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Full Length Research Paper

Effect of agricultural and industrial developments on the quality of water at UMhlathuze River (Northern Coast of Kwa-Zulu Natal, RSA)

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UMhlathuze River is the main recipient of domestic, sewage, industrial and agricultural waste from local industrial and agricultural practices. Scarcity of water resources and the contamination of UMhlathuze River by agricultural and industrial developments make communities around UMhlathuze area susceptible to potential outbreaks of water-borne diseases as well as the risk of ingesting carcinogenic substances. In determination of the effect of human developments on the UMhlathuze River, four different sites representing different human activities were used for sampling along the river. Temperature and pH were monitored *in situ* using potable meters. Spectroquadrant Pharo 300 (Merck) was used for chemical analysis of water. Chemical oxygen demand (COD) was measured using spectrophotometric methods. Microorganisms were isolated and identified using standard biochemical methods. Temperature and pH were found to vary between 19 to 21 and 6.2 to 7.8°C, respectively. COD was found to be higher in areas affected by both industrial and agricultural activities. Agricultural waste recipient area had high concentration of phosphate, ammonia and nitrate. Parts of the river receiving effluent from treated wastewater had high sulphide, nitrate and ammonia concentrations. Industrial areas have a high concentration of heavy metals (for example Aluminium). Microorganisms found in all sites included *Escherichia coli* and species of *Salmonella, Shigella, Citrobacter, Serratia* and *Enterobacter,* although their numbers differed from agricultural to industrial sites. Agricultural and industrial development activities practiced along UMhlathuze River were found to have a huge contribution to the continued deterioration of the quality of water at UMhlathuze River.

Key words: UMhlathuze River, water pollution, water quality, public health, agricultural and industrial developments.

INTRODUCTION

The use of contaminated water has always been a major concern for public health. This results mainly from contamination of the sources of potable water (Friedrich et al., 2009). In rural areas surrounding the UMhlathuze River, this phenomenon has become a daily problem due to human activities such as agricultural practices and industrial activities. Most of the people in this community depend on UMhlathuze River as well as dams, wells and streams as their primary source of potable water (Hall et al., 2004). Communities that are dependent on these sources are using water without prior treatment, exposing themselves to high risks of waterborne illnesses.

UMhlathuze area is situated next to Richards Bay, with the river running from Eshowe to the Indian Ocean in Richards Bay (Figure 1). This region is a fast growing agricultural and industrial sector. These human development activities have potential to contribute in the prevalence of water pollution at UMhlathuze River (Bezuidenhout et al., 2002). Some companies in Richards Bay do not have proper effluent disposal systems. Their effluents are washed off and drained into

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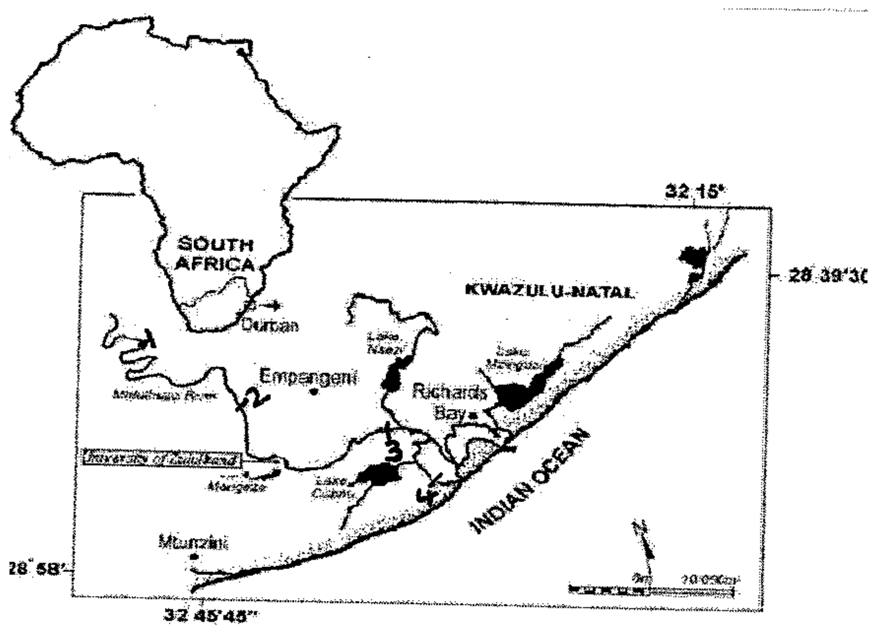

