A NEW TECHNIQUE FOR EVALUATING FLOATING-LITTER TRANSPORT USING TEMPORAL VARIATION RATE OF WATER ELEVATION

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Abstract: To evaluate accurately temporal variations of floating-litter transport L in rivers, we present a new rating curve using the temporal variation rate of water elevation $\dot{H}$. For this purpose, we measured the floating-litter transport L in the Edogawa River flowing into Tokyo Bay, Japan, in two flooding events. In field measurements, we used a rectangular frame for directly collecting floating litter and video monitoring for recording floating litter. The measured results indicate that the peak of the floating-litter transport L appeared in the rising stage of the flooding and the temporal variations of L during the flooding are similar to those of the temporal variation rate in water elevation $\dot{H}$. It should also be noted that a new rating curve using the correlation between L and $\dot{H}$ has higher accuracy for evaluating L than a primitive rating curve using L-Q relations in which Q means river discharge.

Keywords: marine litter, flood, floating-litter transport, temporal variation in water elevation.

1. INTRODUCTION

One of the recent issues in coastal environments is marine litter, also known as marine debris, which causes a wide variety of environmental and safety impacts on coasts and seas. Marine litter is composed of any man-made objects such as plastic, polystyrene, metals, and glass. Furthermore, natural objects like vegetation and trees are also included as marine litter. Since marine litter originates from many sea-based and land-based sources, comprehensive management of marine litter should be performed to prevent and reduce marine litter. Previous studies of marine litter mainly concentrated on litter on coasts and in seas (Kako et al., 2010; Isobe et al., 2011). However, there is little information on land-based sources of marine litter and floating-litter transports in rivers.

From these viewpoints, we conducted field measurements of floating-litter transport in small and large rivers in Japan, mainly in hydrologic events (Nihei and Wakatsuki, 2010; Nihei et al., 2010). For the measurements, we used a rectangular frame with a one-centimeter-mesh net to directly collect floating litter. Video monitoring was also conducted to record floating litter at several stations in a cross-section of the river. The measured results indicate that the peak of the floating-litter transport L in flooding events is significantly different from that of the discharge Q, showing that the temporal variations of floating-litter transport have significant hysteresis in flooding events. Therefore, a rating curve using the L-Q relation was not suitable for evaluating floating-litter transport. A fundamental mechanism for flushing of vegetation and debris as sources of floating litter in rivers is closely related to the temporal variations of water elevation as shown in **Fig. 1**. That is, vegetation and debris deposited near a river bank may be flushed in high-flow conditions.

To evaluate accurately temporal variations of floating-litter transport L in rivers, in the present study, we developed a new rating curve for floating-litter transport using the temporal variation rate in water elevation $\dot{H}$. For this purpose, we measured floating-litter transport in the Edogawa River, Japan, in two flooding events using a rectangular frame for directly collecting floating litter and video monitoring for recording floating litter.

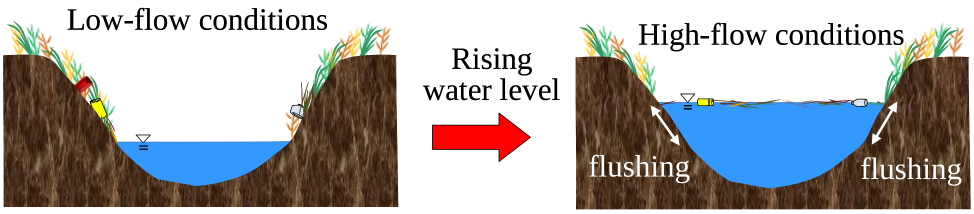


Figure 1 Fundamental mechanism for flushing of vegetation and debris as sources of floating litter in rivers.

