TOXIC ALGAL INCIDENT IN THE GROOTDRAAI DAM, 2001

by

C.E. van Ginkel

INSTITUTE FOR WATER QUALITY STUDIES
DEPARTMENT OF WATER AFFAIRS AND FORESTRY

TITLE:	TOXIC ALGAL INCIDENT IN THE GROOTDRAAI DAM, 2001
REPORT NUMBER:	N/C110/02/DEQ/0401
PROJECT:	Eutrophication Project
STATUS OF REPORT:	Final
DATE:	July 2001

This report should be cited as:
Van Ginkel, C.E. (2001*).* Toxic Algal Incident in the Grootdraai Dam, 2001. Internal Report No. N/C110/02/DEQ/0401. Institute for Water Quality Studies, Department of Water Affairs and Forestry. Pretoria.

EXECUTIVE SUMMARY

Introduction

A request on 20 March 2001 to the IWQS by Mr. Pieter Cornelius, from the DWAF office at the Grootdraai Dam, initiated *ad hoc* monitoring and investigation on 27 March 2001 to determine if the algal bloom in the Grootdraai Dam was toxic.

Study site

The Grootdraai Dam is situated north-east of Standerton on the Vaal River, in the Mpumalanga Province of South Africa and forms an important section in the Usuthu-Vaal transfer scheme. The water of the Grootdraai Dam is used mainly for industrial purposes, and to a lesser extent for domestic and recreational purposes.

Results and Conclusions

The system is turbid and light limitation inhibits the development of extreme phytoplankton blooms. The historical nutrient concentrations within the system support the development of potentially toxic cyanobacterial blooms.

- The cyanobacterial bloom in the Grootdraai Dam was toxic.
- The nitrogen and phosphorus concentration in the Grootdraai Dam on 27 March 2001 supported the development of cyanobacterial blooms that may be toxic.
- The water column was in a state of overturn and diatoms, as dominant phytoplankton group, can be expected to replace the dominant cyanobacteria, during the winter period.
- The toxic cyanobacterial bloom in the Grootdraai Dam poses a domestic health hazard to the local DWAF community, as the water treatment facilities cannot remove cyanobacterial toxins, if present.
- The suspended solid concentration in the Grootdraai Dam during the day of the survey may cause significant to major damage due to fouling for the Category 1 industrial users.

Recommendations

- All domestic and recreational water users should be warned of the potential health hazard immediately when it occurs.

- Sign boards should be put up at the dam to warn recreational users in future to avoid scum affected areas.

- The domestic water treatment facilities at the DWAF community at the Grootdraai Dam should be upgraded to include either:
  - The ability to withdraw water at least 5 m below the surface, or
  - An activated carbon step in the local treatment process to prevent health effects to the local community.

TABLE OF CONTENTS

1. OBJECTIVE

The objective of the *ad hoc* investigation was to determine if the algal bloom present in the Grootdraai Dam, since 20 March 2001, was toxic.

2. PROBLEM STATEMENT

The phytoplankton bloom has been noticed for the last three weeks prior to the investigation on 27 March 2001. Mr. Cornelius reported that the local DWAF town at the Grootdraai Dam experienced problems with the water. Itching, one of the symptoms of cyanobacterial toxins, was reported after showering with locally purified water. Water from the impoundment is also released downstream for domestic purposes to Standerton.

3. STUDY AREA

The Grootdraai Dam is situated on the Vaal River north-east of Standerton in the Mpumalanga Province of South Africa (Figure 1). The Grootdraai Dam is situated upstream of the Vaal Dam and is one of the major dams of the country. The impoundment is part of the Usuthu-Vaal transfer scheme. The water of the Grootdraai Dam is mainly used for industrial (cooling for power generation) purposes, however, recreational use was seen during the investigation. The domestic use of the water directly from the impoundment is relatively limited. Only the local DWAF town of approximately 100 people uses locally chlorinated water.

The main impactor in the catchment of the Grootdraai Dam is the New Denmark Power Station that is situated on the Leeu Spruit. There are, however, also smaller Sewage Treatment Works (e.g. at Morgenzon) in the catchment of the Blesbok Spruit.

