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Short Communication

Seasonal and Spatial Variations of N, P, K and Cd Concentrations in Water of the *Mahakanumulla* Cascade in the Dry zone of Sri Lanka

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ABSTRACT. *Systematic work on water quality aspects, particularly on the accumulation and fluctuation of plant nutrients and heavy metals, has not being carried out at the Mahakanumulla tank cascade in the dry zone of Sri Lanka. Therefore, the main objective of this research was to study the seasonal changes of the concentration of major plant nutrients viz., Nitrogen (NO_3^-), Phosphorus (PO_4^{3-}), Potassium (K^+), and heavy metal Cadmium (Cd^{+2}) in water along the cascade system. The concentrations of NO_3^-, PO_4^{3-}, K^+ and Cd^{+2} in water samples showed significant spatial and temporal variations over the study period and showed a bimodal pattern. The highest concentrations of the measured parameters were observed in months of April and May in the Yala season. Low nutrient concentration observed in the Maha season could be due to dilution effect caused by the comparatively high volume of tank water. Spatial distribution of NO_3^- , PO_4^{3-} , K^+ and Cd^{+2} concentrations in the water of three sampling locations of each paddy tract showed a significant increasing trend from the first sampling point to third point of the paddy field.*

Keywords: *Seasonal changes, plant nutrients, heavy metal, tank cascade system*

INTRODUCTION

The dry zone of Sri Lanka is located in lowest part of island and consists large number of inland valleys. This type of topography, climatic condition, soil and surface hydrological conditions favour the establishment of cascade irrigation system with small tanks in dry zone of Sri Lanka (Pannabokke, 2002). A tank cascade is a series of small tanks that are constructed at successive locations down one single common water course. Small tank systems are perceived as human adaptation to rain fall pattern, a water harvesting system that enables through irrigation, to change the uneven distribution of water. It is not surprising that the tank irrigation system became a permanent feature in the dry zone landscape.

Mahakanumulla cascade system located in North Central Province is a branch type cascade and consists of 27 small tanks. Of all tanks 5 are located along the main valley. The total extend of paddy field under this cascade is approximately 324 ha and around 1600 families live under this cascade (Pannabokke *et al.,* 2002). However, the equilibrium state of tank in relation to the water quality could be disrupted by the intensive agriculture practices and human activities with growing population. Accumulation of nutrient elements in tank water due to the added fertilizers, dung and urine of the large cattle population could degrade water

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quality and brings in potential hazards to the human health (Young *et al*., 2010). Tank cascade system has very specific features and each and every component of the eco system was given due consideration. Recently, attention was only given to all macro land uses such as paddy land, settlement area, chena lands, tank beds etc. neglecting micro land uses such as *Godawela, Iswatiya, Gasgommana, Perahana, Kattakaduwa, Thisbaba, Kiul ela* etc. For instances, main duty of *Gasgommana, Perahana* and *Godawela* is to prevent entering upper catchment irrigation water and sediment directly to tank water. Those micro land uses act as physical barriers and silt trapping filters (Dharmasena, 2004). With the disappearance of most of features due to less attention, runoff water with sediment particles and plant nutrient elements directly enter to the tank water and degrade tank water quality and increase sedimentation. In this *Mahakanumulla* tank cascade system, no systematic work, however, has been carried out on water quality aspects particularly on the accumulation and fluctuation of plant nutrients and Heavy metal. Therefore the main objective of this research is to study the seasonal changes and spatial variations of the concentration of major plant nutrients *viz.* Nitrate (NO_3^-) and Phosphate (PO_4^{3-}) , Potassium (K^+) and heavy metal Cadmium (Cd^{+2}) in water along the *Mahakanumulla* tank cascade in dry zone of Sri Lanka.

MATERIALS AND METHODS

Field work has been carried out in the *Thirappane* area. Main tanks from *Mahakanumulla* cascade, namely *Mahakanumulla, Amanakkatuwa and Siwalagala* were selected for this study (Fig. 1). Three sampling points from water channel along paddy fields under each tank were selected subsequent to a survey to represent the respective areas. Two sets of water samples were taken at monthly intervals from three tanks and from three selected locations of water canal along paddy track from February 2011 to January 2012. One set was filtered and acidified for metals analysis and few drops of chloroform were added for the other set. The chemical analysis the samples was conducted at the Department of Soil Science, University of Peradeniya. In all water samples, NO_3^- and PO_4^{3-} were determined using Sodium Salicylate and Molybdate blue colorimetric procedures respectively. K^+ determination was done using Flame Emission Spectrophotometer (FES). Cd^{+2} of water samples measured using Atomic adsorption spectrophotometer. The data were analyzed statistically with ANOVA and Turkey's Student zed Range test comparison.

