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The Impact of the Surrounding Land Uses on Water Quality of Some Selected Cascade and Perennial Tanks in Anuradhapura District, Sri Lanka[#]

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ABSTRACT

The present study was conducted to evaluate the water quality of the inlet, irrigation outlet, and edges linked to Nuwarawewa reservoir, Mahakanadarawa reservoir, Hurulu wewa reservoir, Sangilikandarawa reservoir, and Nachchaduwa perennial reservoir in Anuradhapura, Sri Lanka. Water samples were taken from a designated position of each inlet, irrigation output, and edges in the second inter-monsoon, northeast monsoon, and first inter-monsoon seasons. Water quality indicators such as pH, electrical conductivity (EC), total dissolved solids (TDS), Na, K, Ca, Mg, Sodium Adsorption Ratio (SAR), NO_3^- -N, NH_4^+-N, dissolved reactive phosphorus (DRP), and heavy metals (Cd, As, Pb, and Hg) concentrations were measured in each water sample. Data was analyzed using SPSS statistica software. Considerable temporal fluctuations in water quality indicators were detected in inlets, irrigation outflows, and edges over the research period. The findings revealed that NO_3^- -N, NH_4^+-N, and DRP in Sangilikandarawa reservoir during the northeast monsoon were close but not above the FAO (1985) maximum levels guidelines for irrigation water. pH, EC, TDS, and heavy metals (Cd, As, Pb, and Hg) in all the other tanks were within permitted values according to WHO drinking water quality standards and FAO (1985) guidelines for irrigation water. This finding further demonstrated that the consequences of surrounding land use on water pollution in inlet water canals linked to Sangilikandarawa and Nuwarawewa are greater. It could be concluded that a pollution management plan needs to be implemented in order to stop further pollution.

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Introduction

The average annual rainfall in Sri Lanka is used to split the island into three climatic zones: wet, intermediate, and dry. As a result, water availability varies by region, and water shortages are one of the most significant obstacles to agriculture in the dry region (Nianthi and Jayakumara, 2010). As a result, agriculture has traditionally relied on rainfall or water collected in community tanks and redirected from the wet zone by large irrigation projects, both of which have been used for decades (Nilusha et al., 2012). There are two major crop cultivaton seasons called *Yala* and *Maha* seasons. Rice fields are prepared from late April to early May for planting in the *Yala* season and late October to early March in the *Maha*. When *Yala* (dry) season comes around, there isn't enough naturally accessible dry zone water to supply the dry zone's dominating regions, even with arriving wet zone water. Because of this, the idea of taking out certain amounts of groundwater for farming has practised from ancient times (Abeywardana and Pitawala, 2019).

Water pollution is the degradation of water quality due to the presence of contaminant substances in the water. Water pollution occurs in waterbodies, such as lakes, rivers, streams, and aquifers (Wang et al., 2008). It entails the discharge of hazardous compounds, pathogenic microbes, substances that need a lot of oxygen to breakdown, substances that are easily soluble, radiations, etc. that accumulate on the bottom and interfere with aquatic ecosystems (García-ruiz , 2010).

When it comes to inorganic pollutants, on the other hand, their vast dispersion and lack of impact on the ecosystem make them less hazardous (Giri and Zeyuan, 2016). Pollutants like lead (Pb), arsenic (As), mercury

(Hg), chromium (Cr), nickel (Ni), barium (Ba), cadmium (Cd), cobalt (Co), selenium (Se), vanadium (V), and pesticides are extremely dangerous and poisonous, even at ppb (parts per billion) levels (Reddy and Behera, 2006). But others including zinc (Zn), copper (Cu), and iron (Fe), come under this group may be beneficial for the health of humans and animals (Wang et al., 2008).

A freshwater resource may be utilized for a variety of different purposes depending on its quality. For this reason, in-depth investigations of the water quality of freshwater resources are needed before choices can be made on the sorts of uses that can be made and the measures that need to be put in place to lessen the degradation of water quality (Verma and Dwivedi, 2013). Since freshwater bodies have such a direct effect on human health, it is imperative that their quality be regularly evaluated. The primary freshwater reservoirs of Anuradhapura district are Nuwarawewa, Mahakanadarawa, Hurulu wewa, Sangilikandarawa, and Nachchaduwa perennial reservoirs. Furthermore, the evaluation of water quality in these reservoirs has been impacted by a wide range of human activities over a long period of time. So, this study focused on the water quality in Nuwarawewa, Mahakanadarawa, Hurulu, Sangilikandarawa, and Nachchaduwa perennial reservoirs during three different seasons.

