

CONTINUOUS MONITORING FOR FLOATING-DEBRIS FLUX IN RIVERS WITH IMAGE ANALYSIS TECHNIQUE

TOMOYA KATAOKA⁽¹⁾, TOMOKI FUJIYAMA⁽¹⁾ & YASUO NIHEI⁽¹⁾

⁽¹⁾, Dept. of Civil Eng., Faculty of Science and Technology, Tokyo University of Science, Noda-shi, Chiba-ken, Japan,
e-mail tkata@rs.tus.ac.jp, 7618529@ed.tus.ac.jp, nihei@rs.noda.tus.ac.jp

ABSTRACT

Marine debris with a lot of plastics has become a global and serious environment issue. In particular, a microplastic which is less than 5 mm has been focused over all the world because microplastics with hazardous chemical substance influence on a lot of marine lives. Marine debris are mostly originated from inland and flowed out into the ocean via rivers. Therefore, it is necessary to conduct monitoring of floating-debris flux in rivers.

At the first step to improve the plastic waste inputs from Japan, we attempt to estimate annual transport amount of riverine plastic debris in Edo River and Ohori River using a monitoring camera system, and also to estimate an amount of unknown plastic waste in the catchment area of these rivers based on waste management data. The annual transport amounts of riverine plastic debris were 2.83 ton in Edo River and 0.0116 ton in Ohori River, respectively. The annual transport amount of Edo River (Ohori River) corresponds to 0.0098% (0.0005%) of the disposal record of plastic waste.

Keywords: riverine debris, marine debris, image analysis, continuous monitoring

1 INTRODUCTION

Plastics in the oceans are one of serious concerns in the global environment because they have been recognized a transport vector of toxic chemicals (e.g., persistent organic pollutants (POPs)) in marine environment (Mato et al., 2001; Thompson et al., 2004). As widely cited in the previous study, 80% of plastic in the oceans originates from land (Jambeck et al., 2015), however, there are a few studies for assessing and monitoring plastic debris in rivers regardless of a major source of plastic debris in the oceans. Nihei et al. (2010) collected a riverine debris using a net from a bridge in Edo River, Japan, and reported that a proportion of plastic debris to total debris was 6%. Kataoka et al. (2013) numerically estimated a loading rate of natural debris from rivers to Tokyo Bay, and they indicates that the loading rate of the debris rapidly increases on flood condition. Gasperi et al. (2014) reported that between 22 and 36 tons of floating plastic debris in Seine River were intercepted annually through use of an extensive regional network of floating debris-retention booms. Apparently, their results show that plastic debris is released from land to the oceans via rivers. In order to evaluate an outflow of riverine debris from land, it is essential to establish a technique for sequentially monitoring an amount of floating riverine debris.

Jambeck et al. (2015) estimated that 4.8 to 12.7 million metric tons (MT) of plastic waste were generated in 192 coastal countries in 2010. According to Jambeck et al. (2015), plastic waste can enter the ocean from Japan with 0.02 to 0.06 million MT. They estimated plastic waste inputs considering waste management level and based on the following equation.

$$M_p = R_w \times r_p \times r_{mis} \times P \times r^1 \quad [1]$$

where R_w and P are waste generation rate (unit: kg/ppy) and population (millions), and r_p , r_{mis} , r^1 are percentages of management data of plastic waste, of unknown waste data estimated by logistic regression model, and conversion rates of unknown plastic waste to marine debris (10%, 25%, 40%), respectively.

Nevertheless, plastic waste inputs estimated by Jambeck et al. (2015) needs to be improved in each country by measuring a transport flux of plastic debris in rivers or using the original waste management data of each country. Here, at the first step to improve the plastic waste inputs from Japan, we attempt to estimate annual transport amount of riverine plastic debris using a monitoring camera system, and also to estimate an amount of unknown plastic waste in catchment area of monitoring river. Then, we compare between former and latter. This research would enable us to more accurately estimate the plastic waste inputs from Japan, and to create a guideline the waste management in other countries.

