Field observation and modeling of combined sewer overflow in upstream region of the Horikawa River

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1. Introduction

The Horikawa River is a contaminated urban river in Nagoya City affected by tidal flow up to 13.8km from the river mouse. Since most part of the basin has combined sewerage system, a combined sewer overflow (CSO) occurs in the rain and this is thought to be a major cause of the water quality degradation. In order to take effective measure of improving water quality, it is necessary to evaluate the contribution of CSO to the total pollution in the river.

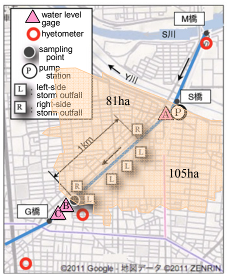


Fig.1 Observation site

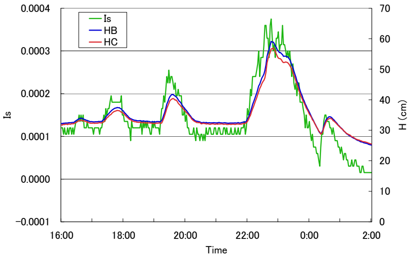


Fig.2 Observed water level and gradient (6/15)

2. Field observation

Field observation of the discharge and water quality was conducted in upstream region without tidal flow shown in Fig.1. The water level was recorded at three sections with the use of pressure type water level gage. The water surface gradient is obtained from the water-level difference between sections B and C (see Fig.2), then the discharge was calculated from the water-level difference and mean water depth, assuming the roughness is constant. The water was sampled and tested for BOD and SS. The observation detail is shown in Table-1.

Table 1 Observation date and detail

Date	2010/6/15	2010/7/29	2010/9/8	2010/10/24	2010/12/3
Time	15–25	0–10	7–14	17–23	0–7
Total rainfall (mm)	49.3	12	32.4	9.9	44.1
Maximum 10minutes reinfall (mm)	5	2.6	5.3	1.5	6.1
Number of CSO	4	1	2	1	1
Precedent no-rain days	22	13.4	25	14.6	10.2
SS maximum (mg/L)	155	105	243	36.5	262
BOD maximum (mg/L)	22.8	65.8	41.8	22.3	58.2

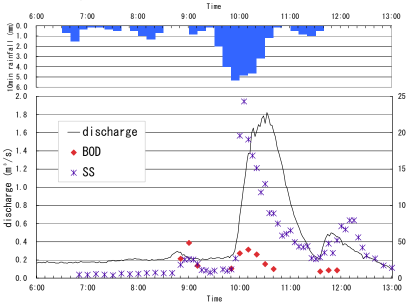
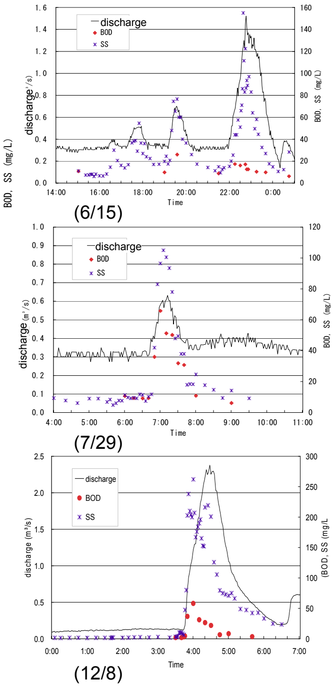


Fig.3 Hyetograph and hydrograph of CSO (9/8)



(6/15)

(7/29)

(12/8)

Fig.4 Other examples of hydrograph of CSO

3. Results and discussion

Fig.3 shows an example of the hyetograph and hydrographs of discharge, BOD and SS at the section C. After the second rainfall, the first CSO was recognized and BOD maximum was observed. After the third intense rainfall, the discharge showed significant peak and SS attained the maximum value. The peak of BOD became smaller than that at the first CSO. At the third CSO, BOD became small whereas SS showed rather high value. Other observation results are shown in Fig.4. It is considered that BOD is not proportional to the outflow discharge but depends on the amount of pollutant accumulation. BOD indicates large value at the first flash event after small cumulative rainfall and deceases with an increase of cumulative rainfall even when the amount of CSO increases (see Fig.5). The peak value of SS is almost proportional to the outflow discharge (see Fig.6).

