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Abundance, type, and origin of litter on No. 1 Bathing Beach of Qingdao, China

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Abstract

Detection of litter along beaches in many countries indicates an anthropoginic source of marine pollution. The abundance and composition of litter were measured for the first time along the No.1 Bathing Beach, Qingdao, China. Surveys were conducted during May to July, 2018 in order to estimate the occurrence and abundance of nine litter types. In total, 4476 litter items were collected with a corresponding weight of 330.2 kg. The most prominent litter was plastic followed by paper, wood, and (cloth and ropes) with corresponding percentages of 49.91, 10.30 and 9.76% of the total litter items. Plastics were the most abundant litter type (38.81%) in term of weight, followed by paper (12.11%) and food items (9.07%). The main sources of litter included human recreational activities, e.g. tourism, fisheries and cafes. Statistically significant differences ($p < 0.05$) were found between the number/weight of different items during the three months of study. The results of the present study will help to administer effective beach litter management programs.

Keywords Litter · Abundance · Items · Weight · Plastic · Beach

Introduction

Beaches are important recreational places in any country located near oceans. As pollution levels are ever increasing with the passage of time, beaches are also suffering from pollution, especially the accumulation of anthropogenic litter and this is of serious concern, as it spoils the aesthetic beauty of beaches across the world (UNEP 2009). At present, it is one of the major emerging issues of global scale. Although, remote areas of the earth have minimum human activity, significant quantities of litter specifically contain non-biodegradable and buoyant synthetic polystyrene and plastic (Ribic et al. 2012). Marine and coastal litter have negative socioeconomic impacts on shipping, fishery and recreational activities by spoiling the aesthetic beauty of coastal amenities (Krelling et al. 2017). Additionally, marine ecosystem is also affected by the presence of anthropogenic litter on beaches with associated economic implications (Watts et al. 2017). Coastal litter is harmful for marine and coastal biota in a number of ways, such as entanglement, accidental ingestion, affecting biogeography, and provision of new habitat via the transport of invasive species (Schuyler et al. 2013; Provencher et al. 2014). Approximately, 370 species have been reported to get entangled in or having ingested marine litter worldwide (Galgani et al. 2010).

Huge amounts of litter enter every day to many beaches/oceans (Kuhn et al. 2015; Jambeck et al. 2015). The most common sources of coastal and marine litter include recreational activities, smoking, oceanic source, and waste dumping into the beach or the sea (Ocean Conservancy 2010). Land-based sources contribute up to 80% of global marine pollution (GESAMP 1991). Many studies have been conducted to determine the origin, composition, abundance, and distribution

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of beach litter across several regions of the globe (Ariza et al. 2008). For example, the UK (Tudor and Williams 2008), Italy (Semeoshenkova et al. 2017), Colombia (Rangel-Buitrago et al. 2017), Cuba (Botero et al. 2017), Morocco (Maziane et al. 2018), and Brazil (Corraini et al. 2018). Such studies demonstrated that beaches have been polluted by a variety of anthropogenic litter, such as, plastic bottles, plastic bags, food wrappers, pellets, packing strips, glass, steel wires, cigar tips, cigarette filters, fishing gears, ropes, styrofoam, nappies, and baby diapers. The number of beaches studied globally indicates the greatest proportion of beach litter as being plastic in origin (Martinez Ribes et al. 2007; Hong et al. 2014). A significant amount of plastic litter, which is durable, degrades very slowly and buoyant (Williams and Simmons 1996) arrive at beaches from the surrounding areas and far away continents via tides, winds, and ocean currents. Photo-degradation of plastic litter in the ocean is slower than on land (Dharani et al. 2003) due to its maritime nature. The buoyant nature of plastic causes its distribution over a large area by ocean currents (Sheavly and Register 2007).

