Journal of Environmental Protection, 2014, 5, 223-231
Published Online March 2014 in SciRes. http://www.scirp.org/journal/jep
http://dx.doi.org/10.4236/jep.2014.54026

Scientific Research

Trend Analysis of Water Pollutant at Summer Rainfall Season

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Received 20 December 2013; revised 15 January 2014; accepted 12 February 2014

Abstract

This study, with Hongdong Reservoir, is intended to evaluate the changes in water quality in the lake before and after rainfall in summer. Various non-point source pollutions are scattered around the reservoir, and to determine the pollution level by pollution source, samples were taken at the same point before rainfall (1st), during rainfall (2nd) and after rainfall (3rd) and concentration was measured. Pollutant concentration curve at the measuring points (HDS1, HDS2, HDS3) appeared to be similar with the hydrological curve. When comparing the concentration immediately before rainfall with event mean concentration (EMC), SS and COD were 4 - 59 times and 1 - 4 times, respectively. However, when it comes to total nitrogen (T-N), concentration arrived at the reservoir stayed the range of 1.3 - 12.0 mg/L in all 3 cases without significant variation, which indicated that total nitrogen load is critical when arriving at the reservoir, irrespective of rainfall, and thus it's necessary to consider non-point source pollution runoff also in addition to point source pollution when developing the water quality improvement measures in reservoir.

Keywords

Rainfall Event; Reservoir Control; Water Pollution; Nutrients; Non-Point Pollution Source

1. Introduction

Reservoirs have been expanded and refurbished as part of the project to improve the water quality and integrated watershed management plan for water quality control was established and introduced. Nutrient salts contained in domestic sewage and industrial wastewater promote the propagation of plankton which increases eutrophication

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How to cite this paper: Lee, Y. and Shin, S. (2014) Trend Analysis of Water Pollutant at Summer Rainfall Season. *Journal of Environmental Protection*, **5**, 223-231. http://dx.doi.org/10.4236/jep.2014.54026

or eutrophication effect. Retention area formed in man-made reservoir in a bid to control the water supply and the flood is known as one of the main factors degrading the water quality [1] [2].

As most of rainfall (60% ~ 70%) in Korea is concentrated on summer season, considerable amount of pollutants originated from non-point pollution source at farmland or mountainous area have been discharged during rainfall duration. Because it's difficult to track the path of such non-point source and efflux varies irregularly, it's also difficult to determine the quantitative solution [3]-[5]. Particularly, the reservoir at farmland or mountainous area is used to hold the water for extended time during rainfall duration for agricultural use. Thus pollutants carried to reservoir with runoff also stay at reservoir and excessive nutrients cause eutrophication, deteriorating the water quality in reservoir. Given the pollutants are mostly from the runoff after initial rain, management technique to effectively deal with the pollutants during rainfall needs to be further developed [2].

In previous studies, water improvement projects using natural purification function were conducted. Vegetation around reservoir has been used as part of natural purification function [6] which also required integrated pollution source management and purification measures and consequently. Domestic study on runoff characteristics of non-point pollution source has made a considerable progress in a way of applying previously-developed technologies and verification, but the data on pollution contribution and loading in small farm reservoirs throughout the nation by non-point pollution source before and after rainfall. Therefore, it's necessary to investigate the pollutant concentration before/after rainfall in a bid to introduce effective reservoir water quality management through the disposal or isolate the runoff after initial rainfall.

This study, for reservoir water quality management, is aimed at identifying the characteristic of reservoir water pollution concentration before/after rainfall and estimating the nutrient salts so as to provide the base to use reservoir water quality management data.

2. Territory and Methodology

The points near the bridges which were easily accessible at three tributaries were designated for investigating water quality during rainfall at the basin around Hongdong Reservoir and the designated points for investigation are indicated in **Figure 1** and the coordinates are in **Table 1**. The points for measuring water level and velocity for flow measurement were designated at the location where the flow was not interrupted from the reservoir as well as is accessible and easy to measure the water level and flow velocity. Three tributaries to Hongdong reservoir were designated to monitor the inflow rate and water quality. For estimating the flow arriving at the reservoir over extended time, water level-rating curve was developed so as to convert to the flow rate from water level. As there's a pier at the level monitoring point in Sangsongcheon, an inflow river to Hongdong Reservoir, water flows on right side of the pier but when depth reaches 20 cm or more, water also runs on the left side of the pier too. The stream is 7.5 m wide and the height from the bottom to the bridge deck is about 4.2 m. Flow rate was measured when rain starts till the water level drops considerably after rain stopped ay hourly interval.

