Sedimentary Characteristics and Status of Water Quality in Polwatta River and Weligama Bay in Sri Lanka

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ABSTRACT

The Weligama Bay is a one of the rocky shorelines in the coastline of Sri Lanka and Polwatta River is the major river which enters to south part of the Bay. The study objectives were to find out the sedimentary characteristic, and water quality status in Polwatta River and Weligama bay. Results indicated that, mean water temperature, pH, NO_3^- -N, PO_4^{-3}, and NH_4^- -N, in Polwatta River and Weligama Bay are 28.2 ^0C ± 1.8, 6.7 ± 0.3, 0.11 ± 0.04 mg/l, 0.73 ± 0.1 mg/l, 0.46 ± 0.1 mg/l and 28.5 ± 1.0 ^0C, 7.57 ± 0.1, 0.51 ± 0.04 mg/l, 0.40 ± 0.1mg/l and 0.20 ± 0.1 mg/l in respectively. The, mean suspended sediment concentrations were recorded in Polwatta River was 241.1 ± 150 mg/l. However, mean gravel, sand and silt percentages in the Weligama Bay are 1.42 ± 1.4, 96.33 ± 0.5 and 2.25 ± 0.3 in respectively. The study of current patterns shows the direction is west to east of the Bay and surface current is 12 cm/s. Results reveal that, nutrients in the Polwatta River and Weligama Bay are within the acceptable limits published by Sri Lanka Standard Institute and draft CEA ambient water quality standard. Also, high concentration of suspended sediment load coming through the Polwatta River during south-west monsoon period and part of that remain in the estuary and other discharge to the Bay. Also, due to currents sediment traverse to southern part of the coast in Weligama.

KEY WORDS: *Polwatta river, Sedimentary characteristics, Sediment transportation, Weligama Bay*

Introduction

The Weligama Bay

The Weligama Bay is located in southern Sri Lanka, the coastline between Galle and Matara. The inner bay is highly abundant with coral habitats and rocky outcrops (Rajasuriya *et al,* 1998). The entire Southern Coastal Zone is underlain by

Precambrian rocks of the Wijayan series. The dominant rock types are charnockites, granites, gneisses, granulites and quartzites (NARA, 1993). Some near-shore sandstone beds of the Miocene age can be observed in a few sites at Devundara, Kottegoda, Ahangama, Hungama and Ussangoda, Most of the low cliffs in the southern coastal zone are formed of either granites or laterite.

The occurrence of laterites becomes more and more frequent as one approach the Wet Zone (Madduma Bandara, 1989). Also, Coral reefs of late Holocene origin occurs along sections of the Weligama Bay in western coastline where the beaches are usually poorly developed and where large rivers do not enter (Rajasuriya *et al*, 1998). Throughout the bay, consists of high coral habitats, the coral reefs in the inner bay may influence to generate strong current patterns within the bay. In addition, a small island in the Bay increases the effect of the coastal currents. Most of the previous studies revealed that the current direction is from west to east (NARA, 1993). Besides, the average current velocity within the bay recorded as 0.2m/s.

Polwatta River and Sediment

Polwatta River has its source above Nakiyadeniya, where it is known as Udugan Oya. It has a catchment area of 235.7 km^2 and traverses nearly 32.19 km before flowing into the sea at Weligama Bay (NARA, 1993). The Upper reaches of the Basin is cultivated rubber with and tea. In the lower reaches, the River flows through large stretches of rice land with coconut plantations. Riverine habitats of Sri Lanka are rapidly altering through many anthropogenic activities such as improper use of agrochemicals, damming, discharging various waste materials and industrial effluent and deforestation (Amarathunga *et al.,* 2010- a).

Also, recent studies were indicated various factors are caused for deteriorate of fresh water resources in streams, rivers and reservoirs in Sri Lanka (Amarathunga and Sureshkumar, 2009; Amarathunga *et al.*, 2010- b; Azmy *et al.*, 2010; Azmy *et al.*, 2012- a; Azmy *et al.*, 2012-b; Hettige *et al.*, 2012; Shirantha *et al.*, 2010-a; Shirantha *et al.*, 2010-b; Sureshkumar *et al.*, 2007; Weerasekera *et al.*, 2009; Weerasekera *et al.*, 2012). In order that, a number of factors influence water chemistry. Gibbs (1970) proposed that rock weathering, atmospheric precipitation, evaporation and crystallization control the chemistry of surface water. The influence of geology on chemical water quality is widely recognized (Gibbs, 1970; Langmuir, 1997; Lester and Birkett, 1999). The influence of soil on water quality is very complex and can be ascribed to the processes controlling the exchange of chemicals between the soil and water (Hesterberg, 1998).

