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Urban garbage disposal and management in China

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Abstract: This paper, probing into the present situation of urban domestic garbage by analyzing its growing trend, compositional change and regional difference, reveals the problems existing in its disposal and management in China. Meanwhile, a questionnaire was conducted in five big cities around China for surveying urban residents' attitudes towards garbage disposal and management policies and measures. Results showed the output of urban domestic garbage in Chinese cities is ever increasing, and the recoverable materials and energy in garbage composition are also increasing. The population growth, economic development, and increase of residents' expenditure level are the main factors influencing the growing output and changing composition of the garbage. Information acquired from the questionnaire showed that majority of the urban residents are in favor of the garbage reduction policies and managerial measures and are willing to collaborate with municipal government in battling against garbage.

Based on the analysis and questionnaire, some policymaking-oriented suggestions such as operating the garbage disposal from a social welfare service to a sector of profit-gaining enterprises, transferring the garbage management from passive end control to active source control, promoting the classified garbage collection in cities around China, and charging garbage fees for its cleanup and disposal, have also been put forward in the paper.

Keywords: urban domestic garbage; garbage collection; garbage disposal; garbage management

Introduction

With rapid social-economic development, the urbanization level in mainland China had gone up to 30.9% by the end of 1999, according to an official estimation (NBS, 2001, through internet inquiry). There are 667 cities in China mainland (NBS, 2001; Department of Comprehensive Financial Affairs, the Ministry of Construction, 2000) and the permanent urban population (in city proper) has reached 455.94 million by the end of October 2000 (NBS, 2001). The urbanization in China is still developing and its increasing speed will surely surpass 1% in the forthcoming 10 years (NBS, 2001).

In the meantime, the living standard of the city dwellers has also increased and the life style changed. This has led to fast increase of annual output of the urban domestic garbage. At present, the average amount of domestic garbage produced per day by an ordinary city dweller is about 1.2 kg in China mainland (PCB-SEPA, 2000). The total amount of domestic garbage cleared up (which means garbage has gone through the whole process of collecting, transporting, and land-filling or incinerating) in all cities in 1999 was 114.15 million tons (DCFA-MC, 2000), and this figure is still increasing at 7% per year (NBS, 2000). All the municipal governments of cities in China are more heavily burdened with the ever-growing output of the urban domestic garbage.

Such problems have also been encountered by many other developing and developed countries and been tackled through improving garbage management, as applying classified garbage collection and mechanical-biological composting (Adani, 2000), economic instruments and more precise garbage fee and levy systems (Buenrostro, 2001; Koathi, 2001), integrated solid waste management (McDougall, 2000) and effective but flexible policies and strict laws to the process of garbage disposal (Bilitewski, 2000; Ebreo, 2000). Those experiences of garbage disposal and management could be referenced by China on the basis of revision for suiting China's national conditions.

This paper, by statistically analyzing growing trend, composition change and regional difference of the urban domestic garbage, reveals the problems existing in the garbage management system and garbage

disposal process in China, and shows the public opinion towards the urban domestic garbage disposal and management through a questionnaire conducted in five big cities around China. Based on the analysis and questionnaire, some policymaking-oriented suggestions have been put forward, to promote urban domestic garbage disposal and management in China.

1 Methods

The statistical data about the urban domestic garbage cited in the paper mainly comes from the Statistical Yearbook of China (1985—2000) and the Statistical Report of Urban Construction in China (1990—1999). Some data are only through general statistic analysis to show the features of output amount, composition and growing trend of the garbage in Chinese cities.

Besides the general statistic analysis, stepwise regression is applied (with software SPSS, ver. 8.0) to analyze the correlation between the output of urban domestic garbage and 3 social-economic indexes including population, gross domestic product (GDP) and annual expenditure per capita. 6 sampling cities in eastern, central and western regions of China have been selected in the regression, representing respectively provincial capital, municipality directly under the Central Government and medium-sized cities. The data of population, economic development level indicated by GDP, and annual expenditure per capita are taken as independent variables and the amount of domestic garbage cleared as dependent variable for calculation. The sampling size is normally 9 to 10 (from 1990 to 1998 or 1999), for the National Bureau of Statistics has calibrated the latest constant price of statistics to the year 1990 (NBS, 1999; 2000).

