

PAPER • OPEN ACCESS

Evaluation of particle removal efficiency in sedimentation tank incorporating bottom grid structure

To cite this article: M.F. Chow *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **551** 012011

View the [article online](#) for updates and enhancements.

Evaluation of particle removal efficiency in sedimentation tank incorporating bottom grid structure

M.F. Chow¹, A. S. Ruzaiman², F. A. Rashid² and S.T. Chong³

¹Sustainable Technology and Environment Group (STEG), Institute of Energy Infrastructure (IEI), Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, 43000, Kajang, Selangor.

²Department of Civil Engineering, Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, 43000, Kajang, Selangor.

³College of Engineering, Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, 43000, Kajang, Selangor.

Abstract. A series of comparative experiments, with and without BGS, were carried out in a 2m x 1m x 1m tank. Samples used were taken from highway runoff and the BGS tested was in 1.3cm x 1.5 cm size. The experimental results indicated that the particle removal efficiencies with the application of BGS were about 6% higher than when tested without the BGS for flow rates ranges from 0.2 l/s to 0.5 l/s. SPLIT was developed in the laboratory to test the effectiveness of the system to retain and treat stormwater particles. A series of experiments were conducted with different inflow rates and particle concentrations. The results showed that SPLIT system was able to remove >80% of the particles (measured as TSS concentration) from the laboratory-simulated stormwater runoff. The particle size analysis also demonstrated that reductions in the d₅₀ of the samples in the laboratory testing from 300 µm (influent) to approximately 50 µm (effluent). Reduction in other pollutants that associate with particles is depending on their concentration association by particle size. The laboratory testing results had proved that SPLIT system was able to retain and remove the particles and pollutants effectively under various inflow rates.

1. Introduction

Urban stormwater runoff carries large loads of particles that are considered a major pollutant with deleterious effects on receiving water bodies [1-3]. Particles washed-off from paved areas contain various sorbed pollutants, and much of the pollutant load associated with stormwater runoff is carried by sediment. These sediment and sediment-associated contaminants are a substantial cause of degradation to receiving waters with associated toxic effects to aquatic organisms [4, 5]. Various treatment methods have been introduced to remove the suspended and colloidal particles, such as detention basins, sedimentation tanks, ponds, wetlands, biofiltration, such as grassy swales and strips, vortex or swirl concentrators, slow sand filters, multi chambered treatment trains and silt traps [6]. Removal of these sediments can therefore result in the removal of a large portion of associated pollutants. The sediments and associated pollutants captured in the pretreatment devices can be removed for disposal during maintenance operations. Sediment removal efficiency of tanks is one of the most informative parameters for measuring the treatment efficiency performance of such facilities, and it is affected by many factors such as influent pollutant concentrations, runoff magnitude, particle size, settling velocity and facility size. Removal efficiency is usually greater for higher influent pollutant concentrations. Because pollutant concentrations tend to decrease as runoff progresses, enhancing initial runoff (i.e., first flush) treatment can improve overall performance of a treatment facility [7-9].

The lack and/or cost of the land dictate that retention ponds are generally small. With short retention times and high inflow rates, it is challenging to obtain high removal efficiencies by gravity settling only, because of large undesirable disturbances by inflow generated turbulence. Turbulence, eddies and diffusion will re-suspend and move the particles back up into the water column. The efficiency of discrete particle settling can be improved by increasing the contact area between the particles and the settling basin surface by inserting lamella plates or settler tubes of different shapes [10,11]. Potential challenges in applying lamellar



plate technology to enhancing particle settling in open-water bodies, such as stormwater ponds, are the needs to prevent sediment resuspension and clean out the settled particles. Thus, it is necessary to develop a new technology enhancing the removal efficiency of solids under high inflow rates and reducing scouring of settled particles. In gravity settling processes, turbulence is generally considered as an adverse factor disturbing particle settling and causing sediment resuspension. Past studies have shown that near the boundary vertical vortices would increase suspended particle flux toward the boundary, but a critical issue remains: how to practically generate controlled vortices serving to enhance sedimentation and keep the approaching particles stay on the boundary (bottom bed) without resuspension.

In order to improve the efficiencies of the sedimentation tank, the issues are explored by introducing a bottom grid structure (BGS) which is designed to convey the trapped particles into a protected location and a number of baffles are generated to scatter the kinetic energy of incoming flow. This paper is aimed to determine the efficiency of particle removal in sedimentation tank with and without the presence of proposed BGS.

