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Generation and Management: A General Industrial Hazardous Waste Survey in China

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The current generation and management of industrial hazardous waste (IHW) in Guangdong province, China were critically evaluated and reported based on a general survey of industrial hazardous waste. The primary statistics and challenges were discussed and analyzed. The results that the generation 1.84 million tons of industrial hazardous waste reported by general survey in 2007 was 95.6 % higher than the data in environmental statistics, indicated that the generation of industrial hazardous waste in environmental statistics was not correspondence with rapid economic growth. It was due to the lack of independent reporting and monitoring system to track all hazardous wastes from generation to disposal. Only 28.1 % generators and 38 % generations of general survey were considered in environmental statistics considering some large quantities of generation manufacturers such as communication equipment, computer and other electronic equipment. It was necessary to build a classification management system and the largest quantity of generators should be addressed. Additionally, an integrated management system for controlling hazardous waste from its generation until its ultimate disposal should be established.

Key Words: Industrial hazardous waste, Survey, Generation, Management.

INTRODUCTION

Hazardous wastes are harmful to the public and environment. The generation amounts of hazardous wastes increase significantly all over the world, which is clearly linked to the degree of industrialization[1]. As developing economies expand their industries with increasing economic prosperity, a forthcoming increase of hazardous wastes is inevitable[2,3]. The same even applies to developed countries like Finland[4], Germany, Italy and other EU countries[5]. The industries generating hazardous wastes increase dramatically with the gradual shift of the economy in Guangdong, China during the industrialization process. The number of industrial enterprises above designated size, or with over 5 millions CNY of annual business revenues increased sharply from 17,980 to 52,217 from 1999 to 2009 with annual growth rate of 11.25 % (2009). In the meantime the gross domestic product (GDP) of Guangdong province of China increased from 925 billions to 3,948 billions CNY, with an annual growth rate of 15.6 %. According to the latest official statistics, the total amount of industrial hazardous wastes (IHW) generated in Guangdong province increased from 592,000 t of 1998 to 992,126 t of 2009 with 5.3 % annual growth rate[6].

The proper management of hazardous waste has been a priority for many countries with long term commitment in putting their environment under proper control. In particular, the managements of hazardous wastes in developed countries such as Japan[7], the United Kingdom[8] and the United States[9], have been evolved over 25 years[10-12]. However, in developing countries, comparatively few resources are available in dealing with environmental health issues concerning hazardous wastes[13]. In China, the management of hazardous waste began with the enactment of two laws: (i) basel convention on the control of *trans*-boundary movements of hazardous wastes and their disposal, 1991 and (ii) Law of the People's Republic of China on the Prevention and Control of Solid Waste Pollution to the Environment (PCSWPE), 1995. Other regulations, standards and technical guidelines targeting the management of hazardous wastes were promulgated since then. According to Article 53 of PCSWPE, hazardous waste generators should be responsible for proper collection, transport and disposal of such wastes. In addition, according to Article 57 of PCSWPE enacted in 2004 for the measures on permit for the operation of hazardous wastes, the provincial environmental protection bureau (EPB) is responsible for the approvals and setting of

conditions for the licensing of hazardous waste treatment and disposal facilities. Large quantities of hazardous wastes produced in Guangdong province with the eye-witnessed rapid economic growth adopting the open and reform policies since 1978, prompted Guangdong EPB to control and manage the sheer volume of hazardous waste in an environmentally sound manner.

A survey on IHW generators in all key industries and operating units under official operation permits should be developed and conducted, in order to obtain a better understanding of the true status-quo of the generation of hazardous wastes and the hazardous waste management. The problems in the hazardous waste management should be uncovered and some suggestions on improvement of measures and corrective actions on regulations of hazardous waste management should be proposed.

EXPERIMENTAL

Methodology for the general industrial hazardous waste survey: The general industrial hazardous waste survey (GS) of hazardous waste generators and facilities of treatment, storage, disposal and recycle were conducted by Guangdong EPB in 2008. The industrial units of 268,968 were surveyed by Guangdong EPB during 2007, as part of the first national pollution source census database. Among which, 26,109 units were found as industrial hazardous waste (IHW) generators. The scope of facilities surveyed was ranged in the census of all 192 facilities that treating, disposing of, or recycling hazardous waste offsite with permitting licenses issued by Guangdong EPB. The facilities that treated, disposed of, or recycled hazardous waste onsite by generators themselves without a special permit and facilities that belong to illegal handler without an official permit, were excluded.

