JOURNAL OF WATER AND LAND DEVELOPMENT

e-ISSN 2083-4535

Polish Academy of Sciences (PAN) Institute of Technology and Life Sciences – National Research Institute (ITP – PIB)

JOURNAL OF WATER AND LAND DEVELOPMENT
DOI: 10.24425/jwld.2023.147236
2023, No. 59 (X–XII): 118–125

Microplastics abundance in domestic wastewater as a pollutant source for the Daroy River, Indonesia

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RECEIVED 28.04.2023 ACCEPTED 17.07.2023 AVAILABLE ONLINE 31.12.2023

Abstract: Domestic wastewater in Gampong Garot, Aceh Besar Regency, Aceh Province, Indonesia is directly discharged to the Daroy River without any treatment process. Domestic wastewater from Gampong Garot has been one of the contributors to microplastics contamination in the Daroy River. The microplastics (MPs) contained in domestic wastewater might come from used soaps and detergent products, as well as the scouring of clothes during washing. Thus, this study aims to investigate the abundance of MPs in domestic wastewater in Gampong Garot. The sampling points were determined based on purposive sampling, with samples taken at the end of the main pipe that directly leads to the Daroy River. Organics in domestic wastewater were removed using 30% H_2O_2 liquid through a digestion process at a temperature of 75°C. MPs characteristics such as size, shape, and colour were visually analysed using a light binocular microscope at 100× magnification, while the polymer type was analysed using Fourier transform infrared (FTIR) analysis. The concentration of MPs in domestic wastewater in Gampong Garot was 30.238 ±1.228 particles·(100 cm)$^{-3}$ sample. The most common sizes of MPs were found to be in the range of 1,001–5,000 μm, while the dominant colour and shape were transparent and fibre-like. Polyester (PES) was the most detected type of MPs. These findings highlight the need for wastewater treatment before discharge into aquatic bodies.

Keywords: abundance, Daroy River, domestic wastewater, Gampong Garot, Indonesia, microplastics

INTRODUCTION

Microplastics (MPs) are plastic particles that are less than 5 mm in size and have been found in various environmental sectors, nowadays (Horton *et al.*, 2017; Li, Liu and Chen, 2018). Since 2014, scientists have discovered that MPs can enter the aquatic environment through the wastewater of the city's wastewater treatment plants (WWTPs) (Mintenig *et al.*, 2017; Lares *et al.*, 2018) via domestic wastewater (Hidayaturrahman and Lee, 2019; Wolff *et al.*, 2019). Primary MPs (microbeads from personal care products, cosmetic lotions, and scrubbers) and secondary MPs (synthetic textile fibres and plastic fragments) were found in the final WWTP effluent. Lv *et al.* (2019) concluded that WWTP effluent was dominated by fragments, followed by fibres, films and foam with polyethylene terephthalate (PET), polystyrene (PS), polyethylene (PE), and polypropylene (PP) polymers. MPs sizes are distributed in the range >500 μm and between 62.5 and 125 μm.

In several municipal WWTPs effluents in many countries, it is known that polymers in the form of fragments and fibres of polyester (PES) which originate from the laundry are found a lot. Other than that, PES and PP originating from daily and kitchen activity were also found a lot (Lv *et al.*, 2019). According to Talvitie *et al.* (2017), the bulk of MPs found in WWTPs were in fibre form, making up 70% of them. This fibre comes from synthetic textiles that are released when washing clothes by more than 1,900 particles (Browne *et al.*, 2011), and 110,000 particles (Almroth *et al.*, 2018).

Washing conditions (temperature, friction, speed, washing duration), usage and type of detergent, and weathering of clothes (Napper and Thompson, 2016; Almroth *et al.*, 2018; Falco de *et al.*, 2018) influence the amount of microplastics produced. Various consumer products, such as glitter, that may release MPs into the wastewater system are sources of MPs from other domestic activities (Napper *et al.*, 2015), contact lens cleaners (Gregory, 1996), personal care products such as liquid soap (Prata, 2018), personal care beauty (Napper *et al.*, 2015), and toothpaste (Vieira *et al.*, 2016). These particles accidentally enter sewers or sewage systems.

