African Journal of Biotechnology Vol. 6 (19), pp. 2251-2258, 4 October 2007
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2007 Academic Journals

Full Length Research Paper

Influence of discharged effluent on the quality of surface water utilized for agricultural purposes

Awofolu Omotayo Rafiu*, Du Plessis Roelien and Rampedi Isaac

Department of Environmental Sciences, College of Agriculture and Environmental Sciences, University of South Africa, P.O. Box 392, Pretoria 0003, South Africa.

Accepted 2 July, 2007

This article reports on the level of toxic trace metals (Cd, Pb, Mn, Zn, Cu and Ni) in surface water and sediment along the Blaauwbankspruit in the West Rand District of South Africa. This spruit serves as receiving channel of wastewaters from sewage treatment plant and a gold mine. Some physical and chemical influences of released wastewater on the quality of the surface water, which is utilized for agricultural purposes was studied. Total trace metals in water and sediment samples were digested using mineral acid and then analyzed by Inductively Coupled Plasma-Atomic Emission Spectrometry. The mean concentrations of analyzed trace metals in water samples ranged from trace – 0.05, trace – 0.11, 4.35 – 942.2, 0.10 – 0.41, 0.08 – 0.88 and 0.15 – 0.42 mg/l for Cd, Pb, Mn, Zn, Ni and Cu, respectively. The mean levels of trace metals in sediment samples also ranged between trace – 0.12, trace – 0.38, 12.3 – 2957.2, 0.13 – 2.57, 0.39 – 1.96 and 0.18 – 2.84 µg/g, respectively, in the above metallic order. Higher metallic load in sediments, compared to those in water samples were obtained. Safety limits, specified by the Department of Water Affairs and Forestry for the use of water for domestic and irrigational purposes were exceeded in many samples. This further highlights the serious concern regarding the use of contaminated surface water. In addition, higher values of determinants obtained from sampling points close to the wastewater treatment plant and the mine exit channels strongly revealed their influence on the general quality of the stream. Detection of metals such as cadmium and lead above acceptable limits has dire consequences across the food chain.

Keywords: Assessment; waste water, surface water, irrigation, Blaauwbank spruit, West Rand, South Africa.

INTRODUCTION

The importance of ground and surface waters in the lives of many rural dwellers in developing countries, including South Africa, cannot be overemphasized. Therefore, it is imperative that the quality of such water systems be evaluated and monitored regularly. Although the influence of natural factors such as the weathering of rocks, erosional processes and variable precipitation on the quality of the stream cannot be ruled out, influence from anthropogenic factors are by far the most predominant (Jarvie et al., 1998). Anthropogenic factors such as run-offs from agricultural activities, discharges from domestic and industrial waste treatment plants, contamination from improperly managed landfill sites, illegal dumping of waste on land and into the water systems are among the major sources of concern of human factors on the quality of ground and surface waters.

Issues of water safety, conservation and protection are of priority to the national government, but more particularly to the Gauteng Provincial Government due to the geographical location of this province in South Africa. Agricultural practices at subsistence and commercial level abound in the province and in order to minimize and conserve the use of potable water, treated wastewater from sewage treatment plants are being utilized for several activities such as irrigation of farmlands and private lawns and to provide water for livestock. The chemical status of the "treated" wastewater would have an influence on the receiving land. For instance, if the

*Corresponding author. E-mail: Awofoor@unisa.ac.za. Tel: +27-12`-3524059. Fax: +27-123534270.

water is contaminated, it might possibly contaminate the produce cultivated on such land. An earlier study has revealed the influence of surface water on the metallic load of agricultural soil and its produce (Awofolu et al., 2005).

Several toxic metals such as lead (Pb), cadmium (Cd), nickel (Ni) and arsenic (As) which are important to environmental and human health, have been detected in aquatic media. These toxic metals are continually monitored due to their health implications since they are non-essential metals and are of no benefit to humans (Borgmann, 1983). The presence of these metals in the aquatic ecosystem has far-reaching implications directly to the biota and indirectly to man. Cd is of environmental and human health concern due to its carcinogenic and endocrine disrupting effects in humans (Goering et al., 1994). It accumulates mainly in the kidney and liver and high concentrations have been found to lead to chronic kidneys dysfunction. It induces cell injury and death by interfering with calcium (Ca) regulation in biological systems. It has been found to be toxic to fish and other aquatic organisms (Woodworth and Pascoe, 1982).

Apart from the health implication, the metal (Cd), together with other elements such as zinc (Zn), form a toxic "soup" that often acts synergistically. Sources of Cd include wastes from Cd-based batteries, incinerators and runoff from agricultural soils where phosphate fertilizers are used, since Cd is a common impurity in phosphate fertilizers (Stoeppler, 1991). Pb, another toxic metal, has been found to be responsible for quite a number of ailments in humans such as chronic neurological disorders found especially in foetuses and children. Sources in aquatic systems include used dry-cell batteries, sewage effluent, runoff of wastes and atmospheric deposition.