2 METHODS

2.1 Study field

The camera systems were installed at Godanuma gate constructed on Edo River (45 km upstream) on 7 July 2017 and Uchino gate constructed on Ohori River (3.6 km upstream) on 26 July 2017 (Figure 1). Edo River (400 m of width; 59.5 km of length; 200 km² of basin area) is the branch of Tone River that is the biggest river of Japan, and thus we should consider riverine debris enters Edo River from the branchpoint of Tone River (i.e., Sekiyado; see Figure 1). Considering the branch from Tone River, urban area is 15% of the catchment area, while forest is predominant over other landuse. Ohori River (30 m of width; 6.9 km of length; 31 km² of basin area) is a small river that reaches Lake Teganuma. 75% of catchment area is urban area, and is predominant over other landuse.

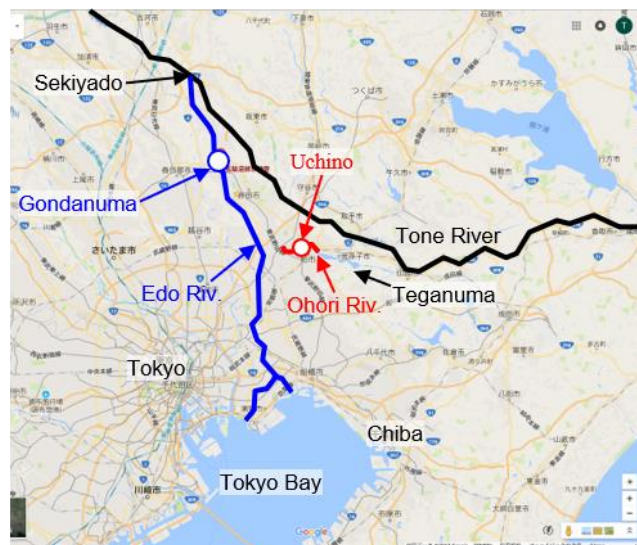


Figure 1 Study field.



Figure 2 Camera system

2.2 Camera system

The camera system consists of a trail camera (SP2, HYKE), a solar system for webcam (HCSO-12V3, HYKE), an extra near-infrared (NIR) light (wave length: 850 nm, distance: 180 m, irradiation angle: 15°), and an extra solar system for NIR light (Figure 2). In general, the trail camera is used to monitor wildlife day and

night, and thus NIR light is built in the camera. However, the built-in NIR light can irradiate an object only 20 m distant, and thus we used the extra NIR light that can be operated with the extra solar system. The camera system installed on Edo River (Ohori River) was operated for one minute every one hour (ten seconds every ten minutes). The movie data was stored on the built-in SD/SDHC card (32 GB).

2.3 Image analysis

Our image analysis consists of the following five steps (Figure 3). (1) The movie file is divided into multiple files. (2) The line image on a certain vertical line (vertical line image; hereinafter, “VLI”) is extracted from all divided images, and then (3) a space-time image (STI) is created by combing all VLIs. (4) We extract pixels of riverine debris by visual observation. (5) Finally, we count the pixels of riverine debris. The transport flux is calculated by dividing the counted pixels by the recording time of the movie.

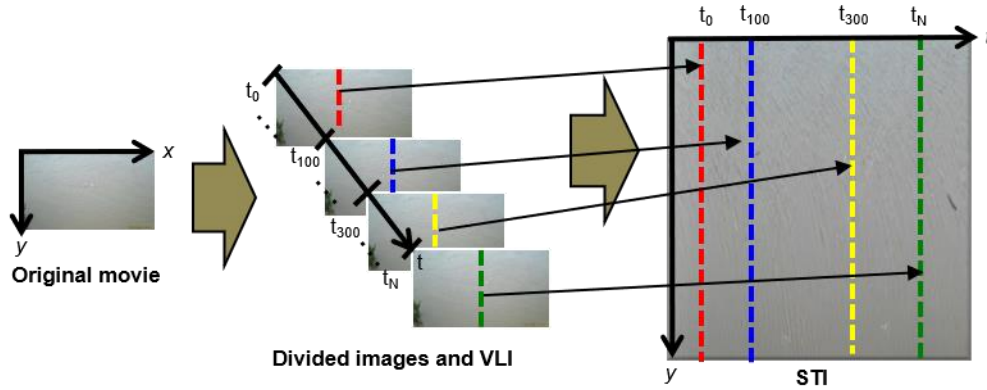


Figure 3 Image analysis flow

2.4 Waste management data

The waste management data in Japan was collected via the websites listed in Table 1. In the present study, an amount of the unknown plastic waste (M_u) was evaluated by the following equation.

