Ruhuna Journal of Science
Vol 12 (2): 97-114, December 2021
eISSN: 2536-8400
http://doi.org/10.4038/rjs.v12i2.105

Analysis of physicochemical parameters and selected potentially toxic elements to assess the water quality of Kattakaduwa reservoir in Hambanthota district, Sri Lanka

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Received: 17th April 2021, Revised: 19th October 2021, Accepted: 16th December 2021

Abstract The study was aimed to assess the water quality of Kattakaduwa reservoir in Hambantota district, Sri Lanka. Reservoir water is not directly used for drinking purposes until purification, but people use it for different purposes such as bathing and irrigation. A comprehensive study on the water quality of this reservoir water was timely needed due to the scarcity of such information. Monthly variation in seven physicochemical parameters and five potentially toxic elements (Mn, Fe, Cu, Cd and Pb) of water at five different sites compared to treated reference water samples were studied for 2017. Sediment analysis of the five elements at four different sites was also carried out. At the site closer to the inlet of the pump house before purification (site 3S), the mean values (± SD) of water temperature, pH, dissolved oxygen, sulphate concentration, turbidity, conductivity, and alkalinity were 33 ± 1°C, 7.5 ± 0.1, 7.19 ± 1.80 mg/L, 57.40 ± 23.60 mmol/L, 36.74 ± 18.87 NTU, 605.3 ± 119.8 µS, and 176.0 ± 32.0 mg/L, respectively. The maximum Fe concentration was observed in March (1.73 mg/L) while the minimum was in January (0.70 mg/L) exceeding the United States federal limits (USFL) and Sri Lankan Standard level (SLSL) of Fe (0.3 mg/L) throughout the year. However, Mn concentration in the same site exceeded the USFL and SLSL (0.05 mg/L) slightly in May, July, and October. The concentrations of the rest of the elements were below the minimum detection limit (MDL) of 1 mg/L. All elements in the treated reference water sample (TR) were below MDL. The concentrations of Fe (15291 ± 10486 mg/kg) in sediments were greater than Mn (1178 ± 1007 mg/kg). These values reflect the higher Fe concentration in the reservoir water compared to Mn concentration that may be due to the leaching of Fe from the sediments to the water.

Keywords: Physico-chemical, potentially toxic elements, reservoir

1 Introduction

Kattakaduwa reservoir is situated in the Hambantota district of the Southern province of Sri Lanka (6.1256˚ N and 80.8741˚ E). It covers 32,000 acre-feet of capacity with

200 acres of surface area (District statistical branch, Hambantota 2012). It is the major water supply reservoir to the whole Hambantota district. Reservoir water is directly used for bathing, irrigation and other domestic purposes. However, the water purification plant is built inside the reservoir by the National Water Supply and Drainage Board to supply purified water (treated reference water) to the whole Hambantota district.

Water pH, temperature, dissolved oxygen in water, alkalinity, turbidity, conductivity, and sulphate concentration are some of the physico-chemical parameters that influence the solubility of potentially toxic elements in water (Bishop *et al*. 1986, Johansson *et al*. 1995, Odunola *et al*. 2013, Li *et al*. 2013, Maranho *et al.* 2014, Copaja *et al.* 2016, Bawa *et al.* 2018, Zhang *et al*. 2018). Nadarajah *et al*. (2019) have studied some physico-chemical parameters on 10 different reservoirs of the Kala Oya river basin in Sri Lanka. At low pH, the solubility of potentially toxic elements is comparatively high (WHO 2004, Zhang *et al*. 2018). The effect of pH on potentially toxic elements released from polluted sediment in the middle of the Xiaofu River in Zibo city, China, has been reported (Zhang *et al*. 2018). They have studied Cd, Ni, and Cu release from river sediment at different pH and results revealed that under acidic conditions, Cd, Ni, or Cu were more likely to be released into the overlying water. Johansson *et al*. (1995) have studied the effect of pH on Cd and Zn concentrations in rivers in southern Sweden. They have found that at lower pH, there was a significant increase of these potentially toxic elements in rivers in southern Sweden by leaching from soils to water.

Water temperature is one of the most important variables in aquatic systems (Odunola *et al*. 2013) as it may influence many other parameters. Li *et al*. (2013) have reported that at higher temperatures (30–35°C), Pb, Cu, Zn, Cr and Cd were released more rapidly than at lower temperatures. The effect of pH, temperature, dissolved oxygen (DO), and flow rate of overlying water on potentially toxic elements released from storm sewer sediments in Xicheng District of Beijing, China was reported (Li *et al*. 2013). Low levels of DO may change the state of substances from oxidized to reduced form increasing the levels of potentially toxic elements (Li *et al*. 2013, Maranho *et al.* 2014, Copaja *et al.* 2016). Kang *et al*. (2019) have shown an increased release of Pb, Zn, and Fe from river surface sediments in an anoxic environment of Hai River in Tianjin, China.

Bishop *et al*. (1986) have reported that the leaching rate of potentially toxic elements from stabilized/ solidified wastes is governed by the amount of alkalinity present in the waste while Zhang *et al*. (2020) have reported that suspended particles provided an adsorption media for potentially toxic elements. Bawa *et al.* (2018) have studied the effect of temperature, mobility, concentration and oxidation state of other metals on the conductivity of water bodies. The United States environmental protection agency (USEPA) proposed the US federal regulation limit for Fe and Mn in drinking water as 0.3 mg/L and 0.05 mg/L respectively (WHO 2004). Sri Lankan standards (SLS) for Fe and Mn in drinking water are also the same as US federal regulation limits. Several investigations have been carried out to assess potentially toxic elements in water (Odunola *et al.* 2013, *Ahsan et al.* 2018, Ayodele *et al.* 2019).