Although, Zn has been found to have low toxicity to man, prolonged consumption of large doses can result in health complications such as fatigue, dizziness, and neutropenia (Hess and Schmid, 2002). Copper (Cu) is classified as essential to life due to its involvement in certain physiological processes. Elevated levels of Cu, however, have been found to be toxic (Spear, 1981). Nickel is a naturally occurring element found in a number of mineral ores including Ni sulphides, oxides and silicates. It is present in the enzyme urease and as such is considered to be essential to plants and some domestic animals. It has not yet been demonstrated that Ni is essential to man (Teo and Chen, 2001). However, Ni-related health effects such as renal, cardiovascular, reproductive, and immunological effects have been reported in animals. Toxicity of Ni to rainbow trout have also been reported (Pane et al., 2003).

While water is a medium commonly used to assess the level of several aquatic pollutants including trace metals, sediment can also provide a deeper insight into the long-term state of pollution of the water-body. Sediment has been described as a ready "sink" or reservoir of pollutants including trace metals where they concentrate according to the level of pollution (Onyari et al., 2003). The need to evaluate the quality and assess possible influence of "treated" wastewater being released from the Percy Stewart Water Care Works in Sterkfontein into the environment has become imperative in view of the health implications that cut across the food strata. The quality of sediment from the water channels in terms of its metallic load would also be assessed.

The research work on which this article is based reports the level of trace metals of toxicological potential (Cd, Pb, Ni, Zn and Cu) in water samples along the Blaauwbankspruit. This spruit serves as discharge channel for the Percy Stewart Water Care Works in the West Rand District of South Africa. The possible influence of discharged wastewater from this treatment plant on the quality of the surface water was evaluated. In addition, the metallic load of the sediment and some physico-chemical parameters of the water were also assessed.

MATERIALS AND METHODS

Study area

Area of study was the Blaauwbank spruit. The spruit (stream) forms part of the Limpopo Catchment Area, as demarcated by the Department of Water Affairs and Forestry (DWAF) as one of the 19 catchment areas of South Africa. It turns eastwards and flows into the Crocodile River. In addition, as a tributary of the Crocodile River, the spruit has significant impact on the quality of water of the Hartbeespoort Dam which is regularly plagued with blooming algae resulting in pressing environmental concern. This study area is of significance because of the likelihood that if water from this stream is polluted, it can negatively affect the water sources of the World heritage. Several users such as livestock and agricultural produce farmers, private property owners for irrigation of lawns and possible utilisation by informal settlers within the area depend on water from this stream. The most plausible impact on this stream are the "treated" effluents from the Percy Stewart waste treatment plant and the mine discharge. Samples were collected from four points: S1 = downstream (Percy Stewart Sewage treatment plant) (S 26° 02m/ 24.1s; E 27° 43m/ 15.8s); S2 = Mid-stream (S 26° 00m/ 32.4s; E 27° 44m/ 02.0s); S3 = Upstream (confluence of Blaauwbankspruit with the Crocodile river) (S 25° 58m/ 53.5s; E 27° 47m/ 17.1s) and S4 = mine discharge (S 26° 06m/ 27.4s; E 27° 43m/ 20.5s).

Samples and sampling treatment

The various sampling sites are as shown in Figure 1. Water and sediment samples were collected from four different sampling points into 1-l Nalgene plastic containers which were thoroughly washed with detergent, rinsed with water and then with distilled water before soaking in 5% HNO_3 for about 24 h. Containers were finally rinsed with double distilled water before use. Water samples were kept cooled en route to the laboratory and stored at 4°C while sediment samples were kept frozen at -18°C until analyzed. Treatment and analysis of samples usually took place within 24 h of collection. Sediment samples were allowed to defrost; air-dried in a circulating oven at 30°C and thereafter sieved mechanically using a 2 mm sieve. All determinations were based on the fine sediment particles obtained, since metals are known to adhere to these fine particles.

