Seasonal Variation of Water Quality Parameters in Different Geomorphic Channels of the Upper *Malwathu Oya* in Anuradhapura, Sri Lanka

P.A.C.T. Perera*, T.V. Sundarabarathy[1], T. Sivananthawerl[2] and U. Edirisinghe[3]

Postgraduate Institute of Agriculture
University of Peradeniya
Sri Lanka

ABSTRACT: *Malwathu Oya is a perennial river in the Dry Zone of Sri Lanka. Water of the nearby paddy lands is diverted to the river from different locations during cultivation seasons. These anthropogenic activities cause stresses on Malwathu Oya by impairing the quality of its water. The main objective of this study was to assess the seasonal fluctuation of nitrate, phosphate, chloride, dissolved oxygen (DO) and turbidity of river water in different locations of Malwathu Oya. The study was carried out in the upper part of Malwathu Oya from Ritigala to Nachchaduwa in the Anuradhapura District. Data were collected continuously for twelve months from March 2012 to February 2013. Factorial analysis was carried out to study the interactions among different factors (study site location, climatic season, channel geomorphic unit and river segment). The mean nitrate, phosphate, chloride and DO concentrations ranged from 1.05 to 5.28, 0.004 to 0.043, 2.63 to 8.72, 3.11 to 8.50 mg/L, respectively, and the mean turbidity level ranged from 81.75 to 256.10 NTU. The nitrate, phosphate and chloride concentrations were significantly higher ($p<0.05$) in all the segments and channel units during the first inter-monsoon season (March - April) in the Paddy growing area. The highest mean DO and turbidity values were observed in the north-east monsoon season. Significant difference was not observed ($p>0.05$) in DO and turbidity in paddy and non-paddy areas. The results concluded that the water quality parameters except turbidity in the investigated area of Malwathu Oya were within the threshold limits for dinking purposes.*

***Keywords**: Climatic season, geomorphic channel unit, paddy, Malwathu Oya, water quality.*

INTRODUCTION

The climate experienced during a year in Sri Lanka can be characterized into four climate seasons *viz*. First Inter Monsoon Season (FIMS) (March-April), South West Monsoon Season (SWMS) (May-September), Second Inter Monsoon Season (SIMS) (October-November) and North East Monsoon Season (NEMS) (December-February). Highest precipitation is observed in the Dry Zone from November to January and minimum from May to September. Farmers cultivate crops (mainly paddy) in two main seasons (*Yala* and

[1] Department of Biological Sciences, Faulty of Applied Sciences, Rajarata University of Sri Lanka
[2] Department of Crop Science, Faulty of Agriculture, University of Peradeniya, Sri Lanka
[3] Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka
* Corresponding author: chintakaperera@ymail.com

Maha) in the area. Sufficient volume of rainwater is received during SIMS and NEMS (*Maha*). However, most of the seasonal water bodies completely dry up during the latter part of the SWMS, thus irrigation water supply becomes an important issue.

Rivers are considered as vital and vulnerable freshwater ecosystems that are important for the sustenance of all life. Untreated discharge of pollutants to a water resource system from domestic sources, storm water discharges, industrial wastewaters, agricultural runoff and the other sources, all can have short term and long term significant effects on the quality of a river system (Singh, 2007). The physico-chemical parameters useful for water quality assessment are determined by the presence of both organic and inorganic compounds that are either suspended or dissolved in water. At the same time, water quality characteristics of aquatic environment arise from a multitude of physical, chemical and biological interactions (Ugwu & Wakawa, 2012). While some of these compounds are toxic to the ecosystem, some are providing nutrients to aquatic organisms and others are responsible for the aesthetics of the water body (Boukari *et al.*, 1999).

Malwathu Oya is a perennial river in the Dry Zone of Sri Lanka (Fig. 1). Communities living in the immediate vicinity of *Malwathu Oya* depend mainly on paddy and other field crops for their livelihood. Most of the Paddy Outlet Canals which have been diverted to *Malwathu Oya,* convey drainage water (*Welpahu Wathura*) from surrounding paddy lands during the two cultivation seasons namely; *Maha* and *Yala* which are synonymous with two monsoons. Paddy farmers in these areas utilize variety of weedicides, insecticides fungicides, rodenticides and inorganic fertilizers expecting high yield. Therefore, the water quality of *Malwathu Oya* may have been affected due to the inflow of drainage water carrying residues of these organic and inorganic compounds.

The objectives of this study were to assess and compare seasonal variations of some drinking water quality parameters (nitrate, phosphate, chloride, dissolved oxygen and turbidity) over four climatic seasons (First Intermonsoon Season, Southwest Monsoon Season, Second Intermonsoon Season and Northeast Monsoon Season) in different locations (Paddy area and Non-paddy area), Channel Geomorphic Units (Pool, Riffle and Run) and river segments (Upper and Lower river segments) of *Malwathu Oya* .

