Achieving Industrial Stormwater Regulatory Concentrations: Filtration, Sedimentation, and Treatment Train Systems

Atteindre les concentrations réglementaires d'eaux pluviales industrielles : filtration, décantation et enchainement d'ouvrages

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RÉSUMÉ

Aux États-Unis, les autorisations de rejet d'eaux pluviales industrielles exigent souvent que les rejets d'eaux pluviales des sites répondent à des critères numériques spécifiques - soit des valeurs de référence, soit des lignes directrices sur les limites des effluents. Cette recherche est axée sur l'évaluation de la décantation, de la filtration et de la combinaison des deux dans des chaînes de traitement pour déterminer leur capacité d'atteindre ces valeurs de référence. Le présent article s'intéresse particulièrement aux sédiments en suspension et au zinc, deux polluants courants dans le ruissellement industriel. Les résultats ont montré que certains systèmes de décantation et de filtration ont été en mesure de respecter les valeurs de référence. Toutefois, tous les systèmes évalués dans chaque catégorie de procédé unitaire n'ont pas été en mesure de satisfaire aux valeurs de référence, ce qui indique qu'il existe des facteurs de conception qui peuvent contribuer au succès d'un dispositif et non d'un autre. Dans le cas des sédiments en suspension, les systèmes de décantation ayant des taux de déversement en surface plus faibles ont réussi à atteindre les concentrations de référence pour la plupart des tempêtes. Dans le cas du zinc, deux systèmes de filtration à base de mélanges de substances inconnues ont permis d'assurer un traitement uniforme du zinc afin d'atteindre le niveau de référence pour l'eau dure, et un autre système a aussi permis d'atteindre celui pour l'eau douce dans la plupart des épisodes pluviaux. Les chaînes de traitement où le prétraitement par décantation était suivi d'une filtration lente à l'aide d'un mélange tourbe-sable ont donné les meilleurs résultats pour traiter à la fois les sédiments en suspension et le zinc.

ABSTRACT

In the United States, industrial stormwater discharge permits often require site stormwater discharges to meet specific numeric criteria – either benchmarks or effluent limit guidelines. This research focuses on evaluating sedimentation, filtration, and the combination of the two into treatment trains for their ability to meet these benchmarks, with this paper focusing on suspended sediment and zinc removals, two common pollutants in industrial runoff. The results showed that representatives of sedimentation and filtration systems were able to meet the benchmarks. However, not all systems evaluated in each unit process category was able to meet the benchmarks, indicating that there are design factors that may make one device successful and not another one. For suspended sediment, sedimentation systems with lower surface overflow rates were able to meet benchmark concentrations for most storms. For zinc, two filtration systems of unknown proprietary media mixes provided consistent treatment of zinc to meet the hard-water benchmark, while one was also able to meet the soft-water benchmark for most storm events. Treatment trains where pre-treatment using sedimentation was followed by slow filtration using a peat-sand mixture provided the most consistent results for treating both suspended sediment and zinc.

KEYWORDS

Benchmarks, filtration, industrial stormwater, sedimentation, treatment train

1 BACKGROUND

1.1 Exposure to Stormwater

Many large industrial sites have operations and equipment that are impacted by rainfall directly onto the site. For example, maintenance yards often park large equipment outside which may leak hydraulic oil that is transported in the stormwater runoff. In shipyards, much of the paint removal and repainting is done outdoors, resulting in potential pollutants entering the runoff. Auto salvage yards often crush cars and stack the cars outside until they are shipped to a processor/shredder, exposing a wide variety of metals and organic compounds to the rainfall.

1.2 US EPA Benchmarks and Effluent Limit Guidelines

In the United States, industrial stormwater dischargers are classified by sector based on the types of activities that the businesses engage in. Certain sectors, because of their potential to generate stormwater pollutants, are required to monitor their stormwater discharges four times per year in the initial year of the permit cycle and if the permit concentrations for specific pollutants are met, the discharger may suspend monitoring. If the permit concentrations are not met, the discharger must improve their stormwater pollution prevention program (SWPPP), potentially including the installation of stormwater control measures (SCMs). Once the SWPP has been improved, quarterly monitoring continues until the benchmarks are met.

SCMs that are typically adopted on industrial sites are based on either sedimentation, filtration, or a serial combination of the two in a treatment train. Many of these devices are proprietary (manufactured and sold by a company, with minimal disclosure of technical features). For example, several vendors will customize a filtration media for a company that is designed to remove the pollutants on the permit to below allowable discharge concentrations, but may not disclose the media components.

