Statistical Analysis in Fluvial Sediments of Selangor Rivers: Downstream Variation in Grain Size Distribution

Analisis Statistik Sedimen Fluvial Sungai-sungai di Selangor: Perubahan Agihan Partikel Saiz di Hiliran

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ABSTRACT

Statistical analysis and downstream variation in the fluvial sediment mixture were studied along three different rivers in Selangor i.e. Sungai Langat (Sg. Langat), Sungai Selangor (Sg. Selangor) and Sungai Tenggi (Sg. Tenggi). The aim of this study is to analyse the changes in grain size distribution in the downstream direction in three different classes of rivers, less, medium and fully development along the river banks. Samples were spatially and systematically collected at a distance about 3-5 kilometers between each point. Sediments were dried, sieved and further characterised using the GRADISTAT software. Results showed that the mean size of bed materials in Sg. Selangor and Sg. Langat were decreasing along the downstream towards the estuary. Meanwhile, an opposite trend was obtained for Sg. Tenggi where the mean size of the bed material was found increasing towards the downstream of Sg. Tenggi's river mouth. Different variation was also observed for sediment parameters of sorting and skewness which reflect decreasing of sediment size follow the downstream of the rivers. Furthermore statistical analysis of kurtosis showed that there were no variation occurs along the three rivers where most of the sediment mixture is a mesokurtic type, normal distribution of bed sediment sizes. Beside that statistical analysis also show from the bivariate plots indicate that the sediments are mostly medium sand, poorly sorted and has profile of either symmetrical or fine skewed.

Keywords: Grain size distribution; Sungai Langat; Sungai Selangor; Sungai Tenggi

ABSTRAK

Analisis statistik dan perubahan hilir bagi campuran sedimen fluvial dikaji bagi tiga sungai berbeza di Selangor iaitu Sg. Langat, Sg. Selangor dan Sg. Tenggi. Tujuan kajian ini adalah untuk menganalisa perubahan agihan saiz partikel mengikut arah hiliran bagi kelas sungai yang berbeza mengikut aras pembangunan di tebing iaitu kurang, sederhana dan sepenuhnya. Sampel diambil mengambil kira ruang dan bersistematik di mana setiap titik persampelan mempunyai jarak di antara 3-5 kilometer. Sedimen dikeringkan, disaring dan seterusnya dicirikan dengan menggunakan perisian GRADISTAT. Keputusan menunjukkan saiz bagi campuran sedimen dasar di Sg. Selangor dan Sg. Langat menurun mengikut arah hulu ke hiliran muara sungai. Sementara itu profil terbalik diperolehi bagi sedimen di Sg. Tenggi di mana didapati saiz purata sedimen dasar meningkat menuju hiliran Sg. Tenggi. Perubahan yang berbeza turut dilihat bagi parameter statistik pengisihan dan kepencongan dengan penurunan pada arah hiliran sungai. Tambahan pula analisa statistik kurtosis menunjukkan tiada perubahan bagi ketiga-tiga sungai dan kebanyakan campuran sedimen bersifat mesokurtik, saiz sedimen dasar bertaburan secara normal. Selain itu, analisa statistik plot dwivariat pula menunjukkan bahawa sedimen fluvial di kawasan kajian adalah kebanyakannya bersifat pasir sederhana, pengisihan lemah dan mempunyai profil kepencongan sama ada simetri atau kepencongan halus.

Kata kunci: agihan saiz partikel; Sungai Langat; Sungai Selangor; Sungai Tenggi

INTRODUCTION

The grain size distribution is parts of the important fundamental physical attributes of soil and it influences on the properties of soil, such as soil erosion, water movement and productivity (Dongwei et al. 2010). Essential factor of regulating channel morphology and hydraulics is bed material size and its rate affects the sediment transportation and the downstream changes (Reid et al. 1997). Previous study shows that downstream fining factor in fluvial systems was due to selective sorting (Ferguson et al. 1996).

Gasparini et al. (1999) stated that river tributaries can disturb the fining patterns in the fluvial system. In their theory, the combination of selective transport with a model of river-basin showed that downstream fining can be produced either with the factors of selective deposition or abrasion.