Elevated suspended sediment particles in rivers have many impacts; increase of turbidity, destroying aquatic habitats, affecting aesthetic quality (Amarathunga, *et al.*, 2010-a). The fertile and flat soils of the river floodplains tend to be highly modified by agricultural land-use, urbanization and industrialization (Smits *et al*., 2000), High suspended solids and turbidity can have an adverse impact on in-stream biological communities and through sediment deposition which result in the formation of appreciable bottom deposits (Christensen *et al*., 2000). The study aims to find out the sedimentary characteristic, and the status of water quality in Polwatta River and Weligama bay.

Methodology

Study Area

Main river basin of the Weligama area is Polwatta River, which discharges its water into the Weligama Bay at a point called Polwatumodera. During the dry season, the Polwatta River is subjected to saline water intrusion at least eight kilometers upstream, which results in salinization of cultivated land. At the mouth of the Polwatta River, fresh water flows out of the top of the underlying ocean water, thus forming a salt wedge. Upward mixing of saline water into the out flowing river water has been reported (NARA, 1993). Normally tides dominate estuarine mixing and cause more or less vertical homogeneity (Boyd *et al*., 1992; Robert and Choi, 2007). Polwatta River, however, where the mouth is narrow and shallow, tidal influences are notably weak, since mixing energy is insufficient for homogeneity (NARA, 1993).

During the study, three field visits were made to measure for water quality and two field visits were carried out to oceanographic study during April 2010 to October 2010. Four sampling locations (S-2, S-3, S-4 and S-5) were selected according to random sampling techniques from Polwatta River and one sampling location from Weligama Bay (S-7).

In addition, three sampling locations were selected from Kapprathota stream (S-8) Polwathumodara podipalama stream (S-1) and storm water runoff drain (S-6) from the Weligama city limits. Locations of the water sampling are given in Figure 01 and Figure 02 shows the oceanography of study area.

Analysis of Water and Sediments

Physico-chemical parameters of water have a dominating limiting effect on the aquatic environment. The chemical nature of water determines the species that can survive and population distribution of species. The following physico-chemical parameters were selected for this study to ascertain the quality of water and to ascertain changes and effects. Water samples were analyzed accordance with standard methods for examination of water and wastewater (APHA, 1998) 20^{th} edition for ammonia nitrogen, ortho-phosphate, nitrate nitrogen, and nitrite nitrogen.

