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The Potential Usage of Porous Channel for Reducing Puddle and Flood in Southern Rayon of Sidoarjo

Nawang Wulan* and Harmin Sulistiyaning Titah

Post Graduate Program of Environmental Sanitation Engineering,
Department of Environmental Engineering,
Institut Teknologi Sepuluh Nopember (ITS) Surabaya, Indonesia

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ABSTRACT

This research was conducted to determine the level of infiltration using porous channel when it was applied in Southern Rayon of Urban Sidoarjo. The application of porous channels in high population area is possible to reduce puddle and flood due to the porous channels does not require large area. The aims of the study were to determine permeation rate to reduce the discharge water of porous channels in its application in Sidokare Watershed and Sekardangan Watershed and to determine water quality from the filtration media channel. A percolation test was carried out in soil around the tertiary channels. Water sample from existing of drainage swale were taken to measure some parameters. Biochemicals oxygen demand (BOD), Total Suspended soild (TSS), detergents and *Escherichia coli* in the water in from existing channel was filtered through permeable media, i.e. natural land, natural grassy land, sand, and gravel. Based on the results, the highest removal of BOD, TSS, detergents and *E. coli* were occured at reactor with natural grassy land. Meanwhile, sand media showed a small differences removal than natural grassy land but it has the highest percolation rate, so it could be applied in a design of porous channel. Porous channel can reduce 40.4% of the discharge water that cannot be accommodated in Sidokare Watershed and 62% in Sekardangan Watershed.
KEYWORDS: drainage swale, percolation test, permeable, pollutants, porous channels

INTRODUCTION

Topography Sidoarjo regency is relatively low and flat. This geographical condition resulted in Sidoarjo potential for flooding because the water is difficult to flow by gravity. The usage of land in Sidoarjo is very quickly changed, especially of agricultural land into residential and industrial. Changes in land use which was originally open being awakened to increase the run-off because of the amount of infiltration or reduced water park. Increasing of run-off can cause over flow of the rain water discharge. It due to the dimensions of existing channels were not enough to accommodate the rain water discharge. It occurred on the drainage system in Southern Rayon of Sidoarjo (Sidokare Watershed and Sekardangan Watershed). Those area were a densely populated urban areas. If the drainage system planning were still apply the old paradigm i.e excess rain water flowed into the sea as soon as possible (drainage), so that the channel dimensions required will be even greater. Eco-drainage must be applied so that the problems in the drainage system could be dissolved. Eco-drainage methods include a ponds, river side polder, development of groundwater protection area, porous channels and infiltration wells [1]. In the urban environment which is identical with the dense population, methods of porous channels most likely to be applied. Porous channels do not require special land, but just change the channel construction of conventional watertight into not watertight.

There are a standard precast hollow channel. The Standard SNI 03-6966-2003 [2] is about specifications of precast hollow channel rain water for neighborhoods but the main requirement is not allowed to receive and drain the wastewater. Drainage channels, especially at tertiary channel which is the first recipient of the local drainage system in Sidoarjo still using the system mixed with domestic waste. This is why the implementation of SNI 03-6966-2003 inapplicble. The need for feasibility study of waste water to be absorbed into the ground whether it will affect the quality of ground water or not.

***Corresponding Author:** Nawang Wulan, Post Graduate Program of Environmental Sanitation Engineering, Department of Environmental Engineering, Institut Teknologi Sepuluh Nopember (ITS) Surabaya, Indonesia. email: wul4n_84@yahoo.com

METHODS

Study Area

The study area in this research using hydrological boundary is on Drainage Systems Sidoarjo South Rayon. Drainage Systems Sidoarjo South Rayon include Sidokare Watershed and Sekardangan Watershed, can be seen in Figure 1 below [3].

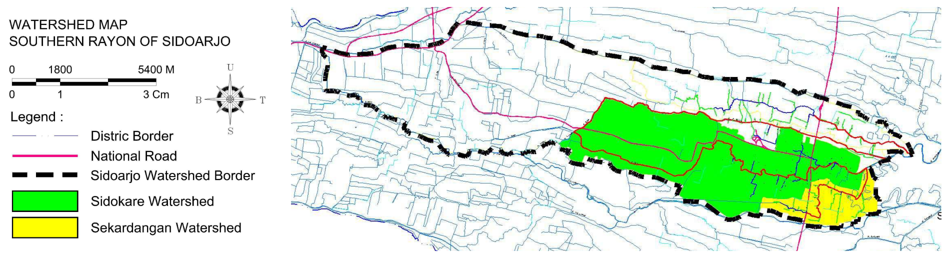

Figure 1. Watersheds Map Drainage Systems Sidoarjo South Rayon

Data Collection

Primary data includes :