The generators and facility survey instruments were evaluated and revised on the basis of the in field pretests. Above 3000 people coming from local EPB were trained with the same survey method and instruments. The representatives coming from generators and operating units were gathered to train how to complete the survey questionnaires correctly by local EPB. A survey update newsletter was released online by Guangdong EPB website periodically to all respondents. The update provided additional information for the completion of complex questions, suggestions to facilitate the instruments and some corrections to the questionnaires. Subsequently, each questionnaire was reviewed for technical accuracy rank by rank by EPB investigators after returned. Telephone follow-up calls to the respondents were made or verifications onsite were developed if necessary. After manual checking, the data were input into special program. The electronic data sheets formed by the program were forwarded to the Guangdong EPB for additional verification and final data processing. Information collected in the surveys were organized into two databases. The facility survey database contained 111 distinct files and the generator survey database contained 26109 distinct files.

The survey questionnaire covered the following information: (1) Generators and operating units (geographical code, code for industrial origin classification, legal name, the physical location, mail address, name and phone number of a correspondent); (2) generation of IHW (the source, characteristics and quantity of hazardous wastes generated; the quantity of hazardous wastes managed on-site and shipped off-site along with the management method used, respectively); (3) reception and management (the source, characteristics and quantity of hazardous wastes received and managed along with the methods used).

RESULTS AND DISCUSSION

Generation of industrial hazardous wastes (IHW)

Quantity and generators distributions: The 1.84 million tons of industrial hazardous wastes (IHW) were generated by the 26109 IHW generators in 2007, where a few of the generators accounted for the most of the hazardous waste generation. Fig. 1 showed the cumulative distribution of the quantity of hazardous waste generated by ranking generators was non-normal distributions. The top 50 generators (0.4 %) produced 48 % IHW and the top 7.2 % generators generated over 95 % of the total hazardous wastes.

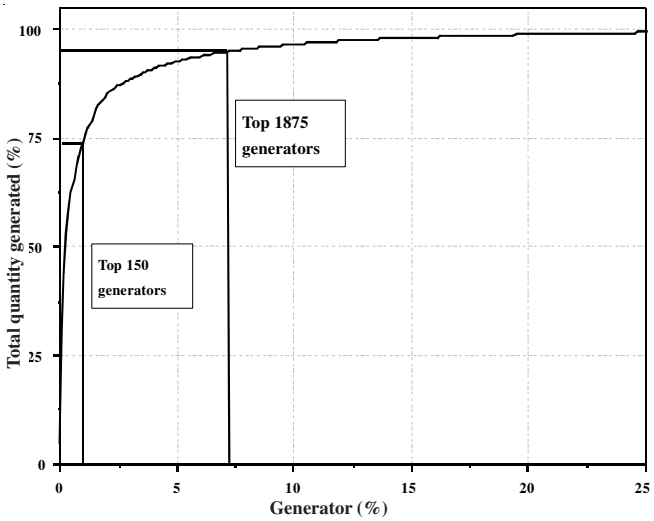

Fig. 1. Cumulative distribution of the quantity of hazardous waste generated in 2007 for the top 25 % of generators (top 6515 generators)

The hazardous waste generated in Guangdong province indicated similar trend but less concentrative degree compared with the data of USA in 2007 (Table-1). The quantity of hazardous waste generated by the 50 largest generators in Guangdong Province and USA accounted for 48 and 83 % of the total generated IHW, respectively. 95.4 % of generators produced less than113.2 tons hazardous waste in Guangdong and 77.5 % in USA. The result was due to the most quantity of hazardous waste generated by generators in Guangdong was lower than in USA, as well as the information of hazardous waste generation obtained from the data of USA was reported by large quantity generators only.

Distribution by industrial categories: In the general IHW survey, the generation was widely distributed in 37 industrial sectors among all industrial 39 sectors defined by National Bureau of Statistics (6 mining sectors and 33 manufacturing sectors). More than 91.4 % hazardous wastes were attributed to 10 dominant industrial sectors. There were the

TABLE-1
A COMPARISON ON NUMBER OF HAZARDOUS WASTE GENERATORS BY GENERATOR QUANTITY RANGE BETWEEN GUANGDONG AND USA (2007)

Generator quantity range (tons)	Guangdong				USA[9]	
	–	%	Tons	%	–	%
0.0-1.1	15,790	60.5	3997	0.2	475	2.9
1.1-13.2	6,265	24.0	28417	1.5	5,462	33.4
13.2-113.2	2,860	11.0	113087	6.2	6,730	41.2
113.2-1,113.2	941	3.6	328101	17.9	2,771	16.9
1,113.2-11,113.2	229	0.9	692827	37.7	703	4.3
11,113.2-111,113.2	24	0.1	670137	36.5	167	1.0
> 111,113.2	0	0	0	0	41	0.3
Total	26,109	100.0	1836567	100.0	16,349	100.0