Materials and Methods

Study Locations and Sampling Sites

The area being studied was in the dry zone, which is an agricultural climatic zone with low annual rainfall and a long dry season. This study was done in Nuwarawewa reservoir (latitude 8°20′, longitude 80°25′), Nachchaduwa perennial reservoir (latitude 8°15′, longitude 80°29′), Mahakanadarawa reservoir (latitude 8°22′, longitude 80°32′), Hurulu wewa reservoir (latitude 8°12′, longitude 80°43′), and Sangilikandarawa reservoir (latitude 8°31′ longitude 80°31′) (Figure 1). The area has an average temperature of 30 ºC and gets an average of 1250 mm of rain each year. Most of the rain falls from October to January during the North East monsoon.

Collection of water samples

Five sample locations (one inlet canal, three edges, and one irrigation outlet canal) were selected to reflect the principal land uses around each reservoir. At each sampling site, a total of three samples were taken. The GPS receiver was also used to record the coordinates of the sampling points. During the months of 2020 October (Second inter-monsoon/ SIM), 2021 January (North East monsoon/ NEM), and 2021 April (First inter-monsoon/ FIM), water samples were collected from the specified sites. All of the water samples were collected into polypropylene bottles that had already been cleaned. Prior to taking the water samples, these bottles were washed with each test site's water and then few drops of 0.1M HNO_3 was added to the water samples. Then the water sample bottles were promptly covered and labeled, and they were transported into the laboratory. The water samples were carefully packed and kept in the refrigerator until the water analysis process was completed.

Analysis of water samples

After taking a sample of the water, immediate measurements were taken as pH, EC, and TDS. Potentiometric methods were used using a multi-parameter (Hanna/HI5588-02) in order to determine the pH, EC, and TDS. In all of the water samples, the levels of nitrate-nitrogen (NO_3^- -N), ammonium-nitrogen (NH_4^+-N), and dissolved reactive phosphorus (DRP) were measured with a UV-Visible Spectrophotometer (Thermo Scientific/Evolution 201), respectively, using the salicylic acid method (Cataldo et al., 1975), the phenate method (Rowland, 1983), and the ascorbic acid method (Watanabe and Olsen, 1965) respectively. An inductively coupled plasma mass spectrophotometer (ICP-MS) (PerkinElmer NaxION 2000B) was used to measure total cadmium (Cd), arsenic (As), lead (Pb), mercury (Hg), sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg). Aforesaid parameters were used to calculate the sodium adsorption ratio (SAR).

