EVALUATING THE CORRELATION BETWEEN WATER DEPTH AND WATER QUALITY IN MINOR RESERVOIRS AND ASSESSING THE IMPACT ON WATER QUALITY FROM THE SLUICE DISCHARGE POINT IN PALAPATHWALA CASCADE SYSTEM AMBANPOLA, KURUNEGALA

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Abstract

Irrigation technology in Sri Lanka has a long history. It has gone through various changes over time. Ancient tank systems consist of several components such as Tank Bund (*Vew Bemma*), and Sluice Gate *(Sorrowua*). Most of them were established to maintain the quality of the stored water for required purposes and efficiently regulate water usage, but from time to time some of these components disappear from the system with the generations. A special feature of the above ancient system is "*Kata Sorowwa*"(Vertical Type sluice which consist of clay pots or blocks to regulate the water). The study is carried out in the Kurunegala Ambanpola area, where nine minor irrigation tanks are situated in a cascade system. All these village tanks are considered seasonal storage tanks. There is a completely dry period in those tanks. Normally in wet conditions, all these tanks have aquatic plants and vegetation on the water's surface. In the dry period, all those aquatic plants die and start to decompose, once the water storage rises, the decomposing process continues under anaerobic conditions. This process will lead to an increase in the acidity of water. Due to sedimentation, the most contaminated particles tend to deposit near the tank bed. Continuously releasing this bottom water can have negative impacts on the environment and as well as the natural water resources quality.

This research aims to investigate the correlation between water depth and water quality in minor reservoirs and evaluate whether the quality of surface water is greater than bottom water and also identify whether changing the sluice discharge point can make a difference in water quality or not, and investigate which parameters have the most significant relationship with water.

The water quality analysis includes temperature, pH, turbidity, total dissolved solids, and electrical conductivity. Data collection is carried out on a spatial and temporal basis. Water Samples were collected as a set of samples taken along a vertical line of water depth. It is decided to have a 0.25m interval of depth water sample as with the depth of the tank. Water samples were collected in every sluice location and an additional 2 sample sets were taken from along the tank bund axis to get an average value. Samples were taken in early January just after the rainfall in December. Sampling was repeated five times with a two weeks interval for more consistency and reliability of results. A comparison was done with water quality standards for irrigation purposes as specified in the National Environmental (Ambient Water Quality) Regulations, No. 01 of 2019 on November 5, 2019.

The study reveals a strong correlation with water depth, with some parameters indicating variation over time. Temperature shows the strongest relationship with water depth. It is gradually increasing with the water height. pH has a strong relationship, though not as strong as temperature, with 85% of data sets showing a coefficient greater than 0.8. which means a very strong relationship value is increased with the water height. DO also shows a strong relationship such as the above two parameters. 89% of the data set shows good and strong relationships, but only 2 data sets deviate completely from the others. EC & TDS values are not indicating a clear relationship with the depth as per the results.

Key Words*:* Irrigation, Tanks, Sluice, Water Quality, Surface Water,

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1.0 Introduction

Irrigation is the term that is used to express, the supply of water to agriculture. So irrigation cannot express or be practiced without agriculture and vice versa. Then and there both these sectors work like two rails on a parallel railway track. Sri Lanka has had an irrigation & agriculture based hydraulic civilization earlier than 450 B.C. (Sirimanna & Prasada, 2022).British Interventions & Technological development of the irrigation sector led to the present status of the sector and the depletion of historical technology (Sajani & Namal Nishantha, 2016). Now this sector can be identified as the main 3 sources of surface irrigation other than direct rainfed cultivation. Those are: Reservoirs (Tanks/Wewa), Anicut (Diversion Weirs), and Natural Streams

From the above, tanks play a vital role in the irrigation era. It has faced various types of overhauls over time. The main purpose of these tanks is to collect water during the rainy seasons, store them and discharge them in dry periods. Then It is clear that this was the reason for water reservoirs are mainly established in dry and intermediate zones (Witharana, 2020) (Witharana, Watershed Album of Sri Lanka, 2007).