MP in the environment raises new concerns due to the impact of MPs on human health (Sharma and Chatterjee, 2017; Rist *et al.*, 2018; Bradney *et al.*, 2019; Imran, Das and Naik, 2019; Lehner *et al.*, 2019). MPs in the environment is found almost at every trophic level, such as zooplankton (Cole *et al.*, 2013; Lee *et al.*, 2013), shellfish (von Moos, Burkhardt-Holm and Köhler, 2012), fish (Rochman *et al.*, 2013; Rochman *et al.*, 2015; Pedà *et al.*, 2016; Rummel *et al.*, 2016; Sembiring *et al.*, 2020), oysters (Sussarellu *et al.*, 2016), and dolphins (Denuncio *et al.*, 2011). In addition, MPs are also found in sea turtles (Tourinho, do Sul and Fillmann, 2010) and birds (Franeker van *et al.*, 2011). If fish from the sea are eaten by humans, MPs will be absorbed into the body. Whereas additives, such as copper ions used in plastic production, have a toxic effect on living creatures (Li, Liu and Chen, 2018).

Domestic wastewater management is only limited to black water treatment utilising a septic tank in Gampong Garot, Aceh Besar District, Aceh Region, Indonesia. Domestic wastewater is discharged through a piping system that includes parcel pipe, service pipe, lateral pipe, and main pipe, which is further discharged directly to Daroy River. Domestic wastewater comes from domestic effluent derived from water used for dishwashing, laundry, bathing and handwashing (Ytreberg *et al.*, 2020). Although there have been many studies on microplastics in wastewater in various countries around the world, Indonesia has never done research on microplastics, especially in domestic wastewater. Domestic wastewater from Gampong Garot's domestic activities has the potential to become a source of MPs in the Daroy River. Thus, this study aims to investigate the abundance of MPs in domestic wastewater in Gampong Garot using visual and Fourier transform infrared (FTIR) analysis methods. This research needs to be carried out because MPs are harmful to living creatures.

MATERIALS AND METHODS

STUDY AREA

The research was carried out in Gampong Garot, Aceh Besar Regency, Aceh Province, Indonesia. The study area and location of sampling points can be seen in Figure 1 and Figure 2.

SAMPLING METHODS

The determination of sampling points and sampling location was obtained based on purposive sampling. In this case, there are seven main pipes utilised for the distribution of domestic

Fig. 1. Location of study area – Gampong Garot, Aceh Besar Regency, Aceh Province, Indonesia; source: own elaboration

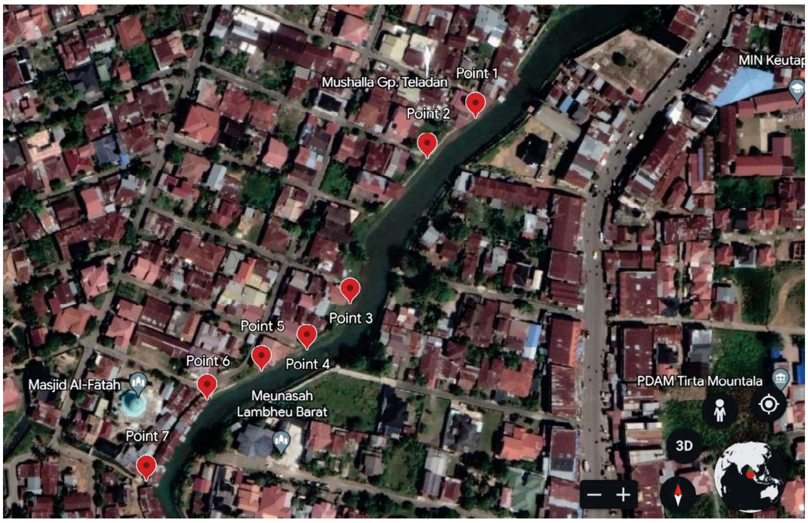

Fig. 2. Location of sampling points; source: own elaboration based on Google Earth

wastewater in Gampong Garot as sampling point locations. Domestic wastewater was gathered for 24 hours from the end of the main pipe which directly leads to Daroy River using a holding tank. The domestic wastewater that was collected after 24 hours was immediately taken to the laboratory for microplastics (MPs) testing. The weather during the sampling process was sunny, so it did not affect the condition of the sample. The coordinates of the sampling points from 1 to 7 and can be seen in Table 1 and Photo 1. Main pipe 7 (Point 7) serves more populations than other main pipes while main pipes 1 and 2 (Points 1 and 2) serve the least number of populations.