A questionnaire was conducted among urban residents in five cities (Beijing, Dalian, Shenzhen, Xi'an and Shanghai), to collect the attitudes of the public. The residents sampled in each city are generally primary or middle school students' parents, because they are ordinary people coming from different social strata and can represent the normal status of residents in a city. The questions in the questionnaire are deliberately designed to obtain data of urban residents' opinions and recognition towards the possible garbage disposal and managerial policies, regulations and measures that are implemented or might be implemented in the future. Nearly 2000 questionnaire sheets (accounting to 98% of the total delivered) were retrieved back with about 400 for each city respectively. More than 95% of the questions on the sheets were answered.

2 Status quo and changing trend of the urban domestic garbage

2.1 General situation

In recent years, the quantity of urban domestic garbage collected in China annually has been increasing rapidly. In 1986, the figure was 50.10×10^6 t, and in 1999 it went up to 114.15×10^6 t with an average increasing speed of more than 7% a year (Fig. 1).

Compared with the developed countries, the composition of urban domestic garbage in China had some unique features, such as low combustible contents, low recoverable contents and high coal ash contents (PCB-SEPA, 2000). In other words, the inorganic constituents were higher than the organic constituents, and the non-degradable more than the degradable. The combustion value of the garbage was 226.8 kJ/kg to 3162.6 kJ/kg in early 1990's (PCB-SEPA, 2000). With the improvement of the city dwellers' living standard and the change of their diet, however, especially with the change of household fuel supply from coal to natural gas or liquid petroleum gas or electricity, the garbage composition has changed. The organic contents have increased while the inorganic decreased. The recoverable and retrievable materials like wasted paper, glass, plastics, and metals increased to 30%—40% of the total in later 1990's. Meanwhile, the combustion value surpassed 3500 kJ/kg (PCB-SEPA, 2000).

2.2 Regional difference

Because China is a vast country and its urban development differs from region to region, there are some variances concerning the quantity per head of population and composition of the urban domestic garbage among eastern, central and western cities, though they share many features in common.

2.2.1 Amount and its growth in recent years

The statistic data from 10 typical cities representing eastern (Shenyang, Tianjin, Beijing, Wuxi, Shanghai, and Guangzhou), central (Wuhan), and western (Xining, Xi'an, and Chengdu) cities respectively were chosen to analyze the regional variation (Table 1). The total output increment of urban domestic garbage in those 10 cities in past 9 (10) years (from 1990 to 1998, 1999) amounted to 6.23×10^6 t, with an average annual increase over previous year by 4.4%. And the average increase in western and central regions is higher than that in eastern region, figuring at 7.6%, 5.8% and 3.8% in central, western and eastern respectively. This difference may be reasoned by the different urban development stages to which each city lies. The cities in eastern region where the economy is more booming have already left behind the first high-increase stage of garbage growth characterized by the household fuel supply relying mainly on coal, which produces more solid residues when burning.

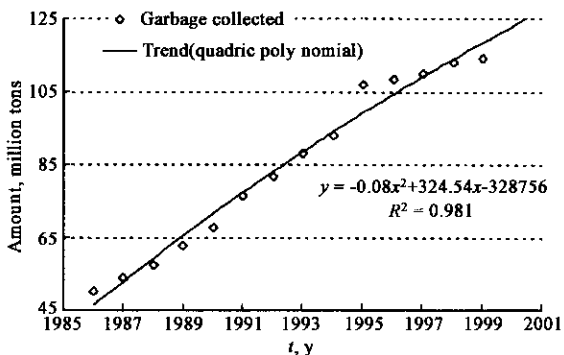


Fig.1 Growing amount of urban domestic garbage in Chinese cities in recent years

Source: National Bureau of Statistics. Statistical yearbook of China (1985—2000).

Table 1 Amount of urban domestic garbage collected in 10 eastern, central and western cities in recent years ($\times 10^6$ t)

