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Instream filtering system for the removal of suspended solids in King Yip Street Nullah, Kwun Tong

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ABSTRACT

The preliminary design of the project "Revitalization of Tsui Ping River" recommended a few water quality improvement measures aiming to enhance the aesthetic appearance and environmental conditions of the existing King Yip Street Nullah in Kwun Tong, including the use of a cost-effective instream filtering system to remove suspended solids (SS) in dry weather flows. However, the effectiveness as well as operational and maintenance experience of instream filtering systems in Hong Kong is not well established. Thus, we conducted a site trial to ascertain its effectiveness before full-scale implementation. The results showed that the sand trap screened a lot of sandy materials during the site trial period, especially during rainfall events. The instream filtering system with a gravel size of 80–120 mm effectively removed SS and total organic carbon from the water. We recommend that for the instream filtering system to be implemented in other nullahs in Hong Kong, larger dimensions (length of 4–9 m) with possible flow control (0.3–1.5 m^3/h) measures could be considered when the site conditions (water depth of 1.1–1.5 m and water turbidity level below 500 NTU) allow. Overall, this study provided indispensable guidance to formulate the future design of filter sizing criteria based on targeted rainfall events and specific hydrological objectives.

KEYWORDS Instream filtering; rock/gravel filter; suspended solids; surface water; sustainable remediation
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Received 18 August 2021

1. Introduction

Since the rapid urban development, stormwater pollution has become a significant problem in Hong Kong, which not only affects the river and coastal environments but also creates odours and visual problems (Chen et al., 2021; Sun et al., 2020). In Hong Kong, misconnection of the sewerage system to the stormwater drainage system and the improper behaviour of directly pouring contaminated water into stormwater drains are the two major sources of stormwater pollution (EPD, 2012). Apart from the above causes, urban surface runoff has also been recognised as a significant cause of stormwater pollution (Müller et al., 2019; USEPA, 2018), as it carries a variety of harmful pollutants from roads, rooftops, and car parks to the drainage system, rivers, and receiving waterbodies.

In the past three decades, the Government of the HKSAR has made great efforts to tackle stormwater pollution problems, including the enforcement of the Water Pollution Control Ordinance and Livestock Waste Control Scheme (EPD, 2017). As a result of the government's work, the overall river water quality compliance rate has been greatly improved from 48% in 1987 to 90% in 2017 (EPD, 2017). However, King Yip Street Nullah in Kwun Tong is still suffering from stormwater pollution problems, especially contamination by suspended solids (SS). In 2016, revitalising the existing King Yip Street Nullah was set as one of the five major focuses in the Conceptual Master Plan version 5.0 (CMP 5.0) released by the Energizing Kowloon East Office. Because of the strong public concern regarding the stormwater pollution problem of the river, improving the river water quality has also been set as a vital objective of the revitalisation project (DSD, 2018).

The horizontal roughing filter, a type of gravel filter, was selected as one of the potential stormwater treatment approaches for improving the water quality in the river. The roughing filter is commonly used for the removal of SS, as it mainly relies on a simple and cost-effective sedimentation process, without supplementary chemical usage, for removing suspended matter (Dashti et al., 2020; Hashimoto et al., 2019). Simplicity of filter design, high effectiveness and stability of filtering suspended solids, and high raw material availability are other advantages of roughing filters (Bakare et al., 2019; Kim et al., 2020). However, there is no known overseas application using roughing filters for instream river filtration. An instream filter tube barrier with a similar design to the horizontal roughing filter was implemented to treat low-flow river water, where geotextile filter tubes incorporated into a porous or non-porous embankment were placed across the streambed (Catchments and Creeks Pty Ltd., 2010). Sediment-laden low-flows were directed into the open end of the pipes and then allowed to filter through the filter tubes.

Thus, a pilot study was commenced to identify the feasibility of using an instream filtering system to control pollution by SS in the King Yip Street Nullah. The objectives of this project were to: i) design an instream filtering system and ascertain its effectiveness in removing