Beach litter surveys have been widely used as a primary tool to monitor litter loads into the marine environment and quantification of marine litter pollution (Ribic et al. 2010). It is beneficial to recognize the origin and activities that lead to litter

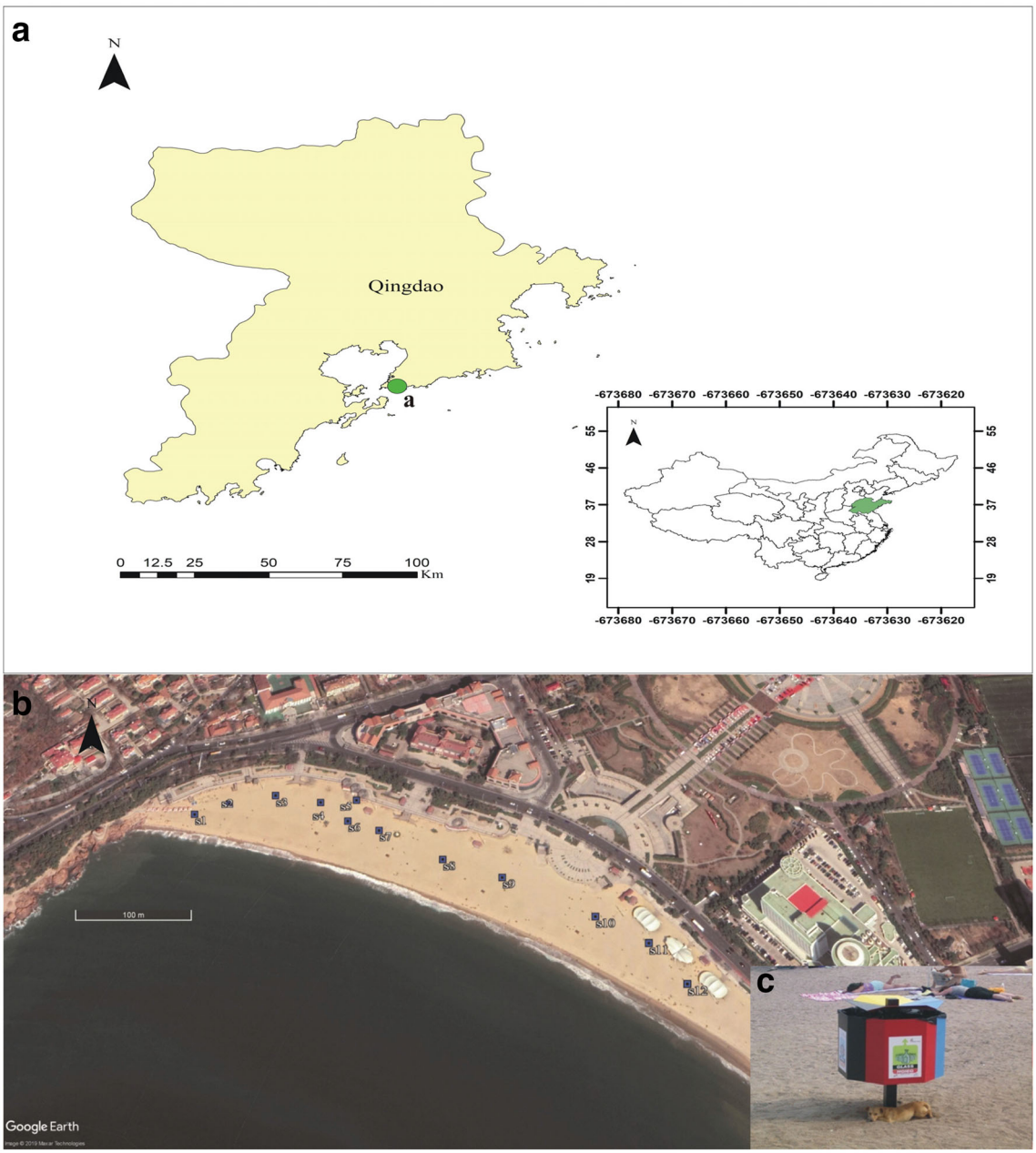

Fig. 1 The study area (**a**) Qingdao and China map, green color shows the Shandong province, and sampling sites s1, s2……s12 (**b**) Sites for sampling collection and **c** Garbage bin used for litter quantification

Table 1 Location and associated various characteristics of litter at the Bathing Beach No. 1 during survey