MATERIALS AND METHODS

Study location

The selected study area is a 30 km long river segment of *Malwathu Oya* between *Ritigala* and *Nachchaduwa* areas in the Anuradhapura District (Fig. 1). The first 17 km of the river is considered as the Upper River Segment (URS) and the other 13 km is considered as the Lower River Segment (LRS).

Sampling sites

Twelve sampling sites were selected along the study area of the river (Fig. 1). Six sampling sites were selected to reflect paddy culture activities in the catchment, which may affect the water quality situation of the river. The other six sampling sites were in non-paddy farming areas in the river catchment. All the sampling sites in the URS and the LRS consist of equal number of three different channel geomorphic units (CGU). Paddy Outlet Canals (C1, C2, C3, C4, C4, C5 and C6) contribute water from paddy fields to *Malwathu Oya*.

Sampling and analysis

Water sampling was done over a period of one year from March 2012 to February 2013. Samples were collected monthly between 8.00 and 10.00 am from each sampling site (Fig. 1) to cover the four distinct climatic seasons, namely First Intermonsoon Season (FIMS), Southwest Monsoon Season (SWMS), Second Intermonsoon Season (SIMS) and Northeast Monsoon Season (NEMS). Turbidity measurements were undertaken *in situ*. High density polyethylene (HDPE) bottles were used to collect samples for the determination of nitrate, phosphate and chloride. Water samples for the determination of dissolved oxygen (DO) were collected into narrow-mouthed glass bottles and fixed in the field with Winkler's reagent. All bottles were cleaned with diluted nitric acid and rinsed several times with tap water, and finally rinsed once with the water sample to be collected. All the samples (except the ones for DO determination) were preserved in an iced box during transportation to the laboratory. Analysis was carried out for five water quality parameters viz. nitrate, phosphate, chloride, dissolved oxygen (DO) and turbidity based on standard methods of APHA (2005).

Statistical analysis

Data were analysed using SAS statistical software (SAS version 9.0). Factorial experimental design was used to study the interactions between different factors. In the SAS procedure, general linear model was used due to missing data in August 2013 during the drought season (SWMS). Study Site Locations (Paddy area, Non-paddy area), Climatic Seasons (FIMS, SWMS, SIMS and NEMS), Channel Geomorphic Units (Pool, Riffle and Run) and River Segments (URS and LRS) were considered as factors. Four climate seasons were considered as levels. Three replicates were taken from each study site.