These Tanks are divided into main 3 types, for administration and control depending on the command area (Cultivated Area). They are as follows: Major Reservoir-More than 1500 Acs Command Area, Medium Reservoir – From 200 Acs Up to 1500 Acs, and Minor Reservoir (Small /Village Tanks) – Up to 200 Acs.There about 15000 Minor Tanks as estimated by the Department of Agrarian Development (DAD). But some scholars have differently estimated this number as 30,000 & 18000 Tanks (Vidanage, Kotagama, & Dunusinghe, 2022). However, about 90% of tanks are established as a single set tank which is called the Village Tank cascade System. All these tanks can be categorized under 1166 cascade systems (Witharana, Watershed Album of Sri Lanka, 2007) (Vidanage, Kotagama, & Dunusinghe, 2022).

The cascaded tank-village system is described as a “connected series of tanks organized within a micro-catchment of the dry zone landscape, storing, conveying, and utilizing water from an ephemeral rivulet” in Official web page of Globally Important Agricultural Heritage Systems (FAO, 2017)This cascade system acts as an agricultural water source and also provides water for fisheries and livestock, controls soil erosion, flood prevention, water quality control, and retains soil health (Vidanage, 2022). To gain those benefits these systems had various ecological components as well as technical features. A special technical feature among those is the "kata sorowwa” type sluice.” kata sorowwa "is a structure that used discharge water through the tank bund. The specialty of this sluice type from other sluices like the "bisoktouwa" type is the water intake designed to discharge the surface water. Earlier stage this was made by burned clay but after rehabilitation work done by the British, it was replaced by concrete blocks. By the time this sluice in the village tank was replaced by the sluice which was called Headwall type sluice & Tower type sluices. Both of these sluice types have a bottom outlet.

In common people's beliefs and scholars ‘statements, it is mentioned that the quality of surface water discharging has a much more positive impact on irrigation water quality & ultimately this will lead to increase soil quality and soil health. And the quality of drainage water to the natural water ways is purer.

This statement may have scientific facts: such as due to aeration and exposure to sunlight the surface water may have a higher quality or contaminated water tends to have more density than pure water then it will settle in the bottom of the tank & Due to anaerobic decomposing of tank bed vegetation, the acidity level of water near to the tank bed can be higher than surface water also. But there is no scientific research regarding this water quality evaluation over the depth. This research is carried out to analyze water quality variation along the water depth. It will give an idea about whether water intake position can make any difference in discharged water quality or not.

1.1 Background

Agriculture is a profession with the largest number of people in Sri Lanka. In Paddy cultivation, about 1,402,113 farmer families can be identified (Witharana, 2020). Cultivation area is recorded as 708,000 Ha at present (Statistics, 2022). Because rice is the staple food of the country, paddy cultivation plays a vital role in the economy & social wellbeing in the country.

Cultivation extent and the number of farmers are not increased in comparison to the population growth of the country and it leads to the importation exponential quantities of rice. It will ultimately have a negative economical political, and social impact. According to the Central Bank report in 2020, a significant decline is reported in GDP contribution by the agriculture sector to the national economy (Kanesh Suresh, 2021). The most effective solution for the above is to increase the yield per unit of land. For that, controlling the causes which led to the decrease in the paddy yield is important.