Microplastics preparation

In order to eliminate organic compounds, the sample was digested with a 30% H_2O_2 solution at 75°C for 30 minutes (Free *et al.*, 2014; Dris *et al.*, 2015; Ziajahromi *et al.*, 2017; Eriksen *et al.*, 2018). After that, it was left to cool until it reached room temperature. With a vacuum filter, the sample was filtered using 1.2 µm Whatman GF/C paper with a diameter of 9 cm (Duis and Coors, 2016; Barrows *et al.*, 2017; Alam *et al.*, 2019; Hidayaturrahman and Lee, 2019).

Table 1. Coordinate of sampling points

Sampling point	Latitude	Longitude
1	5°31'10.465" N	95°18'09.636" E
2	5°31'09.297" N	95°18'08.557" E
3	5°31'06.570" N	95°18'07.276" E
4	5°31'06.051" N	95°18'06.381" E
5	5°31'05.617" N	95°18'05.631" E
6	5°31'05.186" N	95°18'04.687" E
7	5°31'03.463" N	95°18'03.338" E

Source: own elaboration.

Photo 1. Sampling points (phot.: *C.R. Muna*)

Identification of microplastics

A 100-fold magnification Olympus CX-21 light binocular microscope was used to examine MPs adhered to the filter paper. MPs were detected in a zigzag pattern to ensure that the whole surface of the filter paper was visible (Hidalgo-Ruz *et al.*, 2012). For the measurement of observed MP particles, the Raster Image 3.0 program was employed (Nur *et al.*, 2022). This program and a microscope were used to determine the concentration, shape, size and colour of MPs. To assess the type of MPs identified in the domestic wastewater of Gampong Garot, the last stage of MPs was gathered using tweezers (BK-V9 SS-SA, stainless steel) and examined with attenuated total reflection – Fourier transform infrared spectroscopy (ATR–FTIR) (Bruker Alpha II Platinum ATR) to determine the type of MP discovered in Gampong Garot's domestic wastewater (Alam *et al.*, 2019).

RESULTS AND DISCUSSION

CONCENTRATIONS AND SHAPES OF MICROPLASTICS

The results showed that the microplastics (MPs) concentration in domestic wastewater in Gampong Garot was 30.238 ±1.228 particles·(100 cm)$^{-3}$ of sample ($\bar{x}$ ±standard deviation (*SD*), n = 7). In this case, the highest concentration was found at Point 7, while the lowest was found at Point 2 with 32.333 ±2.517 particles·(100 cm)$^{-3}$ of sample and 28.333 ±2.082 particles·(100 cm)$^{-3}$ of sample consecutively ($\bar{x}$ ±SD, n = 3). This occurred due to the number of houses that discharge domestic wastewater into the main pipe 2 (Point 2), which is less than main pipe 7 (Point 7).

However, the concentration difference of MPs at each point is not huge. The number of MPs in each sample can be seen in Table 2 and MPs in various countries can be seen in Table 3. The concentration of MPs found in the domestic wastewater in Gampong Garot is similar to that in WWTPs in other countries, such as Finland (Talvitie *et al.*, 2015) and France (Kazour *et al.*, 2019; Dris *et al.*, 2015). The MPs found ranged from 200 to 600 particles·dm^{-3}.

Based on Figure 3, MP with the shape of the fibre was more dominant than that of fragments and microbead shape. The amount of MP in the form of fragments was almost three times lower than in the form of fibre, while MP in the shape of microbeads was almost five times lower compared to fibre. The shape of MP in each sample was relatively the same as the average percentage of MP, where MP in the form of fibre was 64.455 ±1.195%, fragments – 22.970 ±1.296%, and microbeads – 12.575 ±1.258% ($\bar{x}$ ±*SD*, n = 7). This is in line with Talvitie *et al.* (2017) who concluded that 70% of MPs detected in WWTPs are in the form of fibres. The detected MPs came from resident activities such as the use of soap for bathing, the use of facial wash, the use of hand soap, the use of laundry detergent and the use of dish soap. MPs in the form of fragments can come from the fragmentation of plastic materials (Kapp and Yeatman, 2018) which are called secondary MPs. This form also comes from clothing fibres that are fragmented during the washing process. The shape characteristics of the microbeads were found to be similar to the MPs found in skincare products (Cheung and Fok, 2016; Praveena, Shaifuddin and Akizuki, 2018). In addition, microbeads also come from domestic activities that depend on people's lifestyles (Kang *et al.*, 2018).

