activities for hazardous waste management

As contracted states under the Basel Convention, numbers of laws and regulations have been enacted for hazardous waste management in recently, which was listed in Table 5 [16]. In 2004, "Layout on centralized and safe disposal facilities

Table 5
Current regulations, laws and regulations for hazardous waste management in China

No.	Title of Law and Reg.	Effective date
1	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (International convention for hazardous waste management)	1995
2	Law of People's Republic of China on the Prevention and Control of Solid Waste Pollution (The legal ground and rule for hazardous waste management)	1996 (Revised in 2004)
3	Identification Standard for Hazardous Wastes (Corrosive and toxic identification standards for hazardous waste)	1996
4	National Catalogue of Hazardous Wastes (NCHWs, Lists of hazardous waste, complied to Basel Convention)	1998
5	Measures on the Management of Duplicated Form for Transferring Hazardous Wastes	1999
6	Standard for Pollution Control on Hazardous Waste Storage	2001
7	Pollution Control Standard for Hazardous Wastes Incineration	2001
8	Standard for Pollution Control on the Security Landfill Site for Hazardous Wastes	2001
9	Measure for The Administration of Registration of Hazardous Chemical	2002
10	Regulations on the Administration of Medical Wastes	2003
11	Technical Standard for Medical Waste Incinerator	2003
12	Measures on Permit for Operation of Hazardous Wastes	2004
13	Technical specifications for Centralized Incineration Facility for Hazardous Waste	2005

construction for national IHW and MW generated" had been promulgated by SEPA [17]. In 3 years, Chinese government was preparing to invest US$ 1.9 billion on constructing 13 comprehensive treatment and disposal centers in each province for IHW, seven monitoring centers for dioxin, and one MW disposal centers in each central city.

Actually, above laws, regulations, investment and budget could hardly satisfy the sound management of hazardous waste for, e.g., present national identification methods and standards will continue to hamper and impede the development of hazardous waste management. For one thing, The Chinese National Hazardous Waste Catalogue presently being enacted is based on the so-called Y-Code list of the Basel Convention [18]. Application of the Y-Code list for classification as presently done in China leads to following problems: lacking of unambiguousness in waste classification, due to the subsuming unspecific nature of the waste codes and due to the liberty given to waste generators to choose their own names for the wastes they generate; potential overlapping of source based and constituent based waste codes. For another, there were no identification standards of ignitable and reactive characteristics for hazardous wastes [19,20].

4. Conclusions and recommendations

Along with the demands for preferable environmental quality, and high-speedy development of economy in China, the quantity of generated hazardous waste has increased rapidly. In 2005, the official statistic volume of IHW was 11.62 million tons, of which 0.6% was discharged without controlling. However, compared to official data, the actual investigation data of IHW volume was more than 25.00 million tons, which means the definition of term "hazardous waste" and relevant identification system are unconvinced. South west China had the maximum generation, which accounts for 40%. In 2004, the official statistic quantity of IHW entered into formal disposal centers was 416,000 tons, of which 65% was landfilled and 35% was incinerated. By far, there were 177 national disposal centers for IHW. In additional, the quantity of generated MW was 740,000 tons per year, of which only 10% was soundly managed. HHW should be well managed due to its large quantity. Relevant measures should be enacted for HHW ranging from classifiable collection system to securely ultimate disposal technology.

Hazardous wastes, the main drawbacks of industrialized world, continue to keep their importances because of their potential hazard to human health and environment when improperly identified, treated, recycled, stored, transported and/or disposed. Whereas lots of efforts have been done on this issue in recent years, hazardous waste management is still a hot topic, as well as an urgent problem faced by Chinese government according to above analyses. Thus, various effective measures should be put into effective. First of all, promote the clean production legislation, and reduce the IHW from source control. For instance, a way of designing products and manufacturing processes in harmony with natural ecological cycles could be applied to selected chemical materials and chemical products industry sector, and aims to eliminate toxic wastes and effluents generation. Secondly, demand a far more precise definition of the term "hazardous waste"; construct feasible identification methods and standards, classification guideline, delisting and exclusion systems for hazardous waste management through national and local legislation. An economic and feasible hazardous waste identification and classification system is the cornerstone of hazardous waste management system. Due to the simple procedure and low cost of identification process, an extensive and definite list is still the preferred choice for hazardous waste identification. Thus, current NCHWs system is urgent to be revised or replaced. Thirdly, research and develop the ultimate disposal technology and equipment combined with the characteristic of hazardous waste generation, and propose best available options for hazardous waste recycling, storage, and disposal under Chinese present situation. As less developed countries, China could hardly afford to the initial investment and operation fees for hazardous waste management facilities. Furthermore, improve the awareness on hazardous waste management of generator and local EPB's governors through special education, publicity and training activities.

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