Standards of potable water demand its physico-chemical characters as well as potentially toxic elements to remain below detrimental levels. There is no previous information from the Kattakaduwa reservoir, although it has been a major source of potable water to most of the Hambantota District. Furthermore, the treatment of water of the reservoirs require knowledge on the temporal variation in existing contaminants if any, and the levels of potentially detrimental elements. This article aims to report monthly variation of physico-chemical parameters and selected potentially toxic elements in water and sediments of the Kattakaduwa reservoir in the year 2017. We have analyzed the temperature, dissolved oxygen, pH, alkalinity, turbidity, sulphate ion concentrations, conductivity and five potentially toxic elements (Mn, Fe, Cu, Cd and Pb) of collected water samples from five different sites and the treated reference water. Besides, the sediment samples collected from four sites in the reservoir were also analyzed to understand the role of sediment in the transportation and distribution of potentially toxic elements in the aquatic environment.

2 Material and Methods

The administrative map and the sampling sites in the Kattakaduwa reservoir are shown in Figure 1.

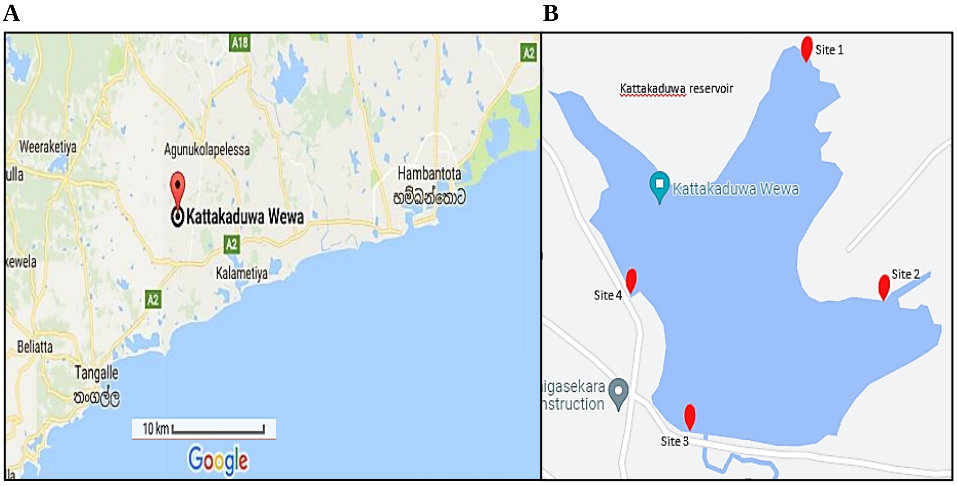

Fig 1. Administrative map of Hambantota District (A) and the sampling site map of the Kattakaduwa reservoir (B).

2.1 Sampling sites

Site 1 (6.128426˚N, 80.87692˚E) and site 4 (6.125368˚N, 80.8728˚E) are two opposite sides of the reservoir. Site 2 (6.124297˚N, 80.87962˚E) closer to an inlet is the opposite side of site 3. Site 3 (6.121889˚N, 80.87402˚E) is the place where the pump house is located, and site 3S is closer to the inlet of the pump house and 3B is ~5m deep in the same place. From each of the sites 1, 2, 3, and 4, surface water and sediment samples were collected separately in triplet at the beginning of each month of the year 2017. At site 3, in addition to the 03 surface water (3S) and three sediment samples, three bottom water samples ~5 m deep (3B) were collected. A treated reference water sample (TR) was collected from a tap line just outside of the reservoir. Though we collected water samples from 5 different sites, sediment samples were collected only from 4 sites (only one sediment sample at site3S and 3B).

2.2. Physico-chemical parameters

Dissolved oxygen was measured by Winkler fixation. Standard BOD bottles (250 mL) were used in collecting water samples underneath water from each study site and treated reference water. Winkler A ($MnSO_4$ 1mL) and Winkler B (alkaline I_2 solution 1mL) were added to the bottle by using a pipette. Airtight bottles were brought to the laboratory and analyzed using the Winkler method.

A Mercury bulb thermometer was used to measure temperature in degrees of Celsius (˚C). pH, Turbidity and Conductivity was measured by a portable pH meter (Smart Sensor, PH818 model), calibrated 2100Q portable turbidity meter (Hach 2100Q model) and calibrated portable pH-conductivity meter (IndiaMART, HI9812-5 model) respectively immediately after the collection of water samples into 100 mL plastic bottles.

Sulphate ion concentration was determined following the Turbidimetric method (Sawyer *et al*. 2000). 100 mL water sample was mixed with 20 mL of buffer solution. With continuous stirring, a spoonful of $BaCl_2$ crystals was added and began timing immediately. The stirring was continued further for 60 ± 2 s at a constant speed. Then the sample was poured into an absorption cell of photometer and turbidity was measured at 5±0.5 min using a 2100 A turbidity meter. Sulphate concentrations were estimated by comparing the turbidity readings with the calibration curve prepared by SO_4^{2-} standards (Series of 0.1N -0.002N H_2SO_4 acid was used for the calibration).

Alkalinity was measured by titration. 100 mL of water sample was taken into a titration flask and 5 drops of Bromocresol green was added until the solution was turned into sky blue colour. The solution was then titrated with standard 0.02M H_2SO_4 solution until the colour became wine red. The volume of titrated H_2SO_4 was recorded and calculated the alkalinity of the sample in mg/L.

2.3 Potentially toxic elements

Three water samples from each study site and treated reference water were collected into 50 mL polypropylene vials for the determination of potentially toxic elements. A 1.0 mL of analytical grade conc. HNO_3 was added right after the collection of the water samples. The shallow sediment samples were collected from ~3 cm in depth to the airtight zip lock bags using the Grab Sampler.

