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National pilot projects for management of diffuse pollution in Korea

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Abstract

Extensive effort through point source controls, such as the construction of wastewater treatment plants, has been continuously made not only to improve the water quality but also to protect the water resources since 1990 in the Han River basin, Korea. However, it is difficult to maintain biochemical oxygen demand (BOD) concentration below 1.0 mg/L and not able to meet the standard for drinking water sources. One of the main reasons for not achieving the target of water quality management is pointed out as to take insufficient measures toward diffuse pollution, particularly in the control of stormwater discharge. In March 2004, the Comprehensive Measures for Non-point Source Pollution Management in the Four Major Rivers were established under the leadership of the Prime Minister's office and through the cooperation of related ministries. The effective control of Non-point Source (NPS) holds the key to the success of fulfilling total maximum daily loading (TMDL) program. As a part of carrying out policies on NPS pollution management, various types of NPS pollution pilot facilities were installed in the Han River basin at the end of 2005 and are continuously being installed in the other major rivers. The research program will be used to identify and design the Best Management Practices for the Han River and other river basins in Korea.

Keywords: Pilot projects; Diffuse pollution; Monitoring; Stormwater; TMDL; Best Management Practices

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1. Introduction

The Korean government has made a nation effort to protect the Han River and its tributaries through the construction of point source controls such as wastewater treatment plants. In spite of these efforts water quality has continued to deteriorate and the biochemical oxygen demand (BOD) of drinking water sources, such as Lake Paldang, has reached 2.0 mg/L. The main reason for not attaining water quality objectives is the contribution of Non-point Source Pollution (NPS), and stormwaters from urban areas. In response the Korean government established the Comprehensive Measures for Non-point Source Pollution Management in March 2004 to protect Korea's four major rivers.

Stormwater runoff from various areas such as urban, agricultural, industrial regions is considered to be a major source of pollution [1–4], and may be an important reason of worldwide eutrophication and deterioration of receiving waters. For this reason, many researchers [5,6] have analyzed the impact of stormwater runoff on water quality and investigated treatment methods or Best Management Practices (BMP) for runoff control [7,8].

This paper describes Korea's national policy for diffuse pollution management as well as a number of pilot projects and preliminary results. The final results of these projects will hopefully become models for long-term policies and techniques for NPS management.

Comprehensive measures for Non-point Source Pollution Management: The Ministry of Environment (MoE), Korea, established the Comprehensive Water Quality Management Measures for the Four Major Rivers between 1998 and 2000. The four major rivers are the Han, Nakdong, Geum and Yeongsan/Sumjin Rivers which serve the water needs of more than 40 million people. The major policies include the implementation of total maximum daily loads (TMDLs), riparian buffer zones, land acquisition, and a water use charge to support the program's efforts.

The MoE is aggressively pursuing the implementation and compliance with TMDL for watershed protection, and effective control of NPS is believed to be the key method for successfully meeting the TMDLs. Fig. 1 shows annual average BOD changes of the four major rivers over the period from 1998 to 2004, and NPS pollution is estimated to contribute 22–37% of the total BOD pollutant load.

In the case of standards for total nitrogen (TN) and total phosphorus (TP), NPS contributions are thought to be higher. The relative NPS contributions are increasing due to the expansion of wastewater treatment plants, which reduces point source discharges, stricter discharge regulations, and the increase of NPS pollution from urban areas, roads and farmlands. It is believed that 45% of the pollutant load in the Paldang water supply results from NPS sources. Without future control measures, it is expected that NPS contribution will rise to 54% by the year 2020. The MoE has recognized this problem and concluded that the needed water quality improvements cannot be obtained without dramatic reductions in NPS pollution.

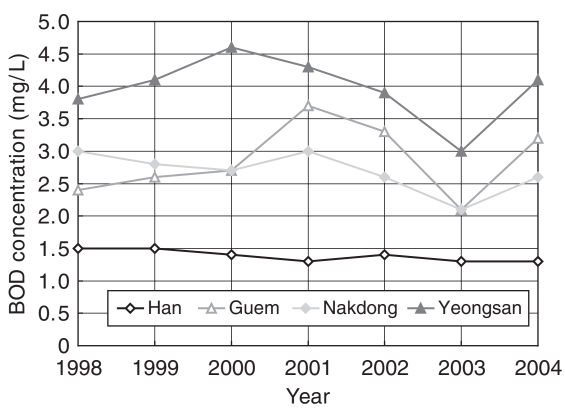


Fig. 1. Annual changes in BOD concentrations (1998–2004) in the four major rivers of Korea.

