# *Nutrient reduction in runoff water from sugarcane farms by sedimentation method*

**Solomon Omwoma, W. Nyaigoti Omwoyo, Joseck O. Alwala, David M. K. Ongeri, Lagat C. Sylus & Joseph O. Lalah**

**The Environmentalist**

ISSN 0251-1088
Volume 32
Number 4

Environmentalist (2012) 32:494-502
DOI 10.1007/s10669-012-9416-3


Springer

Environmentalist (2012) 32:494–502
DOI 10.1007/s10669-012-9416-3

# Nutrient reduction in runoff water from sugarcane farms by sedimentation method

Solomon Omwoma · W. Nyaigoti Omwoyo · Joseck O. Alwala · David M. K. Ongeri · Lagat C. Sylus · Joseph O. Lalah

Published online: 2 September 2012


**Abstract** Due to intensive use of agronomic inputs in sugarcane farming, runoff water from these farms is loaded with high concentrations of nutrients. These nutrients find their way into rivers, lakes and sinks, eutrophicating them. Reducing the levels of these nutrients in runoff water from sugarcane farms before it is discharged into sinks will help solve the problems that arise out of eutrophication. This study employed a simple sedimentation method of making depressions in canals draining runoff water from sugarcane farms and emptying them fortnightly during the rainy season and monthly during the dry season. The method was found to significantly ($p \leq 0.05$) reduce water conductivity (μS/cm), turbidity (Nephelometric Turbidity Units), total phosphates, nitrate–nitrogen, potassium, calcium, magnesium, iron, copper, sodium and zinc (ppm) in the dry season from 52.89, 148.70,0.87, 3.34, 446.00, 420.00, 205.00, 12,941.00, 261.00, 398.00, and 484.00 in untreated canals to 48.33, 30.22, 0.21, 2.95, 120.00, 154.00, 98.00, 456.00, 181.00, 234.00, and 311.00 in treated canals, respectively. And in the wet season, the parameters were reduced from 261.46, 719.30, 820.00, 25.16, 654.00, 549.00, 493.00, 19,230.00, 763.00, 748.00, and 903.00 to 128.67, 365.70, 3.47, 10.12, 136.00, 187.00, 167.00, 654.00, 207.00, 321.00, and 231.00, respectively. Dissolved oxygen significantly ($p \leq 0.05$) increased from 5.11 to 8.14 ppm in the dry season and from 3.82 to 7.92 ppm wet season. Acidity reduced in the wet season from pH 5.02 to 6.20. It is, therefore, recommended that sugarcane farmers adopt this method for sustainability of aquatic systems within these zones.

**Keywords** Nutrients · Eutrophication · Sugarcane farming · Sedimentation · Kenya

## 1 Introduction

Sugarcane farming is a major agricultural activity in the western part of Kenya and other parts of the world (Omwoma 2012). The area under cane cultivation in Kenya is over 122,580 ha of land with small-scale farmers representing 90 % of the total cane surface area (KSB 2003). Farmers use high rates of fertilizers and biosolids for maximum yield in sugarcane farming (Allen et al. 2009; Omwoma et al. 2010). Surface runoff water within these cane plantations has been reported to transfer these agricultural inputs to aquatic systems (Haynes 2000; Zueng-Sang 2000; Günter et al. 2007; Omwoma et al. 2011). Most agricultural inputs in sugarcane farming contain high amounts of nutrients which, if transferred to aquatic systems, will lead to their eutrophication (Omwoma 2012). Some of the aquatic systems in Western Kenya including Lake Victoria are already eutrophicated

S. Omwoma (✉)
Department of Health Sciences, Jomo Kenyatta University of Agriculture and Technology, Kisii CBD Campus, P.O. Box 268-40200, Kisii, Kenya
e-mail: solomwoma@yahoo.com

S. Omwoma · W. Nyaigoti Omwoyo · J. O. Alwala · D. M. K. Ongeri
Department of Chemistry, Maseno University, P.O. Box 333-40105, Maseno, Kenya

L. C. Sylus
Department of Chemistry, Masinde Muliro University of Science and Technology, P.O. Box 190-50100, Kakamega, Kenya

J. O. Lalah
Department of Chemical Sciences and Technology, School of Applied Sciences and Technology, Kenya Polytechnic University College, City Square, P.O. Box 52428-00200, Nairobi, Kenya

(Muyodi et al. 2010), and thus it is urgent and necessary to reduce nutrient loading into these systems for their sustainability.

