Middle-East Journal of Scientific Research 25 (6): 1280-1287, 2017
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2017.1280.1287

Water Quality Study on Giant Tank Situated in Mannar, Sri Lanka during the Rainy Season: Prediction towards Its Domestic Utility

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Abstract: The quality of surface and ground water rely on various chemical components and their concentration that are mostly derived from the biological data of the particular region. However, these water sources are being contaminated due to the improper disposal of industrial waste, runoff from the agricultural farm land and the municipal solid wastes. Therefore, water scarcity problem arises in many countries all over the world. In many parts of Sri Lanka, available water is rendered non-potable because of the presence of excess chemical and biological matters. Water quality is an important parameter to be studied when the overall focus is sustainable development of a country. In this regard, this study mainly focuses on the water quality study of one of the largest ponds, Kaddukarai pond (Giant tank), which is situated in the Mannar district of Sri Lanka. Although this pond contains enough water, it is not consumed for any domestic purposes. Further none of the studies available regarding the quality of this pond water. Thus, this study aims the water quality test by evaluating the physico-chemical parameters and the coliform count. Our result indicates that the physico-chemical parameters of this pond water are in the desirable range, whereas the coliform count found to be higher than normal. Although the physical parameter shows a good agreement with the standards, the coliform count found to be higher in the samples obtained from the Kaddukarai pond. Therefore, if the biological quality is improved, this Giant tank water could also be used for domestic and sustainable agricultural purposes.

Key words: Water quality · Physico-chemical · pH · Giant tank · Dissolve oxygen · Salinity · *E. coli*

INTRODUCTION

Water is an essential natural resource for sustaining life. Water quality is a vital parameter to be studied when the overall focus is sustainable development keeping mankind at focal point [1, 2, 3]. Groundwater is the major source of drinking water in rural as well as in urban areas and over 94% of the drinking water demand is met by groundwater [4, 3, 5]. Access to safe drinking water for every individual regardless of the economic and social status is one of the objectives of the World Health Organization (WHO). Large portions of the populace in developing countries die annually as a result of water borne diseases, such as cholera, typhoid, hepatitis, diarrhea, etc. [6]. *E. coli* and *Enterococcus spp.* members are traditionally used as hygiene indicator bacteria and methods for their detection are essential elements of drinking water regulations all over the world [4, 7]. In addition, there are several standards determine the drinking water quality.

Total dissolved solids (TDS) represents the amount of inorganic substances (salts and minerals) [8]. The principal constituents are usually the cations that include calcium, magnesium, sodium and potassium; and the anions, such as carbonate, hydrogen carbonate, chloride, sulfate and nitrate [9]. High TDS is commonly objectionable or offensive to taste. Hardness is another property of water which prevents lather formation with soap and increases the boiling point of water. Hardness of water mainly depends upon the amount of calcium or magnesium salt or both [11, 9, 12]. Chloride contents in fresh water are largely influenced by evaporation,

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precipitation sea water intrusion, etc. In potable water, the salty taste produced by chloride concentration is variable and depends on the chemical composition of water. Some waters containing 250 mg/L Cl^- may have a detectable salty taste if sodium cation is present. Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism, for example in congestive heart failure.

Nitrate (NO_3^-) is one of the most common groundwater contaminants in rural areas. It is primarily regulated in drinking water because high levels can cause methemoglobinemia or "blue baby" disease [3, 4, 13] [MCCASLAND *et al* 1985]. The high level of nitrates and nitrites (NO_2^-) in the soil and water in the peninsula is attributed to the abundant and indiscriminate use of chemical fertilizers, mainly from urea which contains 46% nitrogen [14]. The problem has been further accentuated by the improper planning of soakage pits and latrines which lead to serious contamination of the ground water by nitrates. In addition, pH of the water must be controlled to minimize the corrosion of water mains and pipes in household water systems. Failure to do so can result in the contamination of drinking-water and in adverse effects on its taste, odor and appearance. All these unequivocally demonstrate that the standard level should be maintained in order to achieve the quality of water [15].

