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Environmental monitoring and fuzzy synthetic evaluation of municipal solid waste transfer stations in Beijing in 2001–2006

LI Chunping[1], LI Guoxue[1,*], LUO Yiming[1], LI Yanfu[2], HUANG Jian[3]

1. *College of Resource and Environment Science, China Agriculture University, Beijing 100094, China. E-mail: lichp-xj@163.com*
2. *Beijing Solid Waste Administration Department, Beijing 100067, China*
3. *Institute of Desert Meteorology, China Meteorological Administration, Urumqi 830002, China*

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Abstract

Transfer station (TS) is an integral part of present-day municipal solid waste (MSW) management systems. To provide information for the incorporation of waste facilities within the current integrated waste management system, the authors measured the existing environmental quality at five MSW TSs. Discharged wastewater, air, and noise were monitored and assayed at the five TSs in Beijing in 2001–2006 during rainy seasons (RSs) and dry seasons (DSs). Except Ammonia (NH_3) and hydrogen sulfide (H_2S), the analytical results of total suspended particles (TSPs), odor, noise, ammonium nitrogen (NH_4^+-N), chemical oxygen demand (COD_{Cr}), biochemical oxygen demand (BOD_5), suspended solid (SS), and fecal coliform concentrations were all degree-varied higher than the criteria limit in China. Using fuzzy mathematics, the environmental quality of MSW TSs in Beijing was classified into five categories, with levels of certainty of belonging to different categories and evaluations. The result indicated that the whole environmental quality of Datun TS, Majialou TS, and Xiaowuji TS, in Beijing, were bad during 2001–2006 in RSs and DSs. Except in 2002, the entire environmental quality of the Wuluju TS during 2001–2006 in RSs was poor. Only in the DSs of 2002 and 2003 was the whole environmental quality of the Wuluju TS good. The whole environmental quality of the Yamenkou TS during 2001–2006 in DSs was bad, which was lower than that of 2001–2006 DSs.

Key words: municipal solid waste (MSW); transfer stations (TSs); pollutant monitoring; environmental quality; fuzzy mathematics

Introduction

Transfer stations (TSs) play an important role in a community waste management system, serving as a link between a community solid-waste collection scheme and the final waste disposal facilities, such as, landfills, incinerators, material recovery facilities, and recycling plants (Tzipi *et al*., 2007).

Because the collection system in Beijing is a commingled gathering operation, massive biodegradable materials have been embedded in municipal solid waste (MSW), when the MSW is collected, stored, and transferred before being disposed. Harmful or toxic gases can be inevitably emitted from such biodegradable materials during natural biodegradation or from the collecting stream (Birnbaum, 1994; Lindberg and Price, 1999; Mutasen *et al*., 1997; Nixon and Murphy, 1998), not only threatening the health of the people nearby (Bunger *et al*., 2000), but also affecting their immediate surroundings. A necessary step of action planning must be urgently taken to assess the environmental quality of each waste site of the TS according to its proximity to the inhabited area (Massam, 1991). Many studies either have assessed the ambient air quality at landfills and incineration sites (Boudet *et al*., 1999; Eickman, 1993; Manca *et al*., 1997; Meneses *et al*., 2004), or have assessed economic feature of MSW TSs (Chang and Lin, 1997; Kirca and Erkip, 1988; Rahman and Kuby, 1995; Tzipi *et al*., 2007), however, there are few researches with regard to the existing environmental quality of TS. This study was an attempt to conduct a fuzzy synthetic evaluation of the environmental quality of the TSs, aiming at incorporating environmental factor into a decision-making process in the future.

1 Description of the study area

1.1 Description of area location

There are five waste TSs in Beijing MSW facilities at present: Xiaowuji TS, Datun TS, Majialou TS, Wuluju TS, and Yamenkou TS, respectively, located in Chaoyang District, Fengtai District, Haidian District, and Shijingshan District. Basically, all the locations are close to the Fourth Ring Road in Beijing municipality. The location of the eight districts in Beijing municipality, together with the waste TSs they offer, can be seen in Fig.1.

* Corresponding author. E-mail: ligx@cau.edu.cn.

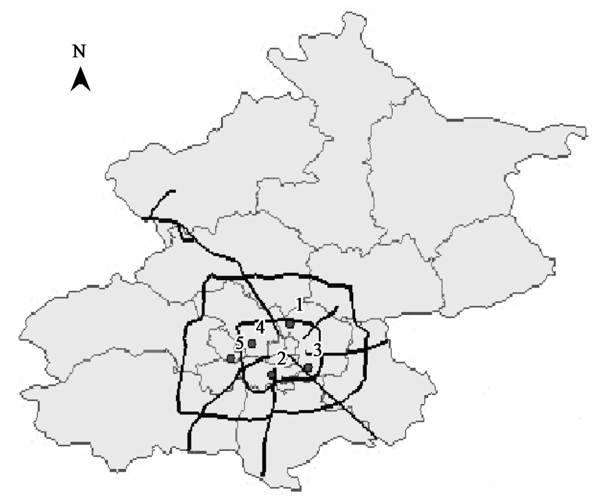

Fig. 1 Location of the five waste transfer stations (TSs) in Beijing. (1) Datun TS; (2) Majialou TS; (3) Xiaowuji TS; (4) Wuluju TS; (5) Yamenkou TS.

