Water Quality in Different Inlet and Outlet Canals Connected to *Nuwarawewa*, *Anuradhapura*, Sri Lanka

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***Abstract*: This study was conducted to assess the water quality of inlet and outlet canals connected Nuwarawewa, *Anuradhapura, Sri Lanka*. Seven major inlets and one outlet canals connected to *Nuwarawewa, Anuradhapura* was identified. Water samples were collected from a selected location of each inlet and outlet canal in one-month interval for three months period. Soil samples (0-30 cm) were collected from each selected location at the second time point. Water quality parameters such as pH, Electrical conductivity (EC), Dissolved Oxygen (DO), Total Dissolved (TDS), NO_3^--N, NH_4^+-N, available phosphorus (Av. P), alkalinity and heavy metals (Cd and As) concentrations were determined in each water sample. Soil samples were analyzed for pH, EC, total N, Av. P, Cd and total As contents. The results showed that pH, DO, TDS, NH_4^+-N, and Av. P of some in some tested water samples were higher and other parameters were within permissible levels according to WHO drinking water quality standards. Higher total N in all tested soil samples and lower Av. P values in many tested soil samples (except one) were observed in comparison to the reference values in literature. According to European Regulatory Standards, As concentrations in many soil samples (except one) within the permissible levels and Cd was not detected. Considerable temporal variations in water quality parameters were observed in inlet and outlet canals during the study period. The chemical properties of soil inside each canal were significantly altered by the quality of water being carried out by the respective canal. These result further revealed that impacts of surrounding land use on water pollution in inlet water canals connected to *Nuwarawewa* are higher. It could be concluded that the implementation of a pollution management plan is required to prevent further pollution through continuous future researches.**

Keywords: Nuwarawewa, Temporal variation, Water quality, Soil pollution.

I. INTRODUCTION

Water is one of the most valuable natural resources in the world. None of the living organisms can survive without water. Every living organism on this planet requires water in some form. Water can be found in every ecosystem being the most important component on earth [12]. Moving water controls chemical flux and cycling within ecosystems in the moist temperate region. However, the distribution of water on the earth's surface is extremely uneven. About 70% of the earth's surface is covered with water including 97% of salt water and only 3% of freshwater. Two per cent of all the earth's water is glacier ice which is locked up in North and South Poles. Less than 1% of all the earth's waters is freshwater consumable for human beings.

The smaller amount of accessible freshwater is being used by human for drinking and many other purposes including transportation, hydroelectric power generation, and industry ([19], [7]). Therefore, water has become one of the politically sensitive limited natural recourses. Even at present, the land use pattern of a given land is determined by the availability of water. In arid regions, many socio-economic conflicts are caused due to unequal access to good quality water. Furthermore, water regulates population growth, healthy functions, and biodiversity of ecosystems including living organisms [16]. Anthropogenic activities such as applications of agrochemicals to agricultural lands, discharge of septic and households' wastewater from residential areas, and chemical wastes from industrial areas, etc. have led to freshwater pollution [24].

Water pollution is a serious environmental problem in Sri Lanka as well as in other developing countries. [15] Defined water pollution as any chemical, physical or biological change in the quality of water that exerts a harmful effect on any living thing that drinks or uses or lives (in) it. Thus, alteration of these water characteristics becoming unsuitable for an expected usage refers to water quality deterioration. Deterioration of water quality in surface freshwater has become a severe threat to the smooth functioning of ecosystems as well as human health. The purposes to which a freshwater resource is to be used, depending on the water quality of a given freshwater resource. Therefore, detailed studies of water quality in freshwater resources are required for decisions making on types of usages and measures to be implemented to mitigate water quality deterioration for a considered water body. The water quality of freshwater bodies needs to be monitored continuously due to the direct impacts of these water resources on human health. *Nuwarawewa* is one of the major freshwater bodies used for drinking water in the *Anuradhapura* district. Moreover, the assessment of water quality in *Nuwarawewa* being influenced by many anthropogenic activities over a long period. Therefore, this study was mainly focused on the evaluation of water quality in *Nuwarawewa* in the Anuradhapura district of Sri Lanka.