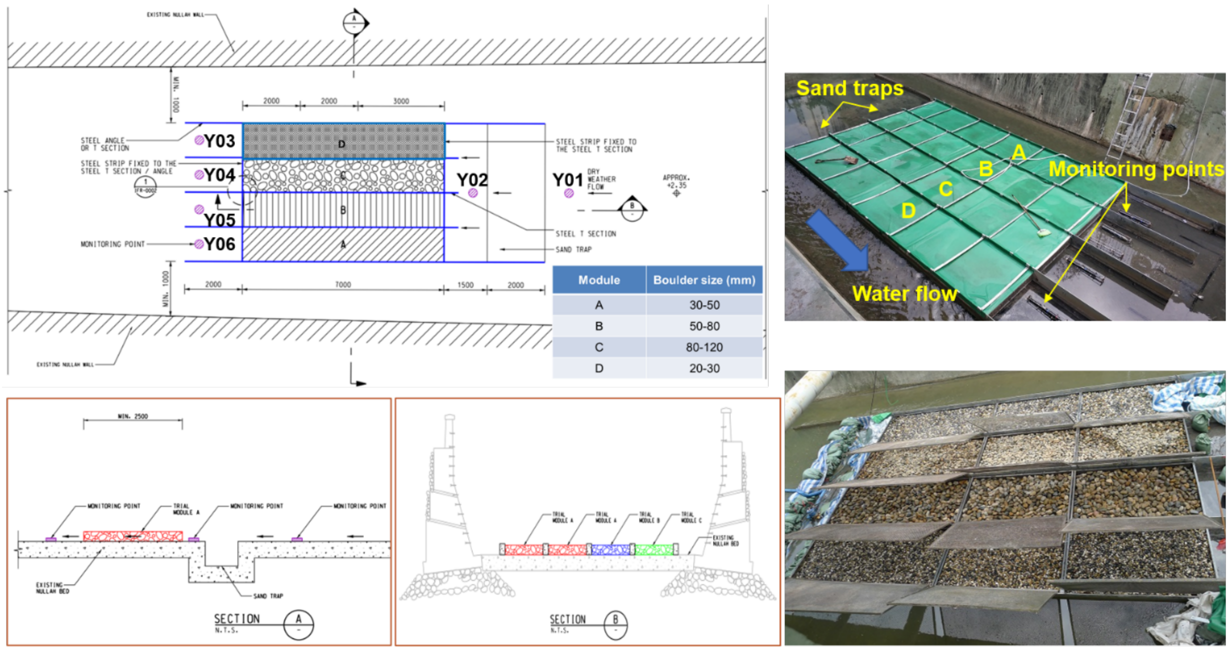

Figure 1. Overview of the instream filtering system onsite.

SS from the dry weather flow through the instream filtering system; and ii) provide recommendations on the instream filtering system and operational experience for adoption in other engineered channels.

2. Methodology

2.1. Design of the instream filtering system

The instream filtering system was constructed in the river bed in the most upstream section of the King Yip Street Nullah with the minimum flow and is the nearest point to the pollution discharge with high volumes of SS in the King Yip Street Nullah (Supporting Information, SI). The design criteria of the instream filtering system were adapted according to the “Surface Water treatment by Roughing Filters: A Design, Construction and Operation Manual” (Martin, 1966) after taking the site limitations into consideration. The instream filtering system consisted of four horizontal-flow gravel filters (7.0m (L) × 1.2m (W) × 0.2m (H)) working in parallel, and a sand trap (2m (L) × 1.2m (W) × 0.8m (H)) was installed in front of each filter (Figure 1). The four filter modules (A, B, C, and D) were packed with limestone boulders of different sizes (30–50, 50–80, 80–120, and 20–30 mm), respectively, which were provided by the local contractor. Roughing filters usually consist of different sizes of filter materials, decreasing in size in the direction of flow. However, in our preliminary site trial (data not shown), the instream filters were easily clogged when different-sized limestone boulders were packed into four serial compartments, possibly caused by the serious contamination of the river. Thus, in this study, the filter systems were designed to test and compare the efficiency of different-sized limestone boulders in removing SS from the river water. The top of the instream filtering modules was covered with canvas. To determine the turbidity removal efficiency by filter modules A to D, six water sensors were placed at the inlet (Y01) and outlet (Y02) of the four sand traps, and the outlet (Y03, Y04, Y05, and Y06) of the four filter modules, respectively (Figure 1).

2.2. On-stie monitoring and sampling

Two rounds of site trial tests under dry-season conditions were conducted as follows: 16/12/2019–26/1/2020 (first Round) and 10/2/2020–26/3/3030 (second Round), which represented the low-turbidity and high-turbidity conditions in dry flow, respectively. The boulders were thoroughly washed with tap water before commencement of the site trial tests. The water quality (pH, dissolved oxygen (DO), and turbidity) and hydraulic condition (flow depth and flow rate) of the river were continuously monitored by the water sensors (Aqual TROL 600 Multiparameter Snode, In-Situ Inc., USA) every 15 minutes. A total of 12 water samples were taken at Y01–Y06 once a week by the contractor and tested for concentration of SS in the local commercial laboratory. General site clearance was conducted every week to remove debris from the site. At the end of Round 1 and 2 site trial tests, eight solid samples at the inlet/outlet of the four filter modules (A-inlet, A-outlet, B-inlet, B-outlet, C-inlet, C-outlet, D-inlet, and D-outlet) were sampled on site, respectively, and were characterised for solid removal efficiency, solid particle size distribution, and solid total organic content (SI).

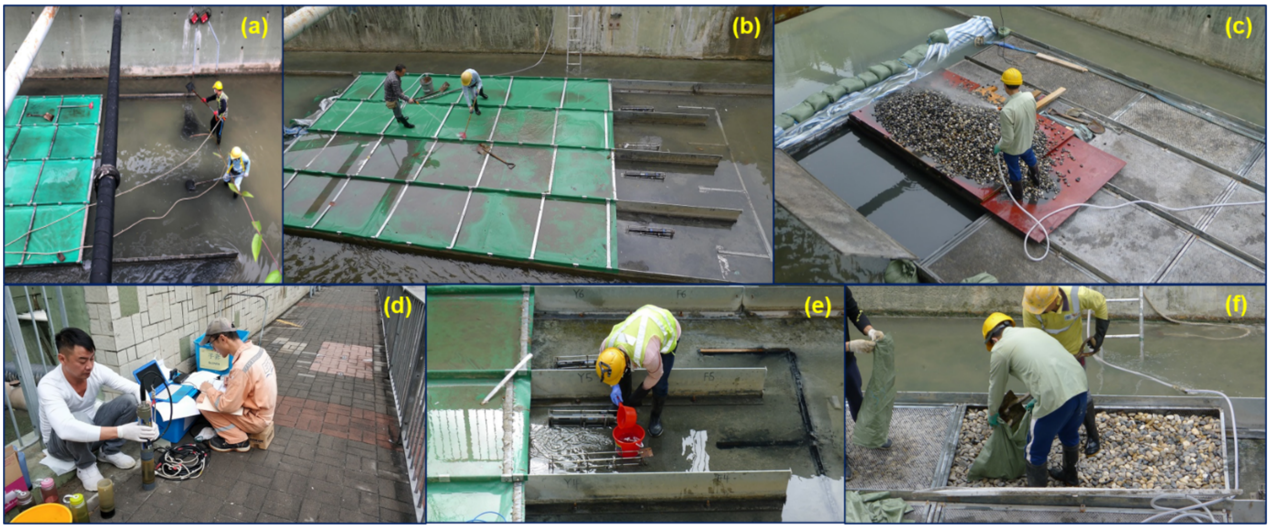

Figure 2. The routine on-site work including desilting of the sand traps (a), canvas cover (b), and boulders (c), calibration of the water sensors (d), and grabbing of the water (e) as well as solid samples (f).

