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An Assessment of the Komati River Water Quality Along the Komati Downstream Development Project (KDDP) Area

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Abstract

Rivers provide the sustainable water for domestic, industrial and agricultural applications. However, it can be polluted by the catchment activities. An experiment was conducted to assess the quality of the Komati River water in the Komati Downstream Development Project (KDDP) area. It had one treatment; the Komati River water with two replications. The WHO water quality guidelines were used as a control. Water samples were collected at three sites (Madlanempisi, Nkambeni and Malibeni) along the Komati River within the KDDP area during the rainy season and the dry season. The river water was tested for physical quality (pH and turbidity) and chemical quality (Nitrate and Phosphate). Data analysis was conducted using one-way ANOVA in SPSS version 2.0 computer software. The results reflected that the physical river water quality in terms of pH at Mandlangempisi, Nkambeni and Malibeni was 7.31, 7.29 and 7.20 during the rainy season and it was 7.30, 7.21, and 7.30, during the dry season, respectively. The turbidity of the river water was 50.85 NTU at Mandlangempisi, 79.90 NTU at Nkambeni and 33.75 at Malibeni during the rainy season. The river water turbidity was 17.06 NTU, 27.75 NTU and 24.90 NTU at Madlangempisi, Nkambeni and Malibeni during the dry season, respectively. The chemical quality of the river water reflected that the mean nitrates of the Komati iver water were higher (1.80 mg/L at Madlangempisi, 1.90 mg/L at Nkambeni and 1.25 mg/L at Malibeni) during the rainy season compared to the dry season (0.31 mg/L at Madlangempisi, 0.59 mg/L at Nkambeni and 0.90 mg/L at Malibeni). This trend was the same with the river water phosphates. It was concluded that the river water met the WHO drinking water quality guidelines for most parameters. The nitrate levels were below the WHO guideline (10 mg/L). However, the phosphate exceeded the WHO guideline (0.1 mg/L). The intense agricultural activities in the KDDP area polluted the Komati River water, however the pollution had not reached extreme proportions.

Keywords

Assessment, Water Quality, Komati River, Komati Downstream Development Project (KDDP)

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1. Introduction

Water is an indispensable commodity; every living creature needs it for survival. Man needs water to drink as well as for domestic purposes, irrigation of arable land to grow crops, hydropower development, industry, navigation and fishing. In simple words there is no life without water. According to Rashida *et al* (2016) water is important in maintaining adequate food supply and a productive environment for the human population and other animals, plants and microbes worldwide. An adequate supply of water is a prerequisite for significant socio-economic development of a community (Whaley and Cleaver, 2017).

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In Africa today, more than half of the population lives without safe drinking water and two thirds lack adequate sanitary means of excreta disposal. Contaminants such as bacteria, viruses, heavy metals, nitrates and salts have polluted water supplies as a result of inadequate treatment and disposal of waste from humans, livestock, industrial discharges and overuse of limited water resources (Beyene *et al*, 2016). The fast growing world population is contributing to the deterioration of the existing water quality and is creating challenges for water managers, industry, fish and wildlife agencies (UNDESA, 2015). Unsustainable use of water resources has an impact on the livelihoods of some of the world's vulnerable communities as they rely on water resources for basic needs.

Rivers and streams drain water that fall within their catchments. Flowing water dilutes and decomposes pollutants more rapidly than stagnant water, however many rivers are significantly polluted around the world. According to Edokpayi *et al*, (2017) river pollution is a serious and emerging problem in the majority of developing countries. This is primarily because all three major sources of pollution; agricultural, industrial and domestic pollution are mostly concentrated along rivers (Paul, 2017; Lenntech, Undated). According to Hess *et al*, (2016), agriculture both irrigated and rain-fed is a major cause of water quality problems in many regions. In a study undertaken in Swaziland, Mhlanga *et al* (2006) concluded that agriculture is the most common source of nonpoint pollution from rainfall runoff as well as return flows from irrigated agriculture. This is because the agricultural inputs like pesticides and nutrients mainly Nitrogen and Phosphorus are often derived from extensive areas and transported overland or through seepage underground to the receiving waters.