Research towards reduction of eutrophication of Lake Victoria from major rivers feeding it has focused on point sources like industrial and municipal wastes disposals (Scheren et al. 2000; Cowi 2002; LVEMP 2003; Odada et al. 2004; Lalah et al. 2008; Ongeri 2008; Curt et al. 2009; Banadda 2011). Non-point sources like agricultural runoffs have been neglected and yet they are documented as major sources of nutrient loads into the Lake (Cowi 2002). Sugarcane farming encompass a large portion of agricultural activities in the Lake Victoria basin, Kenya (Netondo et al. 2010), and yet there are no recommendations on how to reduce nutrients from runoff waters in these farms. The research was, therefore, aimed at developing a method of reducing nutrients from sugarcane plantations into aquatic systems within and outside the plantations.

## 2 Materials and methods

### 2.1 Study area

Nucleus sugarcane estate farms for a sugar factory located at 0°4′55″N–0° 20′11″S, 34°50′49″–35° 35′ 41″E (Fig. 1) was chosen as the site for this research. The farms are located in Bungoma County within the Lake Victoria catchment region which is known to be one of the main sugarcane producing areas in Western Kenya. The sugarcane farms have water canals which run across the farms and discharge waste water into River Kuywa that flows through the farms before joining River Nzoia that finally drains into Lake Victoria.

### 2.2 Experimental design and sampling

A completely randomized design was used in sampling and analysis. Fifty sites were chosen at random within the nucleus estate farms and, at each site, two canals were chosen with one being treated according to the following method. On every canal chosen for treatment (Fig. 2), depressions the width of the canal, 1 m in length and 0.5 m deep were excavated at intervals of every 100 m allowing runoff water to reduce in velocity, settle, and sediment out. After a fortnight in the wet season and a month in the dry season, the depressions were emptied of their contents for the research period that ran for 6 months. Sampling was then done both during the wet season and the dry season by drawing 10 500-ml of water samples towards the end of the canal in the morning, afternoon and evening. Each ten water samples collected were mixed into a composite sample and the three composite samples collected at different times of the day treated as replicates. The water samples collected in Amber glass bottles were placed in an ice box and refrigerated at 4 °C prior to analysis (John et al. 1996).

### 2.3 Physicochemical parameter analysis

Water pH, temperature, dissolved oxygen turbidity and conductivity were measured directly in the field using a pH meter (3071 Jenway), DO meter (HI 9146), turbidity meter (HI 93703) and a conduct meter (Kundoctometer CG 857), respectively.

Ultraviolet spectrophotometric screening method B of standard methods (Franson et al. 1995) was used to determine nitrate–nitrogen present. A water sample of 50 ml was filtered through a Watmann filter paper no. 40 and acidified with 1 ml concentrated HCl (analytical grade). A spectrophotometer (UV-1650 PC-UV–VIS; Shimadzu) was calibrated using standards from potassium nitrate and used to determine the concentrations of unknown samples at 220 nm. The determined concentrations were corrected by a second measurement made at 275 nm, since dissolved organic matter also absorbs at 220 nm but $NO_3^-$ does not absorb at 275 nm (Franson et al. 1995).