Site	Latitude	Longitude	Length (m)	Width (m)
S1	36.057699°	120.333616°	40	43
S2	36.057777°	120.333960°	30	57
S3	36.057824°	120.334427°	42	76
S4	36.057719°	120.334889°	42	78
S5	36.057714°	120.335255°	34	68
S6	36.057512°	120.335165°	23	68
S7	36.057396°	120.335477°	32	69
S8	36.057070°	120.336095°	67	67
S9	36.056859°	120.336662°	59	78
S10	36.056442°	120.337514°	90	75
S11	36.056179°	120.337976°	51	68
S12	36.055818°	120.338259°	47	54

pollution and determine threats to the ecosystem and marine biota (Cheshire et al. 2009). Such kind of monitoring is certainly handy to identify the litter management strategies on the beaches.. China, USA and many European countries are the world's largest producers of plastic litter (Rochman et al. 2013). China has paid less attention to quantify litter on beaches (Zhao et al. 2015) as compared to other regions of the world such as, the United State of America (USA), Brazil, Australia, and Chile (Zhou et al. 2011). Few studies have been documented in the local Chinese literature which reported domestic waste in a small island (Chen and Chen 2010).

The aim of the current study was to investigate the abundance and composition of anthropogenic litter along the Bathing Beach No. 1 during the summer season, as in view that previously none of the study reported these aspects. The data generated from the present work might be useful in estimation of litter types and quantities which can further be utilized for several useful purposes after proper treatment i.e. recycling. The present investigation will also serve as a reference to estimate litter generation and its management strategies on other beaches.

Materials and methods

Study area

The study area is situated in Qingdao city in Shandong province, China. Qingdao is one of the leading cities in the northeast of China (Fig. 1a). Overall, it has been ranked second in China based on its government effectiveness and investment in the environmental sector (Mako 2006 pp. VI). The Bathing Beach No. 1 is located on Huiquan Bay and it is enclosed by hills to its north, west, and east, and its length is 580 m while width varies due to beach geomorphology (Fig. 1b).

Sampling method

The litter surveys were conducted over three months (May, June, and July) of the summer season in 2018 to estimate the monthly litter generation at a time when there was the highest number of visitors and recreational activities on the beach. The beach seems desolate or vacant in winter seasons due to the cold water temperature. Twelve garbage bins were placed in the study area by the beach usage cleaning department of the Qingdao government for visitors. The distance between garbage bins varied according to their placement (Fig. 1b). The designated transect length, which was the distance between the low tide line and the first permanent vegetation line also varied (Santos et al. 2009). Beach cleaning was done daily at 4:00 am, and litter was transferred to these garbage bins. Monitoring of the site was accomplished after beach cleaning at around 8:00–9:00 am. Litter items in the garbage bins were counted and recorded. The GPS of each coordinate was recorded according to the placement of the garbage bins (Table 1) and each type of item was cleaned and weighed separately from each garbage bin.

Anthropogenic litter size greater than 3 cm was taken for beach litter estimations. Small litter. Litter items less than 3 cm were not considered during the investigation because the scope of study centered only macroscopic items. Litter was weighed and size was taken by measuring tape. Moreover,

Table 2 Source-specific indicator items used for the study (OSPAR 2007)

Sources	Indicators
Fisheries	Fish boxes, jerry cans, fishing line and weights, rubber gloves. Cords, nets and rope, octopus pots, mussel bags and oyster nets.
Galley waste	Cleaner bottles, cartons/tetra packs, metal and food cans, spray cans, plastic gloves and crates.
Sewage and Sanitary waste	Cotton bud sticks, panty liners/backing strips/condoms/sanitary towels and tampon applicators.
Shipping	Industrial packaging, strapping bands, wooden pallets, hard hats, light bulb/tubes and oil drums.
Recreational and Tourism activities	Plastic shopping bags, 4–6 pack yokes, plastic food containers, plastic bottles/containers for drinks, crisp/sweet packets, lolly sticks and glass bottles.

Table 3 The quantity of total items for three months

	May		June		July	
Litter type	Items	Weight (kg)	Items	Weight (kg)	Items	Weight (kg)
Cloth and Ropes	137	8	135	10	165	8.53
Food	120	9	135	11	150	9.94
Glass	47	6	25	5	30	4.50
Metal	25	5	34	6	35	5.50
Plastic	582	33.57	829	44.85	823	48.72
Paper	143	12	153	15	165	13.00
Styrofoam	67	5	88	7.13	95	9.56
Wood	86	7	77	8.85	70	6.80
Others	70	8	102	12	88	10.25
Total	1277	93.57	1578	119.83	1621	116.80

natural litter, such as dead leaves, fish bones, and detached wings, etc. were excluded during the survey. The collected items were segregated into various categories (plastics, paper, metal, cloth and ropes, food, rubber, glass, wood, and others (gloves, electronic remains, light bulbs, tubes, and crates, etc.).

