Runoff Characteristics of Nonpoint Source in Orchard Area
- Vineyard -

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1. Introduction

Effects of nonpoint source loads on water quality of rivers and lakes have been increased as the sewage treatment rate increases and economic activity level rises. More than 50% of water pollution load is reported as nonpoint pollution source in the US with high density land use. Treatment of runoff pollutants from nonpoint sources in the facilities is difficult unlike point pollution source. About 80% of total nonpoint source pollutant in the rainfall is discharged during October to April, and during dry season from May to September, about 20% of total annual amount is outpoured. As nonpoint source pollutants are discharged during rain event, the volume of effluence is changed in accordance with daily and seasonal conditions. Nonpoint pollution sources are affected by the basin shape and regional characteristics such as climate, topography, land use and soil, thus accurate data on the water quality and flow amount during rainfall events is required to quantify discharge of nonpoint pollution sources.

In this study, quantitative analysis of nonpoint source pollutants by the volume of runoff was carried out using monitoring result of rainfall runoff from vineyard on permeable soil. The flushing criteria of initial rain effluent, which had been studied in existing impermeable area including downtown, roadway and bridge, was applied to permeable vineyard area to study runoff characteristics of various pollutants and criteria for the amount of first flush. The aim of this study is to provide best management practice for operating management facilities of nonpoint pollution source in permeable area.

2. Method

On-the-spot monitoring examined change in effluent by rainfall type that occurs at target sites, using rain-intensity gauge and flow meter and Meteorological Administration's weather forecast. Rain-intensity gauge used for the survey, which is available to measure 1min unit rainfall, is RG-20 model from Environdata Environmental Monitoring & Management Corporation, Australia, using tipping bucket mechanism. The open channel flow meter, also can measure 1min unit flow, is Flo-Tote3 from American Marsh McBirney Corporation. The flow meter was installed at the final outlet to investigated volume of effluence without inflow of rainfall from outside. Sampling and analysis were performed in accordance with the Rainfall Runoff Investigation Method by Ministry of Environment (National Institute of Environmental research). Rainfall volume was basically measured on the spot using rain-intensity gauge, but when that is not possible, we made use of the nearest Meteorological Administration data.

First flush phenomenon is defined as situation that concentration of rainfall effluence decreases slowly after it soars in rainfall beginning (Matthias et al., 2009). Bedient et al. (1978) analyzed the first flush effects using accumulation flow and load curve, on the basis of the rainfall-runoff investigation in traditional urban, forest land and developing areas. The accumulation of runoff volume and load ratio, obtained by investigating the effluent volume by runoff time and load change by pollutants in each rainfall event, was used for examining the first flush effect. This method can be used as one of technique for deciding the amount of minimum treatment according to the targeted amount of initial rainfall-runoff treatment and contribute to improving water quality through reducing the amount of nonpoint source pollutant in rivers and lakes.

First flush ratio of rainfall-runoff water by precipitation can be quantified about each pollutant and rainfall using MFF(Mass First Flush Ratio) (Han et al., 2006). The quantified value can be expressed by the criterion of accumulated rainfall and rainfall duration time, and this means initial rain standard (Lee et al., 2009).

3. Results

3.1. The characteristics of pollutant runoff by rainfall events

This study was conducted over a two-year period from 2008 to 2009. Among a total of 51 rainfall events during the period, runoff occurred 19 times, and the monitoring result of these 19 rainfall events. Despite permeable soil of the vineyard, runoff occurs in rainfall lower than 30mm. This is because of wet soil layer during the short antecedent dry weather period(ADWP), and more fundamentally, affected by cultivation types of crop. In the case of grape, soil is mulched during May to June to prevent flower fall off before blooming and advance ripening of the fruit. This creates some impermeable area in vineyard and restrains the evaporation of water inside soil, becoming the biggest factor influencing generation of rainfall runoff.

3.2. First flush phenomenon

Fig. 1 illustrates the accumulation curve for the pollutant load and rainfall-runoff volume to analyze the first flush phenomenon of vineyard_A and vineyard_. As shown in the accumulated flow-load ratio curve of Figure 2, the degree of first flush was different by water quality items and rainfall events. The first flush phenomenon happened in vineyard_A and B site for the most rainfall events despite of their permeable soil, showing comparatively stronger effect in vineyard_B. The majority of established researchers have tried to examine the first flush phenomenon in impermeable downtown area or road, and Matthias et al.(2009) confirmed that the first flush phenomenon could happen in permeable area. The first flush phenomenon depending on rainfall characteristics was also verified in this study.