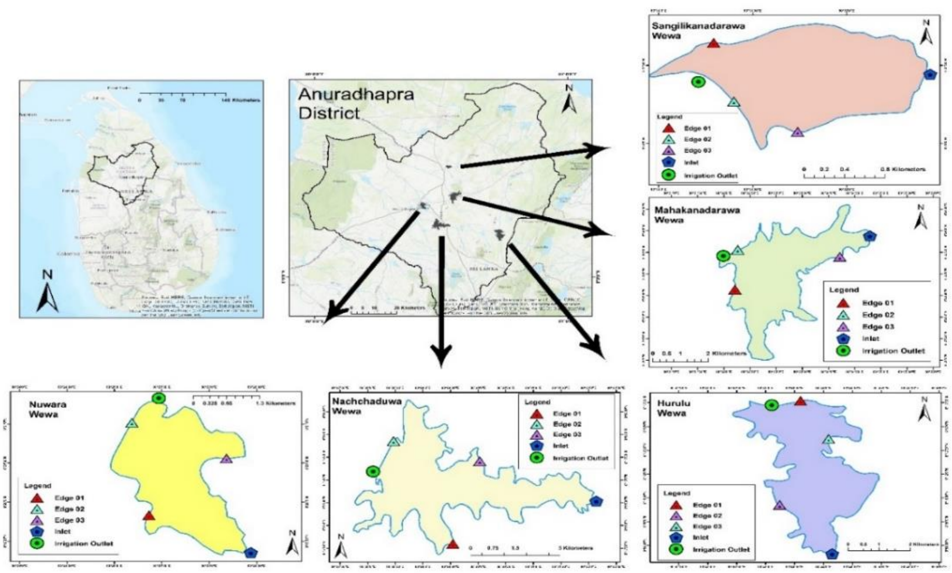

Figure 1. Study area

Data Analysis

SPSS statistical software (version 26) was used for data analysis. The data was checked for normality using the Kruskal-Wallis test for each of the physicochemical variables. To investigate the interaction between multiple components, factorial experiments were utilized. Several factors were evaluated, including reservoirs, sampling points and climatic seasons. Three replicates of each treatment combination were used in the study. In order to make comparisons and determine if the observed findings were statistically significant, the Kruskal- Wallis test was used, followed by the Tukey HSD multiple comparison Post-hoc test. Also, the physicochemical parameters were compared with the WHO permissible limit for drinking water and the FAO (1985) guidelines for irrigation water quality (Perera et al., 2016).

Results and Discussion

Variation of pH, EC, and TDS

The pH scale assesses acidity or alkalinity of the tested water. pH affects enzyme activity and ion solubilization, absorption, and also signifies hardness or softness. When the temperature of water increases, it diminishes oxygen solubility and encourage bicarbonate dissolution, making water more alkaline (WRN, 2016). The measured pH values in the selected tank water samples ranged from 5.75 ± 0.56 to 7.49 ± 0.34. The mean values of pH are significantly different ($P< 0.05$) among the sampling sites of the 5 reservoirs. The highest value was recorded in Mahakanadarawa reservoir at SIM and the lowest was in Nachchaduwa perennial reservoir in the NEM season. All the average pH values were not exceeded the recommended range (6.5–8.5) according to the WHO guideline for drinking water (2007) and FAO (1985) guideline for irrigation standards.

Electrical conductivity (EC) was defined by Sorensen and Glass (1987) as a measure of total dissolved salts or ions in water. In the stream channel, water may pick up dissolved and suspended substances. Water stress occurs when salts build up in the root zone, preventing appropriate water uptake by the crop. Plant growth slows when water intake is reduced (Chaves et al., 2002). The EC of all of the selected tank water samples analyzed varied from 0.19± 0.09 dS m^{-1} to 0.25 ± 0.04 dS m^{-1}. The mean values of EC are significantly different ($P< 0.05$) among the sampling sites of 5 reservoirs. In FIM, the Mahakanadarawa reservoir had the highest value, while in NEM, the Nachchaduwa perennial reservoir had the lowest. According to FAO (1985) guidelines for irrigation, the average of all samples was below the excellent range (0.7 – 3 dS m^{-1}).

TDS is the total dissolved solids in water. Aquatic life depends on dissolved ions for survival, development, and reproduction. Drinking water should contain less than 300 mg L^{-1} of TDS; good water contains between 300 and 600 mg L^{-1} of TDS; poor water contains between 900 and 1200 mg L^{-1} of TDS; and unacceptable water contains more than 1200 mg L^{-1} of TDS (WHO, 2003a). Organic fertilizer may ionize a stream and caused cause an increase in the TDS level in water.

All of the selected tank water samples had TDS levels ranging from 86.73 ± 8.17 mg L^{-1} to 278.80 ± 16.56 mg L^{-1}, according to the measurements. The mean values of TDS are significantly different ($P< 0.05$) among the sampling sites of 5 reservoirs. The Nuwarawewa reservoir during the SIM season had the highest value, while the Sangilikandarawa reservoir during the NEM season recorded the lowest value. All samples were within the appropriate range (less than 300 mg L^{-1}) according to WHO (2003a) standards.

Variation of Na, Ca, Mg, K, and SAR

In the soil and water, if some ions are concentrated, causing plant injury. High-sodium irrigation water harms the soil. Salty water alters soil characteristics and permeability, and in contrast to chloride poisoning, excessive sodium levels in water have been linked to the former (high Na or SAR). Leaf poisoning symptoms include leaf burn, scorch, and dead tissue and will be suspected in less exchangeable magnesium in soils (Chadra et al., 2012). The mean values of Na, Mg, Ca, and K are significantly different ($P< 0.05$) among the sampling sites of 5 reservoirs. According to WHO standards Na, Ca, Mg, and K levels were within the acceptable range during the three climatic seasons (WHO 2003a, 2003b, 2009, and 2011a).

Each sample's SAR value was determined using the formula presented by Richards (1954). During each of the three distinct climatic seasons, the classification based on average SAR values places some tank water samples in the good group and others in the proper category.

