EA - Water quality
Box 3

ENVIRONMENT AGENCY

BLUE-GREEN ALGAL MONITORING 1998

NATIONAL CENTRE FOR
ECOTOXICOLOGY & HAZARDOUS SUBSTANCES

NUTRIENTS SECTION

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CONTENTS

SUMMARY

- This report describes the work that has been carried out by the Environment Agency in England and Wales on monitoring and managing cyanobacterial incidents during 1998, and also discusses Regional differences and temporal trends during recent years.

- An initial monitoring programme in 1989, following the cyanobacterial poisoning incidents at Rutland Water during September of that year, inspected 909 waterbodies. In the subsequent year, a total of 1724 waterbodies were sampled of which 649 (38%) were identified as containing abundant populations of cyanobacteria. Since 1991, a total of 2745 sites have been sampled as part of the reactive monitoring programme, with 1892 (69%) sampled for the first time and 1908 (69%) containing cyanobacteria as the dominant group.

- Annually, between 300-400 waterbodies were sampled, with no distinct annual trend visible, and the majority of sites sampled were in Midlands, Anglian and Thames Regions. Annually, the highest proportion of sampled sites were those sampled reactively for the first time (between 63-80% of the total). Cyanobacteria were the dominant group with approximately two-thirds of the waterbodies sampled containing cyanobacteria; other nuisance algae were reported as diatoms, cryptophytes, and unicellular and filamentous green algae. The warning threshold, which indicates that there is a likely risk of cyanobacterial bloom and scum formation, was exceeded in three-quarters of the waterbodies that contained cyanobacteria.

- The analysis and interpretation of the incidence of algal blooms is complicated by several factors. Firstly, the results are based on a reactive, rather than a comprehensive monitoring programme whereby mainly only sites affected with algal blooms and scums are analysed in response to external enquiries. Sites are rarely investigated which do not have a visible algal bloom/scum present or which have had a history of cyanobacterial problems. Secondly, although the public may indicate an increased alertness and awareness of visible algal blooms and report them more frequently, badly affected sites may not be reported as often. This may be because water owners and managers are also aware of cyanobacterial-related problems, which result in closure of recreational waters and hence have a negative impact on recreation and tourism. Furthermore, other many and complex factors (geochemical, biological and meteorological) affect algal and cyanobacterial distribution and their frequency, with excessive growths of algae and cyanobacteria exacerbated by cultural eutrophication.

- The University of Dundee continues to carry out Research and Development work for the Agency since 1989, on the fate and behaviour of cyanobacterial toxins. Toxicity analysis was carried out on 32 samples during 1998. Sixty two percent of samples examined by bioassay were toxic, the highest incidence of toxicity recorded since 1995. Fifty two per cent of the toxic samples were hepatotoxic and 50% of samples were found to contain a range of microcystins. One scum sample was found to

contain the highest microcystin content of any previously published results in the world. The results are similar to other scientifically published research, therefore, the Environment Agency continues to adopt a precautionary approach, recognising the need to regard all cyanobacterial species and strains as capable of producing toxins, and hence as a threat to animal and human health and safety.

- The Agency is involved in a number of research initiatives and in developing long-term strategies in order to understand better and minimise the problems posed by eutrophication and cyanobacteria. In particular, the Agency has published its consultative report 'Aquatic Eutrophication in England and Wales: a proposed management strategy'. A final strategy is due for publication in early 2000.

1. INTRODUCTION

The first scientifically documented poisoning event attributed to toxins from blue-green algae (cyanobacteria) dates back to 1898 from Australia (Francis, 1898). In England, animal poisoning incidents associated with cyanobacterial blooms have been recorded since the late 1960s (Heaney, 1971, Reynolds, 1980). The problems posed by cyanobacteria following the 1989 major incidents at Rutland Water Reservoir, Leicestershire, and other sites received national media attention and resulted in the creation of immediate management measures. These events in England and Wales have been extensively documented (NRA, 1990a; Turner *et al.*, 1990; Reynolds, 1991). As a result, the potential toxic threat of cyanobacteria and their aesthetic impact has wide implications for the Environment Agency's roles, responsibilities and activities.

It can be argued that there now appears to be a greater awareness of the issue, and cyanobacterial-related problems are becoming accepted for what they are - natural phenomena, which have the potential to re-occur each year, but which may be exacerbated by cultural eutrophication. Eutrophication is defined as the enrichment of water by nutrients, stimulating an array of symptomatic changes. These include the increased productivity of algae and/or higher plants, which may adversely affect the diversity of the biological system, the quality of the water, and the uses to which the water may be put. A range of other complex factors (including suitable geological, chemical, biological and meteorological conditions) also affects algal and cyanobacterial distribution and frequency.

Since the first documented cyanobacterial-poisoning events, deaths of amphibians, fish, birds, and mammals have been reported world-wide and attributed to cyanobacterial toxins (for a review see Moestrup, 1996; Liu and Dutka, 1999). There have been no deaths in humans that can be directly attributed to toxins produced by cyanobacteria in Europe, although in Brazil 55 dialysis patients died from liver failure following dialysis with untreated water from an algal-infested reservoir source containing cyanobacterial toxins. There is also evidence of increased liver cancer incidence in southern China in areas where people regularly drink pond/ditch water containing high numbers of the cyanobacterium *Microcystis aeruginosa*.

There have been many documented reports of human illness associated with the presence of cyanobacteria however, which include contact dermatitis, gastro-enteritis, atypical pneumonia, and hepato-enteritis (NRA, 1990a, Codd and Roberts, 1991). Record outbreaks of hepato-enteritis were recorded in the USA and Australia in chlorinated supplies following algicide-induced lysis of cyanobacterial blooms. It is, however, often difficult to substantiate cyanobacterial-related illness and deaths since many incidents are post-event accounts and descriptions of the events may often be incomplete.

1.1 Action by the Environment Agency in response to cyanobacterial blooms and scums

A fundamental aspect of the Environment Agency's work is to monitor and assess the state of the environment. The Agency achieves this through a framework of 6 basic 'Viewpoints' (Land Use and Resources; Biological Populations, Communities and

Biodiversity; Standards and Targets; Health of the Environment; Long Term Reference Sites; and Aesthetic Quality), which provide information on the state of the environment in order to answer questions and identify areas for further monitoring and surveillance. The monitoring programme for cyanobacteria contributes to the data need in assessing the health of the environment.

The Environment Agency, and its predecessor the NRA, commenced an assessment of the incidence of potentially toxic and nuisance freshwater algae in 1989, and made recommendations for future monitoring and control measures. Routine monitoring programmes of 1989 and 1990 effectively identified high priority waterbodies that were most likely to develop cyanobacterial problems in later years (NRA, 1990b; NRA, 1991).

In 1991, a reactive sampling strategy was adopted. This involved sampling waterbodies, in response to all external enquiries that did not contain abundant populations of cyanobacteria during the earlier routine monitoring. This reduced the repetitiveness of the previous extensive routine monitoring, since as cyanobacteria are likely to reoccur annually once established, routine monitoring would only confirm what was already known. Reactive monitoring continues to provide information to assist in dealing with cyanobacterial problems. In addition, some waterbodies that were reactively sampled in previous years are re-sampled in response to increased public enquiries and specific Agency initiatives.