II. MATERIALS AND METHODS

A. Study Area

This study was carried out in selected inlets and outlet canals connected to *Nuwarawewa* (8° 21' 0" North, 80° 25' 0" East) in Anuradhapura district of Sri Lanka. The area belongs to the agro-ecological zone DL1b. The annual rainfall and the average temperature in the area are 7500 mm and 30 ˚C, respectively. The major soil group of the area belongs to the great soil group of the Reddish Brown Earth and *Aluthwewa* series (USDA soil taxonomy: *Rhodustalf*).

B. Collection of Soil and Water Samples

Seven inlet canals (IN1 to 7) and one major outlet canal (OUT) connected to the studied surface water body: *Nuwarawewa, Anuradhapura* were identified and the GPS locations of sampling points were recorded. Water samples were collected from the selected locations once a month from May 2018 for three months. Figure 1 shows a map of the Nuwarawewa Tank with the sampling points. Pre-cleaned polypropylene bottles were used to collect water samples. These bottles were rinsed with canal water before collecting the water samples. Collected water samples were immediately covered, labelled, and stored in a refrigerator for laboratory analyses.

Soil samples were collected using an Edelman soil auger to the depth of 0 to 30 cm from the same GPS locations at which water samples had been collected. Soils were transferred into the labelled polythene bags. Soil samples were air-dried without allowing them to be contaminated. Aggregates were broken and visual roots and stone particles were removed while air-drying. Air-dried soil samples were passed through a 2 mm sieve and stored in clean polythene bags until the commencement of soil analyses.

C. Soil and Water Sample Analysis

The water samples were analysed for various physicochemical parameters i.e. pH, electrical conductivity (EC), Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Ammonium-Nitrogen (NH_4^+-N), Nitrate-Nitrogen (NO_3^--N), Available Phosphorous (Av. P), Available Cadmium (Cd), Available Arsenic (As) and Alkalinity. Soil samples were analyzed for the selected chemical, physical and biological parameters using standard analytical methods.

Water pH, EC, DO and TDS were measured immediately after the sampling. Water pH, EC, TDS, and DO were determined by potentiometric approaches using a multi-parameter analyzer (Multi-parameter: Hach HQ40d). Colourimetric approaches were used to determine water concentrations NH_4^+-N, NO_3^--N, and Av. P using analytical procedures proposed by [3], [8] and [22] respectively. Water concentrations of Cd and As were determined by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Water alkalinity was determined by titrimetric procedure proposed by [1]. The soil samples were analysed for various chemical parameters i.e. pH, EC, total N, Av. P, Av. Cd, and Av. As. Soil pH and EC of each soil sample were determined separately in 1:2.5 and 1:5 soil/water suspensions respectively, using a multi-parameter analyzer. The Kjeldahl procedure proposed by [6] was used to determine total soil N. Molybtare/ascorbic acid blue method was used to estimate Av. P in soil. Soil total Cd and total As were determined by ICP-OES using by hot acid trace elements extraction procedure proposed by [13].

D. Data Analysis

Analyzed water data were graphically represented using Microsoft Excel and were compared with the WHO drinking water standards [28]. Analyzed total N and Av. P of soil samples were compared with the reference values in the literature. Furthermore, analyzed trace element concentrations in soil samples were compared with European Regulatory Standards [10].