Water level was measured before/after monitoring flow rate and flow velocity was checked at the point with 60% of main stream in depth. Flow rate was estimated in a way of multiplying the measured level by flow velocity after calculating the sectional area using a cross sectional view. **Figure 2** shows the distribution of daily rainfall at Hongdong Reservoir from June through Oct 2005. **Table 2** outlines the dates and rainfall characteristics during rainfall events at Hongdong Reservoir. **Figures 3-5** shows hourly rainfall during monitoring.

3. Sampling the Runoff during Rainfall & Quality Analysis

Samples of runoff were taken at hourly interval along with measuring water level and flow velocity when rain started. As rain lasted for extended time, samples were taken and replaced at regular interval till the water level at the river dropped considerably and measuring water level and velocity and sampling were carried out at three

Table 1. Location of sampling near Hongdong reservoir.

	Location
HDS 1	N 36˚ 30′ 34.28″ E 126˚ 42′ 13.93″
HDS 2	N 36˚ 30′ 27.32″ E 126˚ 42′ 07.16″
HDS 3	N 36˚ 30′ 24.77″ E 126˚ 41′ 47.80″

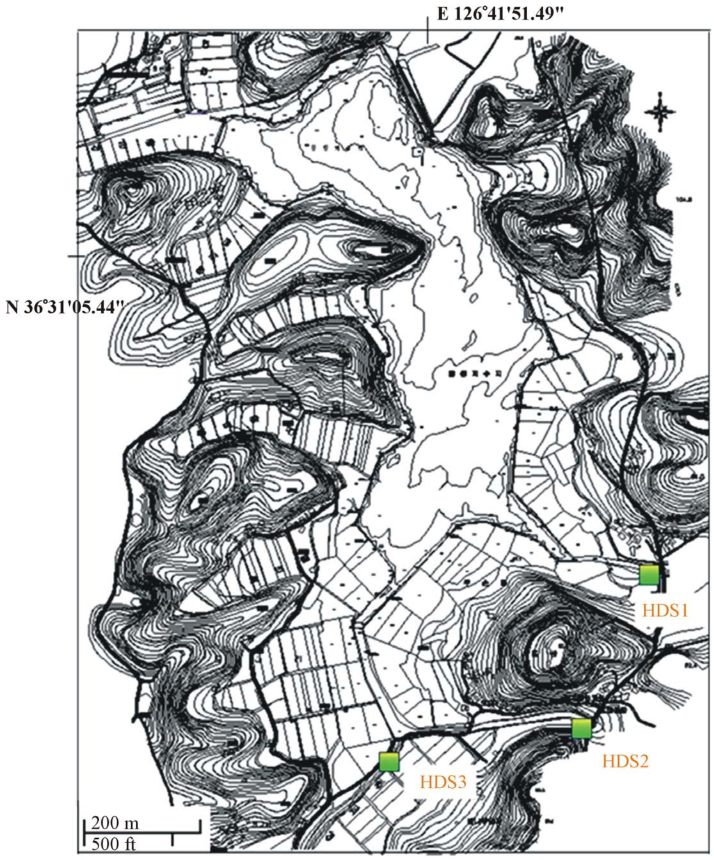

Figure 1. Sampling location at Hongdong reservoir (square: location of the investigation).