The filter systems were thoroughly cleaned at the end of each site trial. The boulders were cleaned manually using a high-pressure water jet followed by grabbing of sediments in the sand trap. The routine on-site working including desilting of the instream filtering system, calibration of the water sensors, and grabbing of the water as well as solid samples are illustrated in Figure 2.

2.3. Performance evaluation of the instream filtering system

The turbidity removal efficiency by the sand traps (Table A1) was analysed by measuring the amount of trapped silty materials during the predetermined period. In the Round 1 and 2 site trial tests, the total silt removal efficiency of the four sand traps was within 0.153−0.250 and 0.190−0.358 m^3/day (Table A1), respectively. More silty materials were trapped after heavy rainfalls. The online monitoring data and analysis data of the grabbed water, as well as gravel samples, were all used for efficiency evaluation. The online monitoring data were classified into (1) "Overflow" data: data with the outlets (Y03−Y06) flowrate higher than the inlet (Y02) flowrate; and (2) "Negative Turbidity Removal" data: data with the outlet (Y03−Y06) turbidity higher than the inlet (Y02) turbidity. The "Overflow" data and "Negative Turbidity Removal" data both suggest that the water does not flow into the filter modules which thus can be used as indicators of filter clogging. The average outlet turbidity removal Equation (1) was calculated as the average value of outlet turbidity removal of a sample point (Y03−Y06) on a certain day after excluding the "Overflow" data and "Negative Turbidity Removal" data. During a certain period of the field test, filter modules with fewer "Overflow" data Equation (2), fewer "Negative Turbidity Removal" data Equation (3), and higher average outlet turbidity removal were considered to have better performance.

$$\text{Average outlet turbidity removal (\%)} = (\text{Inlet turbidity} - \text{Outlet turbidity}) / \text{Inlet turbidity} \times 100\%, \quad (1)$$

$$\text{“Overflow” data (\%)} = \text{number of “Overflow” data} / \text{number of total raw data} \times 100\%, \quad (2)$$

$$\text{“Negative Turbidity Removal” data (\%)} = \text{number of “Negative Turbidity Removal” data} / (\text{number of raw data} - \text{number of “Overflow” data}) \times 100\%. \quad (3)$$

3. Results and discussion

3.1. Filter performance evaluation based on the online monitoring data

From the Round 1 and 2 site trial tests, after excluding the "Overflow" data and "Negative Turbidity Removal" data, the available data of Modules A−D are shown in Figures 3 and 5 and the analysis results are shown in Figure 6 and Tables A2-A3. In the Round 1 site trial test, compared with Modules A, C, and D, Module B had relatively fewer "Overflow" data (19.2−21.7%) and "Negative Turbidity Removal" data (13.7−28.2%), and the highest average turbidity removal (92.6−97.0%) (Table A2). Thus, Module B equipped with 50−80 mm boulders had the best performance. During the Round 2 site trial test, for Modules A and D, the number of "overflow data" almost reached 100%, which suggested that Modules A and D were instantly clogged at the beginning of the Round 2 trial test. Compared with Module B, Module C had fewer "Overflow" data (30.1–47.5%) and "Negative Turbidity Removal" data (0.0–1.9%) as well as higher average outlet turbidity removal (98.6–99.9%) (Table A3). Thus, Module C with 80–120 mm boulders had the best performance.

In the Round 1 and 2 site trial tests, the performances of Modules A–D gradually decreased with time as evidenced by the increasing number of "Overflow" data and "Negative Turbidity Removal" data as well as decreasing average outlet turbidity removal (Figure 6 and Tables A2 to A3). In the Round 1 site trial test, compared with Modules B and C, Modules A and D were more prone to filter clogging with the sudden surge of outlet turbidity (Figure 3), significantly high "Negative Turbidity Removal" data (%) and "Overflow" data (%), and significantly low average outlet turbidity removal in the fourth week of the Round 1 site trial test (Figure 6 and Table A2). Compared with weeks 1–4, the average concentration of outlet turbidity in weeks 5–6 was much higher (Figure A2). The filter clogging at Modules A to D (Figure 4a-d) was observed after the fourth week of the Round 1 site trial test because serious blockage was observed between the cage net (Figure 4e). Thus, the