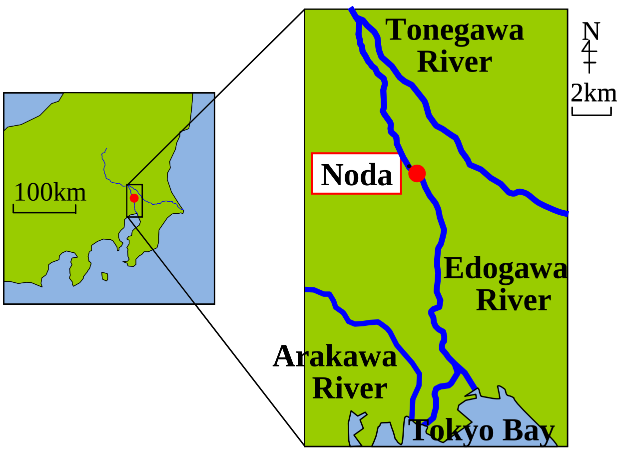


Figure 2 Field measurement site.

2. OUTLINE OF FIELD MEASUREMENTS AND DATA ANALYSIS

2.1 Field site

The field measurement site chosen for the present study is the middle reach of the Edogawa River flowing into Tokyo Bay, Japan, as shown in **Fig. 2**. This river has a compound cross-section with a width of 400 m. The floodplain and bank of the main channel in the cross-section were thickly covered with vegetation such as reeds.

2.2 Direct collection of floating litter

Floating litter in the Edogawa River was directly collected at the Noda bridge to examine the transport and kind of floating litter in the river. As shown in **Fig. 3**, a rectangular frame of 1.0 m squared with a 2.5-cm-mesh net was lowered using two ropes and a wire that was connected to a weight of 60 kg to provide stability. The depth of the frame was set to about 1 meter in the surface layer of the water where there is much floating litter due to the low density of the litter. The direct collection of floating litter using the above frame was conducted in two flooding events that occurred in Sep. 24, 2010 due to typhoon no. 1012 and from Oct. 31 to Nov. 2, 2010 due to typhoon no. 1014.

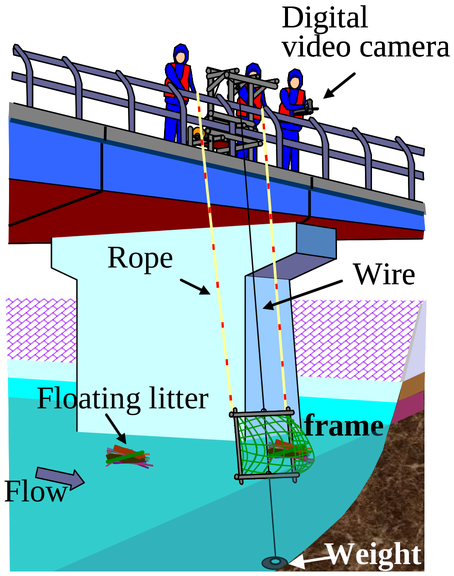


Figure 3 Schematic view of direct collection of floating litter.

2.3 Video monitoring of floating litter

Floating litter is normally non-uniformly transported in a cross-section of a river with a width of more than 100 m like the Edogawa River. Therefore, it is necessary to measure floating-litter transport at several points in the cross-section to evaluate the floating-litter transport for the whole of the cross-section. Direct collection of floating litter at several points in the cross-section is not realistic. For this reason, we performed video monitoring for recording litter floating on the surface of the water. A digital video camera (HDR-XR550V, Sony) was used to record the water surface from the bridge for one minute. While the direct collection of floating litter is done at one point of the cross section, the video monitoring is conducted at several points including the point of the direct collection. An example of floating litter recorded by video monitoring is shown in **Fig. 4**. To evaluate floating-litter transport from the video image, a control line with a length of 1 m is set as shown by the red line in **Fig. 4**. The ratio of floating litter on the control line D_f is estimated for each image. Correlations between the floating litter transport obtained by direct collection and D_f by the video monitoring were evaluated. Lateral distribution of floating litter was evaluated with the video monitoring and the above correlation, and hence the total floating-litter transport through the whole of the cross section were calculated. For evaluation of floating-litter transport, we used two rating curves based on L-Q and L-$\dot{H}$ relations where L is floating-litter transports, Q is discharge, and $\dot{H}$ is the temporal variation rate in water elevation.