In Sri Lanka, six main types of groundwater aquifers had been identified [16, 17, 18, 19]. These are Shallow Karstic Aquifer of Jaffna Peninsula, Deep Confined Aquifers, Coastal Sand Aquifers, Alluvial Aquifers, Shallow Regolith Aquifer of the Hard Rock Region and South Western Lateritic (Cabook) Aquifer. In addition, three main types of coastal sand aquifers have been recognized and characterized in Sri Lanka. These are Shallow aquifers on coastal spits and bars as found in the Kalpitiya peninsula and the Manner Island in the north west of Sri Lanka, Shallow aquifers on raised beaches are found in the Nilaveli-Kuchchaweli, Pulmoddai and Kalkuda in North Eastern region. In addition, the previous studies on the groundwater especially in the Mannararea identified karstic Lower Miocene limestone and fractured Precambrian Basement aquifers as potential water sources. These aquifers located in Mannar area are re-charged mainly during the 3-4 months of rain in the wet 'maha' season and water in these aquifers then get collected in the form of a fresh water 'lens' floating above the denser saline water. The volume of fresh water in these aquifers usually expands during the rainy season and contracts during the dry season with fluctuating brackish and saline boundaries. Any over extraction from these fresh water lenses results in the coming or entering of the underlying brackish water in to the fresh water. In this regard, in our study we have focused on the water quality of the Giant tank, which is located in Mannar administrative district of the Northern Province in Sri Lanka.

The island of Mannar is situated along the northwest coast of Sri Lanka and is about 260 km north of Colombo (Fig. 1). The extent of the Mannar Island is approximately 128 km^2. Catchment area is 38 square mles. The giant tank is one of the largest tanks in the island and it was built by King Dhatusena (459-477) by damming and diverting water from the Malwatu-oya.

The tank is fed by an 8 mile (13 km) ancient canal, recently restored, which carries water from the Malwatu Oya River. The water from this tank is fed to 162 minor tanks downstream and irrigates 11,195 hectares of paddy land. The area of minor tanks is about 11000. The embankment of giant tank is over 7 km in length with a height of 14 feet. This is comparatively a low height considering other reservoirs of same size. But it is clear that ancient irrigation engineers has considered the flat land in the area and increased the volume of the tank by increasing the area of water spread rather than increasing the depth of the tank.

The hydro-geochemical conditions are also responsible for causing significant variations in ground water quality [9]. The Mannar Island falls into the semiarid climate area and receives a mean annual precipitation of about 975 mm. The maximum and minimum mean monthly precipitation are 240 mm corresponding to the month of November and 5 mm corresponding to the month of July respectively. The temperature in the area ranges from a minimum of 23°C to a maximum of 35°C. The nearest pan evaporation measuring station is at Giant's tank which is about 30 km southeast of Mannar Island. The climate at Giant's Tank is similar to that at Mannar Island and it is assumed that the pan evaporation values of Giant's Tank are applicable to Mannar Island. The average monthly pan evaporation values for Giant's Tank for the 20-year period from 1954 to 1973 range from 125 mm corresponding to the month of December to 178 mm corresponding to the month of June. Although, this Giant tank has the above mentioned importance, the water quality scarcity limits the public water utilization from this tank for their domestic use. Further, there are no reports available about the quality of this Giant tank water. Therefore, to fill the gaps