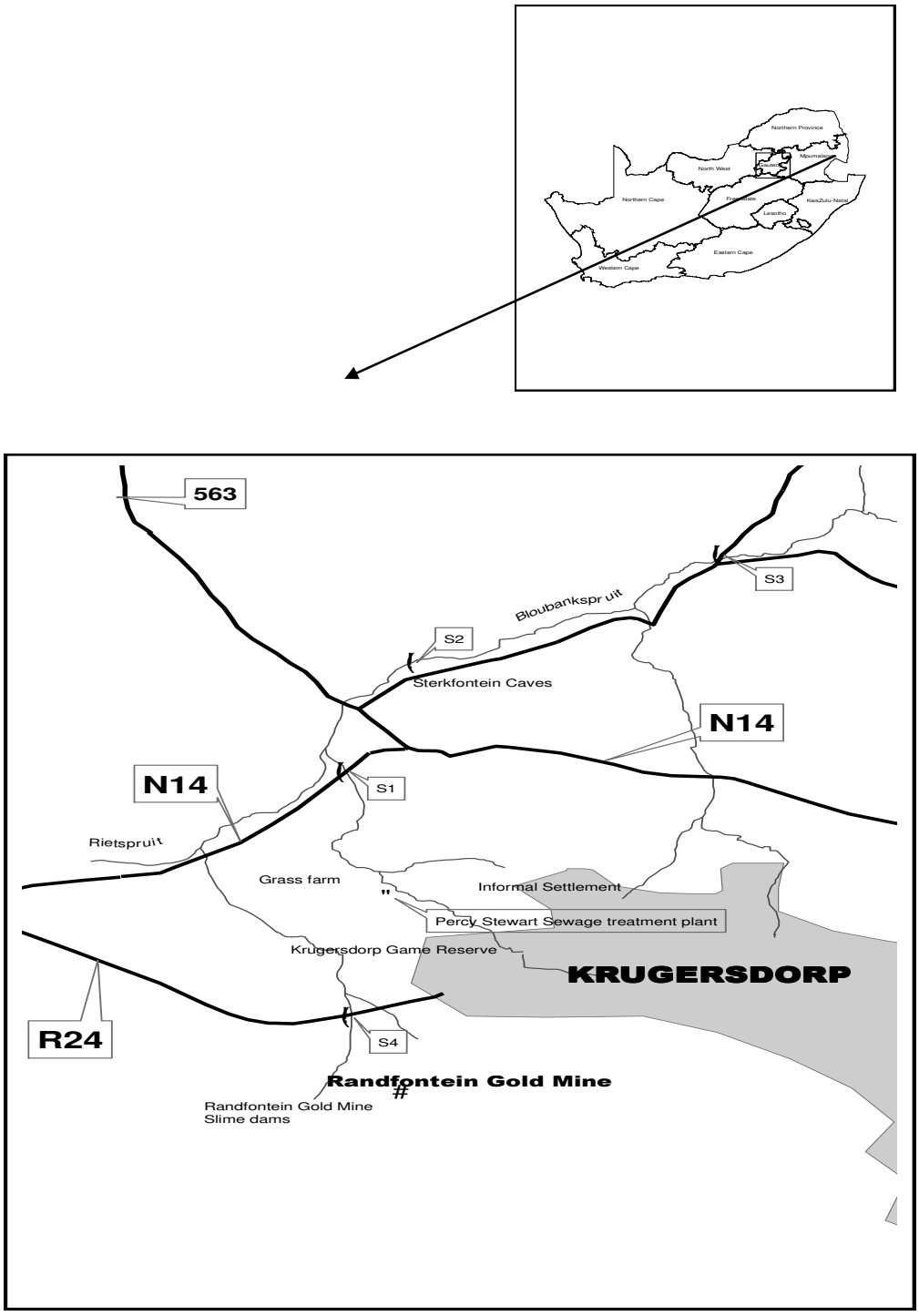

Figure 1. Map of South Africa (top) and the Gauteng province showing areas of sample collection.

Physical parameters

The pH and temperature of the water samples were determined directly on site with the pH meter 330 supplied by Merck NT Laboratory (Pty) Limited. The samples were preserved with 5 ml of concentrated HNO_3. Electrical conductivity (E.C) of the water samples was also determined on site using the Hanna Inc. conductivity meter.

Limits of detection and quality assurance

Limits of detection of the analyzed metals were determined as thrice the standard deviation (3σ) of their lowest detectable concentrations from the mean of six replicate analyses. Good linearity was obtained from the calibration curves prepared from 1,000 mg/l of each metal standard from BDH laboratory, England. The open-beaker digestion method (OBD) as applied and described in Awofo-

Table 1. Detection limits (mg/l) and *mean % recoveries (±SD) of trace metal standards added to double-distilled water and pre-digested sediment.

Metal	Detection limits	Spiked conc.	Recoveries	
			Water	Sediment
Cd	0.002	0.05	95.7 ± 0.002	91.2±0.004
Pb	0.004	0.05	92.3±0.002	82.7±0.005
Mn	0.004	5.0	90.5±0.004	90.3±0.001
Zn	0.005	5.0	87.8±0.001	84.0±0.002
Cu	0.003	5.0	95.5±0.003	86.5±0.003
Ni	0.005	5.0	96.4±0.005	85.6±0.003

*Values are mean of triplicate analyses.

Table 2. Some physico-chemical parameters determined in water samples.

Sampling sites	Dates	Parameters			
		pH	E.C (µS cm^{-1})	Temp (^oC)	Appearance
S1	25/10/06	6.5	7300	24	Partly cloudy
S2	,,	7.6	6200	22	Slightly cloudy
S3	,,	6.8	7420	20	Cloudy
S1	6/11/2006	7.4	6200	23	Slightly cloudy
S2	,,	6.6	6310	20	Slightly cloudy
S3	,,	9.4	820	20	Cloudy
S1	20/11/2006	7.7	6000	25	Cloudy
S2	,,	7.6	6130	23	Slightly cloudy
S3	,,	7.8	6020	20	Clear
S4	,,	9.7	5010	18	Deep brown
S1	04/12/2006	7.6	830	22	Partly cloudy
S2	,,	7.3	900	20	Slightly cloudy
S3	,,	6.8	700	24	Clear
S4	,,	10.9	7500	23	Deep brown

lu et al. (2005) was used in the digestion of water samples. The spiking method of double-distilled water at fortification levels of 0.05 mg/l Cd and Pb, 5.0 mg/l of Mn, Zn, Cu, and Ni was applied. Triplicate analyses of each metal together with a blank were carried carried out. For sediment samples, the quality assurance protocol was done following the procedure described by Shriadah (1999) and previously applied by Awofolu et al. (2005). This method has been widely applied in environmental investigations because it removes metal fractions associated with carbonates, sulphides, soluble salts, organic matter held and Fe-Mn oxide phase (Agemian and Chau, 1976). Triplicate digestion of each sample together with the blank was carried out.