2. Methodology

2.1 Sediment Particle & Litter Interceptor Tank (SPLIT)

The sedimentation tank (SPLIT) proposed in this study has a dimension of 2m (length) x 1m (width) x 1m (depth) as shown in the Figure 1. The SPLIT system comprises an inlet pipe, a circular sedimentation tank with a bottom grid structure, two settling chambers, two separators and an outlet pipe, wherein the circular tank (2) with bottom grid structure (3) at the bottom layer above the collecting cone (4), in which the circular tank is connected with an inlet pipe (1) and having an overflow opening (5), the two settling chambers (6) with bottom grid structures are separated by two baffle walls (7) in between, and the last settling chamber having an outlet pipe (8) to discharge the water.

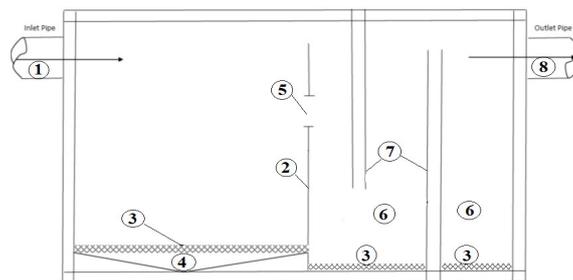


Figure 1. Side view of SPLIT system.

2.2 Laboratory experiment

A schematic diagram of the experimental setup is shown in Figure 2. During experiments, particles will be released from top of the inlet pipe, about 40 cm upstream of the settling tank inlet mouth. In such an arrangement, particles should be well mixed by the incoming fast turbulent flows. After passing through the settling tank, the flow exited through a 0.5 (W) × 0.1-m (D) opening located at the far end of the tank at 0.7 m above the tank bed. Before returning the flow into a large water supply tank, it was filtered through a 63- μm fine screen to prevent particles from returning into the circulation system. The flow was then pumped back to the settling tank via a 51-mm pipe. Between the pump and the inlet, a flow meter and a control valve will be installed, the latter serving to regulate flow rates. The particle samples will be sorted using sieves with mesh sizes of 300, 212, 150, 75, and 63 μm . Any particles smaller than 50 μm will be discarded to prevent the risk of their passing through the capture mesh. The sieved particles will then mixed together again with the weight ratio of 0.2 each. In general, the total 200g sample was used in each experiment, which would meet the experimental design for injecting particles continually for 10 min. The duration of each individual experiment was 15 min, which is much longer than the particle residence time in the test tank, and should contribute to obtaining consistent particle removal rates in the settling tank. As shown in Figure 2, a mixer is inserted near the bottom of the solids feeding pipe to make sure that the injected particles are well blended with the incoming flow in the inlet pipe. After the experiment is finished, the mixture of the retained particles and the captured flow will be drained through a bottom drain and the particles will be captured by a screen located below the exit of the drain pipe. The captured particles will be oven dried overnight at a

temperature of 40°C (to prevent burning) and weighed to determine their total weight. The tests were carried out for many experiments under different flow rates of 0.2, L/S, 0.3 L/s, 0.35 L/s, 0.4 L/s and 0.5 L/s.

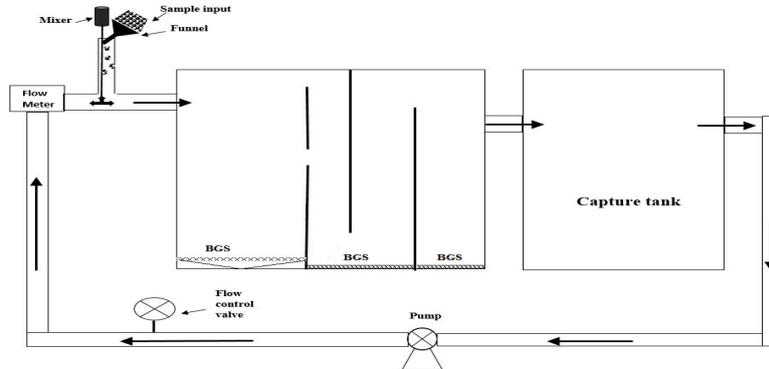


Figure 2. Experimental setup of SPLIT system in the laboratory.

3. Results and Discussion

The results of sediment removal percentage for sedimentation tank with and without BGS are presented in table 1. The efficiencies of removal rate range was between 98.21% to 99.52 % and 96.0% to 99.35% for sedimentation tank with and without BGS, respectively. The sediment removal percentages are also plotted for different flow rates as shown in Figure 3. It shows clearly that when the inflow rate was low, the tested BGS seems not having a large affects on the settling activities. This was due to particle settling behaviour itself was related to gravity, in which the particles could settle down naturally when the inflow rate was low. However, as the inflow rate increases, the BGS started to give better performance in term of trapping and preventing the re-suspension of sediment. The improvement in the sediment removal percentage indicates the efficiencies of the BGS to retain the settled particles in the tank.

Table 1. Sediment removal percentages under different flow rates with and without BGS.

