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# Assessing the impact of industrial and urban wastes on the irrigation water quality of three streams in a semi-arid coastal savannah catchment in Ghana

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**Abstract**

Anthropogenic disturbances have had and continue to have an impact on the aquatic ecosystem of Ghana. The purpose of the study was to investigate the impact of anthropogenic activities on the irrigation water quality of three streams in southern Ghana. In the present study, the chemical quality of three streams under different (industrial and urban) land use within the same catchment in Ghana was examined using standard methods of Environmental Protection Agency (EPA) and American Public Health Association (APHA) to evaluate the effects of human activities on irrigation water quality. Analyses showed that all the streams were neutral to slightly alkaline. Relatively high concentration of salinity ($EC_w$) and Sodium Absorption Ratio (SAR) were found in streams in industrial and high density residential areas. In addition, the mean values of major cations ($Na^+$, $K^+$, $Ca^{2+}$ $Mg^{2+}$) and anions ($SO_4^{2-}$, $Cl^-$ $HCO_3^-$) were high in industrial and high density residential areas. Trace metal ($Fe^{2+}$, $Mn^{2+}$ $Zn^{2+}$$Cu^{2+}$, $Cr^{3+}$, $Pb^{2+}$, $Cd^{2+}$) concentrations were generally low and did not show any trend under different types of land uses. The results showed that all the three streams were generally unsuitable for irrigation and should be used with caution.

***Key words:*** Irrigation, water quality, anthropogenic activities.

## Introduction

Water constitutes one of the most important constraints to increasing food production in the world. The development of industrial and agricultural activities followed by that of general social welfare has, during recent decades, led to an increase in the demand for portable water. This has also led to the production of great quantity of pollutants, with a serious risk of conservation surface and groundwater quality [3-5].

Availability of adequate water of acceptable quality for irrigation in the urban communities of Ghana has been a major concern. About 80–90% of vegetables consumed by people in the urban communities are produced in urban areas where water of acceptable quality may not be available [3, 5].

In many parts of Accra, Ghana, waste water which is disposed to wells, ponds and streams is used to irrigate vegetables. The continuous irrigation with poor quality water can reduce crop yields. Water quality for agricultural purpose depends on its effect on the quality and yield of crops, as well as, on changes it makes on soil properties [2]. The most commonly encountered soil properties considered in water quality evaluation are the effect of water on soil salinity, infiltration rate, soil structure and toxicity to plants and animals [2].

A number of large-scale manufacturing plants including Printex Textile Factory, Interplast-PVC Manufacturing Factory, Coca-Cola-Brewery Factory, Kasapreko-Brewery Factory and a host of other companies are located around the Accra – Tema motorway. Also, the upper and middle portions of the catchment around the motorway are heavily urbanized. Aside the industries and high population density within the catchment, the area is also noted for intensive urban farming due to the availability of three streams within the catchment. The existing industries have been discharging their wastes into the surrounding environment, in particular to the nearby Onukpawahe stream. The Dzorwulu stream which runs through slums at Ashaiman receives domestic and urban wastes from the Ashaiman town and parts of Tema town. Also, there is the risk of polluting the streams within the catchment due to enhanced use of agrochemicals by urban farmers in the area.

Urban farmers within the catchment have been using the contaminated rivers to irrigate cereals, vegetables and fruits. Literature search indicated that despite the fact that many farmers and enterprises have used the three streams for irrigation for a very long time, no study has been conducted to assess the suitability of the rivers in the catchment for irrigation.

Increasing water needs, constraints imposed by water quality for different uses and the growing importance of contamination as a result of urban, industrial and agricultural activities make it very necessary to evaluate the effect of human activities on water quality of streams and rivers in the area. The objective of this study, therefore, was to assess the impact of industrial and urban wastes, on the irrigation water quality of three streams in the catchment. This was done by analysing in the laboratory, water samples from the streams and rivers for $EC_w$, pH, SAR, TDS, $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Cl^-$, $Fe^{2+}$ ,$Mn^{2+}$, $Zn^{2+}$, $Cu^{2+}$, $Cr^{3+}$, $Pb^{2+}$and $Cd^{2+}$.

