Appropriate Methods in Determining the Event Mean Concentration and Pollutant Removal Efficiency of a Best Management Practice

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Abstract

This study attempted to develop and suggest a more appropriate method for the determination of event mean concentration (EMC) and pollutant removal efficiency of a stormwater best management practice (BMP) considering rainfall. The stormwater runoff and hydrologic data gathered from 22 storm events during a 28-month monitoring period on a swirl and filtration type of BMP were used to evaluate the developed methods. Based on the findings, the modified EMC method resulted in lower (average) values than the overall EMC, although the differences were not significant ($P>0.05$). By comparison, the developed ‘Rainfall Occurrence Ratio’ (ROR) method was most significantly correlated ($r=0.967$ to 0.988, $P<0.009$) with the other existing removal efficiency determination methods such as the ‘Efficiency Ratio’ (ER), ‘Summation of Loads’ (SOL) and ‘Regression of Loads’ (ROL) methods. In addition, the ROR method gave the highest efficiency values, with no significant differences with any of the pollutant parameters, unlike the other three methods. These results were obtained because the ROR method integrated both pollutant loading and rainfall, which are not considered by the other three methods. Therefore, this study proved the suitability of the modified EMC and ROR methods for application in other BMP monitoring studies.

Keywords: Best management practice, Event mean concentration, Efficiency, Filtration, Rainfall occurrence ratio method, Stormwater

1. Introduction

The constant expansion of water related infrastructure such as sewage treatment plants by the Korean Government has contributed to a notable reduction of point source pollution. Yet, nonpoint source (NPS) pollution is increasingly affecting water quality [1]. In 2003, the contribution of NPS loadings to major rivers accounted for almost half the total loading, and is predicted to rise to 70\% by 2015 if no adequate control measures are introduced [2]. Sprawl, which is the irresponsible development, is the major contributor to the increase in NPS loadings and volume of stormwater runoff. Bannerman et al [3] found that streets with impervious surfaces contained the highest pollutant loads in most land use categories. Impervious covers can double, triple, quadruple or even quintuple peak discharge [4]. Urban stormwater managers seek technologies that are able to address the flow and water quality impacts of urbanization [5].

The pollutant concentration-restricting approach by the Ministry of Environment (MOE) has not been very effective at improving the water quality of the major rivers in Korea. Consequently, the MOE introduced the total maximum daily load (TMDL) approach in 2004. The TMDL regulates or controls the pollution load discharged below the total amount allowed to attain the water quality target of streams [6]. The MOE is aggressively pursuing the implementation and compliance with the TMDL for watershed protection, and effective control of NPS is believed to be the key method for successfully meeting the TMDL [7, 8]. Changes in management policies have resulted in the introduction of pilot projects, termed ‘best management practices’ (BMP), adopted from the United States. The objectives of the program are to determine catchment areas, determine runoff characteristics and evaluate the treatment performance of structural BMPs, as many introduced in Korea have only been based from literature studies that do not reflect the climatic characteristics and geographical features of the country. The results of BMP case studies will be used to facilitate the design of similar BMP types and optimize NPS management policies (e.g., TMDL) in Korea.

Based on the National Pollutant Removal Performance Database for Stormwater Treatment Practices of the United States

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Received October 01, 2010  Accepted November 22, 2010

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Environmental Protection Agency (U.S. EPA), the median performances of filtering practices for total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) were 86, 32 and 50%, respectively [9]. It has to be emphasized that the median removal efficiency was used instead of the mean that resulted in higher values. The issue of reporting pollutant removal efficiencies needs to be addressed, particularly for each type of BMP because if a wide range of removal efficiencies exists, employing an appropriate stormwater treatment strategy will be difficult. Therefore, this study aimed to develop a more appropriate method for the characterization of stormwater runoff using the event mean concentration (EMC) and calculate the pollutant removal efficiency of a stormwater runoff treatment system for BMPs. Although existing methods are available and currently practiced in most BMP studies, the uncertainties in reporting overall average EMC and removal efficiency values should be eliminated, or at least reduced. The data used in this study was obtained from a 28-month monitoring during 22 storm events on a swirl and filtration system, a type of BMP for the treatment of stormwater runoff.

2. Materials and Methods

2.1. Site Description and Monitoring Scheme

2.1.1. Site Location and Facility Description

A swirl and filtration system (surface area=19.2 m²) was installed in an asphalt-paved parking lot (100% impervious), which drained a 10,700 m² catchment area. The main function of the facility was to remove sediments, suspended solids, particulate pollutants, petroleum hydrocarbons, heavy metals and nutrients from stormwater runoff by means of sedimentation and filtration mechanisms. Fig 1 shows a detailed description of the system. The facility was comprised of two devices in sequence; first, a swirl tank, which provided pre-treatment of the stormwater runoff and was responsible for the removal of sediments, free-floating oil and debris by the mechanism of sedimentation, the runoff then flowed directly to the internal spillways across the second device, which was a filtration chamber that allowed runoff to permeate through the pores of perlite filter cartridges via filtration. Subsequently, the treated runoff was channeled through an outlet pipe and discharged to the adjacent stream.

2.1.2. Storm Event Sampling

A total of 22 storm events were sampled during the monitoring period from 06/2006 to 10/2008 to evaluate the pollutant removal efficiency of the swirl and filtration system in the treatment of stormwater runoff. Continuous flow measurements were performed and rainfall data collected to obtain a relatively unbiased approximation of the pollutant mass loads. The total sampling time was adjusted to approximate the time during which the “first flush” was processed [10]. Generally, at least 12 samples were manually collected at both the inlet and outlet. Typical water quality parameters were measured, including TSS, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved organic carbon (DOC), TN, TP, heavy metals (zinc, lead, etc.), and oil & grease (O&G). Analyses of these parameters were performed in accordance with standard methods [11].

2.2. Calculations and Data Analyses

2.2.1. Event Mean Concentration

The EMC is an important factor in predicting the total pollutant load, which has made the EMC a critical parameter for estimating the contribution of runoff to receiving waters [12, 13]. The EMC was used to quantify the average pollutant load washed off during a storm event with respect to the event runoff volume. The pollutant loading for a storm event is calculated by the summation of loadings during each sampling period using...