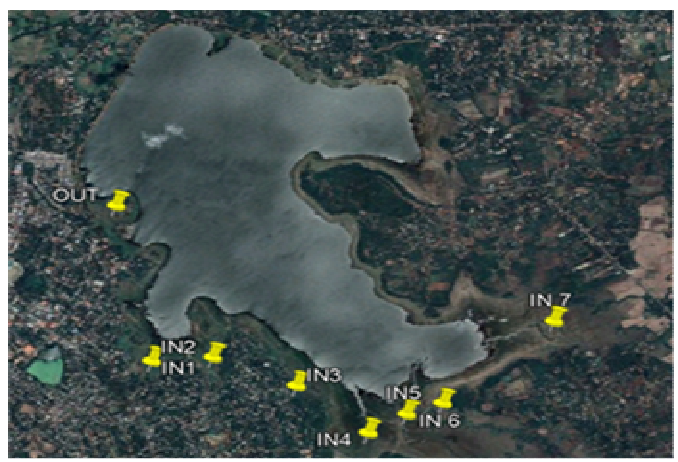

Fig. 1 A map showing Nuwarawewa Tank Anuradhapura and the sampling locations

III. RESULTS AND DISCUSSION

A. Water Quality Characteristics of Inlet and Outlet Canals

Seven inlet canals (IN1 to 7) and one major outlet canal (OUT) connected to the studied surface water body were identified. A considerable variation in water quality parameters was observed both spatially & temporally and the findings are broadly discussed below.

1) pH

Figure 1 shows the measured values of pH, alkalinity (mg/L), TDS (mg/L), and EC (ds/m) in water samples collected from the selected inlet and outlet canals for three months. The dotted lines in the figures show the permissible levels prescribed by WHO for drinking water quality.

The pH value indicates the level of acidity or alkalinity in a particular aqueous solution which ranges from 0 to 14. Water is generally classified into three main categories i.e. acidic (pH < 6.5), neutral (6.5<pH<8.5), and hard (pH>8.5) based on pH (Brian Oram, 2014). Temporal variability of pH, alkalinity (mg/L), TDS (mg/L) and EC (ds/m) in the water samples collected from inlet and outlet canals connected to *Nuwarawewa, Anuradhapura* is shown in Fig.2. The measured pH values in water samples ranged from 7.2 to 8.4 (Fig.2.a). Many samples were within the recommended range (6.5 – 8.5) according to WHO standards. However, higher water pH levels have been recorded in inlet 1, inlet 6, inlet 7, an outlet.

2) Alkalinity

Alkalinity in water is primarily due to carbonate, bicarbonate, and hydroxide contents present. Water alkalinity is used as an indicator to interpret the level of water quality degradation and to determine the measures implemented to treat polluted water [20]. The measured alkalinity values in this study (Fig. 2.b) were ranged from 151.0 to 514.6 mg/L. According to the FAO guidelines, the maximum permissible range of alkalinity in irrigation water should be 610 mg/L [14] and all the water samples collected were within the permissible range.

3) TDS

Measured TDS values in collected water samples varied between 172.5 mg/L to 909 mg/L (Fig. 2.c). The measured TDS values in many inlet canals and the outlet canal were within the permissible limit. However, higher TDS values beyond the maximum permissible TDS level of WHO drinking water quality standards were also observed in some samples. Smaller TDS values are generally reported for natural freshwater bodies. The literature further provides shreds of evidence that anthropogenic activities such as mining and discharge of untreated domestic and industrial wastewater to freshwater bodies. Minerals and organic molecules dissolved in the water contribute to water TDS.

4) EC

The measured EC of the study area varied from 0.05 dS/m to 0.70 dS/m and the highest EC was recorded in IN6 which was surrounded by a residential area. The measured EC values in all water samples were within the permissible level according to WHO guidelines. Water EC generally refers to the ability to pass an electrical current through water. The water has a higher amount of dissolved inorganic ions showed higher EC. Normally, conductivity in the water is affected by the inorganic dissolved solids. On the other hand, organic compounds, as well as temperature, have greater influences on EC.

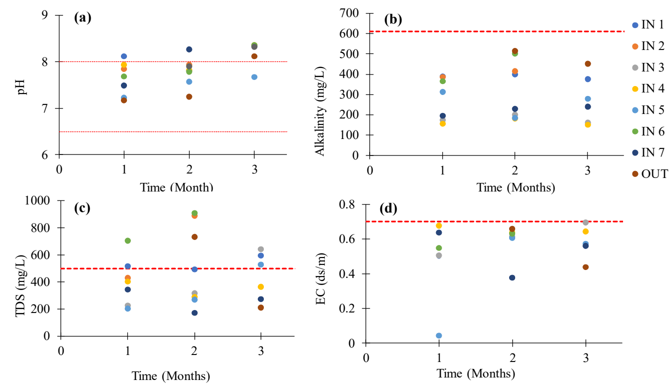

Fig. 2 Measured (a). pH, (b). Alkalinity (mg/L), TDS (mg/L), and EC (ds/m) values of the inlet and outlet canals connected to *Nuwarawewa, Anuradhapura*