Depending on findings from the monitoring programme, standard warning letters are dispatched to the owners of affected waterbodies and relevant organisations/parties (Environmental Health Officers, Ministry of Agriculture, Fisheries and Food officers, and Consultants in Communicable Diseases), promoting precautionary action aimed at avoiding human and animal contact with the bloom and scum. The warning letters are accompanied by an information leaflet on 'Blue-green Algae', which describes the problems associated with cyanobacteria, their potential health hazards and stresses the need to avoid human contact with the bloom and/or scum, and to restrict access of livestock and pets to the affected waters. The monitoring programmes are an essential component of the management strategies for the detection and control of cyanobacteria, and their toxins, acting as an early detection of potentially toxic species, making it possible to take fast, initial action before cell numbers reach dangerous levels.

This monitoring programme is supported through the National Centre for Ecotoxicology and Hazardous Substances (NCEHS). The Nutrients Section of NCEHS provides a focal point for the Agency on all aspects of eutrophication, its causes, symptoms, problems and remedies, which include toxic and nuisance algal issues, and is involved in a number of research initiatives and in developing strategies in order to understand better and minimise the problems in the longer-term. The control and management of cyanobacteria and their toxins should not only rely on one approach, and should include measures in the catchment and source waters. In particular, the Agency has published its consultative report 'Aquatic Eutrophication in England and Wales: a proposed management strategy' (Environment Agency, 1998a). Key elements are the promotion of a partnership approach and catchment based actions within the context of a national management framework. A final strategy is due for publication in early 2000.

1.2 Purpose of this report

The Agency has routinely collated information since 1990, from all Regions, regarding cyanobacterial monitoring and management of incidents. Information from the monitoring programmes is collated by Regional Algal Contacts and sent to NCEHS for reporting via a completed annual questionnaire. Data since 1990 have been summarised into annual reports (Environment Agency, 1998b), available from NCEHS.

Details of the monitoring programmes are available in the 'Monitoring and Management of Blue-green Algal Incidents' policy, available from the Algal Scientist, NCEHS and Regional Algal Contacts.

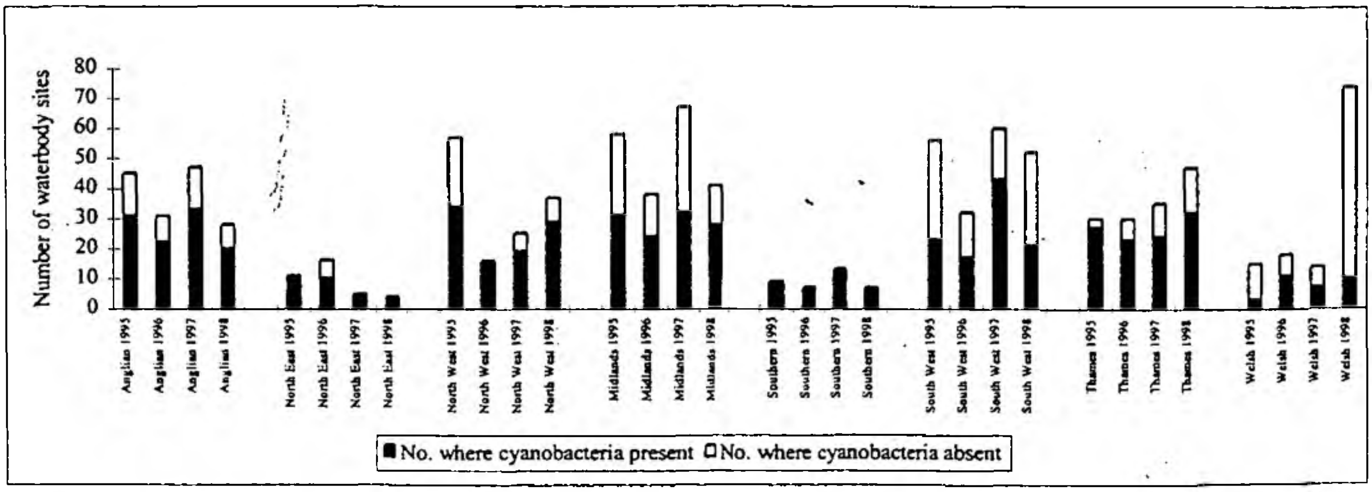
This report describes the work that has been carried out by the Agency on monitoring and management of cyanobacterial incidents during 1998, and discusses Regional differences and temporal trends in recent years.

2. CYANOBACTERIAL MONITORING

2.1 Waterbodies sampled reactively for the first time

The Regional fluctuations in the total number of new sites sampled reactively between 1995-1998 are shown in Figure 1. Waterbodies were sampled at the request of external enquiries (owners, water users and the general public), as part of the reactive monitoring programme. The total number of waterbodies are divided into those which contained cyanobacteria as the dominant group and those where cyanobacteria were absent.

Figure 1. Regional fluctuations in the total number of waterbody sites sampled reactively for the first time between 1995-1998.



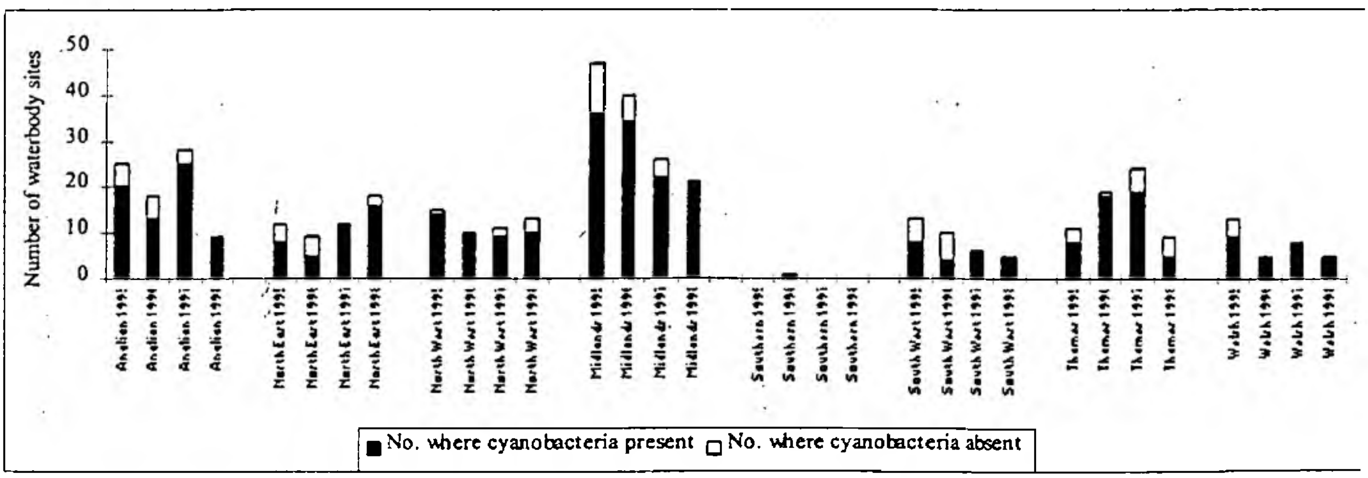
Regionally, no discernible trend is evident in the total number of waterbodies sampled reactively for the first time in the period 1995-1998. This was principally attributed to the reactive nature of sampling. Reactive sampling is carried out at the request of external enquiries in relation to visible algal problems; hence sites which do not have visible algal blooms/scums are rarely investigated. A high proportion of sites sampled however, were found to contain cyanobacteria.

