International Journal of Pure and Applied Science
Published by Cambridge Research and Publications
Vol. 19 No.9
September, 2020.

EFFECTS OF WATER HYACINTH ON WATER QUALITY IN WATER OBTAINED FROM PANDAM LAKE, PANDAM GAME RESERVE PLATEAU STATE, NIGERIA.

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Abstract

Water is one of the most important resources for sustainability of life on earth. The study assessed the water quality in water obtained from Pandam Lake. The main sources of data for the study were physico-chemical parameters. Standard methods were used to analyze the physico-chemical quality in the water in accordance with the American Public Health Association (APHA) and American Water works Association (AWWA). Sixteen (16) parameters were assessed. The results shows that out of 16 parameters assessed, 6 were above WHO guidelines, in both the water hyacinth root water and water hyacinth leave water. The t-test results also showed significant difference between water hyacinth root water and water hyacinth leave water on 5 out of 16 water quality parameters tested for. Finally, the results shows a general high contamination that water hyacinth presence in water as observed in water obtained from Pandam lake. The study therefore recommends among others that there is a dare need to monitor the water body, create database and utilize it in the management of water quality of water body. The enforcement of existing laws is needed so as to achieve compliance to set standards.

Keyword: *Water hyacinth, water quality, physicochemical, WHO, Pandam lake.*

INTRODUCTION

Plant invasions are a serious threat to natural and semi–natural ecosystems worldwide. In many areas, catchment modifications by exotic plants are among the most influential agents of environmental (water and vegetation) degradation (Enright, 2000). Significantly, invasions by exotic species are considered as one of the greatest threats to natural ecosystem and biodiversity components. Many countries are paying dearly for the escape, from garden ponds, of introduced plants of that notoriously prolific exotic invader – the Water Hyacinth (Enright, 2000). In Africa especially, thick mats of this perennial aquatic weed from South America's Amazon Basin are suffocating lakes, wetlands, dams and slow-flowing rivers and canals. Outside its origin, and with no natural enemies to check its growth, the Water Hyacinth is one of the fastest-growing of all aquatic plants. Reproducing primarily by way of runners (stolons), a single plant can produce as many as 45 daughter-rosettes within just 50 days (Gordon and Arne, 2013). Clonal growth rates exceeding 3.4 million new plants over a 200-day period have been documented (Gordon and Arne, 2013). The striking lavender-blue flowers produce large quantities of seeds. The seeds can remain viable on a lake-bed for 15 years (Gordon and Arne, 2013). Hyacinth colonies have been known to double in size within just three weeks (Gordon and Arne, 2013). A single hectare of hyacinth cover may embody more than 400 tonnes of plant biomass. A Water Hyacinth infestation may clog waterways, impeding boat traffic, restricting shore-line access to water and disrupting fisheries (Gordon and Arne, 2013). Thick, spongy mats of the weed block sun light penetration, destroying the phytoplankton communities that sustain a healthy aquatic ecosystem's fish food chain. The decaying plants deplete levels of cyano-bacteria, which further de-oxygenate the water, suffocating native underwater plants and animals. In rivers and canals, dense hyacinth mats restrict water flows and trap debris, increasing siltation and creating breeding sites for mosquitoes and other vectors of disease (Gordon and Arne, 2013).

The quality of available water resources is of major importance to ensure that the multiple uses (for agricultural, domestic and industrial purposes) of water are met in a more sustainable manner (Versfeld *et al*., 1998; Enright, 2000).

Exotic plant species introduced into Nigeria from different parts of the world are affecting indigenous plants and animal communities adversely (Working for Water Programme, 2004). The ongoing and increasing human redistribution of species to support agriculture, forestry, mariculture, horticulture and recreation had resulted in the spread of exotic plants (Working for Water Programme, 2004). In Europe, the Delivering Alien Invasive Species Inventories for Europe (DAISIE) programme has estimated that 11% of exotic plant have negative ecological impacts and 13% have negative economic impacts (Kettunen *et al.*, 2008). The assessment of the annual costs incurred as a result of management work on exotic species in Europe as a whole, exceeded 12 billion euros (Kettunen *et al.*, 2008). In West Africa, Water hyacinth remains a serious problem, despite continuing efforts – in countries such as Niger, Mali, Côte d'Ivoire, Nigeria, Ghana and Senegal – to control its spread (Gordon and Arne, 2013). More than 550 km of the River Niger's course has been invaded. The economic impacts of Water Hyacinth infestations in seven African countries have been estimated at between US$ 20 million and US$ 50 million annually. Impact costs across Africa may exceed US$ 100 million annually (Gordon and Arne, 2013).