Analysis of samples

The open-beaker digestion (OBD) protocols were used for the chemical analysis of water and sediment samples since the quality assurance of both protocols gave acceptable recoveries and reproducibility. Three replicate digestions were carried out for each sample.

RESULTS

Results of the limits of detection of the analyzed metals and the percentage recoveries of the spiked double-distilled water and pre-digested sediment with metal standards are presented in Table 1. The detection limits are 0.002, 0.004, 0.004, 0.005, 0.00.3 and 0.005 mg/l for Cd, Pb, Mn, Zn, Cu and Ni, respectively. Percentage recoveries from the spiked double-distilled water ranged from 87.8 ± 0.001 to 96.4 ± 0.005 mg/l while those of the pre-digested sediment varied between 82.7 ± 0.005 and 91.2 ± 0.004 µg/g. Results of some physico-chemical parameters determined in water samples were as presented in Table 2. The pH, electrical conductivity, (E.C) and the temperature of sampled water from the spruit, across the four periods of collection ranged from 6.53 - 10.88; 820 - 7500 µS/cm and 18 - 25^{o}C respectively.

Trace metals in water and sediment

Figures 2 - 5 present the level of trace metals obtained in the Blaauwbank spruit water and sediment samples at various sampling periods. The mean concentrations of Cd in water ranged from trace - 0.05 mg/l while those in

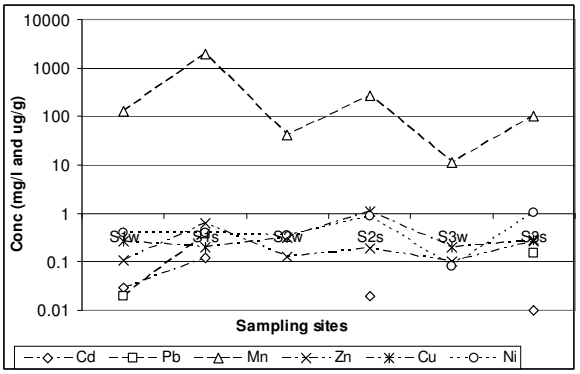

Figure 2. Concentration (mg/ℓ) of trace metals in surface water and sediment (µg/g) samples collected during the first period (25/10/06) of sampling. S = sampling point, w = water sample, s = sediment sample.

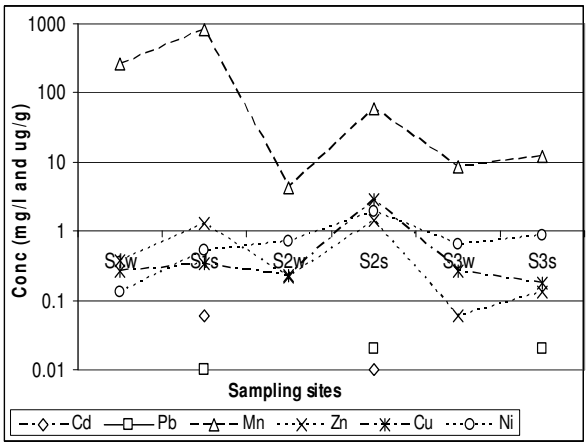

Figure 3. Concentration (mg/ℓ) of trace metals in surface water and sediment (µg/g) samples collected during the second period (06/11/06) of sampling. S = sampling point, w = water sample, s = sediment sample.

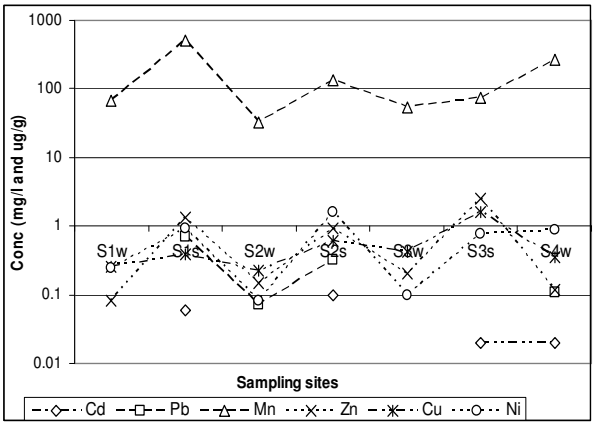

Figure 4. Concentration (mg/ℓ) of trace metals in surface water and sediment (µg/g) samples collected during the third period (20/11/06) of sampling. S = sampling point, w = water sample, s = sediment sample.