a. Perform percolation test were conducted at two (2) locations that have different soil types, those were alluvial taupe and alluvial hidromof. Percolation tests was carried out by making a holesat sampling location. The hole should been covered so the holes were not exposed to rain. This percolation test data was used to measure permeability of the soil..
b. The types of urban soil in Sidoarjo South Rayon (Sidokare Watershed and Sekardangan Watershed) were alluvial hidromof and alluvial taupe. Sidokare Watershed dominated by alluvial taupe [4]. Meanwhile, Sekardangan Watershed consists of two types of alluvial taupe and alluvial hidromof. Locations of percolation tests based on both the type of the soil, so the rate of percolation of the two types of soil can be compared. Therefore percolation test location point was elected in Sidokare Watershed for the kind of alluvial taupe and alluvial hidromof at Sekardangan Watershed. The sampling were conducted using grab sampling method and it used a tube of PVC pipe 4-" to take soil samples.

Procedures

Technical Analysis (Quantity)

a. Measurement of the local percolation rate
   Recording a decrease of water at points percolation test. The experiments were held for 3 times with each experimental trial with 3 days old. Calculated the average rate of the permeate.
b. The calculation of the quantity of infiltration channels Porus
   Percolation tests were used to calculate data of local soil permeability. The permeability values used in the calculation of the quantity of infiltration obtained by using the formula 1 [5]

$$B = \frac{Q}{f.K.H}\left(1 - \exp(-\frac{f.K.T}{b})\right)$$

by: B = length of the channel (m)
b = width of the channel (m)
T = time stream (s)
Q = water discharge (m3 / s)
H = effective depth of the channel (m)
f = geometric factor (m/ m)
K = coefficient of soil permeability (m / s)

Quality Analysis

Environmental quality analysis was carried out using a reactor in laboratory scale. The reactor were made from PVC pipe with diameter of 4" and height of 55 cm. The reactor filled with material as high as 40 cm and 15 cm of water (Figure 2). Those materials were natural land, grassy natural land, sand and gravel (Figure 3). Water samples were taken from the channel at the some points and those were indicated as a initial quality. After that, some of parameters i.e BOD, TSS, Detergent and E.coli were measure at influent and effluent from each reactor [6].

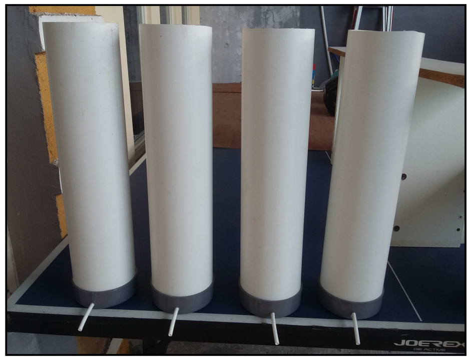

Figure 2. Filtration Tube

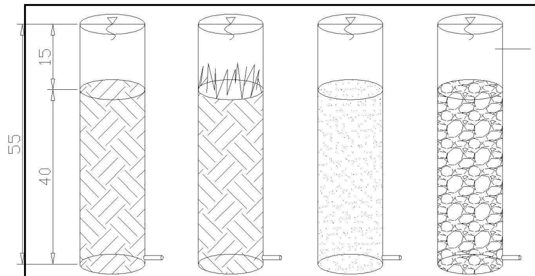

Figure 3. Filtration Tube with permeable material

RESULTS AND DISCUSSION

Technical Analysis

Permeability coefficient (K) was taken from the average value of the three trials, each experiment was conducted over three consecutive days. Permeability coefficient for alluvial soil types taupe is 2.1605 x 10^{-5} cm / sec while the alluvial hidromof 1.1510 x 10^{-5} cm / sec.

The calculation of water discharge was affected by the channel length and a time each flow. This calculation used the formula 1. Calculation was applied to tertiary channels as an example of the Sidokare Watershed and Sekardangan Watershed. The results of calculation in each watershed was shown in Table 1 and 2, respectively.