In Swaziland, water resources are continually threatened by agricultural and industrial activities. Past studies by Mhlanga *et al* (2006); Mthimkhulu *et al* (2005) along the Mbuluzi River indicated that the water quality and the ecosystem health was strongly related to the existing land use activities within the Mbuluzi catchment, which are mainly agricultural and industrial (sugar milling).

The Komati River is one of the major rivers in Swaziland. The lower Komati River is a sub-basin of the Komati River, a trans-boundary river shared by the Republic of South Africa, Swaziland and Mozambique. In Swaziland, a major development by the name Komati Downstream Development Project (KDDP) was established by the Swaziland Water and Agricultural Development Enterprise (SWADE) along this river. The aim was to alleviate poverty and improve the standard of living through the provision of portable water supply and irrigation water supply for commercial agriculture in the surrounding communities. Presently there are Farmers Associations growing sugarcane and other crops in large acreages along the Komati River catchment. Some also practice small scale livestock farming.

Water quality issues in the Komati River have an implication on the development treaty which calls for the protection of existing water quality for downstream domestic and agricultural users (Dlamini, 2009). The lower Komati River is prone to water quality degradation as it is surrounded by intense agricultural activities. The KDDP Farmers Associations grow mainly sugarcane and other crops along the catchment and this involves activities such as tillage, irrigation as well as fertiliser, herbicide and pesticide application. A total of 1800 tonnes of NPK fertilisers are applied per year at the KDDP in the 3000 ha of agricultural land. This was developed within a 3 km distance from the Komati River, which is the main source of water to a population of 27000 people. Locals also practice illegal dagga farming in the catchment along the riparian zones of the river, which also involves the use of inorganic fertilisers and manures. According to Vilane and Tembe, (2016) rivers are an important source of water, but their quality is a function of the catchment activities. The effect of the farming activities in the Komati River catchment is capable of compromising water quality in the Lower Komati River, hence the study. The study was driven by the following objectives.

i. To determine the physical water quality (Turbidity and pH) in the Komati River along the KDDP area.

ii. To assess the chemical water quality (Nitrates and Phosphates) in the Komati River along the KDDP area.

2. Methodology

2.1. Description of the Study Area

The study area lies along the lower Komati River basin. It stretches on both sides of the Komati River from Madlangampisi all the way to Mananga, North-east of Swaziland. Agriculture is a dominant activity in the area with sugarcane being the mainly grown crop. The total area covered by the Lower Komati catchment is 25 000 ha with about 4 500 ha under commercial sugarcane cultivation. The climate is sub-tropical and semi-arid with a mean annual rainfall of 780 mm. Summer rains are experienced between the months October and March, with the cool and dry winter season extending from May until August. Maximum summer temperatures reach 34.8°C, while winter minimum temperatures are about 10°C. Annual evaporation is 2 100 mm with monthly averages of 6 - 8 mm per day. Since sugarcane is grown extensively in the KDDP area, irrigation is thus a necessity and the net applications range from 500 mm to 1 200 mm all year.

2.2. Research Design

The study was experimental in nature. There was one treatment, the Komati River water with two replications. The World Health Organisation (WHO) drinking water quality guidelines were used as a control.

2.3. Sampling Procedure

Water samples were collected using 500 ml sterilized bottles. The grab sampling technique was employed for sampling at approximately 20 cm from the river water surface. The samples were taken at three sites along the Komati River with two replications on each site. The first sampling site was at Madlangampisi Bridge before the KDDP sugarcane fields with the coordinates 25° 93' 65" S and 31° 75' 802" E. The second sampling site was at Nkambeni near the KDDPs Ingcayizivela FA fields with the coordinates 25° 95' 66" S and 31° 72' 259" E. The last sampling site was at Malibeni after the KDDP's Intamakuphila FA fields, with the coordinates 26° 28' 28" S and 31° 34' 30" E. Six samples were collected in total, two at each site. The collection of samples was done during the rainy and dry seasons.