Identification of litter sources

Litter is generated at coastlines from various sources. Monitoring of litter pollution is necessary to estimate the input of litter from different sources for suitable litter management. Litter sources in the present study were determined according to OSPAR (2007) pilot project approach which divided litter sources into five groups; i.e. 1) fisheries, 2) galley waste 3) sewage and sanitary waste, 4) shipping, 5) recreational and tourism activities. The most important items of litter sourcing is given in Table 2. Linear regression and analysis of variance (Two-way ANOVA) analyzed the relationship between the numbers of items and the weight of the litter and the overall significant difference between items and weight of litter.

Results

Quantities of beach litter

During the summer season, cleaning activities were regularly accomplished and recorded by the beach management. A total

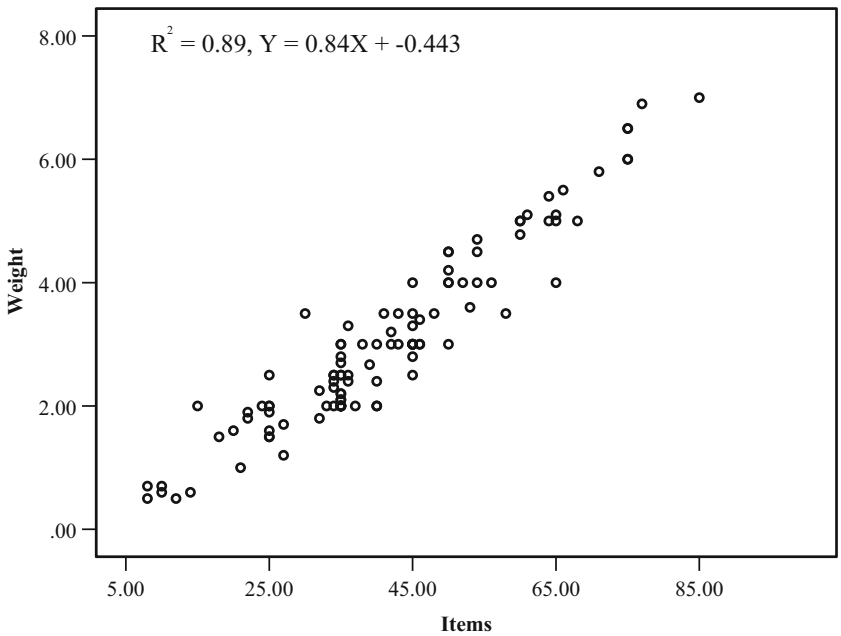

Fig. 2 Overall relationship between litter number/weight

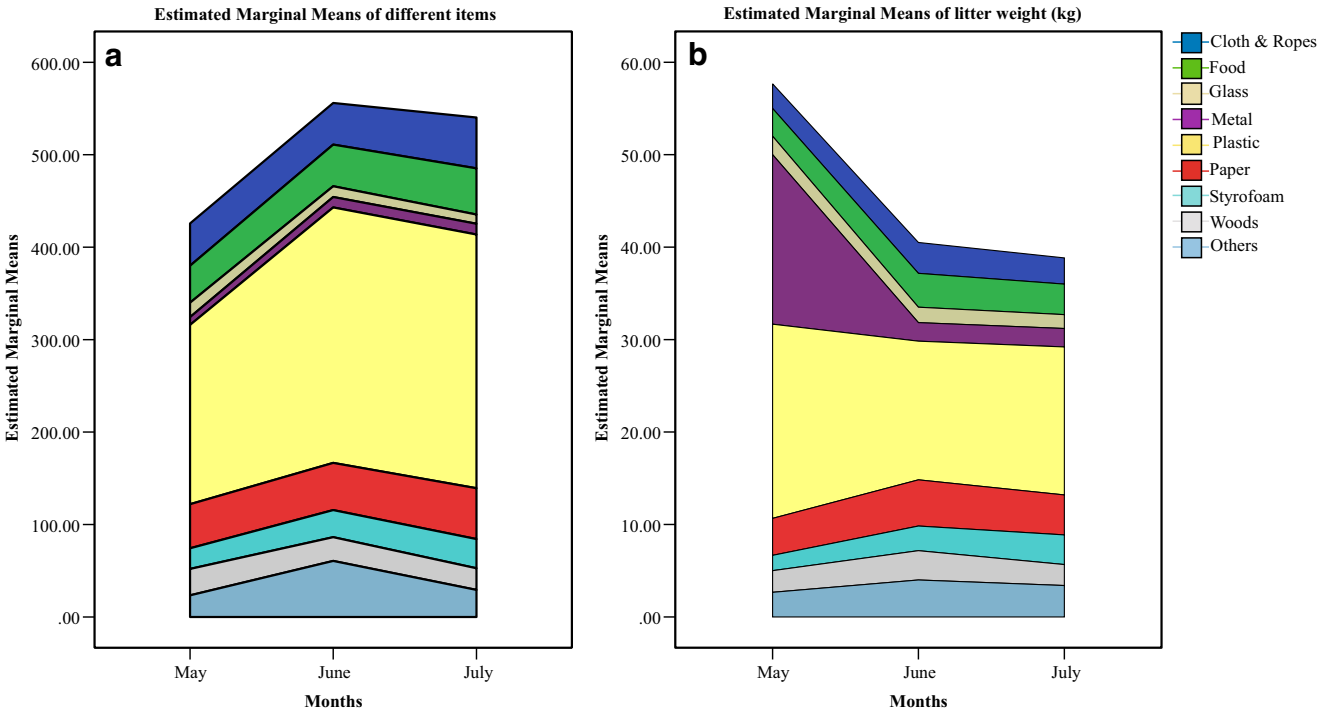

Fig. 3 Relationship between different categories of litter items (**a**) corresponding weight (**b**) for three months (May, June and July) respectively

of 4476 various litter items was counted during the study period with corresponding weight of 330.2 kg. In May, 1277 different litter items weighed 93.57 kg and from garbage bins. During June, 119.83 kg weight was recorded for 1578 items from the same garbage bins followed by 116.8 kg of 1621 items observed in July. Various items with their corresponding weights have been given in Table. 3.

Analysis of variance showed statistically significant differences between litter items and their corresponding weights (Fig. 2). Statistically non significant difference ($p < 0.05$) was noted among the three different data sets (May, June, and July) in both numbers and weight of litter. However, a significant difference ($p < 0.05$) was noticed between different categories of litter collected from the beach (Fig. 3).

The numbers of items observed in different months of the study period were variable. In May, the average number of items was 220.17 in 100 m^{-1}, 272 items were found 100 m^{-1} in June while the in July, 279.48 items 100 m^{-1} (Fig. 4).