2 RESEARCH METHODS

2.1 Industrial Sectors

Performance data for several SCMs were collected over multiple research projects in various industrial settings. The industrial sectors evaluated included shipyard/boat repair, scrap recycling, and transportation/maintenance facilities.

2.2 Pollutants Evaluated

The sites that were selected incorporated a wide range of treatment systems, including proprietary designs and chemical mixtures to site-built ponds and filters. Details on the treatment systems and the types of activities that could be generating stormwater pollutants to the treatment system can be found in Clark and Pitt (2019, in press).

While these projects evaluated many pollutants, including sediment, nutrients, and heavy metals, this paper will focus only on two pollutants – total suspended solids (TSS) and total zinc (Zn). TSS analyses are required of most sectors that perform benchmark monitoring. Sediment performance also is an indication of the removal ability of pollutants that primarily partition to solids, such as lead. Zinc was selected for this paper because it often does not partition primarily to suspended sediment, but may instead be “dissolved” (present in ionic forms) or bound to organic or inorganic ligands and colloidal matter that does not settle.

Statistical evaluation of the system’s performance can be found in Clark and Pitt (2019, in press).

3 RESULTS AND DISCUSSION

3.1 Suspended Solids

Figure 1 highlights the results for suspended solids, comparing the performance of sedimentation-only (left), filtration-only (center), and treatment train SCMs (right). The scatterplots compare the performance of each device to a 1:1 line of no removal and no scour. For the sedimentation devices, HDS1 and Pond 1 consistently provided TSS removal and most effluents were below the 100 mg/L benchmark. Both of these systems were sized for higher flow rates than occurred during field testing. The pond was 4.8% of the watershed area and the average flow rate through HDS1 was only 10 – 25% of the rated flow rate of the device, resulting in lower surface overflow rates (SORs) compared to the other sedimentation systems. Lower SORs resulted in the settling of smaller particles and the reduction of TSS loadings.

For filtration systems, most systems were able to meet the benchmark of 100 mg/L in the effluent concentration. However, the limitation of this study was that few of the filtration systems had influent concentrations that exceeded 100 mg/L. Filter F5 was the only filter with most of the influents exceeding 100 mg/L which was able reduce the effluent to below 100 mg/L. The greatest percent removals were seen by filters F3 and F6 (furthest away from the 1:1 line). Treatment trains produced the most consistent effluent quality, especially treatment trains TT1, TT2, and TT3. TT1 and TT2 are inclined plate sedimentation units followed by slow mixed-media filters. TT3 incorporates rapid sedimentation followed by rapid filtration. TT3's performance, in terms of percent removal was less than TT1 and TT2, indicating the benefits of slow filtration on the removal of suspended sediment.

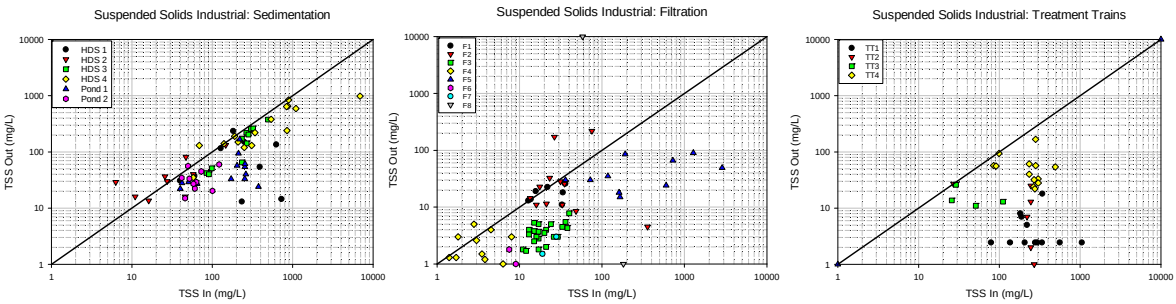

Figure 1. TSS removal in sedimentation (left), filtration (center), and treatment train (right) SCMs

3.2 Zinc

Figure 2 highlights the ability of sedimentation, filtration, and treatment train systems to remove total zinc from the industrial runoff. Zinc benchmarks are based on the hardness of the receiving water with lower benchmarks for softer water. If the receiving water hardness is 50 mg/L, the benchmark is 80 µg/L Zn. For a receiving-water hardness of 200 mg/L, the benchmark is 230 µg/L Zn.