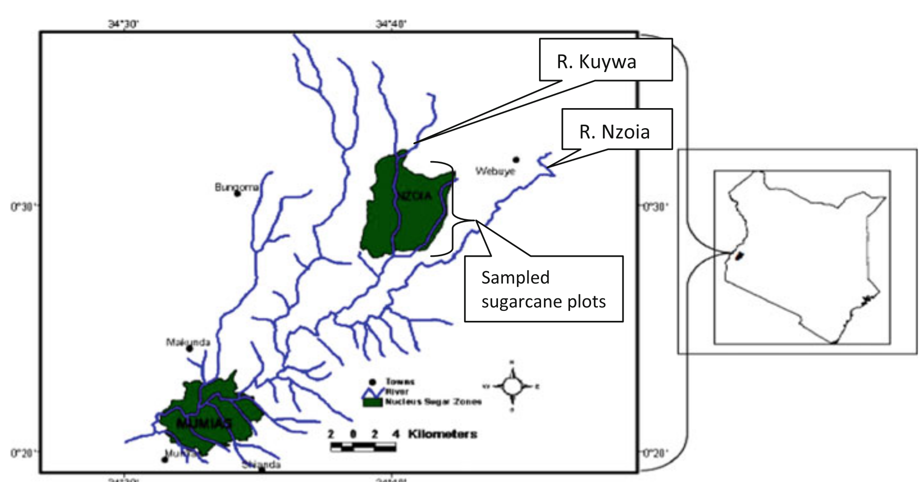


**Fig. 1** The sampled sugarcane farms within Lake Victoria catchments in Western Kenya

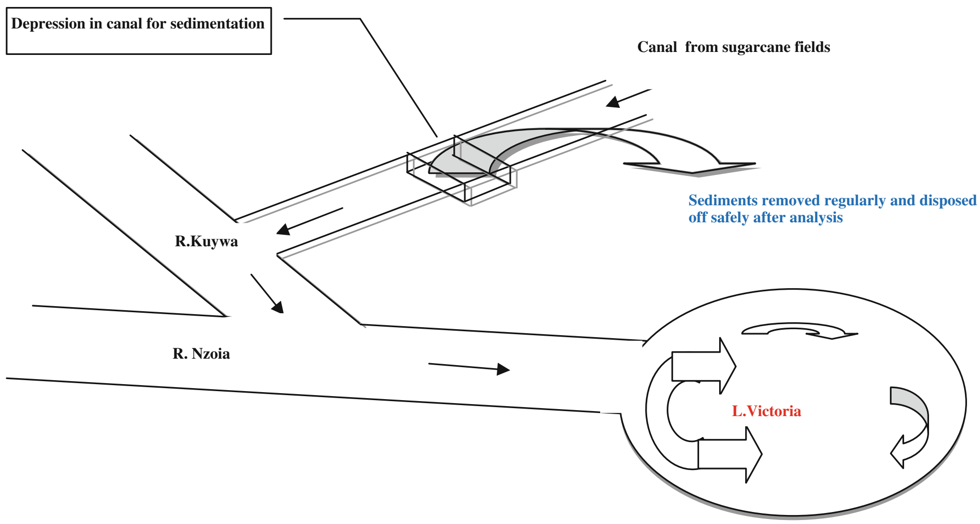


**Fig. 2** A graphical presentation of the method for reducing nutrients in runoff water from sugarcane farms by the sedimentation method

For total phosphates, a volume of 100 ml water sample was digested at 150 °C with 1 ml concentrated sulfuric acid and 5 ml concentrated nitric acid, then evaporated to dryness in a Gerhardt digester. The residue was leached with 5 ml 1 N $HNO_3$ and transferred to a 50-ml volumetric flask. A volume of 5 ml of 10 % ammonium molybdate was added followed by addition of 5 ml of 0.25 % ammonium vanadate in 6 N HCl. The mixture was diluted to the mark with distilled water and left to cool for 10 min. A calibrated spectrophotometer (UV-1650 PC-UV–Vis; Shimadzu) with $KH_2PO_4$ was used to determine the unknown sample concentrations at 460 nm (Anil 1994; Franson et al. 1995).

For determination of macronutrients in water samples, 200 ml of the sample was filtered through a 1-µm cellulose acetate filter with millipores into an acid-washed 500-ml Erlenmeyer flask. The sample was then acidified to 1 % (2 ml) with concentrated nitric acid (analytical grade), placed on a hot plate at 60 °C and allowed to evaporate to approximately 30 ml (Mzimela et al. 2003). The evaporated sample was then transferred to a 50-ml volumetric flask and made up to volume with double-distilled water after addition of 1.5 mg/ml of strontium chloride. The extract was analyzed for Na, K, Ca, Mg, Cu, Fe, and Zn using a calibrated Shimadzu AA-6200 Atomic Absorption Flame Emission Spectrophotometer with the specifications indicated in Table 1.

For all the analytical methods used in analysis, method detection limits were determined using respective standards in accordance with method 40 CFR 136 and recovery studies done by spiking double-distilled water with 20 times the method detection limit concentration (USEPA 2007).

### 2.4 Statistical analysis

Analysis of variance (ANOVA) ($p \leq 0.05$), a two-factorial experiment and least significant differences at $p \leq 0.05$ were used to check the variations. Statistical analysis was performed using MSTAT-C two-factor completely randomized design, with canals (1 = treated, 2 = untreated) as the main factor and seasons (1 = wet season, 2 = dry season) as the sub-factor. An average of all the concentrations for replicate 1 per variable in all the 50 samples (untreated/treated) was determined and used as replicate 1 in the ANOVA analysis. The same procedure was adopted for replicates 2 and 3.

### 2.5 NB

The sediments from the excavated depressions were kept in a large compost pit lined with polythene lining and will be disposed off safely after complete analysis of other harmful pollutants like pesticides, dioxins and dioxin-like compounds that can be found in sugarcane plantations. There was no need to treat the excavated pits against mosquito breeding as all the chosen canals had water flow throughout the year.

## 3 Results and discussion

Mean % recovery values, machine detection limits and method detection limits are recorded in Table 2. The methods used were found to be efficient in detection of the unknown parameters per variable as deduced from the recovery studies (Table 2).