## Materials and Methods

***The study area:*** The project site lies within the dry equatorial climate region of Ghana. The annual mean air temperature is 27.3°C with mean annual maximum and minimum temperatures of 28.7°C and 26.2°C, respectively. The class A pan gives a mean annual pan evaporation rate of about 1820 mm per year. The study area, the Sakumono catchment, occupies an area of about 255 $km^2$ and lies between longitudes of 0° 00' and 0° 05' and latitudes of 5° 35' and 5° 45' with an altitude ranging from 4 m to 12 m above mean sea level. The catchment is located within the Survey of Ghana topographical map sheet No. 0501B. The major water bodies within the catchment are the Mamahuma stream, Onukpawahe stream, Dzorwulu stream and the Sakumono lagoon (Fig. 1).

The rainfall distribution within a year in the catchment area is bi-modal with mean annual rainfall of 681.5 mm and a standard deviation from the mean of 47.7 mm. There is high intensity of rainfall during the months of May to June which define the major cropping season with the minor season occurring in the months of September to October. About 70% of the total rainfall (480.2 mm) occurs in the major season, and 22% (149 mm) in the minor season. Thus, the remaining 8% (52.3 mm) occurs during the off-season. The major growing season begins from March to mid-July and the minor growing season from early September to mid-November. Farmers in the catchment resort to irrigation during the minor season and the dry season. The study was therefore conducted from August to December which spans part of the minor and the dry seasons.

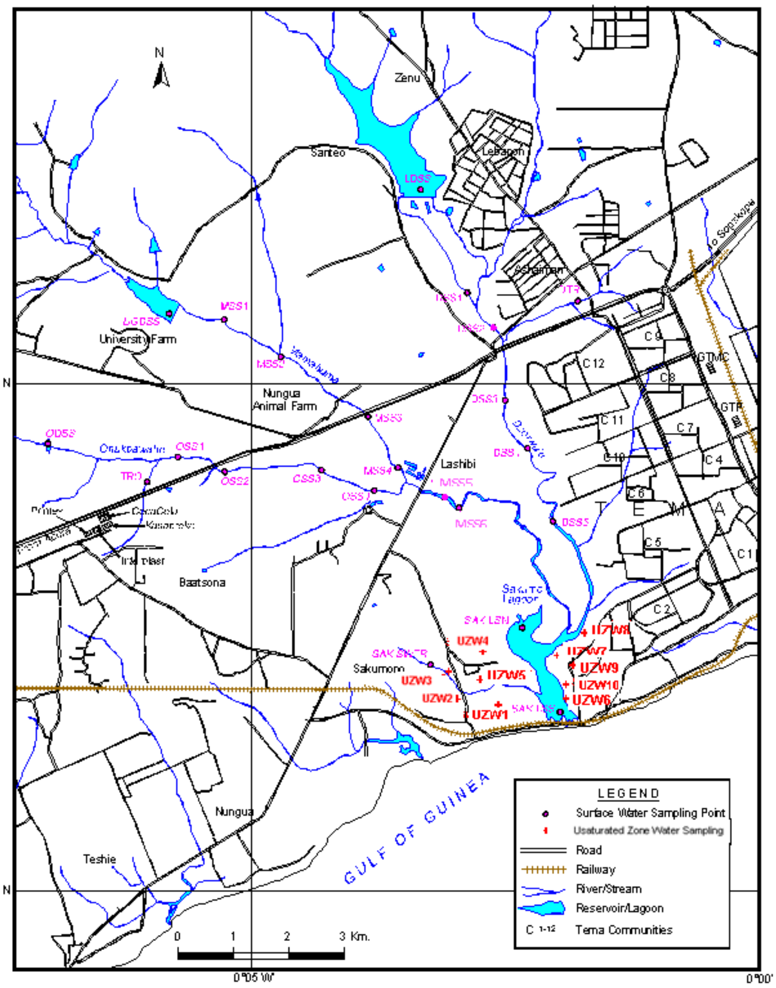


***Figure 1.*** Map of study area showing sampling sites.

Rocks of the study area belong to the Dahomeyan system. Quartz schist rocks mainly underline the study area but close to the southern part of the catchment, marine, lagoonal or fluvial sediments overlie the quartz schist. In lower reaches of the alluvial plains and meandering rivers, clay may be interlayered.

***Surface water sampling:*** Surface water samples from the three streams within the catchment were individually collected into acid cleaned high density 1:1 polyethylene sampling bottles and analysed independently. Based on the outlining of the irrigation sites and waste disposal points, a total of seventeen sites were selected to take water samples within the catchment. Sampling sites in the streams were selected and sampled based on population density, agricultural activity and industrial activity in the area. A dam upstream was also sampled and used as a control. The mean values of the parameters in the control fresh irrigation water source (dam water) and the effluent contaminated streams of the other water sources were compared with the widely accepted standards set by FAO [2]. Sampling was done monthly from August, 2008 to December, 2008 which spans part of the minor and the major dry seasons when irrigation normally takes place.

