Investigation of Ecological Impacts of Agricultural Activities in Tshitavhadudlu wetland, Limpopo Province

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Abstract— Wetlands are fragile ecosystems that support diversity of plants and animal forms and occupy about 6% of world's surface. Agricultural activities refer to activities such as irrigation livestock breeding and crop production. Fertilizers are applied in agriculture to enhance production and if applied unsustainably can cause ecological harm to the wetland ecosystem. Physical and chemical parameters were indicators of the destruction of the wetland which was assessed in the period of 5 months. Physiochemical parameters such as pH, EC, TDS, COD, nitrates, phosphates, sulphates, fluoride and chloride ions were assessed in the Tshitavhadulu wetland from July to November, 2015. The results revealed that physiochemical parameters were below the recommended range by the DWS water quality standards for aquatic ecosystems during the period of study. The results were: electrical conductivity (EC) was 90µS/cm, total dissolved solids (TDS) was 70mg/L, COD was 97 mg/L in October (site C), and nitrates had 16 mg/L in August (site B). The nitrate and chloride were above the recommended DWAF guideline. The high temperature, high evapotranspiration and low rainfall may also contribute to leaching of fertilizers from the agricultural fields. Agricultural activities practiced within Tshitavhadulu wetland may cause negative impact to the wetland on the long term as the growth of toxic cyanobacteria. Therefore monitoring programme and rehabilitation measures for this study site should be undertaken immediately to avoid further destruction of the wetland, and all activities taking place within the wetland should be monitored**.**

Index Terms— Wetland, Subsistence Farming, Eutrophication

I. Introduction

A. Introduction

Wetlands are among the most important ecosystem on earth and constitute major feature of the landscape in almost all parts of the world [1]. As a major component of water resource, wetlands are crucial to life-support functions, human health and the natural environment. In the 19th century wetlands comprised about 6% of the world's surface [2]. Thus the global extent of wetlands in 20th century was estimated to have been declined between 64-71% [3]. In the past wetlands were considered to be wasteland and worthless, hence they are threatened landscape. Wetlands are increasingly perceived as an environment heaven where air, water and land, and their fauna and flora, meet in an attractive and delicate way and this has caught the scientific and popular imagination.

Definitions of wetlands are very broad and differ from discipline to discipline. However, Finneran [4] defines a wetland as an area where water covers the soil or is present either at or near the surface of the soil all year or for varying periods of the time during all year including growing season. In the South African National Water Act[1] a wetland is defined as "*a land which is transitional between terrestrial and aquatic system where the water table is usually at or near the surface or land that is periodically covered with shallow water, which in normal circumstances support or would support vegetation typically adapted to life in saturated soil*." Wetlands are transitional habitats in the sense that they are neither terrestrial nor aquatic, but exhibit characteristics of both. Their boundaries are part of a continuum of physical and functional characters and may expand and contract over time depending upon factors such as average annual precipitation, evapotranspiration and modification to the watershed [5].

Wetlands are classified according to their sites, for example there are coastal wetlands which include marine and estuarine wetlands, and interior wetlands which includes riverine, lacustrine, and palustrine wetlands. Riverine wetland is a type of wetland which is found in the river channel, with perennial intermittent water regimes, fresh water chemistry and it is composed of aquatics, algae, shrubs and forest vegetation types [5].

Agriculture and wetlands are closely linked thus the conversion of wetlands into agriculture around them has caused a major degradation and destruction of wetlands [6]. Irrigation and the use of pesticides and fertilizers are most notable areas where improved farming practices can make considerable impacts. Irrigation has been practiced for the past 4 000 years because it allows for the increased productivity through the more optimal timing water application [7].

Tshitavhadulu wetland is found in Tshakhuma area in a village called Mulangaphuma, and it is along Lutanandwa River, a tributary of the Luvuvhu River. Tshitavhadulu wetland exhibits rich ecological wetland diversity, by different plants and animal species. The Tshitavhadulu wetland can be classified as riverine wetland as it is found in a river channel, with perennial intermittent water regimes, freshwater chemistry and composed of aquatics, algae, shrubs, and forest vegetation types. This wetland expand with annual precipitation, if there is enough precipitation it becomes flooded and expand to the banks, thus the wetland is

Manuscript received August 24, 2016. The climatic data was provided by the ARC-Institute of Soil, Climate and Water in Pretoria, South Africa.

