*Asian Journal of Water, Environment and Pollution,* Vol. 10, No. 3 (2013), pp. 95–101.

# Water Quality of Irrigation Water into and out of an Irrigated Sugar Cane Plantation

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*Received November 25, 2012; revised and accepted May 31, 2013*

**Abstract**: A study was carried out to assess the water quality of incoming, outgoing and a receiving stream water from a furrow irrigated sugar plantation. pH did not vary significantly at the three sampling points in the rainy season, but differences were observed in the dry season with incoming water having the highest value ($p < 0.05$) and outgoing water the least. Dissolved solids were highest ($p < 0.05$) in the incoming water in both seasons while in the rainy season, the lowest value was in the outgoing water. In the rainy season, sulphate and phosphate were higher ($p < 0.05$) in the incoming water while the amounts in the outgoing water and in the stream did not differ. Water hardness was highest in the outgoing and lowest in the incoming water in both seasons. Chloride was highest ($p < 0.05$) in the outgoing water in both seasons and the values in the incoming water and in the stream did not differ. Nitrate was higher in outgoing water compared to the incoming and stream water in the rainy season, while in the dry season, the concentration was highest in the stream. Copper was significantly higher ($p < 0.05$) in the incoming water compared to the other points in the two seasons. All the parameters were below the standard limits and this demonstrated that the threat to water quality in the stream was minimal. The scheme may still cause some grave impact in the receiving stream, such that in a few years, serious water quality deterioration could take place.

**Key words**: Chemical parameters, farmland, pollution, water, season.

## Introduction

Food production is important for the well-being of humans. In most countries, crops are produced by rain-fed agriculture and/or in dry areas, through irrigation. While the latter method is known to increase crop productivity, it may have negative impact on the environment and also on water quality of receiving rivers or lakes through run-off (Stockle and Washington, 2001; Isidoro and Aragues, 2007). For example, studies have shown that the sprinkler type irrigation leads to higher water percolation while flood or drip irrigation leads to over irrigation which, in turn, affects the ecology of the land (Waddell et al., 2000; De Rosanay et al., 2003; Le Roux et al., 2007). In addition, irrigation in general is known to give rise to run off water carrying fertilizers, pesticides, heavy metals, salts and other agrochemical loadings that go on to pollute rivers and other water bodies (Goldar and Banerjee, 2002; Aana and Sridhar, 2004; Oguttu et al., 2008, Omwoma et al., 2012). Studies by Knight et al. (2002) showed that enhanced recharge under intensive irrigated agriculture next to a river resulted in increased discharge of saline groundwater into the river. Other reports have also indicated that agrochemicals, sediments and pesticides are at a higher concentration in streams draining agricultural fields

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with furrow irrigation than in agricultural fields with sprinkler irrigation (Miller, 2005).

Worldwide concern about drinking water with nitrate arising from agricultural practices has prompted considerable scientific interest into the factors influencing nitrate leaching (Mahvi et al., 2005). The loss of nitrate from agricultural soils to surface and ground waters has detrimental effects on rivers, lakes and drinking water quality. Although studies have indicated that small concentrations of copper and zinc do not affect the germination of maize seed, these metals persist indefinitely in the soils and this may be a threat to human health (Mahmood et al., 2005). Unfortunately, with increasing population, adequate food supplies can only be maintained by the use of fertilizers. The world's water resources are getting into a very bad shape due to pollution, and consequently, the declining water quality poses many health hazards to the rural unsuspicious communities and the global ecosystems (Fakaode, 2005; Southern African Research and Documentation Center (SARDC), 2001).