The number of sites sampled was generally highest during 1995 and 1997, attributed to warm years with reduced river flows, and as a result, severe algal blooms developed in running waters. In 1998 over 40 waterbodies were sampled reactively for the first time in South West, Thames and Midlands Regions, with the highest number (78) recorded in Environment Agency Wales. The lowest number of waterbodies sampled reactively for the first time was shown in Southern (7) and North East (4) Regions. Generally, a high proportion of sites sampled in 1998 were found to contain cyanobacteria, ranging from 38% in South West to 100% in Southern Region, the exception being Environment Agency Wales where only 13% of sites sampled reactively for the first time were found to contain cyanobacteria. This is because in 1998 Environment Agency Wales reported a higher proportion of reactive algal samples containing other algal groups.

2.2 Waterbodies sampled reactively in the past which were subsequently re-sampled

The Regional fluctuations in the total number of waterbodies sampled reactively in the past that were subsequently re-sampled are shown in Figure 2. This criterion indicates waterbodies that were re-sampled as part of good public relations, or as part of specific Regional incidents/initiatives. Similarly, the total number of waterbodies are divided into those which contained cyanobacteria as the dominant group and those where cyanobacteria were absent.

Figure 2. Regional fluctuations in the total number of waterbody sites sampled in the past that were subsequently re-sampled between 1995-1998.



Although there is an apparent decline in the number of sites sampled reactively in the past that were subsequently re-sampled between 1995-1998 in Midlands and South West Regions, no discernible annual trend is evident in other Regions during the same period. In 1998, the highest number of sites sampled reactively in the past that were subsequently re-sampled was shown in Midlands (21), and the lowest (zero) in Southern Region.

The proportion of sites found to contain cyanobacteria was generally between 80-100% throughout the Regions – higher than in sites sampled reactively for the first time. This is attributed to the fact that once a site is identified as having cyanobacteria, cyanobacteria are likely to reoccur annually.

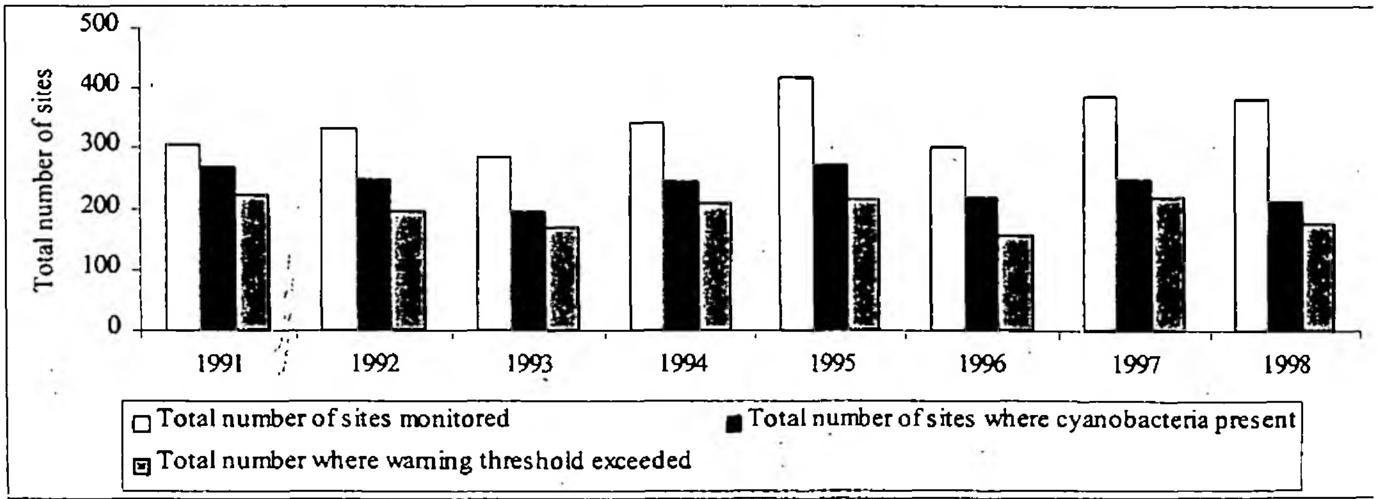
A complete list of the waterbodies sampled Regionally and their details are available from NCEHS on request.

2.3 Annual fluctuations

Initially in 1989, a total of 909 waterbodies were inspected, although it was difficult to know precisely how often many waters were visited or how many samples were taken (NRA, 1990). In the subsequent year, a total of 1724 sites were sampled between January-November, of which 649 (38%) were identified as containing abundant populations of cyanobacteria. This 1990 monitoring programme, in response to the cyanobacterial incidents during 1989, consisted of a mixture of reactive and routine monitoring, hence a direct comparison with subsequent years is difficult.

The total number of waterbodies sampled annually by the Environment Agency in response to external enquiries between 1991-1998 is shown in Figure 3. The total number of sites where cyanobacteria were present as the dominant group, and the total number of sites where the warning threshold concentration was exceeded are also shown. The warning threshold is discussed in section 2.7.

Figure 3. Total number of waterbody sites sampled in response to external enquiries between 1991-1998.



In 1998, a total of 380 waterbodies were sampled, similar to the past year, but no distinct annual trend was evident between 1991-1998 with approximately 300-400 waterbodies sampled annually by the Agency. The total number of waterbodies sampled was highest in 1995 (417), attributed to the warmer weather with severe algal problems occurring in running waters, as mentioned above.

A high percentage of sampled sites contained cyanobacteria as the dominant group, ranging from 56% in 1998 to 88% in 1991, and a high percentage of which (between 68-

83%) had either a bloom and/or scum present. The dominant cyanobacteria were *Oscillatoria*, *Aphanizomenon* and *Microcystis* spp., whereas other major groups reported as causing nuisance and aesthetic problems were diatoms (centric and pennate), cryptophytes, unicellular green and filamentous green algae.

Moreover, out of the total waterbodies sampled which contained cyanobacteria, approximately three-quarters exceeded the warning threshold.

In total, 2745 sites have been reactively sampled between 1991 to 1998, of which 1892 (69%) were sampled for the first time. Annually, the highest proportion of sites sampled were those sampled reactively for the first time, between 63-79% of the total, although no distinct annual trend was evident (Table 1).

Table 1. Incidents of sites sampled reactively between 1991-1998.

ear	otal number of aterbodies ampled as part f the reactive onitoring rogramme	otal number of aterbodies ampled for the irst time (and xpressed as a ercentage of the otal)	otal number of aterbodies ampled in past ears and re-ampled during he year
1991	306	216 (71%)	90
1992	331	218 (66%)	113
1993	284	201 (71%)	83
1994	341	217 (64%)	124
1995	417	281 (67%)	136
1996	302	190 (63%)	112
1997	384	269 (70%)	115
1998	380	300 (79%)	80

2.4 Waterbodies sampled routinely

Historically, routine monitoring was recorded separately to on-going investigations, and differed in that it was carried out specifically for cyanobacteria, whereas on-going investigations were carried out for other purposes with algal samples obtained at the same time. The information has now been amalgamated and is recorded as routine monitoring, shown below (Table 2).

Table 2. Summary of the number waterbodies sampled routinely between 1991-1998.