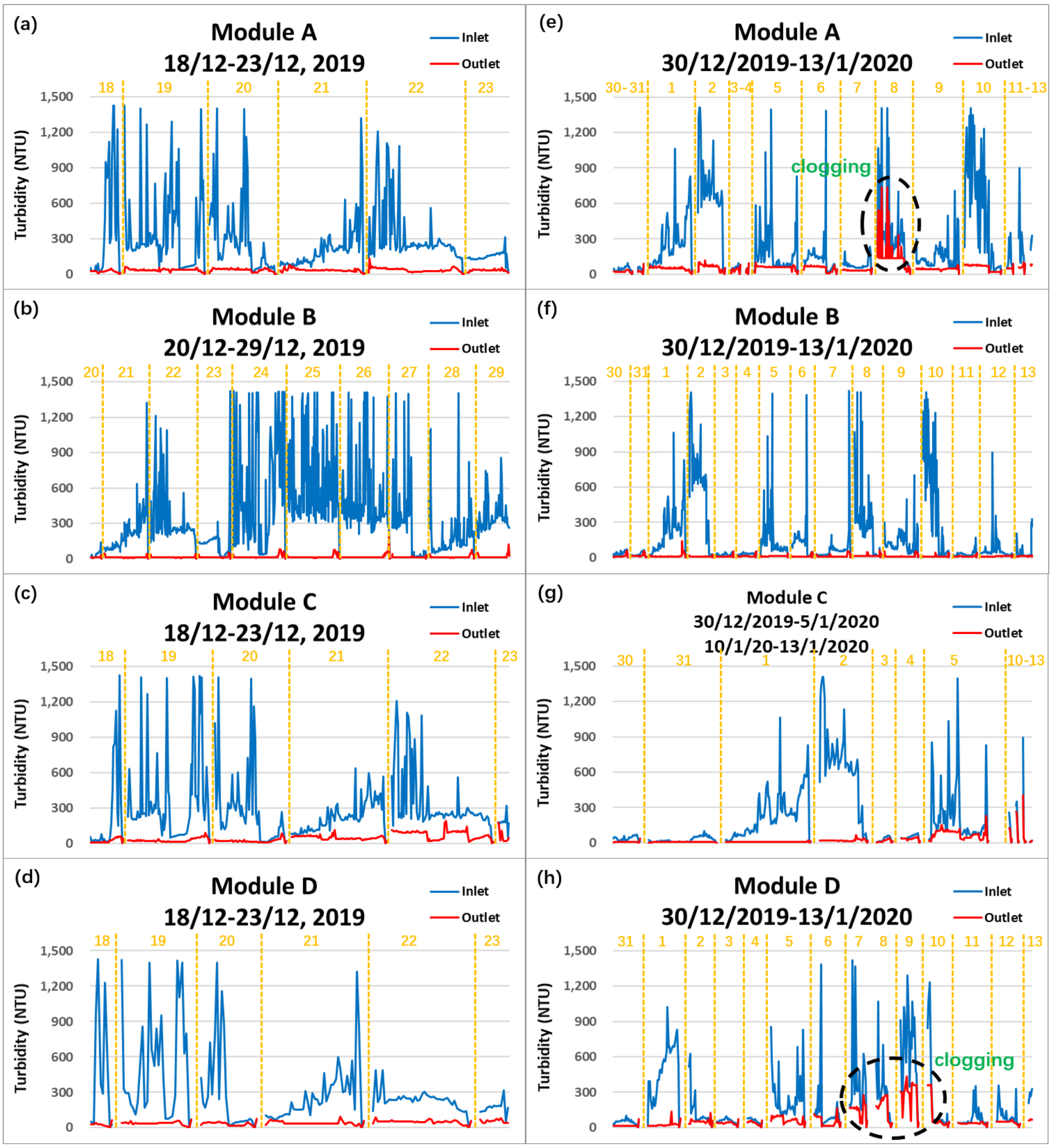

Figure 3. Comparison of the inlet and outlet turbidity of the four filter modules during weeks 1–2 (a-d) or 3–4 (e-h) in the Round 1 site trial test.

Figure 4. Filter clogging observed in the four filter modules (a-d) and between the cage net (e) after the fourth week of the Round 1 site trial test.

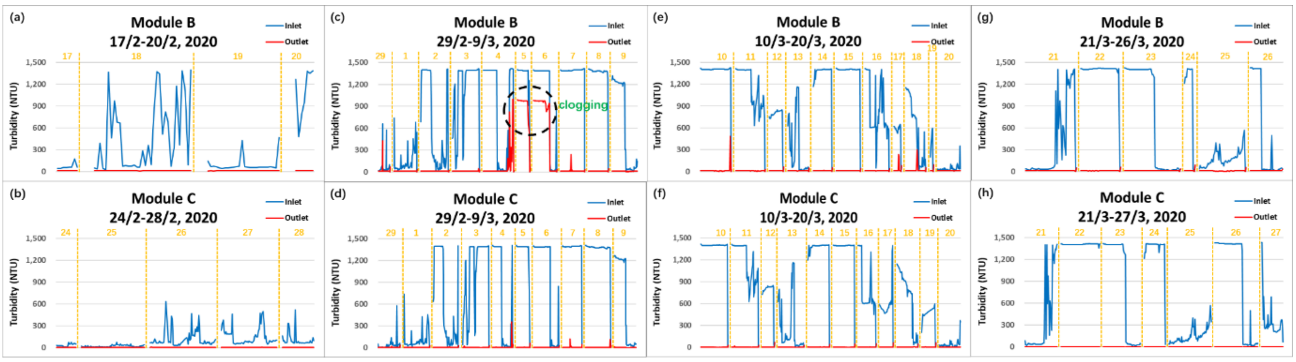

Figure 5. Comparison of the inlet and outlet turbidity of filter modules B and C during weeks 2–3 (a and b), 4 (c and d), 5–6 (e and f), or 7 (g and h) in the Round 2 site trial test.

