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MARINE DEBRIS AT INDRAMAYU TOURISM BEACH, WEST JAVA: DENSITY AND COMPOSITION

Sampah Laut Di Pantai Wisata Indramayu, Jawa Barat: Kepadatan Dan Komposisi

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ABSTRACT

Marine debris is solid material that is intentionally or unintentionally dumped into waters, potentially threatening the condition and productivity of the aquatic environment. Tirta Ayu Beach and Balongan Beach, as tourist destinations, face the threat of marine debris accumulation. The presence of tourists on both beaches contributes to increasing regional and community income, but also has an impact on increasing the amount of waste produced. This accumulation of waste is spread to various locations and has a negative impact on the aquatic ecosystem. This study aims to identify the composition of types, weight, density, and distribution of marine debris on Tirta Ayu Beach and Balongan Beach. Sampling was carried out at eight research stations, then classified and analyzed based on UNEP and KLHK standards. The results of the study showed that the marine debris found included plastic, plastic foam, rubber, paper and cardboard, wood, glass, cloth, and other materials. Plastic is the most dominant type of waste, with a percentage of 89% on Balongan Beach and 81% on Tirta Ayu Beach. Meanwhile, the highest density of marine debris based on quantity and weight was found at Tirta Ayu Beach, with an average of 5.0 ± 1.9 items/m² and a weight of 25.8 ± 16.3 grams/m².

Keywords: Marine trash, pollution, tourist beaches, coastal, plastic waste

ABSTRAK

Sampah laut merupakan material padat yang secara sengaja maupun tidak sengaja dibuang ke perairan, sehingga berpotensi mengancam kondisi serta produktivitas lingkungan perairan. Pantai Tirta Ayu dan Pantai Balongan, sebagai destinasi wisata, menghadapi ancaman dari akumulasi sampah laut. Kehadiran wisatawan di kedua pantai tersebut berkontribusi terhadap peningkatan pendapatan daerah dan masyarakat, tetapi juga berdampak pada peningkatan jumlah sampah yang dihasilkan. Penumpukan sampah ini menyebar ke berbagai area dan

berdampak buruk pada ekosistem perairan. Penelitian ini bertujuan untuk menganalisis jenis, berat, kepadatan, dan pola distribusi sampah laut di Pantai Tirta Ayu dan Pantai Balongan. Pengambilan sampel dilakukan di delapan stasiun penelitian, kemudian diklasifikasikan dan dianalisis berdasarkan standar UNEP dan KLHK. Hasil penelitian mengungkapkan bahwa sampah laut yang ditemukan meliputi busa plastik, plastik, kertas dan kardus, karet, kaca, kayu, kain, serta material lainnya. Plastik menjadi jenis sampah yang paling dominan, dengan persentase 89% di Pantai Balongan dan 81% di Pantai Tirta Ayu. Sementara itu, kepadatan sampah laut tertinggi berdasarkan jumlah dan berat ditemukan di Pantai Tirta Ayu, dengan rata-rata 5,0 ± 1,9 item/m² dan berat sebesar 25,8 ± 16,3 gram/m².

Kata Kunci: Sampah laut, pencemaran, pantai wisata, pesisir, sampah plastic

INTRODUCTION

Marine debris is a persistent solid material consisting of product residues that are intentionally or unintentionally discarded and left in the marine environment (NOAA, 2019; Patuwo *et al*., 2020; Johan *et al*., 2020). The problem of marine debris has become an unresolved global issue. The increasing amount of waste in the waters causes this problem to become more widespread and difficult to control. Jambeck *et al*., (2015) estimate that globally, the amount of marine debris will continue to increase until 2025 if there are no serious handling efforts. According to Johan *et al*., (2020), the problem of marine debris is triggered by an increase in population and various human activities, such as beach tourism activities and daily activities that produce various types of waste, including food waste, paper, cardboard, plastic, textiles, leather, garden waste, wood, glass, metal, used household goods, and hazardous waste.