Flame ionization atomic absorption spectrophotometer was used to analyze all potentially toxic elements in water samples as well as in the sediments. It was calibrated using Fisher Scientific calibration standards. Later on, Graphite furnace atomic absorption spectrophotometer (GF-AAS) (GBC 932 AB Plus model) was used to analyze Fe and Mn in water samples because the concentration values obtained from Flame AAS were below the detection limit of 1 mg/L). For both AAS, the sample size was 1 mL and 1 mg for water samples and sediments. Dissolution of samples was required before analysis. Minimum detection limits of flame ionization AAS for water samples and sediments were 1 mg/L and 1 mg/kg and in GF-AAS the corresponding value for water samples was 0.001 mg/L.

2.4 Statistical analysis

Statistical analysis was carried out using Graph Pad Prism 8.0. A descriptive analysis was carried out for each study site and the treated reference water sample in the calculation of the mean value and the standard deviation. Then, a normality test was carried out for each data set to check whether it is parametric or not. If the data has a normal distribution (parametric), One-way ANOVA test was performed and if the data has no normal distribution (non-parametric), the Kruskal-Wallis test was carried out. Finally, Dunn's multiple comparisons test was carried out to compare the significance among study sites. A computer program developed by Dallal *et al.* (2001) was used to obtain superscripts to affix to means that are not significantly different from each other.

3 Results and Discussion

3.1 Physicochemical parameters

Mean values of physico-chemical parameters of water samples in different study sites and the treated reference water sample (TR) during the study period are given in Table 1.

Table 1: Mean values of physico-chemical parameters of water samples in different study sites and the treated reference water sample (TR) during the study period. Values in each column for a given factor superscripted by the shared letter are not significantly different (P > 0.05).

Site	T (˚C)	pH	Dissolved Oxygen (mg/L)	Sulphate concentration (mg/L)	Alkalinity (mg/L)	Turbidity (NTU)	Conductivity (μS)
Site 1	$34^{a} \pm 1$	$7.5^{b} \pm 0.2$	$7.40^{b} \pm 2.35$	75.70 ± 31.90	$164.0^{ab} \pm 33.0$	$46.04^{a} \pm 27.15$	682.2 ± 123.7
Site 2	$33^{a} \pm 1$	$7.5^{ab} \pm 0.1$	$4.90^{a} \pm 0.90$	56.65 ± 30.10	$189.0^{a} \pm 39.4$	$35.62^{a} \pm 16.34$	648.7 ± 314.0
Site 3S	$33^{ab} \pm 1$	$7.5^{ab} \pm 0.1$	$7.10^{b} \pm 1.80$	57.40 ± 23.60	$176.9^{ab} \pm 32.0$	$36.74^{a} \pm 18.87$	605.3 ± 119.8
Site 3B	$32^{b} \pm 1$	$7.6^{b} \pm 0.2$	$6.70^{ab} \pm 0.90$	69.10 ± 29.50	$167.0^{ab} \pm 34.5$	$38.43^{a} \pm 11.62$	685.3 ± 120.5
TR	$32^{b} \pm 1$	$7.4^{a} \pm 0.1$	$8.20^{b} \pm 0.70$	86.00 ± 35.80	$127.0^{b} \pm 31.0$	1.40 ± 0.91	692.8 ± 119.9
Site 4	$32^{b} \pm 1$	$7.5^{b} \pm 0.1$	$8.00^{b} \pm 1.70$	66.50 ± 28.60	$150.0^{ab} \pm 48.5$	$50.06^{a} \pm 25.82$	676.9 ± 121.3
	*	*	*	NS	*	*	NS

T: Temperature; * $p < 0.05$; NS = no significance

Temperature

A considerable fluctuation of temperature during the period of May to November was observed in all the study sites of the reservoir (Figure 2), but the mean annual water temperature is not significantly different across the study sites.

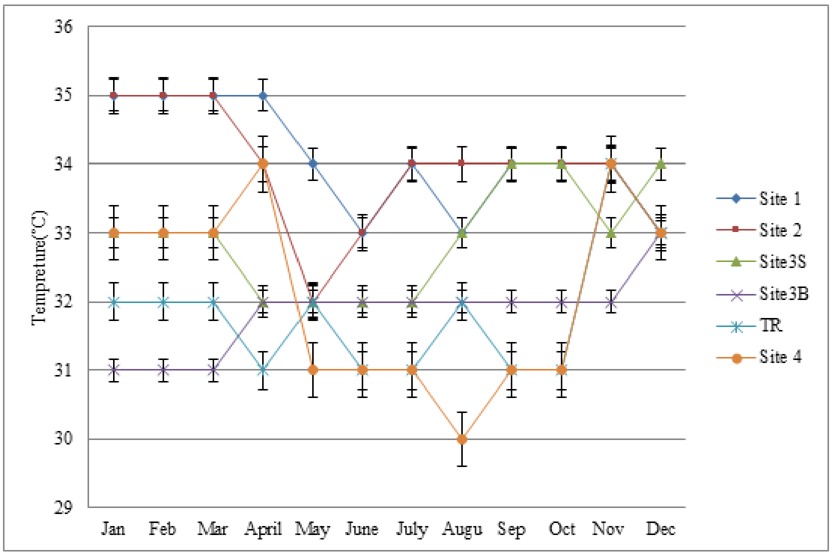

Fig 2. Monthly variation in mean (±SD) temperature in 2017 at different sites of Kattakaduwa reservoir and the treated reference water sample (TR).

As expected, the surface water at site 3 has a higher water temperature than the deep water (5 m in depth), but their annual variation is not significantly different (Figure 3). There is no significant difference ($P < 0.05$) in water temperature between the near inlet (site 2) and pump house (site 3). In general, there is no significant variation in temperature of the water body during the year, although it can change considerably due to variations in incident solar radiation and rainfall. Abeysinghe *et al.* (2017) reported that the temperature varied within the range of 26-28˚C across Kelani River, Sri Lanka during 2017. Li *et al.* (2013) have also pointed out that in tropical countries, the solubility of the gases and potentially toxic elements due to the temperature is virtually consistent in the water body throughout the year.