The following are the causes of the degradation of paddy yield (Suresh, 2021),

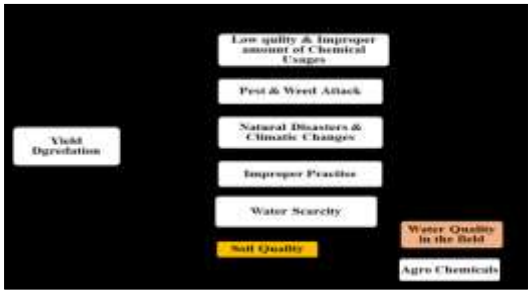

Figure 1 Causes for Yield Degradation

Sri Lanka is a rich country with inland fresh water but, day by day due to various factors, water sources are contaminated. For this contamination, point and non-point sources, both are responsible. Purifying this contaminated water, is not feasible. . But if anyone can use a simple technical solution to fix this issue, will be an added advantage for the sustainability of the water sources. Rice Plant is a plant that is highly sensitive to soil quality. Water sources of the field are one of the major causes of changing soil quality. Then it is clear that irrigation water quality & paddy cultivation has a direct relationship. But it is not a practical & effective thing to use irrigation water after a complex purification process in cultivation. Then if it can be analyzed whether the changing of water intake level can make a significant difference in water quality and

also find whether it has any positive impact on paddy cultivation. It will be a sustainable and more engineering solution.

All these village tanks are considered seasonal storage tanks. There is a completely dry period in those tanks. Normally in wet conditions, all these tanks have aquatic plants and vegetation on the water's surface. In the dry period, all those aquatic plants die and start to decompose, once the water storage rises, the decomposing process continues under anaerobic conditions. This process will lead to an increase in the acidity of water. Due to sedimentation, the most contaminated particles tend to deposit near the tank bed. Continuously releasing this bottom water can have negative impacts on the environment and as well as the natural water resources quality.

1.2 Aim and Objectives

This research aims to investigate the correlation between water depth and water quality in minor reservoirs and evaluate whether the quality of surface water is greater than bottom water and also identify whether changing the sluice discharge point can make a difference in water quality or not and identify the parameters that have the most significant relationship with water

2.0 Methodology

2.1 Study Area

Although the research is based on minor irrigation tanks, the study area is focused on high denser minor irrigation tank areas. Palapathwala cascade system of Abanpola in Kurunegala district.