1.2 Description of the construction mode

Table 1 shows the designing mode, as well as the operating year and the characteristics of the process for each waste TS.

2 Materials and methods

2.1 Sample collection

The first sample collection was carried out in early August, which was rainy season (RS) in Beijing. The second was conducted in April, which was dry season (DS) in Beijing.

Monthly composite gas samples were collected twice at every upwind and downwind directions, according to Ambient Air Quality Standard (Chinese National Criteria, GB3095-1996).

Both seasonally discharged wastewater samples were tested manually at each monitoring station in 2001–2006. Samples were taken, stored, and analyzed for a wide range of biochemical, chemical, and physical parameters, using Water Quality-Technical Regulation on the Design of the Sampling Programs (Chinese National Criteria, GB12997-1991), Water Quality-Guidance on Sampling Techniques (Chinese National Criteria, GB12998-1991), and Water Quality Sampling-Technical Regulation of the Preservation and Handling of Samples (Chinese National Criteria, GB12999-1991).

After establishing sampling spots at the east, west, south, and north of the background of each TS respectively, ambient noise was monitored according to the method for measuring noise at the boundary of industrial enterprises, (GB12349-1990).

Only at the end of 2004 did Yamenkou TS go into operation. There were nonmonitoring values in 2001–2004.

The collected samples of air and water were brought back to the laboratory for assaying. Mean values of each cell were used in this study.

2.2 Assay criteria and methods

Ammonia (NH_3), hydrogen sulfide (H_2S), total suspended particle (TSPs), odor, and noise were assayed during atmosphere monitoring. Five parameters were measured during TSs discharged wastewater monitoring, including ammonium nitrogen (NH_4^+-N), chemical oxygen demand (COD_{Cr}), biochemical oxygen demand (BOD_5), suspended solid (SS), and fecal coliform. The assay criteria and methods of pollutants are shown in Table 2.

Table 2 Assay criteria and methods of pollutants

Atmosphere monitoring		Water monitoring	
Pollutants	Assaying criteria	Pollutants	Assaying criteria
TSPs	GB/T15432-1995	NH_4^+-N	GB/T7478-1987
Odor	GB/T14675-1993	COD_{Cr}	GB/T11914-1989
NH_3	GB/T14679-1993	BOD_5	GB/T7488-1987
H_2S	GB/T11742-1989	SS	GB/T11901-1989
Noise	GB12349-1990	Fecal coliform	GB/T7959-1987

3 Results and discussion

3.1 TSs ambient air quality

Figure 2 presents the mean values (24 h average) of odor levels, TSPs, H_2S, and NH_3 concentrations measured at the MSW TSs in the municipality of Beijing in RSs and DSs during 2001–2006.

3.1.1 Odor concentrations

Figure 2a shows that levels of odor in the ambient air of TSs were in the range of 12.3–110.5 during RSs and 10–62.8 during DSs (24 h average). It is suggested (Chinese National Criteria, Emission Standards for Odor Pollutants, GB14554-1993) that the highest recommended odor value for the ambient air of community and inhabitant is 30. The odor monitoring results exceeded the standard by only 17.3%. The mean concentrations of odor during DSs were much lower than those during RSs in TSs ambient air.

Table 1 Construction mode of each TS

TS	Location	Service area	Operating year	Service life (year)	Designing capacity (t/d)	Process
Majialou	Fengtai District	Fengtai and Xuanwu District	1997	20	980	Screening
Xiaowuji	Chaoyang District	Chaoyang and Chongwen District	1997	20	980	Screening
Datun	Chaoyang District	Dongcheng and Xicheng District	1994	8	1,500	Compressing
Wuluju	Haidian District	Haidian District	1999	8	1,500	Compressing
Yamenkou	Shijingshan District	Shijingshan District	2004	10	500	Compressing

