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PRELIMINARY INFLOW AND INFILTRATION STUDY OF SEWERAGE SYSTEMS FROM TWO RESIDENTIAL AREAS IN KUANTAN, PAHANG

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ABSTRACT

Sewerage system is the sole infrastructure which conveys sewage to sewerage treatment plants. The usage of a sewerage system should be optimized at the design stage to enhance environmental protection and human health. Wastewaters flows are produced from domestic sewage whereas inflow and infiltration come from surface runoff and groundwater. The purpose of this study is to identify inflow and infiltration in sewerage systems around Kuantan. This study was conducted in residential catchments at Taman Lepar Hilir Saujana and Bandar Putra with population equivalent of 1253 and 1694, respectively. ISCO 674 Rain Gauge was used to measure rainfall intensity. ISCO 2150 and 4250 Area Velocity Flowmeters were collected wastewater flowrate data which measured at 5-minute intervals and analyzed separately for wet and dry period. Infiltration rate was obtained by comparing the upstream flow and downstream flow from the two selected manholes. Based on the result, the average infiltration rate of Q_{peak} and Q_{ave} was 13.7% and 21.2% higher than the 5% and 10% stated in Hammer and Hammer. Inflow and infiltration is a concern and more comprehensive studies are needed to initiate the review of a revised infiltration rate that is more relevant to the future climate.

Keywords: *sewerage system; infiltration rate, inflow; surface runoff; groundwater.*

1. INTRODUCTION

Sewerage systems are important and the sole infrastructure that transports untreated wastewater to sewerage treatment plants to undergo treatment before it is released into natural water bodies. (Read, 2004)(Yap & Ngien, 2015). Wastewaters are generated from domestic, residential, industrial and commercial sources (Ansari, Almani & Memon, 2013). Sewerage system plays a critical role in that it supports public health and environmental protection (Ngien & Ng, 2013). Vitrified clay pipe is the most common material used in Malaysian sewer pipeline networks where the pipe diameter is at least 0.225m while the length of the pipes ranges from 0.91m to 2.5m (National Water Services Commission (SPAN), 2009).

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Malaysia is a tropical country, with the area of Kuantan receiving a relatively high rainfall of between 0.16m to 0.19m each year (Win & Win, 2014). Thus, the separate sewer system is usually applied to separate storm water and sanitary water in order to prevent overloading of sewerage treatment plants, which may pose significant risks to public health (Ngien, Othman & Ahmad Abdul Ghani, 2014). It has been found that inflow and infiltration is one of the major problems causing sewerage systems to overflow. The purpose of this study is to identify the pattern of inflow and infiltration in sewerage systems around Kuantan, Pahang.

2. INFLOW AND INFILTRATION

Inflow is defined as water that flows from above the ground into sewer pipelines through either manhole covers or surface drains and reduces the capacity of the sewer pipelines (Bizier, 2007). Generally, inflow will be measured during wet weather. On the other hand, infiltration is defined as underground water that flows into sewer pipelines through cracks in pipeline defects or loose joints (Karpf et al., 20011). Inflow and infiltration becomes critical when rainfall happens due to rainfall runoff and extraneous flows into the sewerage system (Ashley et al., 2008). When inflow and infiltration overwhelms a sewerage system, some of the untreated wastewater will likely overflow onto roads and streets and subsequently make their way into storm drains, ending up in receiving waters without going through any treatment processes. Many factors will lead to foul water overflows in sewerage systems, among them are infiltration, blockages and improper design. In terms of cost, it is very costly to maintain or repair an improperly designed sewerage system. Thus, it is necessary to consider inflow and infiltration when designing a sewerage system (Rahman et al., 2003). The maximum allowable infiltration rate is 50 liters/mm diameter/km of sewer/day as stated in the Malaysian Sewerage Industry Guideline (MSIG), Volume III Clause 2.1.14 (SPAN, 2009). Besides that, according to Hammer and Hammer (2012) the percentage infiltration rate of peak flow and average flow is 5% and 10% (Hammer & Hammer, 2012).