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[1] National Water Act (Act 108 of 1998), chapter 1, section 1(xxix)

periodically flooded. There are different activities happening around the Tshitavhadulu wetland such as substantial and commercial farming which are the most contributors of the fertilizers into the wetland. Other activities which occur close to the wetland are car washing and brick making which also leads to negative impacts of the wetland.

Wetlands are fragile and valuable ecosystems supporting a diversity of species and habitats [8]. Wetlands are defined as a biologically diverse and productive ecosystem with a variety of plant life forms such as floating pond lilies, cattails, Blue Spruce, they also support a diverse communities of invertebrates, birds and carnivores such as Dragon flies, Otters, Alligators and osprey [9]. According to Walters and Koopman [10], conversion of wetlands for commercial development, agriculture and tourism always pose a serious threat to wetlands everywhere. Discharge of fertilizers and pesticides from intensive agriculture, toxic pollutants from industrial waste and construction of dams and dikes are the major threats to wetlands as they enhance the excessive growth of vegetation and increase sediments in the wetland.

Excessive fertilization by agricultural activities strongly affects wetland ecosystems [11]. Fertilizers are the inorganic manufactured products that supply plants nutrients [12], these fertilizers contain excess quantity of minerals such as Nitrogen (N), Phosphorus (P) and potassium (K). Fertilizers are washed to the nearest surface water sources when it rains, where they enhance the excessive growth of plant species more especially algae and alien species. Both phosphorus and nitrogen are the essential nutrients that are used in enhancing crop production and their high quantity in water usually leads to eutrophication. Eutrophication is "*the over-nutrients-rich water causes rapid plant and algal growth, and the rapid spread of undesirable aquatic plants that absorb oxygen in the lakes, ponds and slow-moving waters reduces the ability of the water to support marine life and, of course, affect the quality of drinking water and recreational activities*" [2]. If the water supply is contaminated with high levels of nitrates and is consumed in large quantity may cause methamoglobinaemia (Blue-baby-syndrome) in infants of age 0-3 months and these are the most vulnerable to the disease [14].

II. WETLAND ECOSYSTEM

The classification of wetlands is based soil characteristics, the hydrological regime and vegetation such as hydrophytes [15]. Hydrophytes are plants that are adapted to living abundantly in wet environments. Wetland vegetation affects the hydrology and soil of a wetland by slowing down the flow of water. Wetland vegetation usually produces organic matter that accumulates in soil, thus wetlands act as natural filters that trap and remove the accumulated pollutants and organic matters [15].

Characteristics of wetlands are also by soil types which are found in in wet environments (hydric soils). Hydric soils are formed by the process of reduction, translocation and oxidation of iron and manganese, however such soil type has dark colour which is an indicator of oxidation and iron richness [15]. According to Collins [15] the movement of water through the wetland (surface flow and subsurface inflow) and exit of wetland water (evaporation, surface water outflow and ground water outflow) characterizes the hydrology of wetland ecosystem. Water movement in and out of the wetland is grouped into four mechanisms which are precipitation, evapotranspiration, surface water inflow and outflow and groundwater inflow and outflow. Wetland ecosystems have hydric zones which determine saturation of a wetland.in a wetland there is a permanent hydrologic zone which are saturated all year round; seasonal hydrologic zones which are saturated in some seasons of the year and temporary hydrologic zones which are saturated only for few months of the year.

Thus the aim of the study is to assess the impacts of human activities, particularly agriculture on the Tshitavhadulu wetland. The specific objectives were: to determine the level of nitrates, phosphates and sulphates in the Tshitavhadulu wetland; to quantify the other physiochemical parameters in the wetland as these may have been impacted by human activities (pH, Electrical Conductivity, and chemical oxidation demand).

III. CHARACTERISTICS OF THE STUDY AREA

Tshitavhadulu wetland is a big wetland that is found in Tshakhuma, Limpopo Province, and 25 km east of Thohoyandou (Figure 1). This wetland is situated between two residential areas of Mulangaphuma and a farm along Lutanandwa River, at 23^{0}04'20.50" S and 30^{0} 18' 03.37" E. The ecosystem of the area is mountainous with loamy soil type. The vegetation type is tall grasses, reeds and some trees. Agricultural activities practiced in that area include growing of vegetables (cabbage, tomatoes, spinach etc), and fruits such as bananas, macadamias, and avocadoes. Different organisms are found in the wetland such as frogs, tadpoles, crabs, fish and other aquatic organisms. The climate of Tshakhuma varies from season to season, however the study area is charaterised by summer rainfall with little or no rain during the winter months. Below is the diagram of a map representing the study area, Tshitavhadulu wetland (Figure 1).

