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# An overview of algal bloom in Lough Neagh

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This paper considers the causes, impacts and potential remediations for the 2023 Lough Neagh blue green algae bloom.

## Key Points

The key points raised within this paper include:

- How algal blooms occur widely across the world due to varying causes such as eutrophication, water temperature increases, turbidity, pH and invasive species;
- The impacts of blue-green algae from the blocking of sunlight, using up oxygen, to the production of toxins and their potential impacts on humans and animals;
- The current state of Lough Neagh in terms of water quality, the key nutrients and other contributing factors such as turbidity and water temperature;
- The potential for redress under existing and new policy developments in NI;
- Policy responses to address eutrophic lakes and associated algal blooms. Examples are provided from the UK, EU and globally;
- Practical approaches to address eutrophication and associated algal blooms.The paper includes examples of approaches taken in various jurisdictions from reducing agricultural runoff to removal of nutrient rich lake bed sediment etc.

## Introduction

Lough Neagh is the largest lough in the UK and Ireland, measuring over 300 km². Lough Neagh's shores also fall within the boundaries of five of Northern Ireland's six counties.

At present around 50% of Northern Ireland's raw water, which is then treated to become drinking water, is extracted from Lough Neagh.

Lough Neagh is also the discharge point for treated waste water at a number of points around the lough shore.

In commercial terms Lough Neagh supports an eel fishery and the extraction of sand and gravel. The Lough is also utilised for a range of recreational and sporting activities such as wildfowling and watersports.

The summer of 2023 has witnessed a significant bloom of blue-green algae on the Lough, which has resulted in widespread media coverage and public discourse on the state of the Lough.

This paper provides an overview of the causes, impacts and local remediations to address blue-green algal blooms at both a general and Lough Neagh specific level.

# 1 Freshwater Algal Blooms – causes and impacts

As noted by the UK Environment Agency[1] algae occur naturally in inland waters such as rivers, streams and lakes. Problems however result when these naturally occurring algae see a significant increase in their numbers, a process generally referred to as a 'bloom'.

It is important to note here that the available literature suggests that the majority of freshwater algal blooms are caused by cyanobacteria which is actually a form of phytoplankton.

It should also be noted that this phenomenon occurs widely across the world. Within the United States for example, the Centres for Disease Control (CDC) produces an annual One Health Harmful Algal Bloom System (OHHABS) report, and the data for 2021[2] recorded a total of 368 harmful algal blooms (HABs) across 16 states.

## 1.1 Causes

The drivers for an algal bloom can be myriad, but there is a general concensus in literature on the subject that the following factors can and do contribute:

- Nutrient enrichment of the water by nitrate and phosphate – a process called eutrophication;
- Water temperature increases – either seasonal or prolonged;
- Changes in water condition such as turbidity or pH;
- Changes in local ecology – such as how species interact or new species are introduced.

With regards to eutrophication, key drivers for the increase in nitrate and phosphate levels in water are generally recognised as runoff from agriculture in the form of animal slurry residue or chemical fertilisers and the addition of animal and human sewage. Human sewage addition to the water can be from either water treatment works or in the form of effluent from septic tank systems.

[1] Algal blooms: advice for the public and landowners, UK Environment Agency website, 31 January 2017

[2] Summary Report – One Health Harmful Algal Bloom System (OHHABS), United States, 2021, Centers for Disease Control website

Water temperature increases, which can be seasonal (e.g. summer) or prolonged (e.g. climate change), create an environment which is more favourable to algal growth. The US Environmental Protection Agency (EPA) makes the following observations of the impacts of warmer water on algal growth[3]:

- Toxic blue-green algae prefer warmer water.
- Warmer temperatures prevent water from mixing, allowing algae to grow thicker and faster.
- Warmer water is easier for small organisms to move through and allows algae to float to the surface faster.
- Algal blooms absorb sunlight, making water even warmer and promoting more blooms.