Year	Shenyang	Tianjin	Beijing	Wuxi	Shanghai	Guangzhou	Wuhan	Xining	Xi'an	Chengdu	Total	Increase over previous year by (%)
1990	2.02	2.17	3.84	0.34	2.79	1.05	1.42	0.24	0.58	0.62	15.06	
1991	2.09	2.23	3.97	0.33	2.96	1.24	1.33	0.30	0.67	0.66	15.78	4.8
1992	1.97	2.30	4.31	0.34	3.01	1.25	1.44	0.32	0.65	0.71	16.32	3.4
1993	2.03	2.03	4.46	0.34	3.35	1.55	1.55	0.36	0.66	0.77	17.10	4.8
1994	2.08	2.09	4.67	0.30	3.58	1.99	1.65	0.37	0.67	0.83	18.23	6.6
1995	2.33	1.80	4.84	0.38	3.72	1.55	1.66	0.42	0.70	0.88	18.28	0.3
1996	2.33	1.85	4.83	0.31	4.19	1.76	1.87	0.49	0.78	0.92	19.33	5.7
1997	2.28	1.98	4.87	0.39	4.54	1.89	2.19	0.56	0.82	0.92	20.44	5.7
1998	2.20	2.08	4.95	0.32	4.70	2.22	2.23	0.64	0.89	0.93	21.16	3.6
1999	NA	2.11	5.05	0.34	5.00	NA	NA	0.77	0.95	0.93	NA	

Source: 1) National Bureau of Statistics. Statistical Yearbook of China (1991—2000); 2) Department of Comprehensive Financial Affairs, the Ministry of Construction. Statistical Report of Urban Construction in China (1990—1999)

2.2.2 Composition and its change with time

Accompanying the rapid growth in garbage amount in recent years, the composition of the urban domestic garbage has also been changing (Table 2).

From Table 2, we can obtain the followings: (1) The composition of domestic garbage changed with time in all the cities, i.e., the ratio of inorganic contents decreased while the degradable and recoverable materials greatly increased. (2) In the same year, the organic contents, combustible substances and recoverable materials in eastern cities were all higher than those in central and western cities, which meant greater possibilities of recovery uses of wastes for eastern cities. (3) There was a gradient from southeastern to northwestern cities, i.e., the ratio of ash and dust in garbage of southeastern cities was lower than that

of northwestern cities, especially in recent years. This may be due to the different structure of household fuel supply, since coal is still a major energy source in northern China for cooking and for household heating in winter.

Table 2 Composition of the urban domestic garbage and its changes with time in several metropolitan cities in China

Location and city		Year	Materials containing in urban domestic garbage, %					
			Kitchen scraps	Paper, cloth, plastics	Ash and dust	Glass	Metal	Stone
Eastern region (North)	Beijing	1990	24.89	11.46	53.22	3.10	0.09	7.24
		1995	35.96	30.09	10.92	10.20	2.96	9.87
		1998	37.12	32.35	5.64	10.70	3.34	10.23
Eastern region (South)	Shanghai	1995	59.66	9.88	2.29	3.81	0.91	23.43
		1996	58.55	20.78	2.23	4.06	0.68	13.70
	Guangzhou	1991	41.17	5.61	46.34	1.66	0.66	4.57
		1993	45.54	8.57	37.70	2.16	0.69	5.34
		1995	59.59	17.28	18.88	3.16	0.52	10.57
		1997	59.96	27.75	3.86	3.01	0.79	4.63
Central region	Wuhan	1984	15.75	2.98	77.64	0.60	1.55	1.48
		1994	35.50	6.35	43.98	2.60	2.66	7.66
Western region	Xi'an	1996	10.04	23.77	52.21	2.05	1.12	7.10

Source: National Bureau of Statistics. Statistical Yearbook of China (1985—1999)

2.3 Factors influencing the garbage generation, growth, and composition change

It is recognized that the quantity of domestic garbage generated in a city is related to many factors, such as geographical location, population growth, economic development, resident's income and expenditure, household energy supply (fuel structure) and so on. The significance of those factors, however, varies from region to region and from time to time in China. This can be illustrated by the following results of stepwise regression analysis (Table 3).

Table 3 Key factor(s) influencing the output of urban domestic garbage in six sampling cities in China

Location	Key factor(s)		
	Population growth	GDP (gross domestic product)	Annual expenditure per capita
Eastern city	Guangzhou, Shanghai	Shanghai	
Central city	Wuhan		
Western city	Chengdu		Xining, Xi'an

The key factor(s) leading to the ever-growing amount of domestic garbage output differ(s) from city to city. The population growth, however, is commonly on the list of key factor(s) in all eastern, central and western metropolitan cities (Table 3). This means that the population growth may make larger contributions to the increase of garbage quantity, especially in the metropolitan cities (Fig. 2).

As for the inland cities (Xi'an), especially for the medium-sized inland cities (Xining), the ever-growing output of urban domestic garbage is much related to the level of annual expenditure per capita (Fig. 3).