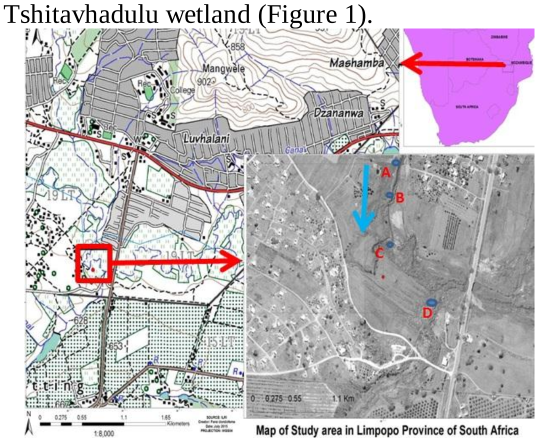

Fig. 1 The location of Tshitavhadulu wetland in the study area. The flow of Lutanandwa River (in blue) into the wetland

IV. MATERIALS AND METHODS

3.1 Sample collection and preparation

The aim of this study was to assess the impacts of agricultural activities on the Tshitavhadulu wetland along Lutanandwa River. Four different sampling sites were selected and water samples were collected in these sampling points. Two sampling sites were selected at the upstream of the wetland, one at mid-stream and the other one downstream of the wetland. Sampling sites were named A, B, C and D for identification, A and B were upstream sampling sites, C was a mid-stream and D was a downstream. All these sampling sites were selected to determine the likely ecological impact of agricultural activities such as application of fertilizers and irrigation on wetlands and to identify levels of nutrients that are available in the water. All samples were collected twice a month from July to November 2015.

Water samples were collected to determine the water quality. The physico-chemical parameters monitored were pH, EC, TDS and Temperature, nitrates (NO_3^-), phosphates ($PO_4.^{3-}$), sulphates (SO_4^{2-}), fluoride (F^-), chloride (Cl^-) and Chemical Oxygen Demand (COD).These parameters were selected because there are agricultural activities taking place around the area and there are also residential areas around the area and these could be impacting on the wetland. Usually nitrates and phosphates are associated with agriculture as they are used as fertilizers, rodenticides and as preservatives [16], in farms and households.

3.2 Sample collection and preparation

All water samples were collected using High Density Polyethylene (HDPE) containers and transported to the lab immediately after collection. All samples were stored in a refrigerator at 4^0C prior to analysis. The samples were analysed on the same day after collection for pH, EC and TDS, while nitrates, phosphates, sulphates, fluoride, chloride and COD were analysed the following day after collection. Physical parameters were monitored using a Jenway pH- conductivity meter Model 430.

Chemical parameters were analysed using a Professional Ion Chromatograph 850 Metrohm for nitrates, sulphates, fluoride and chloride ions. COD and phosphates were analysed by a spectrophotometer method using a Merck Spectroquant Pharo 100.

3.3 Climate data

The data (rainfall, air temperature and evapotranspiration) was obtained from the ARC-Institute of Soil, Climate and Water in Pretoria, South Africa. The data would assist in the interpretation of observed variables.

3.4 Physical-chemical analysis

3.4.1 Determination of Physical Parameters

pH, EC, TDS, and Temperature were analysed using a JENWAY pH- conductivity meter the same day after collection of the samples.

3.4.2 Determination of Chemical Parameters

NO_3^-, PO_4^{3-}, F^- and Cl^- were analysed using an Ion Chromatography (Model 850). COD and phosphates were analysed using a Spectrophotometer (Merck Spectroquant Pharo 100).

Nitrates, Sulphates, Chloride and Fluoride ions were determined in the lab using IC metrohm model. The instrument first was calibrated before the analysis. 5ml of the sample was filtered using syringe filters (Sartorius RC 0.25µm) before injection. The injection volume used was 20µl.