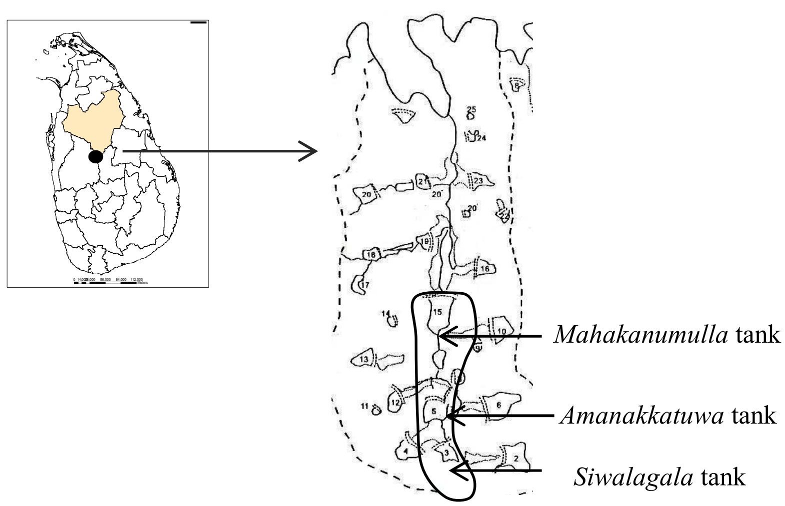


Fig. 1. Mahakanumulla tank cascade

RESULTS AND DISCUSSION

The results of the concentrations of major plant nutrients ; NO_3^- , PO_4^{3-} , K^+ heavy metal Cd^{+2} in water samples of the *Mahakanumulla* cascade from February 2011 to January 2012 are given in Tables 1, 2, 3 and 4. According to the results, three major plant nutrients and Cd^{+2} showed statistically significant spatial and temporal variations over the study period (Fig: 2, 3, 4 and 5)

Temporal and spatial variation of nitrate in the cascade

In dry zone, there are two distinct cropping seasons namely *Yala* and *Maha. Yala* and *Maha* seasons fall in the months of May to September and October to March respectively. In the *Yala* season, land preparation for paddy cultivation is carried out in late April to early May and planting begins in early weeks of May. In this period, fertilizers are applied as basal and top dressings to the fields. Also application of excess amount of fertilizer resulted in enhancement of nutrient content in the surface runoff (Chun *et al*., 2003). It is reported that high quantity of sediment particles transfer via irrigation channel and finally end up with tank during the land preparation period. In this twelve months study period, NO_3^- varied from 2.17-4.87 mgL^{-1} and highest NO_3^-concentration was recorded during the rainy months of April, October and November comparatively to the drier months of July, August and September (Table 1). These high NO_3^- values observed during the months of April to May and October to November were also coincided with the fertilizer application period in rice cultivation of the area. Highest concentration of NO_3^- waters of three tanks was observed in months of April and May in *Yala* compared to the *Maha* season. Low nutrients concentration in the *Maha* period could be due to dilution effect caused by comparatively high volume of tank water during *Maha* season (Wijesundara *et al*., 2011a).

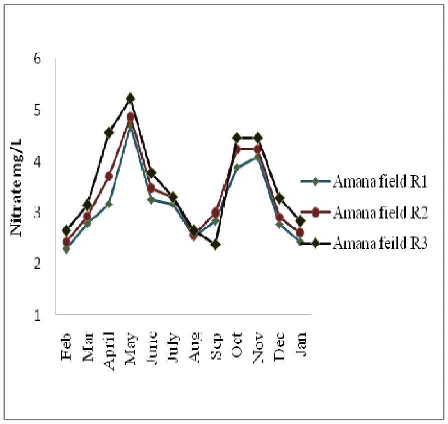
It was also found that the nutrients concentration of waters of these three tanks showed a bimodal pattern which was coincided with the bimodal rainfall of the dry zone (Wijesundara *et al*., 2011b; 2011c). The concentrations of NO_3^- of the water samples collected from the three sampling points along the paddy track of the commanding area of *Siwalagala* and *Amanakkatuwa* tanks were also showed a statistically significant temporal variation and followed a bimodal pattern similar to the NO_3^- fluctuation in the waters of three tanks (Table 1 and Fig 2, 3). During *Yala* season, comparatively high NO_3^- level can be seen in irrigation water. Paddy fields are normally irrigated using tank water in *yala* season. In contrary to this in *yala* season, sufficient amount of rainfall occurs in *Maha* season and thereby irrigation issue is not much arisen. In the *yala* season, irrigation water circulates through whole paddy field and wash off many nutrients from the soil and finally move them to the next field. Therefore high concentration of NO_3^- could be observed during the *yala* season.