Figure 1. Study area of UMhlathuze River showing sampling sites along UMhlathuze River. (1- Kwa-Dlangezwa); (2-Felixton bridge); (3- Mzingazi) and (4- UMhlathuze station). River flows from 1 (Kwa-Dlangezwa) to 4 (UMhlathuze station).

the river. Companies like Exxaro, Ninias query and Mzansi Sand Supply have mining activities along the banks of the river. Effluents discharged during mining are deposited directly into the river. These deposits increase microbial and chemical contamination in the river. Felixton Huletts is another company situated in the heart of the uMhlathuze rural area, which produces sugar, animal feeds, industrial sweeteners, etc. The company owns about 11417 hectares of sugarcane farmland within which the company is situated. This, together with other non-commercial farming by individuals within the community contributes to high agricultural activities in this area. For proper crop development, fertilizers are constantly applied and during heavy rainfalls, remains of unused fertilizers are washed off to the river, causing eutrophication.

Although previous studies were conducted in this area assessing the quality of water at UMhlathuze River and its surrounding community (Bezuidenhout et al., 2002; Lin et al., 2004), the effect of growing agricultural and industrial developments on UMhlathuze River has never been addressed. Evaluation of the effect of these human activities on UMhlathuze River could aid in decision making for the restoration of the quality of water in the river by establishment of preventative measures against agricultural and industrial derived pollution. Thus, the main aim of this work was to investigate if the increasing contamination levels at UMhlathuze River can be attributed to industrial developments and agricultural practices in this area through evaluation of their effect on the quality of water in the river.

MATERIALS AND METHODS

Water samples were collected from four sites along UMhlathuze River situated in the rural area on the Northern coast of Kwa-Zulu Natal (Figure 1). Sites were chosen to represent areas mainly affected by agricultural and industrial activities. The four sites used were Kwa-Dlangezwa (agriculture), Felixton Bridge and Mzingazi (agriculture and industrial area) and UMhlathuze station (industrial area) as shown in Figure 1. Samples were collected monthly from February 2008 to November 2009.

Microbiological analysis

Water samples were collected using Scott bottles and were placed in an ice-cold cooler box and transported to the laboratory where they were analysed within six hours of collection. Sampling was done twice a month. For total and fecal coliform counts and determination, a series of tenfold dilutions were prepared and inoculated on m-FC agar, m-Endo agar, EMB agar, Nutrient agar, S-S agar and MacConkey agars. m-FC plates were incubated at 44.5°C for 24 h while the rest of the plates were incubated at 37°C for 24 h. Membrane filtration technique was also used with above agar plates and temperatures being used. Single colonies were randomly selected from the plates and colonies were identified by Gram stain, biochemical tests and API 20E strips (Biomerix). Identified microorganisms were confirmed by sequencing.

Physical and chemical analysis

Surface water temperature, pH, turbidity and conductivity were monitored *in situ*. Temperature and pH were measured using potable mercury thermometer and pH meter respectively. Conductivity and turbidity were measured using aqualytic turbidity meter (Merck). Chemical oxygen demand (COD), biochemical

Table 1. Average values of water quality indicators measured along different sites at UMhlathuze River.

Parameter	Kwa-Dlangezwa	Felixton bridge	uMhlathuze station	Mzingazi	Limits*
Environmental T (°C)	10.8 - 25.3	15.1 - 26.2	12.4 - 26.6	19.8 - 30.3	N/A
Surface water T (°C)	19	19	21	20	N/A
Rainfall (mm)	96.2	85.4	162	137.6	N/A
Humidity (%)	87	85	89	92	N/A
COD (mg/l)	30	70	23	280	75
BOD (mg/l)	0.44	0.42	0.21	0.11	5
pH	7.8	6.8	6.2	6.5	6-9
Turbidity (%)	1.4	1.4	1.9	1.9	1
Conductivity (mS/m)	48.7	50.8	48	48.7	70
TSS (mg/l)	10	7	4	4	25
Phosphate (mg/l)	1.6	1.8	0.24	0.2	1
Ammonia (mg/l)	1.2	0.6	0.22	0.2	1
Sulphide (mg/l)	2.6	0.8	0.18	0.12	N/A
Chloride (mg/l)	140	100	100	210	100
Nitrate (mg/l)	0.7	0.6	0.33	0.31	6
Fluoride (mg/l)	0.064	0.057	0.037	0.018	1
Manganese (mg/l)	0.29	0.38	0.34	0.6	0.05
Lead (mg/l)	0.28	0.38	0.5	0.3	10
Aluminium (mg/l)	0.17	0.28	1.4	1.62	0.15
Mercury (mg/l)	N/A	N/A	0.25	0.4	1
Cupper (mg/l)	N/A	0.06	0.08	0.08	1
Cadmium (mg/l)	N/A	0.003	0.004	0.004	5
Fecal coliforms/ml	350	455	152	220	0
Total coliforms/ml	5×10^4	5.5×10^4	2×10^4	3×10^4	N/A