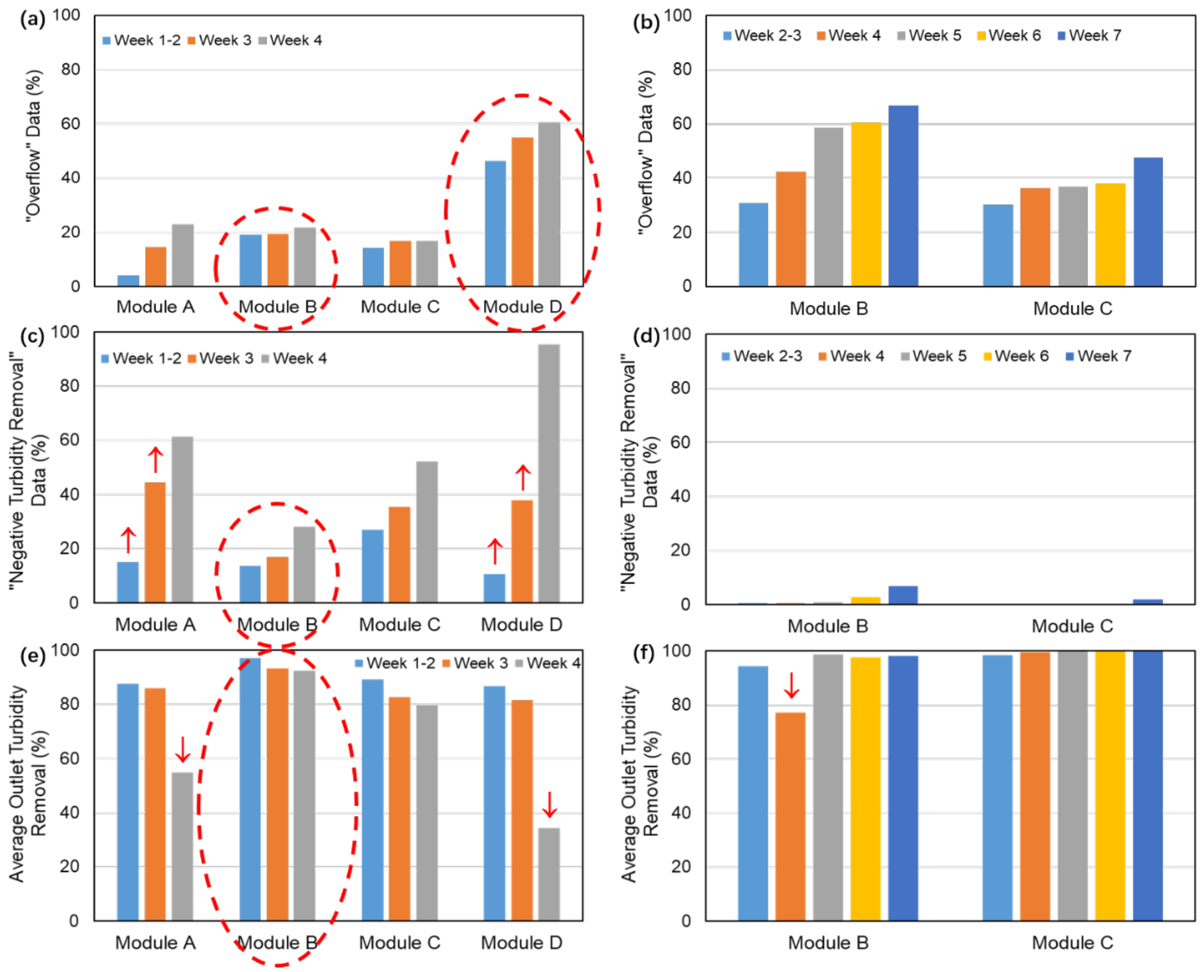

Figure 6. Comparison of the "Overflow" data (a and b), "Negative Turbidity Removal" data (c and d), and average outlet turbidity removal (e and f) of the four filter modules in the Round 1 and 2 site trial tests.

side nest in between the two cages was cut off to prevent filter clogging. In the Round 2 site trial test, a sudden surge of outlet turbidity with obviously decreased outlet turbidity removal was observed in Module B on 5-6/3/2020 (Figure 5), which suggested filter clogging. No obvious sign of filter clogging was observed in Module C.

Thus, the smaller-sized (50–80 mm) boulders with a larger surface trapped more SS possibly due to an enhanced sedimentation-filtration process taking place in the filter. Nevertheless, a low porosity of the limestone boulders might lead to quick accumulation of the separated solids and subsequent filter clogging. Similar phenomenon was also observed in the pilot-scale gravel filters for contaminants' removal from potable water (Tekerlekopoulou and Vayenas, 2007).

3.2. Filter performance evaluation based on analysis of the grabbed water samples

The analysis results of the grabbed water samples of the Round 1 and 2 site trial tests are shown in Tables A4 and A5. In the Round 1 site trial test, compared with Modules A, C, and D, Module B had relatively fewer "Negative Turbidity Removal" data (6) and the highest average SS removal (43.4%) (Table A4). According to the analysis results of the grabbed water samples in the Round 2 site trial test, Module B with higher average removal of SS (35.5%) was better than Module C (13.2%) in regard to turbidity removal (Table A5). Thus, the conclusions regarding the filter modules with the best performance based on analysis of the online monitoring data and grabbed water sample data were sometimes contradictory. The grabbed water sample data could not accurately reflect the filter performance because the water samples were discontinuously taken at different times when the situation of overflow happened in different filter modules irregularly.

3.3. Filter performance evaluation based on analysis of the grabbed solid samples

The amount of removed sand by different filter modules in the Round 1 and 2 site trial tests is shown in

Table 1. Performances of the different filter modules based on analysis of the grabbed solid samples (Round 1 and 2).

