Assessment of Sediment Monitoring of Khashm el Girba Dam

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Abstract

Khashm el Girba Dam (KED) on Atbara River was completed in 1964 with an initial storage capacity of 1.3 BCM. The main purpose of the dam is to supply Halfa agricultural scheme with irrigation water. Over the last five decades, the storage capacity was decreased due to heavy sediment depositions. The present capacity of the KED reservoir is below 50% of its original capacity.

Khashm el Girba Dam authority used to determine sediment concentrations (SC) at upstream and downstream of the dam during flood season by adopting the volumetric method. Long time series of sediment concentration records in (%) are available. However, it is necessary to check the accuracy of such a method and its reliability to provide accurate estimates of sediment concentrations. Laboratory analysis has been carried out to determine sediment concentrations of KED sediment samples over the last two years 2013 and 2014. In addition to volumetric method, two methods were used namely Gravimetric method and by using HACH 2100AN Turbidimeter device.

The results have shown that volumetric method, which is subjected to reading errors, can represent an indicative technique to determine sediment concentration in situ especially during flushing period. However, it is of utmost importance to stick to the ordinary laboratory analysis instead of the volumetric method to establish reliable sediment database for KED which could be used for accurate determination of reservoir sedimentation and for other relevant studies.

Key words: Atbara River, Khashm el Girba dam, sediment concentration

1. INTRODUCTION

The construction of Khashm el Girba Dam (KED) started in 1960. The construction was completed and the dam taken into operation in 1964. The KED is located on the Atbara River approximately 200 km downstream of the Ethiopian border and 72 km downstream the confluence of the Upper Atbara and Setit rivers, Figure 1. The KED reservoir had a design capacity of 1.3 billion m^3 assuming a maximum operating water level of 473 m. At a later stage the maximum operating level has been increased to 474 m. The length of the reservoir is about 80 km length and reaches to the upstream side of the confluence of the Setit and Upper Atbara Rivers. The main portion of the dam is an earthen embankment while the spillway and irrigation headwork sections are concrete gravity structures. Some main characteristics of the dam are listed in Table 1.

Table 1: Dam and reservoir characteristics

Dam characteristics	
Type of dam	Gravity/embankment
Height	47 m
Length	3500 m
River	Atbara River
Spillways capacity	1,000 m^3/s
Lower floodgates capacity	7,700 m^3/s
Reservoir	
Design capacity	1.3 BCM
Catchment area	112400 km^2
Surface area	125 km^2
Normal elevation	474 m
Reservoir length	80 km

The KED was originally designed as a single purpose dam for irrigating the New Halfa irrigation Scheme and providing the local water supply. It is equipped with canal head works on its left bank which divert water into the Girba Main Canal. If water levels in the reservoir are below the canal level, three pumps can provide water into the canal.

Two small hydroelectric power stations are installed in the dam. These have been upgraded between 2002 and 2004. The current total installed capacity is 16 MW which includes a 10 MW turbine discharging into the main river and a 6 MW turbine discharging into the Girba Main Canal.