Based on its size, marine debris can be divided into various types of sizes, including megadebris >1m, macrodebris 2.5 cm - 100 cm, mesodebris 5 mm - 2.5 cm and micro-debris with a size range of 1µm to 5 mm (Opfer *et al*., 2012). Marine debris can be categorized into several groups including plastic, metal, glass, rubber, wood, clothing/fiber and others (NOAA, 2013; Djaguna *et al*., 2013; Patuwo *et al*., 2020). Marine debris is generally produced from anthropogenic activities on land and then enters the sea through the surrounding rivers (Lebreton *et al*., 2017; Bangun *et al*., 2019). Marine debris moves because it is carried by river flows and the physical dynamics of the sea such as tides, waves and currents. Marine debris distributed following the flow of currents and tides will float and experience changes in density so that the marine debris will sink in the middle of the sea or move to the other side of the ocean coast which can cause marine debris to accumulate in one place and result in the accumulation of waste in the waters (Amriani & Tuahatu, 2021). Dynamic ocean movements cause waste to spread widely in the sea to the ocean, even to the deep seabed (Bergmann *et al*., 2017; Van Cauwenberghe *et al*., 2013; Woodall *et al*., 2014; Angiolillo *et al*., 2015; Tassakka *et al*., 2019).

The increase in marine debris in the waters can have many impacts on the waters. Marine debris will increase and have a wider impact if the impact is not handled properly (Djaguna *et al*., 2013; Johan *et al*., 2019). According to Subekti (2010), indiscriminate waste disposal can have a direct impact on the cleanliness and health of the surrounding environment. During the rainy season, waste is carried into water bodies along with the increasing river discharge. This condition causes waste to drift until it reaches the river mouth and finally flows into the sea. The threat of marine waste problems to coastal ecosystems (coral reefs, seagrass and mangroves) has become a phenomenon that greatly influences the existence of coastal biota (Amriani & Tuahatu, 2021). One of the coasts threatened by marine waste pollution is Tirta Ayu Beach and Balongan Beach. Both beaches are tourist destinations. The increase in the number of tourists to Tirta Ayu Beach and Balongan Beach has resulted in accumulated waste

that can be distributed in the waters, resulting in decreased aesthetics, environmental pollution and can endanger the surrounding ecosystem (Lu *et al*., 2018). This is supported by the research results of Hayati *et al*., (2020) which reported that marine waste causes a low coastal clean index of waters and directly affects the level of tourist interest. Referring to this, this study was conducted with the aim of examining the distribution and composition of marine waste at Indramayu Tourism Beach.

METHODS

This research will be conducted at two tourist beaches in Indramayu Regency, West Java, namely Tirta Ayu Beach and Balongan Beach. Sampling was carried out in June 2022. The selection of the research location was based on several criteria, including being accessible at all times, having sandy or gravel characteristics, no breakwaters or piers, having a minimum length of 100 meters with a moderate slope (low-moderate 15º - 45º), and no beach cleaning activities (clean-up) carried out close to the sampling period (KLHK, 2020). The tools used in this study were: scales, cameras, 100 m meters, trash containers, gloves, and ropes. While the materials used were in the form of marine debris samples.

Marine debris sampling

Marine debris sampling was carried out at 8 predetermined stations, where 4 stations were located at Tirta Ayu Tourism Beach and 4 stations at Balongan Beach (Figure 1). Samples were collected using the transect method, where the transect location was determined in advance by determining a transect area of 100 parallel to the coastline and a width following the back boundary of the beach (width according to field conditions, minimum 5 meters). Then the transect line was made in the manner as determined according to the Ministry of Environment and Forestry (2020).