Year	Number of waterbodies sampled	Number which contained cyanobacteria (and expressed as a percentage of the total)	Number where warning threshold exceeded (and expressed as percentage of those sampled)	Number where bloom/scum was present (and expressed as percentage of those sampled)
1991	137	101 (74%)	71 (70%)	44 (44%)
1992	69	43 (62%)	31 (72%)	23 (53%)
1993	80	61 (76%)	60 (98%)	40 (66%)
1994	70	50 (72%)	36 (72%)	46 (92%)
1995	44	35 (80%)	22 (63%)	16 (46%)
1996	39	26 (67%)	12 (46%)	20 (77%)
1997	33	27 (82%)	19 (70%)	21 (78%)
1998	21	18 (86%)	12 (66%)	6 (33%)

There is an evident decline in the number of waterbodies sampled routinely from 137 in 1991 to 21 in 1998. The percentage of waterbodies sampled routinely that contained cyanobacteria has remained high (ranging between 62-86%), a high proportion of sites exceed the warning threshold (with the exception in 1996), and a high proportion of sites contained a cyanobacterial bloom/scum (with the exception in 1998). These trends are not dissimilar from the reactive monitoring programme.

The sites routinely monitored during 1998 are listed below:
Anglian: Covenham (sampled fortnightly), Rutland (sampled weekly), and Pitsford (sampled fortnightly). Extensive monitoring by the Environment Agency continued until the spring of 1999, and has subsequently been terminated.

Midlands: Colmere, The Mere, Whitemere and Crosemere are sampled.

North East: Worsborough, Scout Dike, and Thrybergh reservoirs monitored weekly between July-September 1998.

North West: Preston Docks is sampled weekly and Pennington Flash is also routinely monitored.

Southern: None.

South West: Waterbodies sampled monthly were Loe Pool (sampled between February-October) and Upper Tamar Lake (sampled between January-November).

Thames: Farmoor reservoir sampled monthly.

Environment Agency, Wales: Llyn Padarn and Llyn Tegid are monitored fortnightly and monitoring is continuing, whereas monitoring was also fortnightly at Llyn Penrhyn, Traffwll, Dinan, and Rhos-ddu, but ceased at the end of 1998.

2.5 Long-term monitoring

Currently, each Region monitors one unmanaged site (defined as a site with no nutrient reduction or destratification measures) where cyanobacterial blooms have previously been recorded, in order to provide a minimal national picture of geographical and temporal change in terms of cyanobacterial populations. Long-term monitoring is monthly and continuous, whereas routine sampling is generally more frequent (on a weekly or fortnightly basis). Generally, two sampling points were selected at each site - a fixed point, such as a jetty for example, and one from the lee shore. Water samples taken are analysed for selected deteminands including phytoplankton and, if and when present, cyanobacterial blooms and scums are also taken and sent to Dundee University for toxicity evaluation and analysis.

Environment Agency staff routinely collect data, and certain Regions have collated the data and produced reports. Data and reports are sent to NCEHS for collation and reporting, to be reviewed in the future under the Environment Agency's eutrophication strategy.

Long-term monitoring sites sampled are listed below:

Anglian: Filby Broad has been designated as the site for long-term monitoring. The Broad has been monitored (for phytoplankton and water chemistry) for the past 5 years as part of the Broads project, and since 1995 specifically for cyanobacteria (sampled fortnightly from around March to October and then every 4 weeks for the rest of the year).

Midlands: Bittell Reservoirs (Upper, Lower and Millshrub) have been sampled as of February 1995, and an Action Plan has been produced. Monitoring is continuing.

North East: Greenlea Lough has been sampled from 1995 onwards, initially as part of the Lake Classification project. Continued in 1998 with monthly sampling.

North West: The long-term monitoring site is Pennington Flash.

Southern: Weir Wood Reservoir is sampled, and annual survey data have been produced and sent to NCEHS between 1996-1998. Monitoring is likely to be cut in 1998 (final decision yet to be taken).

South West: The long-term monitoring site is Chilton Trinity Lake. No report produced for 1998 period, although a 1996-1997 report has been produced.

Thames: Farmoor Reservoir I is the long-term site, monitored from 1995 on a monthly basis.

Environment Agency Wales: Llyn Coron is continuing to be monitored on a monthly basis.

2.6 Visual inspections

Although most Regions carried out visual inspections as a matter of procedure during all biological sampling programmes, certain Functions within the Agency that carry out general sampling do not. The degree of inspection varied Regionally, and not all the sites were inspected by algologists/ecologists and most did not keep a record of visual inspections. In South West Region during 1998 for example, North pond, Dunwear was inspected several times due to the severity of the cyanobacterial bloom.

2.7 Counting methodology

Phytoplankton enumeration techniques follow the Standing Committee of Analysts' methodology.

When cyanobacteria have been identified and enumerated, the results are compared with warning threshold levels for individual species at which warnings are given of possible bloom formation. Appropriate action is based on exceeding the warning thresholds. The warning threshold levels have been derived from information on individual species volume, mass or chlorophyll-*a* to be equivalent to a *Microcystis* chlorophyll-*a* concentration of 5 µg/l, and are outlined in the 'Blue-green Algae Monitoring and Management of Incidents' policy. All Regions reported that the warning threshold procedure was used for enumeration and reporting. No count was made, however, when cyanobacterial scums were evident, since the warning threshold procedure is considered inappropriate as samples are assumed to exceed the warning threshold. In such cases, the samples are identified to species and the relative proportions of different species identified.

2.8 The extent of blooms and scums during 1998 compared to previous years

Thames Region highlighted an increase in samples containing cyanobacteria in rivers, possibly attributed to increased public awareness and Agency monitoring, particularly in the river Thames, where cyanobacteria originated as discharge from Farmoor reservoir water treatment works (WTW). In addition, following the very unusual incident at the Hungerford / Kennet and Avon canal, more reactive samples were processed in 1998. The Hungerford / Kennet and Avon incident occurred during the spring and persisted between 4-28th March resulting in over 150 tonnes of dead fish at Berkshire Trout Farm, during the period. Extensive investigations indicated that the causative agent was likely to have been biological (bacterial) in nature (Johnson *et al.*, 1998), but did not identify the causative agent. However, investigations eliminated potential toxicants (e.g. cyanide, heavy metals, pesticides) and physico-chemical parameters (pH, dissolved oxygen concentrations, ammonia, nitrite).

In South West, the bloom in Blagdon reservoir was later in the year than usual, and was attributed to a poor summer. The bloom consisted of *Microcystis* and *Gomphosphaeria* in contrast to *Aphanizomenon* that was observed in previous years.

Midlands observed fewer algal incidents, possibly attributed due to unsuitable weather conditions and a greater awareness of the problem by the public (hence visible blooms were not reported as frequently), with the majority of problems recorded between July and August.

North East and Anglian also reported fewer cyanobacterial blooms and scums in 1998 compared to past years, and attributed them to unsuitable weather during the summer, and to fewer reports particularly from lakes which have had annual blooms in the past, since it was thought likely that the owner/manager was familiar with the problem and was not reporting the blooms. Anglian, however, reported more samples related to problematic and nuisance diatoms.

Although North West Region commented it was difficult to draw any firm conclusions on the frequency and duration of blooms, it was reported that *Oscillatoria* persisted in high concentrations throughout the winter in Preston Docks, during 1998.

Environment Agency Wales and Southern Region recorded no discernible change in the algal fluctuations compared to previous years.

2.9 Blooms in running waters

In Anglian, a repeat of the 1997 incident occurred on Elstow Brook, which received cyanobacteria from Stewartby Lake. The bloom persisted until algal numbers were reduced due to dilution and algal decay. In Northern Area, a diatom bloom was detected in North Brook, attributed as the cause of irritation to fish in trout farm.