Table 1. Nitrate (mgL^{-1}) movement through *Mahakanumulla* cascade – Feb 2011 –Jan 2012

Sampling points	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan
						2011						2012
Siw tank	2.17^{g}_{E}	2.54^{e}_{BC}	2.88^{fg}_{A}	2.53^{f}_{C}	2.37^{g}_{D}	2.15^{g}_{E}	2.16^{g}_{E}	2.25^{e}_{E}	2.84^{g}_{A}	2.65^{h}_{B}	2.42^{f}_{E}	2.15^{e}_{E}
field R1	2.23^{fg}_{F}	2.51^{e}_{D}	2.84^{g}_{B}	2.85^{e}_{B}	2.63^{f}_{BC}	2.49^{f}_{C}	2.31^{f}_{D}	2.35^{e}_{EF}	3.08^{f}_{E}	2.92^{g}_{A}	2.56^{ef}_{B}	2.31^{d}_{CD}
field R2	2.38^{d}_{G}	2.67^{d}_{E}	2.94^{fg}_{D}	3.57^{d}_{B}	3.11^{e}_{C}	2.91^{d}_{D}	2.63^{bc}_{EF}	2.60^{d}_{EF}	3.75^{de}_{A}	3.43^{f}_{B}	2.98^{b}_{CD}	2.48^{c}_{G}
field R3	2.55^{b}_{G}	2.93^{b}_{EF}	3.45^{d}_{CD}	4.85^{b}_{A}	3.56^{b}_{C}	3.49^{a}_{CD}	2.84^{a}_{F}	3.07^{b}_{E}	4.49^{a}_{B}	4.35^{ab}_{B}	3.37^{a}_{D}	2.62^{b}_{G}
Amana tank	2.26^{ef}_{G}	2.66^{d}_{EF}	3.01^{ef}_{CD}	4.56^{c}_{A}	3.14^{e}_{C}	3.16^{c}_{C}	2.44^{e}_{FG}	2.79^{c}_{DE}	3.99^{bc}_{B}	3.87^{d}_{B}	2.64^{de}_{EF}	2.39^{cd}_{G}
field R1	2.29^{e}_{I}	2.80^{c}_{F}	3.17^{e}_{E}	4.69^{bc}_{A}	3.25^{de}_{D}	3.17^{c}_{E}	2.54^{cde}_{G}	2.84^{c}_{F}	3.88^{cd}_{C}	4.08^{c}_{B}	2.78^{cd}_{F}	2.44^{c}_{H}
field R2	2.44^{c}_{I}	2.93^{b}_{G}	3.71^{c}_{D}	4.87^{b}_{A}	3.47^{bc}_{E}	3.30^{b}_{F}	2.57^{bcd}_{H}	2.99^{b}_{G}	4.10^{b}_{C}	4.24^{bc}_{B}	2.91^{bc}_{G}	2.60^{b}_{H}
field R3	2.66^{a}_{H}	3.15^{a}_{G}	4.56^{a}_{B}	5.22^{a}_{A}	3.78^{a}_{D}	3.30^{b}_{E}	2.65^{b}_{H}	3.39^{a}_{E}	4.40^{a}_{C}	4.46^{a}_{BC}	3.28^{a}_{E}	2.84^{a}_{G}
Maha tank	2.29^{e}_{H}	2.54^{e}_{GH}	4.27^{b}_{B}	4.77^{bc}_{A}	3.35^{cd}_{D}	2.80^{e}_{EF}	2.50^{de}_{H}	2.84^{c}_{E}	3.70^{e}_{C}	3.66^{e}_{C}	2.66^{de}_{G}	2.39^{cd}_{HI}

▪Means with same letters are not significantly different. *Siw* tank –*Siwalagala* tank, *Amana* tank-*Amanakkatuwa* tank, *Maha* tank-*Mahakanumulla* tank. (Upper case letters - temporal variation, Lower case letters- spatial variation).