Shanghai, a municipality directly under the Central Government, is the largest metropolitan city in China and somewhat different from others. Its output of urban domestic garbage is much related to both population growth and economic development—indicated by GDP (Fig. 4, Formula (1)).

$$y = 2.057 + 0.03403x_1 + 0.006199x_2 \quad (R^2 = 0.991). \quad (1)$$

Where y is the output of domestic garbage, and x_1 and x_2 represent population and GDP respectively.

Besides those 3 factors, the change of urban residents' life style has also contributed to the higher output of the urban domestic garbage, for the getting-richer residents prefer the "through-away"—ready

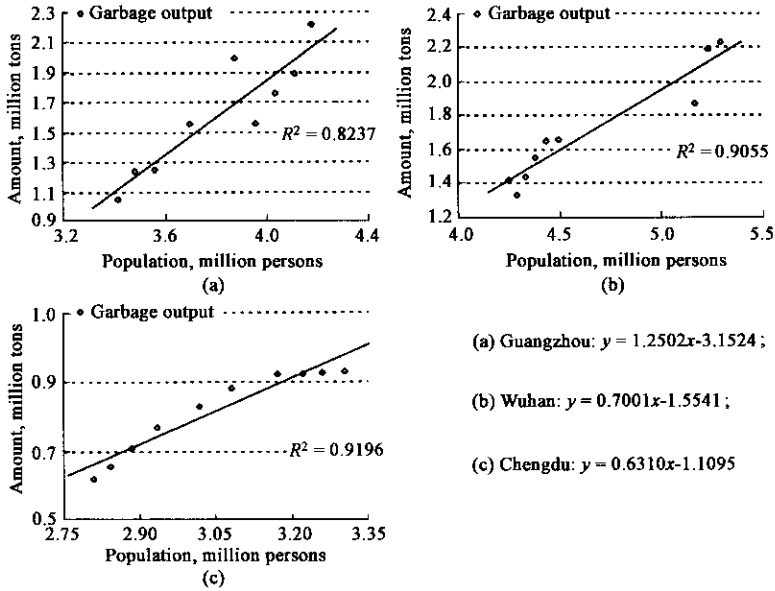


Fig.2 Relationship between population growth and urban domestic garbage collected in certain cities (a) Guangzhou: $y = 1.2502x - 3.1524$; (b) Wuhan: $y = 0.7001x - 1.5541$; (c) Chengdu: $y = 0.6310x - 1.1095$

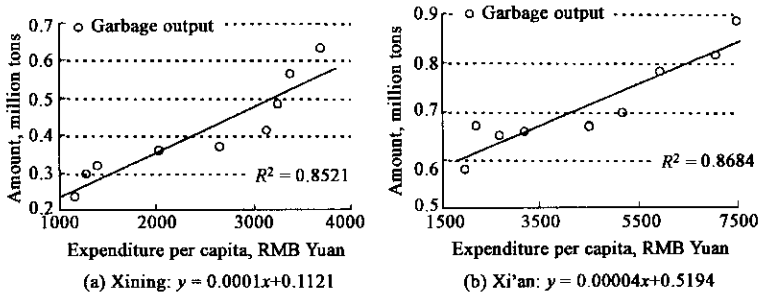


Fig.3 Relationship between the annual expenditure per capita and the output of urban domestic garbage cleared in two inland cities (a) Xining: $y = 0.0001x + 0.1121$; (b) Xi'an: $y = 0.00004x + 0.5194$

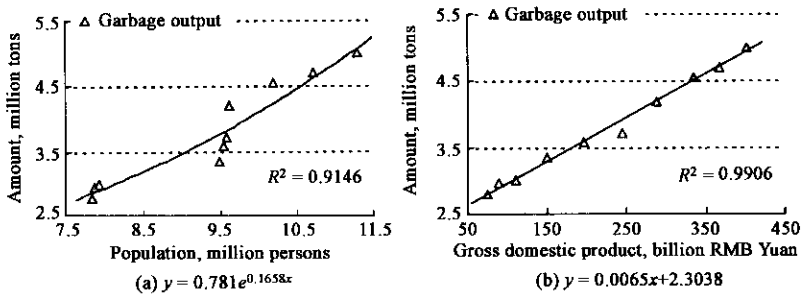


Fig.4 Relationships between population growth and economic development and urban domestic garbage collected in Shanghai City (a) $y = 0.781e^{0.1658x}$; (b) $y = 0.0065x + 2.3038$

disposable—commodities in their easier daily life. A survey conducted by the Bureau of Pollution Control, State Environmental Protection Administration, shows that the higher the income, the greater the production of the domestic garbage (Table 4).