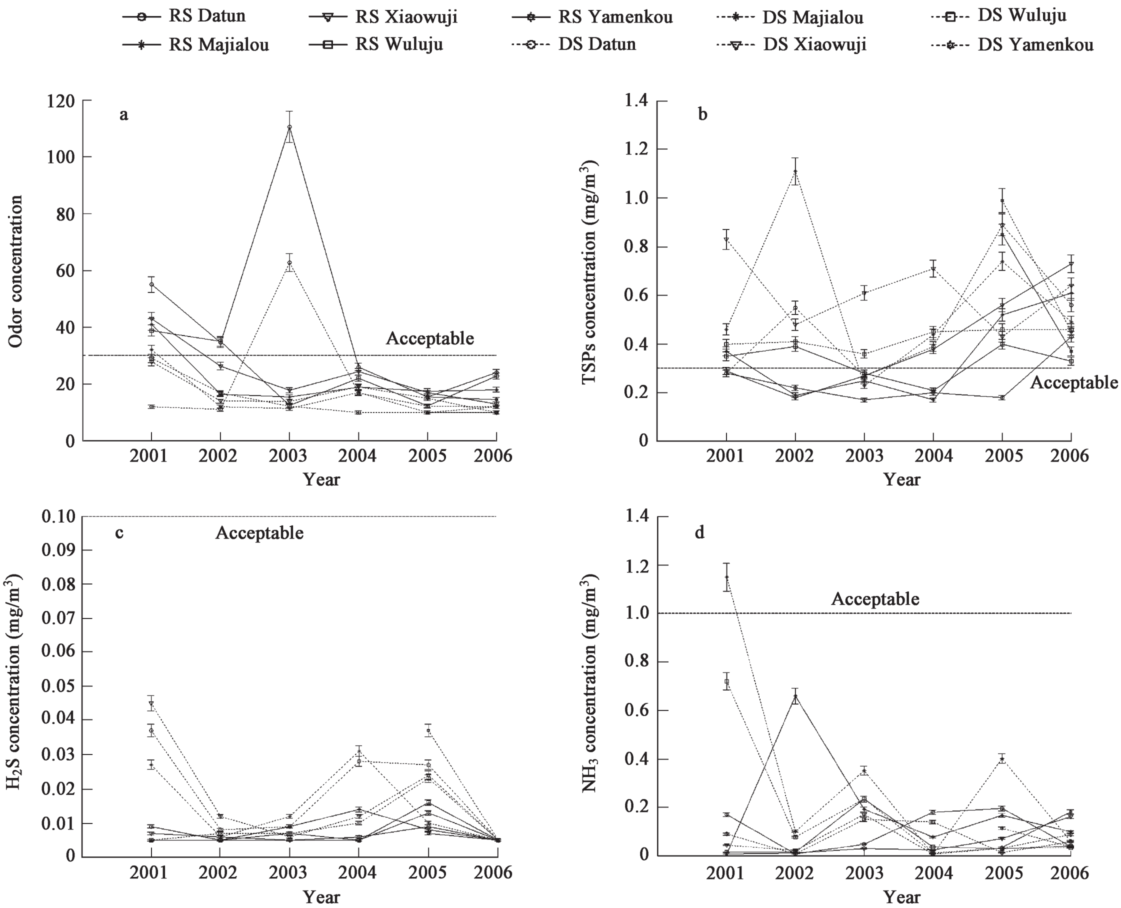

Fig. 2 Mean results for odor (a), TSPs (b), H_2S (c), and NH_3 (d) concentrations. RS: rainy season; DS: dry season.

3.1.2 TSP concentration in TSs ambient air

The results (Fig.2b) of ambient air monitoring in 2001–2006 showed that the TSP levels at TSs ranged form 0.17 to 0.85 mg/m^3 (24 h average) during RSs and from 0.23 to 1.11 mg/m^3 (24 h average) during DSs. According to the Chinese National Criteria, Standard of Environment Air Quality (GB3095-1996), the TSP concentration in a community and inhabitant should not be higher than 0.3 mg/m^3 (24 h average). However, almost 70% of the TSP monitoring results exceeded the Chinese National Criteria during RSs and DSs. The existing TSP concentrations in TSs ambient air were found to be around 1.7–2.2 times higher than the recommended standard. The mean concentrations of TSPs in the TSs' ambient air during the DSs were much higher than those in the RSs, in 2001–2006. The seasonal variation in TSP concentrations was affected by the weather conditions (Muttamara and Shing, 1997).

3.1.3 H_2S concentrations

The highest observed H_2S concentration in TSs ambient air was 0.016 mg/m^3 (24 h average) during RSs and was 0.045 mg/m^3 (24 h average) during DSs (Fig.2c). All the observed H_2S values fell within the permissible range of 0.03–0.1 (24 h average), which was the recommended value for the ambient air standard in China (Chinese National Criteria, GB14554-1993).

3.1.4 NH_3 concentrations

Figure 2d shows that the highest observed NH_3 concentration in the TSs' ambient air was 0.658 mg/m^3 (24 h average) during RSs and 2.0 mg/m^3 (24 h average) during DSs. Regardless of the seasonal variation, the levels of NH_3 in the TSs' ambient air was found to be greatly below the ambient air standard (Chinese National Criteria, GB14554-1993) of 1.0–2.0 mg/m^3 (24 h average).