Malawi's economy is agriculture-based and rain-fed farming is the most common one. However, food shortages experienced due to inadequate rainfall and increasing population growth, has forced the government to embark on intensive irrigation agriculture to ensure food security and foreign exchange generation. Apart from tobacco estates, Malawi's foreign earnings also come from sales of sugar. Malawi has two large sugar plantations and one small-holder cane plantation scheme. The latter has 755 hectares of land that is given to small scale farmers each occupying a plot of about 2.7 hectares. Sugar canes are grown exclusively under intensive furrow irrigation. Each farmer applies fertilizers and herbicides determined by the nutrient deficiency of the soils and although a total blanket amount cannot be determined for the whole estate, there is heavy usage of these chemicals. The waste waters from the fields are discharged into a nearby stream which subsequently empties into the main Shire River within a distance of about 2 km away. There is therefore a possibility that the agrochemicals end up in the rivers whose water are used for domestic purposes by the people living along there. Such polluted waters may be a health hazard to the population utilizing it. So far there has been no study to assess the water quality of the inflow, return flow and stream water resulting from irrigation run off from the plantation.

The objective of this study was therefore to assess water quality of inflow, return flow and stream water from an intensive irrigation sugar plantation. Specifically, the study was carried out to determine the pH, hardness, suspended solids, sulphates, chlorides, phosphates, nitrates, iron, copper and lead.

## Materials and Methods

### Study Area

The work was carried out at a small-holder sugar cane growing scheme in Malawi (Figure 1). The farmers in the area practice intensive furrow irrigation cane growing with heavy usage of fertilizers and herbicides. Water is channeled to the plantation from the main Shire river through the inflow channel and the waste waters from the fields are discharged into a nearby stream through the return flow drainage channel (Figure 1) which subsequently empties back in the main Shire river. The flow of the water through the estate was the normal for furrow irrigation systems and as such, the rates were not determined. The soils of the area are clay-loam.

### Samples and Sampling

Water samples were collected from the incoming water (Figure 1, Point A), from the outgoing water of the main discharge channel (Figure 1, Point B), and from the stream (Figure 1, Point C), a distance of about 300 metres from the discharge point into the Shire river. All samples were collected in one litre polypropylene bottles that had previously been washed with dilute acid, rinsed with distilled water and dried. At each sampling time, four samples were collected at each point and sampling was done three times in the dry season (July-September, 2011) and the wet season (January-February, 2012). After sampling the bottles were placed in an ice cold cooler box and taken to the laboratory for analysis.

### Chemical Analysis

*pH:* It was measured directly in the water at the sampling points using the pH meter.

*Suspended solids*: A sample (200 mL) was left to stand for 20 minutes after which it was poured into a previously weighed platinum dish and evaporated to dryness.

*Hardness:* This was obtained by titrimetric methods according to the Association of Official American Chemists (AOAC) (2002). A 25 mL sample was diluted to 50 mL with distilled water after which two drops of buffer solution (pH 10), sodium cyanide (250 g) and eriochrome black-T indicator powder (200 mg) were added with stirring. The solution was then titrated