*Department of Water Affairs and Forestry, (1996).

oxygen demand (BOD), heavy metals (lead, aluminium, mercury, copper, manganese and cadmium) and inorganic chemicals (total phosphates, ammonia, sulphide, chloride, nitrate and fluoride) were measured using spectrophotometer, Spectroquandrant Pharo 300 as per manufacturer's manual. Rainfall data, environmental temperature and humidity were obtained from South African Weather Service.

Statistical analysis

Pearson's coefficient was used to establish the correlation between the levels of indicators (COD, BOD, TSS, fecal coliforms, chemicals and heavy metals) in samples collected from the river and samples from influents. Results obtained from the river and those obtained from the influents were compared to be establish if there was any relationship/correlation between these two sets of results.

RESULTS AND DISCUSSION

Table 1 present results of water quality indicators tested. Total and fecal coliform counts were found to be high at Felixton Bridge, 455 CFU/ml; followed by Kwa-Dlangezwa, 350 CFU/ml; Mzingazi, 220 CFU/ml and at UMhlathuze station had 152 CFU/ml.

Kwa-Dlangezwa sampling site receives agricultural waste from local agricultural areas. Domestic waste is also introduced in this area/site as has homesteads. Waste from animal farming is also present. Increased microbial counts were observed as compared to UMhlathuze station and Mzingazi in this site. Increased microbial counts at this point may have been introduced from agricultural activities, including animal farming. These observations, however, varied with rainfall patterns. Microbial counts decreased to 300 CFU/ml during dry periods. In the preliminary studies of the samples collected before this point (Kwa-Dlangezwa), low microbial counts were observed. Ammonia and sulphide concentrations were found to be 1.2 and 2.6 mg/l respectively. Between 2001 and 2002, Lin et al. (2004) had found the averages of ammonia and sulphide to be 0.06 and 1.9 respectively. These results indicate a drastic increase of both microbial and chemical contaminants at UMhlathuze River. Cadmium, copper and mercury were not detected at Kwa-Dlangezwa. Heavy metals detected at this site were present in low concentrations. COD was also found to be increased when compared to previous studies. Felixton Bridge is mainly affected by both agricultural and industrial activities. This area also receives treated water effluent from the sewage treatment plant. Contamination from grazing cattle also does occur.

Nitrate, phosphate, total suspended solids and conductivity were found to be higher compared to UMhlathuze station and Mzingazi but less when compared Kwa-Dlangezwa. This may be attributed to activities taking place in this area. Like Kwa-Dlangezwa, mercury was not detected from this site. Effluent deposits from companies situated next to this area may have influenced the detection of heavy metals at this site. The pH was found to be lower (acidic) in industrially affected areas than in agriculturally affected areas. Low pH at UMhlathuze station (pH = 6.2), might have been influenced by high metal concentrations found at this site while high pH in agricultural affected areas influenced by inorganic salt concentrations.

Mzingazi had an average COD of 280 mg/l, which is far above the recommended limit of 75 mg/l (Department of Water Affairs and Forestry (DWAF), 1998; 1996). Mzingazi and UMhlathuze station are within Richards Bay industrial sites. Mzingazi receives pollution from both industrial and agricultural activities from non-commercial farming from the surrounding community while UMhlathuze station receives industrial pollution. Microbial counts from these sites were found to be 220 and 152 CFU/ml respectively. Low microbial counts may have resulted from high heavy metal concentrations detected from these sites as well as low domestic and agricultural practices. Nitrate, phosphate and ammonia are compounds mainly associated with agriculture. These compounds were found in low concentrations at UMhlathuze station, an area affected only by industrial activities but detected in higher concentrations in agricultural affected areas. Lead, mercury, copper, aluminium, manganese and cadmium were detected in higher concentrations at both UMhlathuze station and Mzingazi. Aluminium, in particular, was very high at Mzingazi. This site is nearby BHP Billiton (Aluminium Smelter Company) and Richards Bay Minerals (RBM).