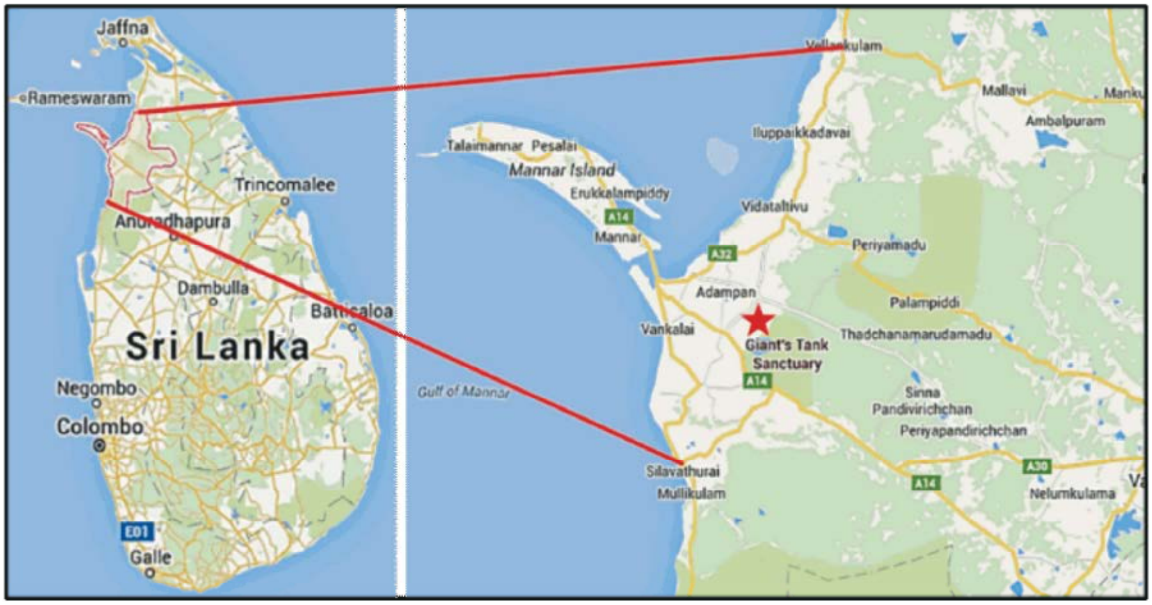

Fig. 1: Situation of Mannar in the Sri Lankan map and the location of Giant Tank

in the literature and enhance the vision of public on the usage of Giant tank water, we have studied the quality of the water in this Giant during the rainy season and we believe that this study will lead to increase the focus on the usage of this water in irrigation as well as the domestic use.

MATERIALS AND METHODS

Reagents and Chemicals: All the chemicals used in this study were of analytical grade (A.R.) and the method used for the preparation of the standard solutions and reagents are as follows.

Standard Titrants

Hydrochloric acid (0.1 mol L^{-1}): Hydrochloric acid (HCl) solution used for the titrimetric determination of carbonate and bicarbonate determination was prepared by diluting concentrated HCl acid. In a typical procedure, 8.54 mL of concentrated HCl was taken and made up to 1000 mL with deionized water in a 1000 mL volumetric flask. The required molarity of the acid solution was confirmed by standardization with the standard sodium carbonate solution.

Sodium Carbonate Solution (0.05 mol L^{-1}): Around 2.5 g of anhydrous primary standard Na_2CO_3 weighted and transferred to a 1000 mL volumetric flask and made up to the mark with deionized water in a 1000 mL volumetric flask.

Silver Nitrate Solution (0.05 mol L^{-1}): About 2.123g of silver nitrate (A.R.) was dissolved in 250 mL deionized water in a 250 mL volumetric flask. Concentration of the prepared solution was examined using titrimetric method with standard sodium chloride (NaCl, 0.05 mol L^{-1}) solution using potassium chromate as an indicator.

Sodium Chloride Solution (0.05 mol L^{-1}): The standard NaCl solution was prepared by dissolving 0.7305 of NaCl salt in 250 mL deionized water in a 250 mL volumetric flask.

Instruments: LPV Series Portable sension$^+$ pH/mV meter was employed for all pH and mV measurements and the standard buffer solutions of pH 4.1, 7.0 and 10.1 were used for calibration at the sampling points. Electrical Conductivity (EC), total dissolved solids (TDS), salinity and temperature of water samples were recorded using HQD Series hand held EC/TDS/Salinity meter after calibration with 1000 µ*S*/*cm* conductivity NaCl standard solution. HQD Series hand held DO/O_2 meter was used for measurement of dissolved oxygen (DO) of the water samples after the saturated air calibration.

Methodology

Water Sampling: Ground water samples for physico-chemical analysis were collected from four two ? different spots of the “Kaddukarai” pond (Giant tank) in Mannar (Labeled as S1 and S2), a well located closed to the Giant tank (S3) and the regular drinking water of the area people at Mannar (S4), Sri Lanka during the period of January to

March 2016. The Ground water samples were collected in different sterilized plastic containers after rinsing out the bottle with the same water samples from the selected spots of the pond. The containers were then sealed and protected from the direct sunlight during the transportation.

Standardization of Hydrochloric Acid: Around 10.0 mL aliquots of the standard (0.05M) sodium carbonate solution was pipette out into a titration flask. Two drops of phenolphthalein indicator was added in to sample. The sample was titrated with the standard HCl (0.1M) to the proper equivalence point. The titration end point was selected with the color change of indicator from pink to colorless. Then two drops of Bromocresol green indicator was added into the same water sample. The sample was titrated with the standard HCl (0.1M) to the proper equivalence point. The titration end point was selected with the color change of indicator from blue to yellow.

Standardization of Silver Nitrate Solution: About 10.0 mL aliquots of standard sodium chloride solution were pipetted out into a titration flask and 2 drops of potassium chromate indicator was added to it. Then the resulting solution was titrated against the above silver nitrate solution. At the end point color changed from pale yellow to red.