5) Dissolved Oxygen

Water DO content is an important parameter that determines the equilibrium of aquatic ecosystems and frequently used to assess water quality [23]. Water DO contents in the analyzed water samples varied between 3.4 mg/L and 11.1 mg/L (Fig.3). The DO concentration in all the samples except one sample was water DO contents in most water samples were higher than 6 mg/L which is the minimum desirable level for the healthy surface freshwater system.

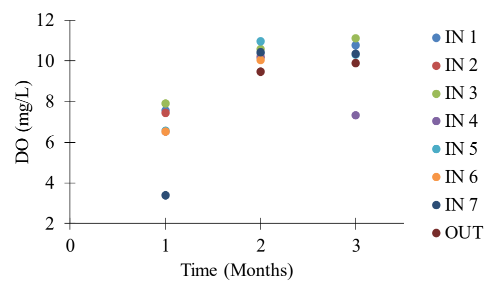

Fig. 3 Measured values of Dissolved Oxygen concentration (DO) (mg/L)in inlets and outlet canals

Dissolved oxygen levels greater than 5 mg/L are sufficient to support most aquatic species. Levels below 4 mg/L are stressful to the majority of aquatic animals, so biodiversity will be affected. Water containing less than 2 mg/L dissolved oxygen will not support aerobic aquatic life. Water DO generally increases in surface water as a result of diffusion from the atmosphere and aquatic plant photosynthesis. Water dissolved oxygen is reduced by the degradation of organic matter in water. The higher concentration of organic molecules in the water sample has resulted in lower DO in water samples. Water DO oxygen fluctuates over the studied period with an increasing trend. Literature provides several shreds of evidence that DO contents will vary by season, location, and depth in freshwater systems such as lakes, rivers, and streams. Water DO values also fluctuate with temperature, salinity, and pressure changes, and dissolved oxygen levels can range from less than 1 mg/L to more than 20 mg/L depending on variations in these factors.

6) Ammonium-Nitrogen and Nitrate-Nitrogen

Figure 4.a shows the variation of measured NO_3^- -N concentration of water samples. According to the figure almost all the samples had lower NO_3^- -N concentration than the FAO guidelines for irrigation water quality and drinking water guidelines [28]. Ammonia (NH_3) is a water-soluble gas that exists at low levels (0.1 mg/L) in natural waters. Nitrogen-containing organic matter and gas exchange between water and atmosphere are the main ways of coming NH_4^+-N to surface freshwater [9]. Moreover, the biodegradation of wastes coming from domestic, agricultural, and industrial areas contributes to the greater NH_4^+-N concentration. Figure 4.b illustrates the measured NH_4^+-N concentrations (mg/L) in water samples obtained from the selected inlet and outlet canals and according to the figure, the values varied from 52 to 114.9 mg/L (Fig.4.b). The maximum permissible NH_4^+-N level prescribed for irrigation water is 5 mg/L [14]. Ammonium nitrate is an indicator of recent pollution of a terrestrial system. This proves the deterioration of the studied water resources due to surrounding land use i.e. domestic, industrial, and agricultural lands.

Available phosphorus (Av. P) concentration of the inlet and outlet canals varied from 0.05 mg/L to 3.35 mg/L during the study period (Fig.4.c). The permissible range of phosphate phosphorous concentration in irrigation water is 0 to 2 mg/L [14]. The critical value for the occurrence of eutrophication for phosphates is 0.08mg/L [27]. At the beginning of the studied period, Av. P levels in IN 4, 6 &7 were beyond the maximum permissible phosphate level of FAO guidelines and Av. P levels in other water samples were below the maximum permissible phosphate level of FAO guidelines. However, according to USEPA guidelines, Av. P levels in almost all the canals were sufficient to occur eutrophication. Phosphate generally enters freshwater from P-rich bedrock, human & animal wastes, laundry & industrial effluents, and runoff from agricultural lands (Sikder *et al*., 2013).