In 1999, Rice proved that Sukunka River downstream fining was not affected by abrasion process and strongly agreed by Ferguson et al. (1996) that sorting was the factor in downstream fining along Allt Dubhaig and Paola et al. (1992) then agreed that selective depositions was the natural factors for downstream fining. Different explanation of

downstream fining in Waipaoa River, proved that concave configuration down along the river profile was controlling the hydraulics outflow transition in response of downstream fining (Gomez et al. 2001). Both fine and coarse size fractions can cause fining in large percentiles and both gravel and sand bed rivers can occur in the fining process (Gomez et al. 2001; Frings 2007). Method of granulometric shows the relation of ancient sediments with recent sediments in their textural properties concentrated from modern sedimentary environments (Amireh 2015).

Previous studies showed that only limited studies examined the distribution in large sand-bed rivers. Frings (2007) reviewed the factor affects the process in downstream fining of the gravel bed river with three categories which were abrasion, selective transport and sediment addition-extraction. Persistent lithologies, small grain size, high degree of rounding, influence of grinding as abrasion process and the dominant in suspended transport mode are the factors of small abrasion rates in large sand-bed rivers. The upstream part of the rivers shows the higher abrasion rate nevertheless. Sometimes the coarse particles show mobility higher than the fine grains in the downstream side with few indicators, differ with abrasion, river with concave profile causes the selective transport produce a 'stable' downstream fining

pattern. A stronger downstream fining rate may sometime be decreased due to the overbank sedimentation in large sand bed rivers and the removal of fine grains from the rivers. Other anthropogenic factors related including dredging effect depends on the volume and the grain size involved. Alternatively, coarse grain loss may occur due to the meander migration from the channel in aggrading circumstances, increasing the rate of downstream fining (Frings 2007).

The aims of this study are to (a) analyses the grain size changes in the downstream direction of selected rives in Selangor districts (b) differentiate the downstream fining variation among three rivers (c) recognize and explain the downstream changes among the selected three rivers.

SAMPLING METHODS

Bed samples were collected from three main rivers in the state of Selangor, south west of Peninsular Malaysia, i.e Sungai Tengi (Sg. Tengi), Sungai Selangor (Sg. Selangor) and Sungai Langat (Sg. Langat). Table 1 shows the details of the river and its catchment area which include seven rivers with total length of 753 km.

TABLE 1. Selangor Rivers and catchment area inventory

No.	River Catchment	Length (km)	District involved
1	Sg. Bernam	216	Sabak Bernam, Upstream Selangor
2	Sg. Tengi	58	Kuala Selangor, Sabak Bernam, Upstream Selangor
3	Sg. Selangor	134	Kuala Selangor, Upstream Selangor, Gombak
4	Sg. Buloh	49	Kuala Selangor, Gombak, Petaling
5	Sg. Klang	98	Klang, Petaling, Kuala Langat, Sepang, Gombak
6	Sg. Langat	180	Kuala Langat, Sepang, Gombak
7	Sg. Sepang	18	Sepang
Total Length:		753	

Sampling area for Sg. Tengi, Sg. Selangor and Sg. Langat are shown in Figure 2 a, b and c, respectively. These rivers were chosen to suit our initial river classification according to the development on the river bank. Three classes were identified as less, medium and fully developed, where Sg Tengi, Sg. Selangor and Sg. Langat fit the description, respectively. These rivers are accessible and cover most of the districts in Selangor including districts of Kuala Selangor, Sabak Bernam, Hulu Selangor, Gombak, Kuala Langat and Sepang.

Series of fieldwork were arranged for sampling collection with the samples were spatially distance in the range of 5 km apart from one to the other which then recorded accurately using a standard GPS. The sampling were designed as such to investigate the longitudinal, vertical and temporal variations in the bed materials (Surian 2002). Samples from Sungai Tengi and Sungai Selangor were collected by boat, and a low cost, self-made vacuum tube (Figure 1) was

designed specially to collect sample in Sungai Langat due to inaccessibility to the river.