In stagnant water-body, the density of exotic grass beds can create temperature gradients having a negative impact on aquatic fauna and flora. This plant cover limits gaseous (oxygen and carbon-dioxide) exchange in the atmosphere (Lejas, 2002). The proliferation of submerged plants, whether exotic or native species, can produce significant variations in the pH and dissolved-oxygen levels during the day that are detrimental to aquatic animals. When oxygen levels in water fall below 2 mg/litre, no fish species can survive (Dutartre *et al.*, 2009). Water hyacinth hinders irrigation by impending water flow, by clogging irrigation pumps, and by interfering with dams/movement of aquatic animals. Multi-million dollar flood control and water supply projects, which require decades to construct, can be rendered useless by water hyacinth infestations. Infestations also block access to recreational areas and make them unattractive, decreasing the value of waterfront properties. Invasive alien species often impact the livelihoods of the communities that depend on fishing and water sports (like swimming) for revenue generation.

The Physiochemical parameters of water bodies invaded by water hyacinth had been reported in the previous studies. However, the water quality status of

Pandam lake is not known. This justifies the need to focus this present investigation on the assessment of the likely effects of water Hyacinth on the Pandam lake water quality (physicochemical). This has implications for water resourse management in the game reserve. The aim of the study is to quantify the effect of water hyacinth on water quality of Pandam lake in Plateau State. This aim will be achieved through the following objectives; Assess the physical qualities response of water to water hyacinth presence in Pandam lake water and Assess the chemical qualities response of water to water hyacinth presence in Pandam lake water.

MATERIALS AND METHODS

Study Site

The experimental activities of the study were carried out in two locations namely, Pandam lake and Federal College of Forestry Jos. Pandam Lake is located within Pandam Wildlife Park, Quam Pan local government area, Plateau State. The area lies between Latitudes 8^0 35'N and 8^0 55'N of the equator and Longitude 8^0 00'E and 10^0 00'E. It is bounded on the East by Namu and Kayarda towns on the West and North by the Dep River (now River Benue) and on the South by Aningo and Pandam towns. Pandam Wildlife Park belongs to the Plateau State Government of Nigeria and is managed by the Plateau State Tourism Cooperation (PSTC), and covers an area of 22.4km^2 and an altitude of 175-315 m above sea level. The wet season lasts from April to October and annual rainfall is 1000-1500 mm (Ezealor, 2002; Akosim *et al.,* 2007, Dami and Manu, 2008).

Federal College of Forestry Jos, in Jos North Local Government Area of Plateau State. The area lies in the Northern Guinea Savannah zone, on latitude 9° 57' N and longitude 8° 54'E with a height of about 118mm above sea level. The mean annual rainfall for the location is between 1200mm and 1250mm and mean temperature of 23°C - 25°C The soil is sandy-loam light to darkish in colour. (University of Jos meteorological Station, 2000).

Methods

Water hyacinth plant and clean water (from area without weed) were collected from Pandam lake in Pandam game reserve. The initial water quality (Physicochemical parameter) of the clean water from pandam were assessed.

The plant was seperated into leaves and roots parts and were further replicated into three equal parts. Each part was placed in a bowl and placed in the college green house to ensure homogenous environmental condition. The bowls were filled with equal volume of water (Pandam lake water), weighed and recorded. The experimental set up was left in the greenhouse for eight weeks to ensure proper diffusion.

Laboratory data analysis

Water samples were taken to the National Vetinary Institute, Vom for laboratory analysis to assess to the physicochemical parameters, using the Standards methods by American Public Health Association (APHA) and American Water Works Association (AWWA) (2005). Water samples were collected and analysed for the following parameters; Physical Parameters (Temperature, Total suspended solids, Total dissolve solids and Turbidity), Chemical Parameters (pH, Calcium, Chloride, Conductivity, Disolved Oxygen, Hardness, Iron, magnesium, Nitrate, Phosphorus and Sulphate).

Statistical analysis

The laboratory analysis result of the water was subjected to standard statistical methods. The statistical analysis carried were descriptive Statistics and Paired sample T-test.