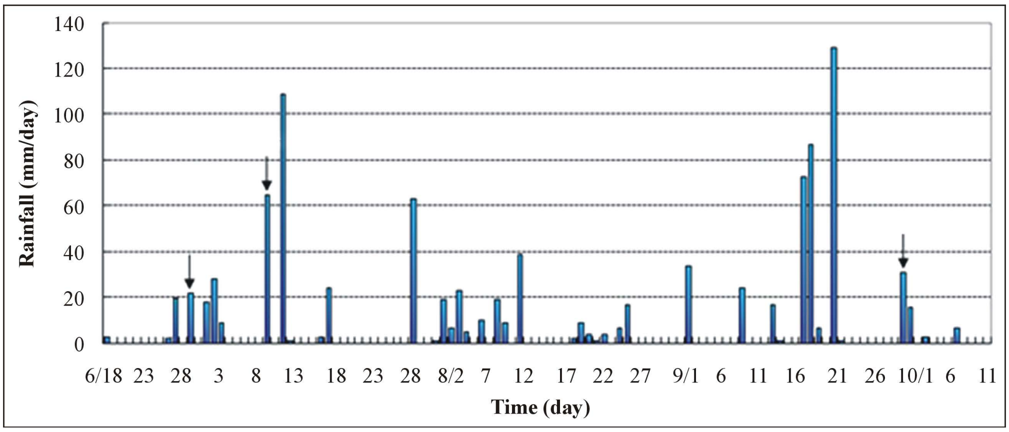

Figure 2. The amount of rainfall measured from June to October at Hongdong reservoir.

Table 2. Rainfall characteristics during the investigation period.

Runoff	Event	Rainfall (mm)	Duration (hr)	Mean rainfall intensity (mm/hr)	Anterior rainfall volume (mm)	Continuous rainfall characteristics like dry days (day)
1st	June 29th	22	3	7.33	2 (20)	2
2nd	July 9th	65	13	5.00	9	6
3rd	September 30th	47	19	2.47	1	7

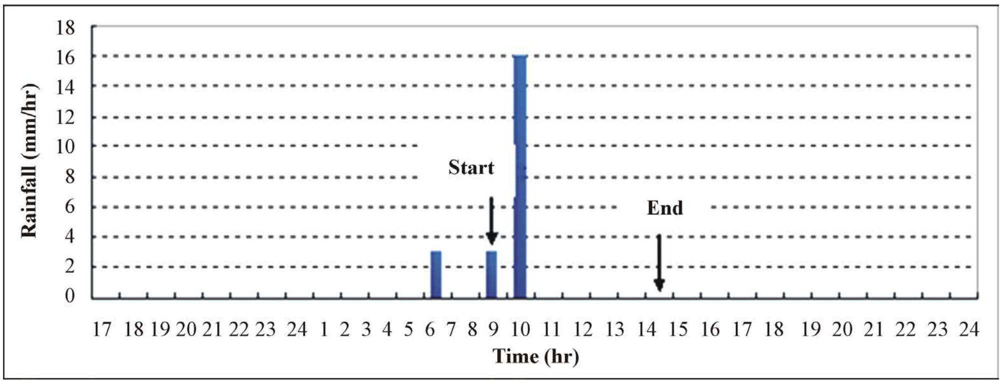

Figure 3. Rainfall measured in the 1st at Hongdong reservoir.

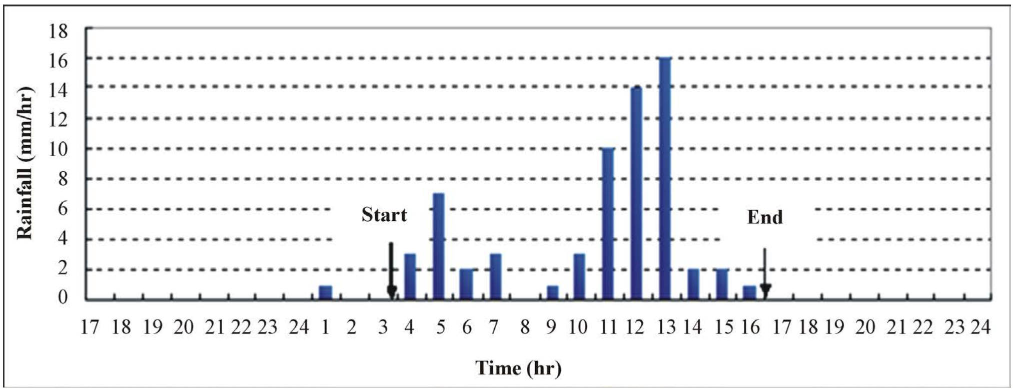

Figure 4. Rainfall measured in the 2nd at Hongdong reservoir.