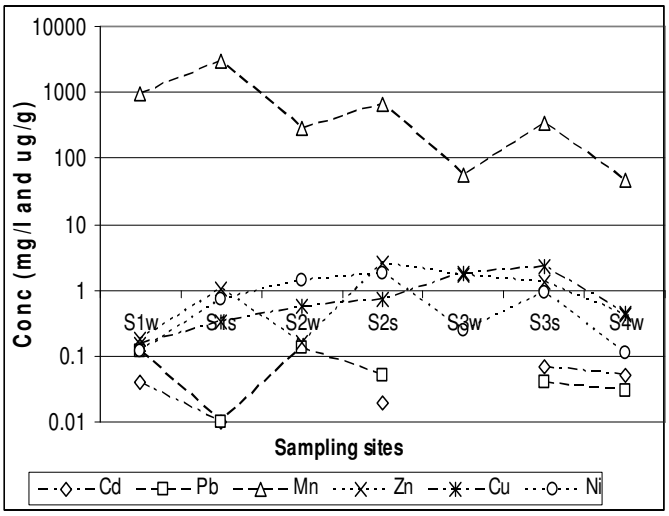

Figure 5. Concentration (mg/ℓ) of trace metals in surface water and sediment (µg/g) samples collected during the fourth period (05/12/06) of sampling. S = sampling point, w = water sample, s = sediment sample

sediment varied between trace to 0.12 µg/g. The metal was not detected in over 60 % of all samples (water and sediment) across the periods of sample collection. However, more detection was recorded in sediment samples than in water across the four sites. Lowest Cd concentration of 0.03 ± 0.01 mg/l (S1) was obtained in water with the highest value of 0.12 ± 0.001 µg/g (S1) in sediment (Figure 2). Concentration of Pb obtained in water samples varied between trace - 0.13 ± 0.03 mg/l while that in sediment ranged from trace - 0.71 ± 0.03 µg/g. The lowest value of 0.02 ± 0.001 mg/l of Pb in water at S1 (Figure 1) was obtained while the highest values of 0.71 ± 0.03 µg/g also at S1 in sediment was recorded (Figure 4). Zn concentration ranged from 0.10 ± 0.002 to 0.41± 0.001 mg/l and 0.13 ± 0.01 to 2.57 ± 0.03 µg/g for water and sediment samples respectively. In Figure 3, 0.06 ± 0.003 mg/l was obtained as the lowest Zn value in water (S3) while the highest value of 2.57 ± 0.03 µg/g was obtained in sediment (Figure 5).

The concentration of Mn obtained across the period of sampling varied from 4.35 ± 0.004 as the lowest value at S2 (Figure 3) - 942.2 ± 7.26 mg/l and 12.3 ± 0.14 - 2957.2 ± 18.4 µg/g as the highest recorded value at S1 (Figure 5) for water and sediment samples respectively. This metal was detected in all analyzed samples, which indicated its prevalence in the aquatic medium. The level of copper in water and sediment samples were from 0.15 ± 0.003 - 0.42 ± 0.001 mg/l and 0.18 ± 0.001 - 2.84 ± 0.03 µg/g, respectively. This metal was also detected in all analyzed samples with the highest value of 2.84 ± 0.03 µg/g obtained from S2 (Figure 3). Ni concentration in sampled water ranged from 0.08 ± 0.004 - 0.88 ± 0.002 mg/l while those in sediment samples varied between

0.39 ± 0.001 - 1.96 ± 0.04 µg/g with the latter as the highest value from site S2 (Figure 3).

DISCUSSION

Good instrumental detection limits of analyzed metals were obtained and recoveries of the spiked concentrations of metals from double distilled water and predigested sediment sample were appreciable. This was an indication of the applicability of the method used in the analyses of water and sediment samples. The hydrogen ion level of water, as measured by the pH was slightly above the Target Water Quality Range (TWQR) of 6 to 9 for pH in water intended for domestic use (DWAF, 1996a). The range obtained was also higher than the recommended range of 6.5 to 8.5 by the United States Environmental Protection Agency (USEPA, 1986).

Water acidity is known to influence the solubility, availability and toxicity of metals in the aquatic ecosystems. Electrical conductivity (E.C) gives a measure of water conductivity as well as an indication of the level of inorganic constituents in water. Typical conductivity values recommended for drinking water ranged from 50 to 1500 $\mu S/cm^{-1}$ (Radojevic and Bashkin, 1999). Most of the water samples exceeded this range, which indicated the presence of high concentration of inorganic substances in the samples. Exceptions to this were samples from site S3. There was no particular pattern in E.C values of water samples from sites S1 – S4 across the period of sample collection. However, the lower E.C value obtained at S2 relative to S1 during the first period of sampling (25^{th} of October 2006) could possibly be attributed to dilution factor of the concentration of ionic constituents in stream water from the higher value obtained at S1. In addition, the higher E.C value obtained at S3, compared to both S1 and S2 during this period might be due to input from other anthropogenic sources such as runoff from agricultural farms along the spruit. It was also observed that conductivity values obtained during the fourth period of sampling (4^{th} of December, 2006) were lower compared to the earlier three periods with the exception of water sample from the mine outlet at S4. This could be due to reduced influence from anthropogenic sources and non discharge of effluent from the waste treatment plant during this period. The values for water temperature obtained were within the Council of European Community (CEC, 1988) recommendation of $25^{o}C$ for water intended for drinking purposes.