$$M_u = M_c - M_w \quad [2]$$

Table 1 Waste management data

Organization	Contents	Notes	Classification
PWMI	Plastic material flow	Plastic production, trade, consumption, waste, 3R	Waste & Consumption
MoE	MSW collection data	Total waste emission in each municipality	Waste
MoE	3R survey data	Ratio of plastics to MSW in six to eight municipalities	Waste
MIC	Census data	Population, area in each municipalities	Population
MIC	Estimation of population	Monthly variation of population	Population

where M_c and M_w mean the masses of plastic consumption and managed waste, respectively. The plastic waste management have published the report of plastic waste management, and investigated the material flow of plastics in Japan as described in Fig. 4. According to the material flow (Fig. 4), the total M_c and M_w in Japan were 9.31 and 9.15 million ton, respectively. A mass of the municipal solid waste (MSW) is 4.35 million ton corresponding to 47% of the total M_w . Applying the ratio of MSW (47%) into the total M_c , the plastic consumption by citizen was estimated as 4.43 million ton. Considering the population in Japan (127.1 millions), the plastic consumption and waste per capita were 35.0 and 34.2 kg/person, respectively. In the present study, we assume that the difference between the plastic consumption and waste per capita was the unknown plastic waste per capita. The mass of unknown plastic waste (M_u) in Edo River and Ohori River were estimated by multiplying the unknown plastic waste per capita by the population in each river basin.

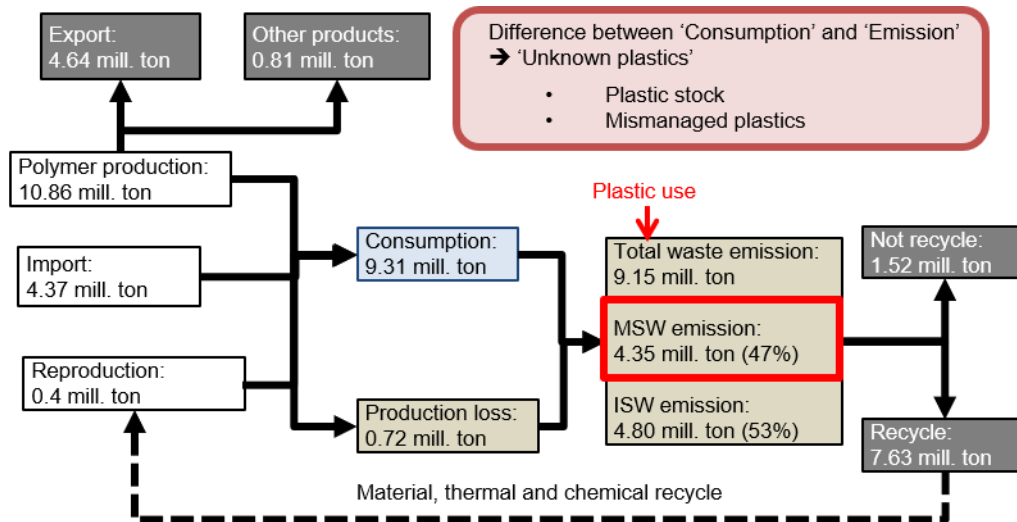


Figure 4 Plastic material flow in Japan (2015)

3 RESULTS AND DISCUSSION

3.1 Annual transport amount of plastic debris in Edo River and Ohori River

In the present study, an amount of the unknown plastic waste (M_u) was evaluated the annual transport amount of riverine debris in Edo River and Ohori River. The transport flux of riverine debris was related with the river discharge (Figure 5). The relationship between the transport flux and river discharge was expressed by the following equation.

$$L = aQ^b \quad [3]$$

where L and Q mean the transport flux and river discharge, respectively. The coefficients of a and b were determined by applying a least square method. In general, this equation is referred to as "L-Q equation". In order to validate the relationship between the transport flux and river discharge, we added the data of Nihei and Wakatsuki (2010) who collected the riverine debris using the net. The relationship from our image analysis is consistent with that of Nihei and Wakatsuki (2010).