Chemical Oxygen Demand was determined by transferring 3ml of sampling water to the tilted reaction cell using a pipette. The content of the cell was vigorously mixed until the reaction cell became hot. The cell was heated at 148^0C in the preheated Thermoreactor for 120 minutes. The hot cell was removed from the Thermoreactor and allowed to cool in a test-tube rack for 10 minutes followed by swirling the cell and then further cooling for at least 30 minutes to room temperature. Thereafter a Spectrophotometer Pharo 100 was used to determine the COD in the reaction cells

Phosphates were determined by transferring 1.0 ml of sampling water to the tilted reaction cell using a pipette and then 5 drops of P-2K (phosphate mixed with 2 moles of potassium) reagent and 1 dose of P-3K (phosphate mixed with 3 moles of potassium) reagent were also added to a reaction cell and vigorously shaken until P-3K was completely dissolved. The reaction was left to stand in a test-tube rack for 5 minutes (reaction time). Thereafter a Spectrophotometer Pharo 100 was used to determine phosphates in the reaction cell.

3.5 Data Analysis

The final results were represented in the form of tables and graphs using Microsoft Office Excel 2010 software. The Spearman correlation analysis was conducted using XLSTAT software free version 2016 between the variables and climate data variables and missing data was estimated using nearest neighbour.

V. RESULTS AND DISCUSSION

4.1 Physiochemical parameters of Tshitavhadulu wetland

The variation of pH in site A, B, C and D of Tshitavhadulu Wetland is presented in figure 2. The pH level was relatively low (above 6) in all sites from July to November. The level of pH shows that water was slightly acidic but this gradually increased to alkaline through the course of the year. The pH was well correlated with chemical oxygen demand (COD) and sulphate variables with p values of 0.022 and 0.001 respectfully.

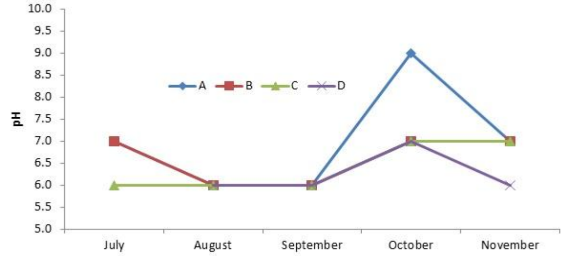

Fig. 2The variation in pH at the study location from July to November

The chemical oxygen demand and sulphate may arise from human contamination of wetland through the washing of cloths (soiled) and motor cars with washing detergents, *Sunlight washing powder* and *Maq washing powder*. The major component of washing detergent is alkylbenzene sulphonates [21]. However, DWAF [17] recommend that pH level should be between 6 and 8, thus some sites are still between the DWAF water quality guidelines and standards for aquatic ecosystem.

During the 2015 year, the weather pattern was characterized by low rainfall and high evapotranspiration and high temperatures (Figure 3).

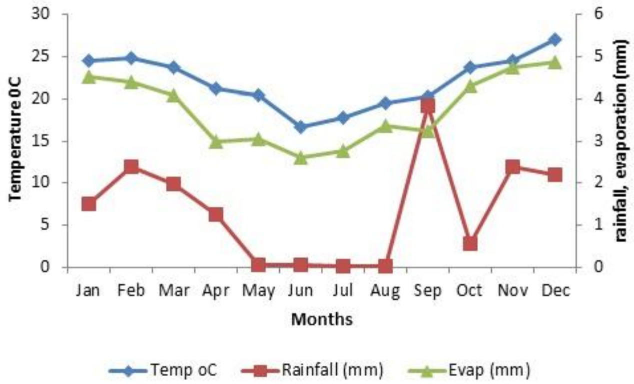

Fig. 3 The climate data during the 2015 year at the study site

These climate events of high temperature and low rainfall may have contributed to the increased electrical conductivity (EC) and total dissolved solids (TDS) from July to December. Since there was little or no rainfall during that period and high evapotranspiration rate could result in low water volume in the wetland and an increase in EC and TDS (Figures 4 and 5). However the EC and TDS were not correlated with climate variables with p> 0.05 respectfully