Temperature is known to influence water chemistry and the toxicity of metals. Generally, the colour of water samples appeared cloudy during sampling with the exception of samples from the mine outlet, which were deep brown. Water samples were collected around mid-morning with relatively high flow rate, which might explain the cloudy nature of the water.

The concentration of Cd obtained in water samples from this study were higher than the tentative South African Target Water Quality Range (TQWR) guideline of 0 - 0.005 mg/l in river water for domestic use (DWAF, 1996a). The values were also higher than 0.005 mg/l as the maximum contaminant level (MCL) specified by USEPA (1986) and that of the South African TWQR of 0 - 0.01 mg/l recommended for irrigation and livestock watering (DWAF, 1996c). This showed that water from the stream is unsuitable for these activities with regard to the value obtained in this study. If water from this stream were to be used for irrigation and watering, it could have detrimental health effects on the users. For example, bioaccumulation of Cd could occur in livestock that drink this water and in ruminates that feed on grasses irrigated with the water. However, the level of the metal was below the instrumental detection limit in some water and sediment samples, for example at S2 and S3 (Figure 3).

Higher levels of Cd (0.01 - 0.26 mg/l) in South African water systems had been previously reported (Fatoki et al., 2002). The higher level of Cd obtained in some sediment samples (S1: 0.12 µg/g) relative to that in water samples (S1: 0.03 mg/l) in Figure 2 might be due to the fact that metals are generally known to bind to organic matter in accumulated sediment under aquatic ecosystems. Contribution from other sources such as agricultural runoff where fertilizers are used cannot be ruled out. Apart from natural sources, other probable sources of this metal in surface water include leaching from Ni-Cd based batteries (Hutton et al., 1987), runoff from agricultural soils where phosphate fertilizers are used (Stoeppler, 1991), and other metal wastes.

Pb was detected in both water and sediment samples across the sites with trace levels in some instances (Figures 2, 3 and 5). Higher levels of Pb in sediment samples relative to those in water were obtained at S1 and S2 (Figures 2 and 4 respectively) while the opposite occur at S2 in Figure 5. The sediment, which is usually referred to as “sink” for pollutants including trace metals could be an influential factor on the level of Pb in water. In addition, site S1 is the up-stream sampling point of the study area, which is close to the sewage treatment plant. Both water and sediment samples from this site contain higher levels of analyzed constituents relative to the mid- and down-stream portion of sampling sites in many instances. Similar higher value was obtained from the mine discharged outlet (S4) to the stream. Higher value of contaminants from these two outlets was an indication of possible influence on the quality of the stream.

The TWQR for Pb in river water for domestic use is 0 to 0.01 mg/l (DWAF, 1996a). The range obtained in this study exceeded this limit, thus making the water unsuitable for domestic use. The presence of informal settlements along the water channel raised the possibility of the use of the stream for drinking purposes. Chronic exposure to Pb has been linked to growth retardation in children (Schwartz et al., 1986). Pb toxicity studies con-

ducted on female mice revealed mostly miscarriages, premature delivery and infant mortality (Taupeau et al., 2001).

Levels of Pb > 0.1 mg/l have been reported to be detrimental to foetuses and children, with possible development of neurological problems. TWQR of 0 to 0.2 mg/l and 0.1 mg/l (DWAF, 1996c) has been set for Pb in river water for use in irrigation and livestock watering respectively. Levels of Pb in water samples obtained in this study were lower than these ranges, with the exception of values of 0.11 – 0.13 mg/l (Figures 4 and 5) which makes the water unsuitable for livestock watering purposes. The possibility that the level of this metal in water samples could become higher than the limit is most probable due to various dynamic influences and interactions of water chemistry and the sediment core. For example, lower water pH can influence metal bio-availability from sediment since higher value of 0.71 ± 0.03 μg/g was recorded in sediment at S1 (Figure 4). The stream water was not noticeably used for recreational purposes because of its aesthetic state. In Figure 3, Cd and Pb were below the detection limits in analyzed water samples while they were all recorded in sediment samples with the exception of Cd at S3. Mn was detected in all samples across the sites how-ever; higher values were generally obtained in sediment compared to water samples. Similar trend was also observed in Zn, Cu (except at S3) and Ni. The relatively higher values of trace metals such as Mn, Zn and Cu obtained at S1 (Figures 3 and 5) could be as a result of the influence of the effluent released from the waste treatment plant. The analyzed metals are more likely to be higher within this circumference while the value reduces with increasing distance from this source due to dilution. Exceptions to this trend were values obtained from Ni which increased at S2 with marginal reduction at S3. The higher Ni values obtained at S2 and S3 might be due to contributions from other sources such wastes from nickel based batteries.

