

IDENTIFYING THE LOCATION AND DISTRIBUTION OF THE OPEN-AIR DUMPS OF SOLID WASTES USING REMOTE SENSING TECHNIQUE

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ABSTRACT:

Due to urbanization increasing, poor planning, lack of financial support and etc, it results in the poor state of municipal solid wastes management in most cities, especially in developing countries. A mass of solid wastes are dumped in the open air without effective environmental conservation measures, which leads to some open-air solid wastes dumps. Management of these dumps is one of the most crucial environmental problems which municipal governors concerns in Beijing. BJ-1 Micro-satellite is a new and advanced member of the Disaster Monitoring Constellation (DMC). It carries double powerful sensors onboard with high resolution, high frequency and multiple spectrums. Via establishing interpretation keys of open-air solid waste dumps, this paper introduces the method to detecting the location of the open-air solid waste dumps in Beijing based on BJ-1 image. By analyzing the results, some distribution characteristics of the dumps have been found. And combining with some statistical data, it also finds that the output and distribution of solid wastes has correlation with the quantity and density of the permanent population. Through this study, it shows that BJ-1 micro-satellite remote sensing images can provide an important support to the open-air solid waste dumps management, and it has potential to reduce the operational costs, so it can meet the challenges of the solid waste management agenda in the near future.

1. INTRODUCTION

Increasing industrialization and urbanization result in environmental pollution and resource scarcity, especially the poor state of municipal solid wastes management in many cities in the world, particularly in developing countries (Xi J Q, Jiang H H, et al., 2003). Beijing, where the 29th Olympic Games will be held in 2008, is also confronted with this problem and should be paid much more attention.

Solid waste is the solid or slurry matter which has been extracted the useful components in the process of manufacture, consumption or daily life. The solid wastes in Beijing are mainly composed of industrial solid waste, construction garbage, household waste, dejecta and so on. A large amount of them are disposed harmlessly through sanitary landfills, composting or incineration. However, about 20% of them are still dumped indiscriminately in the stone pit, kiln pit, low-lying valley in the open air, or even stacked directly on the surface of the wasteland or farmland, without any environmental conservation measures. These solid wastes form the open-air solid waste dumps which not only occupy a large amount of fields but also have tremendous influences on ecosystem and human settlements environment. Therefore, management of these open-air dumps has become one of the most critical environmental problems which the municipal government is concerned about (He H Y, 2005).

To minimize the influence of open-air solid waste dumps on environment, some effective measures have been taken, but there are still some alternative solutions should be considered. First of all, the primary task is to identify, in both quantitatively

and qualitatively, the location of open-air dumps of solid wastes. However, these dumps are distributed randomly and their location changes quickly. Thus, the traditional field-investigation method costs a lot of time, labor and money, and moreover, it can hardly follow the change of solid wastes. In contrast, remote sensing technique can provide a rapid and effective way to detect these dumps, owing to its characteristics of objectivity, real-time and macro-scope view.

The use of remote sensing for detecting solid wastes has been documented in some previous studies, but most of them are based on aerial photographs which are costly and can only be produced at a low frequency (one time a years)(S. Bagheri and R. M. Hordon, 1988; Zhou Z J, Wei W X, et al, 1991; Yang Z G, 1992; Zhao Z C, Liu W, et al, 2000; Zhao J, Zang K, et al, 2005.). In year of 2000, Wu Wenwei and Liu Jing *et al.* investigated the distribution of open-air solid waste dumps within the 5th Ring Road in Beijing based on aerial photographs (Wu W W, Liu J, 2000). In the same way, with the aid of aerial photographs, Beijing Environmental Protection Bureau and Geological Engineering Investigation Institute of Beijing Geological Prospecting Bureau accomplished the risk report on pollution of landfill sites of municipal solid waste in Beijing in March, 2005 (He H Y, 2005). Traditionally, the satellite remote sensing data such as Landsat TM can support the location selection for solid waste disposal sites and the assessment of potential environmental impacts (Guo Y L, 2001; Yaw A. Twumasi, et al; Y. Kwarteng, A. Al-Enezi, 2005a), but they can not identify the small scale variations owing to the limitation of spatial resolution and temporal frequency of the sensor. There is a study on monitoring of solid waste based on Spot 5 images,

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but it only aimed to the garbage landfill (Jia L, Zhao Y S, et al, 2005). Thus, there are scarcely any referred studies on solid waste dumps detection by satellite remote sensing.