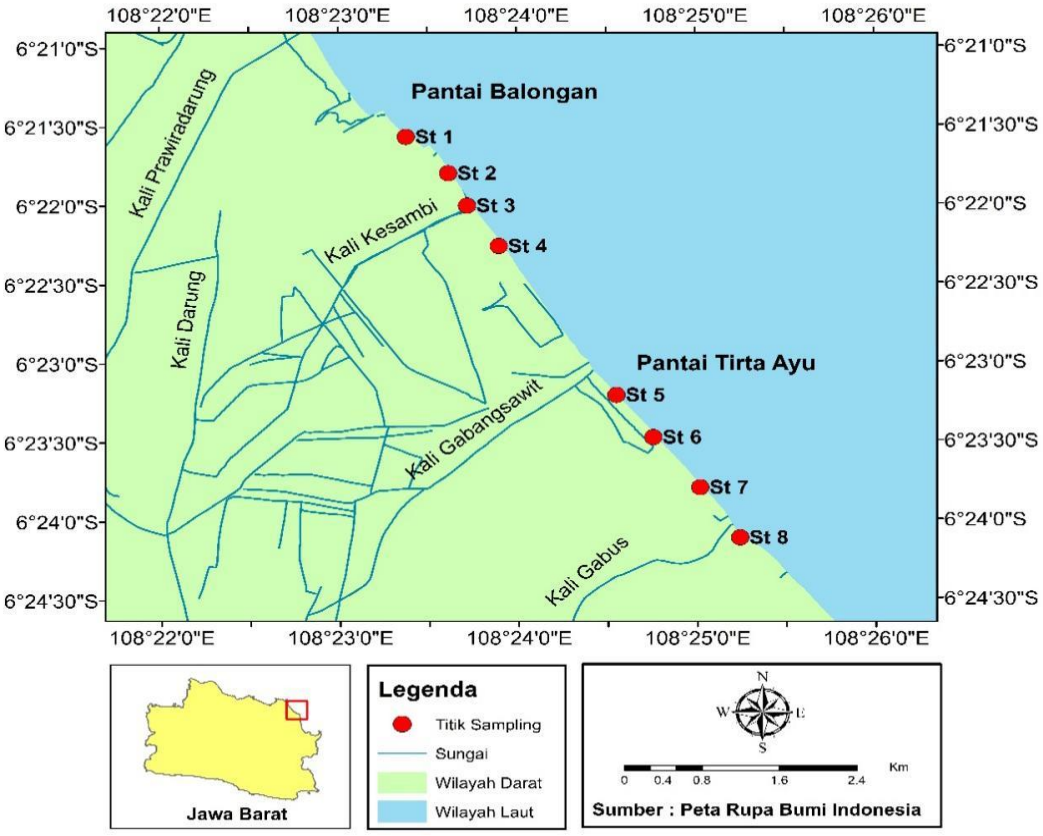

Figure 1. Sampling locations and stations

The marine debris obtained is then cleaned and dried, after which the samples are grouped according to their categories. The classification of marine debris refers to UNEP (United Nations Environment Programme) which consists of plastic, plastic foam, glass and ceramics, cloth, metal, paper and cardboard, rubber, wood, and other materials. The types of waste for each group are as presented in Table 1.

Table 1. Marine Debris Classification System (UNEP, 2009)

No	Material Type	Garbage Code	Waste Classification
1.	Plastic	PL01 - PL24	Bottle caps, knives, spoons, forks, stirrers and cooking utensils, straws, plastic bags, beverage and food packaging (cups, lunch boxes), and other plastics
2.	Plastic Foam	FP01 - FP05	Cooler and packaging insulation corks, cups and food packaging containers, and other plastic foams
3.	Cloth	CL01 - CL06	Clothing, hats, shoes, carpets, towels, other fabric categories (including rags and napkins), and furnishing equipment
4.	Glass and Ceramics	GC01 - GC08	Building materials, fluorescent lamps, bottles, energy-saving lamps, and other glass and ceramic categories
5.	Metal	ME01	Eating utensils (plates and glasses), aluminum cans, foil wrap, wire, metal flakes, wire mesh, other metal categories
6.	Paper and Cardboard	PC01 - PC05	Newspapers, books, magazines, food trays, cardboard boxes and their flakes, cups, food wrappers, beverage containers made of paper, cigarette packs, other paper categories
7.	Rubber	RB01 - RB08	Sandal and shoe soles, balls, balloons, toys, tires, condoms, gloves, rubber bands, other rubber categories
8.	Wood	WD01 - WD06	Ice cream sticks, chopsticks, wooden spoons and forks, wooden pallet crates, toothpicks, wooden tools, wooden matchsticks and firework sticks, other wood categories
9.	Other Materials	OT01 - OT05	Cleaning tools (diapers, cotton buds, tampons, pads and toothbrushes), batteries, equipment and electronics, other materials

Data Analysis

The data analysis used is descriptive analysis. Descriptive analysis is designed to collect information about the real conditions at the present time (Loeb *et al.,* 2017). In this study, marine debris that has been grouped according to its category is then summarized and analyzed. The recapitulation of marine debris data includes:

a. Marine Litter Density (Item)

