BALLASTED SAND FLOCCULATION TECHNOLOGY FOR STORM WATER RUN OFF TREATMENT

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ABSTRACT

Effective storm water management of urban area is of crucial importance and has drawn attention of many scientists and engineers.Storm water runoff from urban areas contains wide variety of pollutants from both anthropogenic and natural sourcesand it act as a major contributor to the pollution of receiving water bodies. Surface water bodies face the problem of siltation and eutrophication due to catchment's storm water runoff. Ballasted sand flocculation (BSF) technology is a high-rate coagulation/flocculation/sedimentation process that utilizes micro-sand as a seed for flock formation can act as an alternative treatment method to treat storm water runoff and wet weather flows (WWFs). The micro-sand provides surface area which enhances flocculation and acts as a ballast or weight. The resulting flock settles very fast, that allow for compact clarifier designs with high overflow rates and short detention times. These designs result in system footprints which are 5 to 30 times smaller in size than conventional clarification systems of similar capacity. In the present study, BSF technology has been applied to evaluate its effectiveness for urban runoff treatment of a hilly catchment area, i.e Nainital, India. The pilot plant of 1 mld capacity was installed near Naina Devi drain which is a major drain in the Lake's catchment (contributes 60% of runoff to the Nainital Lake).Nainital Lake is the principal source of water supply for Nainital town, a popular hill station situated about 1,937 m above mean sea level (MSL), in the lesser Himalayas. The BSF technology performance was assessed under a pilot study for the monsoon season of year 2017. The removal efficiency of Turbidity, TSS, Total Phosphorous, and CODare 86-96%, 69-93%, 75-95%, 41-82% respectively. The performance analysis results of BSF system have been found to be a promising technology for treatment of urban runoff.

Keywords: Ballast, Coagulation, Flocculation, Nainital, Urban Runoff

1 INTRODUCTION

Effective urban runoff management is of crucial importance and has drawn attention of many scientists and engineers. Urban runoff is an important transporting medium for various pollutants to transport from land to surface water bodies such as lakes. The major sources of pollution in the runoff are sewage overflows, road salt and grit, construction debris, soil erosion, nutrients, atmospheric fallout and deciduous leaf litter, etc. These natural and/or anthropogenic sources posses pollutants containing suspended solids, organic load, nutrients, heavy metals, total and fecal coliforms, etc. These pollutants act as major contributor to the pollution of receiving water bodies [1]-[2].Nainital Lake (India) is one such water bodies which receive polluted runoff and thus face the deteriorating water quality problem [3]-[7]. The Nainital Lake is one of the major sources of water supply to the Nainital city, and also attracts thousands of tourists every year due to its scenery beauty. The economy of Nainitalregion is directly or indirectly dependant on this lake.Therefore, there is a need to devise an appropriate storm-water runoff treatment plant to improve the lake water quality. Availability of land is a critical factor in Nainital to adopt a conventional treatment plant. One of the technologies, which proven to be effective for surface water and combined sewerage overflow (CSO) is ballasted sand flocculation, also known as high rate clarifier which require very less space[8]-[10]. The ballasted flocculation technology is mainly based on physical-chemical treatment process that uses a continuous recycled medium along with chemicals to improve the settling properties of suspended solids through improved floc bridging[11]-[14].In the present study, performance of BSF was evaluated for storm-water runoff treatment. There are hardly any attempts to employ the BSF technique at full scale or laboratory scale in India as per author's best of knowledge. The pilot plant of 1 Mld (42 m^3/hr) capacity was installed near storm water drain (locally called Naina Devi drain) Nainital, India. Naina Devi drain is the major drain in the Lake's catchment, which contributes 60% of runoff to the Nainital Lake.

2 MATERIALS AND METHODS

2.1 Description of pilot plant

The BSF unit involves three-stage process i.e injection, maturationand settling.The technical design detail of BSF pilot plant has been given in Table 1.The total hydraulic retention time (HRT) of the plant was 16 min, which corresponds 2-2-6-6 design that means 2 min retention time in coagulation tank, 2 min in flocculation tank, 6 min in maturation tank and 6 min settling time. The coagulation, flocculation and maturation tank were equipped with mixers, which provides high mixing speed (160-180 rpm) in the first two tanks and low mixing speed in the maturation tank (40-60 rpm).Prior to entering into the first stage process of the BSF process, influent was screened to remove large particulates. The next step is the addition of a coagulant in injection tank. In the first stage, a polymer and micro-sand (the ballast materials) are also added to the injection tank. The second stage of the BSF process is maturation in which the ballast material serves to enhance floc formation, resulting in a much faster settling rate relative to traditional coagulants. The third stage of the process is settling. During this stage, the mixed influent and the floc flow downward through the BSF unit. The floc settles by gravity to the bottom of the unit where they are collected in a cone-shaped chamber and clarified effluent was directed to discharge. Ballast from the bottom of the chamber is separated from the sludge and reintroduced into the injection chamber through hydro-cyclone. A hydro-cyclone uses centrifugal force to separate the sludge from the ballast. The sludge was taken to an appropriate handling facility. The schematic diagram and actual experimental set-up (1 MLD pilot-plant) has been shown in Fig 1 and Fig.2.

