Application of Remote Sensing and macro invertebrates to assess the impact of land use changes on and status of water quality parameters and river health: A case of the Orange River in Namibia

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Abstract. Land use activities that have an effect on water quality and river health are believed to have increased along the Orange River in Namibia. These are mainly agricultural activities, notably irrigation, with more than 2000 ha currently under irrigation and approximately 2000 ha planned for future expansion. Other anthropogenic activities include urban development and weir construction along the Orange River. Population increase along the river has resulted in proliferation of unplanned settlements with no proper sanitation facilities. This study was aimed at assessing the current water quality and overall health status of the Orange River in Namibia. The South African Scoring System 5(SASS5) was applied in eight sites where samples for macro invertebrates, physical and chemical water quality parameters such as nutrients in the water, pH, turbidity and presence of bacteria were obtained. Satellite images i.e. Landsat images were also used to assess the land-uses over time in the study area with the view of linking such changes to variance in water quality over time. The SASS5 results indicated a fair water quality and river health condition in category C, indicating that the river is moderately modified. Water quality parameters at all sites varied moderately and were within acceptable limits, except for turbidity and chlorophyll a. There was a significant difference in the mean concentrations of nine water quality parameters among sampling periods, whereby F-value > F-critical at a = 0.05 among sites, F-value < F-critical at a = 0.05, except for turbidity and chlorophyll a. The Landsat images also showed minimal changes in land-use activities between 2002 and 2012, with a net increase of 38 ha in irrigated area. According to National Water Policy White Paper of Namibia of 2000, it was found that policies and legislation address water resources management from a broader spectrum and not specific to river health. Thus, it was concluded that the river health of Orange River is still within acceptable range despite the fact that there is an urgent need to develop an effective and sustainable water quality monitoring and development programme.

Keywords: Water quality, River health, Macro invertebrates, Physicochemical, Landuse

1. INTRODUCTION

Water quality deterioration and river health degradation are directly and indirectly exacerbated by the development activities of a particular catchment. The Orange River in Namibia has not been spared from these developments which could be summed up in land-use. There is fear of pollution from the use of fertilizers (NPK), pesticides and herbicides from the increased large-scale agricultural activities as about 300 ha of land is under irrigation (50% flood irrigation) in Noordoewer (PWC, 2004) for vegetables and table grapes with about 1000 ha planned for future irrigation (Olivier, 2013). Aussenkehr has an area of about 2000 ha under irrigation (www.saflii.org) for table grapes only. Due to inadequate or no sanitation facilities in the settlements at Noordoewer and Aussenkehr, it is not clear how much effluent is disposed of in the river. There have been reports of the eutrophication occurring upstream in South Africa (ORASECOM, 2008) and also high levels of algae at the Sendelingsdrift purification plant. Additionally, the construction of the weir at Sendelingsdrift is believed to disturb the ecological system of the Orange River. All these issues negatively affect water quality and eventually the ecological integrity of the river. Economic development and population increase are some of underlying causes of the above-mentioned factors. The population of Noordoewer and Aussenkehr is increasing that it was estimated at 5000 and 15 000 in 2012 respectively (Muhongo, 2013) and more people are expected to migrate to the area due to new irrigation development.

Thus, the objective of this study was to assess the overall health of the Orange River in Namibia by using biological, physical and chemical parameters of water quality and link them to land-use activities, and to propose management strategies in sustaining the river's ecological integrity. The assessment of ecological integrity of the river system is based on bio assessment of micro invertebrates. In this study, a technique known as South African Scoring System (SASS) (Dallas, 2004) was applied to assess the river health of Orange River. It is a qualitative, multi-habitat, rapid field-based method that requires identification of macro invertebrates to family level (Dallas, 2004). It is intended to be a rapid, inexpensive technique for the detection of water quality deterioration or for revealing trends in water quality change over time (Chutter, 1998). But more broadly, it is used for the assessment of the ecological integrity of river ecosystems (Dickens and Graham, 2002). It is worth noting that, from literature, the approach used in this study has never been applied in the Orange

2. METHODOLOGY

Six sites (Figure 1) were chosen for physic chemical analysis where nine selected physicochemical parameters of temperature, pH, conductivity and Dissolved Oxygen were measured in field with a HACH multi-meter. Turbidity was also obtained in field using a HACH turbidimeter. Meanwhile, sample was sent to the Analytical Laboratory in Windhoek for chemical analysis such as Total Phosphorus, Total Nitrogen, TDS and Chlorophyll a. Field measurements and preservations followed the Australian surface water sampling method. To test for significance in the water quality parameter concentrations, a single ANOVA factor was used. The influence of land-use on water quality was carried out by analyzing the Landsat images of 2000 and 2012 whereby times series water quality data from Namwater plant at Sendelingsdrift were also used. Only five parameters such as Turbidity, Total Nitrogen, pH, Conductivity and TDS were considered due to the ability to determine whether activities like agriculture, tourism, settlements have an impact on the river.