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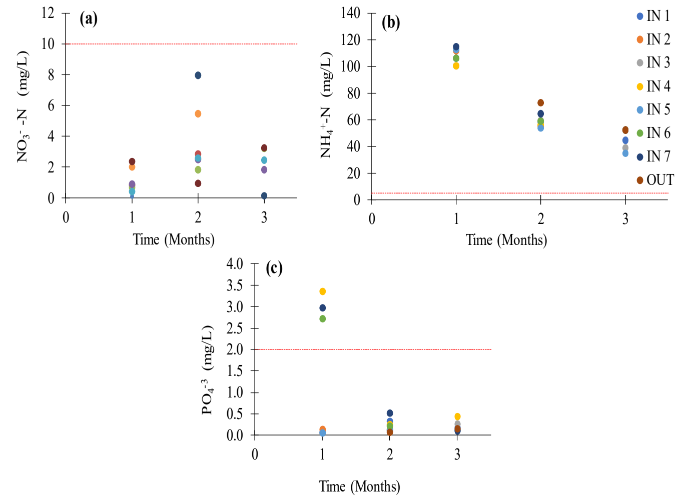

Fig. 4 Measured values of (a). Nitrate (NO_3^- -N), (b). Ammonium (NH_4^+-N) Nitrogen and available Phosphorus (Av. P) concentrations (mg/L)

7) Trace Elements

Arsenic (As) and Cadmium (Cd) can be commonly found in surface and groundwater sources of Sri Lanka mainly due to the overuse of agrochemicals in farmlands ([17], [18]). These two elements are toxic and the occurrence beyond the permissible level in aquatic environments can result in harmful effects on aquatic biological systems. The use of arsenical herbicides and combustion of fossil fuels has resulted in the localized arsenic contamination of soils, water, and sediment [25], [11]. Dissolved inorganic arsenic is highly toxic to both plants and animals in aquatic systems its toxicity, however, depends on its chemical species

However, Cd was not detected in any of the water samples analyzed in this study, and As was detected in some water samples obtained at the third sampling. The WHO recommended maximum concentration of As in drinking water is 0.01 mg/L and the As concentrations in IN4, IN7 and OUT were higher than the recommended level. Based on [2], the maximum allowable limit of As in irrigation water is 0.1 mg/L. Hence, the water is suitable for irrigation.

B. Soil Characteristics of Inlet and Outlet Canals

Analysis of chemical parameters of soil in inlet and outlet canals of the studied freshwater body provides a strong reflection on the quality of associated water. Moreover, maintenance of soil quality is one of the most important aspects of sustainable agriculture and sustainable management of the global biosphere. The study area belonged to DL1b agro-ecological region. The most prominent great soil group in the study site is Reddish Brown Earth. However, soil in the studied area has acquired many hydromorphic characteristics (such as grey colour) for a longer period.

1) Soil pH

The measured pH values in soil samples in this study ranged from 6.9 to 8.6 (Table 01). The measured pH of many soil samples (IN3, IN4, IN6, IN7, and OUT) were higher than the recommended range (6 – 7.5) for RBE [21]. Soils are categorized in to several groups based on PH: Acidic (pH < 6.5), Normal (6.5 < pH < 7.8), Alkaline (7.8 < pH < 8.5) and Alkali (pH > 8.5) [26]. According to the above categorization, studied soils belong to normal, alkali, and alkaline groups. Higher soil pH values might be due to the contamination with alkali compounds such as detergents carried by water in canals. Soil pH is an important property that expresses the acidity or alkalinity of the soil and it is important to determine the availability of nutrients, microbial activity, and physical condition of the soil [26]. Moreover, soil pH affects the chemical reactions between water and soil minerals.