BJ-1 Microsatellite (Beijing Landview Mapping Information Technology Co. Ltd, 2007) of China carries double sensors onboard; one is the Multi-spectral sensor with 32 meters resolution, and the other is the Pan sensor with 4 meters resolution. The wavelength range and spatial resolution of each band is shown in table 1. The satellite revisits a location at a high frequency—every three or four days—and the coverage width of multi-spectral image is 600km. Hence, using its data to investigate the open-air dumps of solid wastes, it will be more efficient, more accurate and lower costly than aerial remote sensing or traditional field surveys. Taking the flat plain area in Beijing as the study area, this paper puts forward the methodology of identifying the locations of open-air dumps of solid wastes based on BJ-1 images and analyzing their distribution characteristics.

Band	Wavelength range (nm)	Spatial resolution (m)
Green	523~605	32
Red	630~690	32
Near Infra-Red	774~900	32
Pan	500~800	4

Table 1. Technical parameters of BJ-1 sensors

2. DATA AND METHODOLOGY

The spectral signature of solid wastes is very complex owing to their complex components. Besides, the degree of freshness also affects their spectral signatures. Thus, it's hard to identify the open-air solid waste dumps automatically. The human-computer interactive interpretation method is adopted in this paper. In figure 1, it shows the workflow of identifying the location and analyzing the distribution of the open-air dumps of solid wastes.

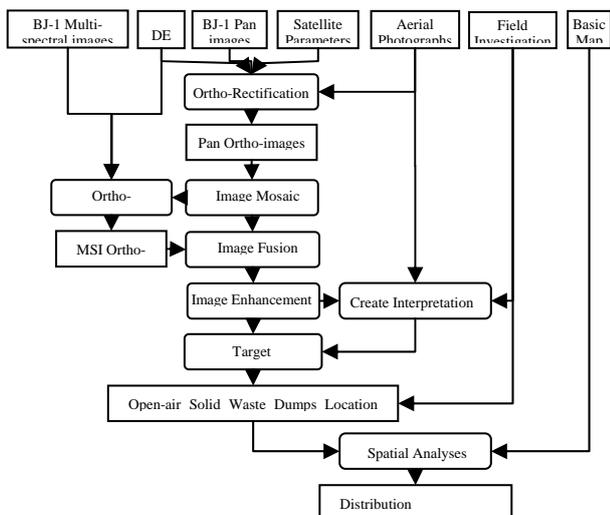


Figure 1. The workflow of identification of the location and distribution of the open-air dumps of solid wastes

2.1 Data and processing

In this paper, we use three BJ-1 panchromatic images, mosaic of which can cover all of Beijing plain area, and one multi-spectral image acquired in spring 2007. Aerial photographs acquired in 2005 are also needed to complete the geometric correction with BJ-1 images and assist to set interpretation keys. To do ortho-rectification, DEM (Digital Elevation Model) of study area is required. For solid waste dumps distribution analysis, some basic maps, such as administrative boundary, land use map and so on, should be prepared.

Before interpretation keys setting and target identification, images pre-processing is needed. The pre-processing includes geometric correction to remove the geometric aberrance and match with the thematic map, such as administrative boundary; radiometric correction to remove the aberrance or distortion of radiation, ortho-rectification to remove the influence of elevation. According to comparison among three different images fusion methods: PCA (Principal Component Analysis), HIS (Hue Intensity Saturation) transform and Brovey, we select Brovey as the optimal method to do images fusion with multi-spectral and panchromatic high resolution images to enhance the resolution of composite images. Using the fusion images of BJ-1, which are displayed as false-color composites with bands as follows: near infra-red band for red, red band for green and green band for blue and later enhanced using histogram extension techniques, we can identify the locations of solid waste dumps by human-computer interactive interpretation.

2.2 Methodology

According to the image features including spectral features, spatial features and temporal features of the open-air dumps of solid wastes, via field investigation and survey, a set of typical interpretation keys of open-air solid waste dumps in BJ-1 image have been summarized as follows.

- (1) Spectral features: including tone and color

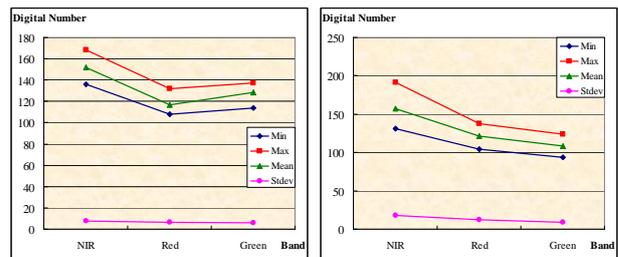


Figure 2. The digital number curves of two typical open-air solid waste dumps

Being composed of different kinds of solid waste, the open-air solid waste dumps always display ambiguous spectral signature. In figure 2, it shows the signature curves of two typical open-air solid waste dumps. It can be seen that the digital numbers vary a lot and have no uniform range in all the three bands. The color of dumps in BJ-1 images is commonly not symmetrical. They are generally in offwhite or white and sometimes mixed with brown spots. The tone changes randomly and the bright and dark appear alternately and unsymmetrical. When there are vegetation covered with the dumps, because the near infra-red band has strong reflects feature, some parts the dumps will be in red or dark red depending on the vegetations fraction. However, the distribution of red is always disordered since the