Based on previous studies in Skudai, Johor, the same conclusion was reached which is that the infiltration rate in the sewerage systems studied are in excess of the infiltration limit stated in MSIG and Hammer & Hammer (Rahman et al., 2007) (Kamran, 2005) (Rahman et al., 2003). Another study in Norway, it was demonstrated that extraneous sources entering into sewer systems would overload the capacity of the sewer pipeline and increase the cost of maintenance required (Beheshti, Saegrov & Ugarelli, 2015). Another case study was done in Columbus where 116 private houses were investigated. The result showed that 68% of the sewer pipeline was tested and inflow and infiltration occurred in the residential area (Pawlowski et al., 2014). This is undesirable as it may decrease the sewer capacity as well as the sewage treatment plant efficiency. More comprehensive studies are needed to initiate the review of a revised infiltration rate that is more relevant to the future climate.

3. METHODOLOGY

This research is more focused on fieldwork. The research is divided into several stages such as information gathering, site survey, data collection and data analysis. The industrial collaborator for this research is Indah Water Konsortium Sdn Bhd. (Pahang branch). Initial preparation work has to be done such as meeting with authorized staff to plan the work and to collect more information on each selected site location. Subsequently, site survey of population equivalent (PE) on the selected sites is needed to get an accurate PE value,

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calculated based on MS 1228:1991 Table 1 (MS 1228:1991). PE survey has to be done based on area serviced by the sewerage system (Ngien & Ng, 2013). In terms of data collection, the flow rate, velocity and depth level of the wastewater were collected in this research. Separate analysis of the data was performed for wet and dry periods.

3.1 Site Study

This research was conducted in two residential catchments in Kuantan, Malaysia. Two running sewers were selected in Taman Lepar Hilir Saujana and Bandar Putra as designated as MH 84 – MH 85 and MH 92a – MH 92b, respectively. The PE for Taman Lepar Hilir Saujana and Bandar Putra was counted to be 1253 and 1694, respectively. The length of running sewer selected of Taman Lepar Hilir Saujana and Bandar Putra was 35.2m and 25.7m, respectively. Meanwhile, the diameter of the sewer pipeline in Taman Lepar Hilir Saujana and Bandar Putra was 225mm and 500mm, respectively. Figure 1 and Figure 2 show the sewer reticulation layout and the location selected. The selection of the sewer pipeline was based on the criteria where the sewers have uniform diameter, no connection and no branch in between the sewer pipeline (Rahman et al., 2003).

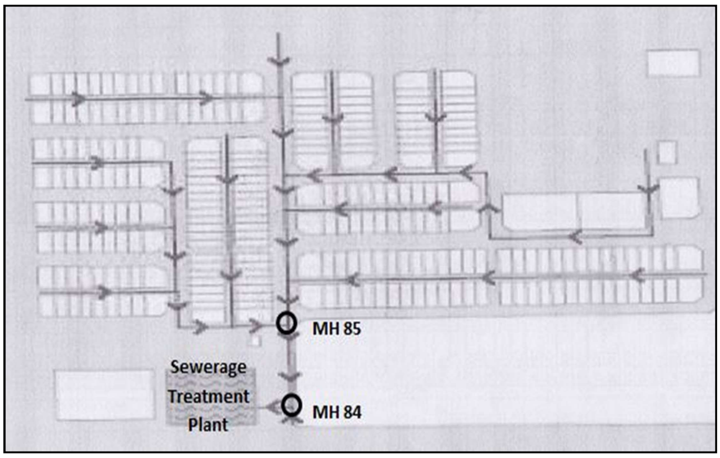

Figure 1: Sewer reticulation layout at Taman Lepar Hilir Saujana

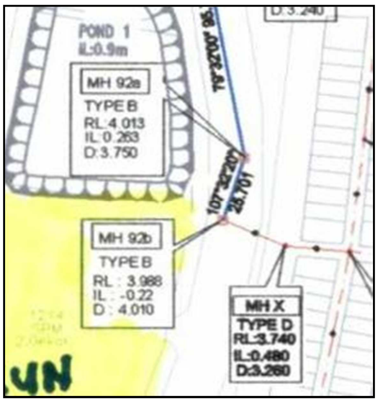

Figure 2: Sewer reticulation plan at Bandar Putra

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3.2 Equipement and Material Used

ISCO 2150 and 4250 Area Velocity Flowmeters were adopted to measure, the foul water flow rate in the selected running sewers and are shown in Figure 3. Calibration of both flowmeters was conducted in the Hydraulics and Hydrology Laboratory of Universiti Malaysia Pahang (UMP). Both flowmeters were installed separately inside two different manhole as shows in Figure 4. Each of the data was captured once every five minutes for the whole duration of the data collection and the ISCO Flowlink 5.1 software was used to retrieve all the data from both flowmeters (Teledyne ISCO, 2012). Meanwhile, ISCO 674 Rain Gauge was used to measure rainfall intensity at an interval of five minutes and was installed within the perimeter of the adjacent sewage treatment plant in order to prevent unwanted theft.