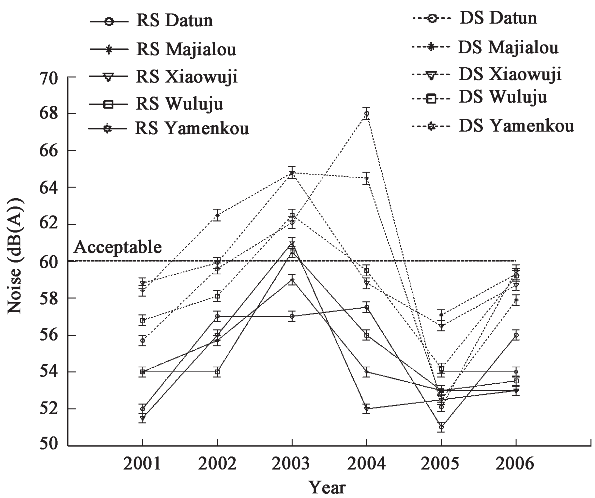

Fig. 3 Mean results for noise assaying.

3.2 TSs ambient noise quality

Figure 3 presents the mean values of noise analyzed at the MSW TSs in the municipality of Beijing in RSs and DSs, in 2001–2006.

It can be observed that the mean value of noise in the TSs' ambient air was from 51.5 to 64.8 dB(A) in 2001–2006. According to the Standard for Noise at Boundary of Industrial Enterprises (Chinese National Criteria, GB12348-1990), the daily noise value should not be higher than 60 dB(A). However, 17.3% of the existing noise values in TSs were found to be higher than the recommended standard during 2001–2006, especially in 2003.

3.3 TSs discharged wastewater characteristics

3.3.1 NH_4^+-N concentrations

Figure 4a shows that the mean concentrations of NH_4^+-N in TSs discharged wastewater from 0.15 to 353 mg/L. During RSs, the NH_4^+-N concentrations varied from 0.2 to 353 mg/L, whereas, during DSs they varied were from 0.15 to 342 mg/L, respectively. According to the Integrated Wastewater Discharge Standard (Chinese National Criteria, GB8978-1996), the NH_4^+-N value should not be higher than 25 mg/L. However, during RSs and DSs, 73.1% of the existing NH_4^+-N values in the TSs discharged wastewater exceeded the recommended standard and some were even around 14 times higher than the recommended standard value. The mean concentrations of NH_4^+-N in