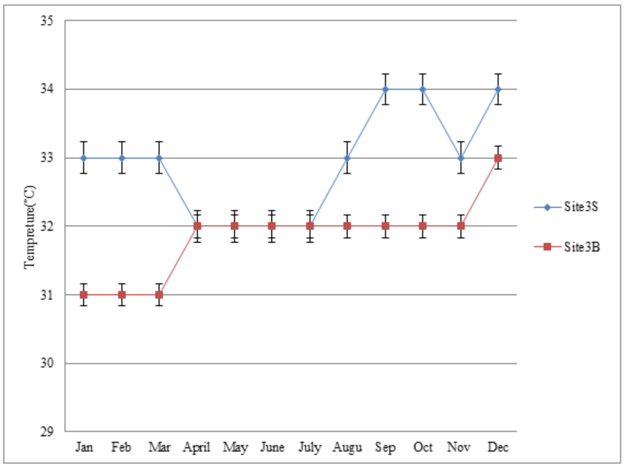

Fig 3. Monthly variation in mean (±SD) water temperature in surface and bottom water (~5m deep) of site 3 in the Kattakaduwa reservoir in 2017.

pH:

The mean pH of all the sites within the reservoir is about 7.5 leaving the water alkaline and has no significant difference among sited. The lowest mean pH, 7.4 is found in the treated reference water sample and is significantly different from the pH of the reservoir water. We paid more attention to site 3 near the pump house because water is pumped to the purification plant from site 3. Water pH at the surface near the pump house at site 3 (3S) varied within the range of 7.3-7.7 (Figure 4) in the year with a mean value of 7.5 ± 0.1. The highest mean pH value, 7.6 is observed in site 3B with the maximum in May (7.9) and the minimum in June (7.3).

Water pH is an important physicochemical parameter that determines the solubility of different potentially toxic elements in water bodies (Johansson *et al.* 1995, Bhaskar *et al*. 2010, Zhang *et al.* 2018). The safest pH level for drinking water is 7.0 (WHO 2004). It has been reported that pH values of water flowing through thick vegetation ranges from 1 to 9 (Lawson 2011). They have suspected that low pH may be due to the organic acids generated from decaying vegetation (Osimen *et al.* 1997, Lawson 2011). Abeysinghe *et al.* (2017) have reported that the pH varied from 6.7-5.9 along the Kelani river, Sri Lanka during the study period of March-August in

2017. It was also reported that the pH varied between 5.8 and 7.3 along the Nilwala river in Sri Lanka (Jayawardana *et al.* 2016). The pH of the water body at Kattakaduwa reservoir lies within a limited range (7.1-7.9). According to Sri Lankan drinking water standards, the highest desirable pH range is 7.0-8.5 (Abeysinghe *et al.* 2017), and hence there is no concern of Kattakaduwa water for human consumption in respect of pH.

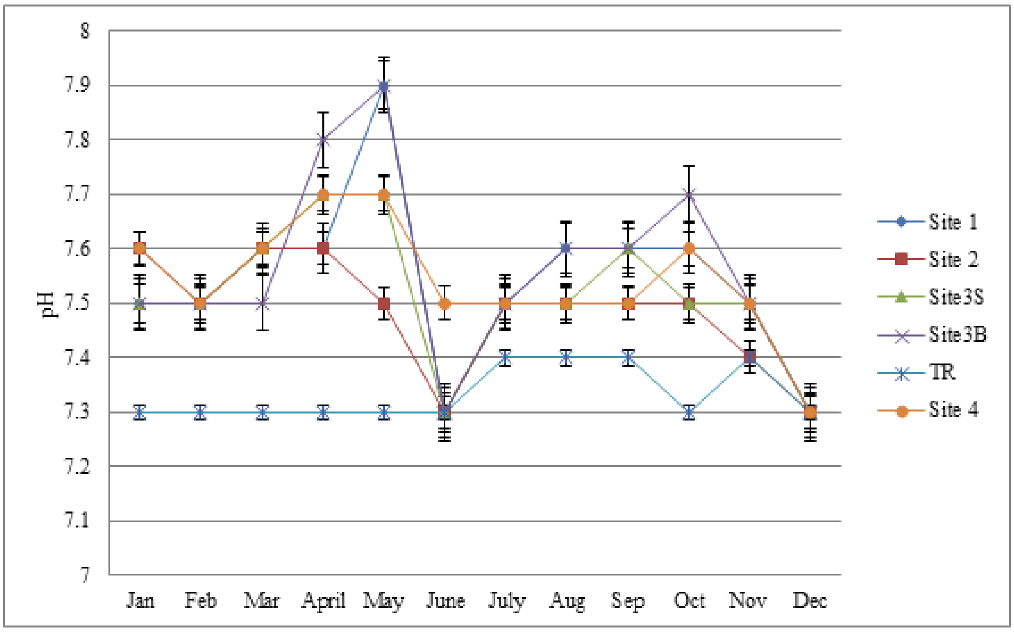

Fig 4. Monthly variation in mean (±SD) pH in the Kattakaduwa reservoir in 2017 at different sites and the treated reference water sample (TR).

Dissolved oxygen

In general, dissolved oxygen in water lies within the range of 3.25 - 9.35 mg/L at all sites with the exception observed for sites 1, and 3S in April, and for site 4 in April and May (Figure 5). As shown in Table 1, dissolved oxygen (DO) was not significantly different ($P<0.05$) among all study sites except site 2. The lowest DO range was found near the inlet at site 2 ranging within 3.25 - 6.05 mg/L (Figure 5) with the average mean value of 4.90 ± 0.90 mg/L which is significantly different from the mean values in all the other sites. DO content near the surface closer to the pump house (site 3S) lies within the range of 5.00 - 11.15 mg/L with a mean of 7.10 ± 1.80 mg/L. There is no significant difference between the DO content of the surface water (3S) and the bottom water (3B) at the same place (site 3). The reason may be the shallow depth (~5m).

