

Evaluation of stormwater BMPs for implementing industrial stormwater permitting strategy

M.-H. Park, I. K. Ridgeway, X. Swamikannu and M. K. Stenstrom

ABSTRACT

This study assesses the performance of stormwater best management practices (BMPs) in industrial sectors and their effluent quality to facilitate the development of technology-based numerical effluent criteria. Generally, retention ponds outperform other BMP types for reducing total suspended solids, and media filter and wetland basins outperform other BMPs for metal removal. Detention basins were not effective in reducing stormwater pollution although they can retain the stormwater before entering surface waters. However, many BMPs show high variability of influent and effluent concentrations and no significant difference between them, which makes it difficult to determine the effectiveness of the BMP. In some cases, low influent concentrations govern the distribution of effluent concentrations and effluent concentrations are often greater than inflow concentrations. The analysis results can be used to assist in the developing a watershed based multisector industrial stormwater general permit to ensure compliance with total maximum daily loads. The results also suggest the need for additional monitoring data.

Key words | BMP, effluent concentration, industrial stormwater, numerical criteria

M.-H. (corresponding author)
Department of Civil and Environmental
Engineering,
University of Massachusetts Amherst,
USA
E-mail: mpark@ecs.umass.edu

I. K. Ridgeway
X. Swamikannu
California Environmental Protection Agency,
Regional Water Quality Control Board,
USA

M. K. Stenstrom
Department of Civil and Environmental
Engineering,
University of California,
Los Angeles,
USA

INTRODUCTION

The current United States Environmental Protection Agency (USEPA) industrial stormwater general permits have limited capability to ensure that best management practices (BMPs) being implemented at industrial facilities reduce stormwater pollution, and that they will be technologically optimized to protect water quality. In practice, these permits promote the use of USEPA benchmarks either for triggering changes in monitoring activity or as a self-evaluation tool. Significantly, the associated stormwater monitoring programs, an essential component of any NPDES permit, have been ineffective and have been of little utility in demonstrating compliance (Lee & Stenstrom 2005). While the multisector permitting approach may have been a first step before advancing to strategies to obtain environmental results, few alternative strategies have been explored since the USEPA's adoption of the Final Rule in 1990 (55 Fed Reg.122). The Los Angeles Regional Water Board (LARWB) adopted metal Total Maximum Daily

Loads (TMDLs) and waste load allocations (WLAs) for industrial stormwater discharges to the Ballona Creek and Los Angeles River Watersheds in June 2005 (LARWQCB and USEPA 2005). This action offers the opportunity to explore an innovative approach to stormwater permitting.

Research performed since 1990 has identified a number of principles and data that can be used to better quantify BMP performance. The behavior of pollutant wash-off from impervious surfaces, essential for improving monitoring programs, have been identified for highways in California (Kim *et al.* 2005). The concept of first flush, which results in an initial high rate of pollutant discharge is now better understood and may transport 40 to 50% of the pollutant mass in the first 20% of the runoff volume (Han *et al.* 2006). The assumption that pollutants are transported on the surface of particles has been validated with several new studies (Pitt *et al.* 1995; Lau & Stenstrom 2005), which makes the performance of BMPs for particle removal more

critical. Particle size distribution (PSD) changes with time as particles aggregate but current recommendations for monitoring particles in stormwater runoff are not practical (Kayhanian 2006). Most design criteria for BMPs do not use PSD information, since it has generally been unavailable, and rely on retention time concepts or filtration rates. This requires that BMPs be selected on suboptimal criteria or by duplicating previous examples cited in case studies.

Biomonitoring is a useful technique to ascertain impacts on receiving waters and possible mitigation of the impacts with BMPs. Biomonitoring adds complexity and expense to a monitoring program but can have additional benefits. For example, Bay *et al.* (1996) and Kayhanian *et al.* (2008) both showed that heavy metals in highway and stormwater runoff had the greatest toxic impact on receiving waters.

It is, therefore, necessary to facilitate the development of technology-based numerical effluent criteria, and an associated monitoring program to verify compliance. This requires identifying the lowest, practical concentrations achievable, which is critical for complying with TMDLs for metals and other pollutants. The objective of this study is to assess the performance of those BMPs to treat stormwater in industrial sectors, which are capable of producing consistent effluent quality with a high level of confidence. The technical information will be then used to assist in the developing a watershed based multisector industrial stormwater general permit to ensure eventual compliance with water quality based standards for metals and other pollutants. We will identify best available technology that can be used for a watershed based general permitting strategy.