Bed samples were taken at the middle of each river (that is the most active region) using a grab sampler and were immediately sealed in an airtight container. A total of 27 samples were collected from these three rivers. There are nine samples for Sg. Tengi, 10 samples for Sg. Langat and eight samples for Sg. Selangor. Samples were dried in the oven at 105°C for 12 hours prior physical sieving using sieve series, including 4.75, 2.36, 1.18, 0.6, 0.3, 0.15 and 0.075 mm in sizes. Sieve analysis is a common procedure used to assess the particle size distribution of a granular material including sand (Sonaye and Baxi 2012).

Statistical analysis was conducted for each collected sample using the formulae developed by Folk & Ward (1975), described in detail Table 2. The main focus in the analysis is to measure the central tendency (mean), degree of scatter (sorting), skewness and degree of peak through kurtosis. The

FIGURE 1. Vacuum tube

statistical characteristics of the particle size distribution were presented in the Wentworth (ϕ) scale as

$$\phi = -\log_2 D/D_0, \quad (1)$$

where, ϕ is the phi scale, D is the diameter of the particle and D_0 is the reference diameter, taken as 1 mm.

RESULTS

MEAN & SORTING

Here, the profile of mean for the three studied rivers is first presented in Figure 3a. The mean bed sediment size of Sg. Langat varies from -1.035ϕ to 2.56ϕ (i.e. 2.049 mm to

FIGURE 2. Map of sampling area (a) Sg. Tenggi (b) Sg. Selangor (c) Sg. Langat. Note that for figures (a)-(c), the point no 01 represents the most downstream, often at the estuary.

TABLE 2. Statistical formulate used in the calculation of grain size parameters using the logarithmic Folk and Ward (1957) graphical measures

Mean	Standard deviation	Skewness	Kurtosis
$(M_z) = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$	$(\sigma_z) = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$	$(Sk_z) = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$	$(K_z) = \frac{\phi_{95} - \phi_5}{2.44(\phi_{75} - \phi_{25})}$
Sorting (σ_z)	Skewness (Sk_z)		Kurtosis (K_z)
Very well sorted	<0.35	Very fine skewed	<0.67
Well sorted	0.35-0.5	Fine skewed	0.67-0.9
Moderately well sorted	0.7-1.00	Symmetrical	0.9-1.11
Poorly sorted	1.00-2.00	Coarse skewed	1.11-1.5
Very poorly sorted	2.00-4.00	Very coarse skewed	1.5-3.00
Extremely poorly sorted	>4.00		Extremely leptokurtic

0.17 mm) and data shows the upstream of the river (SL10 as shown in Figure 2c) has the highest value of mean which is equivalent to -1.035ϕ (2.049 mm). Moving downstream the next point SL9 shows a decreasing in mean value, with -0.009ϕ (1.006 mm) and the pattern continues to decrease until the point SL7, with mean value of 1.947ϕ (0.259 mm). However results shows that there is sudden ascend of mean value at SL6 with 0.253ϕ (0.839 mm). Sudden drop from point SL5 (0.253ϕ) to SL4 (1.661ϕ) (≈ 0.839 mm to 0.316 mm) were occurred. Point SL3 to SL2 shows increase in mean value from 1.588ϕ (0.333 mm) to 0.685ϕ (0.622 mm) and decrease to point SL1 with mean value 2.560ϕ (0.170 mm). Areas of the upstream and downstream of Sg. Langat show the highest value of mean 2.049 mm and lowest value of mean 0.170 mm. Sorting of Sungai Langat show similar trend with mean value. As mean size increases, the sorting value increases, few exceptions were shown in points SL8 and SL2 as the mean size increase, the sorting value decrease. According to the mean value in Figure 3, the downstream fining in diameter size of the sediments in Sg. Langat still occurs at every 20km.

The mean size for sediment mixture collected at Sg. Selangor was found to vary from 0.989ϕ to 2.549ϕ (0.504 mm to 0.171 mm). As shown in Figure 3b the upstream of Sg. Selangor (SS8) has the mean value of 1.671ϕ (0.314 mm) and further increases to SS7 with the mean value of 0.989ϕ (0.504 mm). However starting from sampling point of SS6 to SS1, a decreasing trend in the mean value pattern was observed where the mean value for SS6 is 1.565ϕ (0.338 mm), SS4 (1.627ϕ ; 0.324 mm), SS3 (1.966ϕ ; 0.256 mm), SS2 (2.532ϕ ; 0.173 mm), SS1 (2.549ϕ ; 0.171 mm), respectively. These decreasing pattern of the mean sediment size (from SS7 to SS1) reflects that fining process of 20 km downstream (0.989ϕ to 2.549ϕ) of Sg. Selangor.