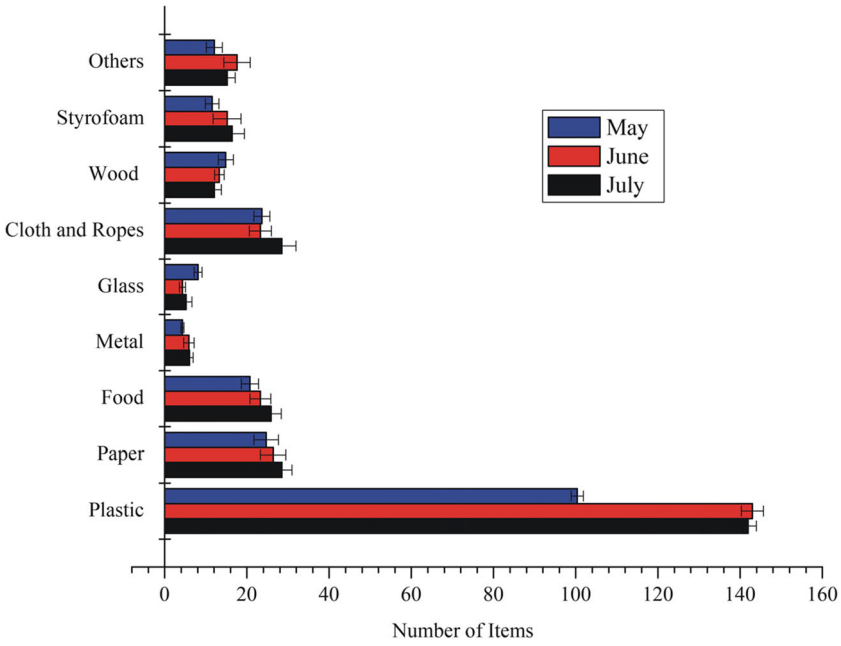

Fig. 4 Number of different litter types in 100 m^{-1}

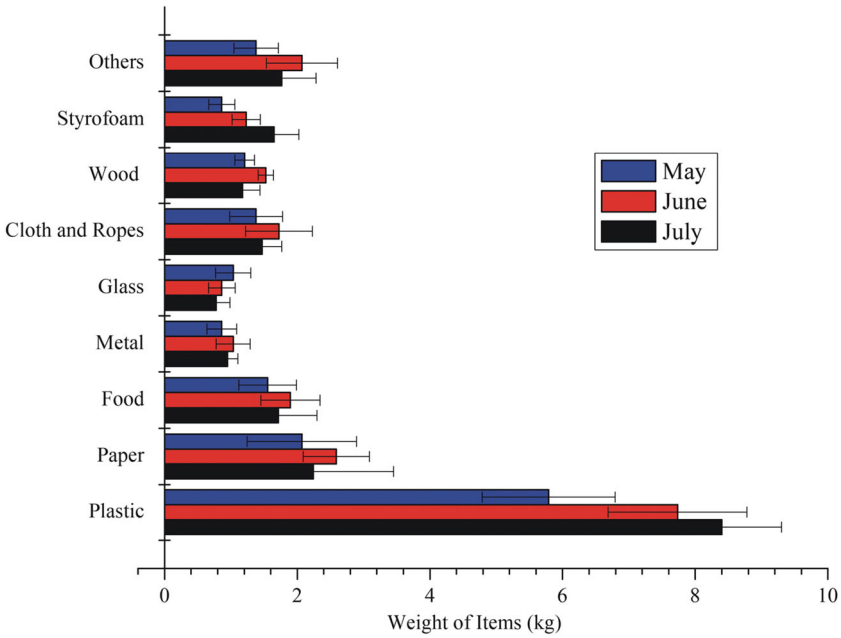

Fig. 5 Weight of quantified litter in 100 m^{-1}

Average litter for three months' was estimated to be 1491.90 items in 580 m^{-1} with a weight of 110.05 kg (Table 4).

The average litter weight found was 16.3 kg per 100 m in May; followed by 20.66 kg per 100 m and 20.14 kg per 100 m respectively in June and July (Fig. 5).

Litter composition

As discussed in the methodology section, different items were categorized into 9 groups. The present findings showed that plastic litter was the most prominent category, followed by paper and then cloth and ropes. Plastic accounted for 582 number of items in May, while 829 and 823 items were recorded in June and July respectively. These corresponded to 33.57%, 44.85%, and 48.72% of the total amounts. Paper was the second most abundant litter category after plastic, with 143 items in May, 153 and 165 items in June and July, with respective weights of 12 kg, 15 kg and 13 kg followed by cloth & ropes with 137, 135 and 165 items, weighing 8 kg, 10 kg and 8 kg, respectively. Food litter counts were less in number as compared to wood, cloth & ropes, although they had slightly greater weights than wood, cloth & ropes (9.98, kg 7.55 kg and 9.94 kg respectively). The proportion of different types of litter for all three months is shown in Table 5.