Van Ginkel *et al.* (2001) showed that cyanobacteria formed the dominant phytoplankton group in the Grootdraai Dam from 1989 to 1999. The chlorophyll *a* concentrations seldom exceeded the 30 $\mu g/\ell$ eutrophication limit, which typically indicates potential bloom conditions. The cyanobacteria in the Grootdraai Dam have previously been found to contain both toxic and non-toxic *Microcystis aeruginosa* forms, but no definite toxicity has been known to occur in the system (Quibell *et al.*, 1995).

A study done by Van Ginkel *et al.* (2001) showed that the historical nutrient concentrations in the Grootdraai Dam were consistently within the required concentrations according to the Phosphorus Management Objective (DWA 1988, Anonymous 1988a, Anonymous 1988b) and the nitrogen Target Water quality objectives of the South African Water Quality Guidelines for aquatic ecosystems (DWAF 1996b). The TN:TP ratio were mostly below 20 and often below 15. TN:TP ratios of below 15 is known to favour cyanobacterial blooms.

The occurrence of toxic cyanobacterial blooms can, therefore, occur in the Grootdraai Dam.

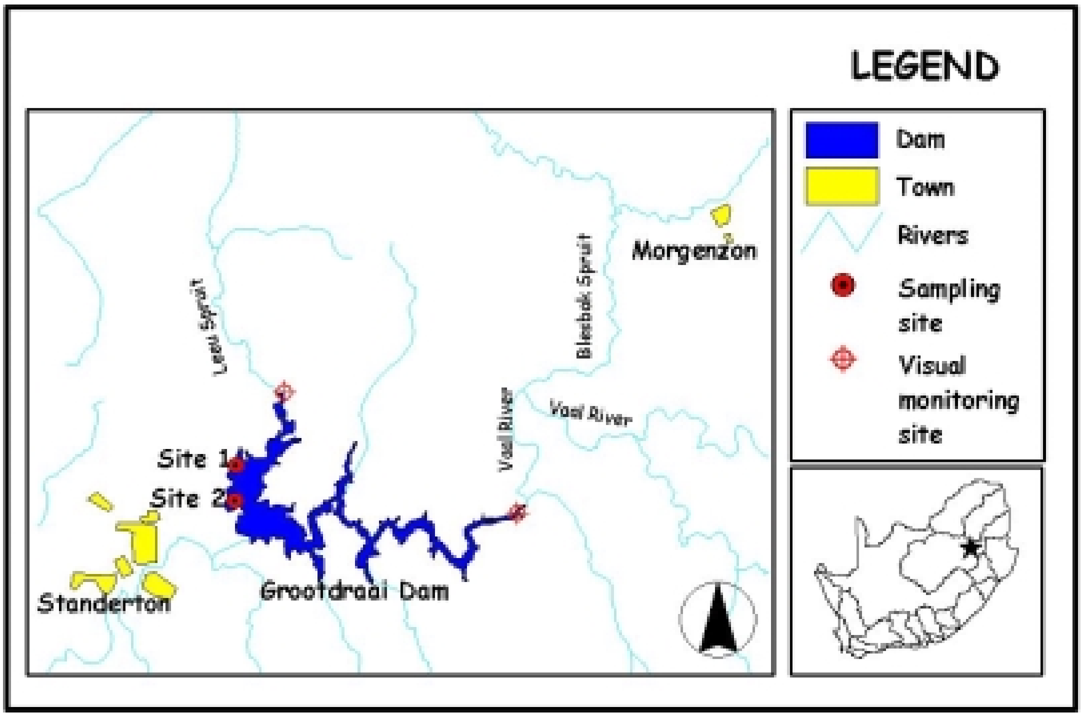

Figure 1. Monitoring and sampling sites in the Grootdraai Dam on 27 March 2001.

