

Investigation and comprehensive evaluation of the litter pollution on the Heishijiao beach in Dalian

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Abstract. From November 2015 to August 2016, this paper conducted an investigation into the classification of the litter on the Heishijiao beach in Dalian, and made a comprehensive evaluation of the litter pollution on the beach in different seasons. According to the results, the litter on the Heishijiao beach in Dalian mainly come from human's offshore activities and other wastes, and spring is the season which witnesses the largest quantity of litter resulting from the activities. Most of the fragmental wastes are glass, plastic and paper, while there is a little metal, rubber and wooden products. On the Heishijiao beach, most of the fragmental litter are small, followed by medium and large ones; outsized wastes are rare. The quantitative density of litter is highest in winter (9.0 items/m²), with the average quantitative density of 4.6 items/m²; the qualitative density of litter is highest in spring (8 g/m²), with the average qualitative density of 6.0 g/m². The results of the comprehensive evaluation show that the litter pollution on the Heishijiao beach stays between "Average" and "Unsatisfactory".

1. Introduction

Marine litter refers to the artificial or processed solid waste in the ocean and in the marine environment [1]. Some of marine litter would be left on beaches, while some would float on the sea or fall onto the seabed. According to statistics, about 6.4 million tons of litter is thrown into the ocean, and the litter visible to human only accounts for 20% of the total litter in the ocean [2]. Marine litter is very harmful to marine creatures and environment[3]. It may be mistakenly swallowed by marine creatures and cause clogging in the respiratory system. Moreover, the heavy metal ions and organic nutritive salt in the litter would pollute the sea water, threaten the life of marine creatures, and lead to the outbreak of poisonous red tide [4]. Marine litter pollution affects offshore landscape, but it can also be taken as an important index of the evaluation of the beach quality [5]. As more is known about marine litter pollution, China listed the monitoring of marine litter as a part of the communiqué of quality of marine environment in 2007; Ministry of Environmental Protection held the National Meeting of Exchanging Experience in the Prevention and Treatment of Marine Litter to promote the prevent and treatment of the marine litter pollution [6-7] in 2008; China gradually monitor, investigate into and analyze marine litter pollution [8-9]. To date, marine micro plastic pollution has even become a marine environment problem attracting global attention[10].

Facing the Yellow Sea, the Heishijiao beach is situated in the west of Dalian City. With a sinuous coastal line, it has a rocky coastal made of limestone. The main beach consists of sand and gravel, and it is an entertainment and tourist destination for citizens. With the beach as the subject, this paper undertook a one-year investigation into beach litter from November 2015 to August 2016, analyzed the types, sources and densities of beach litter in different seasons, and assessed the comprehensive



situation of the litter pollution on the beach in different seasons, with the hope of improving the prevention and treatment of litter pollution on the beach.

2. Basic information about and method of monitoring

2.1. Basic information

The sampling area is the beach between the high-water line and the low-water line, with a 100-meter investigation area. 12 samples, with 2 meters in length and width, were evenly set. The four sampling investigations were conducted in spring, summer, autumn and winter respectively from November 2015 to August 2016. According to the technical guidelines [11] of the monitoring of marine litter pollution, this paper counted the number and analyzed the data with such indexes as the source of litter, the type of fragment, the size of fragment (small: $<2.5\text{ cm}$; medium: $\geq 2.5\text{ cm}$ and $\leq 10\text{ cm}$; large: $> 10\text{ cm}$ and $\leq 1\text{ m}$; oversized: $> 1\text{ m}$), and comprehensive evaluation.

2.2. Method of calculating litter density

As for the investigation into the sampling, the litter quantity in unit area can be calculated with the following equation: $\bar{D} = n/S$

In the equation, “n” refers to the total number (item) of the target objects calculated, and “S” indicates the area of the investigated samples.

2.3. Comprehensive evaluation

Table 1. Indexes, weights and standards of the comprehensive evaluation.

Evaluation Indexes	Weights	Indexes of Comprehensive Evaluation			
		Good [1]	Average [2]	Unsatisfactory [3]	Bad [4]
Plastic bottle (beverage)	1	<2	2-20	21-34	>34
Cap	1	<7	7-65	66-156	>156
Crisp bread and lollipop	1	<2	2-16	17-61	>61
Entwined mesh/thread	1.5	<1	1-6	7-12	>12
Fishing line	1.5	<1	1-10	11-32	>32
Strapping tape	1.5	<1	1-11	12-25	>25
Balloon	1.5	<1	1-8	9-18	>18
Cotton bud	1	<3	3-26	27-56	>56
Rope/thread/mesh $< 50\text{ cm}$	1.5	<6	6-59	60-121	>121
Rope/thread/mesh $> 50\text{ cm}$	1.5	<2	2-16	17-34	>34
Carton/Tetra Pak	1	<1	1-4	5-10	>10
Total from fishing	3	<13	13-119	120-385	>385
Total from navigation	3	<3	3-22	23-88	>88
Total from tourism	3	<6	6-55	56-164	>164
Total from packing	3	<14	14-143	144-336	>336
Total made from plastic/polystyrene	3	<50	50-502	503-1533	>1533