Sample	Gravel Size (mm)	Average sand removal efficiency (mg sand/g gravel)		Average sand weight proportion (%)								Average organic removal efficiency (mg TOC/g gravel)	
				> 1 mm		> 0.6 mm ≤ 1 mm		> 0.18 mm ≤ 0.6 mm		≤ 0.18 mm			
		1	2	1	2	1	2	1	2	1	2	1	2
A-inlet	30−50	14.1	0.060	99.9	71.4	0.0407	28.6	0.0407	N.D.	0.0407	N.D.	0.455	0.779
A-outlet		51.6	0.068	96.4	66.7	1.06	33.3	1.41	N.D.	1.13	N.D.	4.16	1.20
B-inlet	50−80	0.140	0.104	22.6	16.7	9.68	16.7	24.2	16.7	43.5	50.0	5.50	4.29
B-outlet		0.604	0.191	N.D.	4.76	N.D.	14.3	N.D.	28.6	100	52.4	11.5	6.89
C-inlet	80−120	0.161	0.077	37.5	N.D.	12.5	18.2	25.0	18.2	25.0	63.6	2.88	5.06
C-outlet		0.256	0.611	31.7	N.D.	19.0	12.5	22.2	25.0	27.0	62.5	8.53	25.3
D-inlet	20−30	6.06	0.111	98.2	57.7	1.33	34.6	N.D.	3.85	0.498	3.85	0.673	0.481
D-outlet		9.04	0.720	97.7	53.4	N.D.	31.5	0.558	8.22	1.79	6.85	1.20	0.905

N.D.: None detectable.

Table 1. In the Round 1 site trial test, Module A trapped the largest amount of sand (14.1−51.6 mg sand/g gravel), followed by Module D (6.06−9.04 mg sand/g gravel), Module B (0.140−0.604 mg sand/g gravel), and Module C (0.077−0.611 mg sand/g gravel). This result was in accordance with the filter clogging observed in Modules A and D. Compared with the Round 1 site trial test, Module A (0.60−0.68 vs. 14.1−51.6 mg sand/g gravel) and Module D (0.111−0.720 vs. 6.06−9.04 mg sand/g gravel) exhibited significantly lower sand removal efficiency in the Round 2 site trial test. This result was in accordance with previous analysis that Modules A and D were instantly clogged at the beginning of the Round 2 site trial test.

The outlet could screen more sand than the inlet. In general, more large-sized sand (> 1 mm) was trapped in the inlet, while more small-sized sand (< 0.18 mm) was trapped in the outlet (Table 1), which was probably because the sandy materials with a smaller particle size could move with the water inside the filter module. The particle size distribution of the removed sand in the Round 1 and 2 site trial tests (Table 1) suggested that Modules A and D were only capable of removing sand with a particle size larger than 1.0 mm. This observation was consistent with the previous analysis that Modules A and D were easier to become clogged. Module B could remove sandy materials with a wide range of particle sizes, especially smaller than 0.18 mm. In the Round 1 site trial test, Module C could remove sandy materials with a wide range of particle sizes, especially those larger than 1 mm. However, in the Round 2 site trial test, Module C could only remove sand with a particle size smaller than 1 mm and was most capable of trapping sand with a particle size lower than 0.18 mm. In the Round 1 and 2 site trial tests, the largest proportion of 0.18 mm sand trapped in Module B (43.5−100%) and Module C (62.5−63.6%) further indicated their best performance with the lowest level of filter clogging (Table 1).

The amount of removed TOC by different filter modules in the Round 1 and 2 site trial tests is shown in Table 1. In the Round 1 site trial test, Module B had the best performance of TOC removal (5.50−11.5 mg TOC/g gravel), followed by Module C (2.88−8.53 mg TOC/g gravel), Module A (0.455−4.16 mg TOC/g gravel), and Module D (0.673−1.20 mg TOC/g gravel). In the Round 2 site trial test, Module C had the best performance of TOC removal (5.06−25.3 mg TOC/g gravel), followed by Module B (4.29−6.89 mg TOC/g gravel), Module A (0.779−1.20 mg TOC/g gravel), and D (0.481−0.905 mg TOC/g gravel). The outlet could screen more TOC than the inlet, probably because organic carbon content largely attaches to sandy materials with a particle size smaller than 0.18 mm via electrostatic force (Sizirici et al., 2019), and move with the water inside the filter modules. This observation further implied the best performance of TOC removal by Module B and Module C due to trapping the largest proportion (43.5−100% or 62.5−63.6%) of 0.18 mm sand.

3.4. Comparison of filter performance in the Round 1 and 2 site trial tests

The filter performances in the low-turbidity (Round 1) and high-turbidity (Round 2) conditions in the dry season were compared as follows (Table 2): (i) The inlet turbidity in the Round 2 (703−708 NTU) site trial test was much higher than that of the Round 1 site trial test (247−253 NTU), which resulted in much more obvious "overflow" as evidenced by more "Overflow" data (37.7−51.7% *vs.* 16.0−20.1%) observed in the Round 2 site trial test; (ii) Module B (50−80 mm) exhibited the best performance in the low-turbidity condition; however, Module B was more prone to clogging in the high-turbidity condition as evidenced by the lower outlet turbidity removal (93.2% *vs.* 94.3%), sand (especially < 0.18 mm, 51.2% *vs.* 71.8%) removal efficiency (0.148 *vs.* 0.372 mg sand/g gravel), and TOC removal efficiency (5.59 *vs.* 8.50 mg TOC/g gravel); (iii) Module C (80−120 mm) exhibited the best performance in the high-turbidity condition, because larger-sized gravel effectively trapped more sand (0.344 *vs.* 0.209 mg sand/g gravel) (especially < 0.18 mm, 64.4% *vs.* 26.0%) and TOC (15.2 *vs.* 5.71 mg TOC/g gravel) with higher outlet turbidity removal (99.6% *vs.* 83.8%).