MATERIALS AND METHODS

The characteristics of stormwater from industrial sectors and other land uses in Southern California have been analyzed using existing literature and data. The rainfall, runoff coefficient and event mean concentration (EMC) data were obtained from the County of Los Angeles Department of Public Works (LADPW) and annual average pollutant loads from Ballona Creek watershed were estimated. In early 1990s, Stenstrom & Strecker (1993) developed EMC datasets for seven land uses based upon the analysis of all previously collected data for the Santa

Monica Bay Watershed. Certain pollutant parameters were collected to have sufficient data to estimate their EMCs and these were compared to the nationwide urban runoff program (NURP) data, corresponding to the 90th percentile in most cases. The remaining parameters were assumed to also correspond to the 90th percentile of NURP data. LADPW collected data using both grab samples during the initial portion of the storm and flow composite samples using an automated sampler from eight land use monitoring sites throughout the County during 1994–2000 (LADPW 2000). The pollution concentrations from industrial and commercial sectors in Los Angeles region were compared to national monitoring data: NURP and National Stormwater Quality Database (NSQD) (Pitt & Maestre 2005).

Existing BMP databases are assembled to provide a broader dataset for better selection and a comprehensive summary. The datasets include the ASCE International Stormwater BMP Database, USEPA national BMP database, and Caltrans BMP Retrofit pilot study database. In this study, the ASCE international stormwater BMP database (www.bmpdatabase.org) was used to evaluate the performance of different BMP types for stormwater runoff from commercial facilities and industrial sectors because other databases do not provide land use information associated with the BMP types or contain the data only for particular land use other than industrial sectors. It is difficult to evaluate the performance of BMPs for individual commercial and industrial types because it was not provided in the BMP databases. In the ASCE international stormwater BMP database, all BMPs were categorized into selected BMPs and therefore, the same categories were used here: biofilter, media filter, detention basin, retention pond, wetland basin and hydrodynamic devices.

We calculated statistical sets of each BMP for the median and upper and lower quartiles of inflow and outflow concentrations. The assessment provides a statistical measure of pollutant removal by a BMP. Selected stormwater pollution constituents are evaluated: total suspended solids (TSS) and metals because these constituents were one of the most widely reported constituents. Other stormwater pollution parameters were analyzed but not presented here because not all the BMP performance data are available in the International Stormwater BMP Database.

RESULTS

Stormwater characteristics from industrial sectors

Generally, stormwater pollution concentrations from commercial and industrial sectors were higher than those from other land uses. The analysis results show that approximately 30–50% of metal loads in a watershed were generated from industrial and commercial sectors although the size of these areas is only 14% of the entire watershed. Therefore stormwater pollutant loads are not a simple function of land area.

The national stormwater pollution data analysis indicates that stormwater pollution concentrations have declined since the 1980s because the EMC values in NSQD datasets were lower than those values in the NURP datasets that were collected almost 20 years before NSQD datasets, and is confirmed in this work. Previous results (Wong *et al.* 1997) show that EMCs in Los Angeles region were higher by 1.5 to 3.2 times than the national average, except for total lead as shown in Figure 1. More recent EMCs in Los Angeles region monitored by LADPW were clearly lower than the 90th percentile NURP EMCs by Stenstrom & Strecker (1993), and were even lower than mean NURP EMCs, except for zinc, but greater than NSQD EMCs.

Commercial and industrial land uses generated greater zinc EMCs in early 1990s while these land uses generated greater TSS, copper and zinc EMCs in later periods. Especially the lead EMCs measured in the Los Angeles region have been reduced, corresponding to only 3 to 54% of the NSQD EMCs on average for each land use, which probably results from genuine pollutant source reductions, since California was among the first to convert from leaded gasoline (required for new cars in 1976, banned in CA in 1992 vs. nationwide in 1996).

It was, however, difficult to distinguish stormwater quality of industrial sectors from Standard Industrial Classification (SIC) code using the current water-quality parameters (Lee & Stenstrom, 2005). Our previous study also shows that the industrial stormwater general permit (ISGP) data for Los Angeles County have the highest coefficient of variation among the various water data (Lee *et al.* 2007) as shown in Figure 2.

