Characterisation of Sediment Deposition of Bolgoda Lake using Acoustic and Sampling Methods

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Abstract

Bolgoda Lake is one of the main water resources in the western province, which has two major basins explained as Bolgoda south and north lakes. Lake sedimentation is a serious dilemma for water scarcity, productivity, and flooding effect. So, identification of sediment characteristics is most critical. The attempt of this study is to identify the sedimentation pattern, sediment type, and mineral composition of the sediment from the data collected from core sampling, grab sampling, and the bathymetric data obtained from spot depth eco sounder that combines with Magellan 510. Hence, grain size distribution (GSD), scanning electron microscope (SEM), and bathymetric surveys were utilised to recognise sediment type, heavy metal composition, and sedimentation pattern, respectively. These analyses revealed that bottom sediment has poorly sorted, very fine skewed, physical characteristics have statistical distribution and discover the sediment type as sandy silt. Also, bathymetric analysis upholds the sedimentation pattern that accumulates sediment from the left bank to the right bank of the Bolgoda lake via the water column and to identify the sediment distribution along the lake bottom.

Keywords: Bathymetry, Grain size distribution, Kurtosis, Sedimentation, Skewness

1. Introduction

Due to the growth of population and increase of the requirement under the urban development, there is a demand for freshwater. If the water demand is exceeded the available amount, water stress happens. Lakes and reservoirs are some of the main water resources that affect the day-to-day essentials. However, reservoir sedimentation and lake sediment are the major problems that diminish the useful water quantity from the available water resources [1].

Soil erosion due to the effect of the water and wind is one major problem when considering the lake sediment in the lake bottom. As well, sedimentation happens due to the effect from the catchment area and also surface mining, urban construction, etc. [2]. When the water flow energy and velocity are reduced, the sediments tend to settle down along the bottom of the basin of the water resource. Lake sedimentation is a fact that is not to be neglected as it can cause mainly impacts like Biological and physical and Social and economic etc.