Table 4 Relationship between average daily per person discharge of domestic garbage and annual income per capita in several Chinese cities in 1996

City	Beijing	Tianjin	Shanghai	Shenyang	Dalian	Hangzhou	Shenzhen	Guangzhou	Maanshan	Anshan	Mean
Annual income per capita (RMB Yuan)	9820	7475	10952	5339	8160	8751	14507	12259	7797	5904	9096
Garbage discharge, $\text{kg} \cdot \text{d}^{-1} \cdot \text{psn}^{-1}$	1.20	0.99	1.23	1.02	1.03	0.92	2.62	1.20	0.66	0.76	1.16

Source: Pollution Control Bureau, State Environmental Protection Administration, 2000. Management and disposal technology of urban solid wastes

From the analysis above, we can draw a conclusion that in China, the urban population growth, economic development level indicated by GDP, urban residents' expenditure level and ever-changing life style, are factors leading to the growing output and changing composition of urban domestic garbage.

3 Problems existing in the garbage disposal and management

In China the urban domestic garbage is ever increasing, however, its disposal and management are far from perfect and many problems exist in the disposal and management process.

3.1 Landfill characterized by non-classified garbage collection dominating garbage disposal

At present, the disposal of urban domestic garbage in Chinese cities is characterized by non-classified garbage collection. Over 80% of the garbage output is treated by landfill. Among cities dominated by landfill disposal, some only practice primitive landfill, which often leads to serious leakage and methane emission problem. About 19% of the garbage output goes over the composting, and only about 1% goes through the incineration (in Shenzhen and Chongqing cities; Gao, 2000).

On the basis of the national conditions in China nowadays, the landfill is better than other disposal ways like incineration or composting for its low cost, simple procedure and easy operation. It has, however, several deficiencies such as taking up vast land and causing secondary pollution or even leading to the dangerous explosion. In addition, the selection for new landfill site is getting more and more difficult than before.

This situation is aggravated by the non-classified garbage collection, for classified garbage collection is the first step and central link to garbage reduction and resource recovery. Because there is no classified garbage collection, large quantity of potentially recoverable materials and energy containing in urban domestic garbage is treated as useless wastes and at the same time the municipal government has to continually bear more and more heavy burden of landfill.

3.2 Lack of effective measures for garbage reduction and feasible charging system for garbage discharge and proper disposal

Up to now, the garbage disposal management is still at the stage of end-control system. Although the Environmental Protection Agencies advocate reduction of garbage quantity from generating source (source reduction), there are no practical and effective measures to reduce the household garbage. For example, only a few large cities have begun to charge fees for garbage discharge, but the fee is too low and the charge system is primitive, based not on quantity of garbage discharged by the family, but on the number of people within the family. This is not fair and undoubtedly not conducive to the garbage reduction.

3.3 Lack of effective management for garbage resource recovery (material reclamation and energy recycling)

The material reclamation and energy recycling to garbage disposal are in a stage of nearly unmanaged condition, which not only results in massive waste of various resources containing in domestic garbage, but also in low quality and thus sluggish market of reborn products made from garbage materials.

Taking the products in one of the garbage composting disposal plants as an example, because of non-classified collection before the raw garbage material was transported to the plant for composting, the shares of the inorganic matter and non-degradable organic matter were high in raw garbage materials. This led to a poor fertilizer produced by composting with high percentages of glass, plastics and metals that were harmful to farmland soil, and to the low quality products could not find a market, and finally caused the bankruptcy of the enterprise.

From the description above, we know in China there is an urgent need of formulating a series of policies for garbage management and measures for garbage disposal.

4 Public opinions towards the urban domestic garbage disposal and management

To formulate a set of rational and effective managerial policies and measures for urban domestic garbage disposal, public opinions should be understood and considered, for they are the basis of successful public policy formulation and implementation.

Every one of the urban residents discharges garbage and thus the managerial measures of urban domestic garbage must be approved, supported and coordinated by all residents. Only in this way can the measures be feasible.

To understand the residents' opinions, a questionnaire has been conducted and the following are the results of the questionnaire.