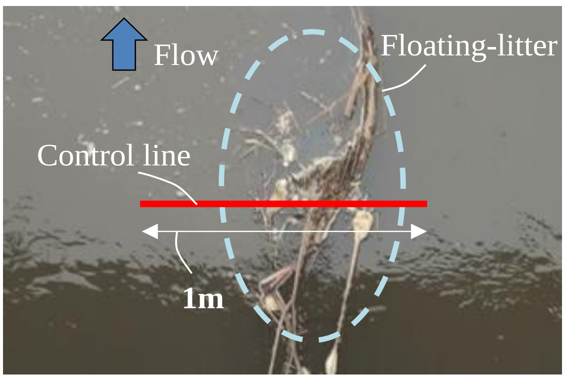


Figure 4 Example of image of floating litter in video monitoring.

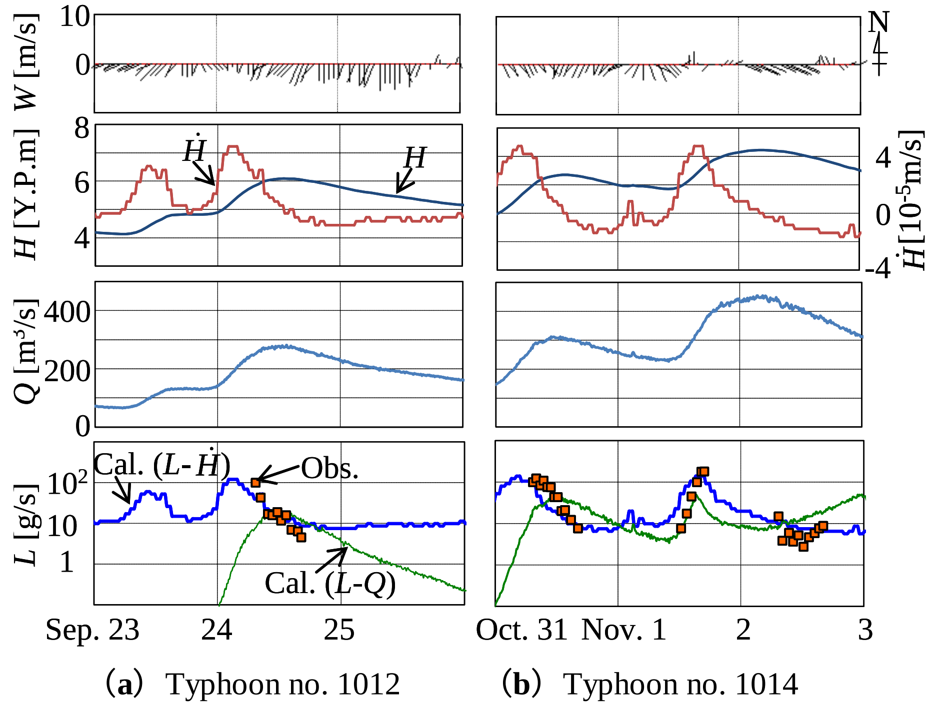


Figure 5 Temporal variations of wind velocity vector W, water elevation H, temporal variation rate in water elevation $\dot{H}$, discharge Q, and floating litter transport L.