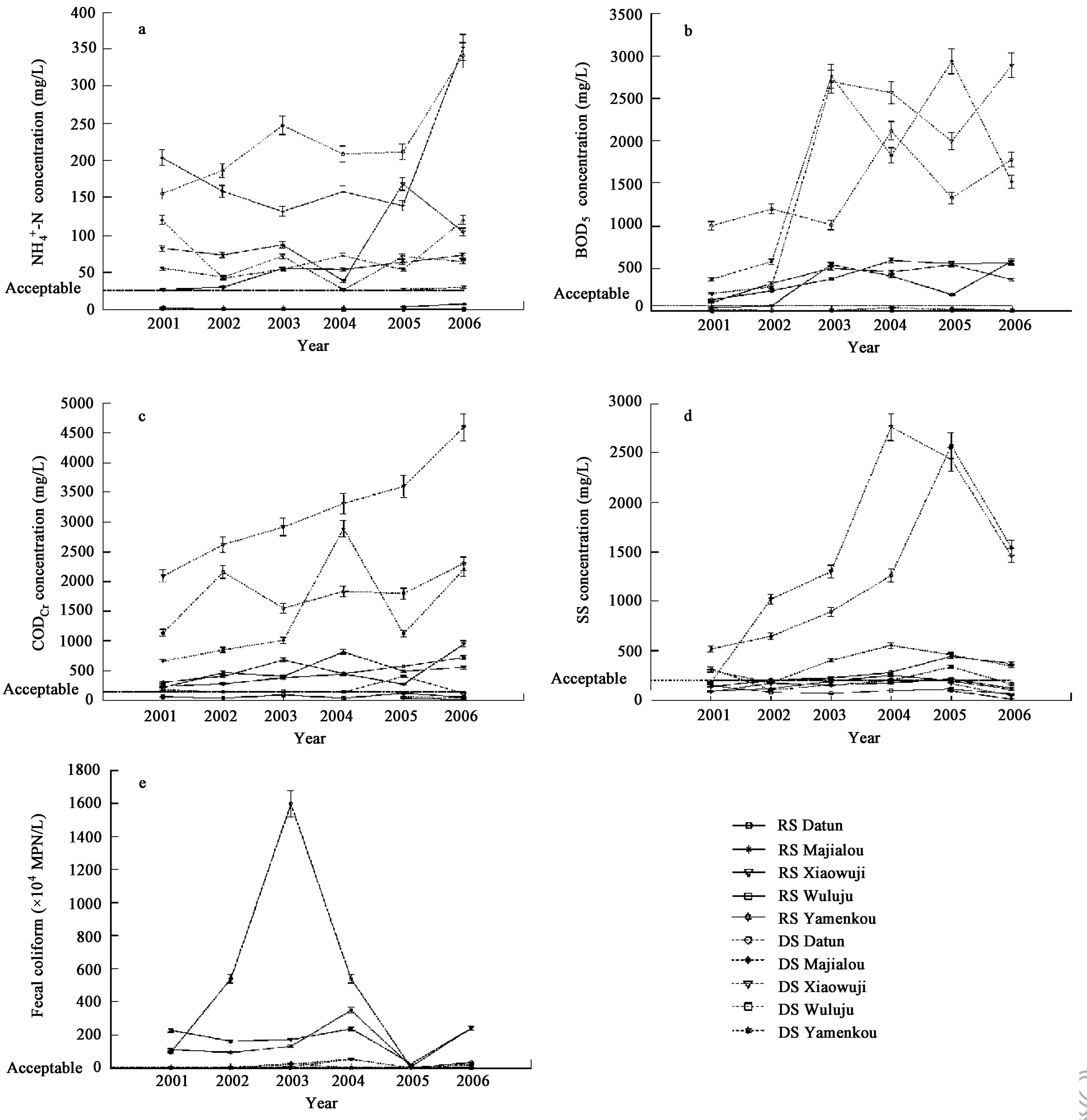

Fig. 4 Mean results of NH_4^+-N (a), BOD_5 (b), COD_{Cr} (c), SS (d), and fecal coliform (e).

the TSs' discharged wastewater in DSs were much higher than those in the RSs in 2001–2006. In RSs and DSs, the lowest concentrations of NH_4^+-N were in Wuluju WTS discharged wastewater. The highest concentration of NH_4^+-N in discharged wastewater was in Majialou WTS during RSs and in Datun during DSs, respectively.

3.3.2 BOD concentrations

Figure 4b presents the mean BOD_5 concentrations of TSs discharged wastewater in RSs and DSs.

In RSs, BOD_5 in TSs discharged wastewater were from 2.00 to 590 mg/L, whereas, during DSs the BOD_5 values were higher, with values from 3.7 to 2,940 mg/L. It is suggested that the recommended BOD_5 value for discharged wastewater should be lower than 60 mg/L (Integrated Wastewater Discharge Standard, Chinese National Criteria, GB8978-1996). All the BOD_5 monitoring results in Datun and Majialou TS exceeded the recommended standard. Less than 20% of the BOD_5 monitoring results in Xiaowuji TS were lower than the recommended standard. It was observed that the BOD_5 in Wuluju TS discharged wastewater had a lower value than the recommended standard during RSs and DSs, in 2001–2006, respectively. The mean concentrations of BOD_5 in TSs discharged wastewater in DSs were much higher than those in RSs, in 2001–2006.

3.3.3 COD_{Cr} concentrations

The COD_{Cr} seasonal variation in TSs discharged wastewater was from 10 to 953 mg/L during RSs and from 42.6 to 4,600 mg/L during DSs (Fig.4c). According to the Integrated Wastewater Discharge Standard (Chinese National Criteria, GB8978-1996), the highest COD_{Cr} value should be lower than 150 mg/L. However, during RSs and DSs, the existing COD_{Cr} values in TSs discharged wastewater were found to be around 2–9 times higher than the recommended standard, respectively. All the BOD_5 monitoring results in Datun, Majialou, and Xiaowuji TSs exceeded the recommended standard. Only 33% of the BOD_5 monitoring results in Wuluju TS were higher than the recommended standard. It was observed that all the BOD_5 in the Yamenkou TS discharged wastewater had a lower value than the recommended standard during RSs and DSs in 2005–2006, respectively. The mean concentrations of COD_{Cr} in TSs discharged wastewater during DSs were much higher than those during RSs in 2001–2006, as given in Fig.9.

3.3.4 SS concentrations

It can be observed from Fig.4d that the SS content in TSs discharged wastewater varied from 14.2 to 446 mg/L during RSs and from 50.9 to 2,760 mg/L during DSs. The highest standard for SS content in discharged wastewater is 200 mg/L (Integrated Wastewater Discharge Standard, Chinese National Criteria, GB8978-1996). Half of the sampling that contained SS, in the TSs discharged wastewater, exceeded the standard concentration. The mean concentrations of SS in TSs discharged wastewater during DSs were much higher than those during RSs, in 2001–2006.