Further analysis shows that the sediments range from poorly sorted to well sorted. About 75% of the samples fall in the poorly sorted category as shown in Figure 3b. All the sediments were characterised as sand, coarse, medium

and fine sand. The best sorted sediment in all sedimentary environments has mean grain size in the range of fine sand size (Griffiths 1967). The mean value shows that the downstream fining possibly occur within 15 km downstream starting from point SS7 to SS1.

Samples obtained from Sg. Tengi showed a varying range of mean values from 1.313ϕ to 3.302ϕ (0.402 mm to 1.101 mm) in the downstream direction. Starting from the upstream point, ST10, the mean value is 2.569ϕ (0.168 mm). The value decreases to the next point ST9 with the mean value of 3.302ϕ (0.101 mm). Further downstream ST7 shows an increase of the mean value to 2.564ϕ (0.169 mm). The mean value then descends back at ST6 with the mean size value 3.356ϕ (0.098 mm). ST5 shows a drastic increase with the mean value 1.716ϕ (0.304 mm) and point ST4 and ST3 show a slightly increase with the mean value of 1.607ϕ (0.328 mm) and 1.313ϕ (0.402 mm) respectively. Meanwhile point ST2 and ST1 shows slightly decreases with the mean value 1.606ϕ (0.328 mm) for ST2 and 1.684ϕ (0.311 mm) for ST11. The sorting shows increasing trend shows as the mean value increases at the first 10 km in downstream direction. However, the variation trend of sorting values decreases as the mean sediment size increases after the 10 km downstream direction. Therefore, no downstream fining trend was observed for Sg. Tengi.

Overall findings show that similar pattern of downstream fining was observed in the mean and sorting of Sg. Langat (within 20 km downstream), Sg. Selangor (within 15 km downstream) and Sg. Tengi (upstream fining within 18 km upstream). Figure 3 shows Sg. Langat is the longest river with highest overall mean sediment size recorded among the three rivers. Meanwhile the sorting recorded does not show any trend in to differentiate the rivers.

SKEWNESS (SK) & KURTOSIS (K)

Value of skewness dictates the distribution of the bed sediment profile about mean. Skewness in the sediment bed at Sg. Langat (Figure 4a) has range between -0.571 to

FIGURE 3. Downstream changes of mean and sorting in Sg. Langat ($\blacktriangle$), Sg. Selangor ($\blacklozenge$) and Sg. Tenggi ($*$)

0.483 ϕ (1.083 mm to 0.715 mm). The sediment follows the downstream directions, whereby the symmetry of the samples varies from very fine skewed to very coarse skewed. Skewness value of SL10 (the upstream of Sg. Langat) shows the value 0.483 ϕ (0.715 mm), followed by SL9 (0.313 ϕ ; 0.805 mm) presenting an increase of very fine skewed. Next SL7 shows increasing skewness by a decrease in skewness for the next point SL8 (0.359 ϕ ; 0.780 mm) within the same range of very fine skewed. Next SL7 shows increasing skewness value (-0.220 ϕ ; 1.164 mm), then decreases to the next point, SL6 (-0.115 ϕ ; 1.083 mm) and increases at sampling point of SL5 (-0.186 ϕ ; 1.138 mm) which exhibit the sediments were in the range of coarse skewed range. Next SL4 and SL3 show decreasing in the downstream direction with the skewness value 0.132 ϕ (0.913 mm) and 0.169 ϕ (0.889 mm) respectively, both were in the fine skewed range. The skewness value increasing at the point SL2 and SL1 with the value of sediment skewness were -0.014 ϕ (1.010 mm) and -0.571 ϕ (1.485 mm) respectively. Both point lies under the range of very coarse skewed particles. About 30% of the samples in Sg. Langat fall in both very fine skewed and coarse skewed respectively, whereas the rest were 20% fall in the fine skewed and 10% falls in symmetrical and very coarsely skewed. The kurtosis of Sg. Langat shows horizontal trend follow the downstream variation. Overall of the samples, 70% were recorded as platykurtic, 20% of samples shows deficiently peaked (leptokurtic) and 10% of the sediments were mesokurtic.