As seen in Fig. 1, most pollutants are related to the first flush phenomenon. Among them, SS displayed the strongest first flush phenomenon, followed by COD, T-N and TOC in order. When examined the relation between rainfall runoff and rainfall, rainfall intensity(RI), rainfall duration time(RDT) and antecedent dry weather period(ADWP),

which could influence outbreak of the first flush phenomenon, ADWP appeared to affect the outbreak for the most. However, it was difficult to examine the close relation between certain runoff factor and first flush phenomenon only with the investigation result of 19 rainfall runoff over 2 years. Therefore, to examine the cause of first flush phenomenon in vineyard more thoroughly, a long-term investigation of various rainfall events including various runoff factors needs to be conducted.

3.3. First Flush Ratio

For 19 runoff among a total of 51 rainfall events in vineyard area during 2008~2009, occurrence of the first flush phenomenon by pollutant was confirmed using accumulated runoff volume-pollutant load ratio curve and the first flush volumes of each pollutant and rainfall were quantified using MFFn(Mass First Flush) which is first flushing ratio.

Table 1 includes calculated MFFn of 19 rainfall runoff by water quality item and "n" value changing from 10 to 90%, and its averages result is displayed in Table 2. As shown in Table 1, the range of minimum and maximum value was different by water quality item and MFFn value became close to "1" as n value increases, confirming that the volume of rainfall runoff and its accumulation ratio of pollutant become similar as runoff continues to the later period.

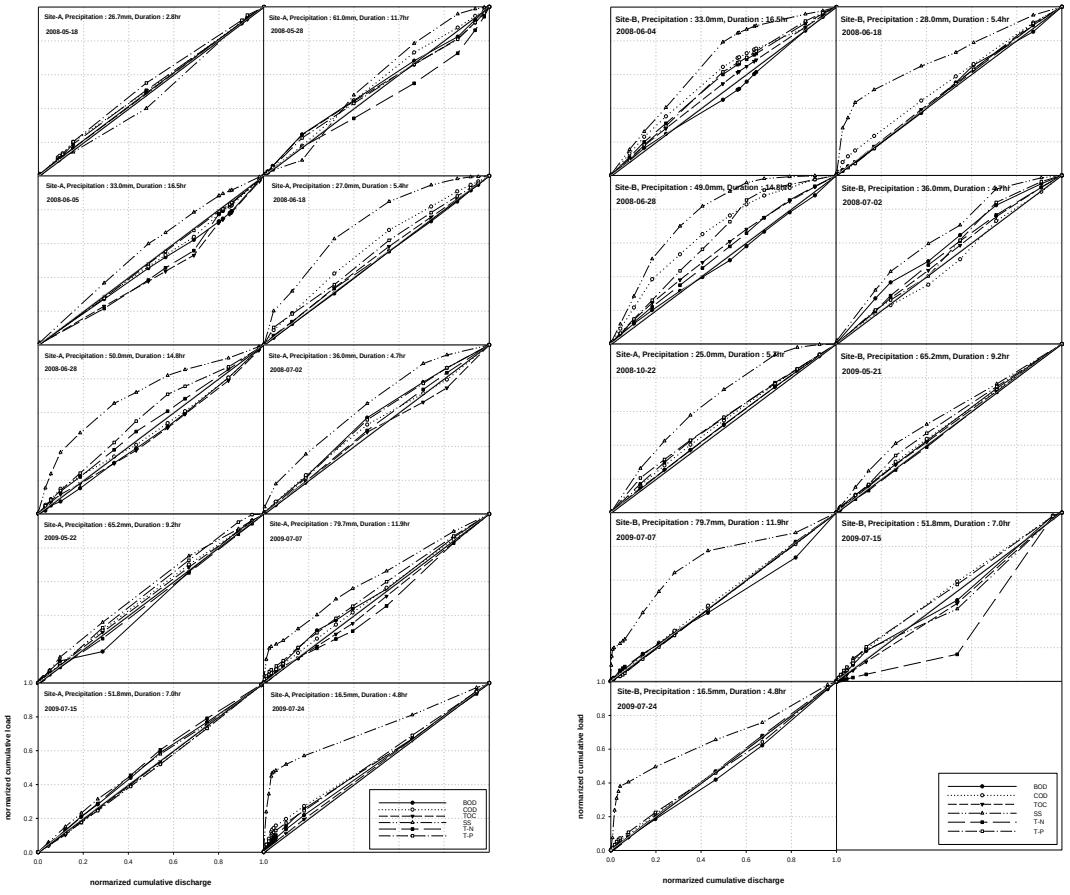

Fig. 1. Normalized cumulative load curve for variation storm events.