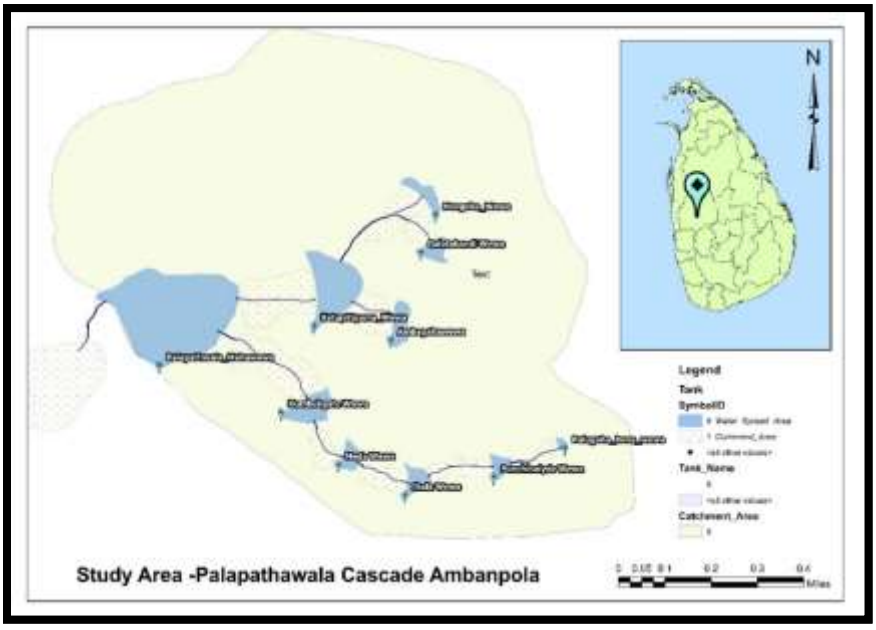

Figure 2 Study Area Map

Table 1 Tank Details of Palapathwala Cascade

Name of The Tank	Location	Maximum Water Height (m)	No of Sluices	Water Spread Area (Acs)	Full Capacity (Acft)
Palugahahena Wewa	7.887763°,80.219179°	0.9	1	0.56	0.88
Punchinayide Wewa	7.886852°,80.216951°	1.6	1	2.47	6.44
Ihala Wewa	7.886291°,80.214161°	1.6	1	3.36	11.39
Meda Wewa	7.887246°,80.212079°	0.9	1	3.95	6.85
Kumbuk Gate Wewa	7.888886°,80.210299°	1.6	1	7.26	22.87
Meegah wewa	7.895055°,80.215129°	0.8	1	1.47	2.02
Galatabandi Wewa	7.893886°,80.214655°	1.6	1	2.62	5.92
Ambagah Wewa	7.891142°,80.213720°	1.1	1	2.51	3.79
Katupitigama Wewa	7.891585°,80.211324°	1.4	2	11.59	34.48
Palapathwala Wewa	7.890339°,80.206495°	2.4	1	34.7	154.8

2.2 Data Collection

Samples are selected as a set of samples taken along a vertical line of water depth. It was decided to have a 0.25m interval of depth water sample. To get temporal variation as well as spatial variation, 3 sets of data collection were carried out on the following dates: 1st Data Collection – 2023/01/11, 2nd Data Collection -2023/02/02,3rd Data Collection - 2023/03/01. Water quality assessment was carried out using Multi-parameter (Hanna-HI9829). On-site readings were taken using this instrument. This instrument can be used to measure the Temperature, Dissolved Oxygen, Electrical Conductivity, Resistivity, Total Dissolved Solid, Salinity, and Turbidity. Standard Probes that use measure these parameters are as follows, pH – HI 7609829-0, Dissolved Oxygen – HI 7609829-2, Electrical Conductivity & Turbidity – HI 7609829-4

3.0 Analysis and Discussion

Data analysis is carried out in two different approaches, Graphical and statistical analysis, and used pre determined quality measures and indicators published by recognized agencies and previous studies and compared with the data. There are 3 data sets plotted in a graph that represent each parameter from every 1st week of January, February & March. The horizontal axis is taken as the depth (measured from the sluice sill level) & Vertical Axis was taken to indicate each parameter. The parameter was selected according to the larger variation in the water height. During the data collection period water level of tanks vary due to rainfall, evaporation & irrigation water issues. pH, Temperature, Ec, Turbidity, Dissolved Oxygen & TDS are plotted in the graph for every 9 tanks.

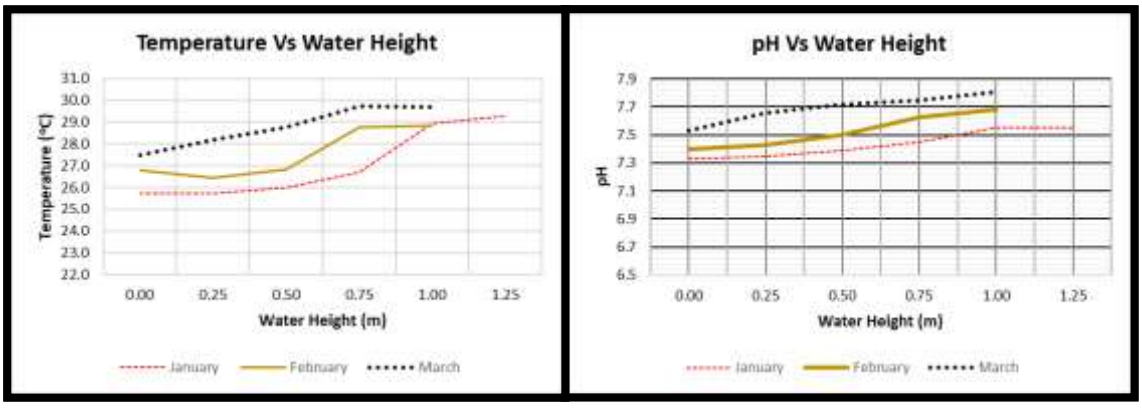

Figure 3 Temperature and pH variation with water height

A complete analysis was done for each graph in each tank.