distribution of vegetation is not regular. When the dumps are only covered by wastes or soil, they will present offwhite or yellow or cyan, their typical images are shown in figure 3.



Figure 3. The images of some typical solid waste dumps

(2) Spatial features: including shape, size, texture, and location (Sun Z, Su S D, Yi J F, 2006)

The shape of open-air solid waste dumps is commonly irregular and has no clear boundary with the surrounding objects. In addition, sometimes they have shadows and each of them presents as many accidented hillocks owing to the height inside varies.

Texture is another important factor that can be used to identify the targets because it indicates important information of spatial change. The texture of solid waste dumps is currently rough.

Location shows the relationship between the objects and their surrounding environment. Since the distribution of solid waste dumps is affected by many factors of city in both space and time, it's an important means to determine whether the object is an open-air solid waste dump or not based on its location. In central urban area where the density of population and building is very high, there scarcely locates any large-scale open-air solid waste dumps. In contrast, there are often some solid waste dumps surrounding the residential areas in the suburb counties far from the downtown, especially in the pits located by side of villages. They are always far from the main roads, but there are still some bypaths that can reach them and the bypaths usually end by the dumps. Sometimes, there are some small bypaths inside the solid waste dumps which occupy a large area.

(3) Temporal features

The interpretation keys vary with time. In spring image, due to the vegetation covered the surface of dumps, there are some red spots in different areas due to the vegetation fraction; in contrast, in winter image, the same regions are offwhite or yellow. Hence, it should be analyzed carefully when interpreted.

Based on the interpretation keys above mentioned, the locations of the solid wastes dumps in the flat plain area of Beijing have been identified from BJ-1 images. Then, some verification in the field has been done with the aid of GPS to correct some mistakes and omissions. The location map of open-air dumps of solid wastes was then produced. Using field sampling investigation, the precision of interpretation can be evaluated. The sampling method adopted is stratified sampling which means selecting the typical samples from the asymmetric objects. Comparing with the field investigation, this study shows high accuracy (90.3%) of the indoor interpretation results using Beijing-1 images.

Utilizing the location map of solid waste dumps, we did some analysis with the above map and some background maps. We

overlaid the location map with the map of administrative boundary, land use, watershed and transportation and then used GIS with some statistical data to perform some spatial analysis.

3. ANALYSIS AND DISCUSSION

3.1 Results analysis

Through analysis process mentioned above, some distribution characteristics of the dumps of open-air solid waste are presented as follows.

(1) There are few large-scale dumps of solid waste within the core districts of capital function (including Dongcheng, Xicheng, Chongwen and Xuanwu); there are some in the ecological preservation development districts (including Mentougou, Huairou, Pinggu, Miyun, Yanqing); there are more in the urban function extended districts which can also be called urban-rural fringe (including Haidian, Chaoyang, Fengtai and Shijingshan), in particularly in districts of Haidian and Chaoyang; there are most in the new districts of urban development (including Tongzhou, Shunyi, Daxing, Changping and Fangshan), especially in Daxing, Shunyi and Tongzhou.

This distribution characteristic is associated with the regional economy development level, and whether or not under the regular municipal management. The primary activities performed in the core districts of capital function are trade, administration, medical treatment, finance and etc. Thus, the solid wastes in these districts are mostly household wastes. However, since these districts are the key management areas of Beijing and represent the figure of the capital of China, environmental protection is done very well, so there are hardly any poor hygiene condition areas.

On the contrary, in the suburb counties far from the downtown, especially in the districts where newly-developed industry are arisen, such as Shunyi, Tongzhou and Daxing, the development of industry produces more industry solid wastes and promote the development of construction at the same time which results in more construction solid wastes. Besides, since the solid waste disposal facilities can not meet the need in the central urban and urban-rural fringe area, a great deal of solid wastes in those areas will easily be transported to the suburb area and be piled up, and it will increase the degree of severity of solid wastes condition.