TABLE-2
TEN LARGEST QUANTITIES OF HAZARDOUS WASTE GENERATED, BY CATEGORIES OF INDUSTRIAL SECTORS

Categories of industrial sectors	Number of generators		Quantity of generated	
	–	%	Tons	%
Manufacture of communication equipment, computers and other electronic equipment	1,693	6.5	662,196	36.1
Smelting and pressing of ferrous metals	225	0.9	197,973	10.8
Metal products	3,562	13.6	174,968	9.5
Nonmetal mineral products	494	1.9	153,566	8.4
Textile industry	1,019	3.9	147,875	8.1
Manufacture of raw chemical materials and chemical products	2,496	9.6	113,850	6.2
Petroleum refining, coking and nuclear fuel processing	82	0.3	112,084	6.1
Manufacture of electrical machinery and equipment	1,093	4.2	48,641	2.6
Smelting and pressing of nonferrous metals	350	1.3	35,811	1.9
Papermaking and paper products	1,111	4.3	31,345	1.7
Others	13,984	53.6	158,258	8.6
Total	26,109	100.0	1,836,567	100

close relation to the quantities of hazardous and the industrial structure. Unlike most of other provinces in China that the largest quantities of IHW generation produced by raw chemical materials and chemical product industry (2005), as shown in Table-2, in Guangdong, the largest quantities of hazardous wastes were made by the manufacturers of communication equipment, computer and other electronic equipment ranking the first place with gross product. Table-2 also showed that the largest quantities of wastes were not produced by the largest number of generators.

Distribution by waste categories: The IHW should be identified by one of the following methods before treatment: National Catalogue of Hazardous Wastes (NCHWs, hazardous waste list in China) or Identification Standards on Toxicity and Corrosivity Characteristic for Hazardous Wastes. There were 46 categories of hazardous waste generated in Guangdong among all 47 categories classified by NCHWs[14]. The categories of IHW in descending order by quantity of generation were listed in Table-3. In Guangdong province, the quantity of top five categories of hazardous wastes were copper wastes, wastes from surface treatment, dyes and paints wastes, phenols wastes and mineral oil wastes, which accounted for 69.7 % of the total generation IHW. The distribution characteristic of IHW categories were in consistent with the industrial structure. For example, copper waste mainly came from the print circuit board manufacturing belonging to the electronic equipment manufacturing sector.

Distributive areas of IHW generation: The level of economic development and structure of the industry result in the quantity of IHW generation. As shown in Figs. 2 and 3, nearly

TABLE-3
TOP 10 CATEGORIES OF IHW GENERATED IN GUANGDONG (CLASSIFIED AS NCHWS)

Code of NCHWs	Wastes catalogues	Generated quantity	
		Tons	%
HW22	Copper wastes	479,761	26.1
HW17	Waste from surface treatment	313,683	17.1
HW12	Waste dyes and paints	224,135	12.2
HW39	Phenols wastes	159,996	8.7
HW08	Waste mineral oils	102,086	5.6
HW35	Waste alkali	96,124	5.2
HW23	Zinc wastes	92,220	5.0
HW34	Waste acid	85,422	4.7
HW13	Organic resins wastes	61,030	3.3
HW31	Lead wastes	46,080	2.5
–	Others	176,029	10
–	Total	1,836,567	100