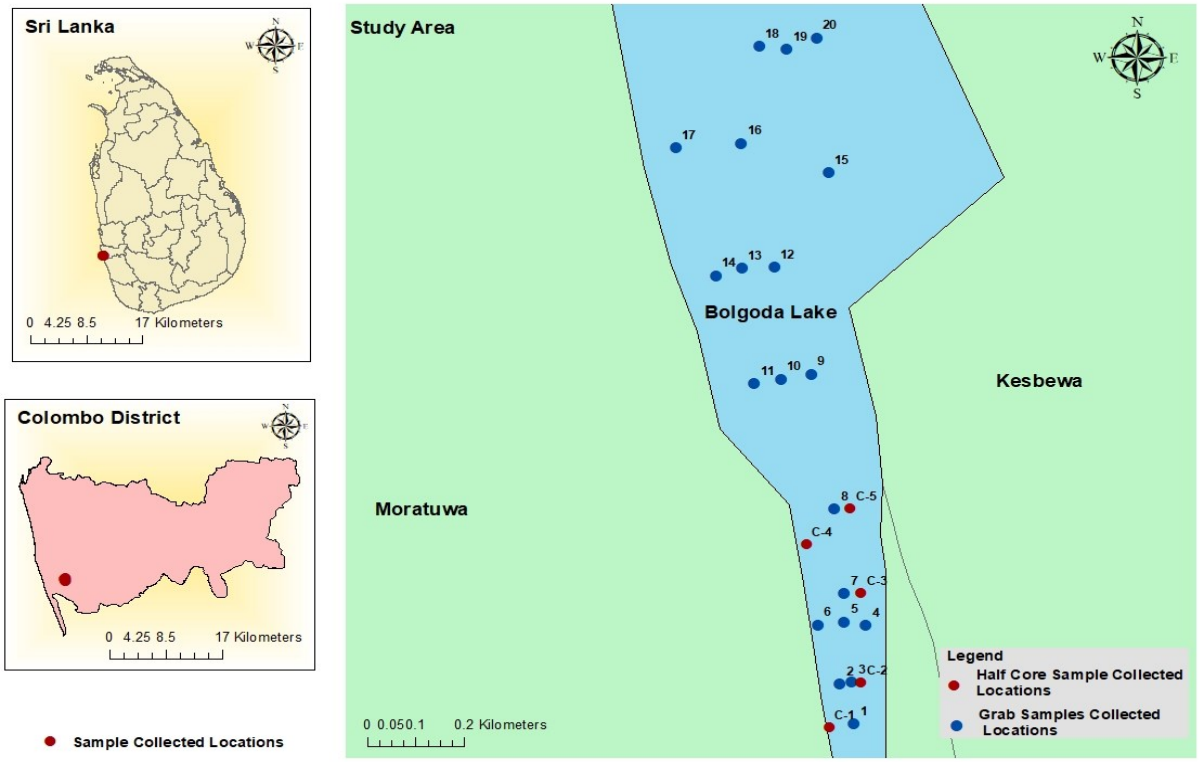

Figure 1: Core sampling and grab sampling locations.

Lake sediments can be categorised as mineral matter's organic matter and inorganic matter. Among these three matters, grain size analysis is done for the mineral maters to identify the sedimentation pattern, to find the origin of the sediment, paleoclimate conditions, etc. [3]. Structure, Texture, and composition are the primary indicators that use to describe the sediment, and they indicate the catchment characteristics, historical conditions, and sediment source, etc. Grain size distribution (GSD) is the main method that is used to identify the critical info about the provenance and nature of the sediment, like transportation and deposition [4]. Hydrodynamic sorting, parent materials, and the way that transport material is indicated by the grain size deposition. As well as GSD is used to identify the mixture of silt, clay, sand in the sediment deposition. The laser diffraction method is the main method used to identify the grain size distribution.

High accuracy results within the nano range can be taken from the GSD. These nanoparticles can be displayed as the 3D image by using the SEM analysis. Also, samples that use GSD analysis can be subjected to the Energy Dispersive X-ray Analysis (EDAX) to identify the elemental distribution of the sediment over the lake [5].

The purpose of this case study is to observe the sediment characteristics and behaviour of the sediment accumulation of the Bolgoda lake by using the core sampling method and grab sampling method. The authors also explore shallow depth environments of the Bolgoda lake by using the acoustic and wave reflection methods.

2. Methodology

2.1 Site Selection

Sri Lanka comprises three main climatic zones called wet, intermediate, and dry zones and also three main morphological regions called coastal lowlands, uplands, and highlands. Bolgoda Lake is one of the main water reservoirs in the western province, which has two major basins explained as Bolgoda south and north lakes. As well as Bolgoda lake is a partially closed low liberation water body [6]. The water flow of the Bolgoda lake finally connects with the Indian Ocean via the

large two openings that exist in the western edges.

The study area of our research project is situated near the boatyard of the University of Moratuwa from the 'Karadiyana garbage pit' to the bridge of 'Piliyandala'. According to the seasonal changes, the lake is subjected to floating ferns, and floating plants categorised as genus Eichhorminia, genus Salvinia, Water Hyacinth, etc. [6]. Also, the bathymetry of the water body can be seen in 1-2 m depth in the study area due to heavy sedimentation, but some areas achieved 3m depth.

2.1 Material and Methods

2.1.1 Sampling method, Particle Size Distribution and SEM Analysis

Van Veen grab sampler was used to collect the surface sediment samples; Core samples were also extracted during the boat ride using half corer. When a new sample was taken, the sampler should clean well. Also, samples should name clearly, like Figure 1. There were 42 samples analysed to gain precious and accurate details.

Observed samples were prepared under the ASTM D 6913/D 6913M standards for the particle size analysis with slandered sieving methods. A laser particle analyser (JNGX HMK-CD2) for the granular range of 0.1–1000 µm was used to analyse the prepared 0.35 mg amount of sediment samples. The GDADSTATv.8 program was used to analyse particle size statistics such as mean, classification, curvature, and kurtosis [7].

The remaining prepared samples were subjected to Scanning electron Microscopy. 3D images and energy-dispersive X-ray Analysis (EDAX) were taken to observe the sediment composition.

2.1.2 Bathymetric Surveying

The bathymetric survey was executed to cover the entire study area by using the pre surveying plan that was prepared. Hondex PS 7 that called Spot Depth Echo Sounder, was used to take the Spot Depth measurements with high accuracy. Navigation data were taken by handheld GPS unit with 3 m precision.