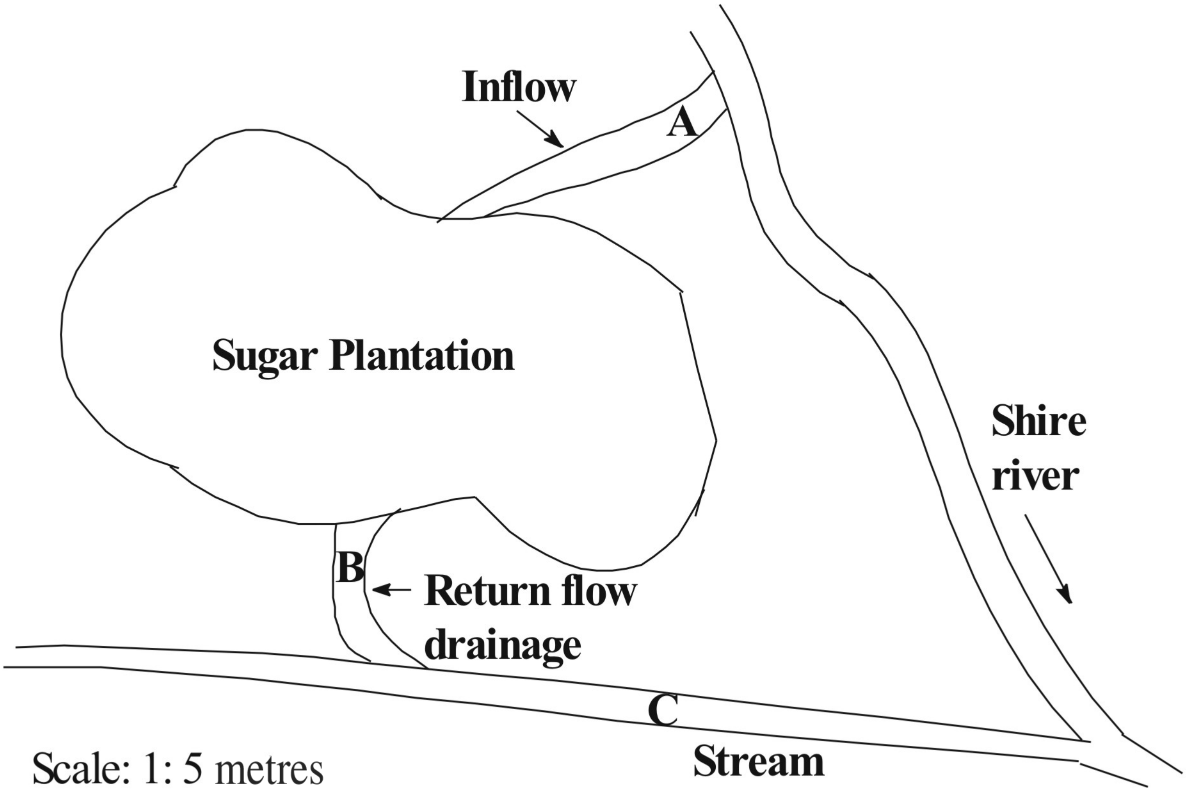


**Figure 1: A sugar plantation showing inflow water (A), return flow drainage and a stream emptying in the main Shire river.**

with 0.01 M Ethylenediaminetetraacetate disodium salt (EDTA) to a blue endpoint. Water hardness was obtained as mg $CaCO_3$ $L^{-1}$.

*Chloride ($Cl^-$):* This anion was determined by titrimetric methods. To a 100 mL sample was added potassium chromate (5%, 1 mL) and titrated with 0.1 M silver nitrate solution to the first appearance of a buff colour (AOAC, 2002).

*Sulphate ($SO_4^{2-}$):* This ion was determined by turbidimetric method (AOAC, 2002). A 5 mL volume of conditioning reagent [a mixture of glycerol (50 mL), HCl (30 mL), water (300 mL), ethanol (100 mL) and NaCl (75 g)] was added to 100 mL sample in 250 mL flask and mixed. While stirring, a spoonful of $BaCl_2$ was added and the mixture stirred for a further one minute. Some solution was then transferred into a cell and the absorbance measured at 420 nm. The concentration of sulphate was read from a standard curve.

*Phosphate ($PO_4^{3-}$):* This was determined by calorimetric methods (AOAC, 2002). To a 50 mL sample was added 8 mL of combined reagent (a mixture of solutions of sulphuric acid, potassium antimony tartrate, ammonium molybdate and ascorbic acid), mixed and left to stand for 10 minutes. The absorbance of the solution was then measured at 880 nm using a Hexios spectrophotometer and the concentration of phosphate obtained from a calibration curve.

*Nitrate ($NO_3^-$):* This was determined by calorimetric methods (AOAC, 2002). To a 10 mL sample in a sample tube was added sulphuric acid (13 N, 10 mL). The tube was placed in a water bath at 10 °C for three minutes after which brucine reagent (0.5 mL) was added. The tube was then placed in boiling water bath for 25 minutes and then cooled. The absorbance of the sample was read at 410 nm using a calorimeter and the concentration of nitrate obtained from a calibration curve.

*Heavy metals—Iron, copper and lead:* These were analyzed using the Atomic Absorption Spectrophotometric (AAS) method.