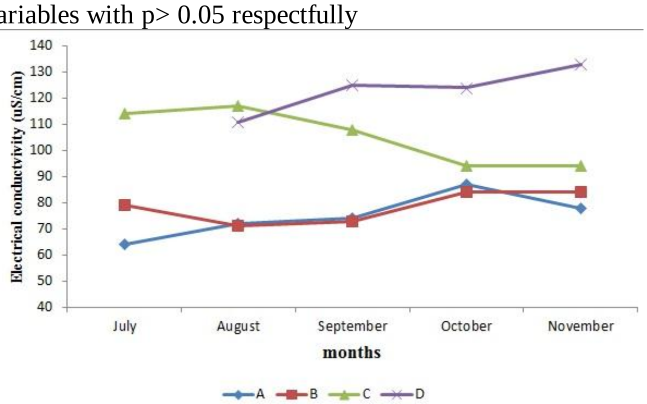

Fig. 4 EC concentrations in four sampling sites

The variation of electrical conductivity (EC) in site A, B, C and D of Tshitavhadulu wetland presented in figure 4. The EC concentration was relatively low (less than 90µS/cm) from July to November in site A and B, the low concentration of EC might be due to absence or little ions. When moving towards downstream (site D and C) the concentration of EC was higher than 100µS/cm from July to September in site C and site D was the highest of all sites.

The sampling sites C and D have higher concentration of TDS with average of 63.52mg/L and 74.34mg/L respectively. Thus the increased concentration of TDS is because of lack of rainfall and evapotranspiration rate as presented in figure 3, when rainfall is minimal a lot of dissolved solids accumulates in water. According to DWAF [17] the concentration of TDS in a well leached soil should be less than 30mg/L, thus TDS concentration does not comply with DWAF[17] water quality guidelines and standards for aquatic ecosystems. Too much TDS concentration affects adaptation of individual species, community structure, microbial and ecological processes such as rates of metabolism and nutrients cycling [17].

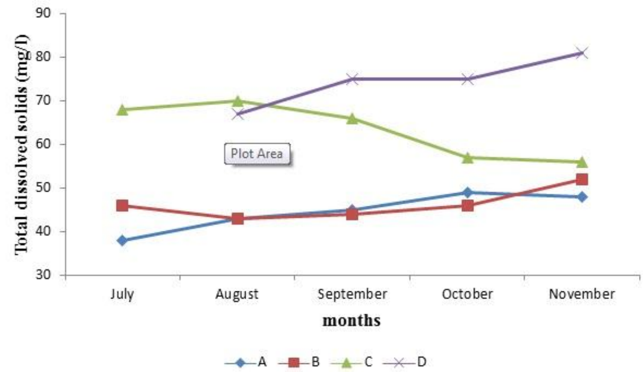

Fig. 5 TDS concentration in four sampling site

The variation of chemical oxygen demand (COD) in site A, B, C and D of Tshitavhadulu wetland presented in figure 6. However the COD levels were correlated with pH and climate (air temperature) with p values of 0.022 and 0.024 respectfully

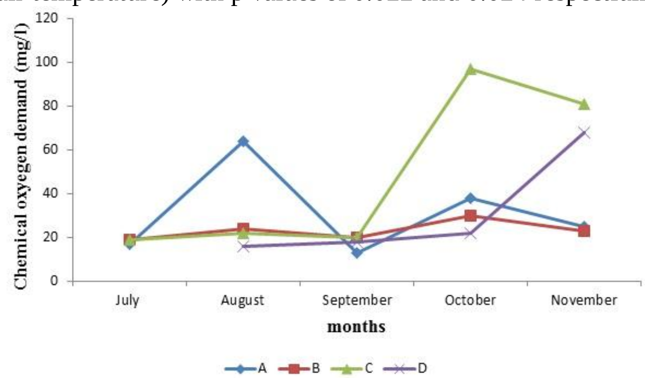

Fig. 6 COD concentration in four sampling sites

The concentration of COD from four sites in July to September was below the recommended range of 80-120mg/L according to DWAF [17]. The high concentration of COD might be because of organics that are deposited in water when the community are doing laundry and suspended organic chemicals from agricultural activities [18]. There was a gradual increase in the level of COD and may correlated with increase in temperature and low rainfall.

In October and November only site C had COD concentration which was within the recommended range of 97mg/L and 81mg/L respectively for aquatic ecosystem while other sites had low COD concentrations [17]. High COD concentration has adverse effect in a wetland and other water sources as sensitive species such as fish and invertebrates depend on oxygen for respiration [17].

The variation of Nitrates in site A, B, C and D of Tshitavhadulu wetland presented in figure 7. In August the concentration of nitrates in site A was highest at 16.179mg/L because of excessive enrichment of the site by agricultural fertilizers and chemicals from washing soap [19] due to rainfall that occurred between August and September as presented in figure 3. However, from July to November the concentrations of nitrates of all sites were below 5mg/L because of little rainfall occurred as presented in figure 3.