Table 4 Three-months average proportion of different litter at No. 1 Bathing Beach of 580 m^{-1}

Litter type	Items	Proportion (%)	Weight	Proportion (%)
Cloth and ropes	145.66	9.76	8.84	8.03
Food	135.00	9.05	9.98	9.07
Glass	34.00	2.28	5.16	4.69
Metal	31.33	2.10	5.5	5.00
Plastic	744.66	49.91	42.38	38.51
Paper	153.60	10.30	13.33	12.11
Styrofoam	83.33	5.59	7.23	6.57
Wood	77.66	5.21	7.55	6.86
Others	86.66	5.81	10.08	9.16
Total	1491.90		1,10.05	

Discussion

The information on the quantities of anthropogenic litter along beaches of various cities of the world is important as it offers easy and economical information that may used to plan management measures at different levels (items linked to their use and sources) Piha et al. (2011). It is hard to compare beach litter items at a particular place with the prevalence of litter on other beaches of the world due to different methodologies and sampling strategies adopted. However, the quantities of litter at No. 1 Bathing Beach (present study) depict that the beach litter was in lesser amounts than other coastal regions around the world (Table 6). Beach litter levels were not a crucial issue because of the efficient and regular beach cleaning management system. On average, 1491.90 beach litter items weighing 189 kg km^{-1} were determined at this beach. The mean macro-litter mass recognized in South China beaches is about 3 g m^{-2} (Cheung et al. 2016).

In the Falkland Islands, 77 litter items km^{-1} (±25; Otley and Ingham 2003) have been found; New South Wales, Australia coastal regions contained 214 (±68) litter items

Table 5 Proportion of items and weight of litter

Litter type	Proportion of number of items			Proportion of litter weight		
	May	June	July	May	June	July
Cloth and Ropes	10.73	8.56	10.18	8.55	8.35	7.30
Food	9.40	8.56	9.25	9.62	9.18	8.51
Glass	3.68	1.58	1.85	6.41	4.17	3.85
Metal	1.96	2.15	2.16	5.34	5.01	4.71
Plastic	45.58	52.53	50.77	35.88	37.43	41.71
Paper	11.20	9.70	10.18	12.82	12.52	11.30
Styrofoam	5.25	5.58	5.86	5.34	5.95	8.18
Wood	6.73	4.88	4.32	7.48	7.39	5.82
Others	5.48	6.46	5.43	8.54	10.01	8.78

km^{-1} (Taffs and Cullen 2005); and in the Gulf of Oman some 1790 (±1040) litter items km^{-1}, weighing 27.02 (±14.48) kg km^{-1} have been reported (Claereboudt 2004). Similarly, beach litter estimated at the Balearic Islands, Bonaire, Caribbean, Belgian and Clifton Beach, Karachi, Pakistan beaches contained 36,000, 115,000 (±58,000), 64,290 (±67,670) and 8665 (±1483) items km^{-1} respectively, with corresponding weights of 32 (±25), 3408 (±1704), 92.7 (±104.5) and 54.83 (±8.58) kg km^{-1} (Martinez Ribes et al. 2007; Debrot et al. 2013; Cauwenberghe et al. 2013; Ali and Shams 2015).

Additionally, prevalence of beach litter was determined during summer and spring seasons 2018, at 56 sites along the various coastal region of Spain. A total of 10,101 litter items (Avg: 0.062 items m^{-2}) was counted in spring, and 20,857 (averaged 0.116 items m^{-2}) in summer (Asensio-Montesinos et al. 2019). On Mediterranean beaches of Morocco, spatial and temporal variations of litter included, 436 ± 253 items per 100 m in Autumn; 345 ± 144 per 100 m in Spring (Nachite et al. 2019). Along the Caribbean coastline of Colombia a total of 5993 items of litter was recorded from 25 beaches, which was divided into 13 categories, with an average abundance of 7 items m^{-1} (Rangel-Buitrago et al. 2018).

The number of litter items and respective weight displayed greater variations at No 1. Bathing Beach, as

Table 6 Litter items and weight per kilometer (km) found along numerous coastal regions of the world

Beach	Items km^{-1}	kg km^{-1}	References
Balearic Islands	36,000	32 (±25)	Martinez Ribes et al. 2007
Bonaire, Caribbean	115,000 (±58,000)	3408 (±1704)	Debrot et al. 2013
Belgium	64,290 (±67,670)	92.7 (±104.5)	Cauwenberghe et al. 2013
Brazil	9100	–	Santos et al. 2009
Clifton Beach, Karachi, Pakistan	8665 (±1483)	54.83 (±8.58)	Ali and Shams 2015
Curaçao, Caribbean	60,000	4500	Debrot et al. 1999
Dominica, Caribbean	1900	153.7	Corbin and Singh 1993
Falkland Islands	77 (±25)	17.3 (±12)	Otley and Ingham 2003
Gulf of Oman	1790 (±1040)	27.02 (±14.48)	Claereboudt 2004
Korean	4809 (±2677)	865 (±786)	Hong et al. 2014
No. 1 Bathing Beach Qingdao, China	2572	189	Present Study
NS Wales, Australia	214 (±68)	–	Taffs and Cullen 2005
Puerto Rico	3900	945	IOC/IOCARIBE 1989
Shilaoren Beach, Qingdao, China	720	14	Pervez et al. 2020
South African	37,400	100.5	Madezena and Lasiak 1997
St. Lucia, Caribbean	11,200	8.2	Corbin and Singh 1993
Sydney, Australia	2664	–	Cunningham and Wilson 2003