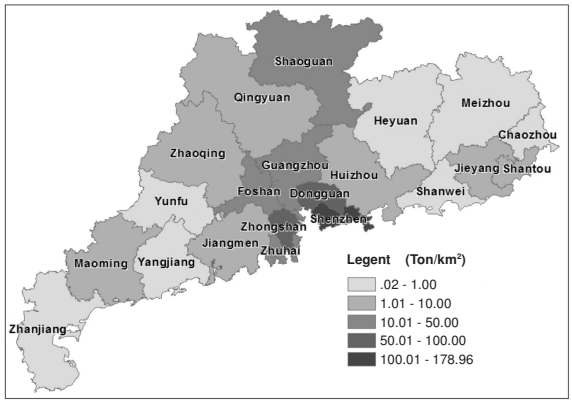

Fig. 2. Distribution for quantity of IHW generated by cities

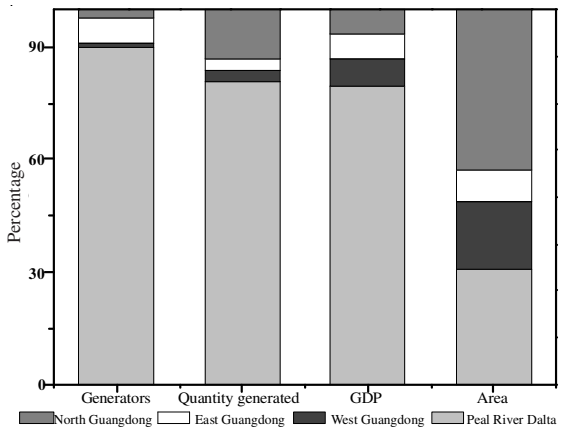

Fig. 3. Regional distribution for IHW in Guangdong

12.5 % of total economic output of China was contributed by Guangdong provinces. The well developed areas of Guangdong concentrated in Pearl River Delta contributed 79.8 % of GDP, 89.9 % of generators, 80.6 % IHW generation, respectively. 76.3 % of total quantities of IHW were contributed by the six largest cities. Maoming and Shaoguan are famous for heavy industry and their dominant industries are petrochemical industry, smelting and pressing of non-ferrous metals, respectively. The IHW generators of these two cities were fewer but their contribution to the GDP and the IHW generations were higher compared with other cities.

Management of industrial hazardous wastes

Waste flow among operating units and generators: According to the generators survey, among the IHW generated in Guangdong, 57.2 % of IHW were recycled, 41 % were treated and disposed, only 1.4 % were stored and 0.4 % were illegally dumped or mixed with municipal solid waste and industrial non-hazardous waste (Table-4). However, it was difficult to track that how many IHW were managed onsite by the generator itself or offsite by other specific units in the generators survey. According to the facility survey, there were 810,975 tons hazardous waste were managed by operating units offsite, which demonstrated lower than 44.2 % IHW were sent to different operating units with permits and it were significantly higher in contrast to the percentage of 15.4 % in USA *ca.* 55.8 % IHW were managed onsite. Large generators preferred to manage their own hazardous waste onsite considering the economy of treatment and disposal activities, the transportation costs and the liability issues. Most offsite operating units with management facilities located in Guangdong province, only almost 100 tons per year. of hazardous waste were shipped to other provinces.

The first three largest quantities of IHW categories recycled were HW22, HW39 and HW23, which were mainly generated from PCB manufacturing, construction ceramic. More than 60.8 % of the share of recycled were occupied them. The first two largest quantities of IHW categories treated and disposed were HW17 and HW12, which were mostly generated from metal products manufacturers, smelting and pressing of ferrous metals industries and textile industries. More than 49 % of the shares treated and disposed were occupied by them and they were often treated using solidification, landfill and incineration methods.

TABLE-4
QUANTITY OF HAZARDOUS WASTE MANAGED BY DIFFERENT MANAGEMENT METHODS (2007)

Method code	Management method	Managed offsite		Total managed	
		Tons	%	Tons	%
R1	Use as a fuel (other than in direct incineration) or other means to generate energy	–	–	180983	9.9
R2	Solvent reclamation/regeneration	14010	1.7	17275	0.9
R3	Recycling/reclamation of organic substances which are not used as solvents	10	0	17715	1.0
R4	Recycling/reclamation of metals and metal compounds	462765	57.1	707995	38.5
R5	Recycling/reclamation of other inorganic materials	15279	1.9	28257	1.5
R6	Regeneration of acids or bases	6464	0.8	10541	0.6
R7	Recovery of components used for pollution abatement	52	0	25	0.0
R8	Recovery of components from catalysts	65	0	236	0.0
R9	Used oil re-refining or other reuses of previously used oil	24338	3	53261	2.9
R10	Land treatment resulting in benefit to agriculture or ecological improvement			911	0.0
R15	Recovery of other effective components	0	0	82664	4.5
R16	Use as other means (*e.g.*, construction material, paving material, *etc.*)	0	0	127296	6.9
	Total recovery	522982	64.5	1227160	66.8
D1	Deposit into or onto land, (*e.g.*, landfill, *etc.*)	69974	8.6	82982	4.5
D2	Land treatment	–	–	9059	0.5
D4	Surface impoundment	–	–	13018	0.7
D5	Specially engineered landfill	–	–	66265	3.6
D6	Release into a water body except seas/oceans	–	–	5775	0.3
D8	Biological treatment	–	–	4174	0.2
D9	Physico-chemical treatment (*e.g.*, evaporation, drying, calcination, neutralization, precipitation, *etc.*)	202116	24.9	146147	8.0
D10	Incineration on land	8630	1.1	79684	4.3
D16	Other disposal means(*e.g.*, co-processing in cement kiln, solidification, *etc.*)	6326	0.8	169348	9.2
–	Total disposal	287047	35.4	576452	31.4
–	Total stored	946	0.1	24801	1.4
–	Total illegal dumped	–	–	8103	0.4
–	Total managed	810975	100	1836567	100.0

Distribution of quantity and operating units: There were 192 facilities in Guangdong province belonging to 111 operating units with governmental permit. 810,975 tons hazardous wastes were managed in 2007 by these facilities. Within the 111 operating units, only a few of them accounted for the most quantity of the hazardous waste management. Fig. 4 illustrated the highly non-normal distribution between managed hazardous waste and operation units. The top 10.8 % of operating units managed 80.8 % of the total quantity of managed hazardous waste in 2007.