A total of 90 water samples were collected from the three streams, their tributaries and the control source. Five sampling points were earmarked for sampling in the Onukpawahe stream and its tributary (OTR) based on farmers using the sampling point water for irrigation. Five samples were taken each month from the Onukpawahe stream giving a total of 25 samples from August to December. For the Mamahuma stream, (MSS) six sampling sites were selected also based on irrigation activities in the selected points. Six samples were taken each month from the Mamahuma stream giving a total of 30 samples during the sampling period. Thirty samples were taken from the Dzorwulu stream (DSS) and its tributary (DTR) from six selected sampling sites. Finally, a sample was taken each month from one sampling point in the control source (LED) giving a total of five samples. Water samples were collected in plastic containers which were previously cleansed with nonionic detergent and finally rinsed with deionized water prior to sampling. As part of the quality control measures, samples were rinsed with sampled stream water before being filled. Samples for trace metal analysis were collected in 1.5 L polyethylene bottles and preserved using 2 mL concentrated $HNO_3$ acid. All samples were preserved at 4°C and transported to the laboratory for analysis. Samples for major, minor and trace metal analysis were filtered through 0.45 µm cellulose membrane filters.

***Analyses:*** Physico-chemical analyses of sampled water followed standard analytical methods. About 100 mL of the samples were collected in a conical flask, using a Mettler Toledo Seven Multi meter to take the pH, electrical conductivity, TDS, and temperature.

Water samples collected in the field were analysed in the laboratory for chemical constituents such as $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Cl^-$, $Fe^{2+}$, $Mn^{2+}$, $Zn^{2+}$, $Cu^{2+}$, $Cr^{3+}$,

$Pb^{2+}$and $Cd^2$. The analyses of trace metals (Fe, Al, Cd, Pb, Co, Cr, Mn, Zn, Ni and Cu) and Ca and Mg ion concentration were done using the Atomic Absorption Spectrophotometry (AAS). The flame photometer was used to determine the concentration of $Na^+$ and $K^+$, while UV/visible spectrophotometer wavelength 200-1000 mm was used to determine the concentrations of nutrient ions ($NO_3^-$ $PO_4^{3-}$ and $SO_4^{2-}$). Finally, $Cl^-$ was determined by silver nitrate titration. The methodologies for the analysis of the chemical constituents are described in the standard methods for analysis of water and waste water [7, 10]. Sodium absorption ratio (SAR) was computed by using the formula in FAO soil bulletin [8]. All reagents used were of analytical grade and instruments pre-calibrated appropriately prior to measurement. Each analysis was repeated two times to ascertain reproducibility and quality assurance.

***Statistical analyses:*** To evaluate the irrigation suitability and assess the quality difference comparison, the values of the chemical variables in the wastewater contaminated streams and the upstream dam water (control), were taken after computing the average of the monthly samples. Differences among means were separated using least significant difference (LSD) using Genstat statistical software. The most widely applicable irrigation water quality guideline, which is set by FAO [2], was selected for suitability evaluation. The assumptions made by the selected guideline were then evaluated against the local conditions and it was generally found that most of the assumptions of the chosen guidelines for evaluation of irrigation water quality of the rivers are similar to the actual conditions of the study area. There were no large deviations between the assumptions of the guideline and the related local conditions of study area. Finally, the values were compared to their respective standards recommended by the internationally accepted guideline [2] in order to evaluate their degree of restriction on use for irrigation.

## Results and Discussion

***Chemistry of the river water:*** The chemical composition of the three streams and the control (LED) are given in Table 1. The hydrochemistry of stream waters with electrical conductivity (EC) between 545.2 and 1856.5 µS/cm and pH values between 7 and 8 is characteristic of the sampled stream waters within the catchment. The three streams varied considerably in their physical and chemical properties. The streams were slightly basic (pH 7-8) but showed a wide range of variation in electrolytic conductivity (545.2-1856.5 µS/cm). The average electrolytic conductivity was highest in the Dzorwulu (1856.5 µS/cm), followed by the Onukpawahe (1284.44 µS/cm) and Mamahuma (545.2 µS/cm). This may be attributed to the fact that Dzorwulu and Onukpawahe receive urban and industrial waste while there is little threat of pollution around Mamahuma. However, the EC of all the streams were below the value of 143.6 µS/cm for the control, indicating the effect of pollutants on the streams (Figs 2-4). This observation matched favourably with hydrochemical characteristics of the three streams documented by Water Research Institute [6] and Coca-Cola Bottling company limited [4].