2.4. Data Collection and Analysis

To avoid decomposition, the water samples were transported to the laboratory in a cooler box with ice cubes on the same day. The samples were tested for physical and chemical quality. The results from the tests were entered in SPSS version 2.0 software utilizing one way ANOVA. The WHO drinking water quality guidelines were used as the control.

2.4.1. Physical Water Quality Analysis Methods

Analysis of the physical quality involved testing for pH and turbidity from the Komati River water samples collected.

a) Turbidity

Turbidity was determined using the Absorptometric Method from the FWPCA for chemical analysis of water and wastes, 275 (1969). The spectrophotometer wavelength was rotated until the small display showed 450 nm and 25 ml of the sample when placed into the cell holder (Hatch company, 1999).

b) pH

The table pH meter was used to measure the pH in the river water samples. An electrode was immersed in each sample, then pH readings were taken after 30 seconds. The electrode was then rinsed with distilled water and wiped to dry. The WHO pH guideline is 6.5 – 8.5.

2.4.2. Chemical Water Quality Analysis Methods

a) Phosphates

The PhosVer 3 Method TNT was used to determine the levels of phosphates in the river water samples. This method is adopted from HACH Company. Using a pipette, 5.0 mL of the sample was added to a Reactive Phosphorus Test N Tube Dilution Vial and mixed. The vial was then inserted into a cell holder and the instrument was set to zero, reading 0.00 mg/L PO_4^{3-}. Then after, using a funnel, the contents of one Phos Ver 3 Phosphate Powder Pillow were added to the vial. The vial was capped immediately and shaken for 20 seconds. The results were read eight minutes after adding the Phos Ver 3 reagent. The WHO guideline value for phosphate is < 0.5 mg/L.

b) Nitrates

The Cadmium Reduction Method for Powder Pillows was used to determine the level of nitrates in the river water samples. A sample cell was filled with 10 mL of the sample and the contents of one Nitra Ver 5 Nitrate Reagent Powder Pillow were added. A stopper was inserted into the cell and then the cell was shaken vigorously for one- minute. After five minutes, the prepared sample was inserted into a cell holder and the results were read from the instrument. The WHO guideline for nitrates is < 10 mg/L.

3. Results and Discussion

3.1. Physical Water Quality Results

a) Turbidity

The results reflected that the mean turbidity of the Komati River water was 50.85 NTU at Madlangampisi, 79.90 NTU at Nkambeni and 33.75 NTU at Malibeni during the rainy season. On the other hand the mean river water turbidity during the dry season, was 17.05 NTU at Madlangampisi, while at Nkambeni and Malibeni, it was 27.75 NTU and 24.90 NTU, respectively (Figure 1).

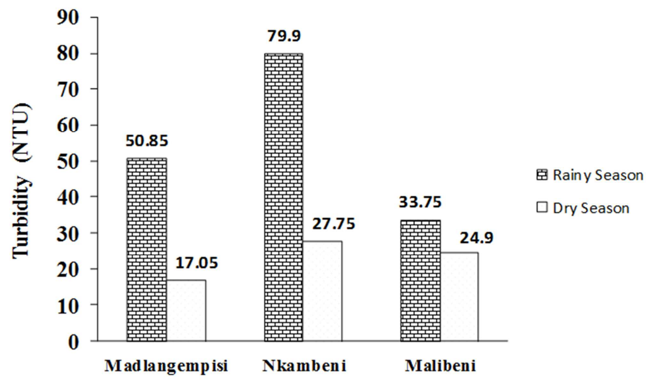

Figure 1. Turbidity of the Komati River water.

The results indicated that in both seasons the turbidity of the Komati River water was above the WHO drinking water quality guideline (5 NTU). Turbidity in the river was high in the rainy season, which could be attributed to runoff that carries with it sediments from fields and riparian zones of the Komati River. High turbidity in the Komati River water may compromise the operation of irrigation systems used within the KDDP farms by blocking or clogging pipes and sprinklers.