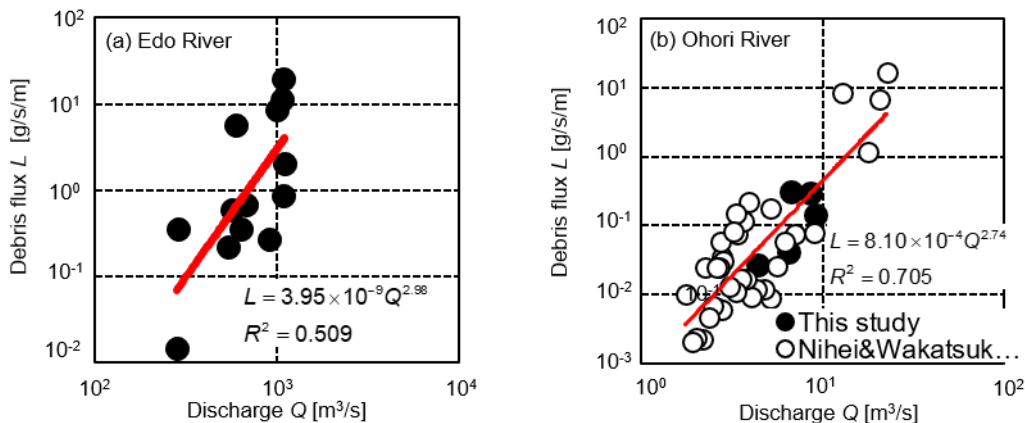


Figure 5 Relationship between transport flux of riverine debris and river discharge

The transport flux of riverine debris was calculated by substituting the river discharges on Edo River and Ohori River into each L-Q equation. The timeseries of transport flux of riverine debris in 2017 was described

(Figure 6). In the monitoring period, the flood mainly occurred on October 2017. Maximum of river discharge in 2017 was 1120 m³/s in Edo River and 25 m³/s in Ohori River.

Annual transport amounts of riverine debris were estimated from the above transport fluxes, and were 47.2 ton in Edo River and 0.193 ton in Ohori River, respectively. In order to estimate the annual transport amounts of plastics, we used the ratio of plastics to all types of riverine debris with natural debris (6%; Nihei et al. (2010)). The annual transport amounts of plastics were 2.83 ton in Edo River and 11.6 kg in Ohori River, and hence the annual transport amount of plastics in Edo River was greater than that in Ohori River. This is because the basin area of Edo River considering the branch of Tone River (2114 km²) was greater than that of Ohori River (14 km²). In order to compare the annual transport amounts in two rivers, we calculated the annual transport amount per unit basin area and per person (Table 2). The annual transport amount per unit basin area in Edo River (1.3 kg/km²) was larger than that in Ohori River (0.83 kg/km²). And also, the annual transport amount per person in Edo River (3.8 g/person) was greater than that in Ohori River (0.19 g/person).