Flow rate (L/s)	0.2	0.3	0.35	0.4	0.5
BGS	99.52	99.57	99.01	98.72	98.21
Without BGS	99.35	98.15	98.01	97.24	96

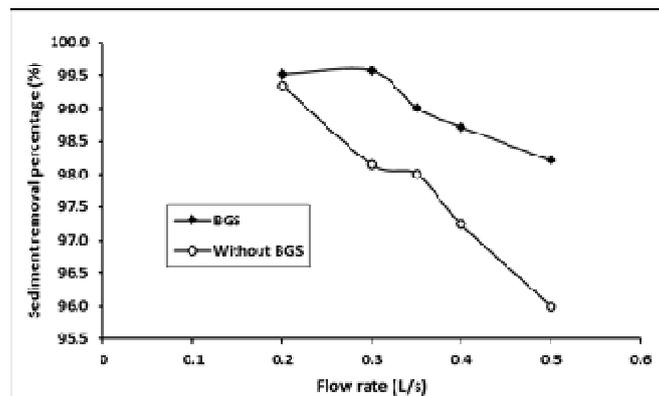


Figure 3. Sediment removal percentages against different flow rates for tank with BGS and without BGS system.

The efficiencies of the BGS started to decline at inflow rate 0.35 l/s. It was possibly due to the vigorous flows restrained the particles from being shifted into and retained in the BGS cells. For very strong turbulent flow in experiment without BGS, the by-passed particles were found in a large amount compared to other experimental with BGS cells. This shows that these particles not able to settle on the settling tank. It was expected because the increased turbulent would generate a negative influence on the settling behaviour. The BGS was designed to capture sediment and prevent re-suspension when dealing with rapid flows. This was likely occur in stormwater ponds at its sediment fore bays, where the flow cross-section area was rather small and the flow velocities were high in most cases. Going deep into the pond, where the flow area increase to a great extent, the flow velocities would reduced, thus resulting the BGS effectiveness to deplete. However, the fast flowing velocities at the sediment fore bays induced positive effects of the vortices that would shift more particles into the cells.

The cell walls provide protection that acted against the negative effects of bottom turbulent disruption which increases the bottom roughness when the BGS was presence, thus consequences in greater rate of removal. Even though extra turbulence occurred at the top surface, particles could still settle on the tank bed in a much larger area due to vertical vortices and cell protection. Particles retained easier when the flow speed changed from very fast flow to a much calm zone, most likely due to optimised combination of the vortices and cell protection. However, if the flow was too high until it causes disturbances at the bottom flows, all particles would be flushed away. As clarified before, where almost all particles could settle down and stay on the bed naturally at slowest velocity discharge, it was because of the same positive and negative effects were exhibited on the particle settling and its negative turbulence could possibly cause a larger influences on the effectiveness of the BGS.

4. Conclusions

The results indicated that the particle removal efficiencies with the application of BGS were about 6% higher than that tested without the BGS for flow rates ranges from 0.2 l/s to 0.5 l/s. The combination of the induced vortices and the preventative BGS cells resulting in better performance of the cells especially when inflow discharge was high. However, the BGS did not appear to have obvious effects in the weak flows since the turbulence produced were not strong that allows the particles to settle to the bottom naturally. The uses of BGS under high flow rates were proved to efficiently enhance the sedimentation and reduce resuspension possibilities of the earlier settled sediment. This would indicate a significant implications for a storm water management operation.

Acknowledgements

The authors would like to thank YCU grant (Project No. 201801001YCU/16) provided by Yayasan Canselor UNITEN (YCU) and Seed Fund provided by Tenaga Nasional Berhad (Project No. U-TG-RD-17-06).

References

- [1] M F Chow *et al* 2014 *Water Sci. Technol.* **69** 244.
- [2] M F Chow *et al* 2013 *Water Sci. Technol.* **67** 1822.
- [3] Chow M F *et al* 2015 *Urban Water Journal.* **12** 240.
- [4] Chow M F *et al* 2017 *Eng. & Applied Sci.* **12** 5379.
- [5] M F Chow *et al* 2016 *Environ. Earth Sci.* **75** 6.
- [6] Aldheimer *et al* 2003 *Water Sci. Technol.* **48** 113.
- [7] Bertrand Krajewski J L *et al* 1998 *Water Res.* **32** 2341.
- [8] Chow M *et al* 2014 *Environmental Earth Sciences* **72** 4047.
- [9] Chow M F *et al* 2017 *Journal of Civil Engineering* **21** 1087.
- [10] A M Razmi, *et al* 2008 *J.Appl.Fluid Mech.* **2** 1.
- [11] Mahdi Shahrokhi *et al* 2012 *Applied Mathematical Modelling* **36** 3725.