Zn was detected in all the analyzed samples however; the levels were lower than 3.0 mg/l as the TWQR for Zn in water for domestic use (DWAF, 1996a). Hence no detrimental effects from domestic water usage could be expected if used for domestic purposes. The TWQR levels of Zn in water for a safe aquatic ecosystem (DWAF, 1996b), irrigation and livestock watering (DWAF, 1996c) are 0.002 mg/l, 0 - 1.0 mg/l and 0 - 20 mg/l respectively. The water is unfit for the sustenance of aquatic ecosystem and irrigation purposes but could still be utilized for livestock watering, since the range obtained for the latter was much lower than the TWQR value. The levels of Zn obtained in sediment samples were generally higher than those in water across the sites (S1 – S3) with the exception of S3 (Figure 5).

The South African guideline for Cu in domestic water supply is 0 - 1.0 mg/l (DWAF, 1996a). The range obtained was lower than the set value, hence adverse effects from domestic use are not expected as far as this parameter and the results obtained are concerned. At neutral or alkaline pH, typical concentration of Cu in surface water is 0.003 mg/l (DWAF, 1996a). The TWQR levels of Cu for irrigation and livestock watering are 0 to 0.2 and 0 - 5.0 mg/l respectively with adverse chronic effects expected at 1 - 10 mg/l, depending on the livestock (DWAF, 1996c). The water is unsuitable for the maintenance of the aquatic ecosystem as well as and for irrigational purposes. However, Cu is not expected to cause any problem if the water is utilized for livestock watering.

Attention has been focused lately on the toxicity of Ni in low concentrations. For instance, it has been shown that Ni can cause allergic reactions and that certain Ni compounds may be carcinogenic (McKenzie and Smythe, 1998). Typical concentrations of Ni in unpolluted surface water are given as 5.0×10^{-4} mg/l (DWAF, 1996d) and 0.015 to 0.020 mg/l (Salnikow and Denkhaus, 2002). The range obtained in this study was much higher than the above limits, indicating that the water is contaminated with this metal. All Ni compounds except for metallic Ni have been classified as carcinogenic to humans (IARC, 1990). Possible sources of Ni in surface water include anthropogenic sources, combustion of fossil fuels (Merian, 1991), old battery wastes, components of automobiles, old coins, and many other items containing stainless steel and other Ni alloys.

Among the known health-related effects of Ni are skin allergies, lung fibrosis, variable degrees of kidney and cardiovascular system poisoning and the stimulation of neoplastic transformation. With regards to Mn, the World Health Organization (WHO, 1996) recommended 0.5 mg/l as the provisional health-based guideline in water for domestic use while a limit of 0.05 mg/l was specified by USEPA (1986). The level obtained in this study for both water and sediment samples were much higher than these limits, hence the water is highly unsuitable to be used for domestic purposes. Although Mn is considered to be an essential element, an excess amount in the body can cause damage to the brain, liver, kidney and to a developing fetus (ATSDR, 2000).

Results obtained from the determination of trace metals in water and sediment samples were subjected to the Pearson Moment Correlation Coefficient. This was to check possible relationship between the analyzed metals in both samples. From Figure 5, good correlations (r = 0.97 and r = 0.98) were obtained between Mn and Pb as well as Zn and Cu respectively in water samples. Also in sediment, good correlation (r = 0.99) was recorded between Cd and Cu while Pb and Ni was poorly correlated (r = 0.82), also from Figure 5. The various correlations obtained between analyzed metals in both water and sediment samples showed common sources of the metals. Generally, all the analyzed metals were detected in water and sediment samples. The influence of released wastewater from the water treatment plant and the mine was observed.

Conclusion

The importance of regular assessment of the level of pollution and monitoring the influence of discharged wastewater on the receiving aquatic systems cannot be overemphasized. This becomes more important if the water body is used for domestic, agricultural and recreational purposes. Some evaluated physico-chemical parameters, notably pH and E.C as well as some metals such as Pb and Cd were above recommended limits. The detection of toxic metals such as Cd and Pb above safety limits for water intended for irrigational purposes gave cause for concern because ruminants that feed on grasses irrigated with this water might be at risk of bioaccumulation. This risk could be passed up the food chain. The influence of the discharged wastewaters on the stream was evident from the higher values of parameters obtained from the STP and the mine sampling points. However, the possibility of other anthropogenic sources cannot be ruled out. The efficiency and effectiveness of the waste treatment operations should be regularly evaluated. In addition, regular monitoring of the quality of receiving surface water should be done in order to ensure sustainable influence on the stream.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. Johan Mostert of the Makiti wedding and conference centre for the assistance towards location of sampling sites and to Ms Lynne Meyer towards mapping of the sampling sites.

REFERENCES

Agemian H, Chau ASY (1976). Evaluation of extraction techniques for the determination of metals in aquatic sediment. Anal. 101:761-767.

ATSDR (2000). Agency for Toxic Substances and Disease Registry, Toxicological profile for manganese Atlantic Georgia U.S Department of Health and Human Services Public Health Service.

Awofolu OR, Mbolekwa Z, Mtshemla V, Fatoki OS (2005). Levels of Trace Metals in Water and Sediment from Tyume River and its effects on an irrigated farmland. Water SA 31(1): 87-94.