Spatial distribution of NO_3^- concentration in the water of three sampling locations of each paddy track showed significant increasing trend from first point to third sampling point of the paddy field (*Siwalagala* field R_3, *Amanakkatuwa* field R_3) in every months. For an example, in paddy track of *Siwalagala* tank inthe month of April, NO_3^- concentration of 2.84 mgL^{-1} in field R1 has been increased to 3.45 mgL^{-1} in field R3 while field R1 of *Amanakkatuwa* tank NO_3^- concentration of 3.17 mgL^{-1} in field R1has been increased to 4.56 mgL^{-1} in the field R3 (Table 1).However, there was a little reduction of NO_3^- concentration when water transfers through tank *thaulla* area. Tank *thaulla* is acting as filter for most of plant nutrients and sediments. However, there was a significant steady increase of NO_3^- concentration from uppermost *Siwalagala* tank to *Amanakkatuwa* tank (middle) and to the lowermost *Mahakanumulla* tank. For an example in the month of April, NO_3^- concentration of 2.88 mgL^{-1} in *Siwalagala* tank increased to 3.01 mgL^{-1} in *Amanakkatuwa* tank and to 4.27 mgL^{-1} in *Mahakanumulla* tank (Table 1 and Fig 4).



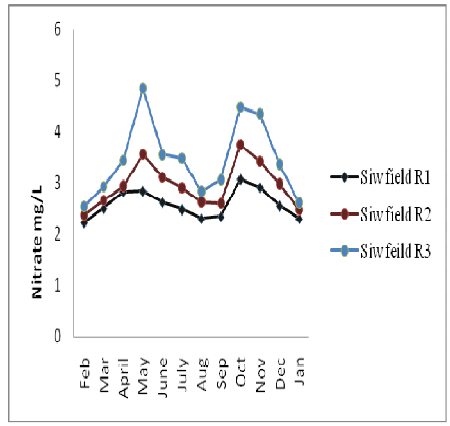
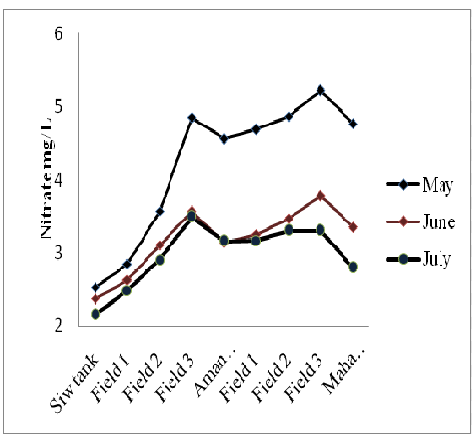


Fig. 2. **Temporal variation of NO_3^- concentration in *Amanakkatuwa* fields**

Fig. 3. **Temporal variation of NO_3^- concentration in *Siwalagala* paddy fields**

This clearly indicates when water moves from upper to lower tanks of the cascade system there is a trend of accumulation of certain elements in the waters of lower tanks. However, the NO_3^-concentration didn't exceed the permissible level of 10 mgL^{-1} (WHO, 2004) for drinking and irrigation water. The NO_3^- values observed in the surface water indicate the low NO_3^- accumulation rate, despite high application rates of nitrate as urea fertilizer as in the recent catchment cultivated areas. Along the bank of irrigation canals, heavy growth of plants are present even during dry period, this indicates that those may absorb nutrients from the water, which carry nutrients from cultivated field. This process may also reduce the nutrient level in water (Hill 1996; Lamontagne *et al.*, 2001).



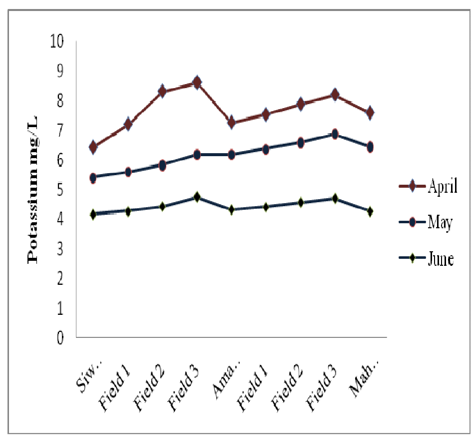


Fig. 4. **Spatial variation of NO_3^-concentration *Mahakanumulla* cascade**

Fig. 5. **Spatial variation of K^+ in concentration along *Mahakanumulla* cascade**

Temporal and spatial variation of phosphate in the cascade

Table 2. Phosphate (mgL^{-1}) movement through *Mahakanumulla* cascade – Feb 2011 – Jan 2012