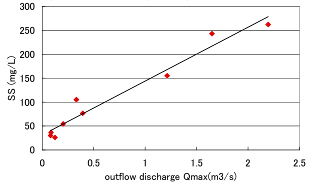


Fig.5 Characteristics of SS in CSO event

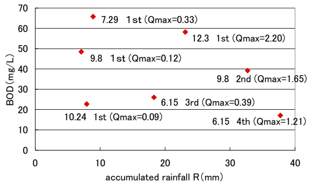


Fig.6 Characteristics of BOD in CSO event

4. CSO modeling

The relation between rainfall and the outflow discharge was modeled by the unit hydrograph concept. The 10 minutes outflow height q(t) (mm) is obtained by overlapping 10 minutes rainfall multiplied by certain coefficients during previous 60 minutes as follows (see Fig.7):

$$q(t)=\sum_{i=1}^{6}a_i r(t-i\Delta t)\quad ,\quad \sum_{i=1}^{6}a_i=1 \tag{1}$$

where *r* is 10 minutes rainfall, a_i is coefficients and Δt=10min. The coefficients a_i were determined to maximize the correlation between observed and calculated discharges. Then, 10 minutes CSO discharge volume Qc (m^3) is expressed using the 10 minutes outflow height q, as follows(see Fig.8):

$$Q_c=1000fA(q-0.50) \tag{2}$$

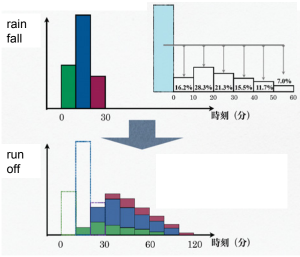


Fig.7 Run off model

where *f* is the runoff ratio and *A* is the basin area (km^2). In this basin, the runoff ratio is extremely small (*f*=0.138) because a pump station is provided. It is understood that CSO occurs when the 10 minutes outflow height *q* exceeds 0.5mm. CSO volume is well predicted by this model shown in Fig.9. BOD and SS are calculated in considering the characteristics that the pollutant load attains a peak during the rising stage and then it decreases rapidly in the falling stage (see Fig.10).

$$B_i(t)=\int_0^t \alpha_i\left(\frac{dQ_c}{dt}\right)dt : t<t_{\max},\quad B_i(t)=B_{i\max},\, t_{\max}<t<t_p,\quad B_i(t)=B_{i\max}+\int_{t_p}^{t}\alpha_i\left(\frac{dQ_c}{dt}\right)dt : t_p<t \tag{3}$$

where B_i is pollutant load, α_i is the coefficients, B_{imax} is the upper limit of the load, t_{max} is the time at upper limit, t_p is the peak time of CSO and *i* means BOD or SS. The coefficients were determined from the observed results (see Table 2). Fig.11 shows the comparison between calculated and observed pollutant load. The calculated loads are almost predicted well but a large discrepancy appears when the outflow discharge is small.

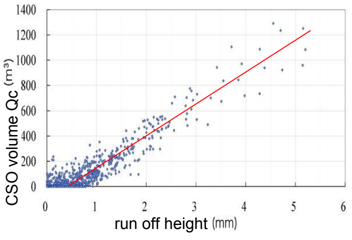


Fig.8 Relation between CSO volume and 10 min. run off height

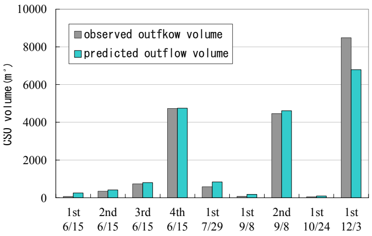


Fig.9 Prediction of CSO volume

Table 2 Model coefficients

number of CSO	1st	2nd	3rd	4th
α_{BOD}(g/m^3)	55.0	21.1	12.6	6.35
α_{SS}(g/m^3)	97.4	75.7	47.9	41.2
$B_{BOD\max}$(g/s)	53.3	29.2	21.7	16.7
$B_{SS\max}$(g/s)	367.0	330.0	293.0	257.0

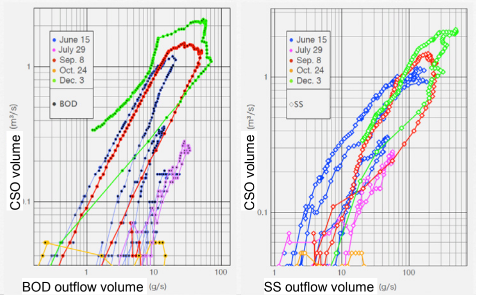


Fig.10 Variation of BOD and SS in CSO event

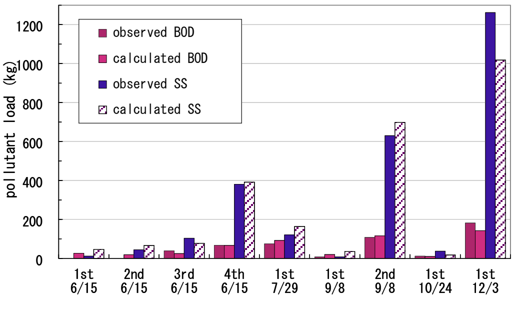


Fig.11 Calculated and observed pollutant load

5. Conclusion

The characteristics of outflow discharge, BOD and SS of CSO were obtained by the field observations. These data are useful to understand the impact of CSO to the water quality management in the basin and to consider measures of reducing the CSO pollutant load.