3.3.5 Fecal coliform levels in TSs discharged wastewater

As Fig.4e illustrates, the fecal coliform levels in TSs discharged wastewater during RSs were in the range of 20 MPN/L and 1.6×10^7 MPN/L. During DSs the fecal coliform values were higher, in the range of 49 MPN/L and 5.4×10^5 MPN/L. The fecal coliform levels should be maintained under 5.0×10^3 MPN/L (Integrated Wastewater Discharge Standard, GB8978-1996). However, the results indicate that the number of fecal coliform in TSs discharged wastewater during the monitoring period was 10^2–10^4 times higher than the recommended standard. It was observed that 61.5% of the fecal coliform value in TSs discharged wastewater was much higher than the recommended standard during RSs and DSs, in 2001–2006. Only in Wuluju TS and Yamenkou TS discharged wastewater, were the fecal coliform values lower than the recommended standard. The mean levels of fecal coliform in DSs were much lower than those in the RSs, in 2001–2006.

3.4 Fuzzy synthetic evaluation of the environmental quality of TSs

3.4.1 Defining alternatives, basic attributes, and forming a hierarchical framework

In this study, the principles and methods referenced from the literature (Zadeh *et al*., 1965; Lu *et al*., 1999; Chang *et al*., 2001; Fisher, 2003; Mario and Giuseppe, 2001; Yilmaz, 2007) were performed.

The total monitoring factors as evaluating parameters

Table 3 Evaluating parameters and grade standards

Evaluating parameter	Limit of classification					Chinese National Criteria
	Level I	Level II	Level III	Level IV	Level V	
TSPs* (mg/m^3)	0.10	0.15	0.20	0.30	0.50	GB3095-1996
Odor*	10	20	30	50	70	GB14554-1993
NH_3* (mg/m^3)	1.0	1.5	2.0	3.5	5.0	GB14554-1993
H_2S* (mg/m^3)	0.03	0.06	0.10	0.30	0.60	GB14554-1993
Noise (dB(A))	52.5	55.0	60.0	65.0	70.0	GB12348-1990
NH_4^+-N (mg/L)	15	20	25	35	50	GB8978-1996
COD_{Cr} (mg/L)	100	125	150	300	500	GB8978-1996
BOD_5 (mg/L)	30	45	60	180	300	GB8978-1996
SS (mg/L)	70	135	200	300	400	GB8978-1996
Fecal coliform ($\times 10^4$ MPN/L)	0.050	0.075	0.100	0.300	0.500	GB8978-1996

* Data are 24 h average.

are chosen and the limits of quality grades defined according to Chinese National Criteria. Subsequently, the environmental quality is classified into five grades: level I (excellent), level II (good), level III (ordinary), level IV (poor), and level V (bad), respectively. The parameters and the limits of quality grades of membership functions are given in Table 3.

3.4.2 Fuzzy membership function

The value of the fuzzy membership function of each factor is related to the five evaluating levels (excellent, good, ordinary, poor, and bad) and can be calculated by a set of equations as follows:

$$r_{\mathrm{I}}(c_i) = \begin{cases} 1 & 0 \leqslant c_i \leqslant S_1 \\ (S_2 - c_i)/(S_2 - S_1) & S_1 < c_i < S_2 \\ 0 & c_i \geqslant S_2 \end{cases} \quad (1)$$

$$r_{\mathrm{II}}(c_i) = \begin{cases} 0 & c_i \leqslant S_1, c_i \geqslant S_3 \\ (c_i - S_1)/(S_2 - S_1) & S_1 < c_i \leqslant S_2 \\ (S_3 - c_i)/(S_3 - S_2) & S_2 < c_i < S_3 \end{cases} \quad (2)$$

$$r_{\mathrm{III}}(c_i) = \begin{cases} 0 & c_i \leqslant S_2, c_i \geqslant S_4 \\ (c_i - S_2)/(S_3 - S_2) & S_2 < c_i \leqslant S_3 \\ (S_4 - c_i)/(S_4 - S_3) & S_3 < c_i < S_4 \end{cases} \quad (3)$$

$$r_{\mathrm{IV}}(c_i) = \begin{cases} 0 & c_i \leqslant S_3, c_i \geqslant S_5 \\ (c_i - S_3)/(S_4 - S_3) & S_3 < c_i \leqslant S_4 \\ (S_5 - c_i)/(S_5 - S_4) & S_4 < c_i < S_5 \end{cases} \quad (4)$$

$$r_{\mathrm{V}}(c_i) = \begin{cases} 0 & c_i \leqslant S_4 \\ (c_i - S_4)/(S_5 - S_4) & S_4 < c_i < S_5 \\ 1 & c_i \geqslant S_5 \end{cases} \quad (5)$$

where, $r(c_i)$ is its membership function to the assessment criterion at each level, c_i is the actual monitoring data of any assessment parameter, and $S_{1\text{–}5}$ indicates the values of each level.