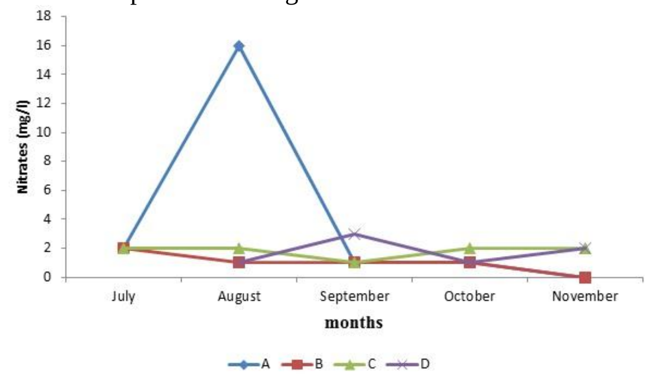

Fig. 7 Nitrates concentration in four sampling points

There was a gradual decrease in the level of nitrates and may correlated with increase in temperature and low rainfall. The reason may be that there was low rainfall input to leach the nitrates from the agricultural fields.

The sampling point A was located upstream near agricultural activities and the gradual increase in the concentration of nitrates may be as a result of leaching of the agricultural fertilisers. The water sources with nitrate concentration between 0.5-5mg/L have high level of species diversity, excessive growth of aquatic plants and blooms of Blue-Green algae, while water sources with nitrate concentrations above 10mg/L have species that are toxic to man, livestock and wildlife.

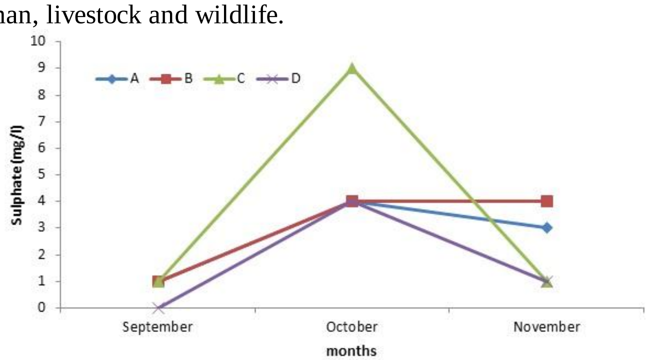

Fig. 8 Sulphates concentration in four sampling sites

The variation of the levels of sulphate in site A, B, C and D of Tshitavhadulu wetland presented in figure 8. The sulphate levels were negatively correlated with rainfall and positively correlated with pH variables with p values of 0.001 and 0.008 respectfully

The concentration of sulphates in site C was higher than other sites in October by 9.358 mg/L which might be because of soaps that are washed away to the wetlands from car wash and where the community does their laundry. The other sites had concentration of lower than 4 mg/L from October to November. This type of concentration does not have adverse effect on the ecosystem as sulphates concentration in untreated water sources (rivers and wetlands) ranges from 12.5 mg/L [20].

The variation of Chloride in site A, B, C and D of Tshitavhadulu wetland presented in figure 9. The chloride levels were negatively correlated with rainfall variables with p values of 0.018.

The concentration of chloride from July to November in all sites was decreasing gradually which might be because of little rainfall occurred as presented in figure 3.

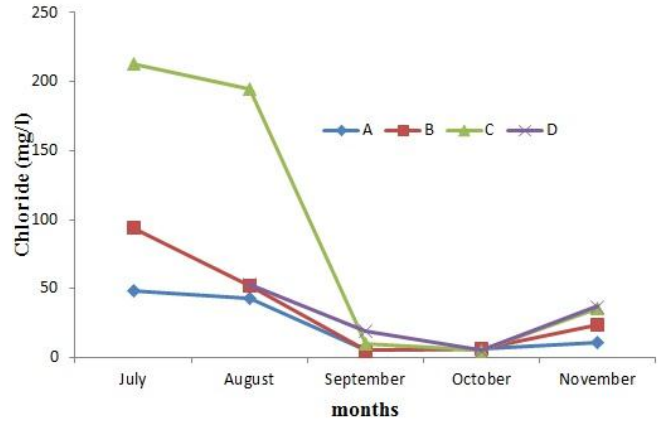

Fig. 9 Chloride concentration in four sampling sites

All sites had the average concentrations of 22.64 mg/L, 36.61 mg/L, 91.96 mg/L and 28.51 mg/L respectively. According to DWAF [17] the recommended water standards and guidelines for aquatic ecosystems of chloride have to be 0-0.2µg/g (5 mg/L). Thus the overall average concentration of chloride is far above the recommended range by DWAF [17]. Too much chloride in aquatic ecosystem poses serious environmental effects to aquatic plants and animals [17].