Waste density (K) is calculated based on the amount of waste per type and per area of the transect box. Waste density data is written in units of the amount of waste per type/m^2 (KLHK, 2020) and is calculated using the following formula:

$$\text{Density Type (item /m}^2\text{)} = \frac{\text{amount of waste per type (item))}}{\text{transect area (m}^2\text{)}}$$

b. Marine Litter Density (Weight)

The waste obtained per square meter (m^2) is the total weight of waste per area of the transect box. Waste weight data per square meter (m^2) is written in grams per square meter (g/m^2) (KLHK, 2020). With the following formula:

$$\text{Density Weight (gram/m}^2\text{)} = \frac{\text{weight of waste (gram)}}{\text{transect area (m}^2\text{)}}$$

c. Composition of Marine Debris

The composition of waste is calculated as a percentage (%), namely waste items per type per total waste in the transect box (KLHK, 2020). The composition of waste with the following formula:

$$\text{Percentage (\%)} = \frac{\text{x}}{\sum_{i=l}^{n} xi}\ x\ 100\%$$

x = trash items per type

RESULT

3.1. Types of Marine Debris

Referring to the classification of marine debris according to UNEP (2009), various types of marine debris were found on Indramayu tourist beaches. There were 6 types of marine debris found on Balongan Beach and 8 types of marine debris found on Tirta Ayu Beach. Marine debris on Balongan Beach consisted of plastic, plastic foam, paper and cardboard, rubber, wood, and other materials (others). Meanwhile, marine debris found on Tirta Ayu Beach was plastic, plastic foam, paper and cardboard, rubber, cloth, glass, wood and others (Figure 2**)**.

Figure 2. Several types of marine debris found on Balongan Beach and Tirta Ayu Beach

Material Type	Examples of samples found	Material Type	Examples of samples found
Plastic		Paper and Cardboard	
Plastic Foam		Rubber	

Cloth		Wood	
Metal		Others	

3.2. Marine Litter Density

The density of marine debris based on quantity and weight is shown in Table 2.

Table 2. Density of marine debris based on quantity (items/m^2) and weight (weight /m^2)

Type of waste	Code	Density of Number (item/m^2)		Density Weight (gram/m^2)	
		Balongan	Tirta Ayu	Balongan	Tirta Ayu
Plastic	PL	3,21 ± 0,3	4,06 ± 1,1	10,8 ± 3,64	9,47 ± 2,22
Plastic Foam	FP	0,17 ± 0,05	0,17 ± 0,2	0,97 ± 0,39	0,91 ± 0,79
Cloth	CL	0	0,03	0	0,24 ± 0,3
Glass and Ceramics	GC	0	0,04	0	0,79 ± 0,92
Metal	ME	0	0	0	0
Paper and Cardboard	PC	0,11 ± 0,04	0,33 ± 0,2	1,01 ± 0,32	1,87 ± 0,64
Rubber	RB	0,08 ± 0,05	0,21 ± 0,2	3,17 ± 2,41	9,62 ± 7,83
Wood	WD	0,05 ± 0,04	0,13 ± 0,2	0,77 ± 0,12	2,44 ± 2,75
Others	OT	0	0,02	0	0,43 ± 0,86
Number		3,6 ± 0,5	5,0 ± 1,9	16,7 ± 6,89	25,8 ± 16,3

3.3. Composition of Marine Debris

Marine debris at Balongan Beach Indramayu consists of plastic, plastic foam, paper and cardboard, rubber, wood, and other materials. While at Tirta Ayu Beach it consists of plastic, plastic foam, paper and cardboard, rubber, cloth, glass, wood and other materials. Types of cloth, metal, and glass were not found at Balongan Beach. This can be caused by the management of marine debris at Balongan Beach which is already quite good, where cleaning around the beach is often carried out. Especially metal and glass waste that is dangerous to

visitors will be prioritized in the cleaning activities. In more detail, the composition of marine debris types is presented in Figure 3.