4. SAMPLING METHODS AND ANALYSES

The water of the Grootdraai Dam was sampled on 27 March 2001 at two sites (Figure 1) to determine the toxicity of the cyanobacterial bloom. The sites were selected according to where enough cyanobacterial scum had accumulated in the impoundment. The inflowing streams were visited to determine whether algal scum also accumulated at these sites. Visual monitoring in the inflowing streams was also conducted on the day of the investigation.

4.1 Sampling methods

An *ad hoc* hose-pipe sample taken at Site 1 was poured into the major inorganic chemical (macro) sampling bottles of the IWQS, preserved with mercury-(II)-chloride and transferred to the IWQS. A grab sample was taken at Site 2 of the cyanobacterial scum for toxicity testing and transferred to the IWQS.

The physical parameters, temperature and dissolved oxygen, were measured *in situ* at the Grootdraai Dam with a YSI 95 oxygen and temperature meter and the pH reading was determined in the Macro Elements Laboratory at the IWQS.

4.2 Visual monitoring

The main inflowing river into the Grootdraai Dam, namely the Leeu Spruit and the Vaal River were visited by Mr. Cornelius and the author for visual monitoring (Figure 1) only.

4.3 Analysis methods

4.3.1 Macro chemical samples including Kjeldahl nitrogen (KN) and total phosphorus (TP) analysis were taken at the dam wall site of Grootdraai Dam. The analyses included are pH, ammonium (NH_4-N), nitrate and nitrite ($NO_3 + NO_2$ as N), fluoride (F), alkalinity as calcium carbonate (ALK), sodium (Na), magnesium (Mg), silicon (Si), ortho-phosphorus (PO_4-P), sulphate (SO_4), chloride (Cl), potassium (K), calcium (Ca), electrical conductivity (EC), and total dissolved salts (TDS). The methods used to determine these variables are discussed in detail in the IWQS (1999) document.

4.3.2 Biological samples were analysed by the biological laboratory of the IWQS. Samples were tested for chlorophyll-*a*, phaeophytin-*a*, total suspended solids (TSS) and algal identifications. The methods used to determine the results are discussed in detail in the IWQS (2000a) document.

4.3.3 The cyanobacterial scum samples were poured into litre bottles and kept in a cool box for transport to the IWQS. At the IWQS ELISA screening was done on the samples. The samples were then frozen and thawed thrice before HPLC analysis were done to determine the presence of cyanobacterial toxins in the samples.

5. RESULTS AND DISCUSSION

Van Ginkel *et al.* (2001) had previously classified the Grootdraai Dam as eutrophic and turbid. According to Mr. Cornelius the presence of a pea-soup like bloom is an annual event over the last ten years. The turbidity of the system prevented eutrophication with the resulting high chlorophyll *a* concentrations, as these concentrations seldom exceeded 10 $\mu g/\ell$.

The Vaal River downstream of the confluence with the Blesbok Spruit showed no cyanobacterial scum. The Leeu Spruit did however present in a large affected area at the site that was monitored visually at the two sites as indicated in Figure 1.

5.1 Water Quality Conditions

The results were assessed using the Industrial (DWAF 1996a) and the Aquatic Ecosystems (DWAF 1996b) guidelines. The domestic and recreational guidelines were not used, as there is such limited domestic and recreational uses of the water of the Grootdraai Dam.

Table 1 Results of the *ad hoc* chemical, biological and physical sampling in the Grootdraai Dam on 27 March 2001. (NA = Not available; NR = Not relevant)