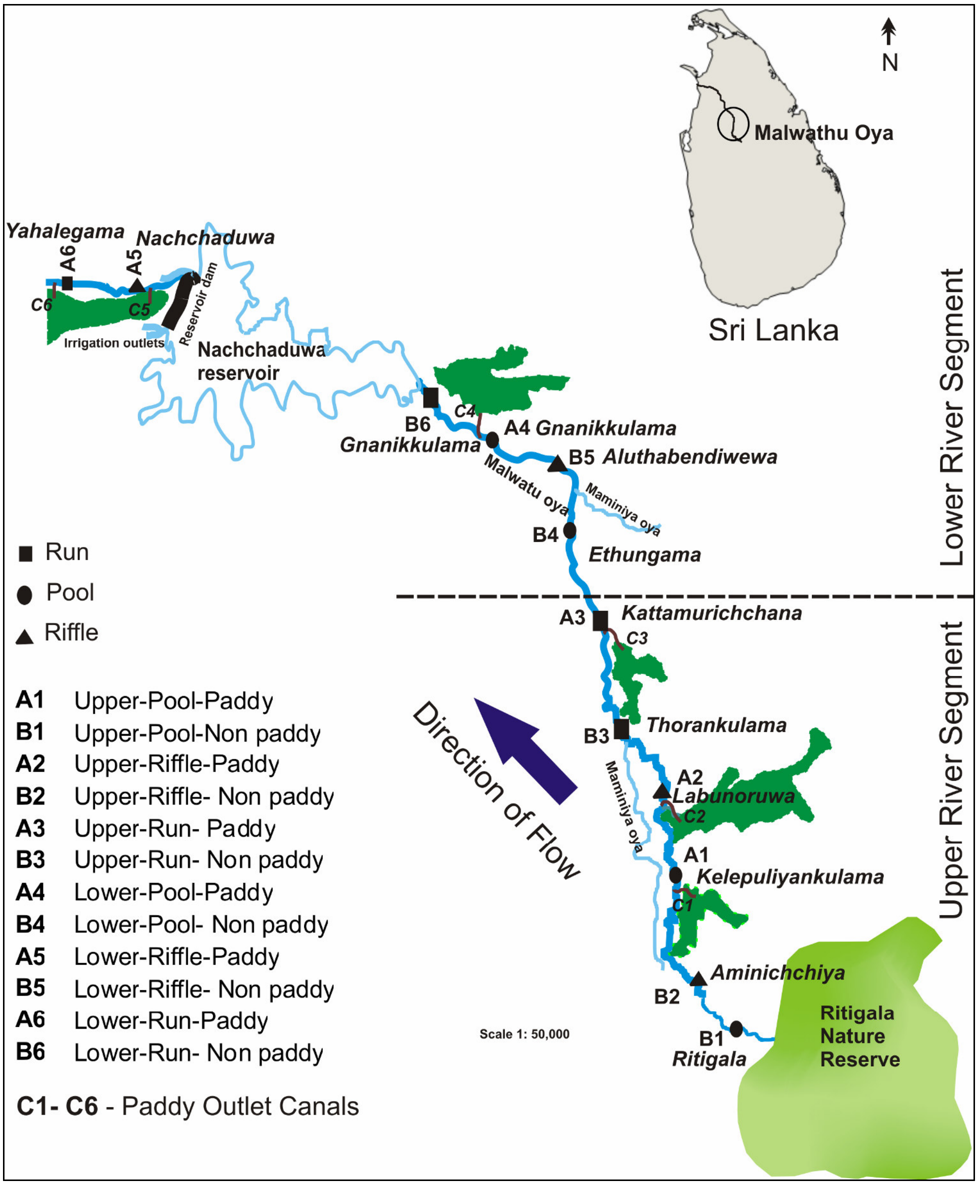

Fig. 1. Map showing the study area and the sampling locations

RESULTS AND DISCUSSION

Seasonal variation of nitrates

Nitrate in natural waters can be traced to percolating NO_3^- from sources such as decaying plant and animal materials, agricultural fertilizers and domestic sewage (Adeyeye & Abulude, 2004). Strebel *et al.* (1989) indicated that intensive use of fertilizer for crops is responsible for nitrate accumulation in both groundwater and surface waters. Irresponsible and excessive application of fertilizer introduce large amounts of nutrients to water bodies; this is especially the case in paddy cultivation (Dissanayake & Weerasooriya, 1987). Young *et al*. (2010) stated that the fertilizer application is high in North Central part of Sri Lanka amounting to six to ten times in excess of the levels recommended by the government. It was clearly observed that intense agricultural practices increase NO_3^- and PO_4^{3-} concentrations as well as other dissolved ions in groundwater (Young *et al*., 2009; Sutharsiny *et al*., 2012).

The highest order interaction of the NO_3^- level showed a significant p-value (<0.0001) than the alpha value (0.05), thus it can be concluded that at least one of the levels of a factor will differ from the other level of another factor. Therefore, mean separation was performed (Table 1). NO_3^- concentration in water samples collected from *Malwathu Oya* during the study period ranged from 1.05 to 5.28 mg/L. When land preparation for paddy cultivation is carried out during the latter part of FIMS, fertilizers are applied as basal and top dressing to the field (Wijesundara *et al*., 2012). Finally, excess water is discharged into nearby Paddy Outlet Canals (C1 to C6 as shown in Fig. 1). All the sampling points of paddy cultivated areas are situated close to Paddy Outlet Canals. Therefore, the detected NO_3^- levels in paddy sites are comparatively higher than non-paddy areas, but lower than the levels compared to that in Paddy Outlet Canals due to dilution (Table 2). Because of further dilution, the detected mean nitrate concentrations are lower in non-paddy sites than paddy sites (Table 1).

Table 1. Mean nitrate concentration (mg/L) of *Malwathu Oya* in four climatic seasons from March 2012 to February 2013

	Study Site	CGU	FIMS	SWMS	SIMS	NEMS
				Paddy area		
URS	A1	Pool	4.64^a	2.38^b	2.85^b	2.38^b
	A2	Riffle	3.18^a	2.14^c	2.61^b	1.45^d
	A3	Run	3.57^a	2.48^c	3.02^b	2.55^c
LRS	A4	Pool	5.07^a	2.85^c	3.35^b	2.88^c
	A5	Riffle	3.10	†	2.94	2.75
	A6	Run	5.28^a	2.49^d	3.00^c	3.48^b
				Non-paddy area		
URS	B1	Pool	2.79^a	2.13^b	2.15^b	2.10^b
	B2	Riffle	2.55^a	†	2.23^b	1.51^c
	B3	Run	2.83^a	1.05^d	2.60^b	2.05^c
LRS	B4	Pool	3.00^a	2.58^b	2.88^a	3.04^a
	B5	Riffle	5.28^a	2.58^b	2.85^b	2.56^b
	B6	Run	3.95^a	2.61^b	2.76^b	2.70^b

[a,b,c, d] are based on LSMEAN (adjusted mean) separation procedure. Values within rows having different superscripts are significantly different (P< 0.05). † - Not measured due to unavailability of water.

Table 2. Nitrate concentration in paddy outlet canals (mg/L)

Climatic season	Mean nitrate concentration (Mean ±SD)					
	C1	**C2**	**C3**	**C4**	**C5**	**C6**
FIMS	9.57±0.47	12.00±0.45	6.85±2.87	5.5±0.95	4.06±0.58	11.07±1.68
SWMS	†	†	†	†	†	†
SIMS	4.51±0.16	4.75±0.05	4.92±0.05	5.25±0.10	4.9±0.11	5.19±0.15
NEMS	2.48±0.07	2.84±0.24	3.13±0.42	2.72±0.07	2.91±0.04	2.69±0.42

† - Not measured due to unavailability of water.

