Stormwater Management in Urban Areas of South Korea

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Abstract. In early start of monitoring, a pathway for high runoff volumes and peak flows during rainfall period towards downstream of a waterbody was provided from storm sewer network, but later on it was realized to deal with stormwater quantity and quality to develop new approaches and management techniques. In early 90’s NPS pollution issue was highlighted in Korea, but only limited studies were conceded out up to the year 2000, however reasonably huge numbers of studies were directed for environmental science. After the recognition of NPS, Ministry of Environment in 1998 has introduced NPS as a major contributor in total maximum daily load management system (TPLMS) and waterbodies impairment, which is one of the guidelines of widespread water improvement strategies for main rivers. It contains a number of agendas that intention is to improve, maintain or restore the water quality in national water systems. It can be potted that stormwater management has evolved during the decades as of understanding with its impacts and it has been evolved from focusing on flood control to now incorporating control for volume, erosion and water quality, which is theoretically based on a watershed concept.

1. Introduction

In Korea, many treatment methods and restoration programs improved the water quality; however, according to National Environmental Policy Act of Korea it could not meet the established standards. Stormwater runoff pollution is a complex monitoring system that needs to measure during rainfall as well as in flow conditions. The monitoring of stormwater runoff from pre-during post construction phases have extreme significance in a newly urban development project. The onsite land disturbing activities such as cutting of trees, clearing, digging, and grading can significantly impair and pollute the water quality from stormwater pollution sources such as industrial, forests, agriculture and an uncontrolled and unmanaged construction industry. The management of these activities are difficult due to construction activities but it can be mitigating through good planning and best management practices because its impact on water quality is transient. During development of urbanization, transformation of land from pervious to impervious cover is an essential part but receiving water bodies have significant impact due to increase in anthropogenic activities and rapid urban growth [1].

The increased percentage of impervious surfaces such as roofs and roads by catchment results of urbanization. Subsequently the water quantity and water quality impact was increased during rainfall as illustrated in Figure 1 & Figure 2 [2]. This study provides the descriptions of the processes used to plan and monitor a successful stormwater runoff study from urban development sites. A large scale watershed monitoring such as river basins do not address directly by the approaches and guidelines of
this study but it emphasizes on specific land use variety as a particular place monitoring to reduce the pollution at the source, prevent, and control.

2. Methodology
Monitoring strategy of the study explain five points of why, what, how, when and where to monitor for stormwater source pollution.

2.1 Monitoring plan
A monitoring strategy developed before the start of monitoring project described by monitoring plan. In previous studies, the development and implementation of monitoring study was suggested by a three phase based approach [3]. The scope of specific monitoring study, determination of local monitoring needs and implementation of monitoring study include in three phase-based approach. There are the chances to lose potential for collecting sufficient data for defining the goal and objectives of monitoring project in its first step. In this study, monitoring plan improved every year according to last year monitoring plan considerations during 2011-2013 period.

A baseline monitoring, management facilities performance monitoring and wet weather event based monitoring are three different ways for stormwater study of monitoring types. Baseline monitoring describes to evaluate the impacts level by determine the reference or pristine and quality of background stormwater in receiving waterbodies earlier to following a development project or urban development. The post development monitoring can utilize the data as reference data by conducting baseline monitoring in catchment before the change of land use or construction. The stormwater treatment facilities performance and efficiency evaluated by monitoring of stormwater treatment facility. The management practices perceive and assess the performance level. The detection of any negative impact on pollutant concentrations were conducted in wet and dry conditions, which provided useful information and data evaluation. During runoff producing rainfall events wet weather event monitoring demonstrated the examination and stormwater evaluation. In this case, monitoring, the key objective is to accomplish site-specific land use and hydrological settings of a catchment during and subsequent storm events.

2.2 Monitoring site selection
The visual inspections through regular field visits are a method of determining the monitoring site selection throughout pre-storm and post-storm conditions. During stormwater event the source area for the exposed pollutants were determined. It pacts with erosion, movement of soil, and checking of clear runoff, waste and chemicals that are exposed. During onsite field visits non-visible pollutants cannot be investigated in many cases and so stormwater analysis and sampling is appropriate and important. Descriptive stormwater pollution parameters from single land use evaluated by a specific study sites involve the samples collection to quantify the effects of certain land uses, and to evaluate Best Management Practices performance. A homogenous land cover and drains out sufficient runoff is defined by this type of site includes source area to the stormwater drainage system. It is selected to capture, control, and treat the pollution at the target source based on provided that a system.

The precise study objectives such as if a monitoring study was directed for highway runoff then several features containing normal daily traffic and others were deliberated for selection of representative sites. In addition, the satisfactory data is necessary for statistical analysis provided by monitoring of stormwater events and number of sites [4]. In previous studies, similar criteria were followed as shown in Table 1.