BMP performance in industrial sectors

Each BMP type shows high variation of influent and effluent concentrations and sometimes no significant difference between influent and effluent mean concentrations,

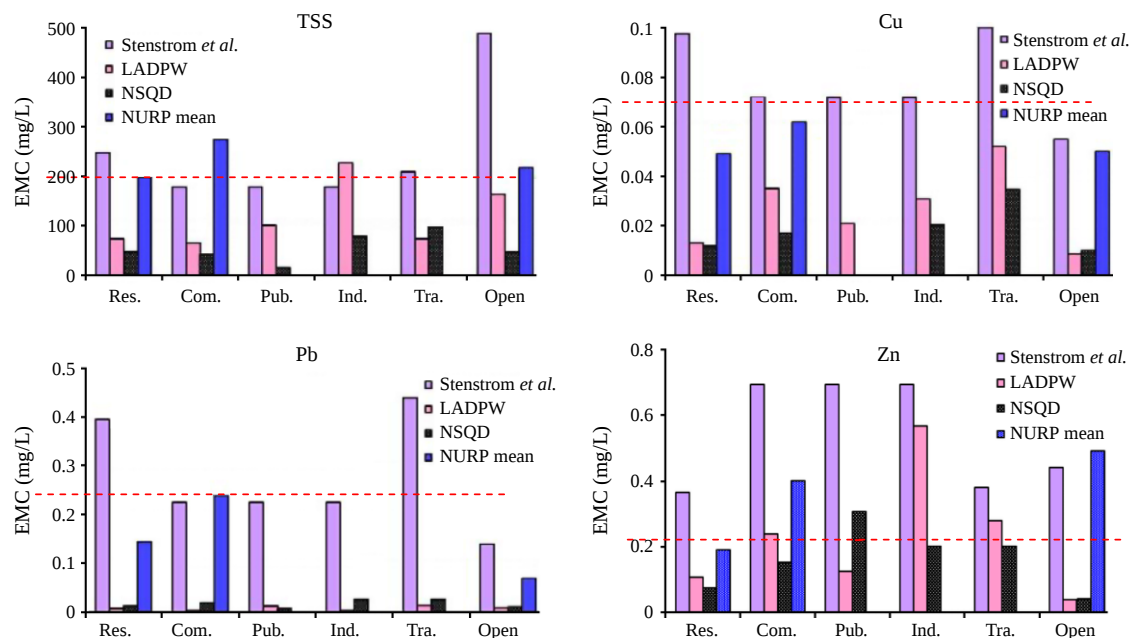


Figure 1 | Comparison of EMCs for each land use (red dashed lines show urban mean EMCs in NURP dataset).

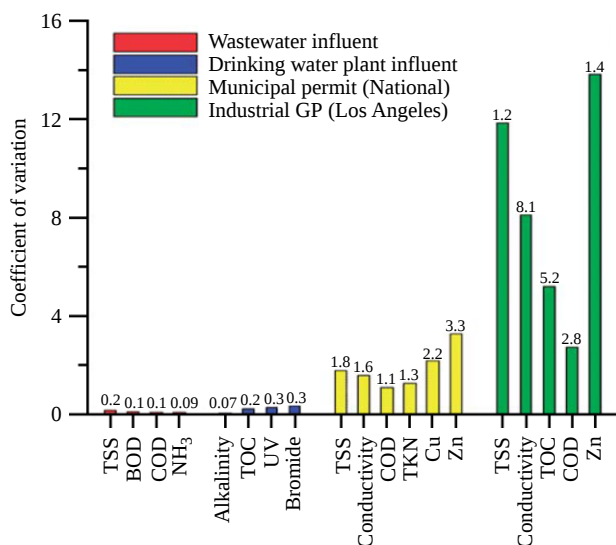


Figure 2 | Coefficient of variation in various water sampling programs for a large waste water treatment plant, a drinking water treatment plant, and two stormwater monitoring programs, illustrating the different variation (from Lee *et al.* 2007).

which makes it difficult to determine the effectiveness of the BMP with any certainty. In some cases, low influent concentrations govern the distribution of effluent values and effluent concentrations often greater than influent concentrations. Moreover, it was difficult to evaluate the performance of BMPs for individual industrial types because they were not provided in the BMP databases.