Sampling points	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan
						2011						2012
Siw tank	0.01^{cd} CDEF	0.01^{b} CDE	0.02^{e} B	0.01^{eB} BCD	0.009^{dD} DEF	0.007^{c} E	0.008^{e} EF	0.01^{cde} CD	0.01^{d} BC	0.02^{b} A	0.02^{ab} B	0.01^{d} DEF
field R1	0.02^{bc} BC	0.02^{ab} BC	0.03^{d} A	0.01^{e} CDE	0.01^{cd} DE	0.009^{c} DE	0.008^{de} E	0.01^{bcd} CD	0.02^{c} BC	0.02^{b} AB	0.01^{bc} CDE	0.01^{bc} CDE
field R2	0.02^{ab} CD	0.03^{ab} BC	0.04^{bc} A	0.03^{d} B	0.01^{bcd} EF	0.01^{b} EF	0.01^{de} F	0.02^{ab} E	0.02^{bc} DE	0.02^{b} BC	0.01^{ab} E	0.02^{ab} E
field R3	0.03^{a} C	0.04^{ab} B	0.05^{a} A	0.04^{cd} B	0.02^{b} E	0.02^{a} CD	0.01^{cd} F	0.02^{ab} E	0.02^{abc} DE	0.02^{b} CD	0.02^{a} DE	0.02^{a} DE
Amana tank	0.01^{cd} CDE	0.01^{b} CDE	0.04^{b} A	0.03^{d} B	0.01^{bc} CD	0.01^{bc} E	0.01^{cde} E	0.01^{de} DE	0.02^{c} C	0.03^{a} B	0.01^{bc} CDE	0.01^{d} E
field R1	0.01^{d} EF	0.02^{ab} C	0.03^{cd} B	0.04^{c} A	0.03^{a} B	0.009^{c} F	0.01^{bc} EF	0.01^{bc} DE	0.02^{bc} CD	0.02^{b} C	0.01^{c} EF	0.009 d F
field R2	0.01^{cd} EF	0.03^{ab} C	0.04^{b} B	0.05^{b} A	0.04^{a} B	0.01^{bc} F	0.01^{a} DEF	0.02^{ab} CDE	0.02^{ab} DE	0.02^{b} CD	0.01^{c} F	0.01^{bc} EF
field R3	0.02^{ab} E	0.04^{ab} C	0.05^{a} B	0.07^{a} A	0.03^{a} C	0.01^{b} FG	0.01^{ab} FG	0.02^{a} EF	0.02^{a} E	0.02^{b} DE	0.01^{bc} G	0.01^{bc} G
Maha tank	0.01^{cd} B	0.07^{a} A	0.02^{de} B	0.01^{e} B	0.01^{cd} B	0.01^{bc} B	0.01^{de} B	0.01^{e} B	0.02^{abc} B	0.01^{c} B	0.01^{c} B	0.01^{d} B

▪Means with same letters are not significantly different. *Siw* tank –*Siwalagala* tank, *Amana* tank-*Amanakkatuwa* tank, *Maha* tank-*Mahakanumulla* tank. (Upper case letters - temporal variation, Lower case letters- spatial variation).

Concentration of PO_4^{3-} of the water of three tanks of the *Mahakanumulla* cascade and three sampling points of the paddy tracks of *Siwalagala* and *Amanakkatuwa* tanks was ranged from 0.009 to 0.05 mgL^{-1} and also showed a significant spatial and temporal variation during the study period (Table 02). The temporal distribution of PO_4^{3-} is concerned, almost similar to NO_3^-, PO_4^{3-} concentration of waters of *Siwalagala*, *Amanakkatuwa* and *Mahakanumulla* tanks were high in the months of April and May of *Yala* season while relatively lower values were recorded for the *Maha* season. Similar trend was also observed with the PO_4^{3-} concentration of water samples collected from the three sampling points along the paddy track of the commanding area of *Siwalagala* and *Amanakkatuwa* tanks.Collectively PO_4^{3-} concentrations of all water samples were showed a significant temporal variation and followed a bimodal pattern which was coincided with the bimodal rainfall of the dry zone. PO_4^{3-} concentration in the waters of *Siwalagala, Amanakkatuwa, Mahakanumulla* tanks and three sampling locations of each paddy track along the cascade showed significant spatial distribution and indicated an increasing trend from first point to third sampling point of the paddy field (*Siwalagala* field R_3, *Amanakkatuwa* field R_3). For an example, in paddy track of *Siwalagala* tank in the month of April, PO_4^{3-} concentration of 0.03 mgL^{-1} in field R1 has been increased to 0.05 mgL^{-1} in field R3 while field R1 of *Amanakkatuwa* tank PO_4^{3-} concentration of 0.03 mgL^{-1} in field R1 has been increased to 0.05 mgL^{-1} in the field R3(Table 2). Hence, during the study period, highest PO_4^{3-} values were detected at lower position of paddy fields under each tank. This may be attributed to surface runoff during land preparation removing a considerable quantity of finer soil particles along with cattle dung and fertilizers from surrounding catchment areas. PO_4^{3-}transport has found similar pattern with NO_3^-, where the lowest content of PO_4^{3-} (0.02 mgL^{-1} in *Siwalagala* field R3) found within the maturity period of paddy (June, July) and the highest (0.05 mgL^{-1} in *Siwalagala* field R3)after the chemical fertilizer application (*Yala* season - April to May, *Maha* season - October to November)(Table 2) . After chemical fertilizer application, PO_4^{3-} concentration increased amazingly and thereafter decreased gradually (May and June). The rate of PO_4^{3-} movement may also be influenced by land preparation. During the drier months where there is no continuous water flow between each field and PO_4^{3-} concentration remained in low concentrations (August, September). PO_4^{3-} is one of the major macro nutrients which is responsible for the eutrophication of open water bodies. According to the Young *et al*. (2010), in some tank waters showed extremely higher values (1.0-2.4 mgL^{-1}). But in this cascade system, none of the water samples exceeded the PO_4^{3-} level beyond the WHO detection level for drinking and irrigation water (2 mgL^{-1}).