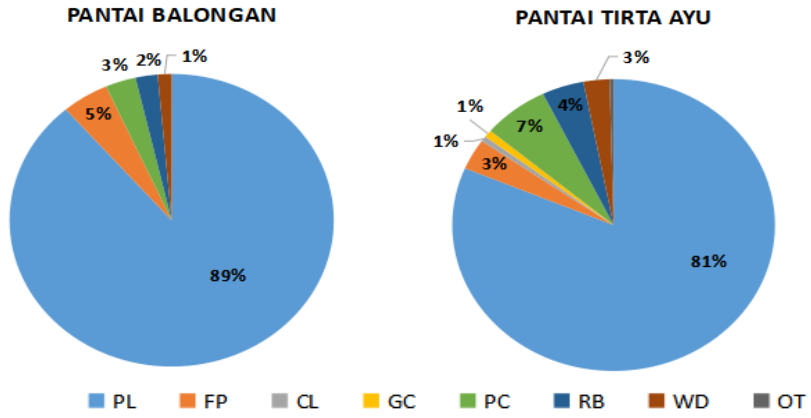

Figure 3. Composition of types of marine debris on Balongan and Tirta Ayu beaches

DISCUSSION

Types of Marine Debris

Figure 2 shows that on Balongan and Tirta Ayu Beaches, many types of marine debris were found from land-based sources and tourist activities. Accumulation of land-based sources such as wooden blocks, sandals and several plastic wrappers which are household waste from land. The results from tourists include styrofoam food containers and single-use plastic food and beverage packaging.

Plastic is the type of marine debris found with the highest density, both on Balongan Beach and Tirta Ayu Beach. Plastic waste has a light resistance so that it can be easily carried by the current and distributed widely. This is in accordance with research by Wessel *et al*., (2019); Azman *et al*., (2021) which states that plastic waste dominates all waters because its light resistance makes plastic waste easily carried by wind, tides and currents.

The large amount of plastic waste found in waters will have a negative impact on the waters and the surrounding environment such as the ecosystem on the beach such as the coral reef ecosystem which disrupts the ecological process of the coral reef (Al-Jufaili *et al*., 1999; Chiappone *et al*., 2002; Carvalho-Souza & Tinôco, 2011; Lamb *et al*., 2018; Mulochau *et al*., 2020).

Marine Litter Density

Based on the results of the research conducted, the average value of marine debris density based on the amount at Balongan Beach was 3.6 ± 0.5 items/m2 and Tirta Ayu Beach was 5.0 ± 1.9 items/m^2, each of which was dominated by plastic marine debris (Table 2). This waste density is lower when compared to the research results of Moningka *et al*., (2021) on the northern coast of Minahasa Beach with a density of 8.16 items/m2 and the research results of Hastuti (2014) and Yusra *et al*., (2021) at Pantai Indah Kapuk, Jakarta and Pantai Purus, Padang with densities of 533 items/m^2 and 62.92 items/m^2 respectively. However, at all of these tourist beaches, plastic waste is the most dominant type of marine debris.

Marine debris is not only a problem at Balongan and Tirta Ayu Beaches, but throughout Indonesia and even various parts of the world. Various studies related to waste on beaches in Indonesia have been carried out, including in West Kalimantan (Jati & Utomo, 2020), Cilacap, Central Java (Syakti *et al*., 2017; Nurito *et al*., 2022), Aceh, Seribu Islands (Willoughby, 1986;

Assuyuti *et al*., 2018), West (Kusumawati *et al*., 2018), Maros, South Sulawesi (Sahar *et al*., 2020), Ambon Island (Evans *et al*., 1995), and Ambon (Tuhumury & Kaliky, 2019). Studies of marine debris in coastal areas have also been conducted in various parts of the world such as in the Mediterranean (Portman & Brennan, 2017), the Persian Gulf (Sarafraz *et al*., 2016), the southeastern Black Sea (Aytan *et al*., 2020) Cornwall in England (Watts *et al*., 2017), and the Santa Catarina Coast of Brazil (Marin *et al*., 2019).

Based on weight, Table 2 shows that the density of marine debris at Balongan Beach is 16.7 ± 6.89 grams/m^2, while Tirta Ayu Beach has a density of 25.8 ± 16.3 grams/m^2. The high density based on weight at Tirta Ayu Beach when compared to Balongan Beach is in line with the high density based on quantity. Tirta Ayu Beach is located close to rivers and settlements so that this beach accumulates more waste and produces more diverse waste, namely household waste such as sandals, motorcycle inner tubes, hair dye bottles, plastic bags, detergent wrappers, straws, and glass drink bottles. In accordance with the research of Büyükdeveci & Gündoğdu (2021) which found that most of the marine waste in the waters comes from land. In addition, uncontrolled waste disposal is also a source of marine waste (Bergmann *et al*., 2017; Galgani *et al*., 2010 ; UNEP, 2009; Büyükdeveci & Gündoğdu, 2021).