**Statistical Analysis**

All data were analyzed using the Statistical Analysis System (SAS) (SAS, 1995). Means were separated by using the General Linear Model (GLM).

## Results and Discussion

The concentrations of parameters obtained in the rainy and dry seasons are shown in Tables 1 and 2 respectively. All concentrations except pH were obtained in mg $L^{-1}$. Water hardness was obtained as mg $L^{-1}$ $CaCO_3$. In the rainy season, there were no variations in pH of the water at the three sampling points; however such differences were significant ($P < 0.05$) in the dry season, the highest value being in the incoming water (Point A) and the lowest being in the stream (Point C). There were no seasonal significant differences observed at the three points.

In the rainy season, significant differences ($P < 0.05$) in the amounts of suspended solids were observed, the highest amounts being in the incoming water and the lowest in the outgoing water (point B). In the dry season, a somewhat similar trend was observed, higher amounts being in the incoming water but this time the lowest was in water in the stream. This variation could be due to the fact that plenty of wastes including silt and clay particles are introduced into the river water in the rainy season during which time, runoff is also much greater than the base flow (Jordan et al., 1997). The Malawi Bureau of Standards (MBS) limit for suspended solids in terms of drinking water is 1000 mg $L^{-1}$ (MBS, 2000) and this is only approached in the rainy season in the incoming water and not the rest of the sampling points. Since most of the solids seem to settle in the cane plantation, the latter does not have any significant adverse impact on the outflow water into receiving river.

**Table 1: Concentrations of parameters in the inflow water (A) to the sugar plantation, return flow (B) and stream water (C) in the rainy season**

| *Parameter* | *Sampling Point* | | |
|---|---|---|---|
| | ***A*** *(Mean± Std dev)* | ***B*** *(Mean ± Std dev)* | ***C*** *(Mean ± Std dev)* |
| pH | 7.21±0.05 | 7.24±0.03 | 7.54±0.01 |
| Suspended Solids | 981.3±23.9[a] | 60.0±21.17[c] | 242.0±22.1[b] |
| $SO_4^{2-}$ | 16.59±0.8[a] | 13.58±1.8[b] | 14.28±1.3[ab] |
| $PO_4^{3-}$ | 0.47±0.03[a] | 0.28±0.02[b] | 0.26±0.01[b] |
| Hardness | 47.51±8.1[c] | 101.29±4.32[a] | 76.7±6.29[b] |
| $Cl^-$ | 12.42±1.2[b] | 18.64±0.5[a] | 13.08±1.0[b] |
| $NO_3^-$ | 0.021±0.01[b] | 0.051±0.01[a] | 0.029±0.002[b] |
| Fe | 0.54±0.05[a] | 0.16±0.01[b] | 0.55±0.01[a] |
| Pb | 0.012±0.002[a] | 0.012±0.001[a] | 0.007±0.002[b] |
| Cu | 0.013±0.002[a] | 0.003±0.002[b] | 0.002±0.0001[b] |

[a-c]Means with the same letter in a row are not significantly different at $P = 0.05$

**Table 2: Concentrations of parameters in the inflow water (A) to the sugar plantation, return flow (B) and stream water (C) in the dry season**

| *Parameter* | *Sampling Point* | | |
|---|---|---|---|
| | ***A*** *(Mean± Std dev)* | ***B*** *(Mean ± Std dev)* | ***C*** *(Mean ± Std dev)* |
| pH | 7.69±0.03[a] | 7.17±0.05[b] | 7.46±0.09[a] |
| Suspended Solids | 39.33±2.51[a] | 21.0±2.64[b] | 16.17±1.04[c] |
| $SO_4^{2-}$ | 18.3±0.02 | 19.63±1.1 | 18.12±2.3 |
| $PO_4^{3-}$ | 0.54±0.04 | 0.57±0.01 | 0.54±0.01 |
| Hardness | 48.72±4.9[c] | 90.11±3.7[a] | 62.88±2.1[b] |
| $Cl^-$ | 10.14±0.8[c] | 17.07±0.73[a] | 14.02±0.89[b] |
| $NO_3^-$ | 0.012±0.001[b] | 0.002±0.001[b] | 0.096±0.004[a] |
| Fe | 0.134±0.003 | 0.11±0.003 | 0.008±0.001 |
| Pb | 0.002±0.001 | 0.001±0.0003 | 0.001±0.0004 |
| Cu | 0.007±0.005[a] | 0.002±0.001[b] | 0.001±0.0001[b] |