The results of further analysis in Table 1 reflected that the river water turbidity at Madlangampisi was not significantly different (P> 0.05) from that at Malibeni. The turbidity of the river water at Nkambeni was significantly different (P<0.05) from that at Madlangampisi and Malibeni, during the rainy season. This could be explained by the numerous hectares of cane fields along the river course between Madlangampisi and Nkambeni. Sugarcane cultivation involves tilling the soil which makes it susceptible to erosion resulting in sediments being carried into the river water nearby during rainfall or heavy irrigation events. As a result the river water at Nkambeni had the highest (79.90 NTU) turbidity. The effect of the Mhlume Water weir between Nkambeni and Malibeni had an impact on the turbidity of the river water on the other side. Sediments settle down in the weir, reducing the turbidity on the lower reaches of the Komati River and this explains the low (33.75 NTU) turbidity of the river water at Malibeni.

Table 1. Komati River water rainy season turbidity analysis of variance.

Sampling Station		Mean Difference	Standard Error	Sig. (P-value)
Madlangampisi	Nkambeni	-29.050	6.642	0.022*
	Malibeni	17.100	6.642	0.082
Nkambeni	Madlangampisi	29.050	6.642	0.022*
	Malibeni	46.150	6.642	0.006*
Malibeni	Madlangampisi	-17.100	6.642	0.082
	Nkambeni	-46.150	6.642	0.006*

* The mean difference is significant at the 0.05 level.

Table 2 indicated that during the dry season the turbidity of the river water at Nkambeni and Malibeni were not significantly different (P > 0.05). The river water turbidity at Madlangampisi was significantly different (P < 0.05) from the river water at Nkambeni and Malibeni. This could be attributed to the heavy irrigation in the sugarcane fields that takes place in winter (dry season) in the absence of rains. Irrigation return flows could be responsible for the increased turbidity at Nkambeni and Malibeni.

Table 2. Komati River water dry season turbidity analysis of variance.

Sampling Station		Mean Difference	Standard Error	Sig. (P-value)
Madlangampisi	Nkambeni	-10.700	1.147	0.003*
	Malibeni	-7.850	1.147	0.006*
Nkambeni	Madlangampisi	10.700	1.147	0.003*
	Malibeni	2.850	1.147	0.089
Malibeni	Madlangampisi	7.850	1.147	0.006*
	Nkambeni	-2.850	1.147	0.089

* The mean difference is significant at the 0.05 level.

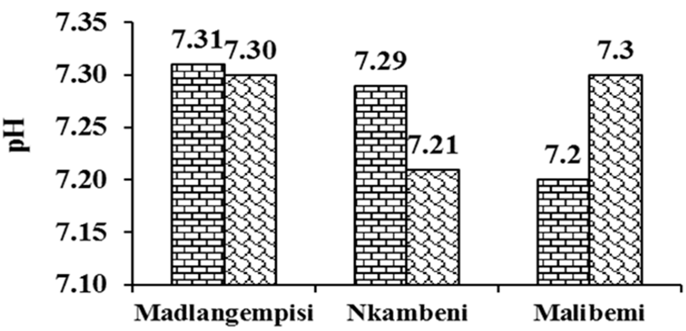

Figure 2. Mean pH of the Komati River water.

a) pH

The results in Figure 2 indicated that during the rainy season, the mean pH of the Komati River water fluctuated from 7.31 to 7.29 and 7.30 within the river course at Madlangampisi, Nkambeni and Malibeni, respectively. The mean pH was 7.30 at Madlangampisi, 7.21 at Nkambeni and 7.30 at Malibeni during the dry season.

It was evident form the results that the mean pH of the Komati River water was within the WHO drinking water quality guideline range of 6.5 - 8.5 in both seasons. The main use of pH in water analysis is for detecting abnormal water. The normal pH range for irrigation water is 6.5-8.4. Irrigation water with a pH outside the normal range may cause nutritional imbalance or contain a toxic ion. Water with lower pH may corrode pipes, sprinklers and control systems. The water pH indicated that the water was in the normal range for irrigation. The river water pH was not significantly different (P > 0.05) between the sampling sites during the rainy season or the dry season (Table 3).

Table 3. Komati River water rainy season pH analysis of variance.