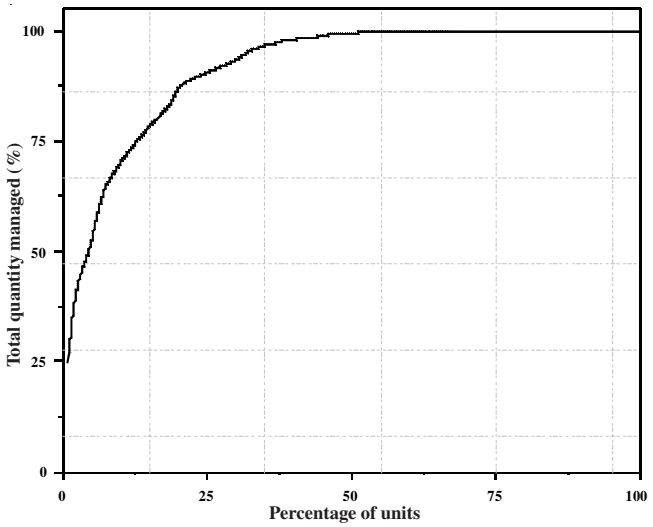

Fig. 4. Cumulative distribution of the quantity of hazardous waste managed in operating units in 2007

Activity type in operating units: Pollution prevention measure is able to prevent waste from being generated at its source under the guidance of waste management strategy and policy formulated by the Chinese government. It is the first option that people are encouraged to take by affording part of clean production auditing allowance by local government. Whenever possible, as the second encouraging measure, industries are encouraged to find ways to recover, reclaim and reuse waste materials if their generation of waste can hardly be prevented. When pollution prevention or recycling is not possible, or after recyclable materials have been recovered, the third preference opt for waste management treatment.

Incineration and other thermal treatment processes are included as hazardous waste treatment activities. Chemical, physical and biological processes to remove or neutralize hazardous constituents are adopted. In addition, solidification process is designed to limit the solubility or mobility of the waste constituents prior to disposal in land-based units. Finally, disposal is the least preferred option in waste management, if somewhat unavoidable.

Table-4 shows the quantity of hazardous waste managed by different management methods according to classification system of annex IV of Basel Convention in operating units during 2007. Only 35.4 % of operating facilities were used to treat and dispose 64.5 % of the recovered hazardous waste managed offsite in operating units.

Recycling/reclamation of metals and metal compounds wastes including copper, zinc and nickel, are the dominant recovery methods. Metals and metal compounds wastes are most valuable materials to be utilized. As an example, PCB etching liquid wastes can be used as the material to produce basic cupric chloride and copper(II) sulfate pentahydrate. More than 32 facilities with operating licenses have the designed utilizing capability to recycle over 600 thousand tons copper wastes annually, but the real quantities of wastes generation severely exceed the design utilizing capability.

Till 2007, there was only one safety landfill and three incineration plants for hazardous waste in Guangdong province. The safety landfill is located in Shenzhen city with a limited landfill capability of 80 thousand tons annually. The three incineration plants are located in Shenzhen, Zhuhai and Guangzhou, respectively, with total 20 thousand tons per year incineration capability.

As the second most frequently used management method, physicochemical treatments are widely used to neutralize alkali or acid wastes, physical precipitation and separation of oil wastewater, *etc*.

Geographical distribution of operating units: As discussed previously in section of distributive areas of IHW generation that the distribution of the economic gross and the quantity of hazardous waste generation were concentrated in Pearl River Delta, the quantity of hazardous waste management and the number of operating facilities in operating units were also centralized in the region of Pearl River Delta. Fig. 5 shows the economic regional distribution of the quantity of managed hazardous waste in operating units. As shown, 86 % of managed hazardous wastes in Pearl River Delta region were accounted for 66 % operating units and 74 % operating facilities, whereas only less than 1 % of the total quantities of managed hazardous wastes in the Eastern Guangdong were managed in those operating units.