Table 2. Concentration of microplastics (MPs)

Point	Concentration (MP particles·(100 cm)$^{-3}$ of sample)
1	29.667 ±1.528
2	28.333 ±2.082
3	30.667 ±0.577
4	30.333 ±1.528
5	29.667 ±1.155
6	30.667 ±1.528
7	32.333 ±2.517
Average	30.238 ±1.228

Source: own study.

Table 3. Microplastics (MPs) in various countries and in Gampong Garot, Indonesia

Country	MPs (MP·dm^{-3})	Reference
South Korea	WWTP 1 = 4,200	Hidayaturrahman and Lee (2019)
	WWTP 2 = 31,400	
	WWTP 3 = 5,840	
Australia	WWTP 1 = 92	Ziajahromi *et al.* (2021)
	WWTP 2 = 98	
	WWTP 3 = 55	
Finland	WWTP 1 = 567.1	Talvitie *et al.* (2017)
	WWTP 2 = 610	Talvitie *et al.* (2015)
France	WWTP 1 = 244	Kazour *et al.* (2019)
	WWTP 2 = 293	Dris *et al.* (2015)
USA	WWTP 1 = 147	Conley *et al.* (2019)
	WWTP 2 = 126	
	WWTP 3 = 147	
Gampong Garot, Indonesia	domestic waste-water = 302.38	this study

Explanations: WWTP = wastewater treatment plant.
Source: own study.

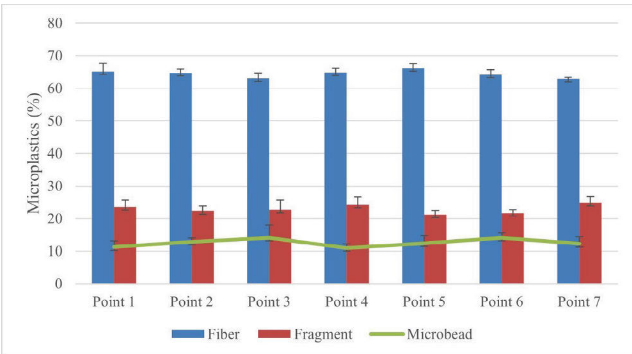

Fig. 3. Shapes of microplastics (MPs); source: own study

SIZES AND COLORS OF MICROPLASTICS

Based on Figure 4, the most detected MPs were 1,001–5,000 μm in size while the least detected MPs were 301–500 μm in size. The size of 1,001–5,000 μm and transparent colour was dominating in MP in the form of fibre. Besides that, purple, blue and green fibres were also found. In the sample, MP sizes of 20–100 μm were also widely detected. Generally, this size of MP was dominated by green, brown and blue microbeads. In addition to these sizes, MP sizes of 101–300 μm and 501–1,000 μm were also detected in the samples. The average size of the MP found in the sample was the size of 20–100 μm (7.952 ±0.559 particles·(100 cm)$^{-3}$ sample), size of 101–300 μm (4.048 ±0.651 particles·(100 cm)$^{-3}$ sample), size of 301–500 μm (2.952 ±0.678 particles·(100 cm)$^{-3}$ sample), size of 501–1,000 μm (4.238 ±0.460 particles·(100 cm)$^{-3}$ sample), and the size of 1,001–5,000 μm (11.048 ±0.591 particles·(100 cm)$^{-3}$ sample) ($\bar{x}$ ±*SD*, n = 7).