Sampling Station		Mean Difference	Standard Error	Sig. (P-value)
Madlangampisi	Nkambeni	0.015	0.043	0.749
	Malibeni	0.010	0.043	0.830
Nkambeni	Madlangampisi	-0.015	0.043	0.749
	Malibeni	-0.005	0.043	0.914
Malibeni	Madlangampisi	-0.010	0.043	0.830
	Nkambeni	0.005	0.043	0.914

* The mean difference is significant at the 0.05 level.

The results in Table 4 indicated that the river water pH was not significantly different (P> 0.05) between the sampling stations during the dry season. This means that the water pH was normal throughout the river course, i.e. it was not affected much by the catchment activities.

Table 4. Dry season pH analysis of variance.

Sampling Station		Mean Difference	Standard Error	Sig. P-value
Madlangampisi	Nkambeni	0.085	0.073	0.332
	Malibeni	0.000	0.073	1.000
Nkambeni	Madlangampisi	-0.085	0.073	0.332
	Malibeni	-0.085	0.073	0.332
Malibeni	Madlangampisi	0.000	0.073	1.000
	Nkambeni	0.085	0.073	0.332

*. The mean difference is significant at the 0.05 level.

3.2. Chemical Water Quality Results

a) Nitrates

Table 5. Komati River water Nitrates.

Nitrates (mg/L)			
Season	**Madlangampisi**	**Nkambeni**	**Malibeni**
Rainy Season	1.80	1.90	1.25
Dry Season	0.31	0.59	0.90

The results in Table 5 reflected that the mean nitrates of the Komati River water at Madlangampisi was 1.80 mg/L, while at Nkambeni and Malibeni it was 1.90 mg/L and 1.25 mg/L, respectively during the rainy season. During the dry season, the mean nitrate levels were 0.31 mg/L at Madlangampisi, 0.59 mg/L at Nkambeni and 0.9 mg/L at Malibeni.

The Komati River water nitrates were within the WHO drinking water guideline of 10 mg/L. However, the nitrate exceeded 0.1 mg/L, which is a limit for natural waters. The nitrates were high during the rainy season. This could be attributed to runoff which carries inorganic nitrates from the KDDP sugarcane fields, where inorganic NPK and Urea fertilizers are used. Meanwhile, for unknown reasons, the results in Table 6 indicated that the nitrates between the sampling sites were not significantly different (P > 0.05) in both seasons.

Table 6. Komati River water rainy season nitrate analysis of variance.

Sampling Station		Mean Difference	Standard Error	Sig. (P-value)
Madlangampisi	Nkambeni	-0.100	0.234	0.699
	Malibeni	0.550	0.234	0.101
Nkambeni	Madlangampisi	0.100	0.234	0.699
	Malibeni	0.650	0.234	0.069
Malibeni	Madlangampisi	-0.550	0.234	0.101
	Nkambeni	-0.650	0.234	0.069

* The mean difference is significant at the 0.05 level.

The results in Table 7 reflected that the river water nitrates were not significantly different between the sampling stations even during the dry season. During the winter (dry) season local people carryout smaller agricultural operations such as vegetable gardening and dagga farming along the riparian zones of the Komati River, especially in the areas before the KDDP farms. These activities contribute nitrates to the river even before it reaches the KDDP area, where irrigation return flows from the sugarcane fields also contribute nitrates into the river water.

Table 7. Komati River water dry season nitrate analysis of variance.

Sampling Station		Mean Difference	Standard Error	Sig. (P-value)
Madlangampisi	Nkambeni	-0.575	0.201	0.065
	Malibeni	-0.590	0.201	0.061
Nkambeni	Madlangampisi	0.575	0.201	0.065
	Malibeni	-0.015	0.201	0.945
Malibeni	Madlangampisi	0.590	0.201	0.061
	Nkambeni	0.150	0.201	0.945

* The mean difference is significant at the 0.05 level.

a) Phosphates

The mean phosphate levels of the Komati River water during the rainy season was 0.17 mg/L, 1.06 mg/L and 0.19 mg/L at Madlangampisi, Nkambeni and Malibeni, respectively. The results indicated that the Komati River water were low in phosphates in the dry season. The mean river water phosphate was 0.19 mg/L at Madlangampisi, 0.30 mg/L at Nkambeni and 0.20 mg/L at Malibeni during the dry season (Table 8).