3.4.3 Evaluation matrix

The monitoring data of each assessment parameter and national standards are substituted into the membership functions. Following this the fuzzy matrix of single parameter, R, is obtained, which can be expressed as:

$$R = \begin{bmatrix} r_{1,1} r_{1,2} \ldots r_{1,n} \\ r_{2,1} r_{2,2} \ldots r_{2,n} \\ \ldots\ldots\ldots\ldots\ldots \\ r_{m,1} r_{m,2} \ldots r_{m,n} \end{bmatrix} \quad (6)$$

where, r_{ij} represents the membership degree of the ith assessment parameter to the assessment criterion at each level. In this study, $m = 10$, $n = 5$.

3.4.4 Determining revised weights

The revised weight equation utilized in this study is $w_i = (\frac{c_i}{s_i}) / \sum_{i=1}^{m} \frac{c_i}{s_i}$, c_i is the monitoring concentration of the ith assessment parameter, s_i is the average of the assessment criteria of the ith assessment parameter, and w_i represents the weight of the ith assessment parameter.

3.4.5 Aggregating final fuzzy sets and ranking the results

Subsequently, the fuzzy algorithm of B is carried out.

$$B = A \times R = \{w_1, w_2, ..., w_m\} \times \begin{bmatrix} r_{1,1} r_{1,2} \ldots r_{1,n} \\ r_{2,1} r_{2,2} \ldots r_{2,n} \\ \ldots\ldots\ldots\ldots\ldots \\ r_{m,1} r_{m,2} \ldots r_{m,n}. \end{bmatrix} = \{b_1, b_2, ..., b_n\} \quad (7)$$

where, A is the weight matrix, and b is the fuzzy comprehensive assessment indices, B is the fuzzy comprehensive assessment matrix.

The highest value of membership decides the classification of the fuzzy set. The operating results are shown in Table 4.

Thus, it can be concluded that the whole environmental quality of Datun TS, Majialou TS, and Xiaowuji TS during 2001–2006 RSs and DSs in Beijing, all belonged to level V, that is to say, the whole environmental quality of Datun TS, Majialou TS, and Xiaowuji TS was bad.

Except in 2002, the whole environmental quality of the Wuluju TS during 2001–2006 RSs belonged to level IV. This meant that the whole environmental quality of Wuluju TS during 2001–2006 RSs was poor. The environmental quality of the Wuluju TS during 2001–2006 DSs belonged to level IV, II , II ,V, IV, and V, respectively, superior to that of 2001–2006 RSs.

The environmental quality of the Yamenkou TS during 2001–2006 DSs was bad, whereas, during 2001–2006 RSs, the whole environmental quality of the Yamenkou TS belonged to levels V and IV, respectively, superior to that of 2001–2006 DSs.

According to the Eleventh Five-Year Plan, seven MSW TSs, 27 MSW PFs, and four garbage DSs will be constructed in Beijing during the next five years. Within five years, the daily receiving capacity of MSW in Beijing will range from 16,510 to 18,215 t. The addition of these facilities has become particularly important given the increasing environmental (green) concerns (Fleischmann *et al*., 2001; Klaussner and Hendrickson, 2000). Several successful pilot projects have demonstrated that air problems caused by MSW flow can be minimized by separating organic waste from residential, commercial, and institutional sources (Alvarez *et al*., 2007). Therefore, to avoid further pollution of air, water, and soil, the Chinese government currently recommends (in most cases) the separation of biogenic waste from MSW at the source (source separation).

4 Conclusions

Except NH_3 and H_2S, the analytical results of the TSPs, odor, noise, NH_4^+-N, COD_{Cr}, BOD_5, SS, and fecal coliform concentrations were all degree-varied higher than the criteria limit in China.

Using fuzzy synthetic evaluation, the environmental quality is classified into five categories, with a level of certainty of belonging to different categories. It can be