USEPA does not provide numeric water quality criterion for TSS but many NPDES construction dewatering and wastewater permits identify 30 mg/L as the average permissible TSS concentration (Geosyntec 2008). Figure 3(a) shows that median outflow concentrations from many BMPs in commercial facilities and industrial sectors were above 30 mg/L. For BMPs treating stormwater runoff from commercial facilities, the outflow concentrations from retention ponds were below 30 mg/L although the inflow concentrations were very high with median concentrations of 117 mg/L. Hydrodynamic devices also showed high removal of TSS. Median outflow concentrations from these two BMPs complied with the NPDES permits. Conversely media filters and detention basins exhibited greater outflow concentrations than inflow concentrations with higher variation. For BMPs for industrial sectors, the outflow concentrations from wetland basins complied with the

NPDES permits regardless of inflow concentrations but the other BMPs did not comply with the permits. Media filters and retention ponds also show reduced outflow concentrations compared to their high inflow concentrations. However, the outflow concentrations of detention basins increased compared to their inflow concentrations. For both cases, retention ponds were the most frequently reported BMPs in the database and the most effective to treat TSS. Wetland basins as well as hydrodynamic devices would be effective BMPs for treating TSS. The range of outflow from retention ponds and wetland basins can be used for establishing conservative permissible criteria for TSS: up to 26 mg/L and up to 27 mg/L for commercial facilities and industrial sectors, respectively.

The seemingly low efficiency of some BMPs relates to the form of the metals. Metals mostly associated with the particulate phase can be removed by sedimentation and filtration type BMPs. Soluble metals are only removed by precipitation or sorption onto solids, which may not have time to occur in most BMPs (Kang *et al.* 2007). Copper, lead and zinc are the most frequently reported metal constituents in the BMP database. Although the numerical criteria for stormwater from commercial and industrial stormwater have not been established, the USEPA established the California Toxics Rule (CTR) to for inland surface waters in California. The criteria include both chronic (4 day average concentration) and acute (1 hour short-term concentration) limits for freshwater and saltwater as shown in Table 1.

Using one-hour short-term concentrations is especially difficult for stormwater monitoring, due to its high variability, and inability to monitor so frequently. Using grab samples, even for detecting 1-hour peaks, is especially difficult (Ma *et al.* 2009).

Most of the BMPs showed reduced outflow concentrations of copper although they did not meet the CTR criteria except media filters for commercial facilities (Figure 3(b)). However, hydrodynamic devices and detention basins showed increased outflow concentrations of copper compared to their inflow concentrations in commercial and industrial sectors, respectively. Media filters and wetland basins would be effective BMP to treat copper with lower variation for commercial facilities and industrial sectors, respectively. Based on these results, conservative permissible criteria for copper can be