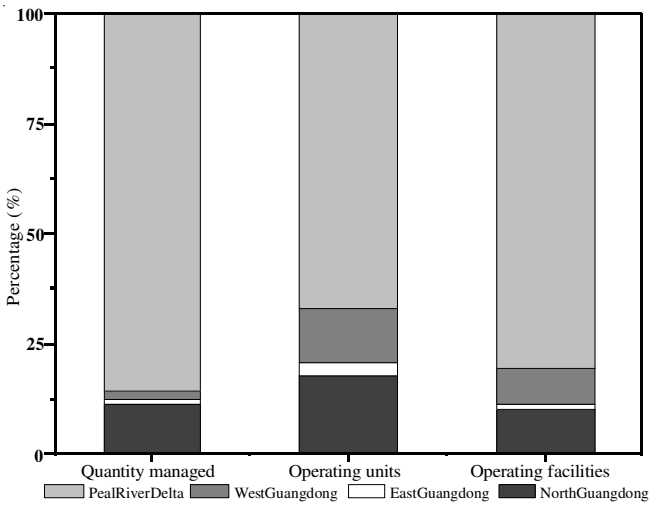

Fig. 5. Percentage of the quantity of hazardous waste managed, operating units, operating facilities in different regions in Guangdong

In addition, the quantity of hazardous waste management and the number of operating units and facilities in each city were shown in Table-5. The top three cities (Shenzhen, Guangzhou and Huizhou) contributed over 68 % of the total quantity of managed hazardous waste in operating units, where 40.2, 18.3 and 9.8 % of the quantity of hazardous waste were treated

TABLE-5
NUMBER OF OPERATING UNITS AND FACILITIES MANAGING HAZARDOUS WASTE AND QUANTITY MANAGED PER CITY IN 2007

City	Quantity of managed		Operating Units	Facilities	
	Tons	%		Number	%
Shenzhen	325888	40.2	8	41	21.4
Guanzhou	148552	18.3	24	38	19.8
Huizhou	79097	9.8	11	26	13.5
Zhuhai	43639	5.4	6	18	9.4
Foshan	35562	4.4	5	6	3.1
Shaoguan	35555	4.4	11	10	5.2
Jiangmen	32105	4.0	7	8	4.2
Heyuan	29313	3.6	3	3	1.6
Qingyuan	24459	3.0	5	5	2.6
Dongguan	17632	2.2	9	14	7.3
Maoming	15725	1.9	10	10	5.2
Zhongshan	13091	1.6	4	4	2.1
Shantao	3340	0.4	1	1	0.5
Meizhou	3079	0.4	1	1	0.5
Chaozhou	2308	0.3	2	2	1.0
Zhanjiang	1236	0.2	3	3	1.6
Yangjiang	393	0.0	1	2	1.0
Total	810975	100.0	111	192	100.0

with 21.4, 19.8 and 13.5 % operating facilities, respectively. The results illustrated again that a few facilities managed the largest quantities of hazardous waste.

It is noted that there is not always universal to see such a trend in recent years in accordance with ES of the generated volume of IHW. In fact, according to a recent survey carried out by Guangdong EPB, the total amount of industrial hazardous waste (IHW) managed by off-site facilities in 2004 was *ca.* 1.05 million tons, which was almost twice the amount of IHW generated in 2004 according to official statistics[15]. Fig. 6 showed that the relationship between ISW generation and GDP per capita was more linear than that between IHW generation and GDP per capita. It also showed a declining trend of the quantity of IHW generation between 1999 and 2004 and again between 2006 and 2008. The results might be explained with following two possible reasons and hypotheses. Firstly, the declining trend and indistinct relationship between the IHW generation and economic situation was due to the screening items under ES might not necessarily include the total quantity of generated IHW. 2727 generators considered in ES only accounted for 10.4 and 45.7 % of total IHW generators and generation in GS, respectively. Additionally, only 28.1 % generators and 38 % generations of large quantities of generation industries such as communication equipment, computer and other electronic equipment manufacturing surveyed by GS were considered in ES.

Moreover, according to the management of these large IHW generators, some IHW generating sources might not always generate sufficient quantity of wastewater or solid wastes, which were accounted for as main pollution sources by ES. The officially registered volume of IHW generated would rather depend liberally on the degree of awareness and knowledge of the management of IHW generators equipped with insufficient to poor knowledge on hazardous waste categorization. In addition, many IHW categories were not even reported by IHW generators, as some IHW might be seemed as sellable commodities for instant financial gain and