RESULTS AND DISCUSSION

Results: Water quality parameters variations of the ordinary water, water with leaves and roots of water hyacinth obtained from Pandam Lake. The water quality parameters analysis is presented on Table 2

Table 2: Physico-chemical quality parameters of the sampled water

Parameters	Ordiary water		Water hyacinth leaves		water hyacinth roots		P-value	WHO
	Mean	SD	**Mean**	**SD**	**Mean**	SD	@ **5%**	**WHO**
Temperature (^{0}C)	22.26	1.26	**21.84**	**0.88**	24.56	0.84	**0.003**	**25**
Turbidity (NTU)	10.6	1.75	**10.22**	**1.65**	10.28	1.56	**0.704**	**5**

TSS (mg/l)	71.8	1.26	**70.98**	**3.35**	70.38	3.66	**0.178**	**20**
TDS (mg/l)	65.66	2.6	**64.78**	**2.4**	64.16	2.84	**0.157**	**500**

(Sources: Aurthor's Field work; WHO, 2011)

Temperature Variation Patterns of the lake: Table 2 shows that the mean water temperature of ordinary water, mean temperature is recorded as 22.26°C, with standard deviation of 1.26. For water with hyacinth leaves (mean: 21.84°C; 0.88) and water from the roots (mean: 24.56°C; 0.84). The statistical differences in temperature conditions between water from the two plant parts considered show significant difference (0.003) @ 5% probability level (Table 4).

Turbidity (NTU): Mean value of Turbidity (NTU) of 10.60NTU; 1.75 were recorded for for ordinary water. 10.22NTU; 1.65 for water with hyacinth leaves and 10.28NTU; 1.56 for the water from the roots respectively. The statistical differences in turbidity conditions between water from the two plant parts considered show no significant difference (0.704) @ 5% probability level (Table 4).

Total Suspended Solid (TSS). TSS recorded mean level of 71.80mg/l; 1.26 for ordinary water, 70.98mg/l; 3.35, for water with hyacinth leaves and 70.38mg/l; 3.66 for the water from the roots respectively. The statistical differences in TSS conditions between water from the two plant parts considered show no significant difference (0.178) @ 5% probability level (Table 4).

Total dissolved solids (TDS) Variation Patterns: Mean value of total dissolved solids for ordinary water is 65.66mg/l; 2.60 (64.78mg/l; 2.40) for water with hyacinth leaves and (64.16mg/l; 2.84) for the water from the roots respectively. The statistical differences in TDS conditions between water from the two plant parts considered show no significant difference (0.157) @ 5% probability level (Table 4).

Table 3: Physico-chemical quality parameters of the sampled water

Parameters	Ordiary water		Water hyacinth leaves		water hyacinth roots		P-value @ 5%	WHO
	Mean	SD	**Mean**	**SD**	**Mean**	SD		**WHO**
Ph	6.72	0.19	**6.42**	**0.57**	6	0.34	**0.036**	**6.5-8.5**
Hardness	10.62	1.75	**12.08**	**0.38**	13.65	0.61	**0.005**	**-**
EC (µs/cm)	12.4	0.72	**11.7**	**0.47**	11.24	0.79	**0.140**	**400**

Sodium (mg/l)	60.08	3.41	**57.6**	**1.08**	55.3	1.92	**0.081**	**250**
DO (mg/l)	3.84	0.27	**3.2**	**0.16**	2.9	0.22	**0.077**	**3**
Calcium (mg/l)	16.7	0.5	**13.78**	**0.7**	12.24	0.8	**0.026**	**200**
Chloride (mg/l)	14.88	0.46	**17.3**	**0.16**	19.2	0.16	**0.162**	**250**
Iron (mg/l)	4.84	0.21	**4.65**	**0.44**	4.2	0.16	**0.093**	**0.3**
Magnesium (mg/l)	9.2	0.16	**7.9**	**0.52**	7.56	0.57	**0.014**	**100**
Nitrate (mg/l)	11.94	0.23	**12.08**	**0.38**	12.4	0.72	**0.227**	**10**
Phosphate (mg/l)	6.72	0.19	**6.48**	**0.69**	6.37	0.6	**0.365**	**5**
Sulphate (mg/l)	6.02	0.31	**5.56**	**0.21**	5.36	0.24	**0.140**	**250**

(Sources: Aurthor's Field work; WHO, 2011)

pH Variation Patterns of the lake: pH recorded mean level of 6.72; 0.19 for ordinary water, for water with hyacinth leaves is 6.42; 0.57 and 6.00; 0.34 for the water from the roots respectively. The statistical differences in P^H conditions between water from the two plant parts considered show significant difference (0.036) @ 5% probability level (Table 4).