Temporal and spatial variation of potassium in the cascade

K^+ content in surface water varies significantly with the season. Fairly high K^+ concentration was detected in surface water falling within the range of 2.14- 8. 61 mgL^{-1}, where the permissible level is 2 mgL^{-1} according to WHO standards (Table 3). Similar to the NO_3^- and PO_4^{3-}, concentration of K^+ in the water of *Siwalagala, Amanakkatuwa, Mahakanumulla* tanks and three sampling locations of each paddy track along the cascade showed a significant statistical spatial and temporal variation during the study period (Table 3). K^+ concentration in surface water was higher in the months of April and May within the *Yala* season while relatively low values were recorded for the *Maha* season. Such elevated contents of K^+ have been observed during the seed sowing period by Gunawardana and Kumuduni (1980) as well.

Table 3. Potassium (mgL^{-1}) movement through *Mahakanumulla* cascade – Feb 2011 – Jan 2012

Sampling points	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan
						2011						2012
Siw tank	2.66^{g}_{F}	3.25^{e}_{E}	6.43^{f}_{A}	5.41^{g}_{B}	4.17^{f}_{D}	2.47^{de}_{G}	2.17^{d}_{H}	3.26^{f}_{E}	4.65^{f}_{C}	5.26^{g}_{B}	3.17^{e}_{E}	2.23^{f}_{H}
field R1	2.69^{fg}_{H}	3.39^{de}_{F}	7.20^{e}_{A}	5.60^{f}_{B}	4.27^{ef}_{E}	2.61^{cd}_{H}	2.32^{c}_{I}	3.40^{ef}_{F}	4.85^{de}_{D}	5.42^{ef}_{C}	3.27^{d}_{G}	2.34^{ef}_{I}
field R2	2.83^{ef}_{G}	3.48^{de}_{F}	8.31^{b}_{A}	5.83^{e}_{B}	4.43^{c}_{E}	2.78^{b}_{G}	2.49^{b}_{H}	3.52^{cde}_{F}	5.06^{c}_{D}	5.59^{cd}_{C}	3.48^{c}_{F}	2.48^{de}_{H}
field R3	2.97^{de}_{G}	3.76^{c}_{F}	8.61^{a}_{A}	6.19^{d}_{B}	4.75^{a}_{E}	3.11^{a}_{G}	2.63^{a}_{H}	3.69^{bc}_{F}	5.29^{b}_{D}	5.79^{b}_{C}	3.66^{b}_{F}	2.68^{c}_{H}
Amana tank	2.82^{f}_{H}	3.56^{cd}_{F}	7.26^{e}_{A}	6.19^{d}_{B}	4.33^{de}_{E}	2.28^{fg}_{J}	2.17^{d}_{J}	3.44^{de}_{G}	4.65^{f}_{D}	5.37^{fg}_{C}	3.31^{d}_{G}	2.51^{d}_{I}
field R1	3.11^{cd}_{H}	3.80^{c}_{F}	7.53^{d}_{A}	6.37^{c}_{B}	4.41^{cd}_{E}	2.39^{ef}_{J}	2.32^{c}_{J}	3.60^{cd}_{G}	4.81^{e}_{D}	5.50^{de}_{C}	3.51^{c}_{G}	2.71^{c}_{I}
field R2	3.53^{b}_{H}	4.22^{b}_{F}	7.88^{c}_{A}	6.58^{b}_{B}	4.57^{b}_{E}	2.55^{cd}_{I}	2.41^{b}_{J}	3.80^{b}_{G}	4.97^{cd}_{D}	5.67^{bc}_{C}	3.69^{b}_{G}	2.91^{b}_{I}
field R3	3.92^{a}_{G}	4.70^{a}_{E}	8.20^{b}_{A}	6.87^{a}_{B}	4.70^{a}_{E}	2.66^{bc}_{I}	2.59^{a}_{I}	4.09^{a}_{F}	5.25^{b}_{D}	5.93^{a}_{C}	3.85^{a}_{G}	3.24^{a}_{H}
Maha tank	3.21^{c}_{F}	3.76^{c}_{D}	7.59^{d}_{A}	6.45^{bc}_{B}	4.27^{e}_{C}	2.19^{g}_{I}	2.14^{d}_{I}	3.48^{de}_{E}	6.30^{a}_{B}	4.48^{h}_{C}	2.83^{f}_{G}	2.58^{cd}_{H}