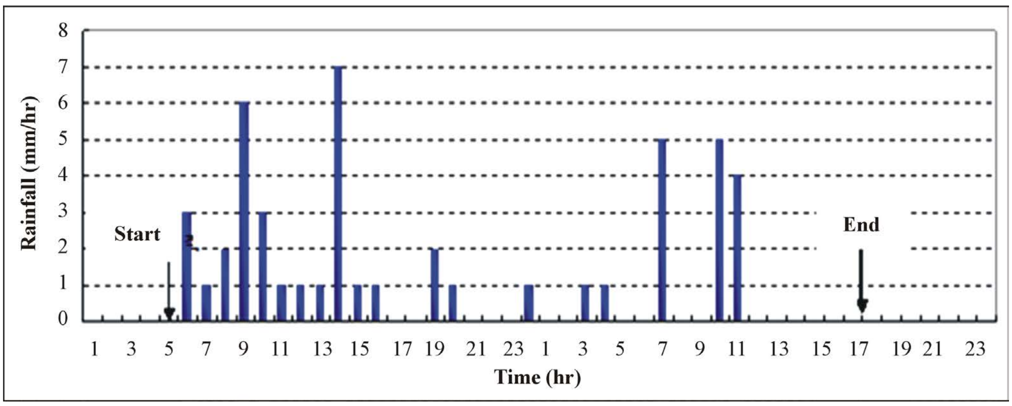

Figure 5. Rainfall measured in the 3rd at Hongdong reservoir.

tributaries flowing into Hongdong Reservoir.

Water quality analysis of runoff during rainfall was conducted using Official Analysis Method for Water Pollutants COD indicating the content of organic materials in sample was measured using manganate method [7]. Total nitrogen (T-N) was analyzed in a way of decomposing in high pressure sterilizer after putting the sample in bottle and adding alkali potassium persulfate and ultraviolet absorption (general spectronic 123) was measured and analyzed, and ammonia nitrogen was analyzed using indophenol test. Nitriteand nitrate were also analyzed using diazoa method and brucine method. For analysis of total phosphorus (T-P), ascorbic acid reduction method was used after decomposing according to Official Analysis Method for Water Pollutants. Concentration of phosphorate-phosphrous was calculated after filtering and coloring using ascorbic acid reduction method and measuring the optical density. TDS and pH were measured using HACH TDS meter and Orion 301 pH meter, respectively and alkalinity in water was analyzed using 0.025 N sulfuric acid solution.

4. Characteristics of Non-Point Source Pollutants from Rainfall Event

Characteristics of pollutants at certain basin area for certain rainfall event are represented by peak concentration, mean concentration, peak load, mean load or sum of load, which are indicated in graph showing hydrograph, pollutograph and loadgraph in **Figure 6**. Then in most of cases, total load from rainfall event is more important than concentration or peak load because given the mixing to some extent in water body, particularly in reservoir or lake where runoff event is relatively short and rainfall runoff joins, pollutant concentration is rather the response to the total load than influence by changes in concentration in runoff (into the reservoir) by rainfall. For nutrients such as nitrogen or phosphoric in reservoir or lake, total load is the most influential variable to water quality and thus total load is considered the most appropriate factor in evaluating the non-point source pollutants with event mean concentration (EMC) and has been widely used. EMC of pollutants is calculated as follows [8].

$$\text{EMC} = \left(\text{Total load of pollutants in total runoff}\right)/\left(\text{total runoff}\right) = \sum Q_i C_i / \sum Q_i \quad (1)$$

Where, Q_i = runoff during micro time on hydrological curve (m^3/hr)

C_i = Pollutant concentration on runoff curve in response to Q_i (mg/L)

EMC = Mean concentration for rainfall event (mg/L)

Table 3 suggests characteristic of runoff, EMC and load analyzed at each point during rainfall. Viewing EMC on **Table 3**, peak flow and total runoff volume appeared to be influenced.