3. RESULTS AND DISCUSSION

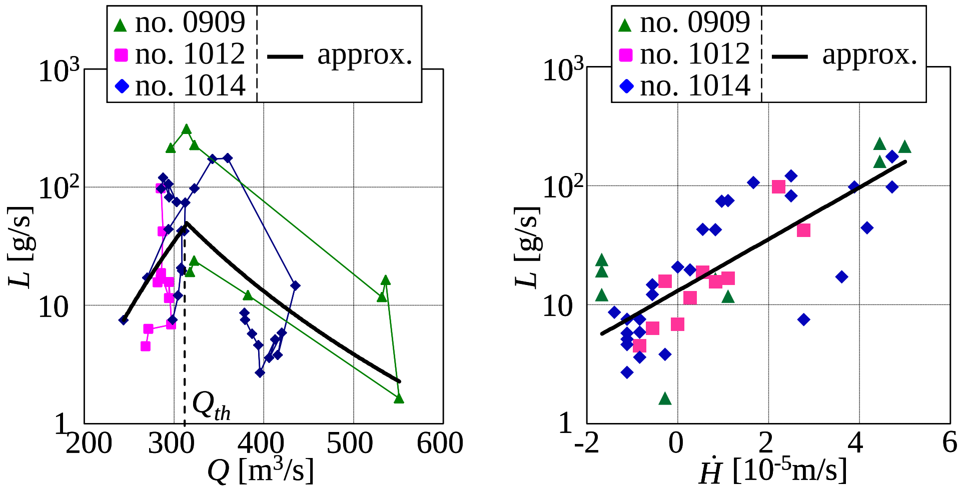
3.1 Temporal variation of floating-litter transport in flood conditions

To clarify the fundamental characteristics of floating-litter transport under flood conditions, **Fig. 5** shows the temporal variations of wind velocity W, water elevation H, temporal variation rate of the water elevation $\dot{H}$, discharge Q, and floating-litter transports L during typhoon no. 1012 and no. 1014. The result indicates that the peak of L appeared in the rising stage of the flooding and L decreased substantially in the falling stage in both events. Furthermore, it should be noted that the temporal variations of L during the flooding are more similar to those of $\dot{H}$ than H itself. This fact suggests that for evaluating floating-litter transport, using the temporal variation rate in water elevation $\dot{H}$ is more suitable than using discharge Q.

3.2 Accuracy of rating curves for floating litter transport

To study the rating curves for floating litter transport, **Fig. 6** illustrates the relations between floating litter transport L and discharge Q and between L and temporal variation rate in water elevation $\dot{H}$. These relations for typhoons no. 1012, 1014, and 0909 are shown in the figure. The L-Q relation indicates that the peak of floating-litter transport L appeared at a discharge Q_{th} (= 310 m^3/s), showing a large difference of rating curves between the present floating-litter transport and the pollutant load in which the peak generally appears at that in the discharge. The approximations for the L-Q relation when $Q < Q_{th}$ and $Q > Q_{th}$ are shown by the thick line in the figure. The correlation coefficients r for the approximations of the L-Q relations are 0.42 and 0.59 when $Q < Q_{th}$ and $Q > Q_{th}$, respectively. In contrast, the L-$\dot{H}$ relations in all flooding conditions are almost the same. The correlation coefficient r for the approximation of the L-$\dot{H}$ relation is 0.79. These facts indicate that the correlation for the L-$\dot{H}$ relation is better than that for the L-Q relation.

To check the accuracy of evaluations of floating-litter transports based on these rating curves, the temporal variations of the floating-litter transports calculated with the *L*-*Q* and *L*- $\dot{H}$ relations is shown in **Fig. 5**. The comparison of observed and calculated results indicates that the results calculated with the *L*- $\dot{H}$ relation show good agreement with observed results, while the results using the *L*-*Q* relation deviate extremely from the observed results. These facts demonstrate that a new rating curve using the correlation between *L* and $\dot{H}$ has higher accuracy for evaluating floating-litter transport than a primitive rating curve using the *L*-*Q* relation.



(a) *L*-*Q* relation **(b)** *L*- $\dot{H}$ relation

Figure 6 Rating curves for floating litter transport.

4. CONCLUSION

In this study, we measured floating-litter transport in the Edogawa River, Japan, in flood conditions and investigated the relationship between floating-litter transport, discharge, water elevation, and temporal variation rate in water elevation. The results indicate that the peak of the floating-litter transports appearing in the rising stage of the flooding and the temporal variations of floating-litter transport *L* during the flooding are similar to those of temporal variation rate in water elevation $\dot{H}$. It should also be noted that a new rating curve using the correlation between *L* and $\dot{H}$ has higher accuracy for evaluating floating-litter transport than a primitive rating curve using *L*-*Q* relations in which *Q* means river discharge.

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