In the urban-rural fringe, economy and society is developing rapidly and there have been developed a great deal of newly-commercial function areas, residential areas, and culture-education occupation areas. In addition, the population there are increasing quickly. Owing to strong economic power and speedy development of many aspects in these regions, the production of solid waste is very high. As it was recorded in Beijing Statistical Yearbook 1997, the solid wastes produced only in Haidian and Chaoyang can occupy 37% of total amount in all the 18 districts in Beijing and 72.7% of total amount in the suburb. Nevertheless, there distributes the great mass of tourism areas, such as the Summer Palace and the Winter Palace, and Olympic venues. As a result, these districts are the key areas of environmental pollution treatment. Besides, as there are sanitary landfills or other kind of solid waste disposal facilities, the condition of solid wastes there is much better than in the suburb counties far from the downtown.

(2)The open-air solid waste dumps are distributed in ring-shaped or zonal arrangement. Some of them, mainly consisting of construction wastes, are located on both sides of the five large rivers, including Qing River, Sha River, Yongding River, Wenyu River and Liangshui River. A majority of these solid wastes are directly poured into rivers and at some parts the rivers are becoming increasingly narrow and even have been blocked, which have affected the quality of water in the rivers badly. Fortunately, Beijing is in the preparing stage of Olympic Games at present and the harness of river is an important aspect of work and the departments concerned have taken some active countermeasures to solve this problem.

Similarly, the open-air solid waste dumps are distributed in typical zonal arrangement on both sides of the main roads, in particular the 5th Ring Road.

Most dumps are distributed circlewise and radially outside the downtown; their density increases from the 4th Ring Road out to the 6th Ring Road, but then decreases outside the 6th Ring Road.

(3)There are more dumps around the residential areas and waste-recycling collection stations, but less inner the residential areas. In the urban-rural fringe and suburb counties far from the downtown, the situation is similar. There is rarely large-scale solid waste dumps inner the villages, but in the tunnels circumjacent villages there are always stacking abundant solid wastes. The solid wastes there are mainly composed of household garbage and a small part of construction garbage.

(4) The solid waste dumps are found mostly in the north-eastern, eastern, south-eastern, southern and south-western areas. This phenomenon is in accordance with the plan of “move to east, extend to south” for manufacturing spatial distribution which was announced in Industry Development Programming of Beijing in the national priority 11th five-year plan by Beijing Municipal Bureau of Industrial Investment and Beijing Municipal Development and Reform Commission in December 2006. The idea in the plan is constructing the manufactory-industry zone in the southeast and moving the barycentre of the city to the east based on the development of District of Shunyi, Tongzhou and Yizhuang in Daxing District.

The production and distribution of the open-air dumps of solid wastes are related to the industrial structure and layout, input and output of the main industries. There are more dumps in the eastern and south-eastern regions while more input and output of industries there, conversely in the western and north-western regions.

(5)In year of 2000, Wu Wenwei and Liu Jing *et al.* (Wu W W, Liu J, 2000) investigated the distribution of open-air solid waste dumps in Beijing in 1987 and 1997 based on aerial photographs. In comparing results in this paper with previous data, which are shown in table 2, some trends are found: the status of solid wastes dumps surrounding the urban area has been improved obviously, the density of dumps has become lower, and the high density area has been transferred to the outside of the 4th Ring Road.

Referred to the website of Beijing Statistical Bureau, some social statistical data have been obtained. Utilizing these data, some further analysis about solid wastes and solid waste dumps distribution can be done. The total permanent population in Beijing from 2003 to 2006 is displayed in Table 3, while the

volume of solid waste and capacity of harmless disposal of garbage is shown in Table 4.

Location	Within 3 rd Ring Road			Between 3 rd and 4 th Ring Road			Between 4 th and 5 th Ring Road		
	1987	1997	2007	1987	1997	2007	1987	1997	2007
Number	87	0	4	406	64	15	1476	187	135

Table 2. The number of open-air solid waste dumps distributed within the 5th Ring Roads during the last 20 years

Year	2003	2004	2005	2006
Permanent Population (10000 persons)	1456.4	1492.7	1538	1581

Table 3. Permanent Population in Beijing

Year	2003	2004	2005	2006
Output of Solid Waste (10000 tons)	299.2	496	537	538
Capacity of Harmless Disposal of Solid Waste (ton/day)	3500	9850	10350	10350
Volume of Harmless Disposal of Solid Waste (10000 tons)		393	436	497.7
Rate of Harmless Disposal of Solid Waste (%)		79.3	81.2	92.5

Table 4. Municipal Environment and Sanitation

As it is shown in table 3 and table 4, the relationship of solid waste and social statistical data can be found out. There is a significant positive correlation between output of solid waste and permanent population. The total permanent population has been increased from 14.564 million to 15.810 million, while the output of solid waste has been correspondingly increased from 2.992 million tons to 5.38 million tons from 2003 to 2006. Figure 4 shows the correlation between output of solid waste and permanent population and the correlation coefficient R is 0.84.