[a-c]Means with the same letter in a row are not significantly different at $P = 0.05$

The concentration of sulphate varied significantly in the dry season, being highest in the incoming water and lowest in the return flow water. Dry season concentrations of this ion did not vary significantly at the three points but the values were higher in absolute terms than in the rainy season. In both seasons, however, the concentrations were much lower than the limit set by the Malawi Bureau of Standards (400 mg $L^{-1}$) in drinking water (MBS, 2000). The low sulphate concentration may be attributed to the pH of the water which averaged 7.45 in the incoming water, 7.2 in the outgoing water and 7.50 in the stream. It is reported (Sharpley et al., 1991) that when the pH is greater than 7.4, most of the sulphate stays in the soil but at lower pH values it goes in solution in exchange for phosphate. It is therefore possible that most of the sulphate at the observed pH was bound in the soil.

There were significant ($P < 0.05$) variations in the concentration of phosphate at the three points in the rainy season, with the highest value being in the incoming water and the lowest in water in the stream. The higher value in the incoming water can be correlated to the high amounts of suspended solids observed at this point. Studies have indicated that phosphate tends to bind to particulate solids such that the higher the amounts of solids in water the higher the concentration of phosphate as well (Jordan et al., 1997; Andraski and Bundy, 2003). Higher ($P < 0.05$) values of phosphate were obtained in the dry season at all the three points compared to the rainy season and this could be attributed to dilution from the rains during the wet season. Significant variations were also observed at the three points in the dry season with the highest value in incoming water and the lowest in the stream. Other researchers (Chimwanza et al., 2006) have also observed a similar trend. The values obtained in this study were however much higher than the values recommended by the World Health Organization (WHO) (0.05-0.1 mg $L^{-1}$). This could probably be attributed to the phosphate fertilizers that are applied in the scheme itself and also the exchange process with sulphate as the pH of the water was close to 7.4.

Water hardness varied from point to point in each of the seasons. In both seasons, highest amount were recorded in the outgoing water while the least were in the incoming water. It seems that the scheme introduces plenty of $CaCO_3$ into river, but probably as a result of dilution the water becomes softer as we go down stream. All values obtained were below the Malawi Bureau of Standards (500 mg $L^{-1}$) (MBS, 2000).

Chloride varied from point to point with the highest amount in the outgoing water in both seasons and relatively lower amounts in the incoming water. Lower concentration of the ion in the stream could be due to dilution effects and possibly increased infiltration into the ground. Reports have indicated that seepage dilutes nutrients and salts in resident groundwater and this in turn improves the quality of return flow (Fernald et al., 2008).

Concentrations of nitrate differed from point to point in both the rainy and dry seasons. In the rainy season, highest value was recorded in the outgoing water while the lowest value was in the incoming water. However, in the dry season, the highest value was obtained from water in the stream. Considering that the irrigation area has sandy loam soils, it is possible that most of this soluble ion percolates through the soils very rapidly and this results in lower concentrations in the return flow water. Studies have indicated that in sandy loam soils, application of large amounts of irrigation water causes nitrate to move rapidly below the root zone (Exner et al., 1991). Other studies have also shown that in well-drained soils, nitrate transport is mainly through subsurface drainage (Jordan et al., 1997). The increased amounts of nitrate in the stream in the dry season could therefore be explained as the sum of the nitrate coming from the return flow and the percolated ion. The much lower concentrations at the outgoing water and in the stream compared to the limit set by the Malawi Bureau of Standards (100 mg $L^{-1}$) in drinking water (MBS, 2000) and WHO (50 mg $L^{-1}$), may be explained as being due to dilution as the water was discharged into the stream. In addition, in the warmer seasons, nitrate levels are likely to be reduced by biochemical processes and by algal assimilation. In the present study area, temperatures are high throughout the year and this could increase the biochemical activities in the water (Altman et al., 1995).