Composition of Marine Debris

Figure 3 shows that based on the number of items found, marine debris at Balongan Beach and Tirta Ayu Beach is dominated by plastic waste. This is in line with the research results of Alshawafi *et al*., (2017), Assuyuti *et al*., (2018), Battisti *et al*., (2019); Giovacchini *et al*., (2018); Maziane *et al*., (2018), Nachite *et al*., (2018), Nachite *et al*., (2019), Mghili *et al*., (2020), Syakti *et al*., (2018), Gregory *et al*., (2019); Bangun *et al*., (2019); and Faizal *et al*., (2021) where the most dominant marine debris is plastic waste. This is thought to be due to human activities which are the main input of plastic waste pollution into the waters. This was also reported by previous research (NOAA, 2016) which stated that plastic waste is the most common and widely found waste throughout the world. The results of research by Addamo *et al*., (2017) and Helcom (2018) also found that the most dominant type of marine waste is single-use plastic.

The plastic waste found on Balongan and Tirta Ayu Beaches is thought to have come from tourism activities and river flow accumulation. Marine pollution originating from land includes various anthropogenic elements originating from domestic, industrial, and agricultural activities (Mutlu *et al*., 2020; Büyükdeveci & Gündoğdu, 2021). Human activity is the main factor in the production of waste on Indonesian beaches, especially in tourist areas, with plastic waste being the most dominant type of waste. The dominance of plastic waste among inorganic waste has also been found in various studies on the coast of East Nusa Tenggara, including in Rote Regency, Kupang Regency, and East Flores Regency (Nawastuti & Lewoema, 2019; Purba *et al*., 2018; Toruan *et al*., 2021).

Beach management is one of the reasons for the large amount of waste found at Tirta Ayu Beach compared to Balongan Beach. Waste management at Tirta Ayu Beach is still relatively minimal with the number of trash bins still lacking and the awareness of the surrounding community regarding waste disposal still needs to be considered so that various types of marine waste are found such as household waste at Tirta Ayu Beach. Poor waste management causes marine debris to accumulate on the Wisata beach. This is in accordance with (Garcés-Ordóñez *et al*., 2020) who stated that poor waste management is the main source of plastic pollution in coastal areas.

In addition to its management, the location of Tirta Ayu Beach is also a reason for the large amount of waste found. Tirta Ayu Beach is flanked by a river and Balongan Beach so that this beach accumulates a lot of marine waste originating from the river and Balongan Beach as well as community activities such as fishing and fishing which are quite active at Tirta Ayu

Beach resulting in many fishing nets being found on this beach. This is in accordance with the statement from Syakti *et al*., (2017) that most people carry out fishing activities and a lot of fishing waste is left at fishing locations. This is also reinforced by MAP/UNEP, (2001); UNEP, (2015) reported that most of the waste reaching the sea comes from river flows, coastal urban centers and industry as well as tourism activities, in addition to marine activities such as shipping and fishing also contribute to the input of waste into the sea (Coe and Rogers, 1997; Carić & Mackelworth, 2014; Vlachogianni *et al*., 2016; Antonella *et al*., 2020).

CONCLUSION

The types of marine debris obtained from Tirta Ayu Beach are plastic, plastic foam, cloth, glass and ceramics, paper and cardboard, wood, rubber and other materials. Meanwhile, the types of marine debris obtained from Balongan Beach are plastic, plastic foam, rubber, wood, paper and cardboard. Based on the marine debris obtained, plastic is the most dominant type of marine debris, both at Balongan Beach (89%) and at Tirta Ayu Beach (81%). The highest marine debris density value based on quantity and weight is at Tirta Ayu Beach with 5.0 ± 1.9 items/m^2 and a weight of 25.8 ± 16.3 items/m^2. Meanwhile, the highest marine debris density value based on quantity and weight is at Balongan Beach with 3.6 ± 0.5 items/m^2 and a weight of 16.7 ± 6.89 grams/m^2.

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