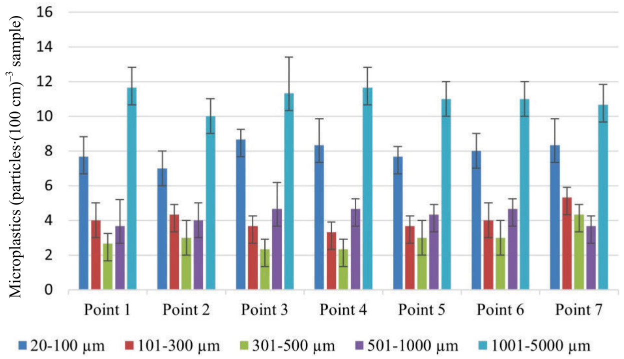

Fig. 4. Distributions of microplastics sizes; source: own study

Based on Figure 5, the transparent colour was the most detected MP colour in each sample. Research conducted by Zhang, Chen and Li (2020), who examined MPs in WWTPs, concluded that transparent colours were the dominant colours found in wastewater. On the other hand, yellow is the least common colour. The yellow colour was only found at Points 1, 3, 6, and 7 and in other samples (Points 2, 4, and 5) were not detected. The number of red-coloured particles found is small. In addition to transparent, yellow, and red colours, the results of the study also found several MP colours such as blue, brown, green, purple and others. Other colours detected were orange, pink, grey, black and navy. The percentages of colours found in the sample were: transparent at 38.782 ±2.756%, blue at 15.246 ±1.426%, red at 3.912 ±1.477%, brown at 8.229 ±2.303%, green at 9.442 ±2.287%, purple at 16.073 ±1.921%, yellow at 1.226 ±1.298%, and the other at 7.085 ±1.472% ($\bar{x}$ ±*SD*, n = 7).

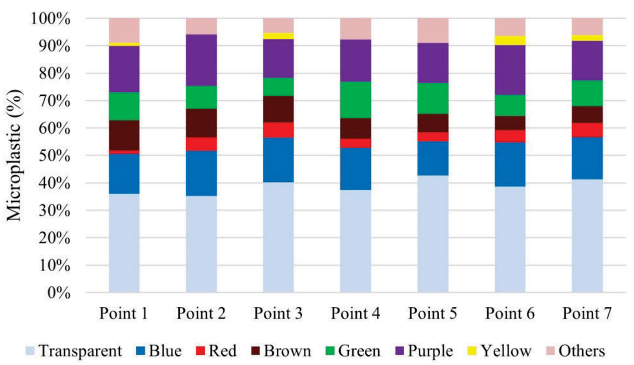

Fig. 5. Colours of microplastics (MPs); source: own study

POLYMERS OF MICROPLASTICS

The types of MP polymers that were detected in the domestic wastewater in Gampong Garot by FTIR were polyester (PES), polyethylene (PE) and polypropylene (PP) with percentages of 56.958 ±5.307%, 24.828 ±3.126%, 18.214 ±3.303%, respectively ($\bar{x}$ ±*SD*, n = 7). The distribution of the types of MP polymers can be seen in Figure 6. These types of MPs come from water used for washing clothes. Clothing materials made of polymer are eroded during the washing process. In addition, MPs also come from household products such as bath soap, shampoo, hand soap and detergent. The presence of PE was 64.07%, PP – 32.92%, PA – 10.34%, PES – 75.36%, PS – 24.17% and PET – 28.09% (Mintenig *et al.*, 2017; Ziajahromi *et al.*, 2017).

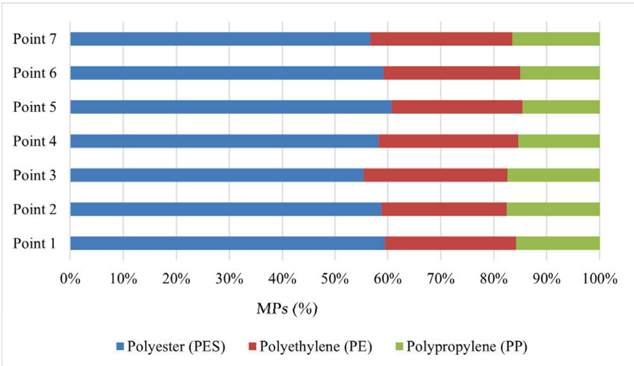

Fig. 6. Polymers of microplastics (MPs); source: own study

VISUALISATIONS OF MICROPLASTICS

Based on the research, various shapes and colours of MPs were found in the samples. The results of observations using a microscope, the shape and colour of MPs can be seen in Photo 2. The most common colours of microbeads are green, blue, purple and brown with a size of 20–100 μm. The microbeads were very rarely found in other sizes because the amount of microbeads found was small. The transparent colour of the MPs was mostly found in the form of fibre with a size of 1,001–5,000 μm. Inversely with the form of microbeads, MPs in the form of fibre were found with a size of 20–100 μm. Fragment forms were rarely found with sizes 501–1,000 μm and 1,001–5,000 μm, but most commonly found with sizes 20–100 μm and 101–300 μm.