2) Electrical Conductivity

The Electrical Conductivity (EC) of the study area during the sampling period ranged from 0.8 dS/m to 2.7 dS/cm (Table 01). Soil EC is a measure of ionic salts in the soil which determines the concentration of ionic charges in the soil solution [4]. Soil EC in Dry zone soils ranges between 0.005 dS/m and 0.04 dS/m [21]. The measured EC values in soil samples were higher than the reference values which might be possibly due to long-term contact of soil with water having a higher salt concentration. Moreover, measured soil EC values were higher than those of water samples. This can be due to the long-term absorption of ions in the flowing water into the soil.

3) Total Nitrogen

Total nitrogen is the sum of nitrate-nitrogen, nitrite-nitrogen, organic nitrogen, and ammonium- nitrogen contents of the soil. The observed values for the total N of this study area varied from 0.18% to 0.40% during the studied period (Table 01). Total N in soil range from < 0.02% in subsoils to > 2.5% in peats; the surface layer of most cultivated soils contains between 0.06% and 0.5% [5]. The observed values were within the range. However, the observed values of total N were higher than the reference total N (around 0.01%) value for RBE [21]. This may be due to the translocation of NO_3^- and NH_4^+ in the water into the soil. The long-term submerged condition might lead to the accumulation of organic matter in higher quantities followed by an increment of total N.

4) Soil Available Phosphorous

Soil Av. P refers to the inorganic forms of P occurring in soil solution and is considered to a fairly good measure of P supplying capacity of soil [5]. During the studied period, Av. P concentration in the studied soil samples varied between 6.5 mg/L to 34.8 mg/L (Table 01). The reference Av. P value for RBE ranged between 3.5 and 24 mg/L [21]. Therefore, Av. P concentration in many of the analyzed soil samples within the range. However, soil Av. P content in IN7 is higher than the maximum limit of the reference ranges indicating higher P concentrations in water carried by IN7. Moreover, Av. P concentrations in soil were higher than that of the respective canal water. These results indicated higher P fixation of in the soil.

Table 1: soil properties in inlet and outlet canals.

S. No	pH	EC (dS/cm)	Total N conc. (mg/L)	Available P conc. (mg/L)	Soil As conc. (mg/L)
IN 1	6.9	1.8	0.33	20.0	0.020
IN 2	7.4	2.7	0.23	6.5	0.006
IN 3	8.2	0.8	0.20	6.6	0.006
IN 4	8.0	0.9	0.19	14.7	0.014
IN 5	7.1	1.3	0.40	14.6	0.014
IN 6	8.6	1.5	0.19	11.6	0.011
IN 7	7.8	1.6	0.18	34.8	0.034
OUT	8.4	1.0	0.28	12.6	0.012

5) Trace elements

Soil arsenic (As) level ranged from 0.006 mg/L to 0.034 mg/L (Table 01). The maximum permissible level for As in soil is 0.02 mg/L according to European community set standards [10]. According to the results, As the content of many of the samples has not exceeded the maximum permissible levels. However, the soil sample collected from IN7 has exceeded the maximum permissible level. The IN7 canal may be carrying water with higher P fertilizer levels, such as TSP which contains As as inert matter. Available P concentration of the one water sample (out of three) obtained from IN7 recorded a higher level than the permissible limit. However, the study should be continued for a longer period to confirm the results. Cadmium (Cd) concentrations in none of the soil samples were not at a detectable level during the studied period.

IV. CONCLUSIONS

Considerable temporal variations of the studied water quality parameters were observed in the inlet and outlet canals during the studied period. The quality of water being carried by different canals was significantly different depending on the land uses in the immediate surroundings of each canal. The chemical properties of soil inside each canal were significantly altered by the quality of water being carried out by the respective canal. The measured water pH, DO, TDS, NH4+-N, and Av. P in some of the water samples were higher and EC, TDS, NO3- -N, alkalinity and heavy metals were within permissible levels according to WHO drinking water quality standards. Continuous supply of polluted water through the inlet canal caused to reduce overall suitability of water in *Nuwarawewa* for drinking purpose as well as to occur many other environmental consequences such as eutrophication. Hence, implementation of the pollution management plan is required to prevent further pollution through conducting continuous future studies.

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