Concentrations of different variables in water samples are recorded in Tables 3 and 4.

The difference in temperature between the treated canals and the untreated canals was not significant ($p \leq 0.05$), hence the developed method had no effect on runoff water temperature change (Table 3).

**Table 1** Atomic absorption flame emission spectrophotometer (Shimadzu AA-6200) experimental parameters

| Element | Na | K | Ca | Mg | Cu | Zn | Fe |
|---|---|---|---|---|---|---|---|
| Lamp current (mA) | 12 | 10 | 10 | 8 | 10 | 6 | 8 |
| Wavelength (nm) | 589.0 | 766.5 | 422.7 | 285.2 | 324.8 | 213.8 | 243.3 |
| Slit width (nm) | 0.2 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Mode | NON-BGC | NON-BGC | BGC-$D_2$ | BGC-$D_2$ | BGC-$D_2$ | BGC-$D_2$ | BGC-$D_2$ |
| Flame | Air-$C_2H_2$ | Air-$C_2H_2$ | Air-$C_2H_2$ | Air-$C_2H_2$ | Air-$C_2H_2$ | Air-$C_2H_2$ | Air-$C_2H_2$ |
| Fuel flow (l/min) | 1.8 | 2.0 | 2.0 | 1.8 | 2.0 | 2.0 | 1.8 |
| Prespraytime (s) | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Intergration time *t* (s) | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Callibrations (ppm) | 0.1–0.6 | 0.1–0.6 | 0.1–0.6 | 0.1–0.6 | 0.1–0.6 | 0.1–0.6 | 0.1–0.6 |
| MDL (ppm) | 0.006 | 0.012 | 0.07 | 0.0035 | 0.04 | 0.011 | 0.08 |

*MDL* machine detection limit, *BGC-$D_2$* deterium background correction (compensates for matrix interferences)

**Table 2** Method detection limit, machine detection limits and recovery studies for various methods used in analyzing nutrients

| Parameter | Machine detection limit (ppm) | Method detection limit (ppm) | Recovery studies (%) |
|---|---|---|---|
| Total phosphates | – | 0.0560 | 93 |
| Nitrate-nitrogen | – | 0.4500 | 89 |
| Iron | 0.0800 | 0.5100 | 78 |
| Sodium | 0.0060 | 0.3500 | 80 |
| Zinc | 0.1100 | 0.0900 | 89 |
| Potassium | 0.0120 | 0.8700 | 96 |
| Calcium | 0.0700 | 0.0800 | 76 |
| Magnesium | 0.0035 | 0.1200 | 87 |
| Copper | 0.0400 | 0.4500 | 89 |

Acidity in the treated canals did not vary significantly ($p \leq 0.05$) during the dry season, but its decrease in the wet season was significant ($p \leq 0.05$) (Table 3). The decrease in acidity of the treated canals was linked to soil erosion through the canals. An earlier investigation of soils from the same farms had revealed highly acidic soils (Omwoma et al. 2010). This meant that the untreated canals carried with them high acidic soils that increased their acidity, while the treated canals that had most of its eroded soils sediment out recorded low values (Table 3).

High acidity values in canals draining water from sugarcane plantations has also been recorded in other areas like canals feeding the Ipojuka River traversing sugarcane plantations in Brazil (Günter et al. 2007). The main source of high acidity in sugarcane plantations has been cited as due to the use of nitrogenous fertilizers that through nitrification processes deposits a lot of hydrogen ions to the soils (Eq. 1) (Shcroeder et al. 1996; Wood 2003; Omwoma et al. 2010)

$$NH_4^+ + 2O_2 \rightarrow NO_3 + H2O + 2H^+ \quad (1)$$

Through surface runoffs and leaching, the hydrogen ions are transported to canals that finally acidify major aquatic systems.

Adequate oxygen levels are necessary to facilitate aerobic life forms which carry on natural stream purification processes (Eduardo 2006). This method significantly ($p \leq 0.05$) increase dissolved oxygen levels (Table 3), and this is beneficial to the aquatic systems. Increases in dissolved oxygen may have been due to the reduction of turbidity in the water of treated canals.