In order to facilitate the implementation of these measures and provide legal backing, the new Comprehensive Non-point Source Pollution Management Measures for the Four Major Rivers were established in March 2004 under the leadership of the Prime Minister's Office and through the cooperation of related ministries. The Comprehensive Measures will implement several major improvements, such as changes in management policies, pilot projects to develop and demonstrate BMP construction and management techniques, research and outreach to develop public support for the measures. Table 1 shows how the areas of concern are being addressed in three phases.

The first phase (2004–2005) focused on policy system improvement and pilot projects while the second phase (2006–2011) will focus on best management projects for the four major rivers. The third phase (2012–2020) will focus on nationwide implementation of NPS pollution management practices.

In the area of policy system improvements, through revisions of the Water Quality Conservation Act, the central government and local authorities will be charged with NPS pollution management. Additionally, laws and rules for NPS pollution will be incorporated into legislation, and guidelines for activities such as environmental impact assessments and city framework plans will be required in the early stages of new urban development projects. Land use laws to strengthen environmentally sound land use practices will also be developed.

With respect to related projects, MoE and other organizations such as the Environmental Management Corporation (EMC) and Korea Water Resources Corporation (K-WATER) are conducting pilot projects for NPS pollution abatement programs in the four major rivers over the period from 2004 to 2009. Each pilot plant in the projects is being selected to match watershed characteristics such as drainage area, land use, slope and etc., and will compile important data and technology, including treatment efficiency and facility operation and maintenance requirements, which will be used to establish guidelines for the construction, operation and maintenance of NPS pollution abatement facilities. As a part of national policy on NPS management program, large expenditures will be allocated for the Han River basin by 2008, while the three other river basins are being investigated in subsequent stages. As of now, approximately 12.1 million US$ has been invested over four years to collect data on runoff characteristics of the catchment area as well as to evaluate the efficiency of several BMPs. Approximately

Table 1
Major goals of measures for each phase

Field	1st phase ('04–'05)	2nd phase ('06–'11)	3rd phase ('12–'20)
Policy system improvements	Build policy foundation (government to establish plan & leads efforts)	Charge responsibility of managing major pollution sources	Continue to strengthen management responsibilities
Related projects	Pilot projects (national)	BMP projects for the site specific conditions in four major rivers (central & local governments)	Full implementation of projects with local government in lead & central government support
Research & public support	Focus on identification of causes and development of treatment technologies	Set technologies for monitoring & standards on treatment facilities	Facility improvements taking into consideration cost and efficiency

equal investment is being made in Nakdong River watershed for the construction of five BMPs with the similar goals and purposes. It is expected that approximately 100 million US$ will be invested by the end of 2011 on NPS programs.

The government, in recognition of the importance of efforts by citizens and local governments in reducing NPS pollution, will develop and distribute education materials to the public, as well as hosting regular workshops and seminars in cooperation with related ministries. The goal of the policy and NPS program is to reduce NPS pollutants by 34.3% from 381 to 250 tons/day in the four major rivers in order to achieve BOD concentrations to 0.20–0.65 mg/L.

2. Methods

2.1. Site description

The Han River has a total watershed area of 26,018 km^2 and has 481.7 km of total watercourse length. It provides raw water for drinking water treatment plants that serve over 20 million people in Seoul metropolitan. It flows into the Yellow Sea through a number of cities where it is expected to provide beneficial use. Combined sewer overflows (CSOs) and untreated stormwater runoff pollutants are intermittently discharged to the river and have been identified as the leading causes of water quality degradation. The Kyung-An Stream has 768.4 km^2 of total watershed area with 76.1 km of total watercourse length and passes through major cities, including Kwang-Ju, Yong-In and I-Cheon. It is a tributary of the Han River; a site study was performed to determine the best locations for several structural BMPs.

Fig. 2 shows the locations of pilot facilities around the Kyung-An Stream, while Table 2 presents the details of the characteristics of sites for pilot facilities; such as treatment type, land use and watershed. The areas for different land uses (e.g. agricultural, highway, forest, parking lot, road and residential area) range from 0.32 to 180.7 ha.

2.2. Best Management Practices

Based on the preliminary tests of water quality and stormwater runoff pollutants, alternative treatment processes have been recommended for Han River. Table 2 shows the characteristics of the 25 different structural BMPs. The BMPs were selected to evaluate a range of practices, such as constructed wetlands, detention basins, grassy swales, percolation trenches, media filters and hydrodynamic devices. Nineteen BMPs were completed by the end of 2005 and the remaining six will be finished by the end of 2006.