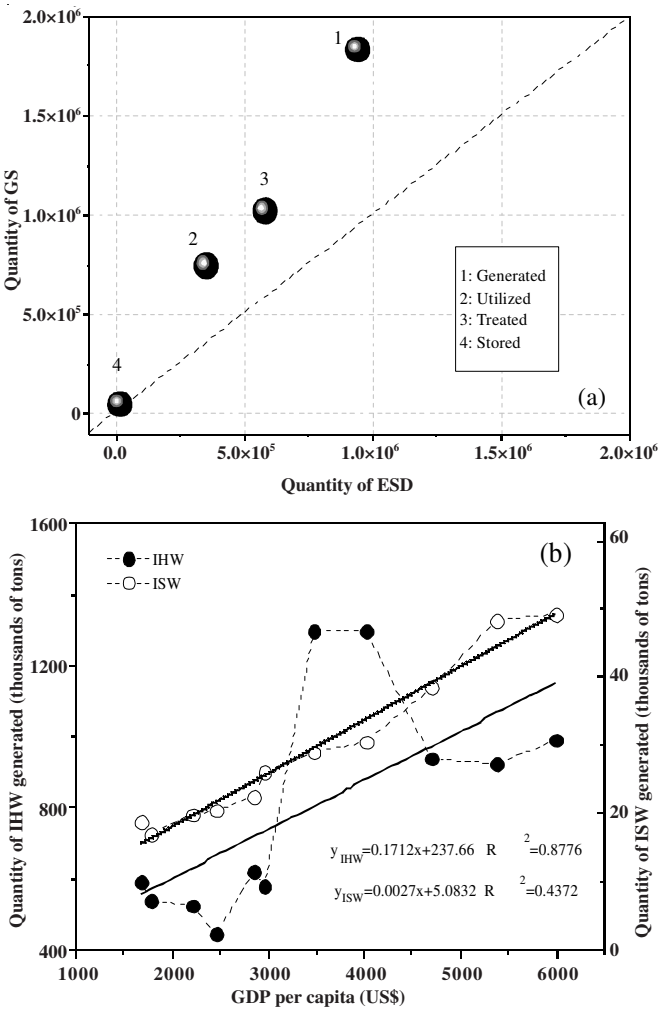

Fig. 6. Relationship between total annual ISW, IHW generation and GDP per capita for Guangdong (Data sources: Guangdong statistical yearbook 1999-2009, China and Environmental Statistical Yearbook 1999-2009) (Ref. 17)

others liquid IHW often were viewed as wastewater for lower level treatment.

The correlativity between the quantities of IHW generated and GDP per capita in ES is lower than that between ISW generated and GDP per capita. The actual investigation data in GS showed that 26,109 generators generated 1,836,567 tons IHW in 2007, in contrast to 2727 generators generated 939,000 tons IHW in ES. It was the first time that the GDP per capita achieved over 4000 USD in 2007. However, about 4144 tons IHW generation per billion GDP with over 4000 USD GDP per capita was higher than that compared with developed countries. As suggested by World Bank[16], usually the IHW generation per billion USD GDP were about 2000 tons in newly industrialized countries and about 5000 tons in countries with developed industry. The results indicated that IHW generation in GS was more suitable for economy situation currently than that in ES.

In generators survey, the hazardous waste generating activities followed a statistic rule that a relatively small number of large scale hazardous waste management facilities generated the majority hazardous waste. The top 7.2 % generators, which posed the greatest threat to human health and environment, generated 95 % IHW of the whole province. Therefore, the

greatest threat to human health and environment can be avoided by building a classification management system and addressing the largest quantity of generators, which had been implemented for many years in many countries such as USA, India[18], Thailand[19], South Africa[20] and Turkey[21]. Hazardous waste generators were classified into three categories on the basis of the amount of waste that they generate in a calendar month and applied different management standards in USA. Large quantity generators were defined as those facilities that generate 1,000 kg or more of hazardous waste percalendar month (approximately 2,200 lbs) or 1 kg or more of acutely hazardous waste per calendar month (*ca.* 2.2 lbs)[22]. It was unfair for the small quantity generator with less risk to human health and environment to share the same responsibility as the large quantity generators do and it was important to improve the poor implementation effect and enhance the management efficiency with a condition of limited administration resources on IHW rules, especially for Guangdong with a rapid economic growth in industrialization.

The quantity of IHW managed and recycled by offsite facilities with EPB licenses were lower than those onsite from the results of the generator and facility survey. In fact, some hazardous wastes were sent to offsite facilities without EPB licenses, however there was no any information provided. The hazardous wastes were hided or not reported for following reasons. One reason was that high transport and treatment costs caused some low valuable or valueless wastes were not further treated though the transfer contract and transport manifest had been implemented. Moreover, most of valuable wastes were sold to the illegal handlers to obtain a higher economic income, except a few wastes was sent to operating units with EPB licenses to meet official inspection. In addition, the lack of integral method to track the generation, transport, treatment and disposal of hazardous wastes, economic benefits only were considered by some generators regardless the environmental responsibility while choosing waste handlers.