This type of fibre comes from the clothing washing process which produces 1,900 polyester fibres per wash (Almroth *et al.*, 2018; Falco de *et al.*, 2018). The fibre is released when washing fabric/clothing which is influenced by clothing material, temperature, time and speed of washing. In addition to the influence of detergents, a good washing process will affect the structure of the reactive groups by weakening the fibre structure, followed by a rise in molecular chain damage and a fall in polymerisation level (Mac Namara *et al.*, 2012).

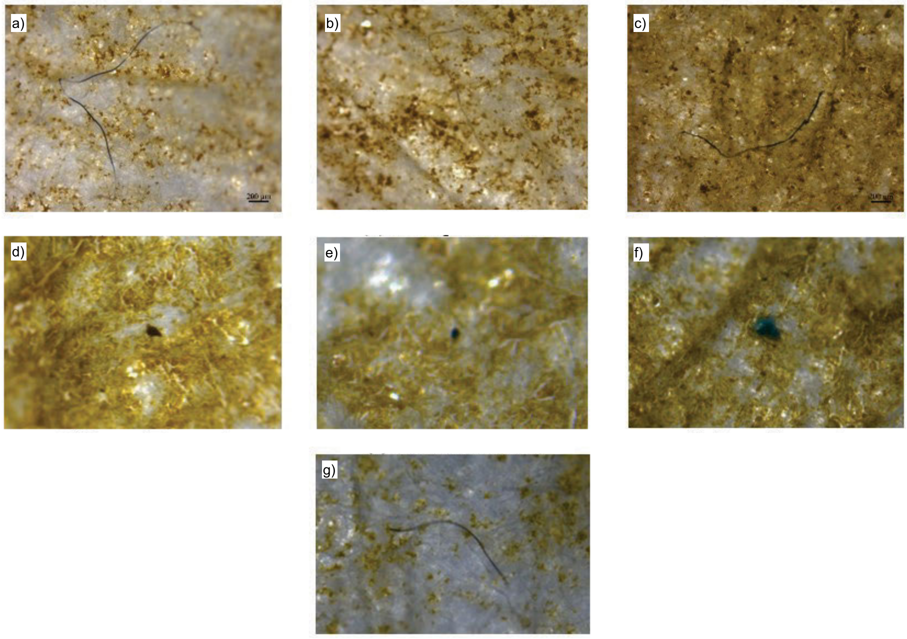

Photo 2. Visualisations of microplastics: a) blue fibre, b) transparent fibre, c) green fibre, d) brown fibre, e) green microbead, f) green fragment, g) purple fibre (phot.: *C.R. Muna*)

CONCLUSIONS

The presence of microplastics (MPs) in domestic wastewater in Gampong Garot comes from household products such as detergent, bath soap, shampoo and hand soap. In addition, MPs come from clothes that are eroded during the washing process. The concentration of MPs found was 30.238 ±1.228 particles·(100 cm)$^{-3}$ sample. The most detected size distribution of MPs is 1,001–5,000 µm in size. Fibres, fragments, and microbeads were among the MPs that were discovered with a percentage of fibres found of 64.455 ±1.195%, fragments – 22.970 ±1.296%, and microbeads – 12.575 ±1.258%. Transparent is the predominant colour of MPs found in domestic wastewater. In addition to transparent colours, various colours such as blue, red, brown, green, purple, yellow and others are also found. Based on FTIR analysis, the types of MP polymers detected were PES, PE and PP with percentages of 56.958 ±5.307%, 24.828 ±3.126%, and 18.214 ±3.303%, respectively. Because domestic wastewater from Gampong Garot is released directly into the river without being treated, it is one of the causes of MPs in the Daroy River. Therefore, domestic wastewater treatment must be done before being released into water bodies for the removal of MPs and other contaminants.

ACKNOWLEDGEMENTS

Thank you to the PPMI FTSL, ITB 2023 and UIN Ar-Raniry Banda Aceh. Thank you to everyone who contributed (all of authors) to the creation of this article.

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