2.3. Monitoring

The monitoring program will utilize a series of grab samples and continuous flow measurements, which will be used to calculate event mean concentrations. The monitoring program calls for the collection of six samples during the first hour after the beginning of runoff during the first 1 h, collected at the beginning of runoff and 5, 10, 15, 30 and 60 min after the beginning of runoff. Short time of intervals was selected at the beginning of the runoff to determine the existence of a first flush. Additional samples are to be colleted at 1 h intervals till the end of the storm, up to a total of 12 samples.

A large suite of parameters will be monitored including organics (BOD, COD and TOC), nutrients and heavy metals, and will be selected based on specific landuses. The BMP removal efficiency for each storm event will be based upon mass removed, but the concentration data will be used to develop an Event Mean Concentration (EMC) database for various landuses as well as understanding the minimum effluent concentrations that can be produced by a given BMP.

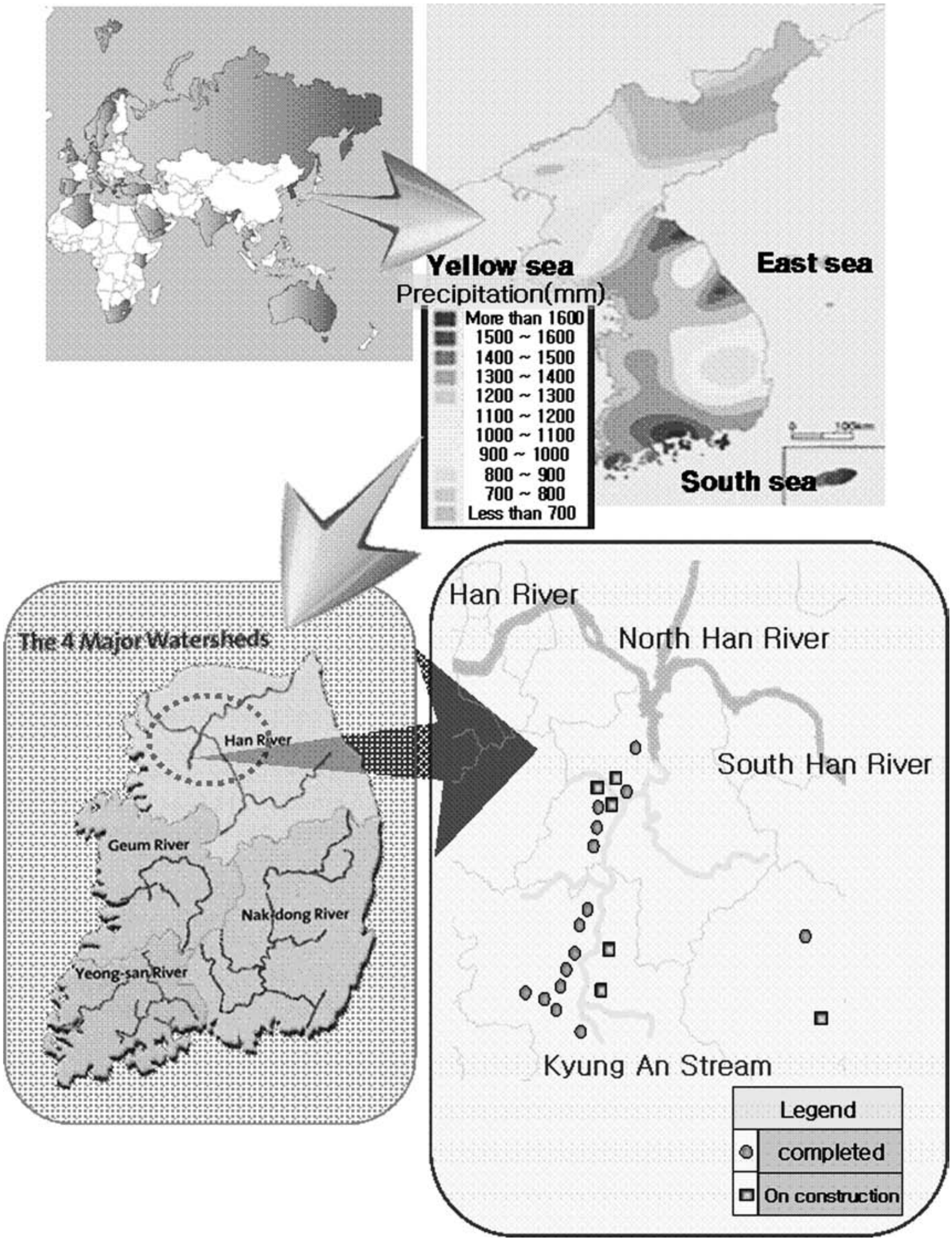


Fig. 2. Location of constructed pilot facilities.