Collected data was post-processed using the Surfer 8 and ArcGIS software.

3. Results

3.1 Grain size distribution

Grain size analysis is directly affected by

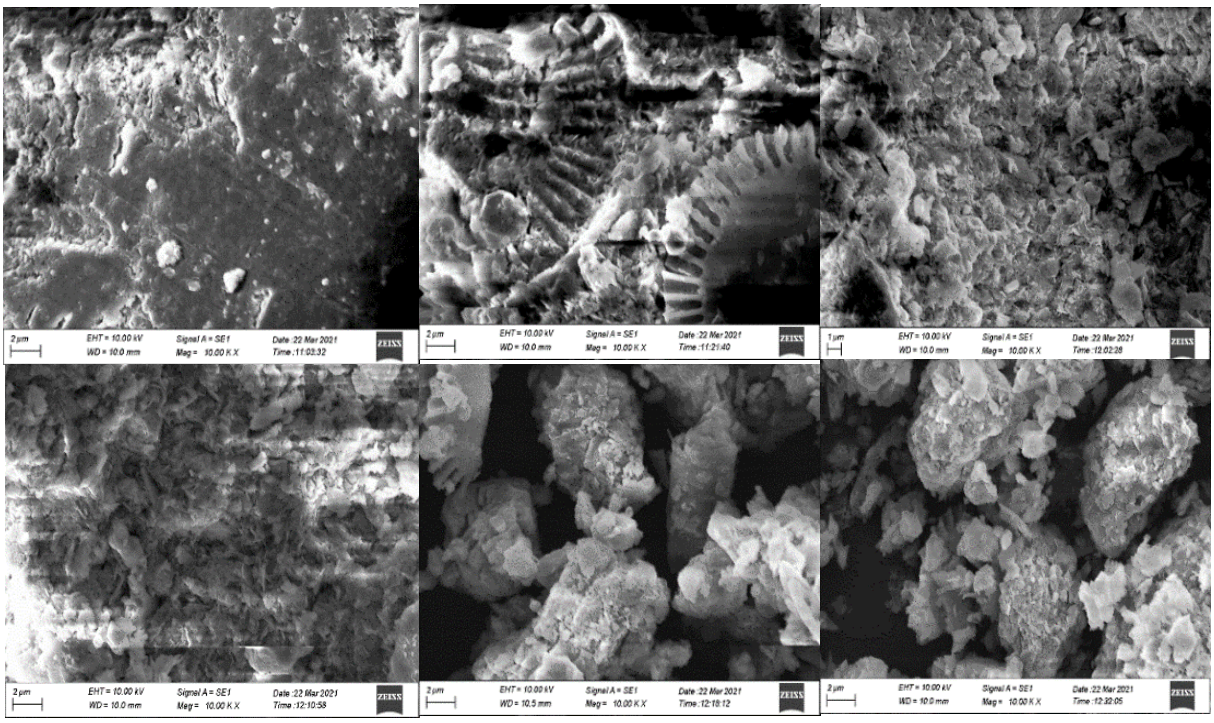

Figure 2: SEM analysis image data.

the lake sediment's geochemical parameters. Also, GSD is given ideas and explanations about the transportation and deposition of the lake sediment. So, the particle size distribution method gives the details about sediment mixture that consists of silt, clay, and sand, etc. The characterisation of the deposit is given by the skewness, mean grain size, kurtosis, and sorting.

The following table shows the grain size distribution taken from the grab sampler and core sampler.

Table 1: Sediment characteristic of the samples (as an average).

Characteristics	Results
Mean	Medium silt
Sorting	Very poorly sorted
Skewness	Very fine skewed
Kurtosis	Platykurtic and very platykurtic

So, the platykurtic nature of the sediment sample observes that two or more particle populations mix together with equal amount or unequal amounts, which explain the polymodal nature of the sediment deposition. It means polymodal sediment mix with silt clay and the sandOnly five samples varied from the other samples because these samples were shown mesokurtic and leptokurtic kurtosis. It means showing a high peak or tail of the grain size distribution curve.