For the South African Scoring System (SASS) protocol (Dallas 2007), were used for sampling macro-invertebrates in February and March 2013. These sites were OR1, OR4, OR5, OR6, OR7 and OR8. In this study, the two sites, OR2 and OR3 were not sampled for macroinvertebrates as they lacked the suitable habitats for this exercise. Data was interpreted using the Orange River Gorge Ecoregion interpretation in Dallas (2007). The link between macroinvertebrates and water quality was also based on macro-invertebrates pollution indicators as highlighted in Adamus and Brandit (1990).

Figure 1: Map of Study Area indicating sampling points

Table 1: Grading Scale for SASS

Ecological Category	Category Name	Description	Color
A	Natural	Unmodified natural	
B	Good	Largely natural with few modifications	
C	Fair	Moderately modified	
D	Poor	Largely modified	
E	Seriously modified	Seriously modified	
F	Critically modified	Critically modified	

3. RESULTS AND DISCUSSIONS

3.1 Aquatic Macro invertebrates

The interpretation of the SASS 5 data obtained from all sampled sites for four sampling periods was based on Figure 2 adopted from Dallas (2007) as per SASS data interpretation. The Orange River falls under Orange River Gorge ecoregion that was used in the interpretation.

Figure 2: SASS Interpretation in the Orange River Gorge Ecosystem (Source: Dallas, 2007)

Overall, macro invertebrates have indicated Fair for water quality and a moderately modified system in category C. However, water quality parameters were within accepted limits except for turbidity and chlorophyll a. This could be due to what Dickens and Graham (2002) and Ollis *et. al*., (2003) stated in their studies that aquatic organisms are able to tell the cumulative effects of pollution; which might have been missed in physico-chemical sampling. This is likely to be happening in this river stretch where flow is determined by dam releases which might have a positive dilution effect on the parameter concentrations.

3.2 Physicochemical Parameters

The water quality is fairly good for its deemed use. pH was found to be alkaline with mean level of 8.56 for all sampling periods. Summer months recorded the hottest as would be expected for temperature with maximum of 30 ^{0}C. Dissolved Oxygen was also normal for all the sampling periods with mean concentration of 8.14. Electrical

Conductivity and Total Dissolved Solids were corresponding such that when the former goes up the latter also increased and vice versa as they indicate the salinity of the water. All parameters, except turbidity and chlorophyll a were within the accepted limits for Namibia, South Africa and USEP standards.

Electrical conductivity was fluctuating in a similar manner that showed slightly high concentrations in low flows. These two parameters tallied as they both indicate the salt concentration and organic and inorganic substances in the water. The dilution effects in high flows might have kept the concentrations relatively low.

3.3 Influence of Land-use activities on water quality

The Landsat images of 2002 and 2012 have shown slight changes in land-use activities especially in the irrigated area. The total irrigated area for 2002 and 2012 were 3579 ha and 3617 ha respectively, with the difference of 38 ha in 10 years. This is somehow showing a relationship between water quality and land use in Namibia whereby both have not shown a tremendous change in the last 10 years. After 10 years, water quality concentrations were still in the same range. The return flow and effluent from the irrigation schemes and settlements at Noordoewer and Aussenkehr might be infiltrating the ground or insignificant to cause major changes in the water quality of the river in Namibia. However, the presence of total coliforms at all eight sites in the river needs to be investigated further. As such, the slight water quality changes in Namibian river reach e.g. turbidity, chlorophyll a; TDS, etc might not be directly due to land-use activities in the country. It might also be that the dam releases are neutralizing the concentrations to a greater extend. Perhaps, the water received from dams upstream is also of compromised

quality. It is stated in the study by ORASECOM (2008) that water quality of the Vaal River system, which feeds Vanderkloof dam, is of low quality due to industrial, urban, mining and irrigation activities in the catchment. Lack of good water quality data made it difficult to really see the connection between land-use and water quality as the only historical data available was irregular and from a single point along the river.

4 CONCLUSIONS

Bio assessment (SASS) results showed that the river is in category C which is a moderately modified system with fair water quality. There was less spatial variation in the water quality parameters. The tested parameters indicated the quality of the water in the Orange River is still fairly good, though with some slight level of deterioration. Although there was no major changes observed in the land use activities especially agriculture, slight water quality changes detected in the river may be a result of combined factors such as land-use activities upstream of the area or cumulative concentrations of the water quality parameters in the river and reduced flow in terms of dilution. However, this study could not establish whether land use activities alone, in the study area, had the influence in the water quality.

Acknowledgements

Authors would wish to thank WaterNet for financially supporting this study through Masters Programme in Integrated Water Resources Management IWRM) at the University of Dar es Salaam, Tanzania

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