As the basis of data sources, neither ES nor the declaring and registration for contamination release (DRCR) could adequately provide the sufficient information to monitor and track the waste flow to ensure the safe and protective management of potentially harmful wastes. Firstly, in ES and DRCR database, there were only five items on IHW including quantity of IHW generated, comprehensive utilized, stored, disposed and released. The essential items such as categories, characteristic of hazardous waste, waste management methods were lacked to monitor and track the waste flow. Secondly many hazardous wastes managed were not included in ES, such as fly ash from municipal solid waste incineration plant, lead-acid batteries from vehicle maintenance, chemicals from laboratory, residue from treatment and disposal of hazardous waste, household hazardous waste and other non-process related waste. Additionally, in China, a generator need not report the volume, category, methods and other information the waste managed to EPB annually and need not a license during the operation of the facility after an environmental impact assessment and "three simultaneousness" acceptance checking during facility construction being finished. Accordingly, a leak occurred for the waste flow management that many generators claim handle IHW by themselves, but actually illegally dumped or delivered to illegal managers on account of economic benefit.

Additionally, it was the main problem existing in management of hazardous waste in Guangdong province of China that excessive competition caused secondary pollution for low down the treatment cost in processing wastes. Most facilities were engaged in activities to recover valuable waste. There were a high recycling rate of hazardous waste (64.5 %) in Guangdong province compared with the 21 % average recycling rate in European Union-15 Member States (2006) and 35.1 % in USA[22]. One of the probable reasons is that some enterprises had send their hazardous wastes to offsite certificated facilities for further utilization, to low down higher disposal costs or they had no sufficient disposal capacity.

The quantity of hazardous waste was closely related to the industrial sectors, operators and waste categories. More than 90 % hazardous wastes were generated from 10 dominant industrial sectors. Manufactures of communication equipment, computers and other electronic equipment (36.1 %) and smelting and pressing of ferrous metals (10.8 %) had the highest share in IHW generation. The quantity of top five categories accounted for 69.7 % of the total IHW generation and HW22 is the largest contributor to the quantity of IHW generation. The top 7.2 % generators, generating over 54.4 tons IHW, occupied 95 % hazardous waste generation of the whole province. The Pearl River Delta contributed *ca.* 79.8 % GDP and 80.6 % IHW. The largest contributor to the quantity of IHW generation is Shenzhen (19 %).

The distribution characteristics of waste categories, industrial categories, generators and district of IHW generation were closely related to the local industrial structures. It provided a good inspiration that if waste avoidance and waste reduction measures were taken to address the categories, industrial sectors, generators and districts that produced the greatest volumes of IHW, the greatest threat posed to human health and environment would be avoided and reduced. As the consensus in hazardous waste management, the control and prevention cost of hazardous waste was 10-100 times lower than the cost spent on cleaning up the environment as a consequence of a case of hazardous wastes[23]. Many countries including developing ones regarded waste avoidance and waste reduction as the first step for the management of hazardous waste. In order to encourage generators to use pollution prevention techniques including using fewer hazardous materials in industrial processes (toxics use reduction) and reducing the quantity or toxicity of the waste those processes generated (source reduction), some environmental economy policy should be implemented to reduce the quantity of toxic waste. If the top 10 % generator reduced their IHW at 10 and 9.6 % of the total generation IHW would be reduced and a lot of costs caused by transport and treatment would be saved.

Conclusion

The hazardous waste generation is currently not proportional to economy situation in Guangdong province of China for unreasonable items screening in ES. Neither ES nor DRCR could provide information which reflected the true flow of waste to monitor and track the generation, transportation, treatment and disposal of hazardous wastes.

The effective measures had been taken to overcome the lack of an integral method to track the generation, transport,

treatment and disposal of hazardous wastes. An independent report and register system for hazardous waste generators had been founded to monitor and track how, by whom, as well as what categories of hazardous waste were managed. Moreover, a integrated management system should be improved to tackle every generators and handlers, no matter whether hazardous waste was handled onsite or offsite.

It is necessary to strengthen the cleaner production, reduce the IHW at source, build a classification management system and address the largest quantity of generators, especially for the important sectors and regions, to low down the generation of IHW per generator compared with those in developed countries. It is important to improve the poor implementation effect and enhance management efficiency with a condition of limited administration resources on IHW rules, especially for Guangdong province with a rapid economic growth in industrialization. Additionally, enforcement of law, standards on hazardous waste management and the construction of final disposal facilities to promote the rational flows of hazardous wastes should be strengthened.

Moreover, essential training and education should be carried out to improve the understanding of hazardous waste system and to cultivate the awareness of participants. Generators should ensure that the hazardous waste produced can be properly identified, managed and treated prior to recycling or disposal through special education, publicity and necessary training activities.

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