▪Means with same letters are not significantly different. *Siw* tank –*Siwalagala* tank, *Amana* tank-*Amanakkatuwa* tank, *Maha* tank-*Mahakanumulla* tank. (Upper case letters - temporal variation, Lower case letters- spatial variation).

Similar to other nutrients, K^+ concentration also showed an increasing trend while nutrient moving through paddy fields and highest values were observed in third sampling location. The recommended K fertilizer for a 5t/ha rice crop in the low country dry zone is only 38 kg ha^{-1}. Runoff water and sediment transport with water may bring this elevated K^+ concentration in the lower part of the paddy field from the applied K fertilizers and the accumulated cow dung and other organic residues in the *thaulla* and commanding area of the tanks. In general, surface waters in Sri Lanka are rich in Na^+, Ca^{+2} and Mg^{+2}. But the K^+ concentration is in low level (Dissanayaka *et al*., 1982).

Temporal and spatial variation of cadmium in the cascade

Concentration of Cd^{+2} of the water of three tanks of the *Mahakanumulla* cascade also showed a significant spatial and temporal variation during the study period (Table 4) and generally falls in a very narrow range (0.09-0.33 mgL^{-1}). The permissible level of Cd^{+2} in drinking water is less than 0.003 mgL^{-1} according to the WHO standard (WHO, 2004). Almost all water samples showed higher values than the permissible level. Almost similar to the major plant nutrients discussed above, Cd^{+2} concentration in tank water was elevated in the months of April and May in *Yala* season while relatively lower values were recorded for the *Maha* season. Though the other major nutrients (N, P, and K) added as chemical fertilizer, Cd^{+2} is not added for any field as it has not any beneficial effect on crop life. But with the chemical fertilizers such as triple super phosphate significant amount of Cd^{+2} could be added to the soil (McLaughlin et al., 1996). Average concentration of Cadmium in triple super phosphate sold in state of Califonia was 100 mg/kg, whereas those in soft-phosphate rock were 130 mg/kg (California Department of Agriculture, 1998).

Table 4. Cadmium (mgL^{-1}) movement through *Mahakanumulla* cascade – Feb 2011 – Jan 2012