5. Investigation and Analysis of Runoff Effect

In urban area where the area is mostly impervious and rainwater and sewage are drained using separate or combined system, the capacity of detention system using the runoff during initial rainfall (or first flush flow) is determined by the amount of suspended solid pollutant during initial rainfall. When pollutants which are easily

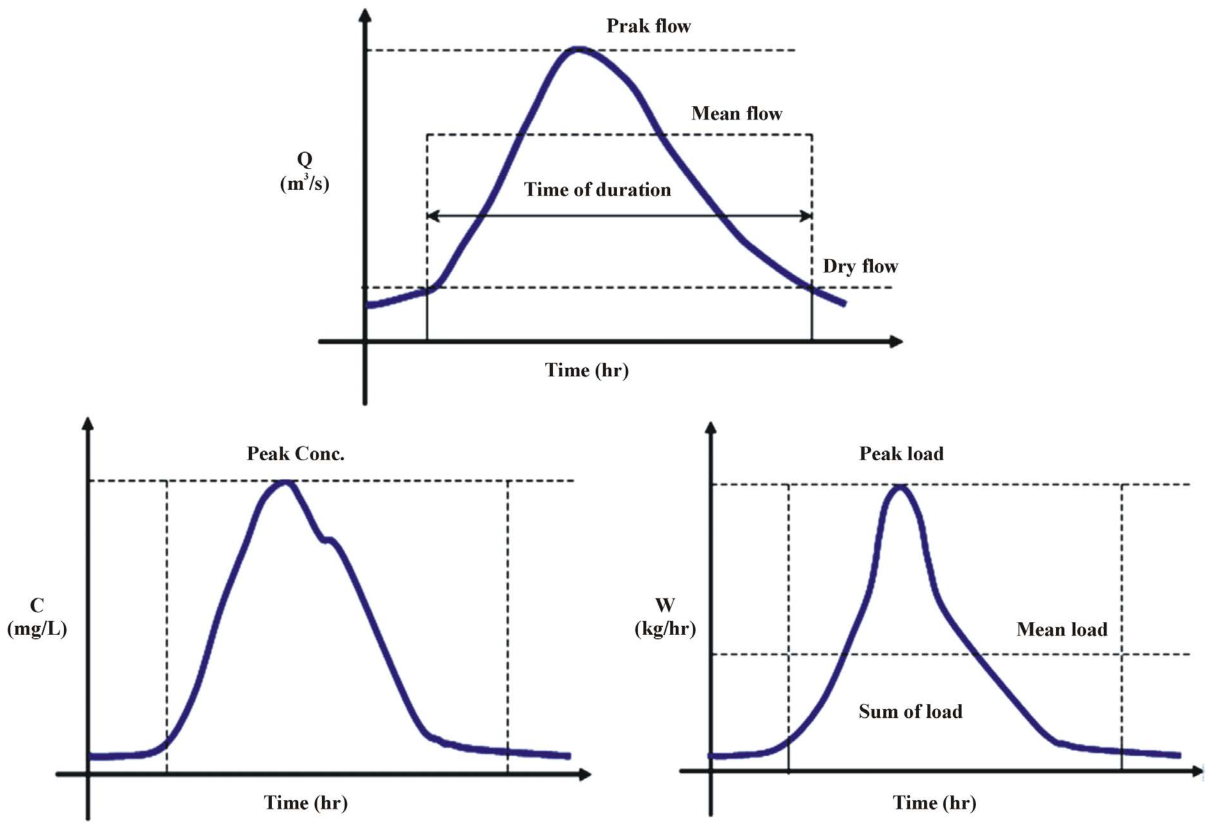

Figure 6. Comparison volume, concentration and weight (loading) at rainfall event.

Table 3. Runoff characteristics of pollutants at HDS1.