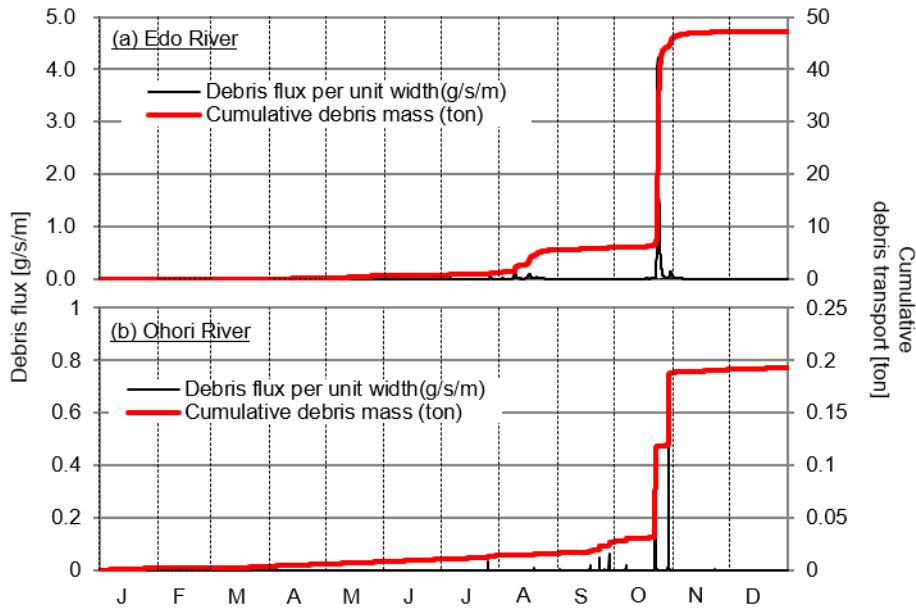


Figure 6 Timeseries of transport flux and cumulative transport amount of riverine debris

Table 2 Summary of our estimates

Contents		Edo River	Ohori River
Annual transport amount	①Amount [ton]	2.83	0.0116
	Amount/basin [kg/km ²]	1.34	0.825
	Amount/population [g/person]	3.80	0.194
Unknown plastic amount	②Amount [ton]	539.0	43.0
	(①/②)	(0.53%)	(0.027%)
	Amount/basin [kg/km ²]	255	723
	Amount/population [g/person]	3,057	718
Plastic waste collection	③Amount [ton]	28,864	2,007
	(①/③)	(0.0098%)	(0.0005%)

3.2 Unknown plastic waste in Edo River and Ohori River

The maps of M_u in Edo River and Ohori River were described in Figure 7. The totals of M_u in Edo River and Ohori River were 539 ton and 43 ton, respectively. In order to compare the totals of M_u in two river basins, M_u per unit basin area and M_u per capita were calculated by dividing the totals of M_u by basin area and population

in each river basin (Table 2). M_u per unit basin area in Edo River (255 kg/km²) was smaller than that in Ohori River (723 kg/km²), while M_u per capita in Edo River (3,057 kg/person) was greater than that in Ohori River (718 kg/person).

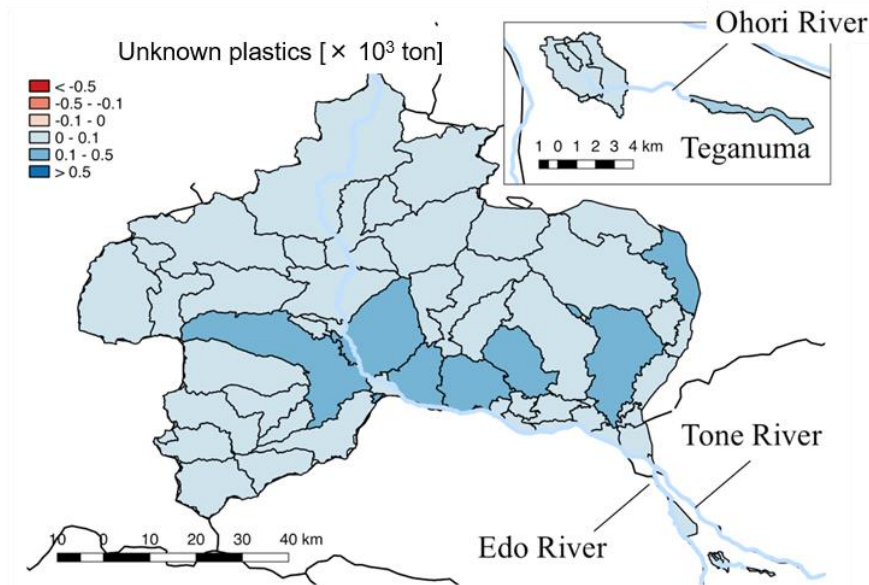


Figure 7 Map of amounts of unknown plastics M_u

3.3 Comparison of annual transport amount of riverine plastic with plastic waste management

We compared the annual transport amount of riverine plastic with plastic waste management. On both rivers, the annual transport amount estimated by image analysis was very smaller than M_u , and corresponded to 0.53% of M_u in Edo River and 0.027% in Ohori River. The estimation of M_u , however, has uncertainty for the fate of plastics, such as stock and movement of plastics. The plastics, for instance, would be always disposed at where they were consumed, and also would be stocked for several years. In fact, in order to verify the plastic waste estimated based on the material flow (i.e., M_w), it was compared with the disposal record of plastic waste (Figure 8) The positive (negative) value means that M_w was overestimated (underestimated) comparing with the disposal record. Hence, it would be difficult to estimate M_u from the collected data.