The following analysis also was carried out using a color gradient varying from red color to green color. Here *NWA-"No Water Available" is used in the table to indicate the point that data was not obtained due to reaching of maximum water height in the tank.

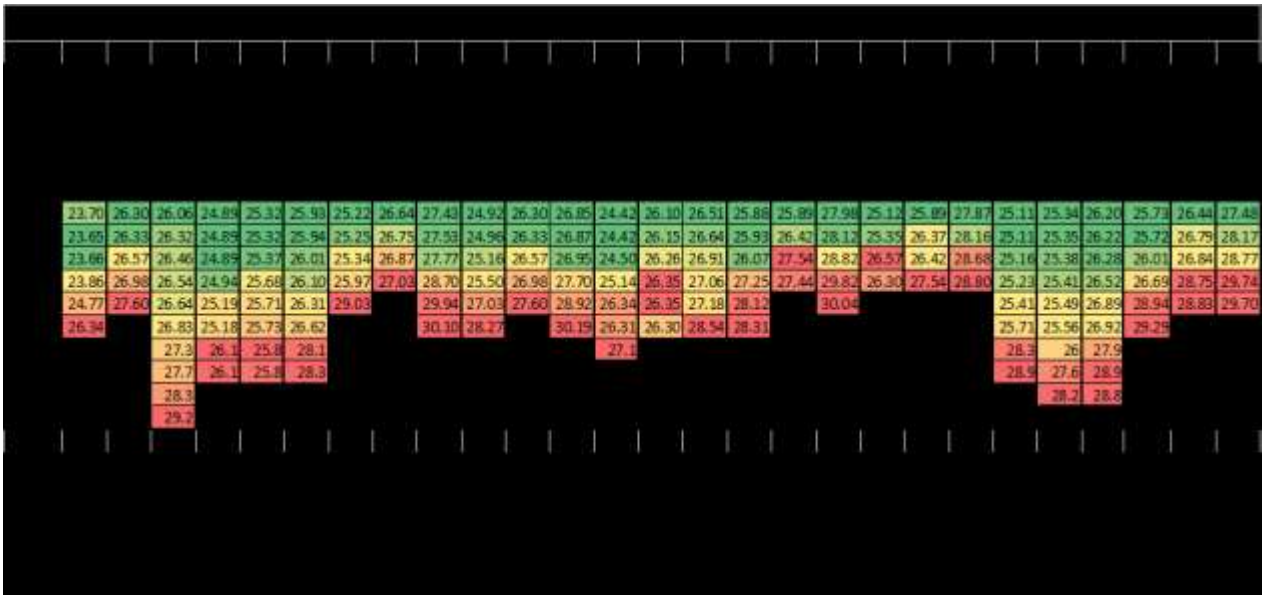

Figure 4 Temperature Variation Palapathwala Cascade

The data set was analyzed using a color variation of a single parameter between all the tanks. The same was carried out for all selected parameters. Co-relationship is analyzed by using the Pearson co-efficient (Ferenz, 2021), (Turney, 2022). Analysis was carried out on each tank separately. According to the Pearson Co-relationship coefficient a leaner relationship was identified & depending on the co-efficient value characteristic relationship is defined. Next, all the data relevant to a single parameter were put into a single table and analyzed with respect tank.