For sedimentation, few of the devices demonstrated consistent removal; only HDS1 and Pond 2 had consistent zinc removals that were substantially different from the 1:1 line. As noted for the suspended sediment removal, HDS1 was the device with the lowest surface overflow rate. Pond 2, however, was the smaller of the two dry detention ponds studied in this project, indicating that size did not improve zinc removal. This could result from zinc associating with larger particles at that site which then settle rapidly, although this cannot be documented with the available data. For both devices, however, effluent quality never met the soft water benchmark of 80 µg/L. They only met the hard water benchmark for approximately 25 – 50% of the monitored events. For filtration systems, most filters, except for F2, were able to consistently demonstrate zinc removal. When comparing the effluent quality to the benchmarks, F3, F5, and F7 consistently met the hard-water benchmarks for >75% of the storm events monitored. Only F7 was able to meet the soft water benchmark for most of the storm events. Treatment trains TT1, TT2, and TT3 were able to remove zinc from the influent water and meet the hard-water benchmarks for all storm events. Only TT1 and TT2 were able to meet the soft-water benchmark. The media in these treatment trains were peat, which has a high affinity for zinc, mixed with sand for hydraulic function.

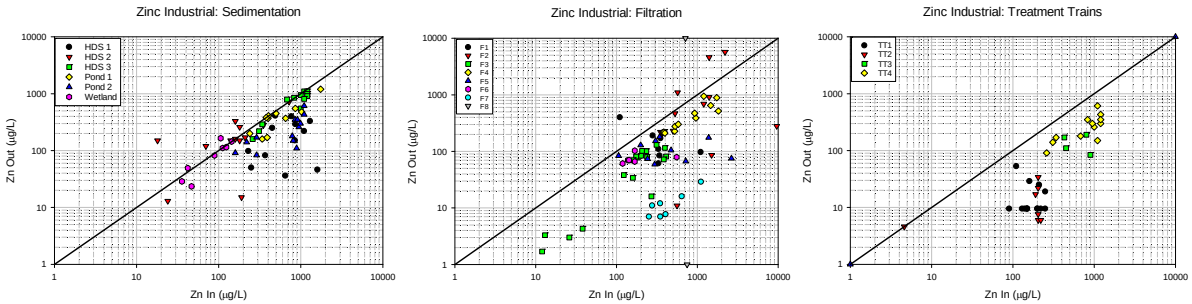

Figure 2. TSS removal in sedimentation (left), filtration (center), and treatment train (right) SCMs

4 CONCLUSIONS

The need to meet benchmark concentrations imposes an additional requirement for stormwater treatment that is not found in treating municipal runoff. While the requirement, if a site does not meet benchmark concentrations, is only to re-evaluate and improve the SWPPP, this often requires the addition of structural SCMs. Therefore, it is important that the treatment performance of these devices is evaluated.

These results showed that sedimentation devices with smaller SORs resulted in improved suspended sediment removal and increased likelihood of meeting the benchmarks. However, this was not seen with zinc removal where the smaller pond with the higher SOR also had the higher percentage of zinc removal and more storm events where the benchmark was met. Filter F5, an unknown proprietary media mixture, was able to consistently reduce suspended sediment concentrations to below benchmarks and was able to meet the hard-water benchmark for zinc for >75% of the storm events monitored. Filter F7, also a proprietary media mix, provided excellent removal for suspended sediment; however, the performance compared to the benchmark could not occur because all influent concentrations were lower than the benchmark. F7 consistently removed zinc to below the benchmarks. Information on the composition of the media in F5 and F7 could provide additional insight on the operating conditions required to meet these benchmarks.

Treatment trains that combined sedimentation followed by filtration consistently performed well for both suspended sediment and zinc. The treatment trains that performed best had initial treatment of sedimentation using inclined tube settlers, which resulted in low SORs, followed by peat-sand filters. The flow rate through these filters was in the ranges suggested for slow sand filters used in water and wastewater treatment. The treatment train with rapid sedimentation followed by rapid filtration was able to meet benchmarks for many of the storm events, but the performance (based on percent removal) was poorer than the treatment trains with inclined tubes and slow peat-sand filters. These results show that lower SORs in sedimentation devices, especially when combined with slow filtration rates through a mixed media that combines an organic adsorbent with sand, can result in consistent effluent quality that meets the benchmarks for suspended sediment and zinc.

LIST OF REFERENCES

“Industrial stormwater: Sedimentation and filtration effectiveness to meet benchmark concentrations.” S.E. Clark and R. Pitt. *Journal of Sustainable Water in the Built Environment*. Accepted for publication, March 5, 2019.