The one of significant aspect in stormwater monitoring strategy is an exact location of sampling site after site selection and watershed has not guideline only regarding spatial features but furthermore in favour within a water body at a known position. The site for sample collection should be recognized where it should signify the total runoff from catchment area and the runoff from the site is discharged towards the receiving stream. The selection of any representative site must follow several considerations but individual local site-specific characteristics were represented from monitoring site [5].
Table 1. Specific examples of source area monitoring applications in previous studies

| Study Objective                                                                 | References |
|--------------------------------------------------------------------------------|------------|
| Study of non-point source pollution in a mixed forest watershed                | [6]        |
| Determine the pollutant loading from roofs                                     | [7]        |
| Pollutant Washoff and Loading from Parking Lots                                | [8]        |
| Characteristics of Stormwater Runoff in Different Land Use Areas               | [9]        |
| Long-Term Monitoring of Infiltration Trench for Nonpoint Source Pollution Control | [10]       |
| Performance of a California Stormwater pond                                    | [11]       |

2.3 Acceptable storm event criteria
The potential features for the selection of specific stormwater sampling and limits the project monitoring in money and personnel, to monitor every storm event described by storm event sampling criteria.

2.3.1 Minimum numbers of events. There is no general defined criterion for determining the number of rainfall runoff events but it depends on statistical evaluation. It should be adequate to provide realistic seasonal variations throughout the year and it should variate in size from low to high rainfall range. In previous studies seven events/year according to US EPA, 12-35 events per application US [12] and 6-8 events/year (north Oakville) were selected.

2.3.2 Antecedent dry period. It defines minimum dry days prior to the storm event. It is directly proportional to the pollutants accumulation and therefore causes more pollution during stormwater event. According to US-EPA with a minimum of 72-hours dry period preceding the storm event is required to monitor.

2.3.3 Stormwater Duration. It defines the adequate runoff duration of stormwater at beginning and end. According to site-specific characteristics consideration this feature mainly depends on rainfall-runoff lag time. For a single site trend characterization, it becomes difficult to estimate the duration of sampling needed. It can vary greatly depending on the purpose of the monitoring program. In previous study, 6 hours minimum stormwater duration was suggested [13].

2.3.4 Rainfall Depth. It is the total depth of rainfall expected to occur over a given time period. It is considered from the period of attention prior to the time of concentration before the last sample being taken. It was observed from literature review that smallest depth is essential to create runoff for appropriate quantity of samples such as 0.15 inches Washington and 0.2mm Francey for urban monitoring sites [13, 14].

2.3.5 Average Rainfall Intensity. The energy supplied and storm event succeeds at the lowest rainfall intensity by pollutant removal from rainfall influences. It depends on site-specific characteristics and study objective.
2.4 Sampling Techniques

This is one of the perilous features in stormwater pollution characterization. In previous studies, two separate strategies have been recommended: time-proportional, time-weighted, or flow weighted or flow-proportional sampling and fixed frequency-sampling strategies. In present work, all monitoring sites considering time and flow throughout the stormwater event was sampled by manual grab sampling. Grab samples are discrete samples. During the stormwater events grab samples can be collected at any time and its flow change. Throughout the storm event the sampling time and the intervals between the samples is of great importance because of flushing and contaminants Washoff features relying on hydrological, site specific and topographical features. Another important aspect of any research is a sufficient number of samples collection and assurance of representative samples. It is suggested that the uncertainty in water quality measurements was reduced by using small sampling intervals.

3. Results

3.1 Monitoring site location

In present study, the criteria for monitoring sites selection was adapted based on pre-development catchment area, initial phase of trees cutting trees; continuous land disturbance activities phase (soil excavation, soil digging, bare land and others) from 1st year to 3rd year of the monitoring period.

First year objective was to monitor stormwater runoff from pre-development and starting phase of under development within same catchment area from Yongin city Korea. Second and third year of the study was involved in monitoring of watershed during continuous land disturbance construction site activities along with other catchment areas to monitor and compare the impact of construction area with other land uses. Figure 1 show all monitoring sites location year wise.

![Figure 1. Monitoring sites location year wise](image)

A specific land use type to a small watershed scale from 2011 to 2013 delivers monitoring sites selection criteria. During construction phase on-site difficulties of diverse flow patterns, unsafe conditions to select catchment area causes the scope of the study was extended and to investigate impact of construction site industry on small-scale watershed catchment.

After site selection, the one of the important aspects in stormwater strategy is exact location of sampling site and instruction not only about spatial features within a watershed but also in concern at a given location inside a water body. The runoff leaves the known catchment without interference of any other site identifies sample collection site. Throughout monitoring period, these locations should be fixed and stable without any alteration or modification in physical drainage pattern. In present work, due to non-stable soil covers, grading, land disturbance activities, digging of soil, excavation and
characteristics of discharge and non-representation of flow construction site location was not similar every year.