Borgmann U (1983). Metal speciation and toxicity of free metal ions to aquatic biota. In: Nriagu JO (ed.) Aquatic Toxicity Advances in Environmental Science and Technology. Vol. 13 John Wiley & Sons New York pp. 47-73.

CEC (1988). Council of the European Communities. Council Directives Relating to the Quality of Water Intended for Human Consumption Regulations (No. 80/778/EC).

DWAF (1996a). Department of Water Affairs & Forestry, Water Quality Guidelines for Domestic Use vol. 1 (2nd edn.) DWAF Pretoria.

DWAF (1996b). Department of Water Affairs & Forestry Water Quality Guidelines, Aquatic Ecosystem Use. Vol. 7 (1st edn.) DWAF Pretoria.

DWAF (1996c). Department of Water Affairs & Forestry Water Quality Guidelines, Agricultural Use and Livestock Watering, vol. 5 (2nd edn.) DWAF Pretoria.

DWAF (1996d). Department of Water Affairs & Forestry, South African Water Quality Guidelines, Field Guide, vol. 8 (1st edn.) DWAF Pretoria

Fatoki OS, Lujiza N, Ogunfowokan AO (2002). Trace metal pollution in Umtata River. Water SA 28 (2): 183-190.

Goering PL, Waalkes MP, Klaassen CD (1994). "Handbook of Experimental Pharmacology" (ed.) Goyer RA, Cherian MG, Vol. 115 Springer, New York pp. 189.

Hess R, Schmid B (2002). Zinc supplement overdose can have toxic effects. J. Paediatr. Haematol/Oncol. 24: 582-584.

Hutton M, Chaney RL, Krishna CR, Murti M, Olade A, Page AL (1987). Group Report In: Hutchinson TC, Meema KM (eds.) Lead Mercury Cadmium and Arsenic in the Environment, John Wiley, New York, pp. 35-41.

IARC (1990). International Agency for Research on Cancer. Monographs on the Evaluation of Carcinogenic Risks to Humans: Chromium, Nickel and Welding 49 IARC Lyon pp. 45.

Jarvie HP, Whitton BA, Neal C (1998). Nitrogen and phosphorus in east coast British rivers: speciation, sources and biological significance. Sci. Total Environ., 210–211: 79–109.

McKenzie HA, Smythe LE (1998). Quantitative Trace Analysis of Biological Materials. Elsevier Amsterdam.

Merian E (ed.) (1991). Metals and their Compounds in: The Environment. Occurrence, Analysis and Biological Relevance. UCH, Weinheim-New York-Basel-Cambridge pp. 35

Onyari MJ, Muohi AW, Omondi IG, Mavuti KM (2003). Heavy metals in sediments from Makupa and Port-Reitz Creek systems: Kenyan Coast. Environ. Int. 28(7): 639-647.

Pane EF, Richards JG, Wood CM (2003). Acute waterborne nickel toxicity in the rainbow trout (*Oncorhynchus mykiss*) occurs by a respiratory rather than ionoregulatory mechanism. Aquat. Toxicol. 63 (1): 65-82.

Radojevic M, Bashkin VN (1999). Organic matter, In: Practical Environmental Analysis. The Royal Society of Chemistry Cambridge pp. 325-329.

Salnikow K, Denkhaus E (2002). Nickel essentiality toxicity and carcinogenicity. Crit. Rev. Oncol./Haematol. 42(1): 35-56.

Schwartz J, Angle C, Pitcher H (1986). Relationship between childhood blood lead levels and stature. Pediatr. 77: 281-288.

Shriadah MMA (1999). Heavy metals in mangrove sediment of the United Arab Emirates shoreline (Arabia gulf), Water Air Soil Pollut. 116: 523.

Spear PA (1981). Zinc in the aquatic environment Chemistry distribution and toxicity. National Research Council of Canada, Association Committee on Scientific Criteria for Environmental Quality Report NRCC No. 17589 Ottawa.

Stoeppler M (1991). Cadmium. In: Merian E (ed.) *Metals* and their Compounds in the Environment: Occurrence Analysis and Biological Relevance. VCH New York pp. 803-851.

Taupeau C, Poupon J, Nome F, Lefevre B (2001). Lead accumulation in the mouse ovary after treatment-induced follicular Artesia. Reprod. Toxicol. 15(4): 385-391.

Teo KC, Chen J (2001). Determination of cobalt and nickel in water samples by flame atomic absorption spectrometry after cloud point extraction. Anal. Chim. Acta 434(2): 325-330.

USEPA (1986). United States Environmental Protection Agency *Quality* Criteria for Water. Office of Water Regulation and Standards Washington DC USEPA-40015-86-001 pp. 256.

WHO (1996). World Health Organisation Guidelines for Drinking Water Quality Vol. 2 second ed. WHO Geneva.

Woodworth JC, Pascoe V (1982). Cadmium toxicity to rainbow trout, *Salmon gairdneri* Richardson. A study of eggs and alevins. J. Fish. Biol. 21: 47-57.