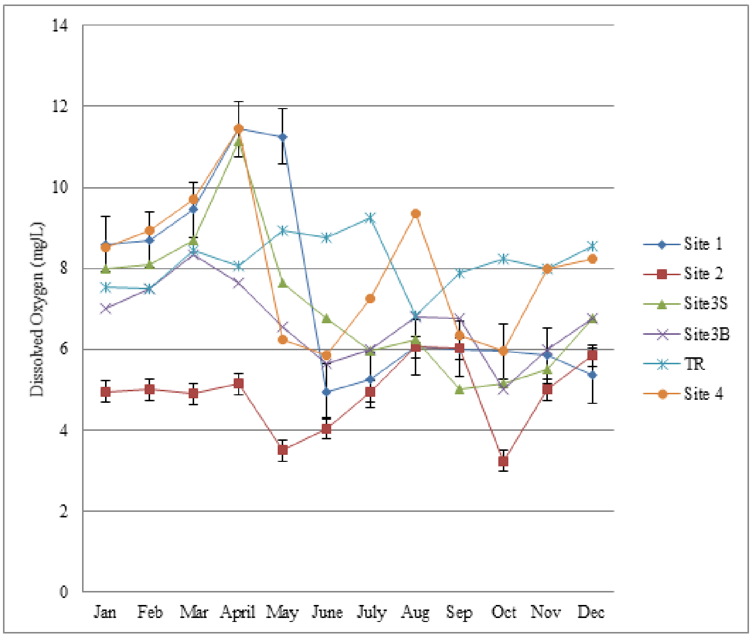

Fig 5. Monthly variation in mean (±SD) dissolved oxygen in the Kattakaduwa reservoir in 2017 at different sites and the treated reference water sample (TR).

Researchers have suspected that low dissolved oxygen in the bottom of water bodies may be due to high organic content from animal/ human faeces, decayed plant materials and domestic wastes accumulated in the bottom of the reservoirs (Uwadiae *et al.* 2009). On the other hand, the treated reference water sample consisted of dissolved oxygen within the range of 6.85-9.25 mg/L with the mean value of 8.20 ± 0.70 mg/L. The study carried out along the Kelani river, Sri Lanka reported variation in DO (as % saturation) between 19.63 and 41.45 (Abeysinghe *et al*. 2017).

In this study, an increasing trend of DO content of water was observed from January to May in many study sites, and then in June, it has returned to normal average. There was a flood and heavy rain received to this area at the end of May. The decrease in DO level may be due to the destruction of the vegetation in the reservoir due to the flooding period and high organic content from surface flowing rainwater. DO content of water in many study sites slightly increased from June to October as seen in Figure 5.

Turbidity

In the Kattakaduwa reservoir, turbidity varied widely throughout the study year. The maximum (72 NTU) was observed at site 2 in June and the minimum (6 NTU) was observed in July. At site 4, the maximum and minimum were about 90 and 14 NTU (Figure 6).

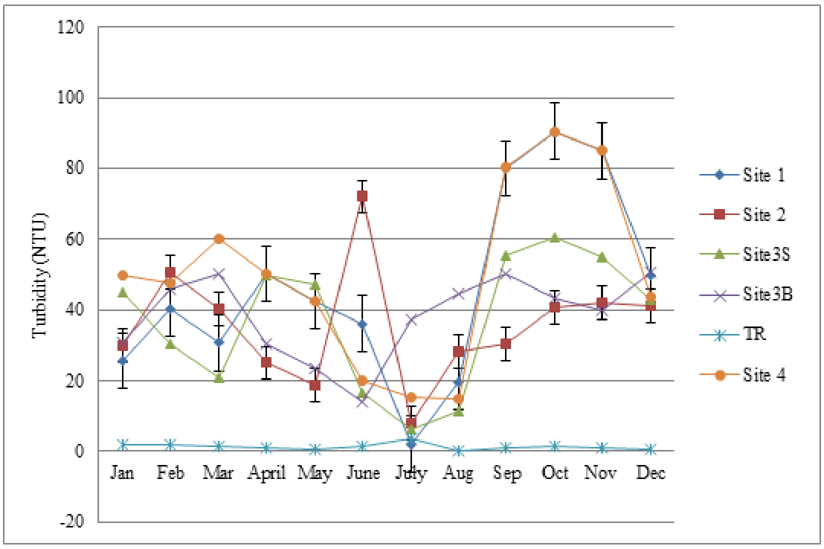

Fig 6. Monthly variation in mean (±SD) turbidity in the Kattakaduwa reservoir in 2017 at different sites and the treated reference water sample (TR).

As shown in Table 1, the variation of turbidity across study sites within the reservoir was not significantly different (P<0.05). Before pumping water for the purification near the pump house at site 3S, turbidity values were in the range of 6.10 - 60.40 NTU with a mean of 36.74 ± 18.87 NTU. Corresponding values for the treated reference water sample were 0.33 - 3.68 NTU (mean 1.39 ± 0.91 NTU) which was less than the WHO standard of 5 NTU and maximum permissible SLS of 2 NTU (WHO 2004, Wanasinghe *et al*. 2018). Though turbidity varied throughout the study period, noticeable lowest values were observed in July. It may be due to the heavy rainy period in late May and the settling down of suspended particles after June. Abeysinghe *et al*. (2017) has reported turbidity values within the range of 11.84 – 4.54 NTU along the Kelani river of Sri Lanka during the year 2017. It was also reported that along the Nilwala river, Sri Lanka, turbidity varied from 5.23 to 149.86 NTU (Jayawardana *et al*. (2016).