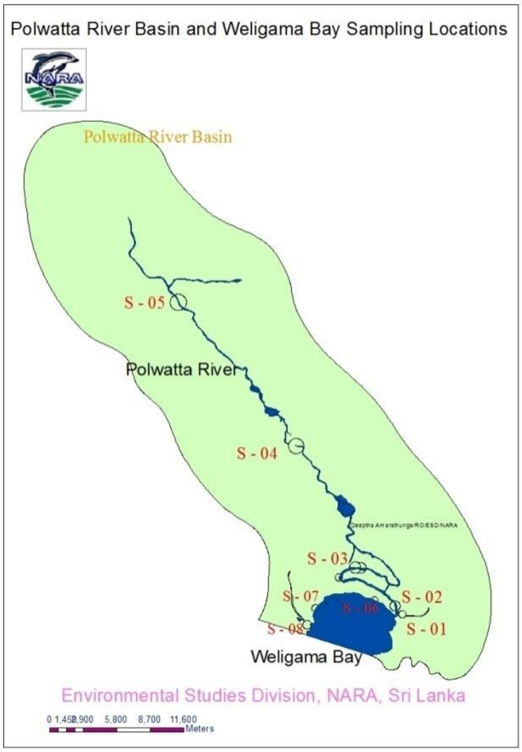

Figure 1: Locations of water sampling

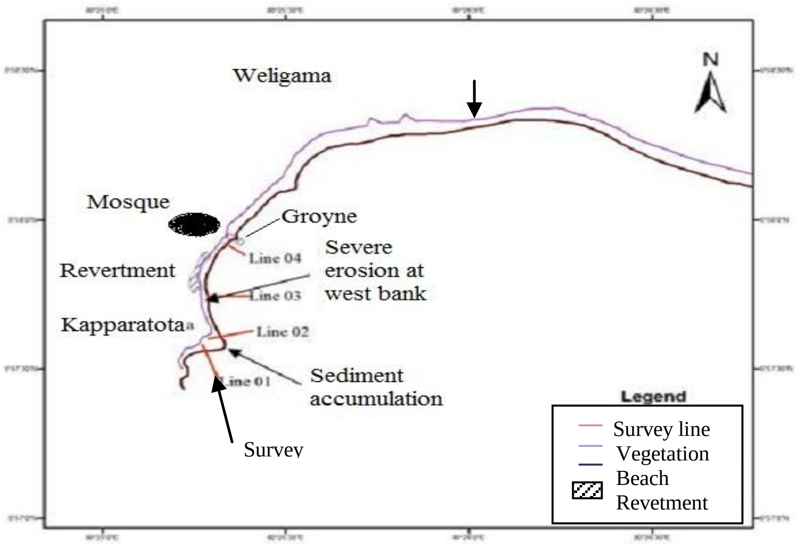

Figure 2: Sediment study area in the Weligama Bay

In-situ analysis were done for the determination of pH measured by a pH meter (Orion 260A), dissolve oxygen (DO) was measured by portable sension DO meter, conductivity and salinity were measured using sension portable multi parameter meter, turbidity level was measured using portable meters (Hach 2100P), biochemical oxygen demand (BOD) level was measured using portable BOD sensors (Aqua Lytic). Suspended sediment concentration (SSC) was determined using a filtration method (Guy, 1969).

The gross weight of the sample (water-sediment mixture) was determined, and the total sample volume was filtered through a Whatman grade 934AH, 24 mm - diameter filter that had been inserted into a crucible and dried at 110 degrees Celsius (°C) ± 2 °C, cooled, and weighed. The filtered sample then was dried until all visible water was evaporated, and heated for 1 hour at 110 °C ± 2 °C. The crucible was cooled in desiccators at room temperature and weighed. The weight of the remaining material in the crucible (milligrams) then was divided by the volume of the water-sediment mixture passed through the filter (liters) to determine the concentration of the sample (milligrams per liter).

Two different oceanographic and sediment studies were carried out. Oceanographic studies mainly focused on current pattern within the Weligama bay. Float drogues were deployed to study the current patterns within the Bay. Current patterns were observed from the floating results are given in graphically. In addition the current pattern studies, nine numbers of sediment samples were collected at different locations in the bay beach and sieve analysis was carried out to study the sediment characteristics of the erosion and accretion beaches to identify the possible sources for generation of sediments. Sediments collected from vegetation line, high water line and lower water line was analyzed separately to study the sedimentological status of the Weligama bay area. The sediment analysis data were plotted on the same diagram with different beach faces.

Results and Discussion

Water Quality

Freshwater input into an estuary from groundwater, streams, and surface runoff follows certain pathways that are constrained by landform geography and subsurface geology. The total area drained by these freshwater flows refers to a watershed. According to the study, mean values of the water quality are given in Table 01. Weligama coastal belt in Matara district suffered heavy damage to the fresh water due to being flooded by seawater, and percolation of seawater into the coastal freshwater aquifer by tsunami stuck to South East and South Asia on 26th December 2004. In the Weligama bay area, the tsunami wave penetrated inland up to 1 km and damaged most of the coastal water bodies. However, according to Ranjana *et al* (2007), Electrical conductivity (EC) of groundwater in tsunami affected area changes with atmospheric precipitation. According to the study, EC in the fresh water sources is within 72.7 and 1244 µS/cm.