Sampling Points	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan
						2011						2012
Siw tank	0.06^{e}_{E}	0.11^{g}_{D}	0.21^{e}_{A}	0.21^{f}_{A}	0.21^{e}_{A}	0.14^{d}_{BC}	0.11^{g}_{D}	0.07^{g}_{E}	0.11^{e}_{D}	0.16^{g}_{B}	0.13^{f}_{CD}	0.08^{f}_{E}
field R1	0.07^{e}_{G}	0.12^{f}_{E}	0.22^{e}_{A}	0.22^{f}_{AB}	0.21^{e}_{B}	0.17^{bc}_{C}	0.12^{g}_{E}	0.08^{g}_{F}	0.13^{e}_{E}	0.17^{f}_{C}	0.14^{f}_{D}	0.08^{f}_{F}
field R2	0.09^{d}_{H}	0.14^{e}_{E}	0.24^{d}_{A}	0.24^{e}_{A}	0.22^{e}_{B}	0.18^{bc}_{D}	0.14^{f}_{E}	0.11^{f}_{F}	0.17^{d}_{D}	0.20^{e}_{C}	0.14^{f}_{E}	0.10^{e}_{FG}
field R3	0.11^{c}_{I}	0.18^{cd}_{F}	0.27^{c}_{B}	0.30^{cd}_{A}	0.27^{c}_{B}	0.20^{b}_{DE}	0.16^{e}_{G}	0.13^{d}_{H}	0.20^{c}_{D}	0.22^{d}_{C}	0.18^{e}_{EF}	0.14^{d}_{H}
Amana tank	0.11^{c}_{F}	0.16^{d}_{D}	0.25^{d}_{B}	0.29^{d}_{A}	0.25^{d}_{B}	0.14^{d}_{E}	0.18^{d}_{D}	0.11^{ef}_{F}	0.18^{d}_{D}	0.22^{d}_{C}	0.20^{de}_{C}	0.16^{c}_{D}
field R1	0.11^{c}_{H}	0.17^{d}_{F}	0.27^{c}_{B}	0.31^{bc}_{A}	0.26^{cd}_{B}	0.14^{d}_{G}	0.20^{c}_{DE}	0.13^{de}_{GH}	0.21^{c}_{D}	0.24^{c}_{C}	0.23^{c}_{C}	0.19^{b}_{E}
field R2	0.13^{b}_{I}	0.19^{bc}_{G}	0.30^{b}_{B}	0.33^{a}_{A}	0.27^{c}_{C}	0.15^{cd}_{H}	0.21^{b}_{F}	0.16^{c}_{H}	0.25^{b}_{E}	0.26^{b}_{D}	0.27^{b}_{CD}	0.21^{a}_{F}
field R3	0.17^{a}_{F}	0.21^{a}_{D}	0.32^{a}_{A}	0.32^{ab}_{A}	0.32^{a}_{A}	0.16^{cd}_{F}	0.20^{bc}_{DE}	0.19^{b}_{E}	0.28^{a}_{C}	0.28^{a}_{C}	0.30^{a}_{B}	0.21^{a}_{DE}
Maha tank	0.18^{a}_{G}	0.20^{ab}_{F}	0.25^{d}_{D}	0.31^{bc}_{A}	0.30^{b}_{AB}	0.23^{a}_{E}	0.27^{a}_{C}	0.23^{a}_{E}	0.29^{a}_{BC}	0.25^{b}_{D}	0.21^{cd}_{EF}	0.18^{bc}_{G}

▪ Means with same letters are not significantly different. *Siw* tank –*Siwalagala* tank, *Amana* tank-*Amanakkatuwa* tank, *Maha* tank-*Mahakanumulla* tank. (Upper case letters - temporal variation, Lower case letters- spatial variation).

Most of tank *thaulla* areas in *Mahakanumulla* cascade used as grassing land for huge cattle and buffalo population. Therefore high load of cattle and buffalo manure and considerable amount of urine are added to tank *thaulla*. It is also reported that Cd^{+2} concentration in buffalo and cattle dung varies 0.5- 7.8 mgL^{-1} (Wijewardana and Gunarathana *et al*., 2004). During the rainy period, dissolved heavy metals and other nutrients reach to the tank water. The presence of elevated concentration of Cd^{+2} in soil and water is greatest concern as a result of the toxicity of Cd^{+2} and its ability to accumulate in soils, and bio-accumulate in biosphere.

CONCLUSION

The concentrations of major plant nutrients; NO_3^-, PO_4^{3-}, K^+ and heavy metal Cd^{+2} in water samples of the *Mahakanumulla* cascade showed statistically significant spatial and temporal variations over the twelve months study period. In the temporal changes of nutrients, high amounts of NO_3^-, PO_4^{3-}, K^+ (5.22, 6.07, 8.20 and 0.32 mgL^{-1} respectively) were observed in waters of three tanks and sampling points of paddy tracks just after application of chemical fertilizer during *Yala* and *Maha* seasons of which highest concentrations were observed in the months of April and May of the *Yala* season. And also the temporal changes of concentrations of NO_3^-, PO_4^{3-}, K^+ and Cd^{+2} in the waters of three tanks and paddy tracks were coincided with bimodal rainfall pattern of the area. Spatial distribution of NO_3^-, PO_4^{3-}, K^+ and Cd^{+2} concentrations in the water of three sampling locations of each paddy track showed significant increasing trend from first point to third sampling point of the paddy field. Therefore, this study also concludes that, there is a tendency to accumulate certain elements in the waters of lower tanks and waters of the lower part of the paddy track of the commanding area as well.

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