Pearson's correlation (Correlation coefficients) of Tanks

Tank		Palapathwala Wewa			Katupitigama Wewa			Ambagaha wewa			Galatabadi Wewa			Meegaha Wewa			Kumbukgate Wewa			Meda Wewa			Ihala Wewa			Punchiniyide Wewa		
Parameter	Unit	January Data Set	February Data Set	March Data Set	January Data Set	February Data Set	March Data Set	January Data Set	February Data Set	March Data Set	January Data Set	February Data Set	March Data Set	January Data Set	February Data Set	March Data Set	January Data Set	February Data Set	March Data Set	January Data Set	February Data Set	March Data Set	January Data Set	February Data Set	March Data Set	January Data Set	February Data Set	March Data Set
Temp.	°C	0.83	0.94	0.93	0.87	0.94	0.88	0.81	1.00	0.95	0.91	0.94	0.92	0.95	0.86	0.87	0.95	0.93	0.97	0.87	0.92	0.98	0.83	0.83	0.93	0.92	0.87	0.97
pH		0.85	0.96	0.96	0.98	0.92	0.97	0.29	0.80	0.98	0.98	0.96	0.98	0.96	-0.68	0.97	0.93	0.49	0.94	-0.66	0.96	0.96	0.93	0.93	0.98	0.97	0.98	0.97
Ec	µS/cm	0.94	0.00	-0.69	0.96	0.74	-0.11	-0.71	NA	0.21	NA	0.00	0.41	0.77	-0.83	0.65	0.92	-0.95	-0.89	-0.09	-0.77	0.60	0.50	0.48	0.91	-0.78	-0.94	-0.32
Turbidity	FNU	-0.45	-0.82	-0.80	-0.97	-0.11	-0.95	-0.22	-0.74	-0.92	-0.71	-0.82	-0.49	-0.55	-0.65	-0.38	-0.73	-0.80	-0.72	-0.84	-0.80	-0.98	-0.78	-0.80	-0.86	-0.81	-0.92	-0.82
DO	%	NA	0.96	0.88	0.94	0.80	0.93	0.23	0.99	0.98	0.97	0.96	0.96	0.94	0.98	0.99	0.95	-0.04	0.95	0.90	0.75	-0.70	0.92	0.86	0.97	0.97	0.64	0.93
DO	ppm	NA	0.96	0.88	0.95	0.77	0.97	0.09	0.99	0.98	0.95	0.96	0.97	0.93	0.98	0.99	0.94	-0.15	0.94	0.90	0.71	0.76	0.93	0.87	0.74	0.97	0.61	0.92
Resistivity	MΩ.cm	-0.83	NA	0.52	-0.58	NA	NA	NA	NA	NA	NA	NA	-0.41	-0.58	0.65	NA	-0.13	NA	NA	NA	NA	-0.26	NA	NA	-0.87	NA	NA	-0.71
TDS	ppm TDS	0.95	NA	-0.69	0.92	0.76	0.00	NA	0.26	0.65	0.39	NA	NA	0.00	-0.62	NA	0.83	-0.77	-0.71	-0.13	0.26	0.89	NA	0.57	0.86	-0.74	-0.88	0.29
Salinity	PSU	0.83	NA	-0.71	NA	NA	NA	NA	NA	-0.41	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-0.83	-0.87	NA

	Between 0.8 to 1.0 & -1.0 to -0.8
	Between 0.5 to 0.8 & -0.5 to -0.8
	Between 0.5 to 0.0 & -0.5 to 0.0
	Not Avilable

Figure5 Pearson's Coefficients of Tanks

Using coefficient value and co-relationship categorization each parameter was analyzed. Parameters which have significant variation with depth were identified with the coefficient values. Water quality analysis was carried out from comparison with the standard parameters related to Irrigation Agriculture published by the CEA & FAO. The analysis was done base on selected points in the data set, Water Surface reading of the tank, bottom level reading of the tank, Maximum value of the data set in each month, and Lowest Values of the data set in each month. Analysis using the above value gives a general & impartial idea about the set of data of each tank.

4.0 CONCLUSION

This research study is carried out to analyze the variation in water quality with water depth. When comparing all the analyses done for each tank for each month, a clear relationship can be identified in certain parameters. Some parameters have a very strong relationship with the water depth. Some parameters show average or weak co-relationships. Few sets of parameters don't show any correlation compared to others. The strong co-relationship does not change much, even over time, and most of the parameter variation patterns are similar in different tanks.