Table 1. Calculation Result Water Discharge in Sidokare Watershed

Channel Name	B (m)	f (m/m)	K (m/sec)	H (m)	T (sec)	b (m)	b' (m)	$Q_{filtration}$ (m^3/sec)
	1	2	3	4	5	6	7	8
Suko Channel	140.72	2.04	2.1605 x 10^{-7}	0.8	288	0.8	0.8	0.3127
Puri 2 Channel	803.5	2.04	2.1605 x 10^{-7}	0.6	1858	0.8	0.8	0.2077
Puri 3 Channel	130.03	2.29	2.1605 x 10^{-7}	0.5	322.2	0.9	0.9	0.1816
Puri 4 Channel	158.24	2.55	2.1605 x 10^{-7}	0.9	284.4	1	1	0.5008
Pondok Mutiara 4 Channel	426.38	2.04	2.1605 x 10^{-7}	0.6	985.8	0.8	0.8	0.2077
Pondok Mutiara 3 Channel	449.42	1.53	2.1605 x 10^{-7}	0.5	1259	0.6	0.6	0.1071
Sumokali 2 Channel	87.05	2.90	2.1605 x 10^{-7}	0.5	200.4	1	1.3	0.2172

Sepande Channel	792.56	3.82	2.1605 x 10^{-7}	0.8	1303	1.5	1.5	0.7301
Sidokare 2 Channel	108.47	1.27	2.1605 x 10^{-7}	0.5	323.4	0.5	0.5	0.0839
Tamanpinang 3 Channel	638.94	3.05	2.1605 x 10^{-7}	0.8	1127	1.2	1.2	0.5442
Sidokare Asri 1 Channel	193.59	2.55	2.1605 x 10^{-7}	0.5	467.4	1	1	0.2071
Sidokare Asri 4 Channel	343.17	2.04	2.1605 x 10^{-7}	0.8	702.6	0.8	0.8	0.3127
Perum Palm Fiesta Channel	74.39	1.27	2.1605 x 10^{-7}	0.4	254.4	0.5	0.5	0.0585
GOR 1 Channel	428.44	3.12	2.1605 x 10^{-7}	0.8	730.8	1	1.5	0.4691
GOR 2 Channel	938.77	4.18	2.1605 x 10^{-7}	0.8	1478	1.5	1.8	0.7623
Magersari 3 Channel	87.71	1.53	2.1605 x 10^{-7}	0.6	225	0.6	0.6	0.1403
Dinas Sosial Channel	557.36	2.55	2.1605 x 10^{-7}	1	966.6	1	1	0.5768
Sidokare Indah 2 Channel	116.34	1.53	2.1605 x 10^{-7}	0.6	298.2	0.6	0.6	0.1405
Sidokare Indah 4 Channel	247.15	6.36	2.1605 x 10^{-7}	0.7	388.2	2.5	2.5	1.1143
Ci Walk 2 Channel	206.45	2.04	2.1605 x 10^{-7}	0.5	353.4	0.8	0.8	0.2337
Gang Daleman Channel	127.97	1.53	2.1605 x 10^{-7}	0.6	327.6	0.6	0.6	0.1406
Magersari 2 Channel	264.58	3.05	2.1605 x 10^{-7}	0.7	482.4	1.2	1.2	0.4279
Teuku Umar 1 Channel	53.46	1.02	2.1605 x 10^{-7}	0.4	178.8	0.4	0.4	0.0478
Teuku Umar 2 Channel	95.76	1.02	2.1605 x 10^{-7}	0.4	319.8	0.4	0.4	0.0479
Ramayana Channel	67.78	3.60	2.1605 x 10^{-7}	0.8	114	1	2	0.4757
BCF 2 Channel	1658.7	2.55	2.1605 x 10^{-7}	1	2877	1	1	0.5770
Perum Bulu Kidul 2 Channel	250.5	1.27	2.1605 x 10^{-7}	0.5	747.6	0.5	0.5	0.0838
Perum Bulu Kidul 3 Channel	564.07	1.27	2.1605 x 10^{-7}	0.5	1683	0.5	0.5	0.0838