In Midlands, the problem was less perceived than in previous years, but cyanobacteria were evident on the Lydney and the Grand Union Canal (GUC), and the river Sow downstream of Copmere.

In North East, a cyanobacterial bloom was detected in the Leeds-Liverpool canal, however it was not as extensive as last year. No cyanobacterial problems were experienced in the river Wharfe, attributed to the relatively high river flows during the summer. A cyanobacterial bloom was detected for the first time however at the Sheffield and South Yorkshire canal.

A diatom bloom was observed in South West region, in a slow-flowing area of the Kennet and Avon canal. *Oscillatoria* was also detected above the warning threshold concentration in still backwaters from a stream in Devon Area.

Following the Hungerford / Kennet and Avon incident, more reactive samples were processes from river sites in Thames Region during 1998. There has also been an increase in reported incidents in the London stretch of the GUC and Regents Canal; no definitive reasons for the increase were given but was possibly related to increased public awareness.

No incidents were reported from Environment Agency Wales and North West Region.

3. CYANOBACTERIAL TOXICITY

Many cyanobacteria are capable of producing toxins, and more than one species in each genus may be toxic and capable of producing several toxins simultaneously. Currently, there are in excess of 96 cyanobacterial toxin variants, which include neurotoxins and endotoxins, although there are more than 60 microcystin (hepatotoxin) variants (Codd et al, 1999). The list of confirmed toxic species is likely to increase in the future due to the discovery and isolation of new species and strains, improved isolation, culturing and analytical techniques. The toxins are more toxic to mammals than to the aquatic biota and the ecological role of the toxins is, as yet, unclear.

Laboratory studies indicate that although environmental factors induce changes in toxicity, most of the toxicity variation is attributed to the fluctuation of species and strains (Chorus and Bartram, 1999). The toxic quotas within the cells may change up to five-fold in response to changes in environmental conditions, with the highest toxin production shown under optimum conditions for each individual species during the logarithmic phase of growth. Subsequently, toxins are released into the surrounding water mainly, but not exclusively during cell senescence, death and lysis.

Individual toxins behave differently, although generally they are extremely stable and are resistant to chemical hydrolysis or oxidation and can remain potent even after boiling. The toxins are weakly retained on natural suspended solids in waterbodies, and algal sedimentation can lead to the accumulation of toxin material in sediments. The toxins can also bioaccumulate in aquatic invertebrates and vertebrates, therefore, there is the potential for the toxic effects to be magnified in aquatic food-chains. There is evidence that under suitable conditions aquatic bacteria may break down the toxins (biodegradation), although research on biodegradation is limited at present.

The Environment Agency therefore continues to adopt a precautionary approach recognising the need to regard all cyanobacterial species and strains as capable of producing toxins, and hence as a threat to animal and human health and safety.

3.1 Toxin analysis and assessment

The University of Dundee continues to carry out Research and Development work for the Agency, on the fate and behaviour of cyanobacterial toxins, as part of the Technical Services agreement. Regions have continued to send cyanobacterial bloom and/or scum samples for toxicity analysis as part of this research work since 1989. The samples have been used to build a library of toxins.

The majority of samples were received from sites sampled on a reactive (one-off) basis, and some of the samples were from sites at which poisoning incidents had been recorded, and from sites previously designated as blue-green algae long-term monitoring sites.

In total, toxicity analysis was carried out from 32 samples during 1998. Sixty two percent of samples examined by bioassay were toxic, the highest incidents of toxicity recorded since 1995. Fifty two per cent of the toxic samples were hepatotoxic and 50% of samples were found to contain a range of microcystins, up to 4 were detected from a scum sample from Farmoor reservoir in 1998. The microcystin content of this sample was higher than the highest microcystin concentration previously published in the world (Codd, 1999). In past years, a similar number of samples were received and analysed for cyanobacterial toxicity by University of Dundee, 30 in 1995, 33 in 1996 and 32 in 1997 (Codd, 1998), and results indicated a similar high incidence of toxicity in samples comparable to other scientifically published research world-wide (Codd *et al.*, 1997).

3.2 Incidents as a result of toxicity

Incidents of cyanobacterial toxicity are well known in many countries providing evidence of lethal and sub-lethal animal poisonings. Cyanobacteria are implicated with the death of wild animals, farm livestock, pets, fish and birds, however, events are difficult to substantiate because many are post-event accounts and descriptions of events may be incomplete. An indication of toxicity may be a contributory factor to death, although a single analysis will not always provide firm evidence of deaths. Generally, deaths may be caused by several other factors, although the rapidity of death and presence of toxins in samples may indicate that cyanobacterial poisoning was a contributory factor. Waterbodies affected with cyanobacterial toxins during 1998, and degree of severity, are documented below in Table 4.

Table 4. List of waterbodies affected with cyanobacterial toxins during 1998.

Region and name of waterbody	Comments
South West	
Chilton Trinity	Low levels of microcystins detected by immunoassay, although the concentration of 1.12µg/litre would not have been acceptable in treated drinking water.
Combwich Ponds	No signs of apparent cyanobacterial toxicity at high dose level – no indications of hepatotoxicity or neurotoxicity present
Poole Park lake (Sand Bar)	Sediment sample – no anatoxin toxins were detected although a microcystin-type was detected. Uncertain as to its potential hazard to health/wildlife; recommended another sample to further test toxicity and microcystins.
Kennet and Avon canal, All Cannings bridge	No microcystins detected in sediment/water sample. If toxins are present in the sediment, it is possible that these would undergo biodegradation.
Environment Agency Wales	
Llyn Tegid	*Oscillatoria agardhii* and *Gomphosphaeria* spp. were present. Sample hepatotoxic by bioassay with medium to high level of toxicity

Table 4 cont. Region and name of waterbody	Comments
Environment Agency Wales	
Sunny hill farm	*Microcystis aeruginosa* present but sample non-toxic
Thames	
Farmoor reservoir 1	Sample of lake water from 13/8/98 contained microcytin at concentration 1270 times higher than provisional World Health Organisation guideline value in drinking water
	Another sample from 2/9/98 (4 different microcystins detected) - acutely hepatotoxic by bioassay
Harrow Lodge Park, Hornchurch	A suspected dog death – may have contributed to death; sample (*Oscillatoria/Phormidium*) was acutely toxic with signs of poisoning typical of neuro and hepatotoxicity.
Midlands	
Knypersley reservoir	Microcystis bloom was acutely hepatotoxic
Stanley pool	*Aphanizomenon* present. Neo-saxitoxins detected
Farm pool at Hinstock	*Aphanizomenon* present. Use of ELISA (immunoassay) indicated presence of neo-saxitoxins not detected by bioassay. Cyanobacterial poisoning may have had contributory factor to death of 7 cygnets.
Anglian	
Rutland Water	Samples from 27/07/98 (containing *Aphanizomenon* sp.) were found not to contain saxitoxins
	Samples from 29/09/98 (containing *Microcystis aeruginosa* and *M. flos-aquae*, *Aphanizomenon flos-aquae*) indicated sub-acute hepatotoxicity, and contained two microcystins according to HPLC-DAD, totalling 0.45 µg M-LR equivalents/mg dry wt of blue-green algal scum

Table 4 cont. Region and name of waterbody	Comments
Anglian	
Nursery Lane, Hoddesdon, Herts	Carp deaths had occurred at this site. Cyanobacteria present (*Anabaena flos-aquae*, *A. circinalis*, *Aphanizomenon* sp.) but no toxicity detected
North West	
Hall Lake Nurseries, Longton	*Microcystis aeruginosa* forma *aeruginosa* in water sample was acutely toxic (3.31 µg M-LR equivalents/mg dry wt of blue-green algal scum). Water was used for lettuce irrigation and the grower voluntarily withdrew crop from market.
Leeds / Liverpool canal at Barrowford	*Anabaena flos-aquae* present, medium/high hepatotoxicity. British Waterways was informed who contacted anglers.
Spring Field Lakes	*Gomphosphaeria*, *Anabaena*, *Microcystis* and *Oscillatoria* present. Sample was not acutely toxic by bioassay and no microcystins were detected by HPLC.
Longridge Lake	*Microcystis aeruginosa* and *M. flos-aquae* present of low toxicity as indicated by bioassay.