Variation of ammonium nitrogen, nitrate nitrogen and dissolved reactive phosphorus concentrations

Ammonia in irrigation water has certain drawbacks and it is due to the conditions and application of the synthetic fertilizer. The goal is to promptly apply N to the crop. A terrestrial system that has been polluted by the presence of ammonium nitrate. This demonstrates that the surrounding land use, including residential, commercial, and agricultural sites, is contributing to the depletion of the quality of the water resources that have been analyzed (Ranasinghe et al., 2021). According to the findings, the ammonium nitrogen (NH_4^+-N) of the tank water samples that were chosen for analysis ranged from 0.86 ± 0.20 to 4.61 ± 0.24 mg L^{-1}. The average levels of ammonium nitrogen at each of the 5 locations are statistically different ($P< 0.05$). The Sangilikandarawa reservoir in NEM had the greatest value, while the Nuwarawewa reservoir in SIM had the lowest value. Both of these reservoirs are perennial. In accordance with the recommendations made by the FAO (1985) about irrigation, the maximum acceptable range (0–5 mg L^{-1}) was not reached by any of the samples.

Irrigation water washes away many nutrients from the soil and transports them to the next crop (Kumari et al., 2013). Contrary to previous watershed farming practices, the NO_3^- levels measured in surface water indicate a low rate of NO_3^- deposition. An irrigation canal with thick plant growth indicates that the plants are receiving nutrients from the water, which is transporting nutrients from the agricultural area. This method may potentially reduce the nutritional value of water (LaMontagne et al., 2003). Based on the results, the nitrate nitrogen of the chosen tank water samples examined ranged between 2.32 ± 0.99 to 9.58 ± 0.62 mg L^{-1}. The mean nitrate nitrogen values varied considerably ($P< 0.05$) among the 5 reservoir sampling sites. The Sangilikandarawa reservoir in NEM had the greatest value, while the Mahakanadarawa reservoir in NEM had the lowest. According to the FAO (1985) irrigation standard, the average of all samples fell below the maximum acceptable range (0-10 mg L^{-1}).

The concentration of PO_4^{-3} increased considerably after chemical fertilizer application, then dropped. Preparation of the field for planting may also slow PO_4^{-3} translocation. During the dry months, little water movement between farms kept the PO_4^{-3} concentration low. PO_4^{-3} is an important macronutrient in eutrophicating open water basins. It is one of the most plentiful macronutrients (Young et al., 2010). Based on the results, the dissolved reactive phosphorous ranged from 0.03 ± 0.02 to 1.61 ± 0.19 mg L^{-1}. Samples from five reservoirs show significant differences in the mean values of available phosphorous ($P< 0.05$). The Sangilikandarawa reservoir had the greatest value in NEM, while the Hurulu wewa reservoir had the lowest in NEM. The average of samples were within FAO (1985) guidelines for irrigation, which stated that the acceptable range (0-2 mg L^{-1}) was met.

Due to a surplus of nutrients in the water, these tanks are able to support a significant number of aquatic plant species. A water body's ecosystem is likely to be dominated by aquatic plants or algae (Glibert et al., 2005). When there are a lot of aquatic plants, the water tends to be clear. When algae takes over, the water becomes darker in color. The fish and other aquatic life in these waters rely on the algae's photosynthesis for their oxygen needs (Harper, 1992). Fisheries may die as a result of algal respiration and bottom-dwelling bacterial respiration when an immense algal bloom arises. Eutrophication is both a natural process and a possible result of what people do to the environment (Khan and Ansari, 2005).

Variation of trace elements

Trace elements are connected to natural and human processes in metal biogeochemical cycles. It is possible that elevated levels of harmful metals in selected tanks are connected to agricultural operations. Most farming practices in these regions rely on long-term agrochemical usage. It is connected to hazardous metals like Cd and As. Rainwater erosion transports hazardous chemicals like heavy metals to the tanks (Tchounwou et al., 2012).

Variation of cadmium concentration

Cd is a non-essential, very hazardous metal, and chronic impacts on human health may arise as a consequence of its buildup in the liver, bones, blood, kidney, and muscles (Wijesekara et al., 2016). Around 50% of the Cd that enters the water is created by human activities such as industrial waste, phosphate-based fertilizers, and animal-derived fertilizers (Guruge et al., 2017). The tentative weekly intake limit (PTWI) for Cd is 0.007 mg kg^{-1} body weight (WHO, 2011b).