Most companies in Richards Bay commercial area have proper effluent treatment and disposal systems. They dispose their treated effluents in the sea through pipe drainages. However, not all companies conform to this requirement. Some companies, particularly companies along UMhlathuze River dispose their treated and/or untreated effluent to UMhlathuze River. Research has indicated that BHP Billiton, an aluminium smelter, has neither effluent treatment nor proper effluent disposal systems, yet it is one of the biggest companies in the area. Industrial effluent is drained or washed off through stormwater and deposited into the river. This may result to increased metal concentrations found in the river.

On the sampling points, industrial effluents entering the river were also tested and found to have high concentrations of water quality indicators (Table 2). COD, turbidity, chloride, manganese and aluminium were found to be above the allowable limits in the environment as per DWAF (1996) requirements. Upon entering the river, these water quality indicators are diluted, thus detected in lower concentrations in the river (Table 1). Stormwater entering the river was also tested during heavy rainfalls to represent agricultural waste/activities. Phosphates, ammonia and microbial counts were high on the receiving water (Table 2), and their concentrations also decreased upon entering the river. Water quality indicators varied from different sites. Sites used were chosen to represent both agricultural and industrial activities taking place in the surrounding area of UMhlathuze River. At Kwa-Dlangezwa it was found that the main source of contamination is agricultural practices while Felixton Bridge and Mzingazi's contamination came from both agricultural and industrial pollutants. UMhlathuze station had its main contamination coming from industrial activities. This is evident because water quality indicators representing agricultural waste were only detected in high concentrations in agricultural affected areas while industrial indicator pollutants were only present in high concentrations in industrial affected area and vice versa. In areas affected by both agricultural and industrial activities, both set of pollutants representing each activity were detected in relatively higher concentrations. Like previous studies by Lin et al. (2004), our study also demonstrated that microbial contamination of UMhlathuze River increases with rainfall (Figures 2 and 3). Findings on agricultural practices leading to river contamination were also proved by Solo-Gabriel et al. (2000), who demonstrated that cyclic variations in microbial counts in the River can be ascribed to runoffs from agricultural farms due to storms.

Results obtained in this study regarding the quality of water in the river shows that the levels of indicators of water quality tested were significantly higher than as previously reported in recent studies (Bezuidenhout et al., 2002; Lin et al., 2004), though most were within the allowable limits. Increased concentration of heavy metals, chemicals and microbial counts is particularly a course for concern because local communities use water from this river for household purposes without prior treatment. The analysis of the relationship between the total level of contamination of UMhlathuze River and the agricultural pollutants (COD, BOD, TSS, fecal coliforms and inorganic chemicals) and industrial contaminants (inorganic chemical and heavy metals) has shown correlation coefficients of average values r = 0.36 and 0.38 respectively. Although previous studies by Lin et al. (2004), has ascribed increased microbial contamination to seasonal variations, water temperature and rainfall, our study, for the first time, has demonstrated a moderate relationship between agricultural and industrial developments to UMhlathuze River contamination. It has been observed in the study that the more agricultural and industrial activities are pursued in the area, the higher the contamination levels of UMhlathuze River. This was also demonstrated by (Cherchi and Gu, 2011). This is however not true with UMhlathuze station and Mzingazi as far as microbial contamination is concerned. Both total

Table 2. Average values of water quality indicators measured from the receiving water at the point of entry from agricultural and industrial affected areas.

Parameter	Kwa-Dlangezwa (Agric.)	Felixton (Agric./Industry)	UMhlathuze station (Industry)	Mzingazi (Agric./Industry)
Environmental T (°C)	10.8 - 25.3	15.1 - 26.2	12.4 - 26.6	19.8 - 30.3
Surface water T (°C)	19	19	21	20
Rainfall (mm)	96.2	85.4	162	137.6
COD (mg/l)	180	180	80	300
BOD (mg/l)	0.65	0.52	0.31	0.41
pH	8.0	6.6	6.0	6.3
Turbidity (%)	1.4	1.4	1.9	1.9
Conductivity (mS/m)	52.7	54.8	50	53.7
TSS (mg/l)	15	13	6	12
Phosphate (mg/l)	2.1	2.5	0.34	0.9
Ammonia (mg/l)	3.2	2.8	0.28	1.2
Sulphide (mg/l)	2.9	1.8	0.19	1.12
Chloride (mg/l)	360	240	140	310
Nitrate (mg/l)	1.7	1.6	0.35	1.31
Fluoride (mg/l)	0.084	0.067	0.038	0.032
Manganese (mg/l)	0.3	0.58	0.7	0.9
Lead (mg/l)	0.38	0.63	1.2	0.9
Aluminium (mg/l)	0.20	0.87	0.89	1.98
Mercury (mg/l)	N/A	N/A	0.29	0.8
Cupper (mg/l)	N/A	0.09	0.14	0.12
Cadmium (mg/l)	N/A	0.006	0.005	0.008
Fecal coliforms/ml	450	459	290	182
Total coliforms/ml	6×10^4	5.9×10^4	2.9×10^4	3.5×10^4