compared with previous studies. Many factors could be deemed responsible for these variations (Table 6). The determining factors could include population density, tourism numbers and industrial activity. Environmental factors, especially wind velocity are recognized as being one of the important factors regulating litter quantity (Orfila et al. 2005). Litter quantity in the coastal region has also been inversely related to geographical distance from population centers and has a direct relationship with the number of people visiting the beach (Gabrielides et al. 1991). Litter quantity is linked with people concentration and crowding (da Silva 2002). Alshawafi et al. (2017) recognized that tourism is a significant litter source in many parts of the world. In the present analysis, the main beach litter sources were recognized as activities like recreation, fishing, tourism, boating and shipping (Table. 2). The abundance of different types of litter,especially the high quantity of plastic containers, plastic bottles, suggested that recreational activities or a land-based origin was its main source. Additionally, it was noticed that many snack bars, malls, markets, fast food shops were located along the coastal region of the study area. Food materials are generally enfolded in plastic wrappers, polystyrene, and bottles, etc., most visitors usually preferred fast or junk food, noodles, mineral water, tin, soft drinks, and Chinese traditional foods. Though the beach is well cleaned on a regular basis by beach management, much litter can be reused or recycled by placement of separate bins for different items, e.g. plastics, general waste, paper, etc., rather than placing all waste in the current garbage bins; and displaying notices educating the public and making them aware about litter categories.

The quantity of plastic items was equivalent to the quantity of plastic litter found on Korean beaches (Hong et al. 2014). The proportion of plastic items varied from 60 to 80% of various Mediterranian and South African beach litter (Derraik 2002), exceeded up to 80% in the Remote Islands (Ribic et al. 2012). Smith (2012) concluded that the Motupore Islands beaches in Papua New Guinea comprised 89.7% plastic items as litter. The plastics can be biodegraded into microplastics (MPs) which may enter into the food chain and thus become a real threat to human health. Browne et al. (2010) found 65% MPs litter in Plymouth, UK while in Portugal, the occurrence of MPs has been documented up to 72% in the coastal region (Martins and Sobral 2011).

Synthetic fishing gears, ropes, net, raw plastics, packing materials, etc., have been observed for several years in the environment (Buhl-Mortensen and Buhl-Mortensen 2017). Beach visitors waste too much food and in the case of China the annual production of waste food is worth 200 billion Yuan (Li et al. 2016). Food waste is considered as an economic, ecological and social problem and the FAO (2013) concluded that every year 1.3 billion tons of food is wasted globally. Wood is also one of the most abundant litter types with respect to weight and is prevalent in different coastal regions of the world (Claereboudt 2004; Hong et al. 2014). Beach surveys highlighted the overall marine litter situation in the given area and hopefully will help reduce, overcome or reuse the litter quantity by adopting various strategies, such as, recycling (Corraini et al. 2018).

Conclusions

This was the first-ever study conducted on beach litter along the Bathing Beach No.1 in Qngdao, China. Beach litter mainly comprised of various litter items such as, plastic, paper, food, (cloth and ropes), metal, glass, Styrofoam, wood and others (condoms, electronic remains, rubber, etc.). Plastic litter was more prominent than other litter types followed by paper, wood and (cloth and ropes) in terms of the number of items. Plastic, paper and food had higher proportions in term of weights as compared to other litter types. Land-based origin was the main litter source in the study area. It is recommended that management strategies such as separate garbage bins and awareness of beach visitors may be beneficial for recycling, as numerous litter types can be utilized for useful purposes because of the high proportion of recyclable materials.

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