Table 2. Comparison of the filter performances (Round 1 and 2).

	Low turbidity (Round 1)		High turbidity (Round 2)	
	Module B (50–80 mm)	Module C (80–120 mm)	Module B (50–80 mm)	Module C (80–120 mm)
Inlet turbidity (NTU)	247	253	708	703
"Overflow" data (%)	20.1	16.0	51.7	37.7
"Negative Turbidity Removal" data (%)	19.6	38.2	2.4	0.4
Average outlet turbidity removal (%)	94.3	83.8	93.2	99.6
Average sand removal efficiency (mg sand/g gravel)	0.372	0.209	0.148	0.344
Average proportion of trapped sand < 0.18 mm (%)	71.8	26.0	51.2	64.4
Average TOC removal efficiency (mg TOC/g gravel)	8.50	5.71	5.59	15.2

3.5. Recommendations

Due to the high content of suspended solids in the river, the filter modules should be thoroughly cleaned every two months in the dry season and at the end of the wet season. Gravel filters are cleaned manually using high-pressure water jets followed by grabbing of sediment in the sand trap. A backwash system with a diffuser installation can be considered within the instream filtering system for automated cleaning of gravel filters. With reference to the "Surface Water Treatment by Roughing Filters - A Design, Construction, and Operation Manual" (Martin Weglin, 1996), the filtering system (length of 4–9 m) would be better located in a river section with a flowrate of 0.3–1.5 m^3/h, water depth of 1.1–1.5 m, and water turbidity level below 500 NTU, which can serve as a useful benchmark for future applications.

4. Conclusions

The in-stream filter system with an appropriate gravel size could effectively remove SS and TOC from the river water. The small-sized boulders (50–80 mm) had the best performance under the low-turbidity (~250 NTU) condition in dry flow; however, filter clogging was observed after the fourth week of the site trial test. After cutting off the side nest in between the two cages to prevent filter clogging, larger boulders (80–120 mm) had the best performance under the high-turbidity (~705 NTU) condition with no obvious filter clogging after two months of operation. Compared with the module inlet, the module outlet could screen more sand especially with a particle size smaller than 0.18 mm and TOC. For the instream filtering system to be implemented in other nullahs in Hong Kong, larger dimensions with possible flow control measures could be considered when the site conditions allow. It is also suggested to formulate future design of filter sizing criteria based on targeted rainfall events and specific hydrologic objectives.

Appendix

1. Characterisation of the grabbed solid samples

The samples taken on-site were thoroughly mixed before testing. Four duplicates were conducted for each test. To determine the sand removal efficiency, a certain amount (250 g) of gravel was put into a glass beaker containing 250 mL of distilled water. The beaker was then placed into an ultrasonic water bath for 15 minutes. After sonication, the gravel was carefully washed with 100 mL of distilled water, and dried in a 60°C oven overnight. The remaining water (350 mL) was filtered by filter paper (10 µm pore size). The solid was dried in a 60°C oven overnight. The sand removal efficiency (mg sand/g gravel) was calculated as: solid weight (mg) / 250 g gravel. To determine the particle size distribution, the dried solid was sieved into particle sizes of ≥ 1.0 mm, ≥ 0.6 mm, and ≥ 0.18 mm, and each proportion was weighed, respectively. The dried gravel was heated at 450°C for three hours. The organic content on the gravel surface was determined by measuring the mass difference. The filtrate was tested by a TOC analyser after passing through a 0.45-µm filter. The organic removal efficiency (mg TOC/g gravel) was calculated as: [filtrate TOC concentration (mg/L) × 350 mL + mass difference of gravel before and after heating (mg)] / 250 g gravel.

Table A1. The silt removal efficiency of the four sand traps during the site trial tests.

Round	Testing period	Trapped silt volume (m^3)	Efficiency (m^3/d)
1	2019/12/16 to 2019/12/27	2.25	0.250
	2019/12/27 to 2020/1/2	1.55	0.222
	2020/1/2 to 2020/1/9	1.23	0.153
	2020/1/9 to 2020/1/16	1.95	0.216
2	2020/2/10 to 2020/2/21	2.28	0.190
	2020/2/21 to 2020/2/28	2.56	0.320
	2020/2/28 to 2020/3/5	2.50	0.357
	2020/3/5 to 2020/3/12	2.52	0.314
	2020/3/12 to 2020/3/19	2.86	0.358
	2020/3/19 to 2020/3/26	1.98	0.283

Table A2. Performances of the different filter modules based on analysis of the on-line monitoring data (Round 1).

Filter Module	Week	Average Inlet Turbidity (NTU)	"Overflow" data (%)	"Negative Turbidity Removal" data (%)	Average Turbidity Removal (%)
Module A	1−2	300	4.20	15.0	87.7
	3	291	14.5	44.4	85.9
	4	261	23.0	61.2	54.7
Module B	1−2	374	19.2	13.7	97.0
	3	197	19.5	17.0	93.2
	4	169	21.7	28.2	92.6
Module C	1−2	302	14.4	27.1	89.1
	3	224	16.8	35.4	82.7
	4	234	16.9	52.1	79.7
Module D	1−2	334	46.4	10.5	86.7
	3	216	55.0	37.9	81.7
	4	268	60.7	95.4	34.4

Table A3. Performances of filter modules B and C based on analysis of the on-line monitoring data (Round 2).