4. EXTERNAL COMMUNICATION

A requirement of the 'Blue-Green Algae Monitoring and Management of Incidents' policy is that standard letters are sent out to relevant organisations and parties, when waters are identified as containing cyanobacteria above warning threshold levels. Relevant organisations and parties include owners of affected waters, Chief Environmental Health Officers (CEHO), Ministry of Agriculture, Fisheries and Food (MAFF) Regional Offices and Consultants in Communicable Disease (CCD). Recently, amended letters have also been sent to water abstractors, public water utility companies and veterinary investigations officers.

In 1998, 462 letters were dispatched, but the numbers have declined since 1995 when a total 702 letters were sent. Highest numbers of letters were sent out during 1995, when severe algal blooms occurred in riverine sites for the first time. Anglian, Midlands and Thames send out greatest number of letters annually, whereas Environment Agency, Wales and Southern send out the lowest. A Regional breakdown of the figures is available from NCEHS on request.

4.1 Liaison and feed-back received between the Agency, waterbody owners, and relevant organisations

Generally, there have been no complaints received concerning the Agency's approach to dealing with cyanobacteria, and the majority of queries were successfully dealt with. Enquiries were still received, however, as to group's/organisation's responsibilities and actions in the event of cyanobacterial blooms and scums, and Agency advice was still required. Notably, in Environment Agency Wales during 1998, abstractors were unclear about cyanobacteria and required clarification concerning the procedures to be adopted. In Southern, EHOs were informed of potentially toxic cyanobacteria in puddles with an aim to raise awareness.

In response, NCEHS has produced 'Awareness Information', which has been disseminated internally, and to EHOs, MAFF, British Waterways and the Communicable Disease Surveillance Centre. This provides additional information on the Environment Agency's approach to eutrophication and potentially toxic cyanobacteria, and the responsibilities and actions of the organisations involved ensuring efficient implementation of duties. It has received positive feed-back.

4.1.1 Publicity

A blue-green leaflet and poster are the Agency's relevant publicity material, and are issued when responding to external queries. In addition, South West staff gave a presentation to a group consisting of EHOs, MAFF, veterinary surgeons and Environment Agency officers, to promote blue-green algae. Similar presentations have been given by other Regions in past years.

5. WATERS CLOSED FOR RECREATIONAL ACTIVITIES

The Agency is not responsible for closing waterbodies for recreational activities, except where it is the owner. The roles and responsibilities of the Agency, owners, EHOs and MAFF officers are outlined in NRA (1990a), and in the 'Blue-Green Algae Monitoring and Management of Incidents' policy.

Once a waterbody has been identified as having a cyanobacterial problem the matter is taken over by the EHOs, owners and local Councils, but since any closure in recreational waters is likely to affect recreation and tourism, incidents of cyanobacteria may not be reported. There is also limited feedback about closures and the Agency is not necessarily told what decision is made, therefore, it is difficult to establish whether all or some recreational activities have been suspended, and for how long. Some Regions reported that owners and operators, who have had previous cyanobacterial problems, often have their own procedures that might not include notification of the Agency.

Table 5 below summarises the sites at which recreational activities were suspended or the site closed, during 1998.

Table 5. Waterbodies where recreational activities were suspended or the site closed.

Region and name of waterbody	Comments
South West	
Trago mills lake	Water use suspended for small boats – bloom lasted ca.2 weeks
Poole park lake	Boating and water skiing suspended by EHOs
Poole, Dorset	Warning signs erected at various points around the lake between July-November
North pond, Dunwear	Fishing suspended and fishery closed for 3 months due to extensive bloom
Combwich ponds	Fishing suspended for 1 month
Southern	
Hilsea moat, Portsmouth	Area taped off to public access due to presence of cyanobacteria in puddles.
Ferry pool, Pagham, Sussex	Livestock access was also restricted following notification of the cyanobacterial bloom
Midlands	
Bredon Hardwick Lake	Fishing suspended for a few weeks
Hartbury College lake	Fishing suspended for a few weeks
Stanley pool	Children's sailing suspended
Hatfield water park	Some activities suspended (no further details)
Colwick lakes	Some activities suspended (no further details)
North West	
Leeds / Liverpool canal	Anglers were recommended not to fish but no formal suspension was issued.
Hall Lake Nurseries	Water used in crop irrigation was discontinued.
Scotsman Flash	Dinghy sailing was suspended for the whole of the 1998 season.

6. ALGAL CONTROL METHODS

Algal populations can be controlled by a wide range of methods (NRA, 1990a). The technique(s) to be used will depend on the individual waterbody, and may be used in conjunction with other algal control methods. There is no easy solution to algal control, however, and care must be taken to ensure that the right options are chosen and that the benefits from introducing the options outweigh the possible damage caused by other control methods being considered.

Notably, in Anglian Region (Northern Area), phosphorus (P) stripping at sewage treatment works (STWs) is continuing upstream of reservoirs (Rutland Water and Pitsford), whereas in North West Region, P-stripping is continuing at the STW discharging treated effluent to Lake Windermere. In South West nutrient stripping has also commenced at Crediton STWs under the EC Urban Waste Water Treatment Directive (UWWTD). In Environment Agency Wales, P-stripping is carried out at Llanberis STW, which discharges into Llyn Padarn and in RAF Valley STW, which discharges into Llyn Penrhyn (Anglesey).

6.1 Barley straw

Many enquiries have been received about the use of barley straw in controlling algae. Generally, enquirers have been referred to the Centre for Aquatic Plant Management (CAPM) who have carried out initial trials with barley straw, and the CAPM leaflet and an Agency pamphlet have been supplied. Reports from Regions indicate widespread use although most is unsubstantiated with unconfirmed reports, with limited results or no data and feedback. The Agency has received mixed reports about the success of barley straw that may be related to the inappropriate method of application, for example some straw has simply been thrown in as tightly-bound bales, which would probably rot under anaerobic conditions. However where straw has been placed loosely, as advised, reports have generally been positive.

In Anglian, lake owners have put barley straw into Fritton lake. Essex and Suffolk Water Company were involved, since they abstract water from the lake, but the degree of success is not reported and unknown.

In Midlands, barley straw use has been applied at Sambourne trout pool for a few years, but *Aphanizomenon* blooms still occur.

Barley straw was applied in Thryberg reservoir, in North East, which has suffered from *Aphanizomenon* and *Oscillatoria* blooms in past years, however no blooms were recorded in 1998.

In North West, barley straw trials are continuing at Preston Docks. The Environment Agency is working in conjunction with the Preston Docks Authority who carry out weekly chemical and algal monitoring.