This study indicated that Onukpawahe and Dzorwulu are not fresh since their total dissolves solids (TDS) exceeded 500 mg/L[9]. The cation concentrations for all the three streams followed the order $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$. For the anions, the ionic concentrations followed the order $HCO_3^- > SO_4^{2-} > Cl^- > NO_3^- >$

**Table 1.** Mean levels of physical and chemical properties for all sampling points in the streams.

| | Name | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LED | MSS1 | MSS2 | MSS3 | MSS4 | MSS5 | MSS6 | DSS1 | DSS2 | DSS3 | DSS4 | DSS5 | DTR | OSS1 | OSS2 | OSS3 | OSS4 | OTR |
| EC | 143.6 | 253.2 | 385.8 | 296.6 | 434.8 | 692.2 | 1209 | 1629 | 785 | 2429 | 1656 | 2883 | 1756.8 | 2186.2 | 1899 | 922.8 | 738.4 | 3048.6 |
| pH | 7.336 | 7.242 | 7.452 | 7.362 | 7.694 | 7.634 | 7.652 | 7.388 | 7.33 | 7.286 | 7.474 | 7.444 | 7.462 | 7.5 | 7.58 | 7.6 | 7.3 | 7.62 |
| Temp. | 28.944 | 27.938 | 27.494 | 27.204 | 27.53 | 27.56 | 28.1 | 26.38 | 27.66 | 28.426 | 26.958 | 28.662 | 27.38 | 28.26 | 27.52 | 27.1 | 27.1 | 27.7 |
| TDS | 71.34 | 130.7 | 209.2 | 238.46 | 225.6 | 375.8 | 642.2 | 793.6 | 398.4 | 1206 | 843.6 | 1430.4 | 902.2 | 1340.8 | 1034 | 552 | 424.2 | 1737.6 |
| Ca | 0.732 | 2.4264 | 1.9196 | 2.14 | 3.021 | 3.163 | 4.485 | 3.2182 | 4.3766 | 8.8702 | 10.286 | 10.784 | 3.584 | 7.634 | 3.69 | 2.944 | 2.326 | 8.7286 |
| Mg | 1.1156 | 1.0764 | 0.7324 | 1.1038 | 1.287 | 1.316 | 2.084 | 2.2528 | 3.2502 | 4.842 | 5.8264 | 6.378 | 1.6566 | 3.422 | 1.628 | 1.396 | 1.04 | 4.144 |
| Na | 57.6 | 83.824 | 86.8 | 67.93 | 102.6 | 575 | 701.4 | 143.13 | 212 | 431.6 | 368.4 | 533.2 | 365.68 | 745.4 | 716.6 | 525.8 | 408.2 | 876 |
| K | 10.2 | 11.69 | 44.4 | 36.34 | 34.65 | 65.73 | 81.75 | 13.442 | 15.2 | 56.084 | 60.112 | 60.2 | 53.3 | 85 | 78.2 | 63.2 | 56 | 107.2 |
| Cl | 0 | 25.941 | 7.5836 | 0.2106 | 0.191 | 9.537 | 2.375 | 32.703 | 53.784 | 165.2 | 126.34 | 260.17 | 109.2 | 10.514 | 8.523 | 6.914 | 3.942 | 13.644 |
| $NO_3$ | 0.0026 | 0.0018 | 0.0048 | 0.1219 | 0.206 | 0.77 | 1.572 | 0.0014 | 0.002 | 0.0016 | 0.0044 | 0.0022 | 0.4574 | 0.69 | 0.45 | 0.28 | 0.284 | 0.219 |
| $PO_4$ | <0.001 | <0.001 | <0.001 | 0.0336 | 0.065 | 0.443 | 0.753 | 0.022 | 0.0484 | 0.7756 | 0.8538 | 0.9024 | 0.8924 | 0.5524 | 0.238 | 0.198 | 0.142 | 0.4702 |
| $SO_4$ | <0.001 | <0.001 | 0.0032 | 22.362 | 31.14 | 40.25 | 23.05 | <0.001 | 0.0002 | <0.001 | <0.001 | <0.001 | 19 | 67.2 | 45.4 | 41 | 34.2 | 93.8 |
| $HCO_3$ | 53.9 | 98.8 | 117.7 | 187.4 | 218.7 | 459.8 | 398.5 | 230.7 | 231.3 | 253.4 | 195.6 | 316.2 | 368.1 | 881 | 774.6 | 597.4 | 231.8 | 881.4 |
| Fe | 0.4044 | 0.4576 | 0.3842 | 0.628 | 0.617 | 0.461 | 0.24 | 0.3494 | 0.1686 | 0.0418 | 0.1962 | 0.2662 | 0.1714 | 0.6622 | 0.48 | 0.3844 | 0.3296 | 3.4402 |
| Mn | 0.0164 | 0.0462 | 0.033 | 0.0332 | 0.04 | 0.048 | 0.04 | 0.0642 | 0.0712 | 0.1474 | 0.1674 | 0.0454 | 0.0504 | 0.07 | 0.058 | 0.0092 | 0.0096 | 0.2266 |
| Zn | <0.001 | 0.0121 | 0.0126 | 0.0153 | 0.011 | 0.009 | 0.011 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.0009 | 0.027 | 0.0125 | 0.01454 | 0.09094 |
| Cu | 0.04 | 0.0408 | 0.0286 | 0.0278 | 0.033 | 0.043 | 0.03 | 0.0522 | 0.0172 | 0.0023 | 0.0226 | 0.0067 | 0.0288 | 0.066 | 0.02 | 0.0414 | 0.06 | 0.15 |
| Cr | 0.0302 | 0.0284 | 0.028 | 0.0476 | 0.041 | 0.022 | 0.05 | 0.0258 | 0.026 | 0.046 | 0.04 | 0.0013 | 0.0198 | 0.0009 | 0.036 | 0.0009 | 0.00954 | 0.0926 |
| Pb | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | 0.009 | 0.009 | 0.009 | 0.009 | 0.009 |
| Cd | 0.0053 | 0.0152 | 0.0204 | 0.0178 | 0.017 | 0.02 | 0.019 | 0.0168 | 0.0196 | 0.0212 | 0.0253 | 0.0172 | 0.0172 | 0.0019 | 0.026 | 0.0148 | 0.01116 | 0.036 |