When climatic seasons are considered, the highest mean NO_3^- concentrations were detected in FIMS and SIMS (Table 1) and the lowest was detected in SWMS (drought). As the Yala season starts in FIMS and the Maha season starts in SIMS, with the onset of these cultivation seasons, paddy land preparation activities and fertilization are carried out. Paddy outlet canals bring water continuously from those paddy lands to *Malwathu Oya* during these cultivation seasons. Cultivation activities are minimum during SWMS due to limitation of irrigation water. During the latter part of the dry period from September-October, some parts of the river ran dry as well as the Paddy Outlet Canals got completely dried up. Mean NO_3^- concentration in NEMS is lower than SIMS. These low levels may be related to very high water level in the river during NEMS due to continuous rains. Detected nitrate concentrations coincided with fertilizer application in the area because the cultivation activities for the *Yala* season commenced during this period, thus the influence of inorganic fertilizers on river water is understandable. Therefore, statistically significant seasonal variation can be observed in the nitrate concentration of *Malwathu Oya* water.

When CGUs are considered, the NO_3^- level obtained from pools, riffles and runs in URS and LRS show bimodal patterns coincide with the cultivation pattern in the Dry Zone. This situation occurs due to the dilution effect with the high precipitation experienced during the NEMS. However, the mean NO_3^- levels detected in URS in non-paddy area during FIMS were considerably lower than other values during the same season. The study sites B1 and B2 are only 5 and 7 km away from the headwaters of *Malwathu Oya* which is situated in Ritigala Nature Reserve area. There were no paddy lands in the area, nevertheless forest cover and shrubbery lands are predominant. Thus the NO_3^- levels detected may be lower due to less stress on the natural water.

A study carried out by Young *et al*. (2009) has clearly shown high NO_3^- values in almost all the surface waters of the Kala Oya river basin; e.g., 23.4 mg/L in the stream. The study carried out in *Mahakanumulla* tank cascade in the Anuradhapura District showed that NO_3^- values varied from 2.17 to 4.87 mg/L (Wijesundara *et al*., 2012). The NO_3^- levels over 10 mg/L in natural waters normally indicate man made pollution, but the measured values in this study were within the acceptable limit for drinking water (WHO, 1993; Eletta & Adekola, 2005).

Seasonal variation of phosphate

Phosphate can enter a water system from the weathering of phosphorous baring rocks and minerals. Man-made sources of PO_4^{3-} in the environment include domestic and industrial discharges, agricultural runoff where fertilizers are used, and changes in land use in areas where phosphorous is naturally abundant in the soil (Chapman & Kimstach, 1996). High levels of phosphorus will be quickly consumed by plant and microorganisms, impairing the water by depleting the dissolved oxygen and increasing the turbidity. The interaction among four factors (Location, Channel Geomorphic Unit and River Segment and Climatic Season) of PO_4^{3-} concentration is significant ($p<0.05$) in *Malwathu Oya*. Concentration of PO_4^{3-} ranged from 0.004 to 0.043 mg/L (Table 3). The seasonal variation of PO_4^{3-} is almost similar to NO_3^-. The concentrations were high in FIMS and SIMS. The lowest level was detected during SWMS. The PO_4^{3-} value is comparatively higher in SWMS than NEMS but lower than SIMS.

This significant seasonal trend in PO_4^{3-} coincided with the two cultivation seasons. Study carried out in *Mahakanumulla* tank cascade in the Dry Zone by Wijesundara *et al.* (2012) states that after chemical fertilizer application in the area, PO_4^{3-} concentration increased drastically and thereafter decreased gradually (May and June). The rate of PO_4^{3-} movement may also be influenced by land preparation. As there is no water in paddy outlet canals and runoff is lacking or completely absent, PO_4^{3-} was very low during the dry period. When both NO_3^- and PO_4^{3-} are present in water in higher amounts than in the natural waters, the accumulation of them may be due to application of fertilizer since it is the only anthropogenic activity in the area contributing to increase of nutrients. Higher concentrations of PO_4^{3-} rarely occur, because after it enters water, it will be rapidly taken up by plants. This may be facilitated by warmer environmental conditions in the area during the latter part of SWMS. Comparatively lower PO_4^{3-} level during NEMS may also be accompanied by dilution effects due to heavy rains in the season.

The observed individual PO_4^{3-} values in paddy areas of the river (Table 3) are lower than the values observed in related Paddy Outlet Canals (Table 4) due to dilution effects. The detected range of PO_4^{3-} in Paddy Outlet Canals was 0.016-0.051 mg/L. Phosphate level is also high in LRS than URS. This may be attributed to the presence of cultivated lands as the river flows down, the forest cover on either side of the river is gradually replaced by paddy fields.