In Southern, Ferry pool, Pagham, Sussex was treated with barley straw. There was no monitoring of its effectiveness, because the straw was applied late in the year. Staff at the nature reserve are also considering pumping salt water into the lagoon to control the algae, although more consideration is to be given to this before proceeding.

In Poole park, South West, barley straw was added in an attempted to control algae, but was unsuccessful.

6.2 Biomanipulation

In Anglian Region biomanipulation work is continuing on the Norfolk Broads, and at

Whisby Nature reserve a project has been running since 1996 examining the role of biomanipulation.

Midlands region reported on work at Bittell Reservoirs as part of their Action Plan, and biomanipulation is being attempted on park lakes in Stoke and Birmingham. The trials are in their first year.

6.3 Novel algal control products and Algicides

The Agency has a duty to control the discharge of polluting substances into 'controlled waters'. The Pesticides Safety Directorate (PSD), an Executive Agency of the Ministry of Agriculture, Fisheries and Food, approve products for use in home garden ponds and/ or aquaria, which include substances that are proposed for controlling algae.

A number of novel treatments available for algal control are being marketed as controlling nutrients and algae in waterbodies. The majority of these treatments appear to be chalk based and can be associated with bacteria that are supposed to reduce bottom sediments. The products claim to act by flocculating nutrients and/or algae from the water column and thereby creating clear water conditions.

The Agency does not enter into product accreditation or endorsement. Although no formal evaluation is carried out by NCEHS, the Environmental Ecotoxicology section within NCEHS is able to provide information and advice on specific active ingredients and/or chemicals present in products, and guidance on dealing with novel algal control products. As there is no available Agency information that could be used to assess any beneficial or detrimental effects on algae from the use of such products, it is proposed that Agency staff should recommend that users monitor (through observation) and report back on whether use of the products proves to be effective.

The use of algicides is not generally advised due to potential environmental impacts and because toxins can be released into the water when cyanobacterial cells break down.

7. RESEARCH AND DEVELOPMENT

Regions commented that they are informed of non Agency-run projects only when information is requested externally.

In Anglian, an undergraduate project has commenced investigating *Prymnesium* in drains.

Two action plans are currently being evaluated in Midlands, on Bittel Reservoir and Sambourne Lake.

In North East a project was carried out comparing 3 reservoirs in the river Don catchment, two of which have suffered from cyanobacterial problems and one where no cyanobacteria were reported.

In South West a post-graduate student was using algal bioassays to assess the role and potential inhibitory properties of humic substances.

Following the Hungerford / Kennet and Avon fish kill, algal monitoring commenced during the spring of 1999 at three sites in Thames region. Water quality deteminands were also measured at automated stations on the Kennet and Avon canal.

In an attempt to aid the identification of cyanobacterial samples collected, and in response to a lack of suitable, practical keys to identify cyanobacteria, University of Durham in collaboration with the Agency have produced a CD-ROM for the identification of Blue-green Algae of the British Isles. The CD-ROM is available nationally to Agency ecologists through the computer network on the Windows desktop, and is also available for purchase from the Department of Biological Sciences, University of Durham, Durham DH1 3LE, UK (contact Prof. Brian A. Whitton or Dr. Pam J. Robinson).

8. BLUE-GREEN ALGAE ACTION PLANS AND THE EUTROPHICATION STRATEGY

Action Plans and management strategies have been developed for specific waterbodies affected by cyanobacteria since 1990, and they have been continually promoted by the Agency. A number of aids for Action Plans have been developed and produced, for example computer models 'PACGAP' (Prediction of Algal Community Growth And Production) and PROTECH-2 (Phytoplankton Response to Environmental Change), discussed in a previous report (Environment Agency, 1998b).

A number of Action Plans are currently running in Anglian, Midlands, North East, South West, and Environment Agency Wales Regions.

8.1 Eutrophication-control strategy

The main work areas of the Nutrients Section, NCEHS are eutrophication, its symptoms and impact, including toxic and nuisance algae, and its effects on water uses and users.

In 1989, the National Rivers Authority predecessor to the Environment Agency adopted an intensive algal bloom-monitoring programme, and since then a reactive monitoring programme has been adopted, principally to cater for those water body owners and users who had not previously contacted the Agency. This approach reduced the earlier monitoring effort, allowing resources to be diverted into development of longer-term eutrophication control initiatives aimed at reducing cyanobacterial problems.

The Agency is therefore involved in a number of research initiatives and in developing strategies in order to better understand and minimise the problem in the longer-term. In particular, the Agency has published its consultative report 'Aquatic Eutrophication in England and Wales: a proposed management strategy' (Environment Agency, 1998a). The strategy has provided a preliminary assessment of the extent of problems and recommended a way forward through a more co-ordinated and integrated approach to management, communication and R&D. Key elements of the strategy are the promotion of a partnership approach and catchment based actions within the context of a national management framework. Remedial action will be pursued through catchment-based action plans using best available tools, techniques and procedures. A final strategy is due for publication in early 2000.

The complexities of eutrophication and cyanobacteria should not be underestimated. There may be a considerable lag between the onset of controls and resultant environmental improvements. In the interim, the acute problems of potentially toxic cyanobacteria must be managed through monitoring, and informing water users of the risks, and how to minimise them. The Agency, therefore, continues to develop policy, drive research and give advice relating to the management of nuisance and potentially toxic algae, in particular cyanobacteria.

9. DISCUSSION AND CONCLUSIONS

Initially in 1989, 909 waterbodies were inspected. In 1990, 1724 waterbody sites were sampled as part of the combined reactive and routine monitoring with 649 sites (38%) containing abundant populations of cyanobacteria. Since 1991, a total of 2745 sites have been sampled as part of the reactive monitoring programme, with 1892 sites (69%) sampled for the first time and 1908 containing cyanobacteria as the dominant group.

In the period 1991-1998, however, no distinct trend is visible and between 300-400 waterbodies are sampled each year. Two-thirds of the waterbodies sampled had cyanobacteria (mainly *Oscillatoria, Aphanizomenon* and *Microcystis* spp.) as the dominant group, and the warning threshold, which indicates that there is a likely risk of bloom and scum formation, was exceeded in three-quarter of the total number of waterbodies sampled. Algal problems attributed to species other than cyanobacteria were also reported, and Regions reported that enquirers were still unsure about the type of algae in a waterbody, therefore, expert advice from the Agency is required.

The interpretation of the incidence of algal blooms as carried out under the Environment Agency monitoring programme is difficult, since the results are based on a reactive, selective procedure whereby mainly only new sites affected with algal blooms and scums are analysed in response to external enquiries. Sites are rarely investigated which do not have a visible algal bloom/scum present or which have had historical cyanobacterial problems. This reactive monitoring programme was adopted from 1991 onwards, since the previous surveys indicated that once cyanobacteria developed at a site they were likely to reoccur annually.

The number of external enquiries received has been highest from central and south-eastern areas of England, therefore, the majority of sites were sampled in Anglian, Midlands and Thames Regions, and several factors may explain this. These sites may be affected by eutrophication to a greater extent than sites elsewhere in England and Wales, and a more vigilant, aware public (whose population density is greater than elsewhere in the country) may be reporting the visible symptoms of eutrophication (algal blooms) more frequently. Conversely, although the public may be becoming more aware of cyanobacteria and their risks, they may not be reporting new sites affected by algal blooms and scums as frequently as in the past, possibly as water owners and managers are becoming more aware of their related problems. Indeed, Anglian and Southern Regions reported that many of the sites that were previously sampled for cyanobacteria might not have been reported again this year, so the number of recurrent incidents may be an underestimation. This may be for commercial/financial reasons (which give rise to negative publicity and a loss of revenue), since when cyanobacteria are reported above the warning threshold, it is the owners' responsibility to take the necessary precautions that may include temporary closure of the waterbody.