Alkalinity

Alkalinity of water in the Kattakaduwa reservoir varied between 85 and 272 mg/L at different sites throughout the study period (Figure 7). As shown in Table 1, variation of alkalinity across study sites within the reservoir was not significantly different

(P>0.05). Most natural drinking water has alkalinity within the range of 30 - 400 mg/L (WHO 2004). As expected, treated reference water showed the lowest average, (127.0 ± 31.0 mg/L) which is significantly lower than reservoir alkalinity but fluctuated in a wide range throughout the year (80.0 - 176.0 mg/L). It seems like carbonate, bicarbonate, hydroxyl anions present in water samples were precipitated with heavy metal ions and other cations in water during April to June. Jayawardana *et al*. (2016) have reported that the alkalinity along the Nilwala river, Sri Lanka in 2016 varied from 19.5 - 177 mg/L.

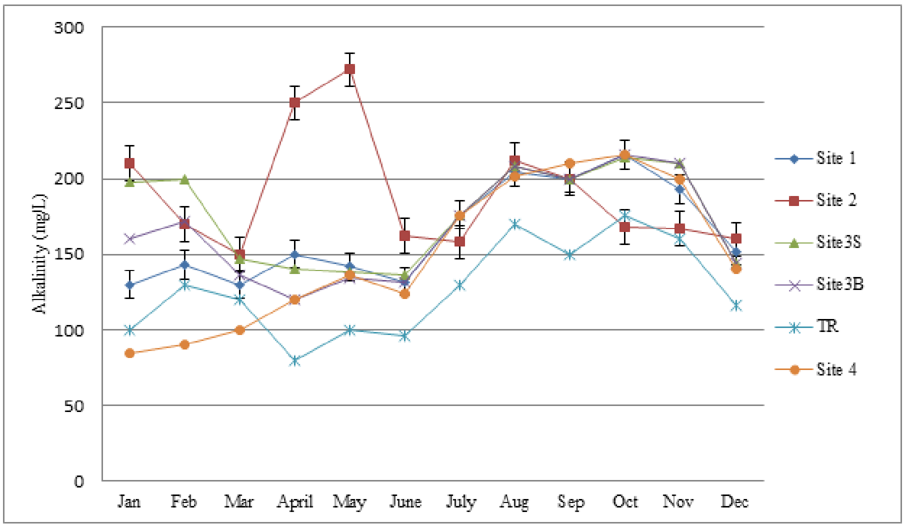

Fig 7. Monthly variation in mean (±SD) alkalinity in the Kattakaduwa reservoir in 2017 at different sites and the treated reference water sample (TR).

Sulphate ion concentration

In general, variation in sulphate ion concentration was observed differently in two periods during the year as shown in Figure 8. The period from January to May before the rainy season showed a higher concentration (above 60 mg/L) except in site 3S and the period from June to December after the rainy season showed a lower concentration (below 60 mg/L). The treated reference water sample followed the same pattern aligning with the two regions.

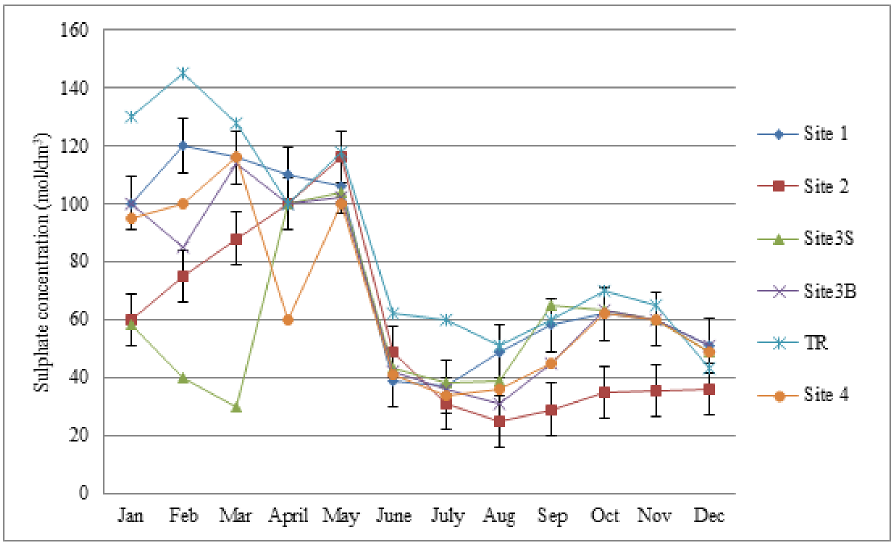

Fig 8. Monthly variation in mean (±SD) sulphate concentration in the Kattakaduwa reservoir in 2017 at different sites and the treated reference water sample (TR).

The variation in sulphate ion concentrations within a site as a whole during the year is large and hence the variation across the study sites during the year was not significantly different ($P<0.05$). Sulphate ion concentration near the pump house before purification (site 3S) was within the range of 30.0 - 104.0 mg/L with a mean of 57.40 ± 23.60 mg/L while the treated reference water sample has sulphate ion concentration of 43.0 - 145.0 mg/L with a mean value of 86.0 ±35.80 mg/L which revealed that there is no change in sulphate ion concentration during the purification. Sulphate ion concentration varied from 4.0 – 404.0 mg/L along the Nilwala river of Sri Lanka in 2016 (Jayawardana *et al*. 2016).

Conductivity

The variation of conductivity in sites within the reservoir and the drinking water sample outside the reservoir were not significantly different (Table 1) except for the abrupt increase in May and abrupt decrease in June in the pumping site, 3S (Figure 9). The mean conductivity value of water at the study site 3S before purification is 605.3 ± 119.8 µS while after purification in the treated reference water sample, it was 692.8 ±119.9 µS. The recorded values of the Nilwala river of Sri Lanka varied from 57.9 µS to 5,057µS in 2016 where the higher values were obtained from urban areas (Jayawardana *et al*. 2016).