Table 01: Mean values of the water quality in Polwaththa River basin and Weligama Bay

Parameters	Polwatta River		Weligama Bay	
	Mean	Std. Dev.	Mean	Std. Dev.
Water Temperature (^{0}C)	28.2	1.9	28.45	1.1
pH	6.7	0.3	7.57	0.1
DO (mg/l)	5.33	0.3	6.3	0.7
EC	462.18 (µS/cm)	30.2	51.85 (mS/cm)	0.6
Turbidity (NTU)	55.95	6.8	8.46	1.5
TDS (mg/l)	224.33	14.8	32.6	0.1
Salinity (ppt)	0.23	0.2	34.35	0.8
BOD (mg/l)	6.25	1.7	9.5	0.7
Ammonia nitrogen (mg/l)	0.46	0.1	0.2	0.1
Nitrite nitrogen(mg/l)	0.003	0.001	0.005	0.004
Nitrate nitrogen(mg/l)	0.11	0.04	0.51	0.05
Ortho-phosphate (mg/l)	0.74	0.1	0.4	0.1
Suspended Sediment (mg/l)	241.13	15.1	34.58	0.1
TSS (mg/l)	16.81	5.8	1.98	0.2

Nutrient Variation

Figure 03 shows the variation of total ammonia in the Polwatta River and its associate waterways. All forms of Nitrogen are biochemically inter convertible and are components of the Nitrogen cycle. Ammonia levels can be critical for survival and growth of fish and this can be happen usually in relation to the direct discharge of an ammonia-bearing waste into waterways (e.g., wastewater effluent, storm water runoff, etc.) (Alabaster and Lloyd, 1980; US EPA, 1985). Because of ammonia nitrogen, free ammonia in the water is stemming up problem impose its own level of stress on fish at rather low (sub-part-per-million) levels. Fish release reduced ammonia-nitrogen through the gill structures (U.S. EPA 1985).

Sampling locations S-6 and S-8 (Kapparathota Ela) have total ammonia concentration of 2.24 mg/l and 2.08 mg/l respectively, at pH 7.0, which is extremely high. According to calculations, free ammonia in the above sampling locations was varied from 0.02 mg/l, to 0.03 mg/l and other locations were recorded less than 0.01mg/l. According to concentration gradient external concentration of free ammonia rises, a fish will accordingly have a harder time releasing ammonia rise. In the case of fish, most of them are extremely sensitive to even minute levels of NH_3 contamination.

When, the level of free ammonia concentration is less than 0.25mg/l, it does not cause detrimental effects, 0.5 mg/l is a sub lethal level and at a concentration of 1.0 mg/l there can be severe lethal effectively such as mass mortalities (U.S. EPA 1985). However, all the sampling locations were within the acceptable limits of free ammonia concentration in water. The ortho-phosphate concentration is higher (1.0 mg/l) in the sample location S-6 (Figure 3).

In addition, other sampling locations recorded relatively high dissolve ortho-phosphate concentrations. A graph shows (Figure. 03) high nitrate concentration was recorded in S-6, and S-8 sampling locations when compared to other sampling locations. Nitrates may also impose their own form of toxicity, but they are less dangerous to fish than is free ammonia. Even then, if the levels of nitrates do reach excessively high levels, it can still kill the fish.

The results for nitrate and nitrite in the sample locations are within the standard level of water quality for preservation of fish and other aquatic life according to portable water quality standards set by the Sri Lanka Standard Institute and draft Central Environmental Authority (CEA) standard (SLSI, 1983). Ammonia nitrogen, ortho-phosphate and nitrate concentrations were higher in Kapparathota stream (S-08) and stream water drainage channel (sample no 06). Due to waste materials and other sources drained in to Kapparathota stream from waste dumping site. Further, sewerage and other waste was drained to stormed water drainage channel from shopping complex and Weligama urbanized areas (S-6).