Turbidity reduced significantly ($p \leq 0.05$) (Table 3) in treated canals due to sedimentation of eroded soils from the water. High turbidity values can be correlated to high suspended solids in the aquatic ecosystems, hence by allowing the canals water to reduce in speed, settle, and sediment out, reduction in turbidity is recorded (Table 3). The suspended particles in untreated canals absorb heat from the sunlight, making turbid waters become warmer, and so reducing the concentration of oxygen in the water. The suspended particles scatter the light, thus decreasing the photosynthetic activity of plants and algae which contributes to the lowering of the oxygen concentration even further in the untreated canals. As a consequence of the particles settling to the bottom, shallow lakes fill in faster, fish eggs and insect larvae are covered and suffocated, and gill structures get clogged or damaged. The suspended particles also help the attachment of heavy metals and many other toxic organic compounds and pesticides. This, therefore, makes the developed sedimentation method very important in aquatic life sustainability as it reduces the suspended solids.

Reduction of conductivity values in the water of treated canals (Table 3) is an indication that both cations and anions that are responsible for electrical conductivity were reduced. High conductivity values in this region come from high metal concentrations in the soils (Omwoma et al.

**Table 3** Mean variations of physicochemical parameters between treated and untreated canals in both dry and wet seasons of runoff water from sugarcane plantations

| | | Dry season | Wet season | Average |
|---|---|---|---|---|
| Temperature (°C) | Treated canals average | 27.00 | 26.00 | 26.50 |
| | Untreated canals average | 26.00 | 24.86 | 25.43 |
| | Average | 26.50 | 25.43 | 25.97 |
| | LSD $p \leq 0.05$ | 0.97 | | 1.81 |
| | Kenya domestic water stds[a] | 20.00 | | |
| | USEPA domestic water stds[b] | 20.00–35.00 | | |
| | Australian aquatic life stds[c] | 20.00–28.00 | | |
| | CV% | 3.05 | | |
| pH | Treated canals average | 6.76 | 6.20 | 6.48 |
| | Untreated canals average | 6.98 | 5.02 | 6.00 |
| | Average | 6.87 | 5.61 | 6.24 |
| | LSD $p \leq 0.05$ | 0.69 | | 0.26 |
| | Kenya domestic water stds[a] | 6.5–8.5 | | |
| | USEPA domestic water stds[b] | 6.00 | | |
| | Australian aquatic life stds[c] | 5.5–9.0 | | |
| | CV% | 13.11 | | |
| Conductivity (μS/cm) | Treated canals average | 48.33 | 128.67 | 88.50 |
| | Untreated canals average | 52.89 | 261.46 | 157.18 |
| | Average | 50.61 | 195.07 | 122.84 |
| | LSD $p \leq 0.05$ | 9.34 | | 3.34 |
| | Kenya domestic water stds[a] | NG | | |
| | USEPA domestic water stds[b] | 400–1,250 | | |
| | Australian aquatic life stds[c] | NG | | |
| | CV% | 13.03 | | |
| Dissolved oxygen (ppm) | Treated canals average | 8.14 | 7.92 | 8.03 |
| | Untreated canals average | 5.11 | 3.82 | 4.47 |
| | Average | 6.63 | 5.87 | 6.25 |
| | LSD $p \leq 0.05$ | 0.62 | | 0.23 |
| | Kenya domestic water stds[a] | 5.00 | | |
| | USEPA domestic water stds[b] | 5.00 | | |
| | Australian aquatic life stds[c] | 5.00 | | |
| | CV% | 13.79 | | |
| Turbidity (NTU) | Treated canals average | 30.22 | 365.70 | 197.96 |
| | Untreated canals average | 148.70 | 719.30 | 434.00 |
| | Average | 89.46 | 542.50 | 315.98 |
| | LSD $p \leq 0.05$ | | 86.58 | 32.87 |
| | Kenya domestic water stds[a] | 5.00 | | |
| | USEPA domestic water stds[b] | 5.00 | | |
| | Australian aquatic life stds[c] | 5.00 | | |
| | CV% | 15.88 | | |
| Total phosphates (ppm) | Treated canals average | 0.21 | 3.47 | 1.84 |
| | Untreated canals average | 0.87 | 8.20 | 4.54 |
| | Average | 0.54 | 5.84 | 3.19 |
| | LSD $p \leq 0.05$ | | 0.88 | 0.33 |
| | Kenya domestic water stds[a] | 2.00 | | |
| | USEPA domestic water stds[b] | 0.10 | | |
| | Australian aquatic life stds[c] | 0.10 | | |
| | CV% | 15.33 | | |

**Table 3** continued

| | | Dry season | Wet season | Average |
|---|---|---|---|---|
| Total nitrate–nitrogen (ppm) | Treated canals average | 2.95 | 10.12 | 6.54 |
| | Untreated canals average | 3.54 | 25.16 | 14.35 |
| | Average | 3.25 | 17.64 | 10.44 |
| | LSD $p \leq 0.05$ | | 1.79 | 0.68 |
| | Kenya domestic water stds[a] | 10.00 | | |
| | USEPA domestic water stds[b] | 10.00 | | |
| | Australian aquatic life stds[c] | 0.03 | | |
| | CV% | 13.35 | | |

*NB* sampling done in February 2009 dry season and May 2009 wet season, $n = 300$, *LSD* least significant difference, *CV%* percent coefficient of variation in replicated samples, *Stds* standards

[a] Kenyan EMCA (WQ) standards (2006)

[b] USEPA standards (1979)

[c] Australian standards (2000)

2010) that eroded into the canals increasing the conductivity. By extension, therefore, it can be deduced that this method will be vital in reducing heavy metal concentrations in aquatic systems.