Filter Module	Week	Average Inlet Turbidity (NTU)	"Overflow" data (%)	"Negative Turbidity Removal" data (%)	Average Turbidity Removal (%)
Module B	2−3	234	30.8	0.7	94.4
	4	1079	42.2	0.7	77.1
	5	1042	58.4	1.0	98.9
	6	622	60.4	2.8	97.5
	7	563	66.6	6.8	98.3
Module C	2−3	86.8	30.1	0.0	98.6
	4	1057	36.3	0.0	99.7
	5	1023	36.7	0.0	99.9
	6	656	37.8	0.0	99.8
	7	692	47.5	1.9	99.9

Table A4. Performances of different filter modules based on analysis of the grabbed water samples (12 samples were taken in total) (Round 1).

Filter Module	Number of "Negative Turbidity Removal" data	Average removal of SS (%)
A	6	25.7
B	6	43.4
C	5	32.9
D	9	27.4

Table A5. Performances of filter modules B and C based on analysis of the grabbed water samples (18 samples were taken in total) (Round 2).

Filter Module	Number of "Negative Turbidity Removal" data	Average removal of SS (%)
B	12	35.5
C	12	13.2

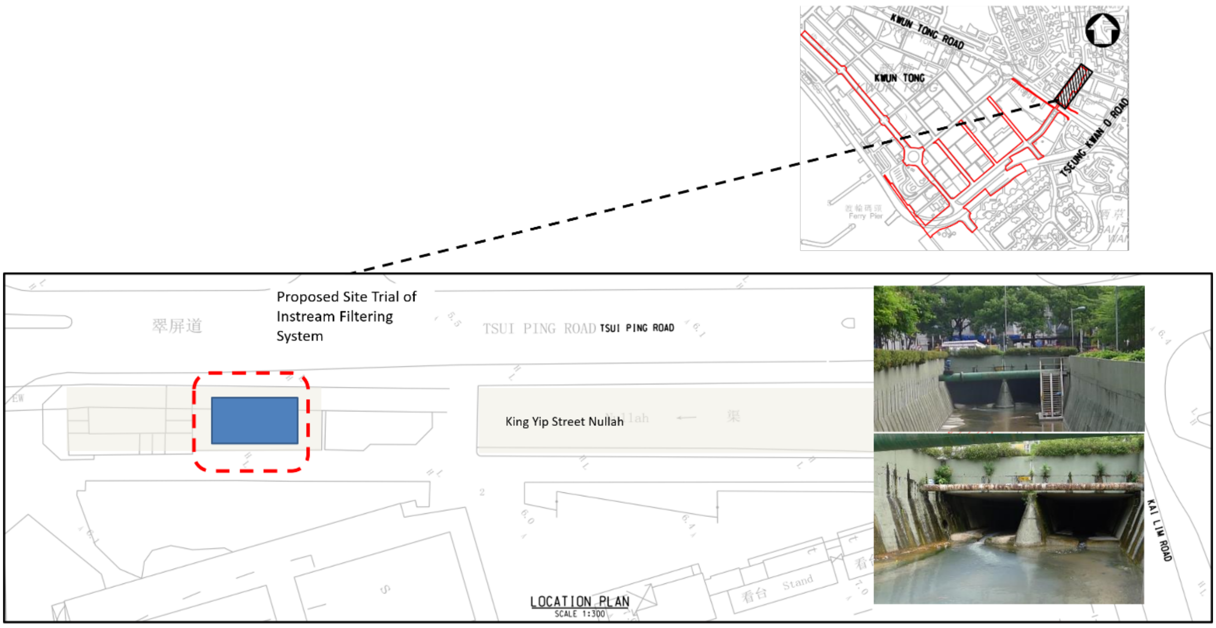

Figure A1. Location of the instream filtering system.

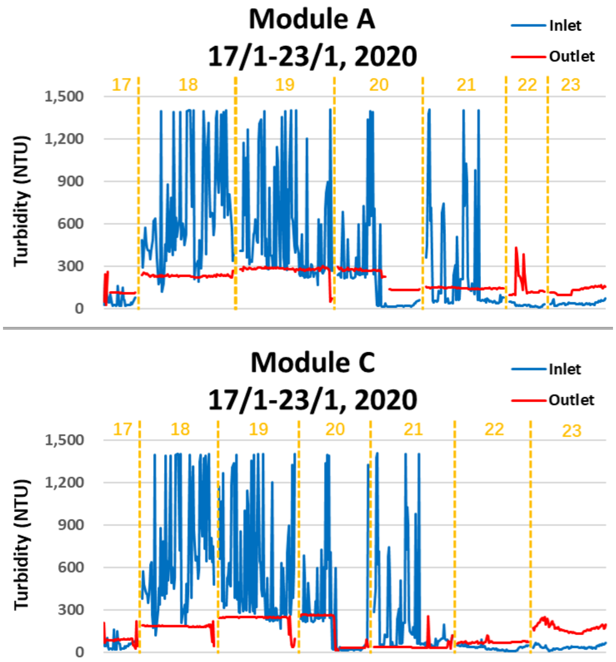

Figure A2. Comparison of the inlet and outlet turbidity of Modules A and C during weeks 5–6 in the Round 1 site trial test.

Acknowledgements

The authors appreciate the financial support from the Hong Kong Environment and Conservation Fund (ECF Project 87/2017) and Drainage Services Department of the Government of the Hong Kong Special Administrative Region for this study. We are also grateful for the tremendous help from Mr Kwan Po Ng and Mr Ho Chuen Tseung in conducting the site trial tests.

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