Here, we suggest that the annual transport amount of plastic debris is compared with the disposal record of plastic waste. Considering the fate of plastics, the plastic consumption (M_c) corresponds to the summation of the amounts of disposal plastics (M_w), riverine plastics (M_r), and unknown plastics (e.g., stock and movement) (M'_u), as the following equation.

$$M_c = M_w + M_r + M'_u \quad [4]$$

where M_u described in 3.2 corresponds to $M_r + M'_u$ (i.e., $M_u = M_r + M'_u$). From Eq. (4), we consider the following indexes for assessing M_r : (1) $M_r/(M_c - M_w)$, (2) M_r/M_c , and (3) M_r/M_w . As mentioned above, it is difficult to assess by the index (1) and (2) because M_u contain the unknown plastics. Meanwhile, the index (3) would be relatively reliable comparing with other indexes because both M_r with M_w are based on the observed data. In the present study, the index (3) in Edo River (0.0098%) was greater than that in Ohori River (0.0005%) (Table 2). In the future, in order to consider the waste management for plastic pollution in marine environment, it is essential to collect M_r and M_w in each country.

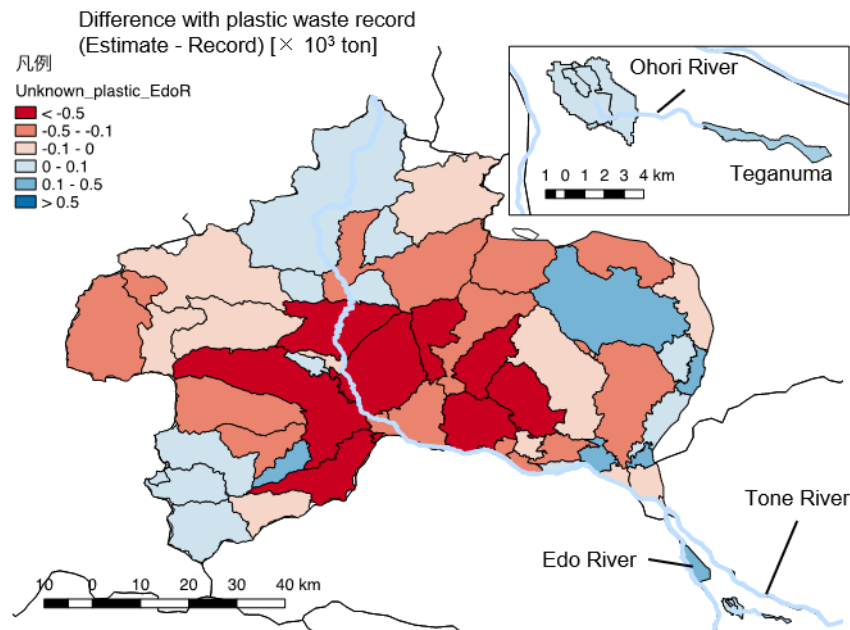


Figure 8 Map of difference between amounts of unknown plastics and plastic waste record

4 CONCLUSIONS

At the first step to improve the plastic waste inputs from Japan, we attempt to estimate annual transport amount of riverine plastic debris in Edo River and Ohori River using a monitoring camera system, and also to estimate an amount of unknown plastic waste in the catchment area of these rivers based on waste management data. The annual transport amounts of riverine plastic debris were 2.83 ton in Edo River and 0.0116 ton in Ohori River, respectively. The annual transport amount of Edo River (Ohori River) corresponds to 0.0098% (0.0005%) of the disposal record of plastic waste. This research would enable us to more accurately estimate the plastic waste inputs from Japan, and to create a guideline the waste management in other countries.

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