4.1 Recognition toward the classified garbage collection

Majority of the people approves of the classified garbage collection (Table 5). On an average 85% of the residents understand the significance of classified garbage collection and are willing to classify their daily domestic garbage before sending it to collection place. But only 61% on the average are willing to practice classified garbage collection in their own house. This figure of recognition among residents in Beijing is higher than that in other cities on the average.

Table 5 Recognition of residents towards the classified garbage collection

Questions	Answer of "Yes", %					Average
	Beijing	Dalian	Shenzhen	Xi'an	Shanghai	
Are you willing to dump up the garbage in classified way?	91	78	84	91	80	85
Do you know the significance of classified garbage collection?	91	80	79	81	90	85
Are you willing to practice the classified garbage collection in your own house?	67	56	62	65	57	61

4.2 Garbage fee

The majority of the residents approve of charging fees for garbage cleanup and disposal services (Table 6). Only 59% of the residents, however, have heard of charging fees for garbage discharge before. When asked how much would be bearable for them to pay for garbage discharge per month, over 94% of the residents answered "one" and more than 60% "two" in RMB Yuan respectively.

4.3 Charging for shopping bag and pledge for wrapping bottles/boxes

As for charging fees for shopping bag, parts of the answers are given in Table 7.

The results showed that the rate of residents who are willing to bring shopping bag with them when they go shopping is not high, though most of residents know the plastic shopping bag is doing harm to the environment. The reasons for this phenomenon might be on one hand it is inconvenient to bring a bag, and on the other hand the plastic shopping bags are free of charge in most supermarkets at present. If there is

a regulation that the shopping bag must be purchased while shopping, the results will be much different (Fig. 5).

Table 6 Recognition of residents towards charging fee for garbage disposal services

Questions	Answer of "Yes", %					Average
	Beijing	Dalian	Shenzhen	Xi'an	Shanghai	
Do you agree to charging garbage fee?	76	90	79	86	66	79
Have you heard of charging fees for garbage cleanup and disposal services?	62	58	65	53	56	59

Table 7 Recognition of residents towards bringing their own shopping bag when go shopping

Questions	Answer of "Yes", %					Average
	Beijing	Dalian	Shenzhen	Xi'an	Shanghai	
Are you willing to bring shopping bag with you when you go shopping?	53	40	15	41	26	35
Do you know the harmful effects of plastic bags?	96	92	89	93	90	92
Do you know it's not conducive to environmental protection using one-off packaging materials?	96	88	87	95	93	92

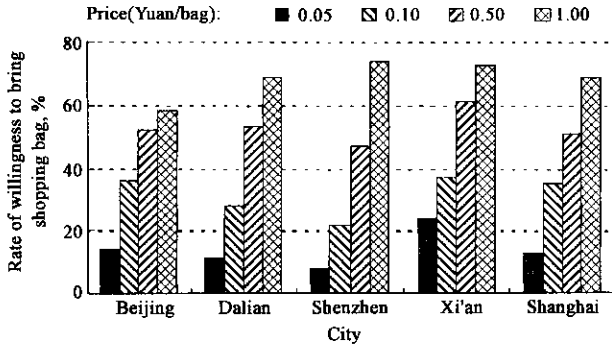


Fig. 5 Rate of residents who are willing to bring their own shopping bag when go shopping under different fee standards

Besides, the Table 7 shows that over 80% of the residents know the harmful effect of one-off (throw-away) packaging materials. But only when the cash pledge for reclaiming bottles/boxes is high enough, would the people like to return the empty bottles/boxes. And the higher the price of pledge is, the higher the rate of residents who are willing to return the bottles/boxes is (Fig. 6).

From the results above mentioned, charging shopping bag fee with a reasonable price and practicing pledge system at a certain level will exert positive influences on

the garbage reduction.

4.4 Salvage collection

The salvage collection in China has been practiced for many years. The residents sell their old, worn out, or used books, newspaper, household utensils, appliances, furniture, etc., that contain recoverable and reclaimable materials and energy such as metals, wood, glass, paper, cloth and plastics to the salvage collection station, and get some money back. This is undoubtedly a good way to reduce garbage and thus abate garbage disposal burden, and to recover the useful resources (both material and energy) in garbage. The rate of residents who practice salvage collection, from the questionnaire, however, is not satisfactory, especially in cities where

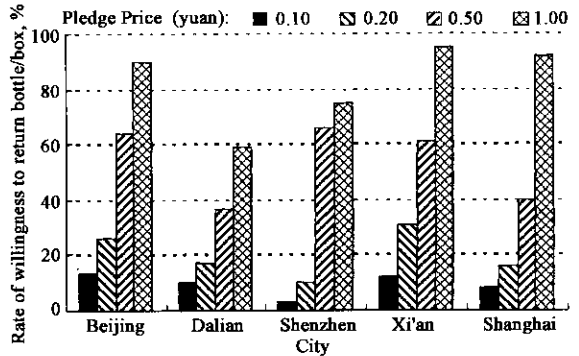


Fig. 6 Rate of residents who are willing to return wrapping bottle/box under different cash pledge standards

the economy is booming (Table 8).