Variable	Industrial Category 1 (DWAF, 1996a)	Aquatic Ecosystems (DWAF, 1996b)	Site 1 (Dam wall)	Site 2
Date			2001-3-27	2001-2-14
Time			10:00	9:30
Surface Temperature (°C)	NA	NA	26	-
Dissolved oxygen (%)	NR	80% -120%	61.4	-
Cyanobacterial species	NR	NA	*Microcystis* *Pseudoanabaena*	-
ELISA Screening Test	NR	NA	Positive	Positive
HPLC (Toxins)	NR	NA	Microcystin-LA	Microcystin-LA
Chlorophyll-*a* (µg/ℓ)	NA	NA	22.41	-
Phaeophytin-*a* (µg/ℓ)	NA	NA	6.64	-
Suspended solids (mg/ℓ)	0 – 3	NA	35.6	-
Secchi depth (m)	NA	NA	0.22	-
pH	7.0 – 8.0	No variation from background	8.0	-
Kjeldahl nitrogen (mg/ℓ)	NA	NA	1.02	-
Ammonium (mg/ℓ)	NA	NA	<0.04	-
Nitrate & nitrite (mg/ℓ) as N	NA	2.5	0.10	-
Fluoride (mg/ℓ)	NA	≤ 0.75	0.2	-
Alkalinity as $CaCO_3$ (mg/ℓ)	0 – 50	NA	72	-
Sodium (mg/ℓ)	NA	NA	12	-
Magnesium (mg/ℓ)	NA	NA	11	-
Silica (mg/ℓ)	0 - 5	NA	6.2	-
Total phosphorus (mg/ℓ) as P	NA	NA	0.066	-
Ortho-phosphorus (mg/ℓ) as P	NA	0.025	0.022	-
TN:TP ratio	NA	NA	2.54	-
PO_4:TP ratio	NA	NA	0.33	-
Sulphate (mg/ℓ)	0 - 30	NA	27	-
Chloride (mg/ℓ)	0 – 20	NA	11	-
Potassium (mg/ℓ)	NA	NA	3.0	-
Calcium (mg/ℓ)	NA	NA	15	-
Electrical Conductivity (mS/m)	NA	NA	24.4	-
Total dissolved salts (mg/ℓ)	0 – 100	Not more than 15 % change (Median of 168)	166	-

The results of the investigation are shown in Table 1. The turbidity of the system is indicated by the Secchi disc reading of 0.22 m. The development of extensive serious toxic cyanobacterial blooms in the Grootdraai Dam are, therefore, inhibited by light limitation rather than nutrients. The total phosphorus concentration (0.066 mg/ℓ) on the day of the investigation is indicative of an eutrophic system (TP > 0.047 mg/ℓ (Walmsley an Butty 1980)), although it is within the Phosphorus Management Objective (PMO) of 0.130 mg/ℓ as published by DWA (1988), Anonymous (1998a) and Anonymous (1988b). This indicates that the PMO may be unrealistically high as toxic cyanobacterial blooms establish it-self at much lower phosphorus concentrations.

The TN:TP ratio indicates that the system was nitrogen limited during the investigation. A TN:TP ratio of less than 15 supports the development of cyanobacterial blooms.

Three variables, namely, suspended solids, silica and total dissolved salts were higher than the South African Water Quality Guideline for Industrial uses (DWAF 1996a; Table 1).

Suspended solids is one of the main causes of fouling and is specifically encountered in steam generation and cooling of water systems, where it causes blockages, impedes air circulation and can lead to localised overheating in boilers with subsequent metal damage. Suspended solids may be abrasive and cause failure of pump seals, bearings or valves and controls. Suspended solids promote microbial growth with the subsequent build-up of slime, which acts as a sediment trap. The build-up of such slimes often contains sulphate-reducing bacteria that are responsible for microbially-influenced/induced corrosion with serious damage to pipelines and equipment. The suspended solids in the Grootdraai Dam water may cause significant to major damage due to fouling for the Category 1 industrial uses.

Sillica is undesirable in boilers as it may form hard scale in the boilers and boiler tubes. In steam-generation systems, silica can volatilise and pass over with the steam, where it will form hard scale on steam turbine blades, which is difficult to remove. The silica concentration present in the water of the Grootdraai Dam during the day of the survey may only cause minor damage due to scaling, have no or negligible interference with the processes for the Category 1 industrial uses of the water.

Total dissolved salts in the water of the Grootdraai Dam may cause minor damage as a result of corrosion, scaling or fouling to equipment or structures in the industrial uses.

5.2 Physical Conditions

The temperature and dissolved oxygen concentration profile in the Grootdraai Dam at the dam wall on 27 March 2001 (Figure 2) indicate that the system was in the process of turnover (complete mixing). There was only a slight decrease in temperature from the surface to 2 m where after the temperature stayed relatively constant further down the water column. The oxygen concentration in the water column was low at the surface (5.5 mg/ℓ) but did not change significantly from the surface to 26 m (4.44 mg/ℓ).