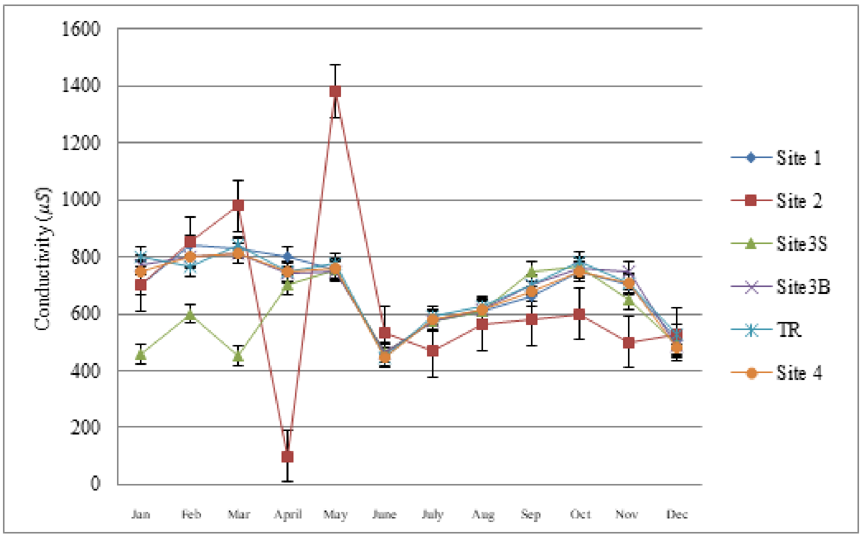

Fig 9. Monthly variation in mean (±SD**) conductivity in the Kattakaduwa reservoir in 2017 at different sites and the treated reference water sample (TR).**

3.2 Metal elements

Metals in water samples

The variation of Fe concentration at individual sites and the treated reference water sample during the year is given in Figure 10. Water samples collected from all study sites within the reservoir before the purification exceeded the USA federal limit (WHO/FAO/IAEA 1996, EPA) and SLS level of 0.3 mg/L.

Most considerable variations of Fe concentrations were detected in the water samples collected at site 3B and site 2 near the inlet. In site 2, it stayed uniform from January to December between 6.32 and 6.00 mg/L except in April, which showed the lowest value of 1.16 mg/L with the mean value ranging 5.72- 1 .44 mg/L during the year (Table 2). The Fe concentration in the bottom of site 3 (3B near the pump house, ~5 m deep) also showed enhanced values with a large fluctuation during the year ranging from 0.89 to 9.50 mg/L with the mean concentration value of 5.02 ± 3.43 mg/L.

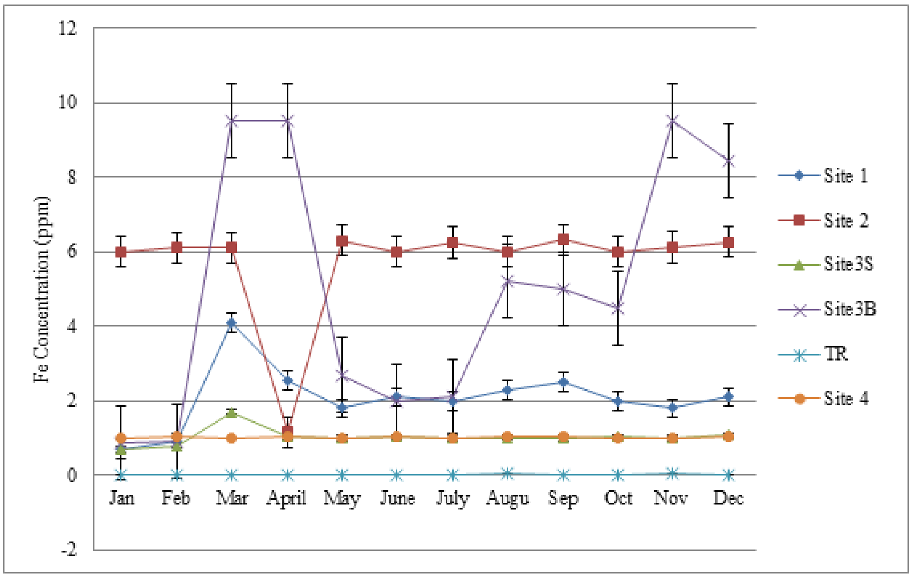

Fig 10. Monthly variation in mean (±SD) Fe concentration in the Kattakaduwa reservoir in 2017 at different sites and the treated reference water sample.

The surface water samples collected from site 3 (3S, near the pump house) showed comparatively lower values of Fe during the year ranging from 0.70 to 1.10 mg/L except for the month of March that reported the highest value of 1.7 mg/L reported in the same month for the bottom water at the same place (3B). The annual mean of Fe concentration in the site 3S is 1.03 ± 0.24 mg/L. These revealed that the Fe concentration of the bottom water was five times more than that in the surface water, and the concentration of Fe in sediment was higher than in water. Treated reference water sample showed a very low concentration of Fe (0.01- 0.04 mg/L), which is much below the US federal limits and SLS limit of 0.3mg/L.

The variation in the Mn concentrations during the year at different sample sites is shown in Figure 11. Except for March (2.1 mg/L) and August (1.1 mg/L) in site 3B, and April in site 5 (2.23 mg/L), Mn concentrations are very low (about 0.03 mg/L) in all the sites throughout the year. Mn concentration at site 3 near the pump house and, surface water (3S) ranged from 0.02 to 0.05 mg/L with the mean value of 0.04 ±0.01 mg/L (Table 2), whereas, at the same place, the corresponding values for bottom water samples (3B) ranged from 0.02 to 2.10 mg/L with the yearly average of 0.31 ± 0.64 mg/L. Mn concentration (0.053 mg/L) in site 3 near the pump house (3S) was slightly above the USA federal regulation limit and SLS limit of 0.05 mg/L in May, July and October.