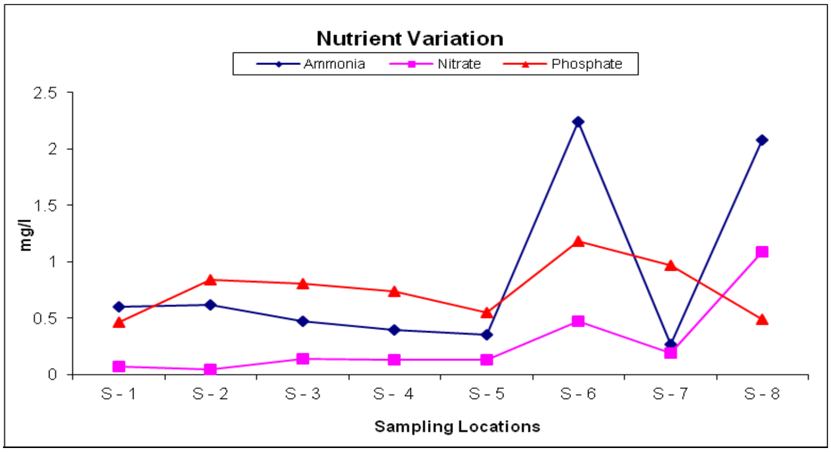

Figure 3: Nutrient variation in different sampling locations

Dissolved Oxygen (DO) and other parameters

Dissolve oxygen variation in Polwatta River, Weligama Bay and its associated waters in the basin is given in Figure. 4. The results indicated that, low levels of mean DO concentrations prevailing in the S-6 sampling location with 2.5 mg/l. However, Polwatta River sampling locations were recorded higher concentration of DO. Biological Oxygen Demand (BOD) shows the polluted condition of water. The results showed highest mean BOD 12 mg/l and 18 mg/l in sampling location S-6 and S-7 and all the other sampling locations are below in BOD concentration compared to standard published by the Sri Lanka Standard Institute (SLSI, 1983).

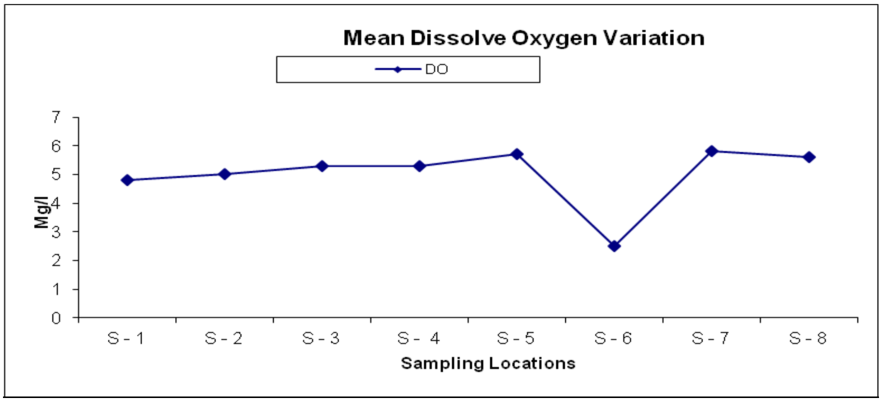

Figure 4: Mean dissolve oxygen variation in different sample locations

Suspended sediment

Sedimentation in Polwatta River estuary and Weligama Bay attributed mainly due to the river runoff carrying sediment. Mean suspended sediment in the Polwatta River is 241.13 ± 15.1 mg/l (Table 1). Suspended sediment (SS) in the study area varies between the 1.7 mg/l to 402.98 mg/l. Highest SS concentrations were recorded in Polwatta River sampling locations (S - 3, and S - 4). In order to that, turbidity was varied between 7.59 NTU to 205.7 NTU. High turbidity and total suspended sediment (TSS) were recorded due to high degree of erosions during the rainy period in the upper catchment of the Polwatta River Basin.