Hardness variation pattern of the lake: Hardness recorded mean level of 10.62mg/l; 1.75 for ordinary water, 12.08mg/l; 0.38 for water with hyacinth leaves and 13.65mg/l; 0.61 for the water from the roots respectively. The statistical differences in Hardness conditions between water from the two plant parts considered show no significant difference (0.005) @ 5% probability level (Table 4).

Electrical Conductivity Variation Patterns of the lake: Mean value of EC (µs/cm) of for ordinary water is 12.40 µs/cm; 0.72, 11.70 µs/cm; 0.47 for water with hyacinth leaves and 11.24 µs/cm; 0.79 for the water from the roots respectively. The statistical differences in electrical conductivity conditions between water from the two plant parts considered show no significant difference (0.140) @ 5% probability level (Table 4).

Sodium Variation Patterns of the lake: Sodium recorded mean level of 60.08mg/l: 3.41 for ordinary water, 57.60mg/; 1.08 for water with hyacinth leaves and 55.30mg/l; 1.92 for the water from the roots respectively. The statistical differences in Sodium conditions between water from the two plant parts considered show no significant difference (0.081) @ 5% probability level (Table 4).

Dissolve Oxygen (DO) Variation patterns of the Lake: Mean value of 3.84mg/l; 0.27 for ordinary water, 4.72mg/l; 0.31 for water with hyacinth leaves and 2.90mg/l; 0.22 for the water from the roots respectively. The statistical differences in DO conditions between water from the two plant parts considered show no significant difference (0.077) @ 5% probability level (Table 4).

Calcium (Ca) variation patterns of the lake: Calcium recorded mean level of 16.70mg/l; 0.50 for ordinary water, 13.78mg/l; 0.70 for water with hyacinth leaves and 12.24mg/l; 0.80 for the water from the roots respectively. The statistical differences in Calcium conditions between water from the two plant parts considered show no significant difference (0.026) @ 5% probability level (Table 4).

Chloride (Cl^-) Variation Patterns of the lake: Chloride (Cl^-) recorded a mean value of 14.88mg/l; 0.46 for ordinary water, 17.30mg/l; 0.16 for water with hyacinth leaves and 19.20mg/l; 0.16 for the water from the roots respectively

Iron (Fe) Variation Patterns of the lake: Iron (Fe) recorded a mean value of 4.84mg/l; 0.61 for ordinary water, 4.65mg/l; 0.44 for water with hyacinth leaves and 4.20mg/l; 0.16 for the water from the roots respectively. The statistical differences in Iron conditions between water from the two plant parts considered show no significant difference (0.093) @ 5% probability level (Table 4).

Magnesium (Mg) Variation Patterns of the lake: Magnesium (Mg) recorded a mean value of 9.20mg/l; 0.16 for ordinary water, 7.90mg/l; 0.52 for water with hyacinth leaves and 7.56mg/l; 0.57 for the water from the roots respectively. The statistical differences in Magnesium conditions between water from the two plant parts considered show no significant difference (0.014) @ 5% probability level (Table 4).

Nitrate (NO_3^-) variation patterns of the lake: Nitrate recorded mean level of 11.94mg/l; 0.23 for ordinary water, 12.08mg/l; 0.38 for water with hyacinth leaves and 12.40mg/l; 0.72 for the water from the roots respectively. The statistical differences in Nitrate conditions between water from the two plant parts considered show no significant difference (0.227) @ 5% probability level (Table 4).

Phosphate (PO_4^{3-}) Variation Patterns of the lake: Phosphate (PO_4^{3-}) recorded a mean value of 6.72mg/l; 0.19 for ordinary water, 6.48mg/l; 0.69 for water with hyacinth leaves and 6.37mg/l; 0.60 for the water from the roots respectively. The statistical differences in Phosphate conditions between water from the two plant parts considered show no significant difference (0.365) @ 5% probability level (Table 4).

Sulphate (SO_4^{2-}) variation Patterns of the lake: Sulphate (SO_4^{2-}) recorded a mean value of 6.02mg/l; 0.31 for ordinary water, 5.56mg/l; 0.21 for water with hyacinth leaves and 5.36mg/l; 0.24 for the water from the roots respectively. The statistical differences in Sulphate conditions between water from the two plant parts considered show no significant difference (0.140) @ 5% probability level (Table 4).