Table 8. Mean phosphate levels of the Komati River water.

Phosphates (mg/L)			
Season	**Madlangampisi**	**Nkambeni**	**Malibeni**
Rainy Season	0.17	1.06	0.19
Dry Season	0.19	0.30	0.20

The phosphate levels in the river water were above the WHO water quality guideline ($P<0.5$ mg/L). The results indicated that the Komati River water phosphate levels were also above the USEPA criterion of 0.01 – 0.03 mg/L PO_4-P for uncontaminated water bodies. The use of fertilizers in sugarcane production could be the source of the phosphates contaminating the river water. Phosphate levels in the river water were higher during the rainy season compared to the dry season. This could be again attributed to the runoff from rains which carry inorganic phosphates from the nearby fields into the river during the rainy season.

The results of further analysis in Table 9 indicated that the phosphate in the river water between Madlangampisi and Nkambeni were significantly different ($P < 0.05$) during the rainy season. Phosphate levels in the Komati River water was not significantly different ($P > 0.05$) between Nkambeni and Malibeni. This could be due to the fact that there are three KDDP sugarcane farms along the river course before Nkambeni, while more than four farms drain into the Komati River before Malibeni. This increases the accumulation of phosphates in the river water going downstream, especially during the rainy season.

Table 9. Komati River water rainy season Phosphate analysis of variance.

Sampling Station		Mean Difference	Standard Error	Sig. (P-value)
Madlangampisi	Nkambeni	-0.890	0.202	0.022*
	Malibeni	-0.700	0.202	0.041*
Nkambeni	Madlangampisi	0.890	0.202	0.022*
	Malibeni	0.190	0.202	0.418
Malibeni	Madlangampisi	0.700	0.202	0.041*
	Nkambeni	-0.190	0.202	0.418

* The mean difference is significant at the 0.05 level.

Table 10. Komati River water dry season phosphate analysis of variance.

Sampling Station		Mean Difference	Standard Error	Sig. (P-value)
Madlangampisi	Nkambeni	-0.025	0.027	0.429
	Malibeni	-0.105	0.027	0.031*
Nkambeni	Madlangampisi	0.025	0.027	0.429
	Malibeni	-0.080	0.027	0.061
Malibeni	Madlangampisi	0.105	0.027	0.031*
	Nkambeni	0.080	0.027	0.061

* The mean difference is significant at the 0.05 level.

The results in Table 10 reflected that during the dry season phosphate concentrations in the Komati River water at Madlangampisi were significantly different ($P<0.05$) to the river water at Malibeni, while the river water phosphate between Nkambeni and Malibeni was not significantly different ($P > 0,05$) as well as the river water between Nkambeni and Madlangampisi. This could be attributed to the irrigation return flows from the KDDP sugarcane fields closer to Nkambeni and Malibeni carrying with it inorganic phosphates into the river water since there are more often than not, no rains in the dry season.

4. Conclusions

The physical quality of the Komati River in terms of the mean pH was within the WHO water quality guideline value range of 6.5 – 8.5 at all sampling sites in all sampling seasons. The turbidity of the Komati River water was higher during the rainy season compared to the dry season. The turbidity of the water was above the WHO drinking water standard guideline value of 5 NTU in both seasons. It was concluded that based on the turbidity, the physical quality of the Komati River water was not acceptable.

The chemical quality of the Komati River water in terms of the mean nitrate was within the WHO drinking water quality guideline (< 10 mg/L) in both seasons. The Komati River water phosphate level was acceptable on the basis of the WHO water quality guideline (< 0.5 mg/L). However at Nkambeni, the mean phosphate level was above the WHO water quality guideline value during the rainy season. It was concluded that even though the sugarcane growing in the KDDP area contributed nutrients into the Komati River water, the water was currently safe for domestic use based on the Nitrate and Phosphate concentrations, but may reach levels above water quality guidelines as seen in the river water at Nkambeni during the rainy season.

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