Table 1. Technical design detail of BSF pilot-plant

Parameters	Unit	Value
Design flow	m^3/hr	42
Coagulation tank size	m^3	1.62
Flocculation tank size	m^3	1.62
Ballastation tank size	m^3	5.76
HRT	minutes	16
Rise rate	m/hr	42

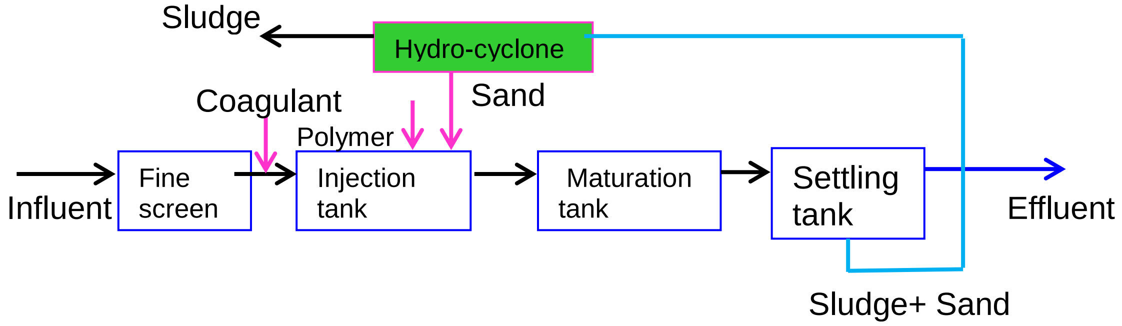

Figure 1. A schematic line diagram of BSF unit (source: [8])

Figure 2. Actual experimental set up (1 Mld pilot-plant) at Nainital, India

2.2 Sample collection, analyses and instrumentation

The inlet and outlet samples of BSF unit were collected during nine different storm events. Number of samples for each storm event varied from three to seven depending upon the duration of event. Samples were collected after 10 minutes of rainfall initiation and then after, at every twenty minutes interval till the flow in drain reach to its initial flow. Grab samples were collected and analyses was performed as per procedure given in the standard methods for the examination of water and wastewater. The parameters analyzed for pH, alkalinity, turbidity, total suspended solids(TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD),ammonical nitrogen (NH_4^+-N), nitrate nitrogen(NO_3-N) and total phosphorous(TP).pH of the samples were measured by Hach, HQ30d portable meter, and turbidity was determined by Hach, AN 2100 Nephelometer. All colorimetric analyses such as NH_4^+-N, NO_3-N, COD and TP were done by UV-visible spectrophotometer (Model no: DR-6000^{TM}, Hach Inc.). TSS and alkalinity were determined through gravimetric and volumetric method.

3 RESULTS AND DISCUSSION

Table 2 summarizes the results (influent-effluent concentration and removal rate of pollutants) obtained during the study period. There are large fluctuations in the influent concentration for all the parameters. The concentrations of pollutants detected are comparable with other data found in the literature for storm water runoff [15-17]. The value of COD and BOD reached maximum level upto 388and 224mg/l respectively (Table 2) indicates that there may be mixing of sewage due to bursting or choking of sewer pipeline during some events.Total phosphorous concentration ranges from 0.08-1.2 mg/l, which is much higher than the threshold value causing eutrophication in the lake.