Table 2. Calculation Result Water Discharge in Sekardangan Watershed

Channel Name	B (m)	f (m/m)	K (m/sec)	H (m)	T (sec)	b (m)	b' (m)	$Q_{filtration}$ (m^3/sec)
	1	2	3	4	5	6	7	10
Sumokali 3 Channel	246.09	1.53	1.151 x 10^{-7}	0.6	630.6	0.6	0.6	0.1405
Larangan Permai 1 Channel	87.23	2.04	1.151 x 10^{-7}	0.8	178.8	0.8	0.8	0.3122
Tenggulunan 1 Channel	279.63	2.55	1.151 x 10^{-7}	0.8	525.6	1	1	0.4256
Larangan Permai 2 Channel	245.6	2.39	1.151 x 10^{-7}	0.8	463.8	0.8	1.1	0.3389
Larangan 1 Channel	171.69	1.53	1.151 x 10^{-7}	0.6	439.8	0.6	0.6	0.1405
Kepodang Channel	105.32	1.02	1.151 x 10^{-7}	0.4	386.4	0.4	0.4	0.0436
Kahuripan Channel	213.49	1.27	1.151 x 10^{-7}	0.5	637.2	0.5	0.5	0.0838
Celep Channel	211.41	1.78	1.151 x 10^{-7}	0.7	479.4	0.7	0.7	0.2161
Sumbawa 1 Channel	191.07	1.78	1.151 x 10^{-7}	0.7	433.2	0.7	0.7	0.2161
Sekardangan Indah Channel	251.12	1.53	1.151 x 10^{-7}	0.6	643.2	0.6	0.6	0.1406
Sumbawa 2 Channel	191.07	1.78	1.151 x 10^{-7}	0.7	433.2	0.7	0.7	0.2161
Green Park Regency 1 Channel	948.16	4.30	1.151 x 10^{-7}	1	1327.8	1.5	1.9	1.0714
Bumi Intan Channel	245.5	1.15	1.151 x 10^{-7}	0.45	804.6	0.45	0.45	0.0618
Citraloka Residence Channel	203.08	0.76	1.151 x 10^{-7}	0.3	1047.6	0.3	0.3	0.0174

The result of the calculation of discharge that can not be accommodated were shown in Table 1 and 2, respectively. Those results can be used to determine the potential reduction of puddle and flooding. Reducing of over flow discharge were occurred due to Table 3 and 4. Total of overflow discharge on the existing condition of 28 (twenty eight) channel tertiary Sidokare Watershed was 14.19 m3 / sec while after it impregnated to 8.46 m3 / sec. The application of porous channels can reduce the flow of water can not be accommodated 5.73 m^3 / sec or 40.4%. Total of overflow discharge on the 14 (fourteen) tertiary channel in Sekardangan Watershed was 3.81 m3 / sec. Debit that could not absorbed was reduced to 1.44 m3 / sec after the application of porous channels. Reduction of overflow discharge in Sekardangan Watershed was 2.37 m3 / sec or 62%.

Table 3. Q overflow reduction on teritery channel in Sidokare Watershed

Channel Name	Q_{design} (m^3/sec)	$Q_{channel}$ (m^3/sec)	$Q_{overflow}$ (m^3/sec)	$Q_{filtration}$ (m^3/sec)		$Q_{overflow\ after\ filtration}$ (m^3/sec)
	1	2	3 (1-2)	4	(3-4)	
Suko Channel	0.61	0.23	0.38	0.31	0.07	0.07
Puri 2 Channel	0.69	0.14	0.55	0.21	0.34	0.34
Puri 3 Channel	1.52	0.11	1.41	0.18	1.23	1.23
Puri 4 Channel	0.72	0.39	0.33	0.50	-0.17	-
Pondok Mutiara 4 Channel	0.43	0.14	0.29	0.21	0.08	0.08
Pondok Mutiara 3 Channel	0.74	0.06	0.68	0.11	0.57	0.57
Sumokali 2 Channel	3.62	0.14	3.48	0.22	3.26	3.26
Sepande Channel	1.44	0.55	0.89	0.73	0.16	0.16
Sidokare 2 Channel	0.39	0.05	0.34	0.08	0.26	0.26
Tamanpinang 3 Channel	1.09	0.41	0.68	0.54	0.14	0.14
Sidokare Asri 1 Channel	0.38	0.12	0.26	0.21	0.05	0.05
Sidokare Asri 4 Channel	0.4	0.23	0.17	0.31	-0.14	-
Perum Palm Fiesta Channel	0.23	0.03	0.2	0.06	0.14	0.14
GOR 1 Channel	1.21	0.42	0.79	0.47	0.32	0.32
GOR 2 Channel	0.74	0.61	0.13	0.76	-0.63	-
Magersari 3 Channel	0.27	0.09	0.18	0.14	0.04	0.04
Dinas Sosial Channel	0.6	0.46	0.14	0.58	-0.44	-
Sidokare Indah 2 Channel	0.28	0.09	0.19	0.14	0.05	0.05
Sidokare Indah 4 Channel	1.1	0.8	0.3	1.11	-0.81	-
Ci Walk 2 Channel	0.23	0.14	0.09	0.23	-0.14	-
Gang Daleman Channel	0.15	0.09	0.06	0.14	-0.08	-
Magersari 2 Channel	1.11	0.34	0.77	0.43	0.34	0.34
Teuku Umar 1 Channel	0.15	0.03	0.12	0.05	0.07	0.07
Teuku Umar 2 Channel	0.16	0.03	0.13	0.05	0.08	0.08
Ramayana Channel	0.53	0.44	0.09	0.48	-0.39	-
BCF 2 Channel	0.58	0.46	0.12	0.58	-0.46	-
Perum Bulu Kidul 2 Channel	1.02	0.05	0.97	0.08	0.89	0.89
Perum Bulu Kidul 3 Channel	0.5	0.05	0.45	0.08	0.37	0.37
	QNA existing Total		**14.19**	**QNA reduction Total**		**8.46**