Nutrients (their loadings and concentrations) are one of the range of factors that influence algal growth in standing waterbodies on a site-specific basis. Algal growth is exacerbated by nutrient enrichment (eutrophication), with excessive growths (blooms) of cyanobacteria being one of the visible symptoms of eutrophication. The Royal Commission on Environmental Pollution in UK has also inferred the increased incidence of algal blooms, in particular cyanobacteria, to be widespread as a result of increasing cultural eutrophication (Royal Commission on Environmental Pollution, 1992), and English Nature indicated that eutrophication is adversely affecting many stillwater sites of special scientific interest, SSSIs (Carvalho and Moss, 1995).

There are, however, other many and complex factors affecting the incidence of algal blooms (including light attenuation, water temperature, lake morphometry, water circulation, and grazing by zooplankton), since each type of algae thrives under a specific range of environmental conditions. Moreover, these determine the annual sequence of species composition and abundance.. Generally, in eutrophic waterbodies, diatoms tend to dominate during spring, are followed by green algae, with cyanobacterial maxima during summer/autumn periods. More complex cycles are evident depending on the productivity of the waterbody, water column stability, and weather patterns.

Generally, cyanobacteria are slow growing and develop high biomass during stable, warm weather conditions (during periods of high water column stability), and are normally more abundant towards the end of the growing season, mid- to late summer. However, should conditions be suitable, they will persist during other periods.

Cyanobacteria are also able to dominate and outcompete other phytoplankton species in waterbodies under certain conditions, because of a number of physiological adaptive features (NRA 1990a). These include the ability to fix atmospheric N_2 gas, the capability to store P internally when supplies are plentiful and, therefore, they are able to maintain growth during subsequent periods of external P deficiency. Cyanobacteria are also able to withstand high light intensities while other phytoplankton suffer from photo-oxidative damage in response to high radiance. Adaptive features also include buoyancy regulation through the use of gas vacuoles, which enables some species to move vertically within the water column to maximise their growth rates, and gas vacuoles also reduce loss rates through the water column. Cyanobacteria are not as extensively grazed upon by crustaceans as other phytoplankton species, because of endotoxin production, the formation of rafts by certain species making ingestion difficult, and because cyanobacteria are nutritionally poor. In addition, morphologically adaptive strategies include the production of spores and vegetative cells (akinetes), which may overwinter on the sediments and migrate up to the surface, therefore, cells may be recruited from these sources in subsequent months.

The use of Agency data as a robust indicator of the incidence of algal blooms and the extent of eutrophication in England and Wales, must be treated with caution. This is because of the range of influences on the frequency of blooms and because the data are from a primarily reactive monitoring programme. The collation of such data, and hence of sites affected by eutrophication should however continue, since this is the best available national information on the incidence of algal blooms. Further and better evidence can be obtained from more frequent monitoring at specific sites under the long-term and routine monitoring programmes, discussed above. However, with reduced monitoring activity, as indicated by an annual decline in the number of routinely monitored sites, and the cessation of monitoring at some sites, it will be difficult to describe and explain fluctuations and incidences of algal blooms.

The need to increase awareness of the health hazards presented by cyanobacterial toxins among water-users, associated organisations, water industry and public health professionals continues, and although knowledge on the type of toxins, occurrence and levels of toxins, exposure routes, acute/chronic effects is also continuing, further work is required especially for setting policies and guidelines.

Work carried out since 1989, initially by the NRA, has supplied cyanobacterial bloom and scum material to the University of Dundee for toxicity analysis from sites sampled as part of the Agency's reactive monitoring programme, from sites where poisoning incidents have occurred, and from long-term monitoring sites where cyanobacterial blooms and/or scums have occurred. The material is also used for future reference and research. Past research indicated a high incidence of cyanobacterial toxicity world-wide, between 44-88% (Codd *et al.*, 1997), and similar results have been shown from recent years (Codd, 1999). Toxicity analysis has also indicated fluctuations in toxicity levels, for example in Farmoor reservoir, a scum sample from 1997 was found to be non-toxic, whereas the highest microcystin concentration in a toxic scum was detected in 1998. This confirms the need to regard all cyanobacterial species and strains as capable of producing toxins. Research on cyanobacterial toxicity is continuing at the University of Dundee and elsewhere, and the Agency continues to ensure that ad hoc cyanobacterial bloom and scum samples are taken and sent to Dundee for toxicity evaluation from reactively sampled sites, as necessary, and routinely from long-term monitoring sites when they are encountered.

Research is also continuing in a number of institutions into key factors that promote the growth of cyanobacteria, into factors that influence the toxicity of cyanobacteria, into monitoring methods and toxin analyses that are able to detect novel toxins, and into improving guidelines for cyanobacterial concentrations at which waters becomes unsafe for human use (Chorus and Bartram, 1999).

There are a number of potential cyanobacterial toxin exposure routes that include skin contact, drinking water, inhalation, food consumption and haemodialysis, therefore, the potential toxic threat of cyanobacteria continues to have wide implications for the Environment Agency's roles, responsibilities, and activities, and hence the Agency continues to adopt a precautionary approach recognising the need to regard all cyanobacteria as capable of producing toxins, and hence as a threat to animal and human health and safety.

All Regions continued using the standard counting methodologies as outlined in the 'Monitoring and Management of Blue-green Algal Incidents' policy, and it is recommended that this is maintained to ensure a consistent approach throughout the Regions.

Currently, the system for reporting the number of enquiries received regarding algal problems is complex, since most are handled by public relations, catchment officers, algologists/ecologists, and by NCEHS. To improve this and create a formal system, a national database (Biology for Windows, B4W) has been provided to ensure a consistent coherent approach.

Regions commented there were no problems noted in responding to enquiries. Moreover, leaflets and relevant information are sent out, if required. A 'blue-green algae' poster, in addition to the leaflet, is also available for dissemination and display at affected sites. Suggested methods for increasing publicity were proposed, targeted at specific user groups, anglers, windsurfers, conservation groups, informing people of responsibilities and outlining possible actions and management options. This may take place at local or county shows, if required. Seminars to discuss the roles of Agency, EHOs and other relevant bodies, and to discuss recent specific issues have been carried out in Thames, South West and Anglian Regions with success. Moreover, good working relations are encouraged within the Agency, and between the Agency and external bodies, such that notification letters are quickly dispatched, and external organisations are fully aware of their roles and responsibilities. An Information/Awareness pack has been produced to aid understanding of the problem and ensure efficient implications of duties, and has been disseminated to all relevant groups/parties/organisations. Positive feed-back has been received.

Cyanobacteria are visible symptoms of eutrophication, and in order to understand better and minimise the problems in the longer-term, the Agency has published its consultative report 'Aquatic Eutrophication in England and Wales: a proposed management strategy' (Environment Agency, 1998a). A final strategy is due for publication in early 2000. Even so, an overnight solution, as evident by an improvement in water quality, will not be achieved. Therefore, algal and cyanobacterial monitoring in response to blooms must continue (acting as an early detection of toxic species, making it possible to take fast, initial action before cell numbers reach dangerous levels), and water users and managers must continue to be informed of the risks and how to minimise them.

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