There was also a significant geographical and temporal fluctuation in the concentration of Cd in the water of five tanks of the Anuradhapura throughout the research period, which normally falls below the WHO guidelines. The mean values of Cd are significantly different ($P< 0.05$) among the sampling sites of 5 reservoirs. The maximum amount of Cd that can present in drinking water, according to WHO guidelines, is 0.003 mg L^{-1} (WHO, 2011b). During the research period, however, the inlet (2.56 ± 0.05 µg L^{-1}) water Cd concentrations in the Sangilikandarawa reservoir were reordered as the highest reading at NEM climatic season and the lowest was recorded in the irrigation outlet (0.42 ± 0.02 µg L^{-1}) in the Nachchaduwa perennial reservoir at SIM climatic season (Figure 2a). Cadmium may, however, be added to the soil with the use of synthetic chemical fertilizers such as triple super phosphate (McLaughlin et al., 1996). During the rainy season, the tank water becomes contaminated with dissolved heavy metals and other minerals.

Variation of aresenic concentration

It's regarded as one of the most dangerous substances in the environment, and exposure to it may cause a wide range of health concerns including cardiovascular, hematological, renal, and pulmonary difficulties (Oremland, 2003). The toxic effects of arsenic are very dependent on the kind of arsenic present. As a general rule, arsenic found in drinking water is more hazardous than arsenic found in marine food (Chappell et al., 1999). Despite the fact that arsenic may occur both organically and inorganically, inorganic arsenic is more frequent in water and is considered more dangerous (Oremland, 2003).

Over the course of the investigation, the content of As in the water of five Anuradhapura tanks varied significantly geographically and temporally. The mean values of As are significantly different ($P< 0.05$) among the sampling sites of 5 reservoirs. The WHO recommends a maximum As content of 0.01 mg L^{-1} in drinking water (WHO, 2011c). Collected all samples were below the WHO guidelines. According to the findings, water As concentrations in the inlet (8.75 ± 0.07 µg L^{-1}) in Sangilikandarawa reservoir at the NEM climatic season was the highest and low Cd level was recorded in Nachchaduwa perennial reservoir's irrigation outlet (1.42 ± 0.20 µg L^{-1}) at the SIM climatic season (Figure 2b).

Variation of Pb concentration

Lead is one of the most common metals, and it can be found in almost every part of the environment (Castro-González and Méndez-Armenta, 2008). Lead is one of many environmental toxicants that can be found in all phases of the inert environment and all living organisms (Wijesinghe et al., 2018). Pb can't be more than 0.01 mg L^{-1} in water, according to the WHO (2016) and SLS standards (614:2013). Lead is thought to be one of the causes of CKDu because it can damage the kidney, immune system, circulatory system, and neurons, and it can also cause joint diseases (Siraj and Kitte, 2013).

The content of Pb in the water of five tanks in Anuradhapura fluctuated significantly geographically and temporally during the study period and generally lies within a WHO recommendation (WHO, 2016). The mean values of Pb are significantly different ($P< 0.05$) among the sampling sites of 5 reservoirs. Furthermore, Nuwara wewa reservoir exhibited the highest Pb levels throughout the NEM climatic seasons at Inlet (7.94 ± 0.33 µg L^{-1}). Low Pb levels were also observed during the NEM climatic season at irrigation outlet (1.49 ± 0.05 µg L^{-1}) in the Nachchaduwa perennial reservoir (Figure 03a).

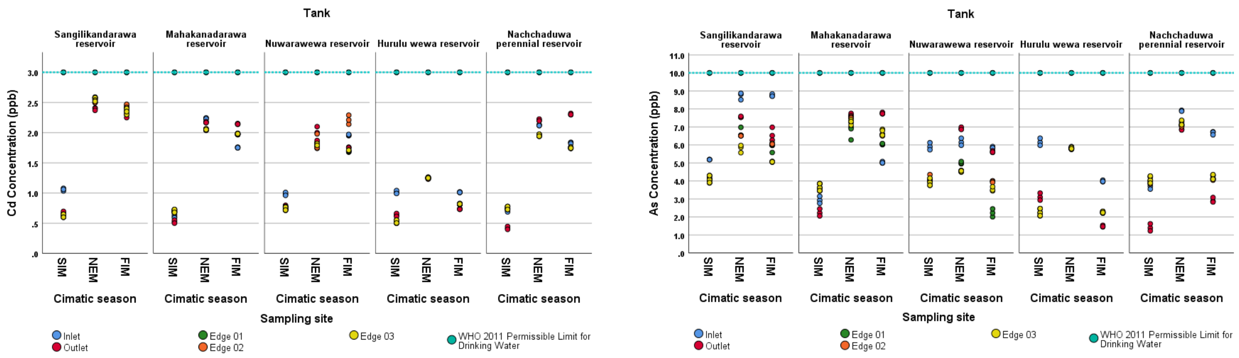

Figure 2. The (a) Cd, and (b) As values of the tanks' inlets, edges, and irrigation outlets