Table 2
Characteristics of sites for installed facilities

No.	Location	BMP type	Land use	Area (ha)
1	Yong-In	Constructed wetland (1)	Agricultural	10.4
2		Grassy swale (2)	Agricultural/highway, forest	6.6
3		Percolation trench (2)	Highway	0.8
4		Vegetated filter strips (2)	Agricultural (dry field, forest)	9.6
5		Media filters (1)	Highway	0.65
6		Media filters (2)	Parking lot	4.57
7		Hydrodynamic devices (2)	Highway, residential, parking lot	3.66
8		Media filters (1)	Highway	0.77
9		Detention basin (1)	Agricultural	90.8
10		Infiltration basin (1)	Agricultural/highway	9.1
11	Kwang-Ju	Media filters (1)	Parking lot	0.5
12		Media filters (1)	Highway	0.32
13		Hydrodynamic devices (2)	Residential, highway	3.56
14		Media filters (1)	Highway	0.52
15		Hydrodynamic devices (3)	Residential, highway	180.7
16	I-Cheon	Constructed wetland (1)	Road, agricultural, residential	10
18		Percolation trench (1)	Residential, forest	1.6

Number of facilities are given in parenthesis in the BMP type column.

3. Results and discussions

Fig. 3 shows the precipitation records over the last 10 years (1992–2001) in Kwang-Ju and Yong-In areas.

The average monthly rainfall and number of rainy days per year are shown, and are similar for Kwang-Ju and Yong-In: 108 mm and 8.6 days, and 122 mm and 8.4 days, respectively. The average yearly rainfall for Korea including Kwang-Ju and Yong-In cities is approximately 1400 mm/yr, which is somewhat greater than the world's average precipitation (973 mm). More than 70% of rainfall occurs in the rainy season from June to August. The average yearly precipitation varies from 700 to 1600 mm across the country. The annual precipitation per capita is approximately 2705 tons/yr, and is just one tenth of the world's average. Of this precipitation, approximately 1550 tons per capita is available as domestic water resources. Both the climate characteristics mentioned previously and the limited available land for BMP construction are main impediments for designing and construction of BMPs.

Prior to the BMPs selection, the rainfall-runoff characteristics were determined for all sites. Fig. 4 shows a cumulative pollutant discharge for a typical storm. The *Y*-axis is the normalized pollutant mass and the *X*-axis is the normalized runoff.

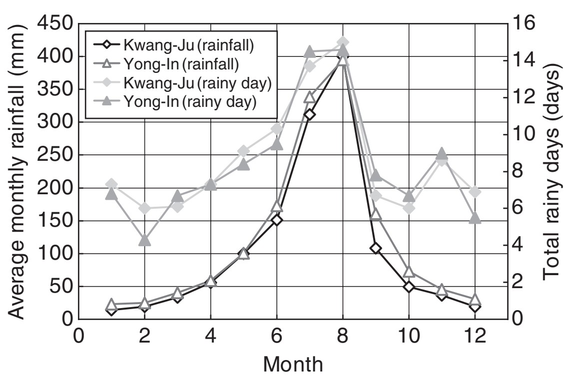


Fig. 3. Precipitation monitoring records for the demonstration facilities.