2.3.1. Evaluation indexes, weight, evaluation standards, and indexes of comprehensive evaluation

At present, the standards for the evaluation of marine litter are not available. In this paper, the multi-norm evaluation system proposed by Marcus Schulz [12] from University of Osnabruck and others was adopted to define the indexes, weight and standards of the comprehensive evaluation of beach litter, as shown in Table 1.

2.3.2. Calculation of comprehensive evaluation indexes Comprehensive evaluation index is calculated to reflect the overall environment of the beach. The equation is as follows:

$$\bar{X} = \frac{\sum_{i=1}^n w_i * x_i}{\sum_{i=1}^n w_i} \quad (1)$$

In the equation, \bar{X} is the Comprehensive evaluation index; “W”, weight; “ X_i ”, the score of evaluation index; “n”, the number of index.

3. Results and analysis

3.1. Analysis of sources

The statistical method of Northwest Pacific Action Plan (NOWPAP) was adopted to calculate and analyze the sources of marine litter. In general, the litter is classified into five groups, namely, human’s offshore activities and entertainments, other wastes, navigation/fishing, smoking-related objects, and medical/sanitary products. The investigation results in the four seasons were calculated and analyzed with the classification, and the results are shown in Figure 1. The statistical results demonstrate that most of the litter on the Heishijiao beach come from human’s offshore activities and other wastes; most of the other wastes are glass fragments; there is no significant change in season in medical/sanitary products; the beach litter from navigation/fishing increases in summer; the litter from human’s offshore activities accounts for the largest proportion in spring; in winter, other wastes occupy the largest proportion, and most of them are glass fragments.

3.2. Analysis of types of fragments

The investigation results of the four seasons were classified according to the type of fragments, as is shown in Figure 2. The statistical results indicate that most of the fragmental litter on the Heishijiao beach is glass, plastic and paper and that there is a little metal, rubber and wooden products. There is a significant change in season in terms of paper, with more in spring and less in autumn; plastic and glass increase in winter and summer and decrease in spring and autumn.

3.3. Size of fragment

The litter samples collected in the four seasons were classified according to the size of fragment, as is shown in Figure 3. Most of the fragmental litter on the Heishijiao beach is small; medium and large fragmental litter is average; outsized litter is rare. Small fragmental litter increases in winter, but showing insignificant change in other seasons.

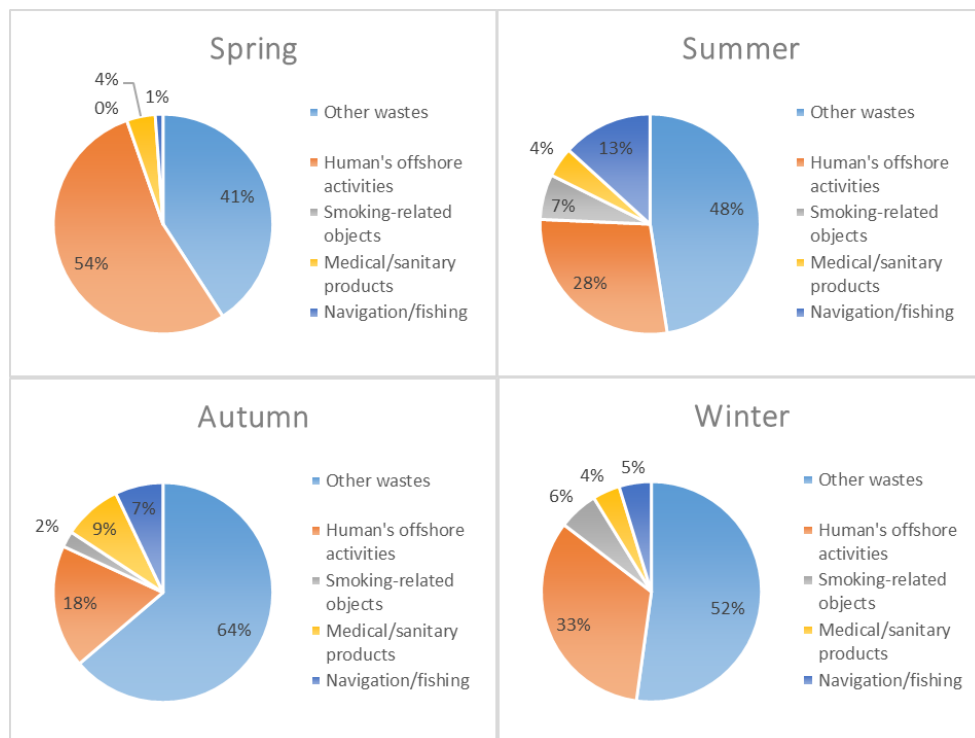


Figure 1. Classification of litter sources .