		1st				2nd				3rd			
Runoff characteristics	Duration (hrs)	5.3				12.0				34.0			
	Mean flow (m^3/hr)	1911				4884				1145			
	Peak discharge (m^3/hr)	4533				15,257				2422			
	Total runoff (m^3)	151,901				879,048				584,128			
	Anterior rainfall (m^3/hr)	42				59				161			
EMC* (mg/L)	SS	215.3				220.2				44.1			
	COD	23.7				18.5				11.3			
	T-N	8.0				3.4				5.5			
	T-P	0.9				0.4				0.3			
Concentration (mg/L)	Item Characteristics	SS	COD	T-N	T-P	SS	COD	T-N	T-P	SS	COD	T-N	T-P
	Max.	675.7	29.6	12.0	1.7	418.0	28.8	5.0	0.7	111.0	15.2	10.9	0.5
	Mean	175.1	20.2	6.9	0.8	144.2	14.9	3.2	0.4	39.1	11.0	4.9	0.3
	Min.	23.0	12.8	1.6	0.2	18.0	7.2	1.5	0.1	13.0	8.5	1.9	0.2
	Before rainfall	53.2	15.6	3.5	0.2	16.4	7.5	2.8	0.1	6.6	6.4	2.7	0.3
Loadings (kg/hr)	Item Characteristics	SS	COD	T-N	T-P	SS	COD	T-N	T-P	SS	COD	T-N	T-P
	Max.	3063.3	134.2	54.6	7.6	6377.3	439.4	76.6	10.3	268.8	36.8	26.5	1.2
	Mean	334.7	38.6	13.1	1.5	704.2	72.5	15.4	1.9	44.8	12.6	5.6	0.3
	Total loadings (kg)	32,699	3594	1210	141	193,583	16,248	2956	392	25,787	6607	3240	176
	Before rainfall	2.2	0.7	0.2	0.01	1.0	0.5	0.2	0.01	1.1	1.0	0.4	0.04

washed away by runoff exist at drainage region, peak concentration and load appear prior to reaching to peak flow and thus if designed with tolerable critical concentration or load capacity (for instance, 90% capacity in Germany), it would be very efficient in determining the capacity (m^3) to deal with non-point source pollutants.

To identify the existence of initial rainfall runoff effect, investigation of time difference between peak flow rate and peak load after overlapping SS, COD, T-N and T-P load curve on hydrological curve. **Figures 7-9** show is the result after overlapping pollutant load curve on hydrological curve using the data analyzed during the 1st rainfall at Hongdong Reservoir.

According to **Figures 7-9**, no time difference between peak flow and peak load which could prove the effect of initial rainfall runoff at farm reservoir area appeared to all rainfall events. And no cleaning effect between rainfall events at same basin area appeared, but reduction in load was much larger when flow was reduced than the case of flow rising.

6. Conclusion and Consideration

In this study, investigation was conducted at Hongdong Reservoir to identify the pollutant discharge and distribution of the volume over time and the effect of initial rainfall runoff sampling of runoff during rainfall was arranged at regular interval when monitoring water level and flow velocity during rainfall and the sample representing peak flow was included. As rainfall duration is extended, the samples were selected at equal time inter-