All parameters are in mg/L except pH, no units, temperature °C, and conductivity, µS/cm.
LED, MSS, DSS, DTR, OSS, OTR: Lebanon dam, Mamahuma sampling site, Dzorwulu sampling site, Dzorwulu tributary, Onukpawahe sampling site, Onukpawahe tributary.

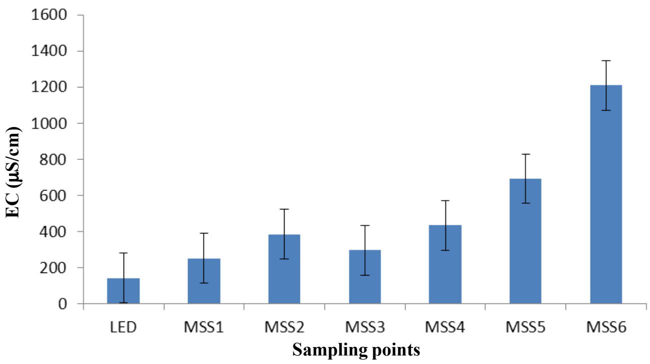


***Figure 2.*** Mean levels of EC in the Mamahuma stream and the control (LED).

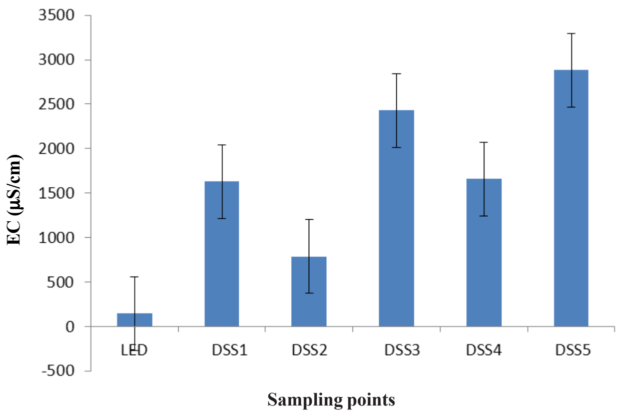


***Figure 3***. Mean levels of EC in the Dzorwulu stream and the control (LED).

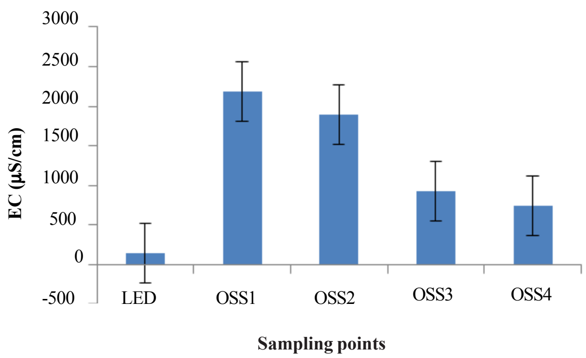


***Figure 4.*** Mean levels of EC in the Onukpawahe stream and the control (LED).

$PO_4^{3-}$ for both the Mamahuma and Dzorwulu streams and $HCO_3^- > Cl^- > PO_4^{3-} > NO_3^- > SO_4^{2-}$ for the Onukpawahe stream.

***Stream water quality:*** The mean levels of the water quality parameters are given in Table 2 and Table 3 summarizes the mean separation statistic for quality differences between the three streams and the control. The mean levels of $Ca^{2+}$ and $Mg^{2+}$ were highest in Dzorwulu with the control having the least values. However, the mean levels of $Na^+$ and $K^+$ were highest in Onukpawahe when compared with the control which again had the least value. There was a significant difference ($p = 0.05$) in calcium concentrations for all the three streams compared to the control (Table 1). Magnesium concentration in Dzorwulu was different from the control with Onukpawahe and Mamahuma showing insignificant $Mg^{2+}$ concentration from the control. Sodium and potassium concentrations in the three streams were also different from those of the control but there was no significant difference for $K^+$ between Mamahuma and Dzorwulu. There were average chloride ($Cl^-$) and phosphate ($PO_4^{3-}$) concentration spikes in Dzorwulu with the least concentration in the control. Nitrate ($NO_3^-$) concentration was highest in Mamahuma with Onukpawahe recording the highest sulphate ($SO_4^{2-}$) and bicarbonate ($HCO_3^-$) concentrations. Chloride, nitrate, bicarbonate, electrical conductivity and total dissolved solids in the three streams showed significant difference from the control. The computed sodium adsorption ratio (SAR) was highest in Onukpawahe with the least value in the control. Only Onukpawahe showed a significant difference in SAR values from the control. Iron ($Fe^{2+}$) and to some extent manganese ($Mn^{2+}$) recorded appreciable levels of trace metals. Other trace metal

**Table 2.** Mean levels of physical and chemical properties for the three streams and the control.

| Parameter | Mamahuma | Dzorwulu | Onukpawahe | LED(Control) |
|---|---|---|---|---|
| EC | 545.200 | 1856.500 | 1284.440 | 143.600 |
| pH | 7.500 | 7.400 | 7.412 | 7.300 |
| Temp. | 27.600 | 27.600 | 27.484 | 28.900 |
| TDS | 303.660 | 929.000 | 745.160 | 71.340 |
| $Ca^{2+}$ | 2.860 | 7.500 | 4.181 | 0.732 |
| $Mg^{2+}$ | 1.270 | 3.940 | 1.901 | 1.116 |
| $Na^+$ | 269.590 | 337.670 | 541.320 | 57.600 |
| $K^+$ | 45.760 | 41.010 | 65.960 | 10.200 |
| $Cl^-$ | 7.640 | 127.640 | 14.402 | 0.000 |
| $NO_3^-$ | 0.450 | 0.002 | 0.380 | 0.002 |
| $PO_4^{3-}$ | 0.220 | 0.520 | 0.232 | <0.001 |
| $SO_4^{2-}$ | 19.470 | <0.001 | 45.560 | <0.001 |
| $HCO_3^-$ | 246.800 | 245.440 | 538.960 | 53.900 |
| $Fe^{2+}$ | 0.460 | 0.460 | 0.526 | 0.404 |
| $Mn^{2+}$ | 0.040 | 0.099 | 0.039 | 0.016 |
| $Zn^{2+}$ | 0.010 | <0.001 | <0.001 | <0.001 |
| $Cu^{2+}$ | 0.034 | 0.020 | 0.048 | 0.040 |
| $Cr^{3+}$ | 0.036 | 0.027 | 0.019 | 0.030 |
| $Pb^{2+}$ | <0.01` | <0.010 | <0.010 | <0.010 |
| $Cd^{2+}$ | 0.018 | 0.020 | 0.011 | 0.005 |
| SAR | 30.641 | 26.210 | 62.968 | 9.893 |

All parameters are in mg/L except pH, no units, temperature °C, and conductivity, µS/cm.