Samples collected from Sg. Selangor has skewness varies from -0.165 to 0.643 ϕ (1.121 to 0.64 mm) shows that the samples skewed from very fine skewed to coarse skewed as can be seen in Figure 4a. The upstream of Sg. Selangor SS8, shows the skewness value 0.009 ϕ (0.994 mm) lies under the range of symmetrical skewness. The next point SS7 decrease in skewness value with 0.643 ϕ (0.640 mm) shows the sediment range in fine skewed. Then increasing trends of skewness were observed for sampling point of SS6 and SS5 with the magnitude of -0.165 ϕ (1.121 mm) and (0.027 ϕ ; 0.981 mm) respectively which both points represent the skewness of coarse skewed and symmetrical. Skewness for point SS4 and SS3 decreases in downstream direction

with magnitude of 0.164 ϕ (0.893 mm) for SS4 and 0.265 ϕ (0.832 mm) for SS3 showing fine skewed range. Point SS2 shows increase in skewness value -0.083 ϕ (1.059 mm) and decreases to -0.014 ϕ (1.010 mm) at point SS1. Both samples at SS2 and SS1 show the skewness range in symmetrical.

Figure 4a shows Sg. Tenggi skewness range from -0.089 to 0.466 ϕ (1.064 to 0.724 mm). The range falls within very fine skewed to symmetrical. Sg. Tenggi upstream point (ST10) shows the skewness value -0.0869 ϕ (1.064 mm) decrease to the next point ST9 (0.451 ϕ ; 0.732 mm) which represent the symmetrical very fine skewed respectively. Moving downstream ST7 having a skewness value of 0.140 ϕ (0.908 mm) then ST6 with 0.005 ϕ ; 0.996 mm. Both shows decreasing in skewness value follows the downstream direction and lies under fine skewed and symmetrical, respectively. Magnitude of skewness for point ST5 is -0.149 ϕ (1.109 mm) displays some increase with the skewness range of fine skewed. Further calculation exhibit a decrease in skewness at point ST4 and ST3 from 0.247 ϕ (0.842 mm) to 0.466 ϕ (0.724 mm). ST4 is fine skewed whereas ST3 in the range of very fine skewed. Point ST2 shows increasing in skewness value compared to the previous point with 0.199 ϕ (0.871 mm) and decreased at point ST1 with the skewness values of 0.209 ϕ (0.865 mm). Both sediments showed the value under the fine skewed. Overall analysis present 60% of the sediment is in the fine skewed and the other 20% in the very fine skewed and 20% is in the symmetrical sediment size group.

The value of kurtosis in Figure 3b for the upstream Sg. Selangor point at SS8 displays a leptokurtic range. Then point SS7 shows an increase in kurtosis value of 0.496 ϕ (0.709 mm) that is in very platykurtic sediment group and going further to point SS6 with the kurtosis value of 1.208 ϕ (0.433 mm), categorised as leptokurtic. Point SS5 has an increase kurtosis value of 0.804 ϕ (0.573 mm) and further decreased at point SS4 to 1.108 ϕ (0.464 mm). Therefore, SS5 has platykurtic distribution and sample at SS4 is mesokurtic. The next point SS3 displayed a descending in kurtosis value of 0.872 ϕ (0.546 mm) which can be categorised as platykurtic. SS2 shows an abrupt drop in kurtosis value of 10.75 ϕ which is under the extremely leptokurtic. Point SS1 shows increasing kurtosis value compared to previous point with 1.498 ϕ (0.354 mm)

that is leptokurtic kurtosis. Most of the samples for Sg. Selangor (about 50%) were identified as deficiently peaked, that is either extremely leptokurtic or leptokurtic.