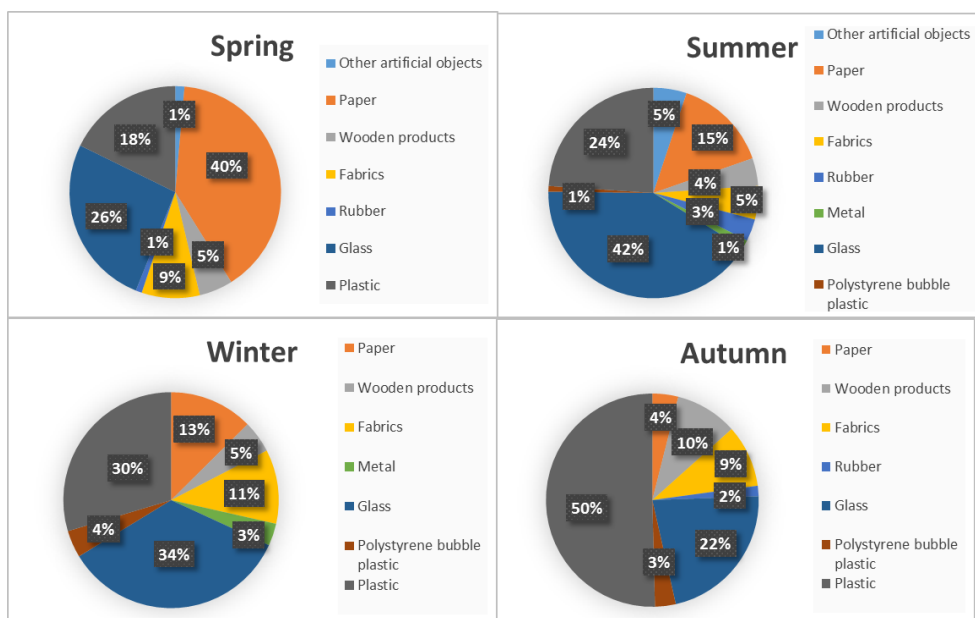


Figure 2. Classification of fragmental litter.

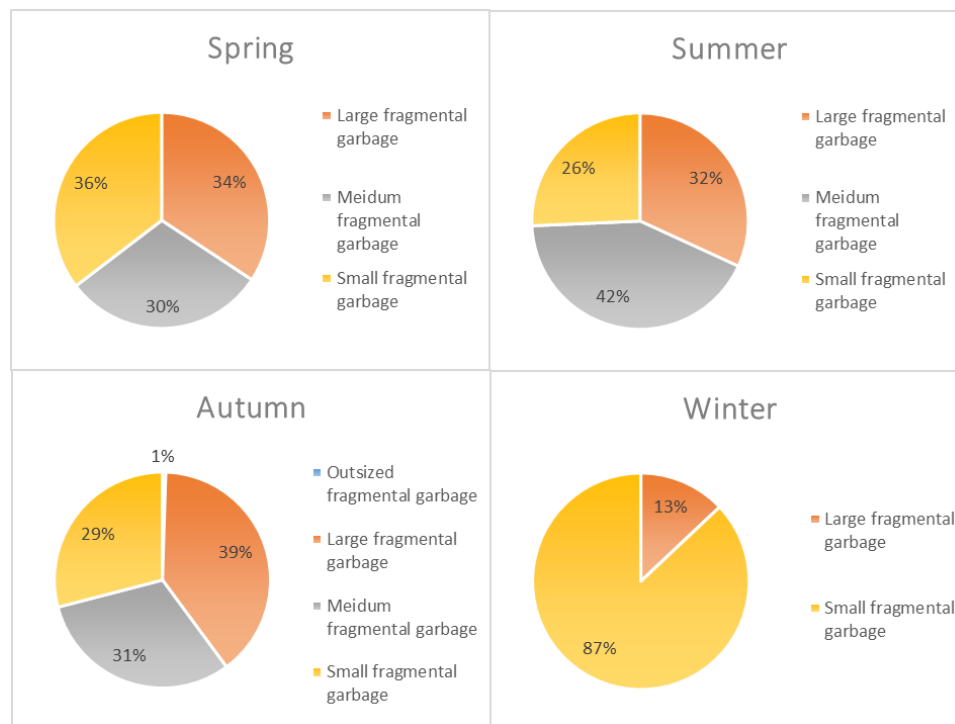


Figure 3. Size-based classification of fragmental litter.