Physico-Chemical Analysis: The various physico-chemical parameters were examined using the standard methods for the examination of water and waste water (APHA 1987) and listed as follows.

Determination of the Amount of Carbonate and Bicarbonate: The carbonate and bicarbonate contents were determined by titration with a standard solution of a hydrochloric acid. In a typical procedure, 25.0mL aliquot of water sample was pipetted into the titration flask and two drops of phenolphthalein indicator was added into it. The sample was titrated with the standard HCl (0.1M) to the proper equivalence point. After obtained the color change from pink to color less, two drops of Bromocresol green indicator was added into the same water sample. Then the sample was titrated with the standard HCl (0.1M) to obtain the proper equivalence point by observing the color change from blue to yellow.

Determination of the Amount of Chloride: The chloride content of the ground water was determined by the Mohr's Method. In this method, 10.0 mL aliquot of the water sample was pipette out separately into a titration flask. Then 2 drops of potassium chromate indicator solution was added into it. The resulting solution was titrated against the standard silver nitrate solution (0.05M) by observing the color change from pale yellow to red.

Coliform Count: Water quality was further determined by the standard multiple tube fermentation technique [20]. Coliforms were detected by inoculation of samples into tubes containing lactose broth. The three-tube procedure using lactose broth [21] was used to detect the coliform and determine the most probable number (MPN) of coliform bacilli [22, 23, 24]. Around 10 ml, 1 ml and 0.1 ml of water samples were inoculated into tubes with 10 ml of lactose broth and incubated at 35 ± 0.5°C. The productions of gas (a bubble filling the concavity of inverted Durham's tube) were considered presumptive positive growths of coliforms. Cultures showing no production of gas in 48h were considered negative. The tubes showing gas were inoculated on endo or eosine-methylene-blue agar and one or more typical colonies are picked off into Brilliant Green Bile broth [25] and studied microscopically to see whether the contained organisms have the morphological and staining properties of coliform bacilli.

RESULTS AND DISCUSSION

Physical Appearance: The samples collected for this research work were odorless. However, some of the samples pose slightly colors. The water samples S2, which was collected from deepest part of the pond. The sample S3 was found slightly pale yellow in color. The reason for this observation may be due to the spots selected from the pond, which has slightly muddiness than other spots selected in this study. In addition, the color is probably associated with the presence of inorganic or organic contaminants in water.

Quality of Ground Water: The chemical analysis results of four different samples examined in this study are listed in Table 2. These studies indicate the suitability of this ground water for the application of domestic and irrigation.

The temperature noted for the entire sample studied was similar and it seems that the temperature is not the factor in the variation of the chemical properties of the samples. The analytical data shows that the pH of all the samples were found to be in the range from 7.50 to 7.69 with an average of 7.60 and these result indicate that all

Table 1: Methods used to find out the chemical properties of water

Parameters	Technique of the method
HCO_3^-	HCl titration using Bromcresol green as indicator
CO_3^{2-}	HCl titration using Phenolphthalein as an indicator
Cl^-	$AgNO_3$ titration with the indicator of Potassium dichromate indicator)
NO_3^-	DR/1900 Spectrophoto meter

Table 2: Physico-chemical parameters of the ground water obtained from Mannar, Sri Lanka

Parameters	S1	S2	S3	S4
Temp (°C)	28.30	28.20	28.20	28.20
pH	7.62	7.60	7.50	7.69
EC (µS/cm)	397	398	479	1116
TDS (mg/L)	191	192	231	551
Salinity (ppt)	0.19	0.19	0.23	0.55
DO (mg/L)	3.41	2.56	6.90	7.56
ORP (mV)	267	266	270	274
NO_3^- (mg/L)	0.40	21.20	ND	0.80

EC, TDC, DO and ORP refer to the Electric conductivity; Total dissolved solid, dissolved oxygen and Oxidation reduction potential, respectively. S1, S2, S3 and S4 refer to the four different samples obtained from the two spots of Kaddukarai pond (Giant-tank), well located closer to the Kaddukarai pond and regular usage water, respectively. ND refers to not determined

the samples lies the pH range, which is close to neutral. Comparing these with the standards, the pH levels of the water samples investigated are within the permissible range of 6.5 – 8.5. Above all the previous studies on the underground water samples have also characterized by either a weakly acidic or weakly basic pH and are within the maximum permissible pH level (6.5-8.5) of the National standard of drinking water quality (NSDWQ) and our studies also falls in the desirable range [8, 26, 5]. This slightly higher value of pH ($>$ 7) obtained in this study can be related to higher ionic content of water, such as the slightly large amount of bicarbonate in the water and the discontinued supply of CO_2 during this season. In addition, the alkalinity [27, 24] of the samples S1, S2, S3 and S4 was calculated as 188, 157, 157 and 377 ppm and the sample S4 shows the highest value compared to other water samples. This reflects in the pH of the water sample S4, which shows slightly alkaline pH value.