Meanwhile for Sg. Tenggi, the values of kurtosis were in the range from 0.849ϕ to 8.301ϕ (0.003 to 0.555 mm), displaying a platykurtic to extremely leptokurtic kurtosis pattern. The upstream point ST10 showed the kurtosis value of 8.301ϕ (0.003 mm) which is extremely leptokurtic. The next points are ST9 and ST7, presenting an increase in kurtosis value of 0.942ϕ (0.732 mm) and 1ϕ (0.500 mm)

with both are mesokurtic. Then, ST6 has a kurtosis value of 2.166ϕ (0.223 mm) which is very leptokurtic. The last five points including ST5, ST4, ST3, ST2 and ST1 following the downstream direction showed a horizontal trend with the value recorded within the range 1.177ϕ to 0.849ϕ (0.442 mm to 0.555 mm). All point lies under platykurtic, mesokurtic and leptokurtic kurtosis. In summary for Sg. Tenggi, 60% of the samples fall under mesokurtic and another 10% were fall in platykurtic, extremely leptokurtic, very leptokurtic and leptokurtic.

FIGURE 4. Downstream change of skewness and kurtosis in Sg. Langat ($\blacktriangle$), Sg. Selangor ($\blacklozenge$) and Sg. Tenggi ($*$)

BIVARIATE SCATTER GRAPHS OF GRAIN SIZE PARAMETERS

Figure 5 shows the bivariate plot of mean versus sorting (Figure 5a), sorting versus skewness (Figure 5b) and skewness versus kurtosis (Figure 5c). Bivariate plot used to single out the different depositional setting follows the expectation of statistical parameters accuracy which reflects the fluvial mechanisms of sediment transportation and deposition (Sutherland and Lee 1994). Figure 5a below shows relationship of mean grain size and sorting of the three rivers. Tucker (1990) stated that mean grain size and sorting can show some covariance and both are hydraulically controlled (Griffiths 1967).

The best sorted sediments in any sedimentary environments will have the mean grain size within the fine sand size range. Figure 5a, indicates a positive the trend increase of sorting values with the increasing magnitude of mean. More than half of the sediments were poorly sorted with the mean size clustered in the medium sand and very fine sand range. Few samples collected in Sg. Tenggi deviate from others and were categorized as very poorly sorted with medium sand range.

Figure 5b shows the relationship of sorting and skewness and most of the sediments in were poorly sorted and fall on fine skewed and symmetrical range. More than half of the sediments were considered as positively skewed. It simply shows that sediment were grouped in sorting range $0.5 \phi > \sigma_1 > 0.5 \phi$ and $-0.6 \phi > S_k > 0.6 \phi$ (Folk and Ward 1957). Few sediment samples in Sg. Tenggi have very poorly sorted range with the fine and very fine skewness.

Figure 5c shows plotting of skewness against kurtosis which is an impressive tool in interpreting the sediment genesis with the evaluation the degree of normality of the distribution size (Folk 1966). Majority of the sediments lie within positively skewed and accumulates in mesokurtic and leptokurtic group. This shows that the influence of medium grain size group and the collateral of few coarse and fine grain sizes give the positively skewed. This suggests that the present of more fine sand in the sediment will give the positively skewed results, and the coarser sand give the negatively skewed. However, the fluvial sediment of this three river shows there are from fine sand and less gravel follow the downstream.

CONCLUSIONS

From fieldwork data and analysis show the inconsistent downstream variation in the fluvial sediment mixture of Sg. Selangor, Sg. Langat and Sg. Tenggi. It can be seen that within the given data, Sg. Selangor and Sg. Langat have the profiles of the downstream fining where the mean size of particle is decreasing towards the estuary. However different trend of fining could be observed for Sg. Tenggi probably due to the least developed area along the river bank compare to Sg. Selangor and Sg. Langat area. As a conclusion, the bed sediment for Sg. Selangor, Sg. Langat and Sg. Tenggi mostly consist of medium sand at the upstream and is categorized as fine sand as reaching towards the estuary.

FIGURE 5. Sector plot showing the bivariate relationship between (a) The grain size and sorting, (b) Sorting and Skewness (c) Skewness and Kurtosis of the Sg. Langat (◄), Sg. Selangor (◆) and Sg. Tenggi (*).

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