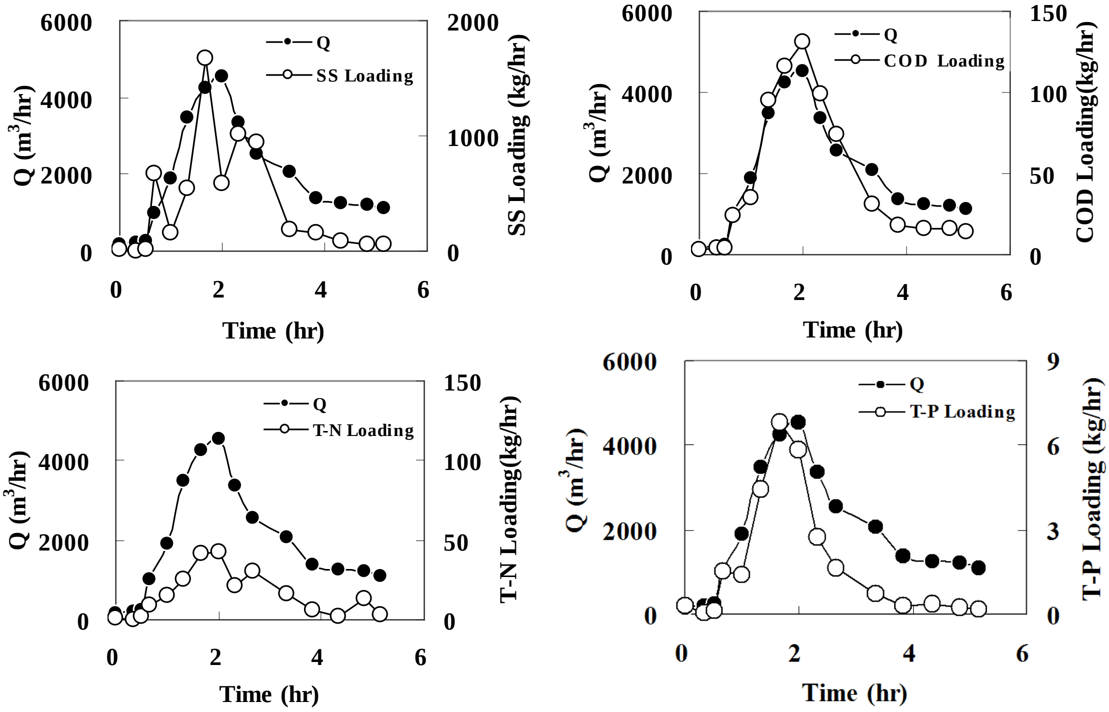

Figure 7. Distribution of time vs. flow and loadings at HDS1 (1st investigation).

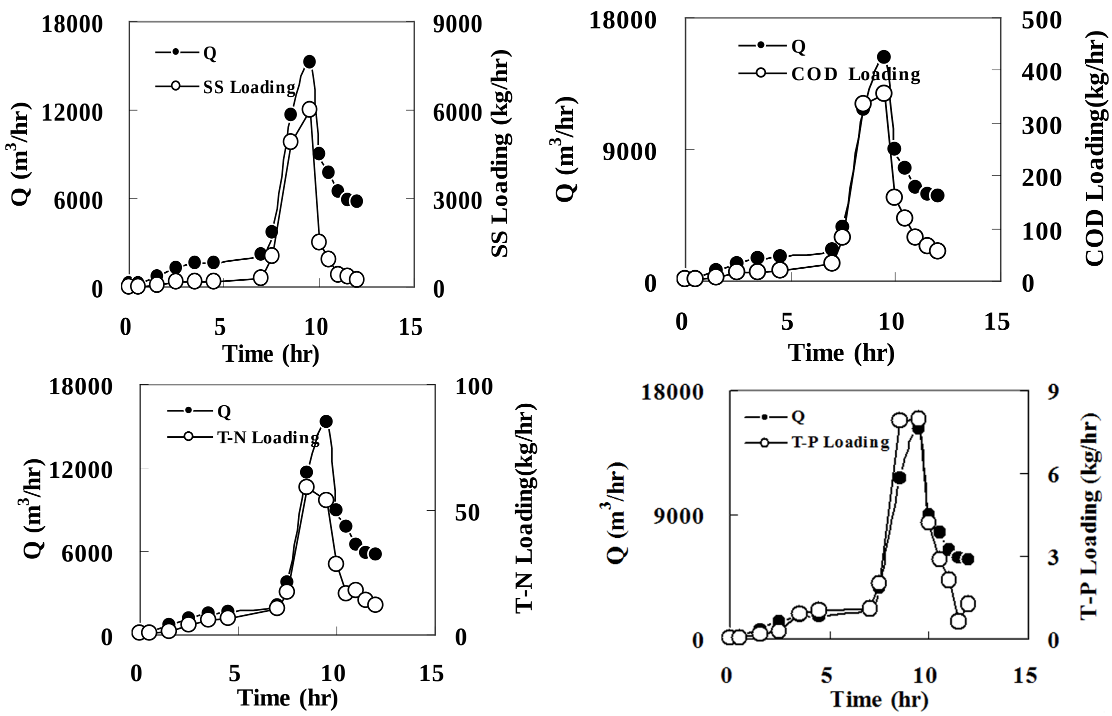

Figure 8. Distribution of time vs. flow and loadings at HDS1 (2nd investigation).

val for replacement till the water level dropped sufficiently after rain stopped. Included in the items for analysis were SS, COD, SCOD, nitrogen, total phosphorous and phosphorate phosphorous. Samples were taken three times at each basin area on June 28, July 9 and September 30, 2005. During rainfall at investigation sites, hydrological curve and SS, COD, T-P concentration curve pattern (rise-fall) appeared the same. But with regard to ni-