3.4. Analysis of density of beach litter

The quantitative and qualitative densities were calculated according to the investigation results, as is shown in Table 2. According to the results, most of the fragmental litter on the Heishijiao beach in winter is small, with the highest quantitative density of 9.0 items/m² and the average quantitative density of 4.6 items/m²; in spring, most of the fragmental litter is medium and large, with the highest qualitative density of 8 g/m² and the average qualitative density of 6.0 g/m². The qualitative and quantity density of Heishijiao beach litter are higher than those in Shandong coastal area and east China Sea.

Table 2. Quantitative density and qualitative density of litter of Heishijiao beach in Dalian.

season	Heishijiao beach in Dalian				Coast of Shangdong Province[13]	East China Sea[8]
	Spring	Summer	Autumn	Winter		
quantitative density (item/m ²)	2.9	3.8	2.6	9.0	0.88	0.31
qualitative density (g/m ²)	8	6.2	3.1	6.9	1.26	1.63

3.5. Results of comprehensive evaluation

The calculation of the indexes of the comprehensive evaluation of the litter on the Heishijiao beach is shown in Table 3. According to the multi-norm evaluation system of litter pollution on beaches, which was proposed by Marcus Schulz, the litter pollution on beaches can be divided into levels, namely, “Good=1”, “Average=2”, “Unsatisfactory=3” and “Bad=4”. The results of the comprehensive evaluation show that the litter pollution on the Heishijiao beach stays between “Average” and “Unsatisfactory”.

Table 3. Results of the comprehensive evaluation.

Spring	Summer	Autumn	Winter
2.0	2.4	2.0	2.1

4. Discussions

From November 2015 to August 2016, this paper conducted a one-year investigation into the litter on the Heishijiao beach in Dalian, analyzed the sources of the litter. According to the results, the litter on the Heishijiao beach in Dalian mainly come from human's offshore activities and other wastes, accounting for 84.5%, followed by navigation / fishing activities and medical / sanitary supplies, accounting for 6.25%. The amount of beach litter from smoking supplies is the least, only 3.75%. The result is similar to the Shandong coastal survey [13].

Dalian Heishijiao Beach is a public beach, mainly for the public recreational activities. Fishing and breeding activities are less. We think this is the main reason for the distribution of beach litter sources. According to the type of waste materials, plastic and glass have the highest proportion, respectively, accounting for 32.5% and 31%. Followed by paper (18%), fabric (8.5%), wood (6%), other materials marine litter are less than 2%, metal has the lowest proportion, about 1%. Plastic beach litter are mostly food packaging bags, plastic tableware, beverage bottles, etc. Glass beach litter mainly is the beer bottle debris. The distribution of the proportion of waste material types is inseparable from human activities at Heishijiao Beach. On the Heishijiao beach, most of the fragmental litter are small, followed by medium and large ones; outsized wastes are rare.

The quantitative density of litter is highest in winter (9.0 items/m²), with the average quantitative density of 4.6 items/m²; the qualitative density of litter is highest in spring (8 g/m²), with the average qualitative density of 6.0 g/m². Heishijiao Beach is close to the city, surrounded by Dalian Natural Museums and Heishijiao square entertainment, people flow is relatively large, which is the main reason for the relatively high density of the beach litter.

China National Oceanic Administration released the Marine litter Monitoring Technology Guide. At present the biggest problem is that the marine litter monitoring and evaluation of technical standards have not yet introduced. One of the target of this paper is to take the Dalian Heishijiao Beach as an example, and introduce a multi-criteria evaluation system and thus provide reference for the comprehensive evaluation of Chinese beach litter. The results of the comprehensive evaluation show that the litter pollution on the Heishijiao beach stays between "Average" and "Unsatisfactory". The evaluation results show that the Heishijiao beach litter pollution situation is not optimistic.

The development of offshore entertainment and tourism has imposed higher requirements as well as greater pressure on the beach environment. Currently, the litter pollution on beaches has not gained adequate attention; worse still, the beach cleaning cost much time and labor due to the geographical features of beaches. Therefore, it is highly necessary to conduct the research on the prevention and treatment of the litter pollution on beaches.

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