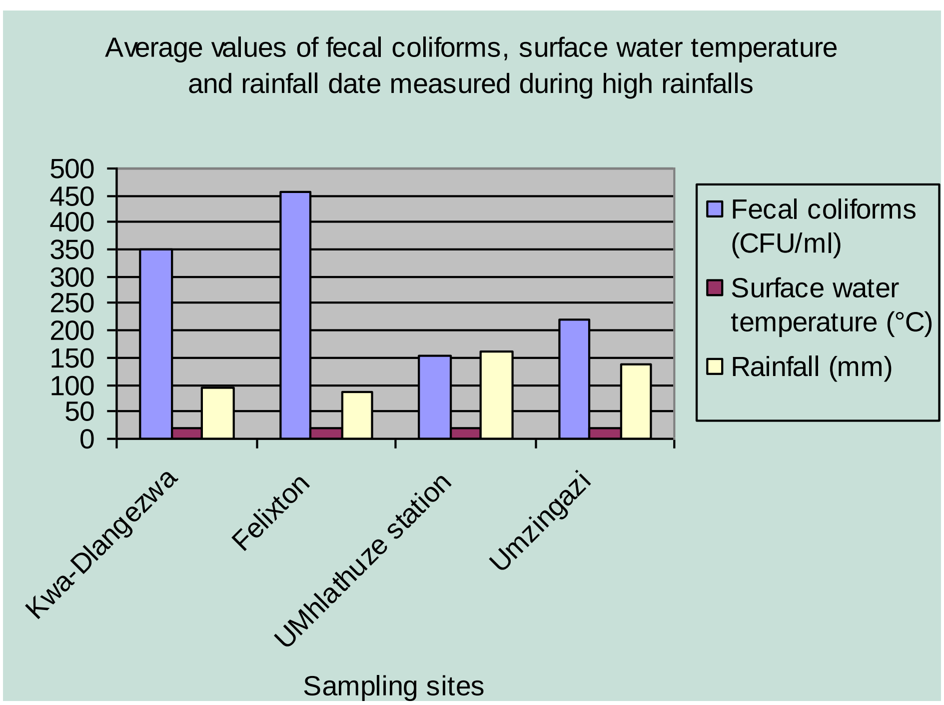

Figure 2. Fecal coliforms, surface water temperature and rainfall data measured along UMhlathuze River during high rainfall periods.