The electrical conductivity (EC) [27] of the samples S1, S2 and S3 lies in a narrow range between 397 and 497 µS/cm, whereas the sample S4 shows higher conductivity of 1116 µS/cm Relatively higher value for the sample S4 may be due to the purification process done for the regularly used for that sample, which may contain some ions, such as Cl^- in it. The conductance is related to the ionic contents of the water sample and is an invaluable indicator of the range into which hardness and alkalinity values are likely to fall. The similar trend can also be seen that the total dissolved solid (TDS) of ~ 191 mg/L was obtained for sample S1 and S2, which was taken directly from the pond, whereas the other samples S3 and S4 show relatively higher values for TDS. However, all the values obtained was in the permissible range reported by WHO [28]. The TDS and the conductivity show a linear correlation in our studies and thus, it can be claimed that the TDS and EC can delineate each other [29]. Further, the higher value in the electrical conductivity can also be correlated with the saline nature of water and applicable with the parameter named salinity.

Salinity of the samples obtained from different spots of Kaddukarai ponds (S1 and S2) show similar values of 019 ppt, whereas the samples withdrawn from the cannel near by the pond shows slightly higher value of 0.23 ppt and the sample S4 shows almost double the value of 0.55 ppt for salinity [27, 29].

These values have a good correlation with the TDS values and all the values obtained for salinity found to be in the acceptable range published by the BOI, Sri Lanka [30]. In addition, these values were in good approximate with the calculated salinity values from the titrimetric method and the results are shown in Table 3. It can be clearly seen that the difference between the calculated and the measured value was found to very small and negligible. It is noteworthy to mention here that the chloride does not pose a health hazards to human and it is important in human fluid as an electrolyte. However, the higher chloride content renders the freshwater unsuitable for agricultural irrigation.

The dissolved oxygen (DO) was found to 3.41 and 2.56 mg/L for the samples S1 and S2 respectively and it was found to very lower than the acceptable limit. However, the samples S3 and S4 show the acceptable values of 7.56 and 6.90mg/L. The oxidation reduction potential (ORP) of all the samples studies show similar

Table 3: The differences in the calculated and measured salinity of the water samples

Sample	Chlorinity (ppt)	Salinity-Cal (ppt)	Salinity-Mes (ppt)	∆sal
S1	7.93E-02	0.14	0.19	0.05
S2	1.13E-01	0.20	0.19	0.01
S3	1.32E-01	0.24	0.23	0.01
S4	3.12E-01	0.56	0.55	0.01

S1, S2, S3 and S4 refer to the four different samples obtained from the two spots of Kaddukarai pond (Giant-tank), well located closer to the Kaddukarai pond and regular usage water, respectively. Chlorinity was calculated by using titrimetric method and ?Salrefers the differences between calculated and measured salinity values.

Table 4: *E. coli* count and the thermo tolerant *E. coli*

Sample No.	No. of positive presumptive test		No. of positive confirmatory test 37°C for coliform	44°C for Faecal-coliform	MPN Index per 100 mL 37°C for coliform	95% Confidence Limits Lower	Upper	MPN Index per 100 mL 44°C for Faecal-coliform	95% Confidence Limits Lower	Upper	*E-Coli count* Indol test	*E-Coli thermo tolerant* Indol test
S1	10	4	4	4	40	14	100	40	14	100	2	4
	1	4	4	4							0	1
	0.1	2	1	1							0	0
S2	10	5	5	5	1600	400	4600	540	150	1700	4	2
	1	5	5	5							4	3
	0.1	4	4	2							1	1
S3	10	0	0	0	Nil			Nil			Nil	Nil
	1	0	0	0								
	0.1	0	0	0								
S4	10	2	0	0	Nil			Nil			Nil	Nil
	1	0	0	0								
	0.1	0	0	0								

S1, S2, S3 and S4 refer to the four different samples obtained from the two spots of Kaddukarai pond (Giant-tank), well located closer to the Kaddukarai pond and regular usage water, respectively. Multiple-tube method for coliforms & thermo tolerant (fecal) coliforms. Five 10 mL, 1 mL and 0.1mL test portions were used.