The surface concentration of dissolved oxygen of 61.4 % (Table 1) is lower than the required oxygen saturation for aquatic ecosytems (DWAF 1996b).

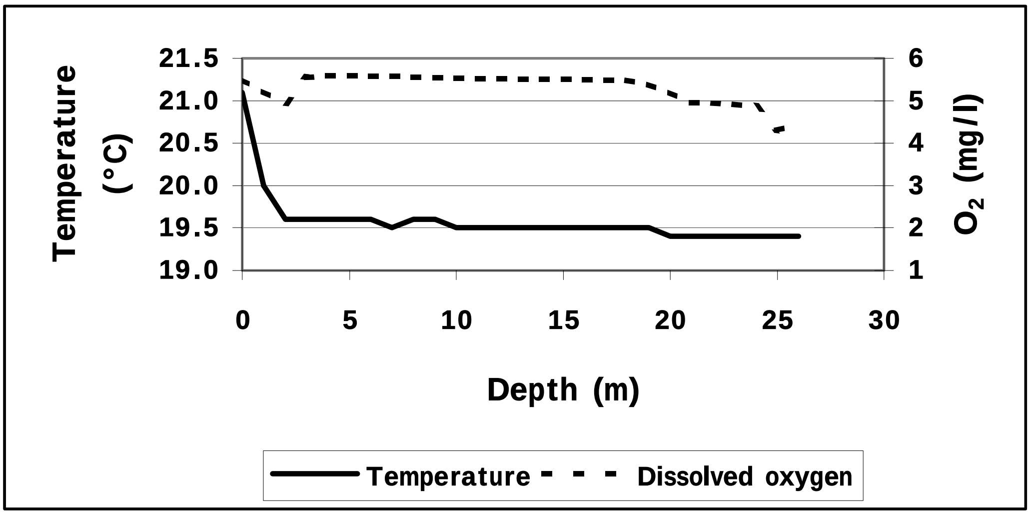

Figure 2. The temperature and dissolved oxygen concentration at Site 1 in the Grootdraai Dam at the dam wall on 27 March 2001.

5.3 Biological Conditions

The Grootdraai Dam had a clear phytoplankton (algal) bloom that was established at the dam wall (Figure 3 A & B) on the day of the investigation. The main basin only showed streaks of algal biomass at the surface, while the rest of the water showed the high turbidity present in the water column (Figure 4).

At Site 2 the bloom was, according to Mr. Cornelius, more distinct during the previous weeks than on the day of the investigation (Figure 5 A & B). The clear blue-green and whitish colour of the cyanobacterial bloom was however, still present at Site 2.