During the nitrification process (Eqs. 2, 3), a lot of nitrates and phosphates from fertilizers such as di-ammonium phosphate and urea build up in soils and hence a transport medium (runoffs and erosion) will facilitate the movement from the soils to the aquatic ecosystems. Therefore, sedimentation of runoff water before entry into major aquatic systems significantly reduces nitrates and phosphates levels ($p \leq 0.05$) (Table 3).

$$(NH_4)_2CO + 4O_2 \rightarrow 6H^+ + 2NO_3^- + CO_2 + H_2O \quad (2)$$

$$(NH_4)_2HPO_4 + 4O_2 \rightarrow 3H^+ + 2NO_3^- + H_2PO_4 + 2H_2O \quad (3)$$

Nitrates and phosphates are the major macronutrients that are responsible for eutrophication of aquatic systems (Muyodi et al. 2010). Hence, reduction of these elements in agricultural water runoffs is of great importance in solving the problem of eutrophication that has threatened to render life in Lake Victoria extinct in future (Cowi 2002; LVEMP 2003; Muyodi et al. 2010). Levels above which eutrophication is likely to be triggered are approximately 0.03 mg/l of dissolved phosphorus and 0.1 mg/l of total phosphorus (USEPA 1980). Higher concentrations than these threshold values were recorded in this study of the untreated canals (Table 3). It is, therefore, evident that sugarcane farming has a negative impact on nitrate and phosphate concentrations, hence their significant ($p \leq 0.05$) reduction by the developed method could help in solving the problem of eutrophication. Other nutrients that also aid in aquatic plant growth and algal blooms like potassium, calcium, magnesium, copper, iron, sodium, and zinc were also reduced significantly ($p \leq 0.05$) by the method we have developed (Table 4).

Nutrients in the untreated canals were above nationally and internationally recommended threshold values for both aquatic life and domestic water, but in the treated canals most of them were within allowable limits (Tables 3, 4).

## 4 Conclusions

The developed sedimentation method was found to significantly ($p \leq 0.05$) reduce the nutrient loads in aquatic systems. In addition, some water quality physical/chemical parameters like acidity and dissolved oxygen increased significantly in the treated canals as others such as turbidity and conductivity reduced.

## 5 Recommendations

Small-scale, large-scale and nucleus sugarcane farms within the Lake Victoria basin should adopt the developed sedimentation method. This will go a long way in reducing the problems that arise out of eutrophication within this region and other similar regions around the world. However, other measures should be incorporated in this method if it has to be used in waterways that do not have a continuous water flow. Such measures are being further investigated by use of allelochemical-producing plants that may be planted on the edges of canals to repel harmful insects from taking advantage of stagnant waters.

**Table 4** Mean variations of physicochemical parameters between treated and untreated canals in both dry and wet seasons of runoff water from sugarcane plantations