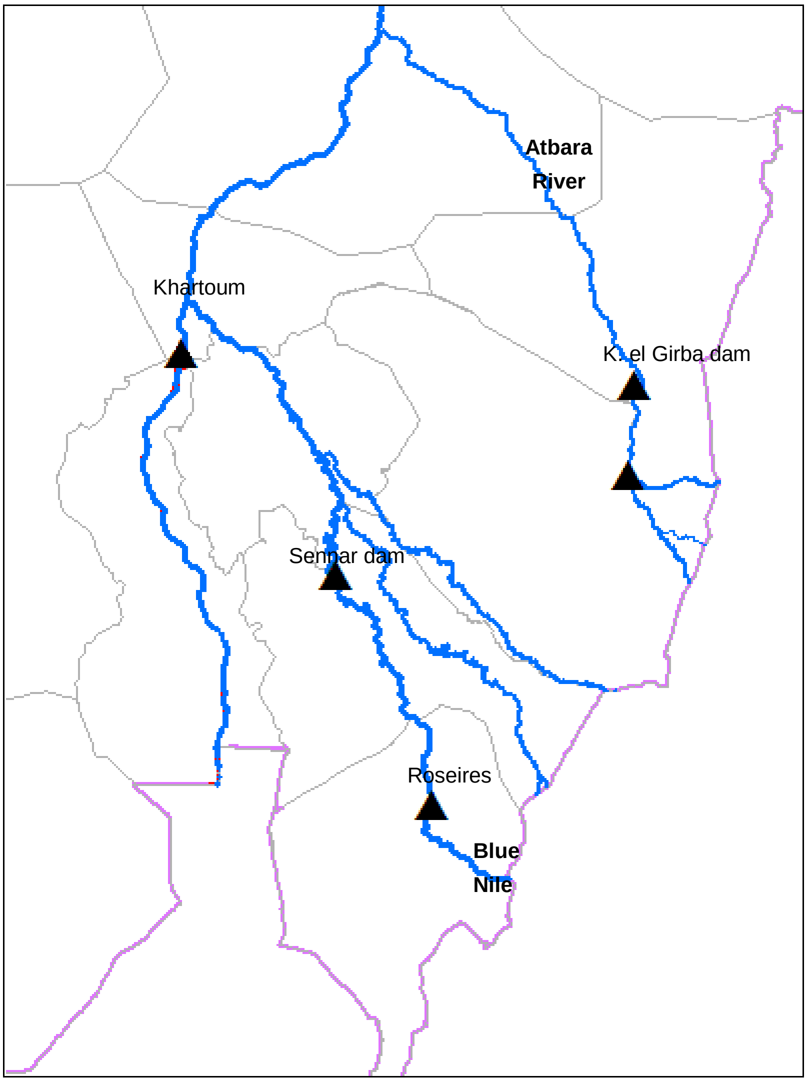


Figure 1: Location of Khashm el Girba Dam on Atbara River

2. OBJECTIVE

To assess sediment monitoring of KED by evaluating the accuracy of the volumetric method which is adopted by Khasm el Girba dam authority for sediment concentration measurements and to assess the reliability of long time series records available at the dam authority.

3. MEASUREMENTS OF WATER LEVELS AND SEDIMENT CONCENTRATIONS AT KED

At the KED site, water level is measured on both the upstream (reservoir level) and the downstream side. Figure 2 shows examples of gauged water levels over the period 2008-2013.

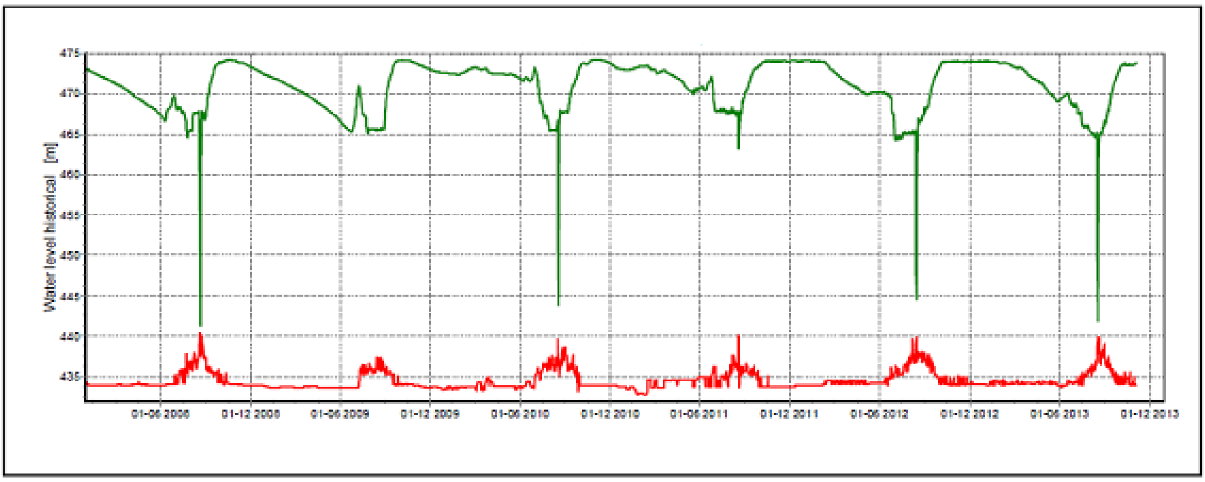


Figure 2: Water levels at upstream (green line) and downstream (red line) of KED

At KED, time series of sediment concentrations are available for the period 1992-2013. It is worth noting that sedimentation has reduced storage capacity. However, the KED management practices flushing since 1971 and seems to have effective results. In KED, low level outlets for flushing are provided close to the original riverbed level with sufficient hydraulic capacity to achieve full drawdown.

The flushing usually takes place over three to five days in August each year. During flushing period, sediment samples from the upstream and downstream sides are usually collected. On the downstream side, samples are also taken for longer period covering July, August and sometimes September. As it can be seen from Figure 2, flushing was implemented in 4 out of the last 6 years.