Legend : Secure Channel

Table 4. Q Not Acomodate (QNA) reduction on teritery channel in Sekardangan Watershed

Channel Name	Q_{design} (m^3/sec)	$Q_{channel}$ (m^3/sec)	$Q_{overflow}$ (m^3/sec)	$Q_{filtration}$ (m^3/sec)		$Q_{overflow\ after\ filtration}$ (m^3/sec)
	1	2	3 (1-2)	4	(3-4)	
Sumokali 3 Channel	0.59	0.09	0.5	0.14	0.36	0.36
Larangan Permai 1 Channel	0.36	0.23	0.13	0.31	-0.18	-
Tenggulunan 1 Channel	0.5	0.32	0.18	0.43	-0.25	-
Larangan Permai 2 Channel	0.49	0.29	0.2	0.34	-0.14	-
Larangan 1 Channel	0.45	0.09	0.36	0.14	0.22	0.22
Kepodang Channel	0.48	0.02	0.46	0.04	0.42	0.42
Kahuripan Channel	0.26	0.05	0.21	0.08	0.13	0.13
Celep Channel	0.32	0.15	0.17	0.22	-0.05	-
Sumbawa 1 Channel	0.22	0.15	0.07	0.22	-0.15	-
Sekardangan Indah Channel	0.52	0.09	0.43	0.14	0.29	-
Sumbawa 2 Channel	0.31	0.15	0.16	0.22	-0.06	-
Green Park Regency 1 Channel	1.49	0.95	0.54	1.07	-0.53	-
Bumi Intan Channel	0.29	0.09	0.2	0.06	0.14	0.14
Citraloka Residence Channel	0.21	0.01	0.2	0.02	0.18	0.18
	QNA existing Total		**3.81**	**QNA reduction Total**		**1.44**

Legend : [ ] Secure Channel

Quality Analysis

The result of laboratory tests can be seen in Table 5 and 6. The laboratory test result showed that the different in value for each parameter at each reactor. Natural land and grassy natural land were most effectively to remove BOD, TSS, Detergent and *E.coli* but it has a low percolation rate [7]. Capability of sand to remove pollutant were slightly below natural land and grassy natural land. Percolation rate of sand was very high. Therefore sand could be applied in a design of porous channel.

Tabel 5. Laboratory Tests Suko Channel

	Suko Channel				
	Basic	**Natural Land**	**Grassy Natural Land**	**Sand**	**Gravel**
TSS (mg/L)	24	14	16	20	90
BOD (mg/L)	20	16	10	36	22
Detergent (mg/L)	5.97	0.03	0.04	1.01	5.15
***E. coli* (/100mL)**	16×10^6	15×10^4	14×10^4	12×10^6	28×10^5

Tabel 6. Laboratory Tests Sekardangan Channel

	Sekardangan Channel				
	Basic	**Natural Land**	**Grassy Natural Land**	**Sand**	**Gravel**
TSS (mg/L)	72	36	14	14	136
BOD (mg/L)	193	9	6	15	207
Detergent (mg/L)	17.28	0.22	0	0.58	0.58
***E. Coli* (/100mL)**	28×10^8	19×10^6	18×10^6	22×10^6	23×10^7

CONCLUSION

The application of porous channels can reduce discharge of water debit that can not be accommodated at 5.73 m^3/sec or 40.4% on Sidokare Watershed and or 2.37 m^3/sec or 62% Sekardangan Watershed. The best media filtration to reduce pollutant was the grassy natural land media. But when viewed from a more effective seepage the sand filtration media was more effective.

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