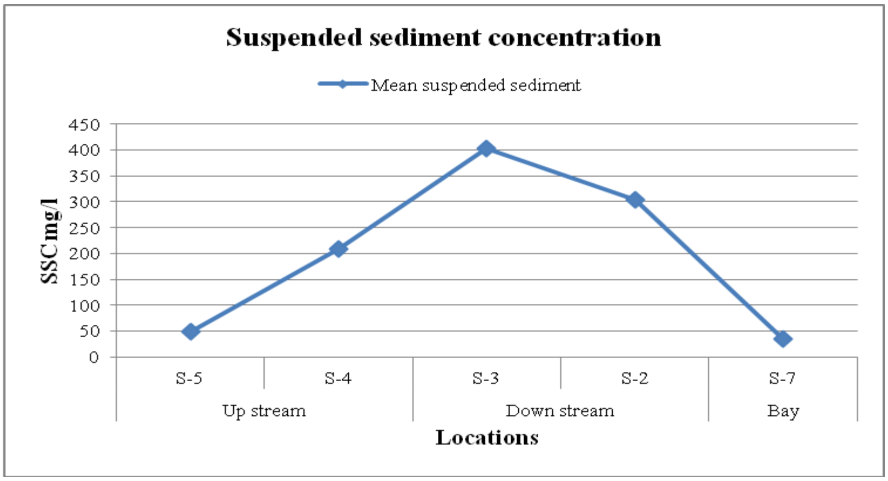

Figure 5: Suspended sediment concentration in Polwatta River

Bed Sediment data

Sieve analysis results received from vegetation shows similar graphs in each location. Table 2 showed the locations and visual observations of the sediments samples in the Weligama Bay. Different type of sediments were visually observed such as; angular fine grained sediments, sub angular grains with shell fragments, fine to medium grained, fine grained sediments with high concentration of shell fragments, fine grained sand, medium grained sediments, medium to coarse-grained sediments etc.

Table 2: Visual observations of the sediments

Sample No	Location		Descriptions
	Lon	Lat	
Line no 1 (L11)	080 ° 25.294’	05 ° 57.85’	Angular fine grained sediments with small shell fragments. Whitish colour
Line no 1 (L12)	080 ° 25.307’	05 ° 57.587’	Sub angular grains with shell fragments. Fine grained sediments with whitish brown colour.
Line no 1 (L13)	080 ° 25.311’	05 ° 57.885’	Fine to medium grained sediments with highly Shelly sub angular sediments
Line no 2 (L21)	080 ° 25.296’	05 ° 57.609’	Fine grained sediments with high concentration of shell fragments. Sub angular and brownish colour.
Line no 2 (L22)	080 ° 25.298’	05 ° 57.612’	Fine grained sand with shell fragments. Angular grains with brownish colour.
Line no 2 (L23)	080 ° 25.301’	05 ° 57.613’	Medium grained sediments with shell fragments (over 75%). Angular, Grey in whitish colour
Line no 3 (L32)	080 ° 25.264’	05 ° 57.731’	Medium grained sub angular sediments. Greyish black colour. Black mineral is present.
Line no 4 (L42)	080 ° 25.321’	05 ° 57.906’	Medium grained sediments with whitish grey colour. Sub-angular, mainly quartz is present
Line no 4 (L43)	080 ° 25.323’	05 ° 57.904’	Medium to coarse-grained sediments, grey colour, sub angular to sub rounded grains.

Table 3: Sediment classification

Sample No.	Gravel (%)	Sand (%)	Silt (%)
L11	2.59	94.50	2.91
L12	0.26	97.23	2.51
L13	0.96	96.97	2.07
L21	0.13	97.71	2.16
L22	0.00	98.06	1.94
L23	2.66	93.80	3.53
L32	0.33	96.03	3.64
L42	1.57	97.90	0.53
L43	4.27	94.79	0.94

However, sieve analysis sediment results are showing in table 03 and it indicate that around more than 95% sand in the Weligama Bay. In addition, results reveal that, some places having more than 2% gravel and sediments. According to these results it is clear that, Polwatta River sediment load is not impact to the Weligama Bay.