The variation in the levels of fluoride in site A, B, C and D of Tshitavhadulu wetland presented in figure 10. The fluoride levels were negatively correlated with rainfall variables with p values of 0.011.

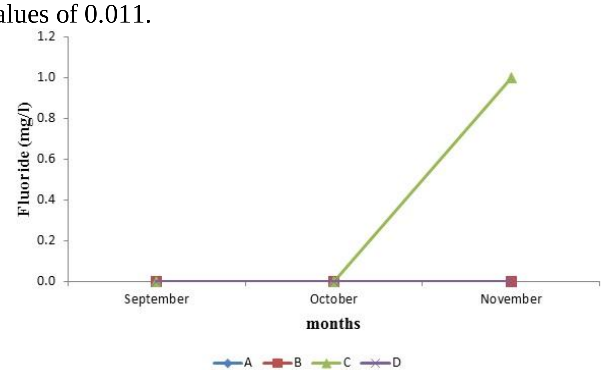

Fig. 10 Fluoride concentration in four sampling sites

The concentration of fluoride from September to November in all sites was zero with the exception sample point C that recorded 1 mg/L in November because of little rainfall occurred as presented in figure 3. According to DWAF [17] water standard guidelines and standards for aquatic ecosystem of fluoride should be 750µg/g (0.0013mg/L). However, the results show that the concentration does not comply with [17] water quality standards and guidelines for aquatic ecosystems.

The variation of phosphate levels in site A, B, C and D of Tshitavhadulu wetland is presented in figure 11. The concentration of phosphates in July to August for site A and C was relatively high compared to other sites, in October the concentration of site C because there was no rainfall to wash away agricultural fertilisers containing phosphates to the wetland dropped from 5.866 mg/L to 0 mg/L as presented in figure 3. There was a gradual decrease in the level of phosphate and may correlated with increase in temperature and low rainfall. The reason may be that there was low rainfall input to leach the phosphate from the agricultural fields.

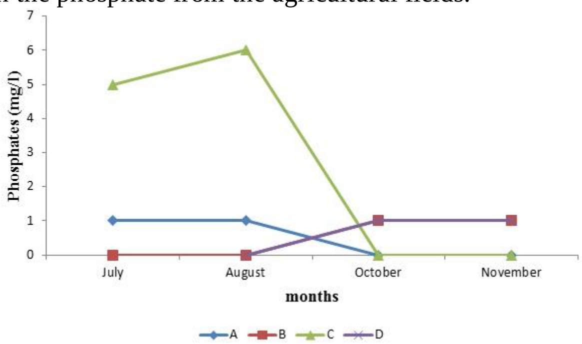

Fig. 11 Phosphates concentration in four sampling sites

Sampling point D was downstream near the small stream coming from the subsistence farming, the concentration increased from August because of the agricultural fertilisers applied in subsistence farming [19], which was transported by the small stream to the wetland. The Site D had phosphates concentration of 0.754 mg/L. This concentration is relatively low compared to DWAF [17] water quality standards and guidelines. Water quality guidelines and standard of DWAF [17] for aquatic ecosystem is 5-250 mg/L, thus, phosphate concentration above 5 mg/L pose adverse effect to the environment such as eutrophication of freshwater bodies.

VI. Conclusion

The results shows that most of the analysed physiochemical parameters determined were above the recommended range for aquatic ecosystem by DWAF water quality guidelines. In October and November most physiochemical parameters were found to be below the recommended range with the exception of nitrate and chloride which were above recommend range. This was suspected to have happened because of low rainfall which occurred during these months which could not leach fertilisers, detergents and suspended solids from nearby farms and households. However, all activities that are taking place within the wetland are causing a serious effect on wetland ecosystem.

VII. Recommendations

With the results obtained during study, I recommend that all human activities around the wetland should be monitored on regular basis to reduce the likely impacts on the wetland ecosystem.

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