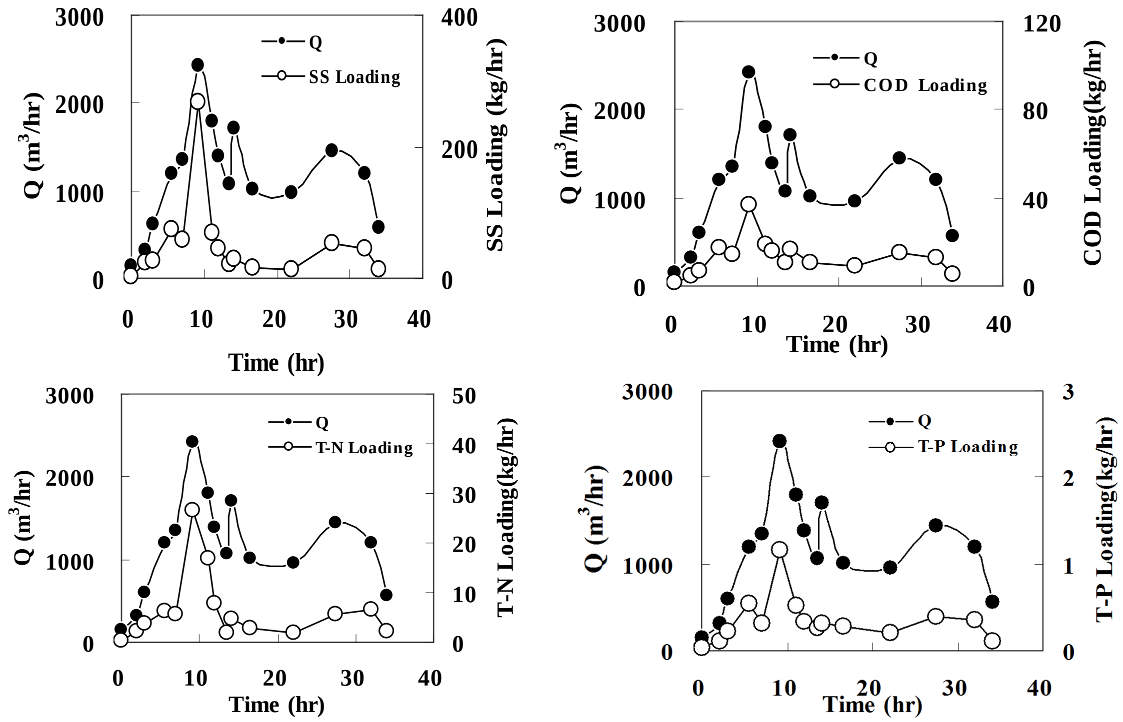

Figure 9. Distribution of time vs. flow and loadings at HDS1 (3rd investigation).

trogen concentration, inflow rate during non-rainfall was also an important factor, besides runoff during rainfall, irrespective of runoff volume during rainfall and non-rainfall, which shall be considered in establishing the measure to deal with the non-point source pollutants. Moreover, identifying the characteristics of pollutants flowing into the reservoir is very important in establishing the disposal plan.

According to the analysis of correlation between data on SS and COD & T-P collected during rainfall, pollutants were mostly carried by granular materials, which was attributable to suspended material and soil transported by rainfall energy or kinetic energy of runoff and thus retarding basin at upper stream of the reservoir, if installed, would possibly reduce the organic material and total phosphorous load arrived at the reservoir. But for management of reservoir in steady manner, the facilities to deal with domestic sewage, livestock manure and non-point source pollutants to dispose of illegal discharge or on road are more than important.

The data on characteristics of runoff during rainfall and pollutants including contamination load presented in this study would help establish the reservoir management plan and the data on characteristics & concentration of pollutants and total sediment deposit from the investigation of sediment deposit would provide the basic data in determining the dredging in reservoir or reuse. However, given that this study includes the data obtained from rainfall during short time and the measurements were limited, it may be partially difficult to analyze the findings and thus more in-depth and long-term studies are required to supplement such challenges.

Acknowledgements

This study was conducted as part of the project supported by the Korea Rural Community Corporation for which we extend the deepest gratitude.

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