4. METHODS OF SC DETERMINATION

4.1 Volumetric Method By Ked Authority

During flushing time in August, the sediment samples are collected on 3-5 hours basis by the KED authority. The sediment concentration is calculated in percentage (%) by making visual observation of the sediment quantity, which completely settled within 6-9 hours in the graduated bottle sample, in comparison with the total volume of water.

4.2 Laboratory Methods at Hrc-Sudan

Classical Gravimetric Method

The sediment concentration of a water body is defined as the ratio of the mass of dry sediment in a water-sediment mixture to the mass of the water-sediment mixture. It is expressed in milligram of dry sediment per liter of water-sediment mixture.

The sediment concentration (SC) was determined using the classical gravimetric method in the laboratory. The mass of the bottle plus the water sample is weighed using a 2 digit weighing balance. The water sample is left for 24 hours to get the sediment settled. The clear water was carefully poured out while the sediment was poured in a dish. The sediment in the dish is dried in an oven to remove all water vapours. The dried soil is reweighed again using a 2 digits weighing balance to measure the weight of the suspended solids. Finally the SC in ppm is calculated by taking the difference between the total mass of soil and dish and empty dried dish, divided by the weight of the water sample and multiplied by10^6. This procedure is repeated for all water samples.

Turbidity Measurements

Turbidity was measured using HACH 2100AN laboratory Turbidimeter. The turbidity readings (T) were reported in Nephelometric Turbidity Units (NTU).

All the bottles containing water samples were manually shaken thoroughly for a couple of seconds to ensure uniform mixing. The water samples were poured in a vial glass (30ml) and the turbidity level is measured immediately using the calibrated Turbidimeter. The procedure was repeated for all water samples. The 2100AN Turbidimeter measures only turbidity up to 10,000 NTU. In case of out of range of turbidity readings, the original sample has to be diluted to be within the range of the instrument.

Figure 3: Turbidimeter device

5. RESULTS AND DISCUSSIONS

The Figure 3 shows time series of the SC and T at upstream and downstream of KED by the three methods as carried out at HRC soil mechanics laboratory in year 2014. It can be seen that the sequence of the records are harmonic.

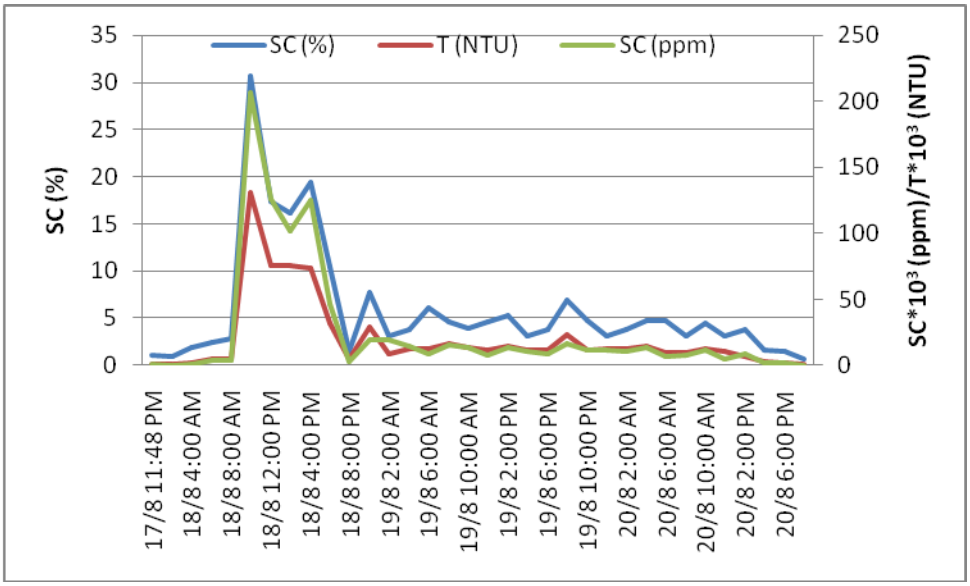


Figure 3a: Sequence of SC/T records in 2014 (US of KED)