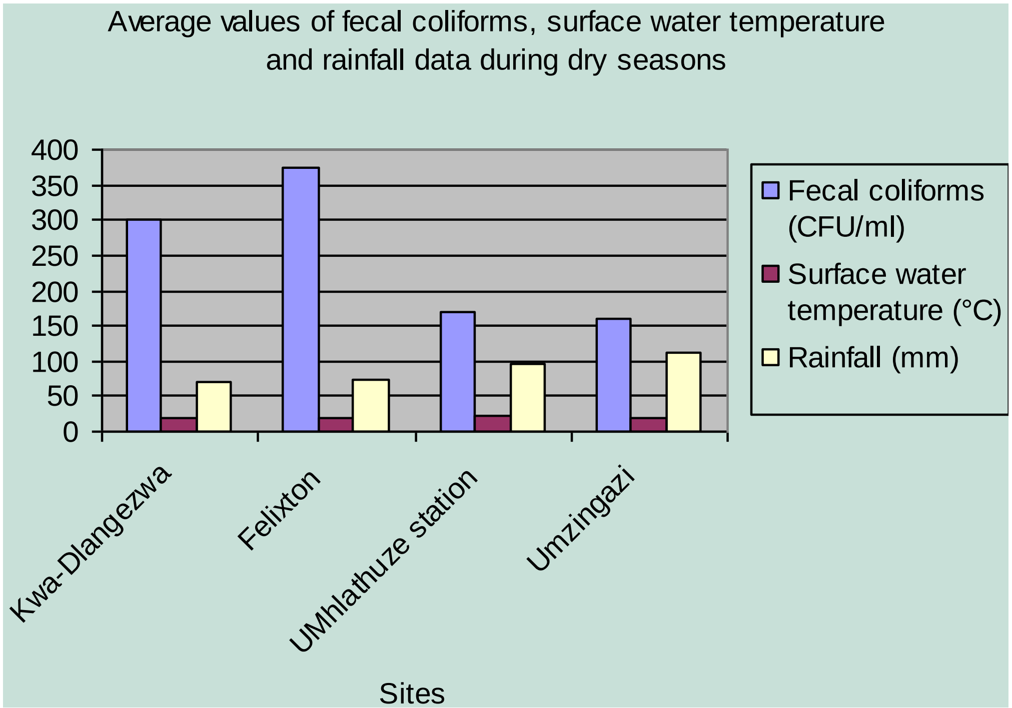

Figure 3. Fecal coliforms, surface water temperature and rainfall data measured along UMhlathuze River during dry seasons.

and fecal coliform counts decreased at these sites. The decrease of the organisms could be attributed to activities in these areas which have lethal effects to microorganisms. In overall, the comparison of UMhlathuze River water quality indicators to influents has shown a significant correlation. This implies that there is a direct relationship between UMhlathuze River contamination to human activities (Cherchi and Gu, 2011). UMhlathuze River flows from Kwa-Dlangezwa to Mzingazi. The decrease of coliforms may have also resulted from dying off and entrapment of microbes as water flows along the river, thus decreasing from one site to the next. This study is not intending to stop or prevent any developments that may take place in the area but rather suggest the use of more “river friendly” technologies that will not compromise the quality of water at UMhlathuze River.

Conclusion

The results of the study have shown an increase in contamination levels at UMhlathuze River when compared to previously conducted studies. It can be concluded that the main source of UMhlathuze River pollution is from growing agricultural and industrial developments in the surrounding environment as well as expanding human settlements. While the contributions from industrial activities are steady throughout the year, microbial and chemical contaminations from agricultural impacts fluctuate with seasons. Substitution of currently used synthetic fertilizers with more environmental friendly bio-fertilizers can reduce pollution in the river coming from agricultural practice. With a steady increase of contamination since the inception of industries along the river, government intervention is required. The Department of Water Affairs and Forestry in South Africa should enforce its rules and regulations to the companies to follow the standard requirement and guidelines of wastewater treatment and effluents disposals. This exercise can drastically reduce the overall levels of pollution entering the river; thereby prevent increasing contamination currently experienced at UMhlathuze River which could have a significant impact on the improvement of public health.

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REFERENCES

Bezuidenhout CC, Mthembu N, Puckree T, Lin J (2002). Microbial evaluation of the Mhlathuze River, KwaZulu-Natal (RSA). Water SA., 38(3): 281-285.

Cherchi C, Gu AZ (2011). Effect of bacterial growth stage on resistance to chlorine disinfection. Water Sci. Tech., 64(1): 7-13.

Department of Water Affairs and Forestry (DWAF) (1996). South African Water Quality Guidelines, Domestic Water Use, 2nd, Pretoria, pp. 77-99.

Department of Water Affairs and Forestry (DWAF) (1998). Department of Health and Water Research Commission, Qual. Domestic Water Supply, Vol 1: Assessment Guide.

Friedrich E, Pillay S, Buckley CA (2009). Carbon footprints for increasing water supply and sanitation in South Africa: A case study. Cleaner prod., 17(1): 1-12.

Hall J, Hoghson G, Kerr KG (2004). Provision of safe potable water for immunocompromised patients in hospital. Hosp. infect., 58(2): 155-158.

Lin J, Biyela PT, Puckree T, Bezuidenhout CC (2004). A study of the water quality of the Mhlathuze River, Kwa-Zulu Natal (RSA): Microbial and physico-chemical factors. Water, SA., 30(1): 17-22.

Solo-Gabriel HM, Wolfertma MA, Desmarais TR, Palmer CJ (2000). Sources of *Escherichia coli* in a coastal subtropical environment. Appl. Environ. Microbiol., 66(1): 230-237.