Lee et al. (2009) reported that the value of average MFFn reduces continuously to MFF_{90} after marking maximum value at MFF_{30}, and this study also displayed similar result. According to Table5, the volume of pollutant runoff load at 10% of rainfall runoff volume appeared high, SS item showing the highest MFFn value of 2.87 at n=10 followed by COD and TP. MFFn value was the highest in SS in the change of all of the "n" values such as "n"=20, 30, except for "n"=90.

The MFFn value by water quality item at "n"=30, generally regarded as the standard of the first flush effect, was SS 1.65, TP 1.20, COD 1.17, BOD 1.08, TOC 1.03 and TN 1.02, and 49.5% of SS, 36% of TP and 35.1% of COD appeared to be discharged from 30% of rainfall-runoff volume. On the basis of the average MFFn value, clear first flushing phenomenon was not shown for water quality items except SS.

Table 1. The Range of MFFn in vineyard area(rainfall range : 16.5 ~ 79.7 mm)

	MFF_{10}	MFF_{20}	MFF_{30}	MFF_{40}	MFF_{50}	MFF_{60}	MFF_{70}	MFF_{80}	MFF_{90}
BOD	0.75 ~ 2.14	0.82 ~ 1.56	0.65 ~ 1.51	0.65 ~ 1.24	0.79 ~ 1.24	0.71 ~ 1.18	0.71 ~ 1.16	0.71 ~ 1.16	0.71 ~ 1.06
COD	0.87 ~ 2.09	0.85 ~ 2.09	0.85 ~ 1.73	0.79 ~ 1.60	0.79 ~ 1.44	0.71 ~ 1.38	0.68 ~ 1.29	0.68 ~ 1.17	0.68 ~ 1.08
TOC	0.83 ~ 1.63	0.84 ~ 1.42	0.84 ~ 1.42	0.86 ~ 1.19	0.86 ~ 1.15	0.86 ~ 1.13	0.86 ~ 1.10	0.89 ~ 1.07	0.89 ~ 1.03
SS	0.50 ~ 5.20	0.48 ~ 3.17	0.48 ~ 3.17	0.45 ~ 2.01	0.45 ~ 1.79	0.43 ~ 1.59	0.41 ~ 1.44	0.41 ~ 1.25	0.41 ~ 1.10
T-N	0.30 ~ 1.60	0.31 ~ 1.42	0.31 ~ 1.42	0.30 ~ 1.42	0.30 ~ 1.12	0.30 ~ 1.12	0.30 ~ 1.10	0.84 ~ 1.08	0.92 ~ 1.03
T-P	0.76 ~ 2.31	0.92 ~ 1.53	0.93 ~ 1.53	0.95 ~ 1.38	0.96 ~ 1.37	0.96 ~ 1.42	0.98 ~ 1.34	0.94 ~ 1.23	0.97 ~ 1.08
Ave	1.50	1.25	1.19	1.13	1.07	1.03	1.02	1.01	1.00

Table 2. The average value of MFFn in vineyard Area(rainfall range:16.5 ~ 79.7 mm)

	MFF_{10}	MFF_{20}	MFF_{30}	MFF_{40}	MFF_{50}	MFF_{60}	MFF_{70}	MFF_{80}	MFF_{90}
BOD	1.18	1.13	1.08	1.01	1.01	1.00	0.99	0.99	0.99
COD	1.40	1.22	1.17	1.12	1.06	1.03	1.02	1.00	0.99
TOC	1.10	1.04	1.03	1.02	1.01	0.99	0.98	0.99	0.99
SS	2.87	1.87	1.65	1.46	1.26	1.18	1.10	1.06	1.02
T-N	1.12	1.03	1.02	1.01	0.97	0.97	0.96	1.00	1.00
T-P	1.31	1.22	1.20	1.14	1.11	1.09	1.08	1.05	1.03

4. Conclusion

In this study, the runoff characteristic of rainfall effluent, which was produced in vineyard area in the rainy event, was analyzed through EMCs, first flush effect, flush ratio and quantification of the flush by pollutant. Also, quantitative effect of changes of rainfall-runoff water on the amount of pollutant runoff was presented with stepwise changes of runoff volume by pollutant. The results are as follows:

1) According to the analysis results of the flushing effect by pollutant, all investigation items displayed week effect, except for SS which showed especially strong first flush effect. Also, COD, TN and TOC presented strong first flush effect in order by water quality item.
2) When examined the flush ratio of rainfall runoff using MFFn value, average first flush ratio of SS was the highest of 49.5% at MFF_{30}, which means "n"=30, followed by T-P 36.0%> and COD 35.1% at the same "n" value.
3) The maximum first flush ratio of the items in the 19 rainfall events was 95.1% in SS, 51.9% in COD and 45.3% in BOD at MFF30.

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