Table 4 Results of the fuzzy mathematics evaluation of environmental qualities

TS	Year	Season	Aggregating final fuzzy sets $B = A \times R = \{\ \}$	Level	Environmental quality
Datun	2001	RS	{0.002, 0.002, 0.002, 0.003, 0.984}	V	Bad
		DS	{0.010, 0.028, 0.033, 0.033, 0.306}	V	Bad
	2002	RS	{0, 0, 0, 0.001, 0.997}	V	Bad
		DS	{0.006, 0.019, 0.019, 0, 0.380}	V	Bad
	2003	RS	{0, 0, 0, 0, 0.998}	V	Bad
		DS	{0, 0, 0.006, 0.010, 0.813}	V	Bad
	2004	RS	{0, 0, 0, 0.001, 0.995}	V	Bad
		DS	{0.010, 0.010, 0, 0.032, 0.351}	V	Bad
	2005	RS	{0.040, 0.040, 0.034, 0, 0.370}	V	Bad
		DS	{0.019, 0.019, 0, 0, 0.249}	V	Bad
	2006	RS	{0, 0.005, 0.005, 0.010, 0.914}	V	Bad
		DS	{0.003, 0.008, 0.008, 0, 0.64}	V	Bad
Majialou	2001	RS	{0.002, 0.002, 0.002, 0.003, 0.977}	V	Bad
		DS	{0.025, 0.054, 0.054, 0.128, 0.232}	V	Bad
	2002	RS	{0.001, 0.002, 0.002, 0.004, 0.972}	V	Bad
		DS	{0.013, 0.033, 0.042, 0.042, 0.335}	V	Bad
	2003	RS	{0.001, 0.002, 0.002, 0.003, 0.979}	V	Bad
		DS	{0.004, 0.004, 0.014, 0.014, 0.577}	V	Bad
	2004	RS	{0.001, 0.001, 0.001, 0.001, 0.991}	V	Bad
		DS	{0.002, 0.002, 0.004, 0.006, 0.881}	V	Bad
	2005	RS	{0.015, 0.015, 0.015, 0.02, 0.74}	V	Bad
		DS	{0.023, 0.023, 0, 0.05, 0.615}	V	Bad
	2006	RS	{0.001, 0.001, 0, 0, 0.982}	V	Bad
		DS	{0.007, 0.020, 0.020, 0.041, 0.357}	V	Bad
Xiaowuji	2001	RS	{0.001, 0.001, 0.001, 0.001, 0.993}	V	Bad
		DS	{0.025, 0.076, 0.076, 0.167, 0.232}	V	Bad
	2002	RS	{0, 0.001, 0.002, 0.002, 0.991}	V	Bad
		DS	{0.077, 0.077, 0.04, 0.091, 0.449}	V	Bad
	2003	RS	{0.001, 0.001, 0.001, 0.002, 0.985}	V	Bad
		DS	{0.016, 0.016, 0.007, 0.007, 0.697}	V	Bad
	2004	RS	{0.001, 0.001, 0.001, 0.002, 0.991}	V	Bad
		DS	{0.002, 0.003, 0.003, 0.003, 0.833}	V	Bad
	2005	RS	{0.007, 0.007, 0.009, 0.012, 0.898}	V	Bad
		DS	{0.008, 0.019, 0.019, 0.034, 0.324}	V	Bad
	2006	RS	{0.001, 0.001, 0, 0, 0.986}	V	Bad
		DS	{0.002, 0.006, 0.006, 0, 0.658}	V	Bad
Wuluju	2001	RS	{0.14, 0.14, 0.168, 0.304, 0.304}	IV	Poor
		DS	{0.057, 0.030, 0.400, 0.441, 0.100}	IV	Poor
	2002	RS	{0.143, 0.143, 0.154, 0.248, 0.348}	V	Bad
		DS	{0.365, 0.365, 0.215, 0.001, 0.001}	II	Ordinary
	2003	RS	{0.113, 0.097, 0.283, 0.314, 0}	IV	Bad
		DS	{0.329, 0.329, 0.238, 0.238, 0}	II	Ordinary
	2004	RS	{0.102, 0.211, 0.200, 0.298, 0}	IV	Poor
		DS	{0.056, 0.100, 0.199, 0.250, 0.361}	V	Bad
	2005	RS	{0.148, 0.148, 0, 0.326, 0.326}	IV	Poor
		DS	{0.106, 0.106, 0, 0.230, 0.230}	IV	Poor
	2006	RS	{0.233, 0.233, 0.166, 0.345, 0.150}	IV	Poor
		DS	{0.045, 0.159, 0.159, 0.276, 0.297}	V	Bad
Yamenkou	2005	RS	{0.159, 0.159, 0, 0, 0.600}	V	Bad
		DS	{0.036, 0.123, 0.123, 0.118, 0.512}	V	Bad
	2006	RS	{0.200, 0.275, 0, 0.452, 0.350}	IV	Poor
		DS	{0.060, 0.140, 0.219, 0.250, 0.391}	V	Bad

RS: rainy season; DS: dry season; *A*: weight matrix, *R*: fuzzy matrix of a single parameter; *B*: fuzzy comprehensive assessment matrix.

concluded that the whole environmental quality of Datun TS, Majialou TS, and Xiaowuji TS, in Beijing, was bad during 2001–2006 RSs and DSs. Except in 2002, the whole environmental quality of the Wuluju TS during 2001–2006 RSs was poor. Only in the DSs of 2002 and 2003, was the whole environmental quality of the Wuluju TS good.

The whole environmental quality of Yamenkou TS during 2001–2006 DSs was bad, whereas, during 2001–2006 RSs, the whole environmental quality of Yamenkou TS belonged to level V and was superior to that of 2001–2006 DSs. The best way to keep TSs from further pollution is source separation.

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