Discussion

This study aimed to understand how the presence of water hyacinth had influenced the physico-chemical environment of Pandam Lake ecosystem. The T-test on the physicochemical parameters revealed that there was significant difference with respect to temperature between water hyacinth leaf and root plant parts; however the root part had a higher temperature. This agrees with report of Navarro and Phiri, (2000). Meina *et al*. (1999) have also shown that floating water hyacinth mats may have a profound influence on the diurnal temperature fluctuation. The water hyacinth plants can stand both highly acidic and highly alkalinic conditions, but more vibrant growth is supported by neutral water bodies (Gopal, 1987). According to Gopal, (1987), water hyacinth plants do not survive in water media with pH equal to or less than 4.0 and given that in Pandam Lake the average value for ordinary is 6.72, this is one of the contributing factors as to why water hyacinth continues to proliferate. In this study dissolved oxygen was found to be low under the root of water hyacinth (2.9mg/l) while in ordinary water, it was fairly high with an average value of 3.84 mg/l. According to Kasulo (1999) the water hyacinth mat effectively prevents the vertical diffusion of dissolved gases and plays a more important role in preventing the entrance of oxygen into the water than carbon dioxide going out, as the latter gas is highly soluble in water. The large biological input of carbon dioxide by the anaerobic decomposition of the decaying water hyacinth leaves or detritus on the bottom and within the mat, as well as the repeated respiratory activities of its inhabiting organisms, are responsible for the high sustained levels of this gas as reported by Mathooko (2000) in riverine ecosystems. Although some of the dissolved carbon dioxide is utilized in photosynthetic fixation by the water hyacinth (Robarts *et al*. 1982) or part remains unutilized. It can therefore be deduced that water hyacinth mats have altered the physico-chemical properties of Pandam Lake and should be eradicated.

Phosphate and nitrate concentrations were found to be significantly lower under water hyacinth water than ordinary water (Table 3). Water hyacinth took up nitrate preferentially to phosphate in the lake as indicated by the study's results. This was under the prevailing conditions and at the concentrations of nutrients in the lake during the sampling period. Further, the relative difference between nitrate concentrations at areas with water hyacinth and at sites without water hyacinth was larger than between phosphate concentrations at these sites. Such a local decrease appears to be generally more pronounced in nutrient rich lakes, like was the case with the study area, than in oligotrophic lakes (Maine *et al*. 1999; Rodriguez and Betancourt, 1999). In comparison with early records of the water quality in Lake Naivasha presented by Adams *et al*. (2002) some marked differences with this study's measurements were noted: pH values in this study were much lower than in the earlier records (pH 7.1–7.2). The results of this study revealed that there was a high growth of the water hyacinth in all the sampled areas at this field work. However, water hyacinth was not analysed to ascertain the concentration of these nutrients on the plant. The total amount of nitrogen and phosphorus accumulated in the plant biomass is, however, usually low compared to those of the sediments and water column (Aoyama and Nishizaki, 1993).

Furthermore, a net loss of phosphorus from the water column to the sediments is likely to occur due to sedimentation. Degradation of water hyacinth is hampered because of the low nutritional value of its tissue and the presence of a waxy-cutin resistant outer layer (Battle and Mihuc, 2000). Although the nutrient uptake rate of water hyacinth is high compared to that of other macrophytes, which may potentially result in a significant impact on concentrations and turnover rates of nutrients in a lake (Pinto and Greco, 1999). This paper has thrown light on the physico-chemical properties of water hyacinth of Pandam Lake.

Conclusion

Effects of water hyacinth on the Physicochemial quality of Pandam Lake water was investigated using ex-situ approach. The study observed that the presence of water hyacinth has been shown to lead to a condition of eutrophication; a process of low dissolved oxygen due to the respiratory activity of the masses of the leaves and roots of water hyacinth. The reduced dissolved oxygen creates an in-conducive environment for aquatic organisms and consequently leads to decrease in growth, fauna abundance and activity in the Lake.

Recommendations

1. There is need for improvement of land use management in the catchment and along the lake so as to reduce silt and nutrient loads as a mechanism for controlling the proliferation of water hyacinth.
2. It is recommended that all stakeholders of Pandam Lake be involved in water hyacinth control attempts.
3. Enlightenment campaigns should be carried out to sensitize and mobilize riparian communities on the impact of water hyacinth infestation in Pandam Lake.