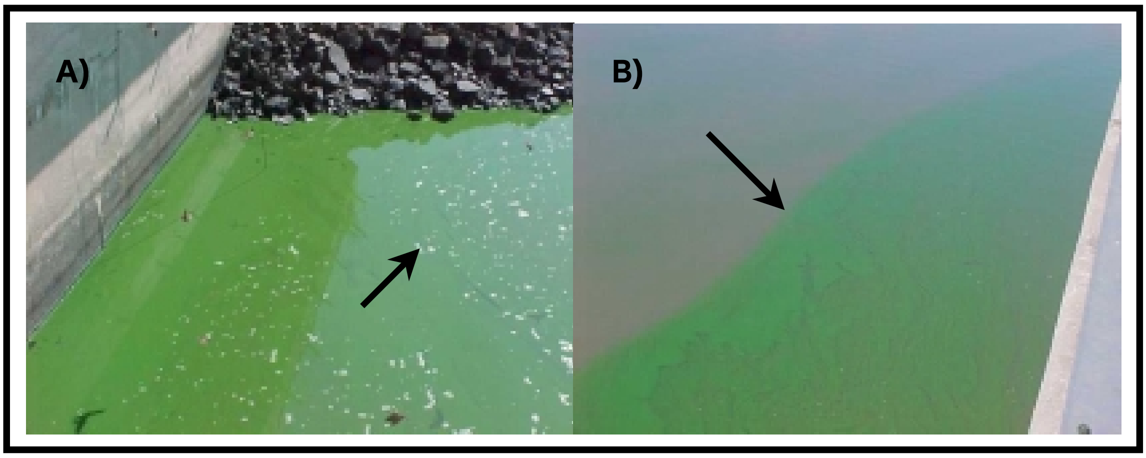

Figure 3. Phytoplankton bloom as live scum at the Grootdraai Dam wall at Site 1. A) Cyanobacterial bloom showing slight scum formation (arrow) at the top. B) Cyanobacterial scum showing the distinct surface scum and the turbidity of the water

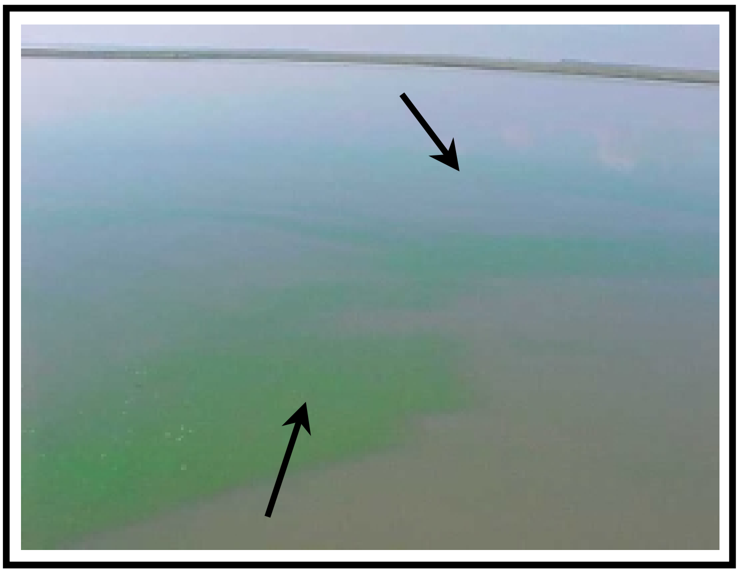

Figure 4. The water surface of the main basin of the Grootdraai Dam showing the streaks of the phytoplankton bloom.

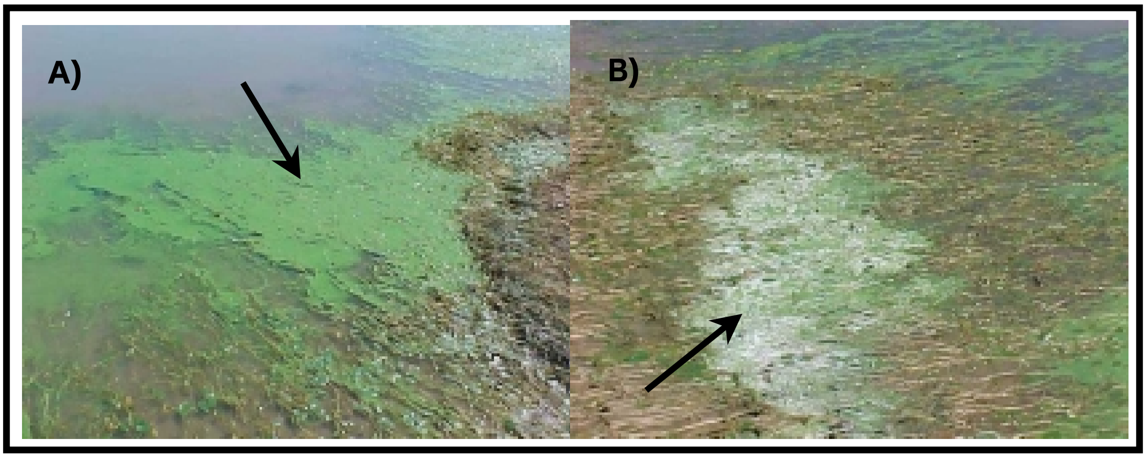

Figure 5. The cyanobacterial scum still present at Site 2 in the Grootdraai Dam on 27 March 2001 between aquatic weed growth. A) The cyanobacterial bloom in a viable state. B) The cyanobacterial bloom indicating the distinct blue-green to whitish dead material.