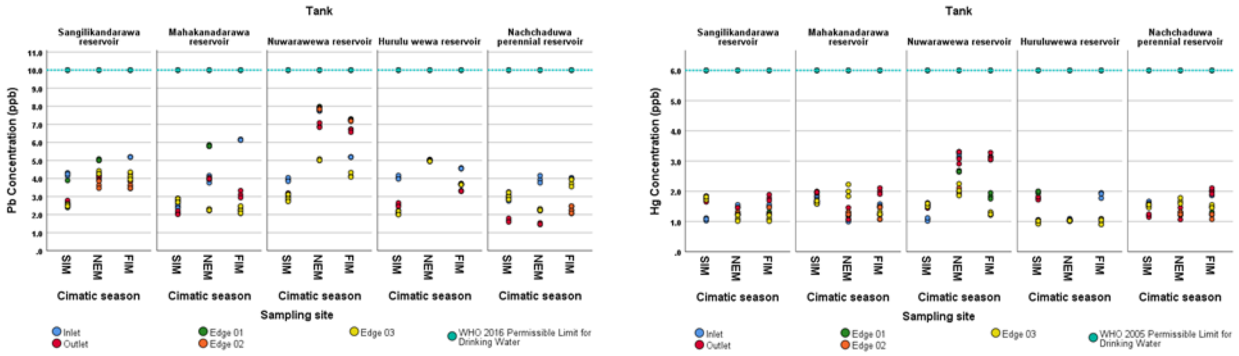

Figure 3. The (a) Pb, and (b) Hg values of the tanks' inlets, edges, and irrigation outlets

Variation of Hg concentrations

Mercury and its derivatives are becoming increasingly dangerous, even in small concentrations. Because mercury compounds affect the nervous system, kidneys, and skin, they are highly contaminated (Clarkson et al., 2003). Mercury emissions have risen due to increased industrialization connected to fossil fuel burning, mining, and industrial goods and processes (Sundseth et al., 2017). The concentration of Hg in the water of five tanks in Anuradhapura varied significantly geographically and temporally during the study period, but often fell within a WHO recommendation. According to WHO recommendations, the maximum permitted content of Hg in drinking water is 0.01 mg L^{-1} (WHO, 2005). The mean values of Hg are significantly different ($P< 0.05$) among the sampling sites of 5 reservoirs. Additionally, Nuwarawewa reservoir exhibited the highest water Hg levels throughout the NEM climatic seasons at inlet (3.23 ± 0.09 µg L^{-1}). Low water Hg levels were observed during the FIM climatic season in the edge point 03 (1.01 ± 0.09 µg L^{-1}) in the Hurulu wewa reservoir (Figure 03b).

Conclusions

When the canals were tested during the three climatic seasons, significant temporal variations in the studied water quality parameters were observed in the inlet, outlet, and edge canals. In the immediate vicinity of each canal, the quality of the water carried by different canals varied significantly depending on the land use in the surrounding area of each canal. The readings for pH, TDS, EC, Na, K, Ca, Mg, NH_4^+-N, NO_3^--N, DRP, cadmium, arsenic, lead, and mercury were all within the permissible limits set by WHO drinking water quality standards and FAO (1985) irrigation guidelines for irrigation use.

The NEM season had higher levels of NH_4^+-N, NO_3^--N, DRP, cadmium, and arsenic in the Sangilikandarawa reservoir than in other seasons. The reservoir is associated with a number of land use issues, one of which is the widespread use of agrochemicals in agricultural practices in the surrounding area. Continuous delivery of contaminated water through the inlet made the water in the Sangilikandarawa reservoir may be caused a lot of other negative impacts to happen to the environment, like eutrophication. Additionally, due to the high concentration of urban areas in Nuwarawewa reservoir, the levels of Pb and Hg are higher during the NEM season. Hence, a suitable pollution management plan needs to be put forward to minimize the pollution of tanks in Anuradhapura, Sri Lanka.

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