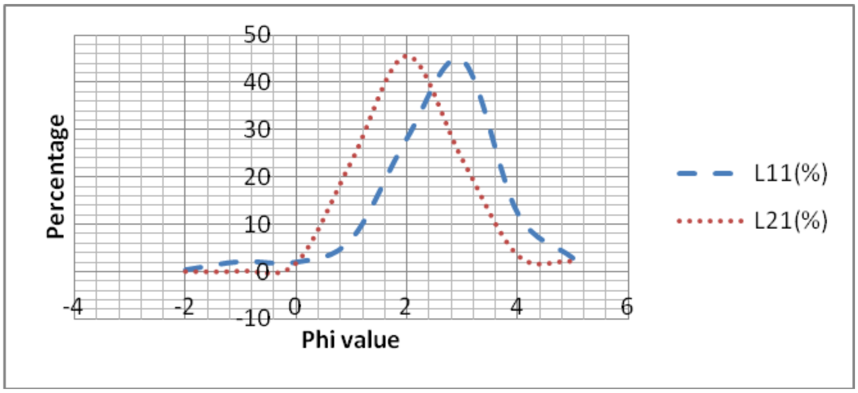

Figure 6: Sediment analysis results from vegetation

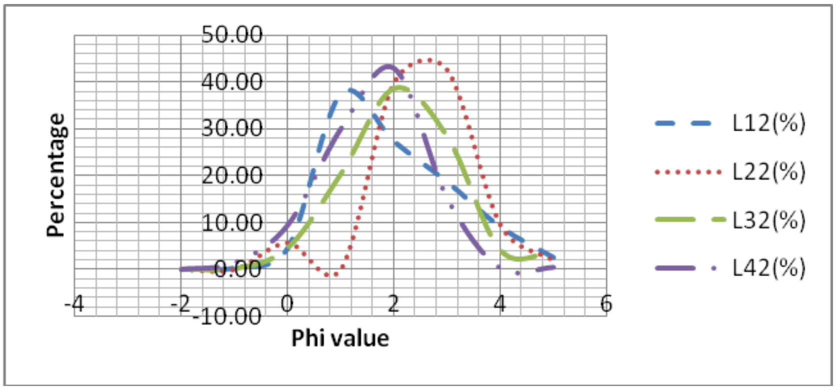

Figure 7: Sediments analysis results from high water level

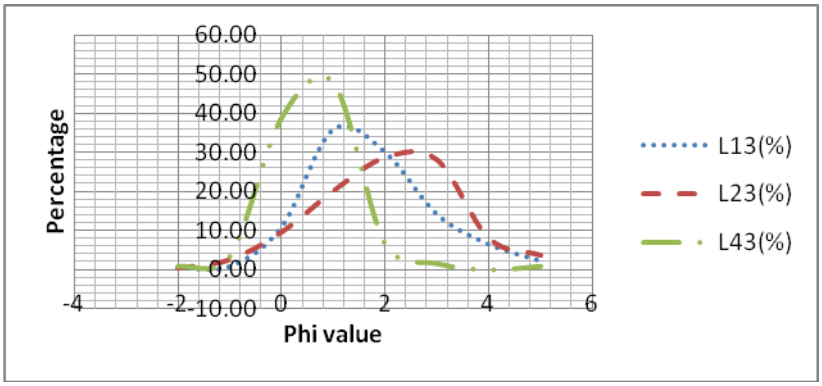

Figure 8: Sediments analysis results from low water level

Sediments from the high water line and low water lines showed a very good relationship on each other and it suggest the sediments derived from erosion at dumping site are deposited on Kapparatota Point (Figure 6, Figure 7 and Figure 8). In addition to that, there were coarse-grained carbonated materials deposited on the Kapparatota Point which suggests materials come from offshore sources. The study of current patterns shows the possible current direction is west to east of the Bay. Calculations shows that the average current velocity of the surface current is about 12 cm/s.

Conclusions

Results reveal that, the nutrients in the Polwatta River are within the acceptable limits published by the Sri Lanka Standard Institute. In addition, high concentrations of suspended sediments come through the Polwatta River during the southwest monsoon period and part of that remain in the estuary and rest discharge to the Bay. The study of current patterns shows the possible current direction is west to east of the Bay and sediment traverse to the southern part of the coast in Weligama due to the effect of currents. Therefore, little amount of sediment recorded in the Weligama Bay compared to higher sediment lord bringing by Polwatta River.

Also, nitrogen contamination is higher in Kapprathota Ela (S-8) due draining of waste materials from to dump site and storm water runoff drain (S-6) bringing untreated waste water to the Bay. Therefore, high risk is for bathing in Weligama Bay. Furthermore, the severe erosion on the western bank is noticed after 2004 tsunami and establishment of the groyne behind the mosque.

In addition, there was an old revetment in front of the Galle to Matara main road to keep control the coastal erosion. However, the revetment and the groyne may cause to accelerate the coastal erosion at the dumping site. There was no indication of bottom current direction or velocity of the area. So, the information on bottom current is required to make a conclusion in sediment formation of the Weligama Bay.

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