**Table 3.** Mean separation for the physico-chemical parameters in the three streams and the control.

| | Streams | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ |
|---|---|---|---|---|---|
| Cations | LED (Control) | 0.73a | 1.12a | 57.60a | 10.20a |
| | Mamahuma | 2.86b | 1.27a | 269.59b | 45.76b |
| | Dzorwulu | 7.50c | 3.94b | 337.67c | 41.01b |
| | Onukpawahe | 4.18d | 1.90a | 541.32d | 65.96d |
| | $LSD_{0.05}$ | 1.12 | 0.85 | 22.68 | 7.36 |
| | | $Cl^-$ | $NO_3^-$ | $HCO_3^-$ | |
| Anions | LED (Control) | 0.00a | 0.002a | 53.90a | |
| | Mamahuma | 7.64b | 0.45b | 246.8b | |
| | Dzorwulu | 127.64c | 0.002a | 245.44b | |
| | Onukpawahe | 14.40d | 0.38b | 538.96d | |
| | $LSD_{0.05}$ | 5.34 | 0.13 | 47.76 | |
| | | EC | TDS | SAR | |
| Others | LED (Control) | 143.60a | 71.34a | 9.893a | |
| | Mamahuma | 545.20b | 303.66b | 30.641a | |
| | Dzorwulu | 1856.50c | 929.00c | 26.21a | |
| | Onukpawahe | 1284.44d | 745.16d | 62.97b | |
| | $LSD_{0.05}$ | 170.33 | 92.06 | 22.68 | |

Values in the same ionic type (cation, anion and others) and column followed by different letters are significantly different for p=0.05. All parameters are in mg/L except, EC, µS/cm and SAR, no units.

concentrations were generally low and did not show any trend under the different streams. Almost all parameters measured in the three streams were above values recorded in the control sample.

All the three streams and the control sample originate from the same neighboring catchments areas with more or less the same geological and biophysical characteristics, the quality of the streams water is assumed to be the same unless otherwise another external element, like industrial effluents and urban waste are introduced in the streams. Anthropogenic effect might therefore be responsible for the spikes in values of the three streams compared to the control sample.

***Suitability of streams for irrigation:*** The suitability of water for irrigation was evaluated based on the criteria indicative of its potential to create hazardous soil conditions to crop growth, the effect of the applied irrigation water was referred specifically in terms of salinity, water infiltration, specific ion toxicity and related miscellaneous problems.

*Salinity:* Salinity of irrigation water was evaluated based on its electrical conductivity in dS/m or total dissolve solids in mg/L. The mean electrical conductivity of the control irrigation water was 0.14 dS/m and is put as none restricting for irrigation. The electrical conductivity of Onukpawahe and Dzorwulu rivers increased to 1.28 and 1.86 dS/m, respectively. Based on the standards of FAO [2], these figures plunge nearer to a potentially slight degree of restriction to use for irrigation. The water in the control and Mamahuma posses no salinity threat for irrigation while waters from Onukpawahe and Dzorwulu can pose salinity hazards to the soil if used for irrigation (Tables 4-6).

*Soil water infiltration:* The sodium adsorption ratio is used together with electrolytic conductivity in evaluating the suitability of water for irrigation as far as water infiltration through the soil is concerned [2]. The SAR value of the control 9.89 together with its EC value of 0.14 dS/m comes with a severe restriction on use for irrigation. Again, all the three streams had levels of SAR and EC which correspond to a severe restriction on use for irrigation. The streams in the catchment are therefore likely to cause infiltration problems when used for irrigation.

*Specific ion toxicity:* The specific ion toxicity considered in this study included sodium, chloride and some selected trace metals, but the toxicity effects need to be explained by taking into account indicator crops, which is not the intention of this particular study. However, the assessment of these ions in the water of the streams could show the general trends with the associated risks of toxicity

**Table 5.** FAO values for SAR and $EC_W$ and the restriction on use for irrigation.

| Degree of restriction | | | |
|---|---|---|---|
| SAR | $EC_w$ | | |
| | None | Slight to Moderate | Severe |
| 0.0-3.0 | > 0.7 | 0.7-0.2 | < 0.2 |
| 3.0-6.0 | > 1.2 | 1.2-0.3 | < 0.3 |
| 6.0-12.0 | > 1.9 | 1.9–0.5 | <0.5 |
| 12.0-20.0 | > 2.9 | 2.9–1.3 | < 1.3 |
| 20-40 | > 5.0 | 5.0-2.9 | < 2.9 |