Table 3. Mean phosphate concentration (mg/L) of *Malwathu Oya* in four climatic seasons from March 2012 to February 2013

	Study site	CGU	FIMS	SWMS	SIMS	NEMS
				Paddy area		
URS	A1	Pool	0.021^a	0.010^b	0.020^a	0.004^c
	A2	Riffle	0.030^a	0.012^b	0.015^b	0.007^c
	A3	Run	0.022^a	0.010^b	0.020^a	0.010^b
LRS	A4	Pool	0.036^a	0.010^b	0.032^a	0.010^b
	A5	Riffle	0.043^a	†	0.024^b	0.011^c
	A6	Run	0.041^a	0.017^b	0.030^c	0.012^b
				Non-paddy area		
URS	B1	Pool	0.010^a	0.007^b	0.010^a	0.008^b
	B2	Riffle	0.041^a	†	0.015^b	0.010^c
	B3	Run	0.011^b	0.008^c	0.015^a	0.007^c
LRS	B4	Pool	0.020^a	0.014^b	0.011^b	0.010^b
	B5	Riffle	0.030^a	0.012^b	0.013^b	0.011^b
	B6	Run	0.031^a	0.014^c	0.028^b	0.010^c

^{a,b,c} are based on LSMEAN (adjusted mean) separation procedure. Values within rows having different superscripts are significantly different ($P< 0.05$). † - Not measured due to unavailability of water.

Table 4. Phosphate concentration in paddy outlet canals (mg/L)

Climatic season	Mean phosphate concentration (Mean ±SD)					
	C1	C2	C3	C4	C5	C6
FIMS	0.049±0.02	0.050±0.01	0.051±0.01	0.043±0.01	0.046±0.02	0.050±0.01
SWMS	†	†	†	†	†	†
SIMS	0.034±0.01	0.041±0.01	0.039±0.01	0.034±0.01	0.030±0.01	0.040±0.01
NEMS	0.020±0.01	0.017±0.01	0.024±0.01	0.029±0.02	0.016±0.02	0.021±0.02

† - Not measured due to unavailability of water.

Though NO_3^- and PO_4^{3-}fluctuation seems to have a relationship upon fertilizer application most of the PO_4^{3-} seems to be adsorbed onto clay particles or precipitated with calcium in the area (Young *et al*., 2009). This is facilitated by extremely low flow rates of pools of *Malwathu Oya*. However, the PO_4^{3-} values detected in riffles and runs are also comparatively low. Other than the precipitation, when the water flows, the plants in the river banks also absorb PO_4^{3-} (Young *et al*., 2009). After PO_4^{3-} enters river, it will also be rapidly taken up by plants. (e.g., Phytoplankton). Therefore, low PO_4^{3-} level was detected in the water of *Malwathu Oya*. However, none of the water samples of *Malwathu Oya* exceeded the PO_4^{3-} level beyond the WHO recommended level (2.0 mg/L) for drinking water.

Seasonal variation of chloride

Chloride occurs naturally as minor contaminant (Kelly *et al*., 2012). It is generally combined with calcium, magnesium or sodium, thus widely distributed in nature as salts (NaCl, KCl and $CaCl_2$) of them (WHO, 1996). Detected Cl^- values of *Malwathu Oya* ranged from 2.63 to 8.72 mg/L. Chlorides in surface water varies significantly with the climatic season. The detected Cl^- values were high in FIMS and SIMS (Table 5).

Table 5. Mean chloride concentration (mg/L) of *Malwathu Oya* in four climatic seasons from March 2012 to February 2013

	Study site	CGU	FIMS	SWMS	SIMS	NEMS
			Paddy area			
URS	A1	Pool	7.21^a	2.90^c	7.24^a	4.67^b
	A2	Riffle	8.31^a	3.94^d	6.89^b	4.23^c
	A3	Run	8.72^a	4.67^b	8.21^a	3.65^c
LRS	A4	Pool	7.76^a	3.83^c	6.75^b	4.12^c
	A5	Riffle	7.48^a	†	5.40^b	7.41^a
	A6	Run	7.63^a	3.45^d	5.87^b	4.58^c
			Non-paddy area			
URS	B1	Pool	5.21^a	2.69^c	5.89^a	4.20^b
	B2	Riffle	6.43^a	†	5.36^b	4.33^c
	B3	Run	5.34^b	3.97^c	8.32^a	4.32^c
LRS	B4	Pool	5.95^a	2.64^c	5.47^a	4.10^b
	B5	Riffle	6.20^a	2.63^c	5.89^a	4.04^b
	B6	Run	6.11^a	2.74^c	4.93^b	4.71^b

$^{a, b, c, d}$ are based on LSMEAN (adjusted mean) separation procedure. Values within rows having different superscripts are significantly different (P< 0.05). † - Not measured due to unavailability of water.