Figure 3: ISCO 2150 and 4250 Area Velocity Flowmeter

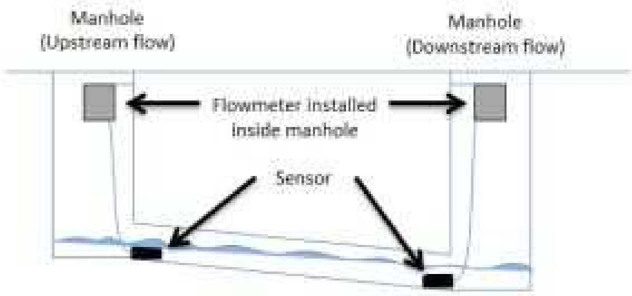

Figure 4: Flowmeters installation in the manholes

3.3 Inflow Infiltration Measurement

Inflow and infiltration can be determined by using the hydraulic concept.

$V_d = V_u + V_{(\text{inflow and infiltration})}$

Where, V_d is the volume of downstream water in the sewer pipeline, V_u stands for the volume of upstream water in the sewer pipeline. $V_{(\text{inflow and infiltration})}$ is known as the volume of inflow and infiltrate into the running sewer. The unit used in this equation is m^3. Meanwhile, infiltration rate can be calculated using the equation below.

Infiltration rate $= (Q_d - Q_u)/(L_{pipe} \times \emptyset_{pipe})$

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Where, Q_d is the downstream flow in m^3/day, Q_u is the upstream flow in m^3/day, L_{pipe} stands for the length of sewer pipeline between the two manholes with unit of km, $\emptyset_{pipe}$ known as the diameter of the sewer pipeline in *mm*.

4. RESULT AND DISCUSSION

This research was conducted at two locations and analyzed separately for wet and dry period. Data for Taman Lepar Hilir Saujana was collected from 30 September 2015 to 17 October 2015 whereas fieldwork for Bandar Putra was done from 26 February 2016 to 9 March 2016.

Figure 5 shows the hyetograph versus infiltration rate at Taman Lepar Hilir Saujana during wet period where rain happened on 1 October 2015. From the hyetograph it can be clearly seen that when rainfall occurred, the infiltration rate at that time will experience a related increase. There was not much increase in infiltration rate due to limited rainfall within that period. Figure 6 shows the downstream flow and upstream flow versus rainfall from 30 September 2015 to 3 October 2015 at Taman Lepar Hilir Saujana. It can be seen that the downstream flow is higher than the upstream flow during the whole period. There was significantly high flow in the sewer when rainfall occurred. Moreover, there was a trend which shows that from 6am to 6.30am as well as from 7pm to 7.30pm, a peak in the flow formed every day even though there was no rainfall. This is because students and workers have to clean themselves up before and after going to school and work. Figure 7 shows the upstream flow and downstream flow together with the rainfall in a hyetograph at Bandar Putra. The graph also shows a similar result where the wastewater flow will gradually increase when rainfall occurs.

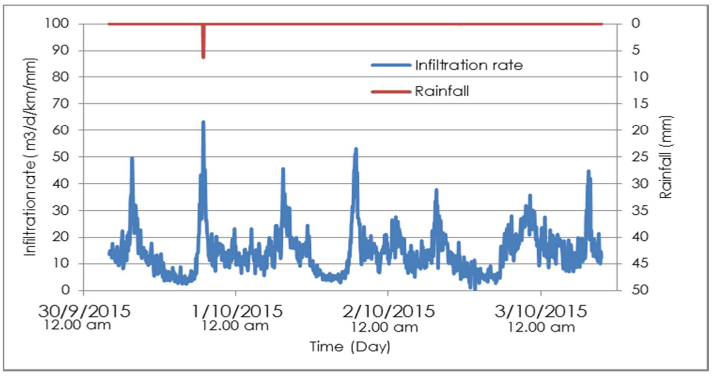

Figure 5: Hyetograph vs inflow and infiltration rate at Taman Lepar Hilir Saujana