3.2 SEM analysis data

Generally, grain size analysis using nanoscience is one of the important things to gain high accuracy results. We used six samples for the SEM analysis, and 3D images were taken. Samples were taken within the 10*X magnitude to identify characteristics of the sediments. Figure 2 display the high-resolution 3D images that are used to identify the non-circular, 20-100 µm size particles consist in the sediments.

Finally, the composition of the data was obtained by using the EDAX analysis.

According to Table 2, Sample number 7 and sample number 19 are only subjected to the EDAX analysis and observe the weight deference of material in the two locations.

Table 2: eZAF smart quant results.

Element	Weight Percentage%	
	Sample 07	Sample 19
Carbon	15.05	15.75
Oxygen	47.44	49.15
Sodium	0.72	0.50
Magnesium	0.57	0.38
Aluminium	12.63	11.52
Silicon	11.72	14.53
Sulphur	2.33	1.29
Chlorine	0.53	0.43
Potassium	0.40	0.33
Calcium	-	1.17
Titanium	0.63	0.67
Ferrous	7.97	4.27

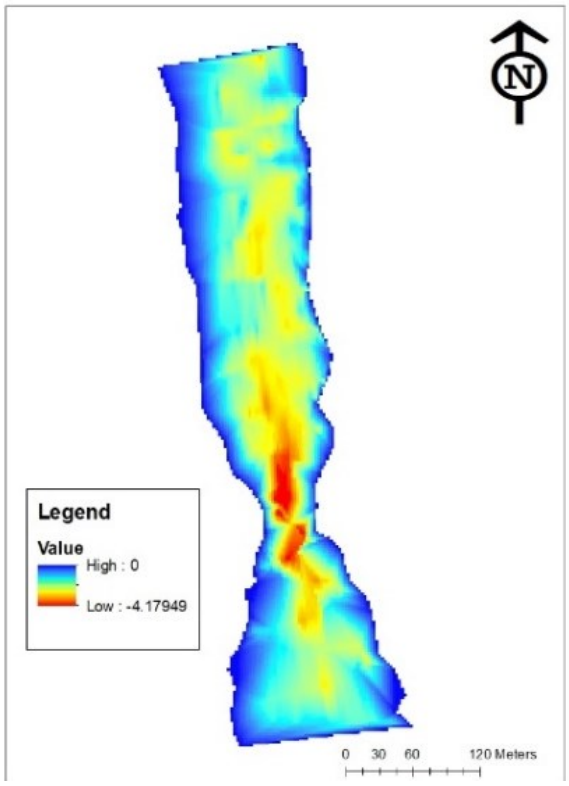

Figure 3: Raster file created using ArcGIS.