Table 6. Chloride concentration in paddy outlet canals (mg/L)

Climatic season	Mean chloride concentration (Mean ±SD)					
	C1	**C2**	**C3**	**C4**	**C5**	**C6**
FIMS	10.34±0.23	8.70.±0.13	10.19±0.12	9.23±0.11	8.56±0.021	8.39±0.27
SWMS	†	†	†	†	†	†
SIMS	8.21±0.21	7.89±0.10	9.54±0.14	8.97±0.23	8.90±0.45	10.67±0.26
NEMS	7.91±0.10	7.45±0.13	6.43±0.20	6.11±0.12	6.32±0.09	7.44±0.41

† - Not measured due to unavailability of water.

Similar to NO_3^- and PO_4^{3-}, the detected Cl^- values were high during paddy cultivation seasons in FIMS and SIMS and relatively low values were observed in NEMS. The lowest values were detected in SWMS. The mean Cl^- value in A5 is higher in paddy areas in NEMS than other study points. The mean Cl^- value in A6 is also slightly higher in the same season. During the NEMS, these areas received spill water of *Nachchaduwa* reservoir. Silva (2004) has detected 56 to 151 mg/L of Cl^- in *Nachchaduwa* reservoir in year 2002. The higher Cl^- values may be attributed to high Cl^- containing water of *Nachchaduwa* and runoff water due to heavy rains. As Cl^- ion is highly mobile, it is transported easily to close waters during the rainy season. Comparatively, Cl^- values were higher in paddy areas than that in non-paddy areas. This may be attributed to high Cl^- containing water bring through Paddy Outlet Canals (Table 6). During SWMS, fewer chances are there to get these contaminants mixed with river water. Therefore detected Cl^- values were low.

There was no apparent relationship in observed Cl^- values of pools, riffles and runs. According to Silva and Manuweera (2004), detected Cl^- level in Dry Zone midland and lowland rivers in Sri Lanka ranged from 1.64 to 14.5 mg/L.

Seasonal variation of Dissolved Oxygen (DO)

The model with highest order interaction of the DO concentration showed a significant p-value (< 0.0001). Significant seasonal variation was observed in DO level of *Malwathu Oya* (Table 7). Detected DO level of *Malwathu Oya* ranged from 3.11 to 8.50 mg/L.

Table 7. Mean Dissolved Oxygen (mg/L) of *Malwathu Oya* in four climatic seasons from March 2012 to February 2013

	Study site	**CGU**	**FIMS**	**SWMS**	**SIMS**	**NEMS**
			Paddy area			
URS	A1	Pool	7.14^b	4.80^c	7.50^b	8.50^a
	A2	Riffle	6.98^c	3.11^d	7.70^b	8.20^a
	A3	Run	6.91^b	4.70^c	7.12^b	8.01^a
LRS	A4	Pool	6.94^a	4.61^b	7.51^a	7.90^a
	A5	Riffle	6.99^c	†	7.52^b	8.10^a
	A6	Run	6.78^b	3.62^c	7.02^b	8.32^a
			Non-paddy area			
URS	B1	Pool	8.03^a	4.52^c	6.76^b	7.92^a
	B2	Riffle	7.60^b	†	7.64^b	8.40^a
	B3	Run	8.13^a	3.88^c	7.28^b	8.20^a
LRS	B4	Pool	8.07^a	4.46^c	7.29^b	7.99^a
	B5	Riffle	7.85^a	4.34^c	7.26^b	8.17^a
	B6	Run	7.68^b	3.97^d	6.97^c	8.33^a

$^{a, b, c, d}$ are based on LSMEAN (adjusted mean) separation procedure. Values within rows having different superscripts are significantly different (P< 0.05). † - Not measured due to unavailability of water.

The highest mean DO level was observed in NEMS. This is attributed to occurrence of frequent heavy rains. The DO values observed in FIMS and SIMS were higher than SWMS but lower than NEMS. Consequently, considerable precipitation is received by the area in FIMS and SIMS. However, minimum DO level was recorded in SWMS. This may be due to minimum precipitation during this season. It was observed that there was no rain and water level of the river declined drastically in July and August. Water became greenish in colour. At this time, fish either swim towards water retaining areas of *Malwathu Oya* or evacuate (to nearby waters). However, some dead fish were found in the river because of their habitat loses and intolerable harsh environmental conditions during the drought in August 2012. This situation can increase microbial activity and oxygen will be consumed out of the water by them. As a result, DO in water retaining areas of the river may decline.

Any Significant difference in DO level in paddy and non-paddy areas was not observed. The seasonal variation of DO level in these areas is the same. However, the DO values observed during FIMS in non-paddy areas are slightly higher than paddy area. This may be attributed to the production of oxygen by phytoplankton. However, plankton count was not included in this study. Dissolved Oxygen level in URS and LRS was also not significant. Any obvious relationship in DO level in pools, riffles and runs was not detected. Although nutrient concentrations of river water are high in Paddy Outlet Canal areas, the spatial variation is not considerable. In general, a DO saturation level of at least 5 mg/L is required. Values lower than this can place stress on fish, and levels reaching less than 2 mg/L may result in death. Unfavourable DO concentration could be observed only during SWMS (Table 7).