| | | Dry season | Wet season | Average |
|---|---|---|---|---|
| Potassium (ppm) | Treated canals average | 120.00 | 136.00 | 128.00 |
| | Untreated canals average | 446.00 | 654.00 | 550.00 |
| | Average | 283.00 | 395.00 | 339.00 |
| | LSD $p \leq 0.05$ | 89.00 | | 54.00 |
| | Kenya domestic water stds[a] | NG | | |
| | Australian aquatic life stds[b] | ≤100 | | |
| | CV% | 17.00 | | |
| Calcium (ppm) | Treated canals average | 154.00 | 187.00 | 170.50 |
| | Untreated canals average | 420.00 | 549.00 | 484.50 |
| | Average | 287.00 | 368.00 | 327.50 |
| | LSD $p \leq 0.05$ | 98.00 | | 29.00 |
| | Kenya domestic water stds[a] | ≤250 | | |
| | Australian aquatic life stds[b] | NG | | |
| | CV% | 21.00 | | |
| Magnesium (ppm) | Treated canals average | 98.00 | 167.00 | 132.50 |
| | Untreated canals average | 205.00 | 493.00 | 349.00 |
| | Average | 151.50 | 330.00 | 240.75 |
| | LSD $p \leq 0.05$ | 45.00 | | 23.00 |
| | Kenya domestic water stds[a] | ≤100 | | |
| | Australian aquatic life stds[b] | ≤1,500 | | |
| | CV% | 22.00 | | |
| Iron (ppm) | Treated canals average | 456.00 | 654.00 | 555.00 |
| | Untreated canals average | 12941.00 | 19230.00 | 16085.50 |
| | Average | 6698.50 | 9942.00 | 8320.25 |
| | LSD $p \leq 0.05$ | 2138.00 | | 1004.00 |
| | Kenya domestic water stds[a] | 300.00 | | |
| | Australian aquatic life stds[b] | ≤10 | | |
| | CV% | | | |
| Copper (ppm) | Treated canals average | 181.00 | 207.00 | 194.00 |
| | Untreated canals average | 261.00 | 763.00 | 512.00 |
| | Average | 221.00 | 485.00 | 353.00 |
| | LSD $p \leq 0.05$ | 65.00 | | 34.00 |
| | Kenya domestic water stds[a] | 100.00 | | |
| | Australian aquatic life stds[b] | ≤5 | | |
| | CV% | 18.00 | | |
| Sodium (ppm) | Treated canals average | 234.00 | 321.00 | 277.50 |
| | Untreated canals average | 398.00 | 748.00 | 573.00 |
| | Average | 316.00 | 534.50 | 425.25 |
| | LSD $p \leq 0.05$ | 213.00 | | 123.00 |
| | Kenya domestic water stds[a] | 200.00 | | |
| | Australian aquatic life stds[b] | NG | | |
| | CV% | 21.00 | | |
| Zinc (ppm) | Treated canals average | 311.00 | 231.00 | 271.00 |
| | Untreated canals average | 484.00 | 903.00 | 693.50 |
| | Average | 397.50 | 567.00 | 482.25 |
| | LSD $p \leq 0.05$ | 345.00 | | 232.00 |

**Table 4** Mean variations of physicochemical parameters between treated and untreated canals in both dry and wet seasons of runoff water from sugarcane plantations

| | Dry season | Wet season | Average |
|---|---|---|---|
| Kenya domestic water stds[a] | 500.00 | | |
| Australian aquatic life stds[b] | ≤10 | | |
| CV% | 23.00 | | |

*NB* sampling done in February 2009 dry season and May 2009 wet season, $n = 300$, *LSD* least significant difference, *CV%* percent coefficient of variation in replicated samples, *Stds* standards

[a] Kenyan EMCA (WQ) standards (2006)

[b] Australian standards (2000)

**Acknowledgments** We thank all the technical staff of the Department of Chemistry, Maseno University for their help. This work was partly supported by the IAEA CRP Project 13695/RO.

## References


Allen DE, Kingston G, Rennenberg H, Dalal RC, Schmidt S (2009) Effect of nitrogenous fertilizer management and water logging on nitrous oxide emission from subtropical sugarcane soils. Agric Ecosyst Environ 136:209–217

Franson MH, Andrew, DE, Lenoe SC, Arnold EG (1995) Standard methods for the examination of water and wastewater, 19th edn. American Public Health Association, Washington, p 936, 450, 1021–1032

Anil KD (1994) Environmental chemistry, 3rd edn. New Age International (p) limited, New Delhi, pp 237–247

Australian standards (2000) Australian and New Zealand guidelines for fresh and marine water: 9.4. Aquaculture and human consumers of aquatic foods. Found at www.mincus.gov.au/_data/assets/pdf_file/0020/316145/gfmwq_guidelines_vol3-9-4.pdf

Banadda N (2011) Characterization of non point source pollutants and their dispersion in Lake Victoria: a case study of Gaba landing site in Uganda. Afr J Environ Sci Technol 5(2):73–79

Curt JS, Robert EH, Dustin G, Brian FC, Hedy K (2009) Diatom evidence for the timing and causes of eutrophication in Lake Victoria, East Africa. Hydrobiologia 636(1):463–478

Eduardo JG (2006) Design, manufacture and performance of solar powered floating fountaing. MSc thesis, Florida State University

EMCA (WQ) (2006) Environmental management and coordination (water quality) regulations, 2006 (L.N. No. 120 of 2006). Kenya Gazette Supplement No. 68 of 29 September 2006, 1–25

COWI (Consulting Engineers) (2002) Intergrated Water Quality Liminology Study for Lake Victoria, Lake Victoria Environmental Management Project part II Technical report Kenya