References

Adams, C. S. Boar, R. R., Hubble D. S., Gikungu, M. Harper, D. M. Hickley, H. and Tarras-Wahlberg, N. (2002) The dynamics and ecology of exotic tropical species in floating plant mats: Lake Naivasha, Kenya. *Hydrobiologia* 488 115-122.

Aoyama, I. and Nishizaki, H. (1993) Uptake of nitrogen and phosphate, and water purification by water hyacinth, Eichhornia crassipes (Mart.). *Water Sci. Technol*. 28, 47–53.

Akosim, C., Kwaga, B. T. and Mamman, G. S., (2007). Flora Resources and Structure in Pandam Wildlife park, Pandam, Plateau State, Nigeria. *Agricultural Journal.* 2(6): 740-747.

American Public Health Association (APHA), American Water Works Association (AWWA), and the Water Environmental Federation (WEF), (1998). *Standard Methods for Examinations of Water and Wastewater*, 20th ed. United Book Press, Inc. Baltimore, Maryland

Battle, J. M. and Mihuc, T. B. (2000) Decomposition dynamics of aquatic macrophytes in the lower Atchafalaya, a large floodplain river. *Hydrobiologia* 418, 123 –136.

Dami, F. D. and Manu, S. A. (2008). The Bird Spcies of Pandam Wildlife Park and the

Surrounding Farmlands. *Science World Journal Vol* 3 (2007). www.scienceworld journal.com

Dutartre, A., Henry, J. E. and Peltre, M. C. (2009). Invasive plant management coordination in France: Role of territorial working groups. 4th International Symposium on Weeds and Invasive Plants. 18 -23 March, 2009, Montpellier, France.

Enright, W. D (2000). The effect of Terristrial Invasive Alien plants and water resources in South Africa . *Physics, Chemistry Earth*, 3 (25), 237 -242.

Ezealor A. U. (2002). Critical Site for Biodiversity Conservation in Nigeria NCF, Lagos, Nigeria.

Gopal, B. (1987). Water hyacinth. Elsevier, Oxford, UK. Aquatic Plant Studies, No. 1. 471 pp.

Gordon, B. and Arne, E. 2013. Invasive Alien Plants and Their Management in Africa. Synthesis Report. UNEP/GEF.

Kasulo, V. (1999) "The impact of invasive species in African Lakes'' a paper presented at the workshop on Economics of Invasive species, University of York, U.K.

Kettumen, M., Genovesi, P., Gollasch, S., Pagad, S., Starfinger, U., Brink, P., and Shin, C. (2008). Technical support to EU strategy on invasive species (IAS) - Assessment of the impacts of IAS in Europe and the EU (final module report for the European Commission). Institute for European Environmental Policy (IEEP), Brussels, Belgium. 44 pp. + Annexes.

Lejas, S. (2002). *Distribution, autoecologie et impacts de Ludwigia peploides et ludwigia ur uguauensis doms l'hydrosysteme ligerien. DIRS*, Universite Francois rabelais, tours. 70pp. + annexes.

Pinto, R. M. and Greco, M. K. B. (1999). The contribution of water hyacinth (Eichhornia crassipes) and zooplankton to the internal cycling of phosphorus in the eutrophic Pampulha Reservoir, Brazil. Hydrobiologia 411, 115 –127.

Rodríguez-Gallego, L. R., Mazzeo, N., Gorga, J., Meerhoff, M., Clemente, J., Kruk C., F. S.,

Lacerot, G., García, J. and Quintans F. (2004). The effects of an artificial wetland dominated by freefloating plants on the restoration of a subtropical, hypertrophic lake. *Lakes and Reservoirs*, 9, 203-215.

Versfeld, D. B., Le Maitre, D. C and Chapman, R. A. (1998). Invading alien Plants and Water Resources in South Africa. Water Research Commission, Technical Report NO.TT 99/98. Pretoria.

Working for Water Programme (WfW). (2004). The Working for Water Programme–A multi-departmental initiative. Accessed March 15, 2018 from http://www-dwaf.pwv.gov.za/idwaf/projects/wfw.

World Health Organization (WHO), (2011). Guidelines for Drinking Water Quality.Vol. 1.World Health Organization.Geneva, p.129.