Seasonal variation of turbidity

Watershed features, such as geology, agricultural activities, urban development activities, and topography, vegetation, and precipitation events can all greatly influence raw water turbidity (APHA, 1992). High concentrations of particulate matter can cause increased sedimentation and siltation in a stream, which in turn can ruin important habitat areas for fish and other aquatic life.

The model with highest order interaction of turbidity showed a significant p-value (<0.0001). Significant seasonal variation in turbidity of river water was observed in almost all locations. Detected turbidity level of *Malwathu Oya* ranged from 81.75 to 256.10 NTU (Table 8). Turbidity in surface water varies significantly with the climatic season. The highest mean turbidity levels were observed in NEMS. As heavy rains and fast-moving water are erosive, they can pick up and carry enough dirt and debris into *Malwatu Oya* especially with heavy rains (e.g., NEMS). The turbidity in FIMS and SIMS were higher than that in SWMS. This is also attributed to intermonsoon rains. Generally the amount of rain received during SIMS is higher than FIMS. Therefore, seasonal precipitation is concerned; the comparative higher turbidity values can be understood. Similarly, after the drought, with the onset of monsoon rains, paddy farmers commence land preparation activities. The minimum seasonal turbidity was recorded in SWMS is attributed to the minimum rainfall during this season. In SWMS, turbidity has noticeably increased in study points A4 and B4 (Table 8). This situation is due to anthropogenic activities. Inhabitants in the area clear up shrub lands to cultivate minor crops and extensively utilize water of *Malwatu Oya* for their cultivations during the drought. Excessive agitation of water with machineries in these pool sites cause to decline the aesthetic qualities of water. Muddy colour water was observed frequently in the area during the sampling period. Significant difference in turbidity in paddy and non-paddy areas was not found. Also, turbidity values observed in paddy and non-paddy areas and in URS and LRS were not significant. Any obvious relationship in turbidity in pools, riffles and runs was not detected. However, turbidity level of water of *Malwathu Oya* exceeds the Sri Lankan limiting range of potable water (8 NTU) of Sri Lanka.

Table 8. Mean turbidity (NTU*) of *Malwathu Oya* in four climatic seasons from March 2012 to February 2013

	Study Site	CGU	FIMS	SWMS	SIMS	NEMS
				Paddy area		
URS	A1	Pool	105.56^{c}	96.45^{d}	168.03^{b}	204.66^{a}
URS	A2	Riffle	122.87^{c}	93.03^{d}	155.36^{b}	255.10^{a}
URS	A3	Run	136.50^{c}	90.53^{d}	161.85^{b}	223.23^{a}
LRS	A4	Pool	118.76^{d}	240.10^{a}	155.76^{c}	219.10^{b}
LRS	A5	Riffle	129.33^{c}	†	170.03^{b}	224.66^{a}
LRS	A6	Run	124.66^{c}	90.70^{d}	160.70^{b}	245.06^{a}
				Non-paddy area		
URS	B1	Pool	101.43^{c}	81.75^{d}	141.66^{b}	200.23^{a}
URS	B2	Riffle	139.70^{c}	†	156.30^{b}	238.66^{a}
URS	B3	Run	136.20^{c}	82.92^{d}	163.92^{b}	238.76^{a}
LRS	B4	Pool	138.33^{c}	207.00^{a}	162.00^{b}	214.00^{a}
LRS	B5	Riffle	145.26^{b}	93.66^{c}	153.00^{b}	242.06^{a}
LRS	B6	Run	140.70^{b}	84.73^{c}	151.06^{b}	256.10^{a}

^{a,b,c,d} are based on LSMEAN (adjusted mean) separation procedure. Values within rows having different superscripts are significantly different ($P < 0.05$). † - Not measured due to unavailability of water. * Nephelometric Turbidity Units

CONCLUSIONS

Both natural and anthropogenic activities affect water quality of *Malwatu Oya.* Paddy cultivation can be considered as one of the anthropogenic activities in the study area. However, the intensity of these effects is rather seasonal. It was observed that the concentrations of NO_3^-, PO_4^{3-} and Cl^- in water samples of the *Malwathu Oya* showed statistically significant seasonal variations over the twelve month study period. High amounts of these nutrients in sampling points of *Malwathu Oya* close to paddy Outlet Canals were observed. High values of them were detected in FIMS and SIMS after application of chemical fertilizer with the onset of *Yala* and *Maha* seasons. Dissolved Oxygen and turbidity levels are highest in NEMS during December to February. Nutrient concentrations, DO and turbidity are comparatively lower in SWMS especially during the latter part of the dry period.