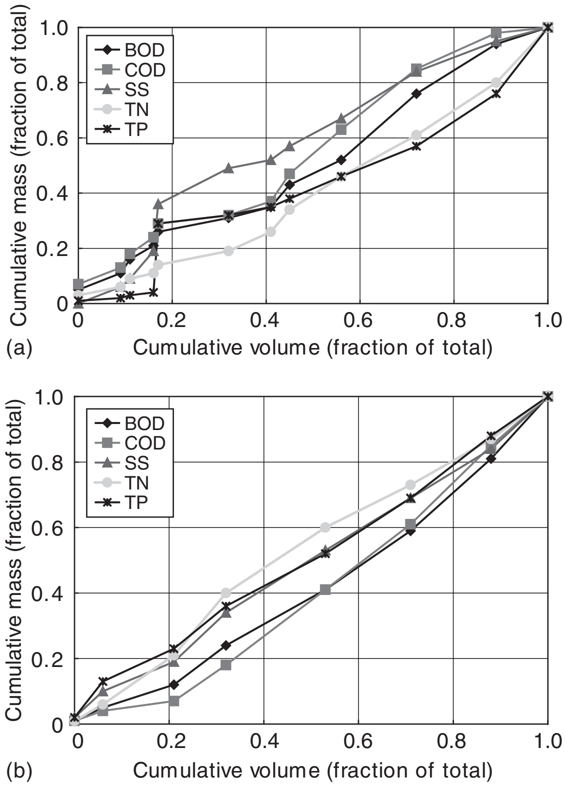


Fig. 4. Cumulative mass runoff vs. cumulative volume runoff (fraction of totals) for study areas: (a) highway and (b) agricultural.

When the slope of the mass vs. volume curve is greater than 1.0 as occurs in Fig. 4(a), the initial runoff is higher in concentration and suggests a first flush. Hydrodynamic devices were preferentially considered for these areas as candidate BMPs. In the case of lower slopes (less or no first flush), as observed in Fig. 4(b), other types of BMPs were considered better candidates.

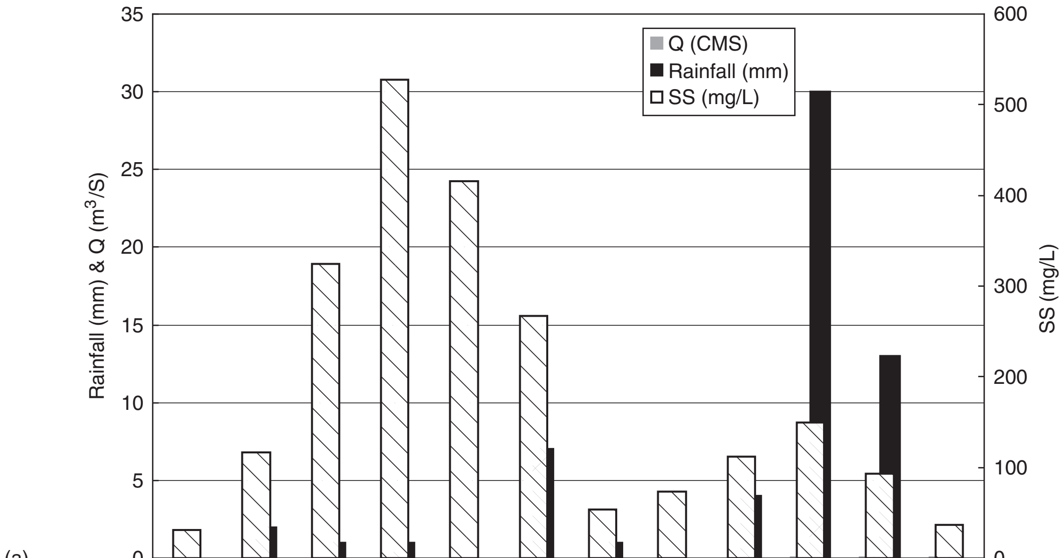
Fig. 5 describes the relationship between water quality and rainfall for two study areas, where different types of stormwater runoff could be observed. In the case of Fig. 5(a) showing a highway area, the first flush of suspended solids (SS) appeared even for small events within the first 2 h. No such tendency was observed at the agricultural catchments area as shown Fig. 5(b), and no first flush effect for SS was observed. These generation and discharge characteristics of NPS pollutants as a function of landuse should be considered when selecting BMPs.

The standard used to select sites varied depending on factors such as local hydrology, land use, receiving water characters and specific requirements of the BMP type to be evaluated. In general, the following criteria were used at all sites:

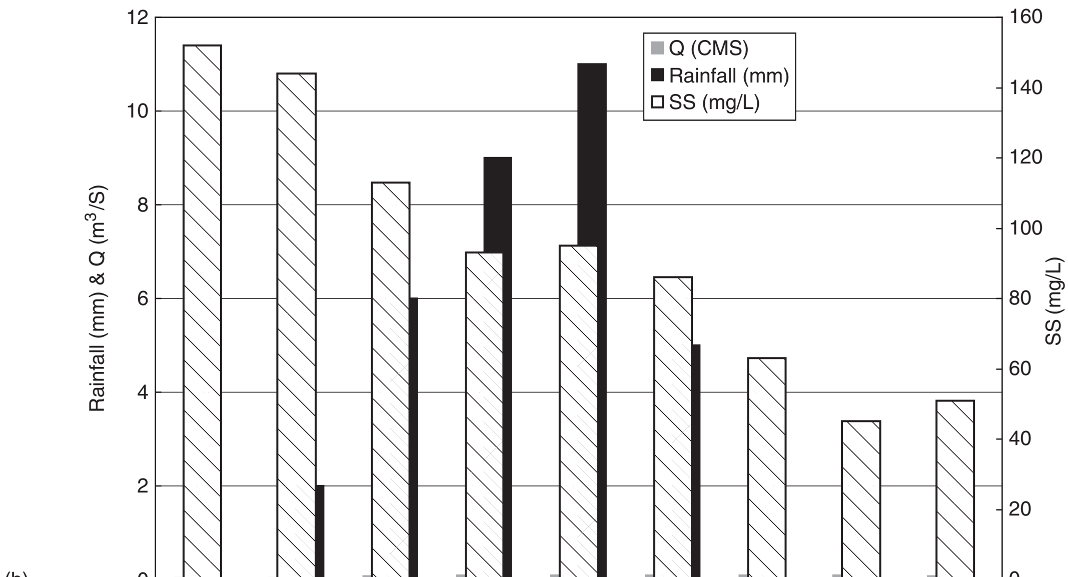
- Available space must be able to accommodate the BMP.
- Natural drainage should be used and no pumping was considered.
- Ease of maintenance, including access.

These criteria created a preference for locating the BMPs in the riparian zones, state-owned lands and riverbeds. Since more than 80% of the storm events produced 20 mm or less rainfall, 20 mm was selected as a design storm and the BMPs were sized to treat the associated runoff for each landuse type. Runoff was estimated using rainfall intensity and runoff coefficients. Precipitation records for the last 10 years showed that 90% of the rainfall events had intensities of 15–20 mm/h or less. Runoff coefficients of 0.7–0.9 were assumed for impervious areas such as highways, parking lots and residential areas, and 0.1–0.3 was assumed for pervious areas, such as agricultural and forested areas. The BMPs were also selected to remove target pollutants as a function of the landuse characteristics.

The early monitoring data suggests that the media filters were achieving substantial water quality improvements and discharging relatively high quality effluent, in spite of maintenance requirements such as the filter clogging. The pollutant removals observed in the storage type devices combined with vegetation such as grassy swales, vegetated filter strips and constructed wetlands were less than reported by others [9,10], which is mostly likely caused by improper management and the longer time required to establish stable vegetation.



	17:30	19:00	19:30	20:30	21:00	0:00	1:00	2:00	4:00	5:30	7:00	8:00
Q (CMS)	0.01	0.0173	0.0095	0.0127	0.0045	0.0138	0.026	0.0095	0.0159	0.029	0.0307	0.0293
Rainfall (mm)	0	2	1	1	0	7	1	0	4	30	13	0
SS (mg/L)	31	117	324	528	416	267	54	73	112	150	93	37



	9:30	12:10	12:40	13:30	14:00	15:00	16:00	17:00	18:00
Q (CMS)	0.0413	0.0387	0.0691	0.0859	0.0982	0.0931	0.0859	0.0849	0.0701
Rainfall (mm)	0	2	6	9	11	5	0	0	0
SS (mg/L)	152	144	113	93	95	86	63	45	51

Fig. 5. Relationship between SS and rainfall for study areas: (a) highway and (b) agricultural.

Monitoring protocols used in the US Nationwide Urban Runoff Program [11] combined with other references [12–14] were systematically employed, since procedures and policies specific to Korea have not been developed. This project is the first of its kind in Korea, and it is expected that many or most of these protocols will be replaced or changed to optimize monitoring for Korea-specific situations.

4. Conclusions

The Ministry of the Environment in Korea has established the Comprehensive Measures for Non-point Source Pollution Management in the Four Major Rivers in 2004 and approximately 12.1 US$ million over the previous 4 years have been invested to determine catchment areas, collect runoff characteristics and evaluate the treatment performance of 25 BMPs.

From the feasibility study, it is concluded that site-selection criteria should consider local hydrology, land use, receiving water characteristics and specific requirements of the BMP types. Although not all BMPs have been evaluated, early results suggest that media filters are capable of producing substantial water quality improvements, while BMPs requiring vegetation present challenges for management and requiring longer start-up time, necessitating longer monitoring program to obtain representative results. The results of pilot facilities will be used to identify, to design BMP types and to optimize NPS management polices of Korea.

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