According to the ELISA Screening (Table 1) the cyanobacteria scum at both site 1 and 2 tested positive for microcystin toxins. The HPLC analysis indicated that the toxin present was Microcystin-LA.

The dominance of *Microcystis* , the identified culprit species in the Grootdraai Dam, is usually restricted to late summer and autumn and then replaced by diatoms. This phenomenon will probably also take place in the Grootdraai Dam, as the impoundment is situated in an area that are extremely cold during winter.

6. CONCLUSIONS

6.1 The cyanobacterial bloom in the Grootdraai Dam was toxic.

5.1 The nutrient contents in the Grootdraai Dam supports the development of cyanobacterial blooms.

5.2 The water column was in a state of overturn and diatoms, as dominant phytoplankton group, shall soon replace the dominant cyanobacteria, during the winter period.

5.3 The cyanobacterial bloom and the presence of Microcystin-LA poses a domestic health hazard to the local DWAF community.

5.4 The suspended solid concentration in the Grootdraai Dam during the day of the survey may cause significant to major damage due to fouling for the Category 1 industrial users.

7. RECOMMENDATIONS

- All domestic water users should be warned of the potential health hazard.

- Signboards should be put up to warn recreational users in future to avoid scum affected areas.

- The domestic water treatment facilities at the DWAF community at the Grootdraai Dam should be upgraded to include either:
  - The ability to withdraw water at least 5 m below the surface, or
  - An activated carbon step in the local treatment process to prevent health effects to the local community.

8. ACKNOWLEDGEMENTS

7.1 The author wants to thank the IWQS Laboratories for sampling analysis without which this report would not have been possible.

7.2 The author wants to thank Mr. P Cornelius for his assistance during the investigation on 27 March 2001.

7.3 The author wishes to thank Dr. A. Kühn and Dr. P. Kempster for constructive comments.

9. REFERENCES

ANONYMOUS, (1988a) Phosphate standard now strictly enforced. *SA Waterbulletin*, vol. 14, no. 5 p22. Pretoria.

ANONYMOUS, (1988b) Special phosphate standard for sensitive catchments. *Water sewage and Effluent*, vol. 8, no. 4 pp 10-11. Pretoria.

DWA, (1988) Important announcement on implementation of the Special Phosphate standard in sensitive catchments. *IMIESA* (Johannesburg), vol13, no. 9, p 35.

DWAF (1996a). *South African Water Quality Guidelines Volume 3 Industrial use*. Department of Water Affairs and Forestry. PRETORIA, South Africa.

DWAF (1996b). *South African Water Quality Guidelines Volume 7 Aquatic Ecosystems*. Department of Water Affairs and Forestry. PRETORIA, South Africa.

IWQS (1999). *Macro Elements Laboratory Test Methods and SOP Manual.* Revised edition. Institute for Water Quality Studies. Department of Water Affairs and Forestry. PRETORIA. South Africa.

IWQS (2000a). *Biology Laboratory Test Methods and SOP Manual.* Revised edition. Institute for Water Quality Studies. Department of Water Affairs and Forestry. PRETORIA. South Africa.

QUIBELL, G., BADENHORST, J.E. & CARELSEN, C.I.C. (1995). *A national toxic blue-green algal surveillance programme for South Africa.* IWQS, DWAF Report N/0000/DPQ/1094, PRETORIA.

VAN GINKEL, C.E., B.C. HOHLS, A. BELCHER, E. VERMAAK & A. GERBER. (2001) *Assessment of the Trophic Status Project.* Internal Report No. N/0000/00/DEQ/1799. Institute for Water Qulaity Studies. Department of Water Affairs and Forestry. Pretoria.

WALMSLEY, R.D. AND BUTTY, M., (1980) *Guidelines for the control of eutrophication in South Africa.* Special Report, Water Research Commission, PRETORIA, South Africa.