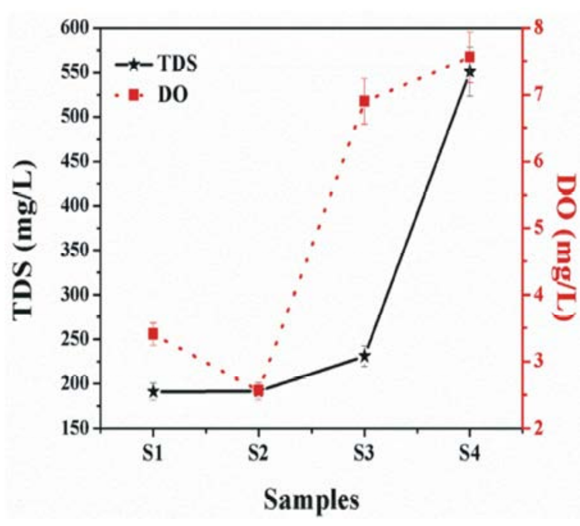

Fig. 2: The two-way plot explains the correlation between the TDS and the DO. S1, S2, S3 and S4 refer to the four different samples obtained from the two spots of Kaddukarai pond (Giant-tank), well located closer to the Kaddukarai pond and regular usage water, respectively

values between 265 and 275 mV. These values indicate that the water samples analyzed in this study are oxidizing agent and the results are in the accepted range of drinking water standards. In addition, it can be observed that the higher values of ORP obtained with the samples, which have higher amounts of dissolved oxygen.

Nitrate is another factor that affects the drinking water quality and the acceptable level of NO_3^- is 50 mg/L. Nitrate itself is not a direct toxicant; however, it is hazard to health, if it converts to nitrite. All the samples studied show the NO_3^- levels lower than the acceptable range and only the sample S2 shows slightly higher value of 21.2 mg/L in comparison to other samples S1 and S4, whereas the S3 level was not in the detectable limit.

***E. coli* Study:** *Escherichia coli* is a faecal bacterium [25, 31, 32] which is found in the intestinal canal of man and warm-blooded animals and is discharged with feces [25, 32, 33]. Enterotoxigenic *E. coli* (ETEC) is a common cause of "traveler's diarrhea" in developing countries infecting only humans and transmission occurs through water and food contaminated with human waste.

The water quality analyzed in this study for the samples obtained from the Giant tank showed significant deterioration in quality in view of global standards. These two samples were contaminated with coliform bacteria, may be resulted mainly from anthropogenic activities, especially discharging of domestic and agricultural wastes directly into the tank. Coliform count has positive relation with anthropogenic activities [31].

The other two samples S3 and S4 had no coliforms at all, thus, it is consumable for all the necessary human needs, including drinking.

In addition, it can be clearly seen that this coliform test has good agreement with the dissolved oxygen amount and the TDS obtained in the analytical study [21, 11]

The Fig. 2 explains the correlation of TDS and the DO and these results show a good proximity with each other and an inverse correlation with coliform count. The samples S1 and S2 show lowest dissolved oxygen amount of 3.14 and 2.56 mg/L whereas its MPN index were found to be higher as 40 and 1600 cfu/100 ml at 37°C. The MPN index at 44°C was also in the same trend with the previous results observed at 37°C and found to 40 and 540 cfu/100 ml for the samples S1 and S2, respectively.

These results show that this Giant tank is experienced a comparatively higher bacterial load. The presence of *E. coli* in water indicates potentially dangerous contamination requiring immediate attention. However, the physico-chemical results show the usability of water from this Kaddukarai pond. Therefore, the water from the Kaddukarai pond can be used for some domestic purpose after a chemical treatment and this may help to fill the water scarcity during the dry weather season.

CONCLUSIONS

Our results indicate that all the physico-chemical parameters tested for the collected samples from the Giant tank in this study were found to be in the drinking water quality range. The sample S1, S2 and S3 were compared with the sample S4, which is used by the public in regular basis for their domestic use. Almost all physico-chemical parameters fall in the similar range in comparison to the water used regularlyby the public, except the nitrate level found in the sample S2, which was relatively high. Although the physical parameter shows a good agreement with the standards, the coliform count found to be higher in the samples obtained from the Kaddukarai pond. These results indicate that the future work should focus on improving the biological quality of this Giant tank water for domestic and sustainable agricultural practices.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Divisional Secretary Nanattan, Mannar for his assistance in collecting the samples for this study.

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