Table 8 Attitude of residents towards salvage collection

Questions	Answer of "Yes", %					Average
	Beijing	Dalian	Shenzhen	Xi'an	Shanghai	
Do you practice salvage collection (selling your household "wastes", such as old utensils, used paper, ... to salvage collection station)?	83	47	26	82	63	60.2
	No time					
	23	28	37	27	31	29.2
If not, what is the main reason?	Service inconvenient					
	21	24	40	18	12	23.0
	Price low					
	17	14	14	19	17	16.2

The reasons for not practicing salvage collection among residents are various. But if the service is more available and convenient and/or the price is higher enough, the situation may be much changed.

Those preliminary conclusions above indicated that in different cities there should be different policies for garbage disposal management. The policies and measures should be suitable for the local conditions and living standard. When we apply the economic instruments to the garbage disposal practice to raise the efficiency of the garbage management and to improve the garbage disposal services, we should distinguish the different economic development stages in different areas and charge different fee standards accordingly. The personal income in Shenzhen and Shanghai is higher than that in other cities, for example, thus the residents there can bear a comparatively higher fee on garbage collection and disposal. Or we may say that they should get more and better garbage cleanup and disposal services.

5 Policy and regulation formulation suggestions for garbage disposal and management

China has begun to reform its centralized planning economy so as to adopt market economy in the past few years. With this reformation, the urban domestic garbage disposal and management are also subjected to change and new policies and regulations should be formulated.

Based on the conclusions of analyses in above sections, here we put forward a few policymaking-oriented suggestions for solving the disposal and managerial problems towards urban domestic garbage.

(1) Operating the garbage disposal process (garbage reduction, resource recovery and energy recycling) as an industrial sector, and changing the managerial system of garbage disposal from the social welfare services capitalized by government to the free enterprises gaining profit by charging fees from the residents receiving the garbage cleanup and disposal services.

(2) Transferring the strategy of garbage management from passive end control to the active source control and whole course of management—an integration of garbage reduction, resource recovery and hazardous-free disposal.

(3) Promoting the classified garbage collection and stipulating strict timetable for its implementation in as many as cities around China. This policy can be understood by and get strong support from majority of the residents in all cities around China. Providing convenient facilities and services around residential areas for residents' easily dumping classified domestic garbage without taking up much limited household space, and providing equipment and machinery for follow-up classified transportation, classified treatment and classified resource recovery are the keys to guaranteeing the success of classified garbage collection.

(4) Applying economic instruments to the garbage reduction practice. Charging garbage fee for services of cleanup and disposal, for example, is an effective environmental management measure of internality of external diseconomy, and is a common practice for garbage management in many countries (Scheffold, 1993). The garbage fee can control the garbage discharge amount through its economic function on one hand and can raise partial funds for garbage treatment on the other hand.

It can also promote the resource recovery and material reclamation. The garbage fees should be graded and charged according not to the family or the number of people in a family, but to the amount (weight or volume) of garbage discharged by that particular family. This is essential for the garbage reduction. Meanwhile, different cities should charge different graded fees based on their average personal incomes.

(5) Implementing pledge system for reclaiming packaging bottles/boxes and charging shopping bag fees, to reduce plastics pollution and promote the recycling use of packaging materials. The prices for bottle/box pledge and for shopping bags should be high enough not only to balance their cost but also to raise customers' interest in redeeming the pledge.

(6) Enhancing the salvage collection system. Providing more convenient services, such as increasing the number of salvage collection stations, establishing salvage collection nets, serving resident customers at regular time and place and even to the doorsteps, may improve the effects of salvage collection and raise the rate of resource recovery from garbage.

Meanwhile, there must be as many as drop-off centers, material reclamation facilities (MRFs), and waste-to-energy (WTE) techniques for supporting the implementation of those suggestions.

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