Günter G, Jan K, Maria S, Hendryk R, Suzana M, Joana A (2007) Sugarcane industry as a source of water pollution—case study on the situation in Ipojuca River, Pernambuco, Brazil. Water Air Soil Pollut 180:261–269

Haynes D (2000) Pesticides and heavy metal concentrations in Great Barrier Reef sediment, seagrass and dugong (*Dugong dugon*). PhD thesis, University of Queensland

John ED, Terrence H, Dale VH, Georgia T, Luis T, David MK (1996) Freezing as a method of sample preservation for analysis of dissolved inorganic nutrients in seawater. Mar Chem 53:173–185

KSB (2003) Kenya Sugarcane Board yearbook of statistics. Kenya Sugar Board, Nairobi

Lalah JO, Ochieng EZ, Wandiga SO (2008) Sources of heavy metal input into Winam Gulf, Kenya. Bull Environ Contam Toxicol 81:277–284

LVEMP (Lake Victoria Environmental Management Project) (2003) Lake Victoria Environmental Management Project Phase 1, Revised Draft Scientific Stocking Report- Progress During LVEMP1 and Challenges for the Future, World Bank. Washington DC

Muyodi FJ, Mwanuzi FL, Kapiyo R (2011) Environmental quality and fish communities in selected catchments of Lake Victoria. Open Environ Eng J 4:54–65. URL: http://benthamscience.com/open/toenviej/articles/V004/54TOENVIEJ.pdf

Mzimela HM, Wepener V, Cyrus DP (2003) Seasonal variation of selectedmetals in sediments, water and tissues of groovy mullet, *Liza dumerelii* (Mugilidae) from the Mhlathuze Estuary, South Africa. Mar Pollut Bull 46:659–676

Netondo GW, Fuchaka W, Lucy M, Tabitha N, Nelly M (2010) Agrobiodiversity endangered by sugarcane farming in Mumias and Nzoia Sugarbelts of Western Kenya. Afr J Environl Sci Technol 4(7):437

Odada EO, Daniel OO, Kassim KMN, Shem W (2004) Mitigation of environmental problems in Lake Victoria, East Africa: causal chain and policy options analyses. AMBIO 33:1–2

Omwoma S (2012) Environmental impacts of sugarcane farming, Kenya. LAP Lambert, Germany. http://www.bod.de/index.php?id=296&objk_id=668720

Omwoma S, Joseph OL, David MKO, Maurice BW (2010) Impact of fertilizers on heavy metal loads in surface soils in Nzoia nucleus estate sugarcane farms in Western Kenya. Bull Environ Contam Toxicol 85(6):602–608

Omwoma S, Lalah JO, Ongeri DMK, Owuor PO (2011) Impact of agronomic inputs in sugarcane farming on surface river water quality in the Lake Victoria Catchments. National Council for Science and Technology of Kenya conference on dissemination of research results, held on 3rd to 6th May 2011 at K.I.C.C. Nairobi, Kenya

Ongeri DMK (2008) Physicochemical parameters, heavy metal residue levels and their speciation studies in Lake Victoria Basin. PhD thesis, Maseno University

Scheren PAGM, Zanting HA, Lemmens AMC (2000) Estimation of water pollution sources in Lake Victoria, East Africa: application and elaboration of the rapid assessment methodology. J Environ Manage 58(4):235–248

Schroeder BL, Turner PET, Meyer JH, Robinson JB (1996) Advances in quantifying soil acidity and acidification rates in the South African sugar industry. In: Wilson JR, Hogarth JR, Campbell JA, Garside AL (eds) Sugarcane: research towards efficient and sustainable production, pp 256–258. CSIRO Division of Tropical Crops and Pastures, Brisbane

USEPA (United States Environmental protection Agency) (1979) Lead; ambient water quality criteria. Criteria and StandardsDivision, Office of Water Planning and Standards, Washington, DC

USEPA (United States Environmental protection Agency) (1980) Ambient water quality criteria for copper and lead. Springfield, VA: National Technical Information Service, PB 81: 117681. Washington, DC

USEPA (United States Environmental protection Agency) (2007) 40 CFR parts 136 and 503 guidelines establishing test procedures for the analysis of pollutants; analytical methods for biological pollutants in wastewater sewage sludge; final rule EPA–HQ–OW–2004–0014; FRL–8228–1 Federal Register 72(57)

Wood AW, Noble AD, Bramley RGV (2003) Sugar research and development corporation. Final Report project no. CSR024

Zueng-Sang C (2000) Relationship between heavy metal concentrations in soils of Taiwan and uptake by crops. Department of Agricultural Chemistry, National Taiwan University Taipei 106, Taiwan