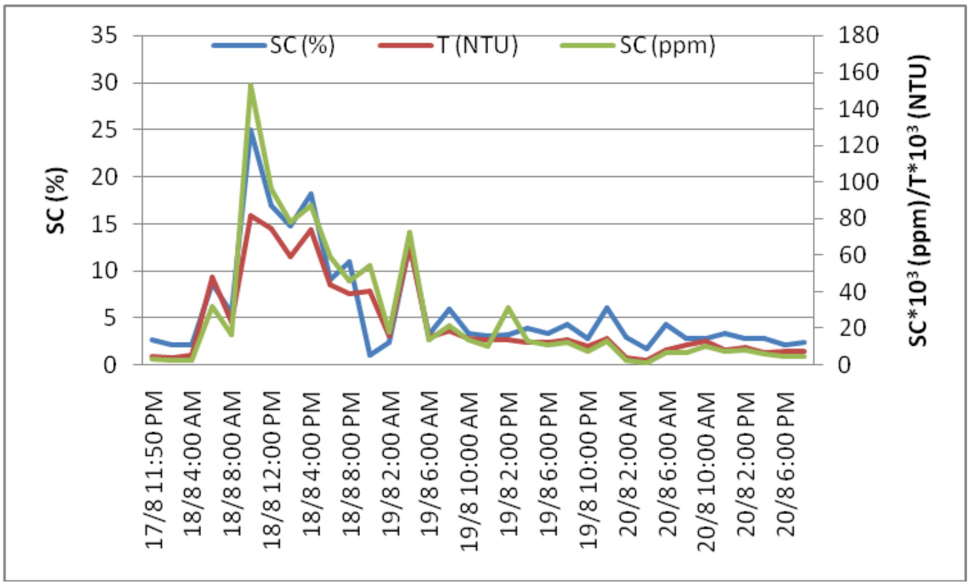


Figure 3b: Sequence of SC/T records in 2014 (DS of KED)

On the other hand, results of SCs (ppm) and turbidity levels (NTU) are compared for years 2013 and 2014. The Figure 4 below shows the established correlations. It can be observed that very good correlations were derived at upstream and downstream of KED and this ensures the good accuracy of the two methods.

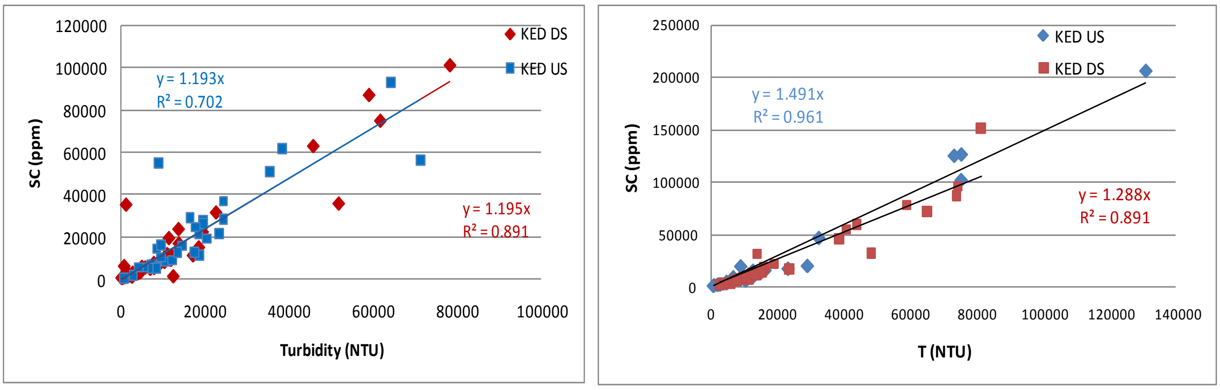
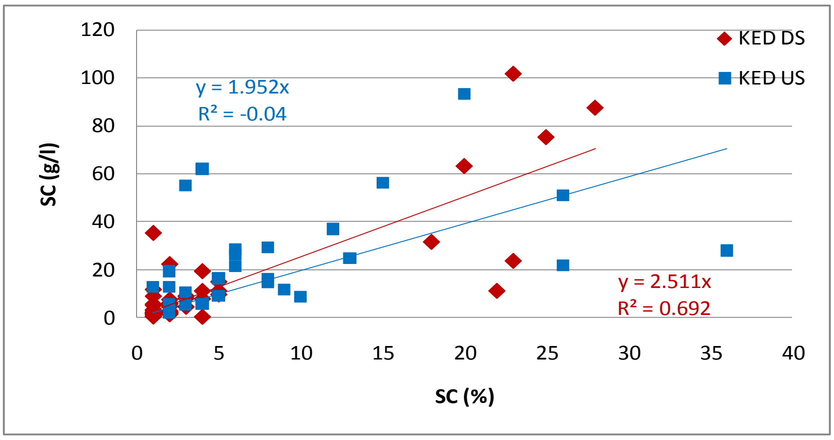


Figure 4: Correlations between SC (ppm) versus T(NTU), Year 2013 (left) and Year 2014 (right)

On the other side, results of volumetric measurements (in %) versus laboratory measurements (in g/l) were also compared to evaluate the accuracy of the Volumetric method. It is to be noted that SCs (%) of year 2013 is taken from KED authority as volumetric method was only adopted by HRC laboratory in 2014. Comparing the derived correlations as shown by Figure 5, it is obvious that in year 2014 a very high consistency is achieved more than the case of year 2013 in which highly scattered data points are obvious.