Table 2. Characteristic of influent, effluent and removal of pollutants during storm events

Parameters	Influent Concentration Average(min-max)	Effluent concentration Average(min-max)	% Removal Average(min-max)
pH	7.54(6.8-8)	7.31(6.9-7.8)	-
Turbidity (mg/L)	135(21-635)	2.45(1.2-4.8)	95(86-96)
TSS (mg/L)	185(38-864)	14(6-45)	88(69-93)
COD (mg/L)	118(21-388)	30(12-78)	71(41-82)
BOD (mg/L)	46(7-224)	08(3-34)	72(29-82)
NH_4^+-N (mg/L)	1.53(0.26-3.55)	1.3(0.12-3.50)	8(0-46)
NO_3-N (mg/L)	0.62(0.10-2.25)	0.75(0.13-2.71)	No removal
TP (mg/L)	0.47(0.08-1.2)	0.07(0.02-0.22)	83(75-95)

The chemical dosages of the plant were optimized by conducting modified jar test in the laboratory before the field application of the plant. Modified jar tests were conducted for stormwater with different turbidity values of 52, 92, 204, 572 and 698 NTU. Alum (Al2(SO4)3. 18H2O) as coagulants, cationic polymer as flocculant and micro-sand (silica) of size 130 µm as ballast were used for the study. The optimum chemical dosages ranged between 20 - 80 mg/l of alum (Al_2SO_4. $18H_20$); 30-120 mg/l of ferric chloride ($FeCl_3.6H_2O$) and 8 g/l of micro-sand.

The removal efficiency of pilot plant is presented in Table 2. Results showed that BSF unit is highly efficient in removing particulate matter and phosphorousand it also exhibit a significant removal of other pollutants. Turbidity, TSS and TP removal rates ranged from 85 to 99%, 64-95% and 63-95% whereas COD and BOD removal rate ranged between 43-88% and 29-82%. The average removal rate of ammonical nitrogen is 8 % but no removal of nitrate nitrogen was found out. Phosphorous removal is important, as phosphorous is the limiting factor for eutrohication of Nainital Lake. Storm event-wise average removal rate of pollutants are shown in Fig.3(a) and(b). The average removal rate of turbidity,TSS and TP are 95%, 88% and 83% while for COD and BOD are 76% and 72%.The removal efficiency of pollutants is comparable with other reported studies based on the performance of BSF systems for CSO/surface water of similar characteristic of influent [11, 13].

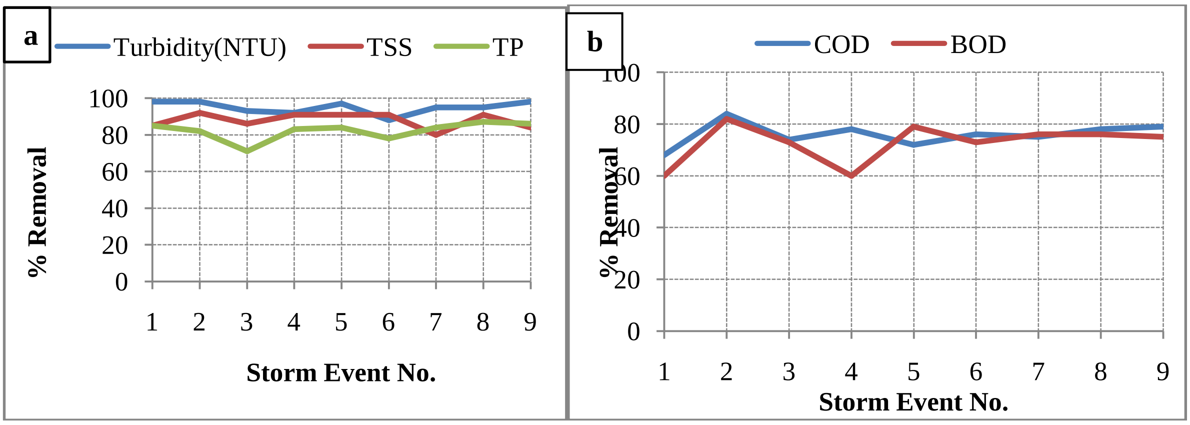

Figure 3. Event-wise average removal efficiencies of BSF unit for (a) turbidity, TSS and TP (b) COD & BOD

4 CONCLUSIONS

The performance of BSF unit was evaluated for urban runoff treatment of a hilly catchment area i.e Nainital, India. A 1 Mld pilot-plant was installed near Nainadevi storm-water drain which carries variety of pollutants. The plant was run for two months covering nine storm events during monsoon season, 2016. The particulate matter, phosphorous, COD and BOD showed a very good removal during the overall experimental campaigns. The treatment of storm water runoff with average removal rate was found out to be 95% for turbidity, 88% for TSS, 83% for T-P, 76% for COD and 72% for BOD. Findings of present study suggest that the BSF unit can be suitable for treatment of urban runoff. The urban runoff carries trace metals, pesticides, pharmaceutical and personal care product and therefore their removal efficiency should also be studied.

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