Temperature shows the strongest relationship with water depth. It is gradually increasing with the water height. From the 27 data sets that were analyzed in the study 100% of the data sets show a greater than 0.8 Pearson correlation coefficient value, which is considered a very strong correlation. And also, most of the time clear sudden increase in temperature near to surface can be identified. It can be a cause of water surface exposure to sunlight.

pH has a strong relationship, though not as strong as temperature, with 85% of data sets showing a coefficient greater than 0.8. which means a very strong relationship value is increased with the water height. Temperature & pH show similar variations most of the time. But special two situations can be identified in Meegahawewa -February & Medawewa January Dat set. Even though a co-relationship can be identified pH value is shown a sudden drop near the tank water surface. Analyzing those data pH values is varying between 0.1 & 0.18. One of the major reasons for this phenomenon is the decomposition process of vegetation in the tank. This process may lead to an increase in the acidity level of water.

DO also show a strong relationship such as the above two parameters. 89% of the data set shows good and strong relationships, but only 2 data sets deviate completely from the others. In Ambagaha wewa January data set near to surface clear decreases of Do can be identified. This may be caused by aquatic plants near the surface. These normal variations in the increasing DO level caused by the water level have a direct impact on surface aeration.

More than 81% of the turbidity data shows a good & strong relationship. Normally, turbidity decreases with the water height. Due to the sedimentation normally occurring near the tank, the turbidity level is higher when compared with the water surface. All these tanks are very small tanks due to that minor turbulence also can vary these values occasionally.

Other than the above parameters, Ec & TDS shows some values of the Pearson coefficient. Certain pattern similarities are hard to identify when comparing other parameters. But in a few cases, there can be some patterns in the data, but these proofs are not enough to express an overall idea about the Ec & TDS co-relationships. But the behavior of the TDS and Ec always shows similarities when compared with all tanks.

Temperature, pH, and DO decrease from surface to bottom, while turbidity increases from surface to bottom, according to the summaries above. These findings prove the following statements made by general farmers: Normally, farmers say when they open the sluice gate after some time; an unbearable odor is coming from the sluice gates. It gives an indicator of quality decreases in the bottom water.

When the data are compared with the quality standard, dissolved oxygen shows a higher amount of unsuitability values for every tank. Also, EC is increases in February. When compared to other months, January receives very little rainfall, which may result in low water renewal and higher water concentrations.

5.0 RECOMMENDATION

In this case, some parameters show a significant variation in quality with the water depth. Then it may emphasize that changing water intake can have an impact on water quality. But to put that into practice, it is essential to carry out the research in a much more advanced way. This research and analysis was done in January, February, and March. In Sri Lanka, there are two main seasons (Yala and Maha). The yala season is considered the drier of the two. During the Yala season, tank water was mostly used, which was also stored during the Maha season. And farmers practice increased water-saving techniques due to the low level of rainfall. All these reasons lead to the accumulation of stagnant water in tanks for longer periods. This means water quality is more subject to change than during the maha season. Also, since this research is also performed at the end of the maha season, it didn't capture the variation in the rainy season. It is strongly recommended to perform this throughout a complete year with at least at 2-week interval of data collection.

The selected parameters are basic water quality parameters. But research should be improved to analyze nutrient data such as NO3-N (Nitrate Nitrogen), NH4+-N (Ammonium Nitrate), PO43-(phosphorous), and also chloride & heavy metals. Then it can get a clear idea about the environment sector and various sectors other than agriculture.

Generally, this study has demonstrated that the ancient irrigation components have a variety of impacts beyond their main function. Most of them were introduced by the ancient people through

long-term practice, and these structures have undergone a long-term evaluation process, replacing them with modern structures without proper studies and investigations will have various consequences beyond what we can imagine.

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