When URS and LRS (distance to study points from its headwaters) are considered, NO^{3-}, $PO_4{}^{3}$- levels are higher in LRS. Pools in paddy and non-paddy areas of URS and LRS showed comparatively lower PO_4^{3-} concentrations than riffles and runs. NO^{3-} level in Pools and riffles in paddy and non-paddy are slightly higher than run areas. There was no apparent relationship in observed Cl^- values of pools, riffles and runs. However, CGUs of the river, URS and LRS did not affect river water considerably. Nevertheless, the observed nutrient levels in water of *Malwathu Oya* are coincided with the cultivation pattern in the Dry Zone.

All the above mentioned water quality parameters except turbidity were within the threshold limits for drinking purposes. Nevertheless, DO level in SWMS is unfavourable for most aquatic fauna including the fish. This is mainly due to extreme drought condition in the area from July to September.

REFERENCES

Adeyeye, E.L and Abulude, F.O. (2004). Analytical assessments of some surface and ground water resources in Ile – Ife, Nigeria. J. Chem. Soc. Nig. *29*, 98-103.

APHA-American Public Health Association. (1992). Standard methods for the examination of water and wastewater.18th ed. American Public Health Association, Washington, DC.

APHA -American Public Health Association. (2005). Standard methods for examination of water and waste water. 21st Edition, Washington D.C.

Boukari, Y., Bawa, L.M. and Djaneye-Boundjou, G. (1999). Characterization of some Togo surface waters. Bull.Chem.Soc. Ethiop. *13(1)*, 11-21. ISSN 1011-3294.

Chapman, D. and Kimstach, V. (1996). Selection of water quality variables. pp. 96. In: Deborah Chapman (Ed.) Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition. E&FN Spon, an imprint of Chapman & Hall, University Press, Cambridge. ISBN 0 419 21590 5 (HB) 0 419 21600 6 (PB). [online]. [Accessed 20/06/2013]. Available at: http://www.who.int/water_sanitation_health/resourcesquality/watqualassess.pdf

Dissanayake, C.B., Weerasooriya, S.V.R. (1987). Medical geochemistry of nitrates and human cancer in Sri Lanka. Int J Environ Stud. *30*, 145-156

Eletta, O.A.A. and Adekola, F.A. (2005). Studies of the Physical and Chemical Properties of Asa River Water, Kwara State, Nigeria. Science Focus, *10(l)*, 72-76.

Kelly, W.R., Panno, S.V., Hackley, K. (2012). The Sources, Distribution, and Trends of Chloride in the Waters of Illinois, Champaign, Illinois. Bulletin B-74. [online]. [Accessed 04/07/2012]. Available at: http://www.isws.illinois.edu/pubdoc/B/ISWSB-74.pdf

Silva, E.I.L. (2004). Quality of Irrigation Water in Sri Lanka Status and Trends. Asian Journal of Water, Environment and Pollution, (1 & 2), pp. 5-12.

Silva, E.I.L. and Manuweera, L. (2004). Surface and Rainwater Chemistry in Sri Lanka- A Risk of Acidification. Asian Journal of Water, Environment and Pollution, *1*(1 & 2), pp. 79.86.

Singh, L.B. (2007). River Pollution. 1st Edn., APH Publishing, New Delhi, ISBN-10: 8131300854, pp. 192.

Strebel, O., Duynisveld, W.H.M. and Bottcher, J. (1989). Nitrate pollution of groundwater in Western Europe. Agric Ecosyst Environ. *26*, 189-214

Sutharsiny, A., Pathmarajah, S., Thushyanthy, M. and Meththika, V. (2012). Characterization of Irrigation Water Quality of Chunnakam Aquifer in Jaffna Peninsula. Tropical Agricultural Research Vol. *23 (3):* 237 - 248.

Ugwa, A.I. and Wakawa, R.J. (2012). Study of seasonal physicochemical parameters in river Usma, American Journal Environment Science, *8*(5), 569-576. ISSN: 1553-345X.

WHO (World Health Organization). (1993). Guidelines for drinking water quality-I, Recommendations, 2ndEd.

WHO (World Health Organization). (1996). Guidelines for drinking-water quality, 2nd ed. Vol. 2. Health criteria and other supporting information, Geneva, WHO/SDE/WSH/03.04/03, [online]. [Accessed 20/06/2012]. Available at:
http://www.who.int/water_sanitation_health/dwq/chloride.pdf

Wijesundara, W.M.G.D., Nandasena, K.A. and Jayakody, A.N. (2013). Seasonal and Spatial Variations of N, P, K and Cd Concentrations in Water of the *Mahakanumulla* Cascade in the Dry zone of Sri Lanka. Trop. Agric. Res. Vol. *24(3)*, 279 - 288.

Young, S.M., Pitawala, A. and Gunatilake, J. (2009). Effect of agricultural practices on chemical quality of water in *Kala Oya* river basin. Journal of Geological Society of Sri Lanka, *13,* 97-104.

Young, S.M., Pitawala, A. and Gunatilake, J. (2010). Fate of phosphate and nitrate in waters of an intensive agricultural area in the dry zone of Sri Lanka. Paddy Water Environ, *8*, 71–79. DOI 10.1007/s10333-009-0186-6