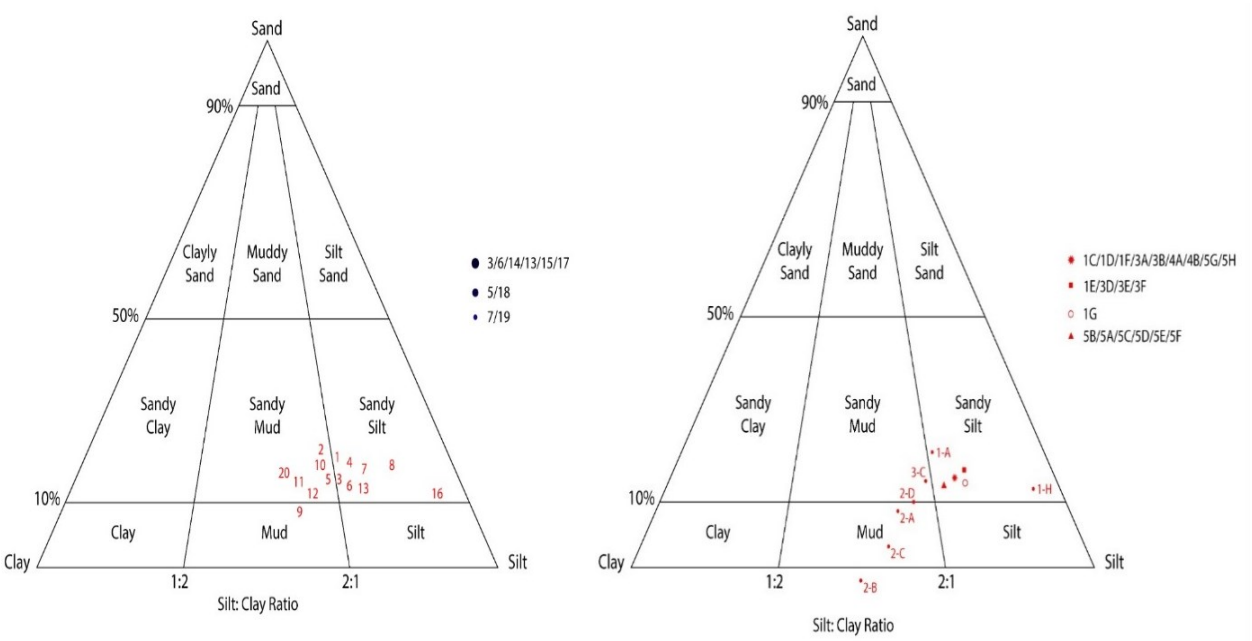

Figure 4: SSC diagram for grab and core sampling.

3.3 Bathymetric Surveying and Map Preparation

Bathymetric Surveying data could not obtain directly. It had to be taken via the post-processing platforms like Surfer 8 and ArcGIS. Using the Surfer 8 3D maps, Sedimentation patterns, shallow and deep areas can be obtained.

Figure 3 shows depth data mapping obtain from the ArcGIS. Also, Figure 4 exhibits the bathymetric analysis that was taken from the Surfer8.

4. Discussion

Folk and Ward's classification can be used to identify the sediment distribution along the lake. Properties of the sediment samples are mentioned in table 1. These results reflect that sediment has not had proper time to sort. Normally lake sediments are well-sorted towards the downstream of the lake, but according to these results, very poorly sorted sediment distribution can be identified towards the downstream. According to the geometric values acquired from the particle size analysis test, a negative skewness value is shown for the data obtained in the lake area. These results also reflect that the lake area is favourable to sediment dispositioning. There is sediment accumulation, but due to the flow rate, accumulated sediment is eroded and distributed downstream. The platykurtic nature of the sediment sample observes that two or more particle populations were mixing with an equal amount or unequal amounts, which explains the polymodal nature of the sediment deposition. It means polymodal sediment mix with silt clay and sand also.

According to [7], sediment types can be classified using the Sand-Silt-Clay(SSC) Diagrams and Gravel Sand Mud Diagram (GSM). It explains the textural group and sediment type of Bolgoda Lake. Figure 5 shows the SSC diagrams for both grab sampling data and core sampling data. According to these data. These results illustrate the Sediment as Sandy Silt and Sandy mud sediment.

SEM analysis results also give an idea about the composition of bottom lake sediment, particle size, shape, and roundness of the sediments. However, these results interpret the same mineral composition around the study area with slightly different weight and atomic percentages. The difference can happen due to the water flow rate and the sediment current of the lake. Table 2 shows the weight percentages near the "Karadiyana garbage pit" and the

university area from EDAX. As well, the atomic percentage also displays the same slim difference as the weight percentages. It clarifies that there is a difference in Calcium minerals when comparing the two locations. Calcium may be accumulated due to the effect of the garbage contamination.

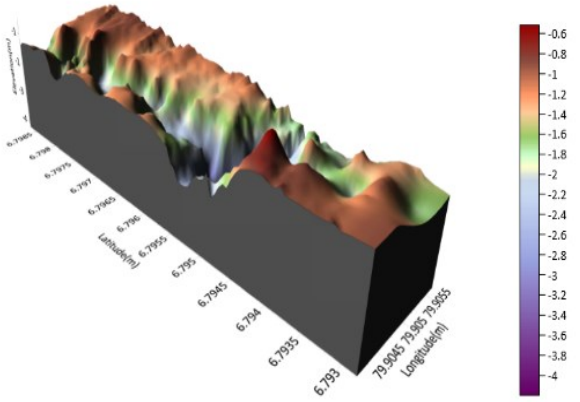

Figure 5: Bathymertic analysis from Surfer8.

It is preferable to do XRD and XRF tests for the sediment sample to extract accurate mineral composition around the lake and to confirm the effect from the Karadiyana garbage pit.