Table 2: Mean (±SD) concentration values of Mn and Fe in studied water samples at different study sites in Kattakaduwa reservoir and the treated reference water sample (TR) in 2017 (Jan-Dec).

Sampling site	Concentration of heavy metal (mg/L)	
	Mn	Fe
Site 1	$0.045^{ab} \pm 0.048$	$2.075^{abc} \pm 0.855$
Site 2	$0.044^{ab} \pm 0.047$	$5.718^{a} \pm 1.440$
Site 3S	$0.036^{ab} \pm 0.014$	$1.033^{bd} \pm 0.237$
Site 3B	$0.310^{a} \pm 0.641$	$5.020^{ac} \pm 3.429$
TR	$0.022^{b} \pm 0.006$	$0.021^{d} \pm 0.011$
Site 4	$0.221^{ab} \pm 0.633$	$1.025^{bcd} \pm 0.024$
	*	*

* Significant levels are given $\alpha = 0.05$; Values in each column for a given factor superscripted by the shared letters are not significantly different ($P > 0.05$).

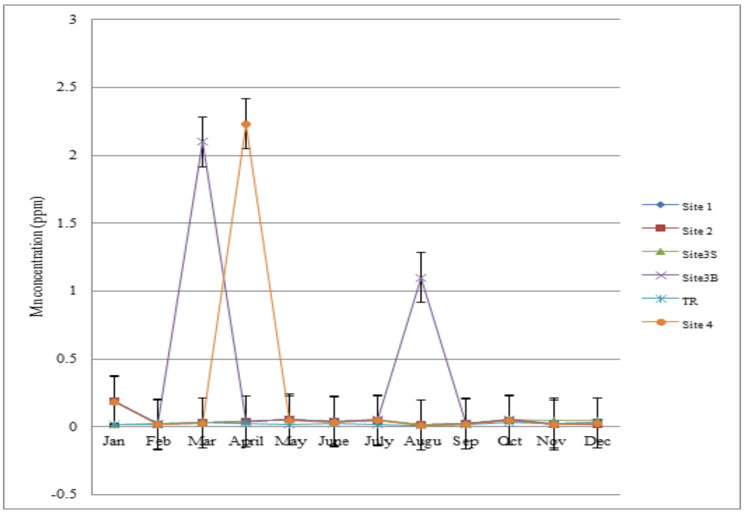

Fig 11. Monthly variation in mean (±SD**) Mn concentration in the Kattakaduwa reservoir in 2017 at different sites and the treated reference water sample.**

Mn concentrations in the treated reference water sample are in the range from 0.01 to 0.03 mg/L with a mean value of 0.02 ± 0.01 mg/L which is lower than the USA federal regulation limit and SLS limit. The concentrations of the other three metals, Pb, Cu, and Cd in the water of the reservoir throughout the year are below the detection limit of 1 mg/L.

Metals in sediment

As shown in Table 3, the concentrations of Fe and Mn in sediments are far higher than those of Pb, Cu and Cd, which were not detectable in the water of the reservoir.

The variations of Fe and Cd concentrations in sediments among the sites were not significantly different. The amount of Mn and Fe in sediment samples of site 3B near the pump house (~5 m below) was higher than the rest of the other sites. It is not surprising as site 3 is the deepest place of the reservoir among study sites and hence all heavy metals can be easily concentrated in site 3B. In comparison, Fe concentration in the sediment was more than ten times of Mn concentration by the presence of a higher concentration of Fe in the water body than Mn. Further, the solubility of Fe in water under general conditions is electrochemically favourable than Mn (Zhang *et al*. 2020).

Table 3: Mean concentrations of selected heavy metal ions in the sediment samples collected at different study sites in Kattakaduwa reservoir during 2017 (Jan-Dec).

Sampling site	Concentration of heavy metal (mg/kg)				
	Mn	Pb	Cd	Cu	Fe
Site 1	135.2^{a} ± 124.5	0.825^{a} ± 0.331	0.160 ± 0.067	0.289^{a} ± 0.092	5893 ± 5130
Site 2	984.0^{b} ± 704.2	1.628^{ab} ± 0.615	0.176 ± 0.103	4.190^{ab} ± 4.115	11497 ± 9710
Site 3B	1178^{b} ± 1007	4.038^{a} ± 0.324	0.349 ± 0.287	11.340^{bc} ± 8.726	15291 ± 10486
Site 4	295.5^{ab} ± 249.0	1.095^{b} ± 0.454	0.149 ± 0.074	15.950^{c} ± 9.320	11905 ± 8376
	*	*	NS	*	NS

*Significant levels are given as $\alpha = 0.05$; NS indicates no significance; Values in each column for a given factor superscripted by the shared letter are not significantly different ($P > 0.05$).

4 Conclusions

Five studied physicochemical parameters out of seven were significantly different among different study sites. Variation of the individual physicochemical parameter in a particular site is small and hence studied physicochemical parameters do not have a significant influence on dissolved potentially toxic elements in reservoir water. The concentration of Fe in reservoir water before the purification exceeded the USA federal limit and SLS limit of 0.3 mg/L while Mn concentrations exceeded the USA federal limit and SLS limit of 0.05 mg/L only in March and August in the site 3B, and April in the site 4 in 2017. Other than this isolated increase, in general, Mn concentration in the water body is negligible. The Pb, Cd, and Cu in the reservoir water are undetectable as well as their presence in sediments is negligible compared to that of Fe and Mn. The concentration of Fe in sediments, especially in the reservoir water, is considerably high compared to Mn. Therefore, Fe in sediments has easily leached to water, enhancing Fe's concentration in the water body.

Acknowledgements

Financial assistance from the Faculty Research Grant – 2017, Faculty of Natural Sciences, The Open University of Sri Lanka. Comments of two anonymous reviewers were helpful to improve the initial version of the manuscript.

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