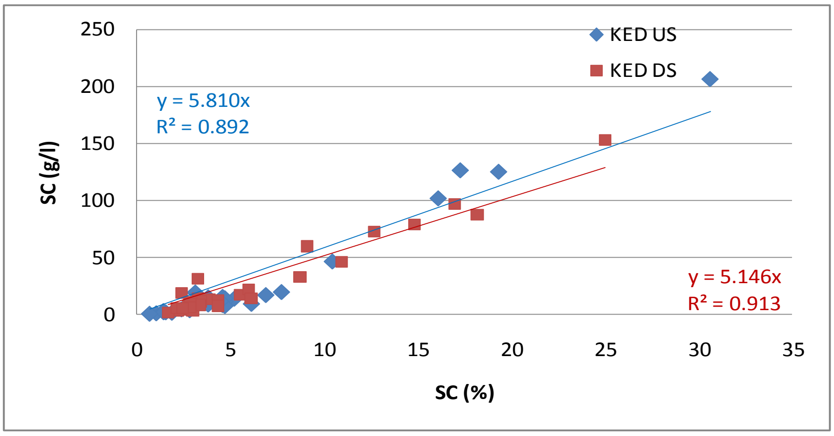


Figure 5: Correlations between SC (g/l) versus volumetric measurements (%), Year 2013 (above) and Year 2014 (bottom)

Attention is to be paid to the conversion factor from SC in (%) into SC (g/l) as it varies from year to year. These factors can also be compared with the derived ones by Sogreah in 1971. Sogreah (1971) has established a correlation between volumetric measurements and ordinary lab measurements, Figure (6).

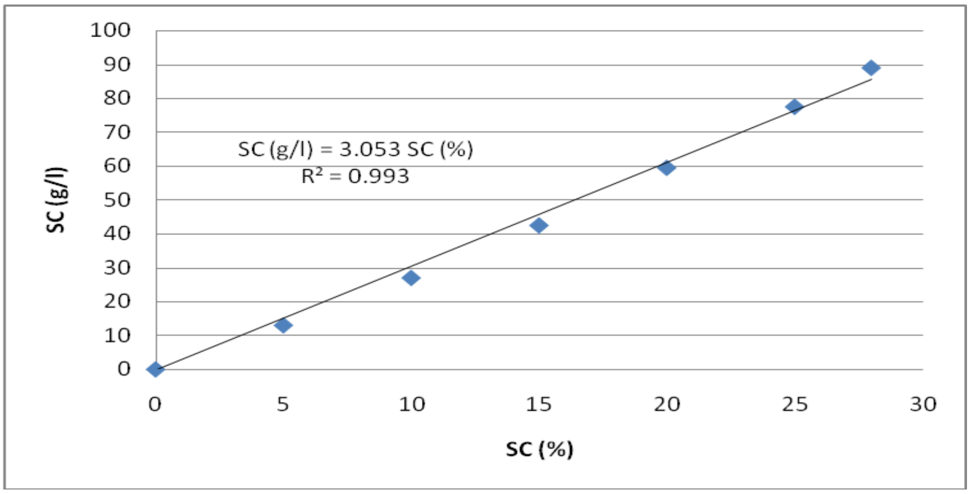


Figure 6: Established correlation: SC (g/l) Vs SC (%), Sogreah, 1971

6. CONCLUSIONS AND RECOMMENDATIONS

It can be concluded that:

i. Obtained results have shown that SCs (in %) almost follow the same sequence as SCs (in g/l).
ii. Volumetric method can represent an indicative technique to determine sediment concentration in situ especially during flushing period.
iii. Volumetric method can be subjected to reading errors.
iv. The correlation factor differs from year to year; this can be attributed to changes in sediment properties and concentrations.
v. The currently available historical records of sediment concentrations at KED authority cannot lead to precise quantification of reservoir sedimentation.

It is recommended that:

vi. To stick to the ordinary laboratory analysis instead of the volumetric method to establish reliable sediment database for KED.
vii. Regular verification of the conversion factor is of utmost importance.

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