All the heavy metal concentrations were low at all the three points. This is expected considering that none of these metals are used in the area. The concentrations were also below the limit set by the World Health Organization, 1 mg $L^{-1}$ for iron, 0.05 mg $L^{-1}$ for lead and 1.5 mg $L^{-1}$ for copper. However, although the concentrations were low, of major concern would be the possibility that continual exposure to relatively low levels of these heavy metals through the domestic use by the population utilizing the waters in the stream may entail adverse health effects (Gbaruko and Friday, 2007).

## Conclusion

The results have shown that all the parameters studied were below the limits as set out by Malawi Bureau of Standards. Although suspended solids were higher in the source water during the rainy season, these were less than the allowable limits in the outgoing and stream water suggesting that the threat to water quality was minimal. However, once a trend in pollution sets in, it generally accelerates with intensification to cause greater deterioration. The scheme may, in the long run, bring some grave impact on the water quality of the receiving river, such that in few years time, serious water quality deterioration may take place. This may in turn be harmful to the communities utilizing the waters in the river. Therefore continuous monitoring is needed to avert such adverse effects.

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# Calendar of Events

**Asia Pacific Water Recycling Conference**
1st to 4th July 2013
Brisbane, Australia
Website: http://www.awa.asn.au/recycling13
Contact person: AWA Events
Organized by: Australian Water Association, Water Services Association of Australia, WaterReuse Australia

**2nd International Conference on Geological and Environmental Sciences (ICGES 2013)**
6th to 7th July 2013
Hong Kong, China
Website: http://www.icges.org/
Contact person: APCBEES Editor
Organized by: CBEES

**Water, Wastewater & Isotope Hydrology**
25th to 27th July 2013
Bangalore, Karnataka, India
Website: http://www.ijwwish.com/iwwish-2013.pdf
Contact person: Dr. M. Inayathulla
Organized by: Water Resources Engineering Group

**International Society for River Science: 3rd Biennial Symposium**
5th to 9th August 2013
Beijing, China
Website: http://www.2013isrs.org/
Contact person: Tao Sun, Xinan Yin
Organized by: International Society for River Science, Beijing Normal University

**3rd Journal Conference on Environmental Science and Development (3rd JCESD 2013)**
24th to 25th August 2013
Singapore
Website: http://www.ijesd.org/jcesd/3rd/
Contact person: IJESD Committees
Organized by: CBEES

**2nd International Conference on Hydrology & Ground Water Expo**
26th to 27th August 2013
Raleigh, North Carolina, United States
Website: http://www.omicsgroup.com/conferences/hydrology-groundwater-expo-2013/
Contact person: Hydrology-2013

**2013 International Seminar and Workshop on Hydrography**
27th to 27th August 2013
Batam, Indonesia
Website: http://mhi.or.id/seminar
Contact person: Wiwin Windupranata
Organized by: Indonesian Hydrographic Society

**Water and Society 2013**
4th to 6th September 2013
New Forest, Hampshire, United Kingdom
Website: http://www.wessex.ac.uk/watersoc2013
Contact person: Irene Moreno Millan
Organized by: Wessex Institute of Technology, UK

**3rd International Conference on Energy and Environmental Science (ICEES 2013)**
7th to 8th September 2013
Shanghai, China
Website: http://www.icees.org/
Contact person: Ms Ruth Lee
Organized by: IACSIT

**2013 International Conference on Renewable Energy and Environment (ICREE 2013)**
23rd to 24th September 2013
Phuket, Thailand
Website: http://www.icree.net/
Contact person: Ms Eve Li
Organized by: CBEES