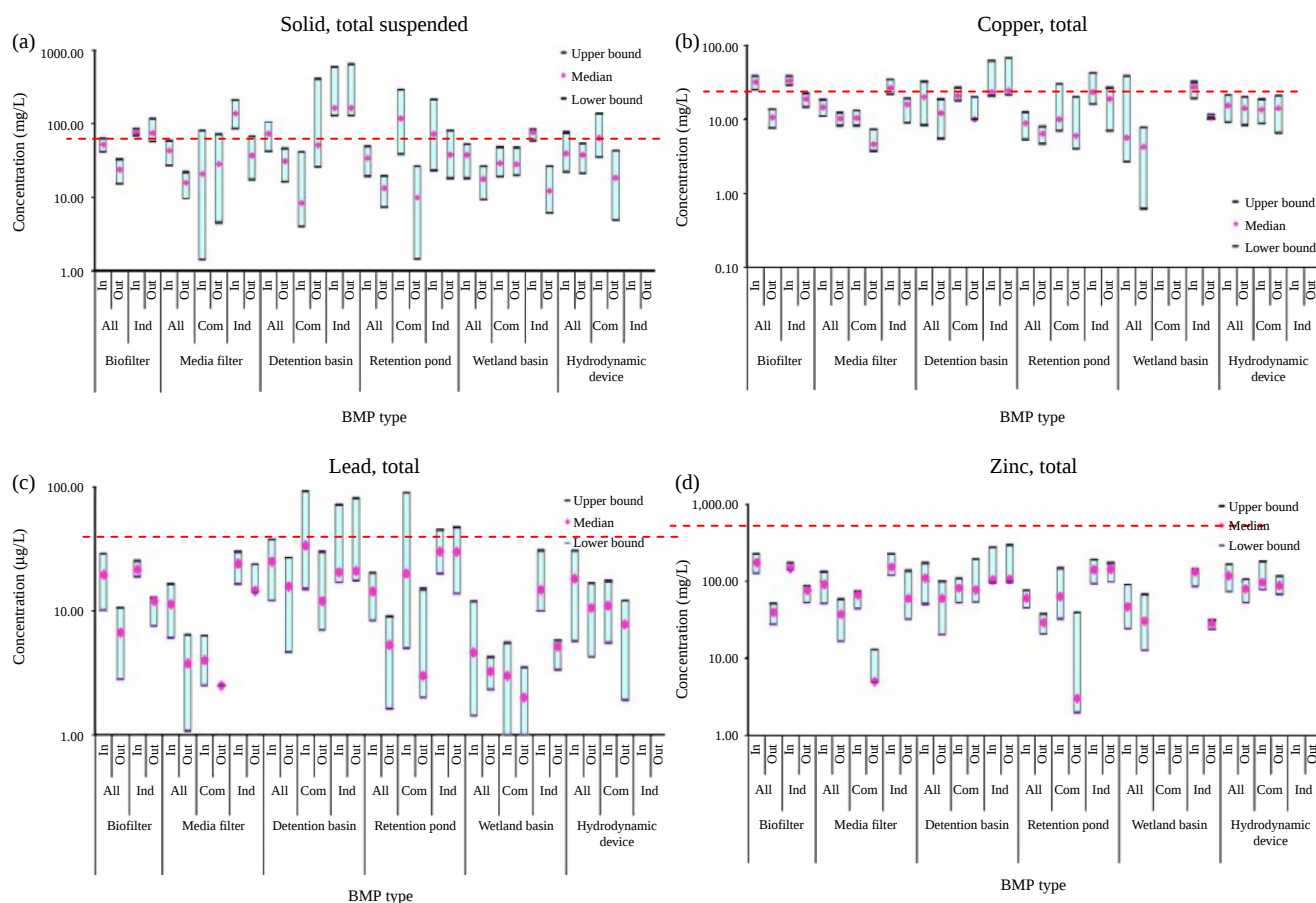


Figure 3 | Influent and effluent pollution concentrations for each BMP (top red dashed lines show NPDES permit limits, lower dashed lines show CTR chronic toxicity limits).

established: up to 7 ng/L and 12 Hg/L for commercial facilities and industrial sectors, respectively.

The outflow concentrations of lead from all reported BMPs were reduced although most of them did not often meet the CTR criteria (Figure 3(c)). Especially media filters and wetland basins would be effective in removing lead from commercial and industrial stormwater, respectively. The range of outflow from these BMPs can be used for establishing conservative permissible criteria for lead: up to 3 ng/L and 6 ng/L for commercial facilities and industrial sectors, respectively.

Many of the reported BMPs to treat zinc showed lower outflow concentration distribution and complied with CTR criteria (Figure 3(d)). But detention basins showed higher outflow concentrations for both commercial and industrial stormwater, and retention ponds also showed higher outflow concentrations for industrial stormwater. Media filters and wetland basins would be effective BMPs

for treating zinc from commercial and industrial stormwater with low variation. The results can be used for establishing conservative permissible criteria for zinc: up to 13 µg/L and 32 µg/L for commercial facilities and industrial sectors, respectively.

Generally, retention ponds were most frequently reported but not necessarily the most effective BMPs for treating metals. Media filter and wetland basins appeared

Table 1 | California Toxics Rule criteria for freshwater (µg/L)

Parameter	Acute limit	Chronic limit
Copper	13	9.0
Lead	65	2.5
Zinc	120	120

Note: from http://www.calwater.ca.gov/Admin_Record/C-036947.pdf

to be most effective in removing metals for commercial facilities and industrial sectors. Conversely, detention basins and hydrodynamic devices often showed higher outflow concentration distributions than inflow concentrations. However, the performance of these BMPs was not reported for some constituents and therefore it is necessary to collect more data for these BMPs to understand their effectiveness.

CONCLUSIONS

Stormwater pollution concentrations from commercial and industrial sectors are generally higher than those from other land uses. In Los Angeles, stormwater pollution concentrations have been reduced for the last two decades, but the EMCs of industrial and commercial land uses are still much higher than national mean values. Therefore, it will be effective and efficient to regulate and control stormwater runoff from small area of commercial and industrial land use in order to achieve significant reduction of stormwater pollutant loadings.

It is useful to perform statistical analysis of existing BMP performance in order to set permits for stormwater pollution from commercial facilities and industrial sectors. The use of median concentration and upper and lower quartiles would provide conservative permissible criteria. However, the variation of stormwater quality and BMP performance is so large that in most cases the untreated and treated stormwater qualities are not statistically different. The application of expensive BMPs might not produce observable differences in water quality although pollutants are obviously reduced by BMPs. Our results emphasize the need for improved monitoring and performance data to reduce the uncertainty of water quality and BMP performance estimates.

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