**Table 6.** Mean SAR and ECw levels of the three streams and the restriction on use for irrigation.

| Name | SAR | $EC_w$ (dS/m) | Restriction on use |
|---|---|---|---|
| LED (Control) | 9.89 | 0.144 | Severe |
| Mamahuma | 30.64 | 0.545 | Severe |
| Dzorwulu | 26.21 | 1.856 | Severe |
| Onukpawahe | 62.97 | 1.284 | Severe |

The mean sodium ion concentration of the control water was less (57.6 mg/L) and none restriction on use, but the levels in effluent mixed water of Dzorwulu (337.67 mg/L) and Onukpawahe (541.32 mg/L) rivers were higher and can pose moderate restriction on use for irrigation. The increased level of sodium at the effluent contaminated streams can be attributed to the presence of caustic soda, for the purpose of washing, in the effluents of Printex Textiles, Coca cola factory, and Kasapreko brewery factory.

The mean concentration of chloride was quite low in all three streams and control, and the restriction on use for irrigation is none. Trace metals measured in the study ($Fe^{2+}$, $Mn^{2+}$ $Zn^{2+}Cu^{2+}$, $Cr^{3+}$, $Pb^{2+}$, $Cd^{2+}$) were also low and within the FAO limits for irrigation.

Miscellaneous evaluation includes measurements of nitrate, bicarbonate and pH of the irrigation water. Nitrate concentrations in the three streams were low and come with no restriction. The mean concentration of bicarbonate in the control irrigation water (59.3 mg/L) was low and has no restriction on use for irrigation. However, the wastewater contaminated Onukpawahe stream had a mean value of 538.96 mg/L, falling under the severe restriction on use category. The other two streams, Mamahuma and Onukpawahe recorded bicarbonate levels of 4.04 and 4.02 mg/L. These values place a slight to moderate restriction on use for irrigation. The pH of all the streams falls within the limits for irrigation [2].

**Table 4.** Salinity as potential irrigation problem evaluated using of ECw or TDS compared with the three streams.

| | This work | | Degree of restriction on use (FAO) | | | Degree of restriction on use (FAO) | | |
|---|---|---|---|---|---|---|---|---|
| | TDS (mg/L) | $EC_w$ (dS/m) | TDS (mg/L) | | | $EC_w$ (dS/m) | | |
| Name | | | None | Slight to Moderate | Severe | None | Slight to Moderate | Severe |
| Control | 71.3 | 0.14 | <450 | 450-2000 | > 2000 | < 0.7 | 0.7-3.0 | > 3.0 |
| Mamahuma | 303.7 | 0.54 | <450 | 450-2000 | > 2000 | < 0.7 | 0.7-3.0 | > 3.0 |
| Onukpawahe | 929.0 | 01.28 | <450 | 450-2000 | > 2000 | < 0.7 | 0.7-3.0 | > 3.0 |
| Dzorwulu | 745.2 | 1.86 | <450 | 450-2000 | > 2000 | < 0.7 | 0.7-3.0 | > 3.0 |

## Conclusions

The Accra Tema motorway area is one of the few areas in Ghana with a relative greater number of large-scale manufacturing plants including Printex Textile Factory, Interplast-PVC Manufacturing Factory, Coca-Cola-Brewery Factory, Kasapreko-Brewery Factory and a host of other companies. At the same time in this region there are multiple anthropogenic influences from municipal and domestic wastes. Anthropogenic disturbances have had and continue to have an impact on the aquatic ecosystem of Ghana. Hydrochemical data from this study indicate that $Na^+$ $HCO_3^-$ and $K^+$ are the dominant ions. Data from this study shows that urbanization and intensive use of land for industrial activities has impacted greatly on the quality of the waters in the streams within the catchment. With the exception of the control sample which is above the effluent contaminated streams, it can be said that all the three streams are generally unsuitable for irrigation based on FAO standards and have to be used for irrigation with a lot of caution.

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## Abbreviations

AAS - Atomic Absorption Spectrophotometry; APHA - American Public Health Association; CSIR - Council for Scientific and Industrial Research; EPA - Environmental Protection Agency; FAO - Food and Agricultural Organization of the United Nations; SAR - Sodium Adsorption Ratio; WRI - Water Research Institute; ECw – Electrical conductivity of Irrigation water (dS/m); TDS – Total Dissolved Solids (mg/l); LED – Lebanon Dam; MSS – Mamahuma Sampling Site; OSS – Onukpawahe Sampling Site; ODSS – Dzorwulu Sampling Site.