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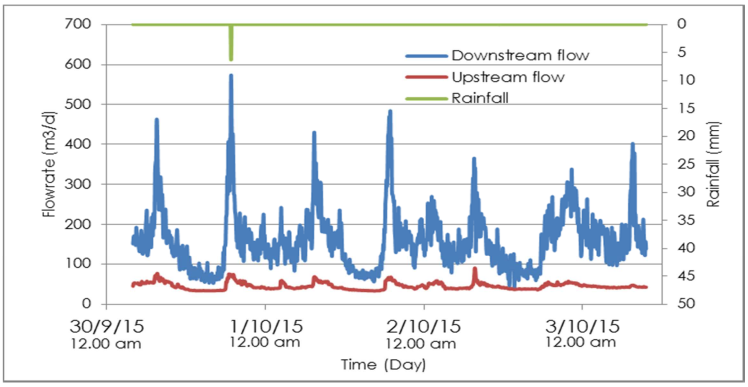

Figure 6: Wastewater flowrate from 30 September 2015 to 3 October 2015 at Taman Lepar Hilir Saujana

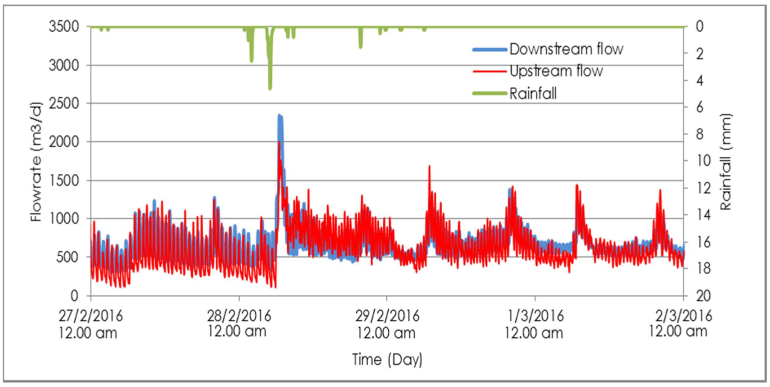

Figure 7: Upstream flow and downstream flow at Bandar Putra

Table 1 showed the infiltration rate results for Taman Lepar Hilir Saujana along 18 days from 30 September 2015 to 17 October 2015. The average infiltration rate at Taman Lepar Hilir Saujana was measured 3.04 $m^3/mm/km/d$. Peak hourly flow was indicated the peak hourly infiltration rate of the day. The highest peak hourly flow was occured on 2 October 2015 with amount of 22.25 $m^3/mm/km/d$. The ratio of downstream flow and upstream flow for Taman Lepar Hilir Saujana was 1.19.

Table 2 showed the summarised infiltration rate at location of Bandar Putra from 26 February 2016 to 9 March 2016. The infiltration rate result showed the range from 0.95 $m^3/mm/km/d$ to 19.41 $m^3/mm/km/d$. Meanwhile, The ratio of downstream infiltration rate to upstream infiltration rate was calculated with amount of 1.20 as well as similar to Taman Lepar Hilir Saujana. This indicates the infiltration in the particular sewer pipeline was occurring.

Based on the result, the resultant infiltration rate of both location Q_{peak} and Q_{ave} were 13.7% and 21.2% higher than 5% and 10% recommended in Hammer and Hammer. Overall, the downstream flow infiltration rate is higher than upstream flow infiltration rate in both locations. Percentage of Q_{peak} infiltration rate was calculated by infiltration rate divided to peak hourly flow from data retrieved. Percentage of Q_{ave} infiltration rate was measured infiltration rate to upstream infiltration rate, where upstream infiltration rate was averaged by every hour in a day. When no rainfall distributed, the infiltration rate was still occurred at Taman Lepar Hilir Saujana and Bandar Putra. This may have happened due to other water

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such as groundwater infiltrating from the ground into the sewer monitored. Groundwater will infiltrate into sewer pipeline through defective pipes and pipe joints.