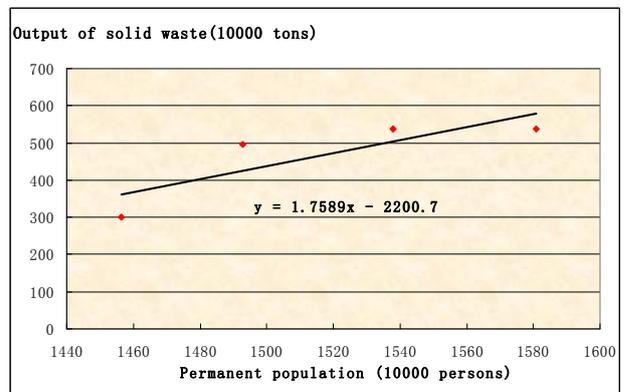


Figure 4. Correlation between output of solid waste and permanent population in Beijing

Nevertheless, the number of open-air solid waste dumps is related to not only the output of solid waste but also the volume of harmless disposal of solid waste. From table 4, we can know that the output of solid waste in Beijing was 3500 ton per day in 2003 and rose to 10350 ton per day in 2006. The rate of harmless disposal of solid waste has been improved from less than 80 percent to 92.5 percent. As a result, the amount of solid waste which is not harmless disposal has not added but reduced significantly though the output of solid waste has increased by nearly 100 percent.

Analyzing the permanent population density in each district in Beijing in 2006 which is shown in table 5, we can find another characteristic of the open-air solid waste dumps distribution. The number of open-air solid waste dumps has positive correlation with permanent population density. Except the central district of capital function where the environmental management is well done, the highest permanent population density locates in urban function extended districts where there are many solid waste dumps. In the new districts of urban development, this phenomenon is more obvious. In Tongzhou, Daxing and Shunyi, the population density is higher than that in Fangshan, while the solid waste dumps in these districts are much more. In the ecological preservation development districts, the population density is generally low and the solid waste dumps there are correspondingly less.

District	Land Area (sq.km)	Permanent Population Density (person/sq.km)
Total	16410.54	963
Core Districts of Capital Function	92.39	22308
Dongcheng	25.34	21744
Xicheng	31.62	21063
Chongwen	16.52	18220
Xuanwu	18.91	28715
Urban Function Extended Districts	1275.93	6063
Chaoyang	455.08	6397
Fengtai	305.80	5284
Shijingshan	84.32	6191
Haidian	430.73	6238
New Districts of Urban Development	6295.57	675
Fangshan	1989.54	445
Tongzhou	906.28	988
Shunyi	1019.89	704
Changping	1343.54	617
Daxing	1036.32	887
Ecological Preservation Development Districts	8746.65	202
Mentougou	1450.70	191
Huairou	2122.62	155
Pinggu	950.13	445
Miyun	2229.45	202
Yanqing	1993.75	143

Table 5. Permanent population density in each district

3.2 Discussion

From what has been discussed above, we can forecast the volume of solid waste piled indiscriminately as long as we know the permanent population and the capacity of harmless disposal of solid waste. Furthermore, if we have the information of permanent population density, we can also estimate the distribution of open-air solid waste dumps. This information is very useful for solid wastes management and comprehensive disposal them. Of course, the distribution of open-air solid waste dumps still has relationship with some other factors and we should make all things considered.

4. CONCLUSIONS

To ensure a successful Olympic Games in 2008 in Beijing, the Beijing Municipal Government has established the "Action Plan for Beijing Olympic Games" pointing out to deal with the solid wastes synthetically before the Olympic Games. By using BJ-1 micro-satellite remote sensing images, this paper put forward the methodology of identifying the locations of open-air dumps of solid waste, and analyzes the distribution characteristics of the dumps. Due to the limitation of spatial resolution, some high resolution images should be used to identify the dumps in further study in order to improve the accuracy of location identification.

Via this study, some important information, such as the amount and spatial distribution characteristic of open-air dumps of solid waste in Beijing has been extracted during a short time. The results have been adopted by Beijing Municipal Administration Commission. This study shows that remote sensing is feasible to monitor open-air dumps of solid waste, and moreover, it has potential to provide update of the database for establishment of the information management system for comprehensive management of the municipal solid wastes in order to help their management efficiently.

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