Bathymetric data obtained from Surfer8 is illustrated in Figure 6. The cross-section data obtain from the two places show the sediment accumulation pattern. So, we can ensure that sediments are accumulated in the lakes are like the cross-section of Figure 6. According to bathymetric data, the middle of the lake has a low sedimentation rate, and the side of the lake has higher sedimentation.

5. Conclusions

According to this study, the sediments of the lake mainly come from the upstream area of the Bolgoda lake and due to the erosion of the bank. SSC diagrams show that sandy silt is the sediment that accumulates in the river bottom and geometric values give the idea about sedimentation rate and percentages weights of lake sediments.

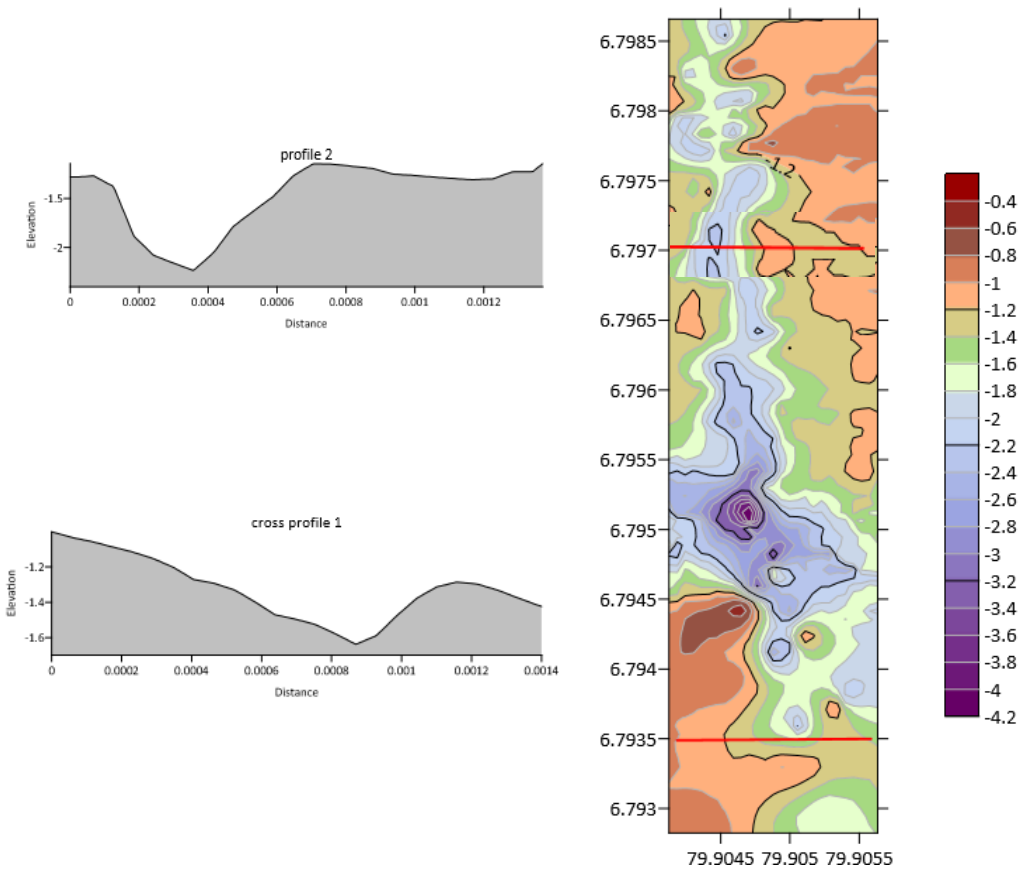

Figure 6: Cross section of the Bolgoda Lake.

It is important to introduce a proper method to minimise the sediment accumulation in the Bolgoda lake to minimise future accumulation.

To reduce the sediment accumulation, mitigation measures have to be done for the upstream area, and a proper urban development plan should be introduced for construction near the lake area.

Future Direction

Bathymetric surveying was done by the Spot depth eco sounder, and research should be done again by using a sub-bottom profiler to identify the sedimentation pattern, sediment thickness, and accumulated capacity.

Identified sediment can be used in the fertiliser industry, construction industry, and ceramic industry, etc. Proper environmental and legal action should be followed before commencing the dredging.

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