Table 1: Data and results for Taman Lepar HIlir Saujana

Site	**Date (Year of 2015)**	**Downstream Infiltration Rate (*D*),** $m^3/mm/km/d$	**Upstream Infiltration Rate (*U*),** $m^3/mm/km/d$	**Total Rainfall,** mm	**Infiltration Rate (*I*),** $m^3/mm/km/d$	**Ratio** $= \left[\frac{\sum D}{\sum U}\right]$	**Peak Hourly Flow (*P*),** $m^3/mm/km/d$	**Infiltration Rate (%)** (Q_{peak}) $\left[\frac{I}{P}\right]$	(Q_{ave}) $\left[\frac{I}{U}\right]$
Taman Lepar HIlir Saujana (PE: 1253)	30 Sep	22.98	17.57	0	5.41	1.19	20.62	26.26	30.83
	1 Oct	19.76	16.52	6.30	3.24		20.42	15.88	19.63
	2 Oct	19.49	16.48	0	3.01		22.25	13.53	18.28
	3 Oct	20.43	16.46	0	3.97		18.12	21.88	24.09
	5 Oct	18.82	16.57	0	2.24		18.45	12.16	13.53
	6 Oct	18.37	16.63	0	1.74		18.57	9.37	10.46
	7 Oct	17.12	16.01	0	1.11		17.91	6.19	6.92
	8 Oct	17.52	16.10	0	1.43		19.33	7.37	8.85
	9 Oct	17.36	16.79	0	0.57		21.21	2.71	3.42
	10 Oct	17.81	16.46	0	1.35		17.39	7.75	8.19
	11 Oct	18.58	16.14	0	2.44		17.01	14.33	15.10
	12 Oct	17.51	15.56	0	1.95		16.71	11.67	12.53
	13 Oct	19.91	16.19	36.30	3.72		21.60	17.22	22.98
	14 Oct	21.85	15.62	0	6.23		16.58	37.55	39.86
	15 Oct	19.79	16.19	0	3.59		17.85	20.13	22.19
	16 Oct	21.30	16.32	24.90	4.98		18.42	27.02	30.49
	17 Oct	21.30	16.61	0	4.69		20.45	22.95	28.26

Table 2: Summarised results for Bandar Putra

Site	**Date (Year of 2016)**	**Downstream Infiltration Rate (*D*),** $m^3/mm/km/d$	**Upstream Infiltration Rate (*U*),** $m^3/mm/km/d$	**Total Rainfall,** mm	**Infiltration Rate (*I*),** $m^3/mm/km/d$	**Ratio** $= \left[\frac{\sum D}{\sum U}\right]$	**Peak Hourly Flow (*P*),** $m^3/mm/km/d$	**Infiltration Rate (%)** (Q_{peak}) $\left[\frac{I}{P}\right]$	(Q_{ave}) $\left[\frac{I}{U}\right]$
Bandar Putra (PE: 1694)	26 Feb	50.95	49.32	0	1.63	1.20	80.50	2.03	3.31
	27 Feb	55.70	47.69	0.51	8.01		88.44	9.05	16.79
	28 Feb	70.69	71.64	38.61	0.95		83.17	1.14	1.32
	29 Feb	66.93	65.59	1.02	1.34		93.25	1.43	2.04
	1 Mar	63.44	58.78	0	4.66		67.19	6.93	7.92
	2 Mar	60.31	50.77	0	9.54		97.20	9.82	18.80
	3 Mar	61.01	50.30	0	10.70		93.31	11.47	21.28
	4 Mar	53.13	49.67	0	3.46		80.65	4.29	6.96
	5 Mar	62.49	44.56	7.00	17.93		97.52	18.38	40.24
	6 Mar	57.73	38.75	0	18.98		83.75	22.67	48.99
	7 Mar	57.10	38.57	0	18.52		85.48	21.67	48.03
	8 Mar	56.57	39.34	0	17.23		83.32	20.68	43.81
	9 Mar	56.03	36.62	0	19.41		104.78	18.53	53.01

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5. CONCLUSION

In this research, inflow and infiltration in the sewerage systems of Taman Lepar Hilir Saujana and Bandar Putra, Kuantan, Pahang have been determined. The result shows that the average infiltration rate of Q_{peak} and Q_{ave} at both locations were 13.7% and 21.2% higher than 5% and 10% which mentioned in Hammer and Hammer, respectively. This indicates that there is an enormous amount of water from both above and below ground surface that is infiltrating into sewer systems. It can be concluded that there is a relationship between rainfall and wastewater in sewerage system. Wet period will be contributing more infiltration compared to dry period. This research should be extended to other catchment areas to initiate the review of a revised infiltration rate that is more relevant to the future climate.

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