During field visits for site location, more than two inlets were found in sedimentation pond. Therefore, it was difficult to select one discharge point as monitoring site location. It is advisable and important to collect discharge of catchment area from one single pipe outlet or drainage channel, therefore multiple inlets from different land disturbing areas should be connected all together to represent as one single discharge point.

Practices during different phases of construction and development work were not exercised which caused polluted runoff entrance to road runoff, soil erosion and direct discharge of runoff to receiving water body without prior control practices as shown in figures. In this study it is suggested to install and fix temporary management practices such as sedimentation trap from small disturbed area, silt fences, storm drain inlets protection, according to land disturbance activities in construction phase.

3.2 Acceptable stormwater criteria
Precipitation is an important feature in stormwater monitoring to select representative events. In this study, it is categorized according to different rainfall classes reviewing past 10 years’ rainfall data (<4mm, 4-10mm 10-30mm, 30-50mm, and >50mm) and therefore minimum of 8 to 10 representative stormwater events was selected. Result findings and literature review reveal that the lowest numbers of stormwater events are essential six times in a year. In case of antecedent dry period, more than one dry day period in 1st year and three or more than that were selected for remaining years. Stormwater duration was followed according to beginning of the runoff till it becomes clear due to unpredicted trend of construction site runoff. In general, minimum of six hours’ duration was fixed because shorter duration can cause insufficient and poor representative samples. Urban site was observed with 1 mm minimum depth of rainfall to the total rainfall event, whereas, rainfall depth >4mm was obtained from stream sites and mix catchment that was monitored for the events. While the requirement for minimum rainfall depth was observed >10mm in case of construction, agriculture, and further pervious sites. Therefore, two different criteria were followed such as at least 1mm rainfall for impermeable cover area and 10mm for pervious area. Similarly, average rainfall intensity was fixed as > 1.5mm/hr for pervious sites and > 0.2mm/hr for impervious sites but it was observed that they depend on total rainfall and site-specific characteristics.

3.3 Stormwater monitoring
Discrete sampling was conducted in this study to reduce the sampling error and capture within storm variability. It is simple to manage therefore recommended to estimate pollutant loads during low flow conditions and small runoff duration. Throughout the stormwater event, manual grab sampling was obtained for all monitoring sites considering flow and time. Sampling methodology and interval time for each monitoring site is described below.

3.3.1 Small catchment. It represents the discharge from two or more land use areas. It can be one outflow to a receiving waterbody or a stream channel. In this type of monitoring site, usually two cases need to be considered: i.e. time-spaced sampling (due to surrounding impervious urban areas) and flow weighted sampling (due to discharge from agriculture, construction and other pervious areas). In this study, average lag time between the start of rainfall and start of runoff was early start of runoff due to urban site impact and peak concentrations were observed with increase in flow rate in later period of runoff for all stormwater events in 2012, 2013 as shown in Figure 2 (a) and (b). Due to surrounding urban land use impact the initial peak concentration was obvious whereas later peak concentration due to runoff flow from concentration site. Moreover, it was perceived after few hours of start time that runoff from pervious areas discharge impact occurred and sustained for limited hours consequently sampling was nonstop till the runoff becomes clear and clean and also the flow in runoff is reduced.
3.3.2 Construction site. Due to devegetated ground land, deposition, infiltration, and soil disturbance activities the average lag time between the start of rainfall and start of runoff was observed more than 3 hours. The peak flow rate was preceded by the peak concentration but in the year 2012 it was not correlated and it was correlated in the year 2013. It occurs due to phase construction and drainage pattern activities changed very much.

The stormwater events with no base flow conditions resulted occurrence of peak pollutants concentration within 2 hours of initial runoff in the year 2012 as shown in pollutograph, therefore time spaced technique in 1st part of runoff can be considered, whereas, results with base flow conditions in 2013 showed peak concentration in the later period of rainfall event and flow spaced technique can be considered in overall event as shown in Figure 3 (a) & (b).

3.3.3 Urban Site. Urban area delivers the discharge for this site. Average lag time was less than 30 minutes of rainfall between the start of rainfall and start of runoff. Due to high imperviousness and urban land use impact early flushing peak concentration was observed as shown in Figure 4 (a) & (b).

So, it is important to capture initial stormwater runoff sampling and hence it is considered by time weighted sampling. Pollutants concentration trend was decreased slowly and consequently quantity of samples can be decreased in middle and later period of storm event.
Figure 4. (a) Discharge from urban area 2012  
(b) Discharge from urban area 2013

4. Conclusions
The two major runoff effects including stormwater quantity and quality by urban expansion leads in change from natural land and pervious cover to impervious cover and unnatural land. In addition, it increases peak flow and runoff volumes within the watershed; globally it is a common aspect of urban development. This study summarizes the understanding of stormwater monitoring plan, sampling strategies and techniques, determining the trends for problem parameters and evaluating the hydro-pollutograph trend according to site-specific conditions. This research provides better understanding of temporal variability for hydrological and water quality variables during inter-intra storm events.

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