With regards to water turbidity, which refers to the cloudiness of water determined by the volume of particles suspended in it, the available evidence seems to suggest that algal blooms can be either stimulated or repressed by changes in water turbidity. More specifically some evidence suggests that a decrease in water turbidity can increase the risk of an algal bloom by allowing more sunlight to reach further down into the water column which encourages phytoplankton growth. Conversely, there is other evidence that suggests increased turbidity can encourage an algal bloom, particularly if the increased turbidity represents an enhanced nutrient level in the water.

The pH of the water in a lake or river also appears to play a part in whether an algal bloom is likely to occur. A 2013 paper in the Journal of Applied Ecology[4] highlighted the fact that cyanobacteria are generally absent, or in very low abundance, in low-alkalinity lakes, particularly in Northern Europe. The preference of cyanobacteria for neutral to alkaline waters is generally recognised.

[3] Climate Change and Harmful Algal Blooms , United States Environmental Protection Agency website, 26 September 2023.

[4] Laurence Carvalho, Claire McDonald, Caridad de Hoyos, Ute Mischke, Geoff Phillips, Gábor Borics, Sandra Poikane, Birger Skjelbred, Anne Lyche Solheim, Jeroen Van Wichelen, Ana Cristina Cardoso, Sustaining recreational quality of European lakes: minimizing the health risks from algal blooms through phosphorus control, Jouranl of Applied Ecology, 26 February 2013

Changes in local ecology which encourage the growth of algae can theoretically be multiple in nature. The impact of the introduction of invasive species such as zebra mussels is an area which has been subject to academic study in the United States. A Michigan State University study[5] into the relationship between blue-green algae and invasive zebra mussels on Gull Lake, concluded that the presence of the mussels increased the blue-green algal population due to the fact that the mussels didn't feed on the blue-green algae (Microcystis) but did feed on its competitors. The lack of competition led the Microcystis to multiply and cause algal blooms on Lake Gull.

## 1.2 Impacts

The impacts of algal blooms on the environment, wildlife and people remain areas of ongoing study. The focus for this section of the paper is on the impacts of cyanobacteria/blue-green algae within freshwater.

It is important to note that the impacts from cyanobacteria can be direct, indirect, immediate or delayed.

The UK Environment Agency identifies some of the impacts from freshwater algal blooms as follows[6]:

- Can produce toxins called cyanotoxins which can kill wild animals, livestock and pets;
- Can produce toxins called cyanotoxins which can also harm people, producing rashes after skin contact and illnesses if swallowed;
- Will block sunlight from reaching other plants in the water -which can adversely affect their growth and role in aquatic ecosystems;
- Will use up oxygen in the water at night which can suffocate fish and other creatures;
- Will use up oxygen in the water as they die and decompose which can affect other creatures within the water.

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[5] Christie A. Bahlai, Clarisse Hart, Maria T. Kavanaugh, Jeffrey D. White, Roger W. Ruess, Todd J. Brinkman, Hugh W. Ducklow, David R. Foster, William R. Fraser, Hélène Genet, Peter M. Groffman, Stephen K. Hamilton, Jill F. Johnstone, Knut Kielland, Douglas A. Landis, Michelle C. Mack, Orlando Sarnelle, Jonathan R. Thompson, Cascading effects: insights from the U.S. Long Term Ecological Research Network, Ecosphere Journal, 17 May 2021

[6] Algal blooms: advice for the public and landowners, UK Environment Agency website, 31 January 2017

Additional sources identify impacts such as the smell produced by decay of the dying blue-green algae.

### 1.2.1 Human health impacts

In terms of the toxins that can be produced by blue-green algae, it is important to recognise that there is considerable diversity here in terms of specific toxins and potential effects on human health. Table 1 below provides a summary of the main toxins and their potential impacts on human health.

It should be recognised that these symptoms are generalised and factors such as extent (e.g. length of time) and nature (e.g. skin contact, inhalation or ingestion) of exposure to the toxin will determine severity of the impacts. Furthermore, there is no suggestion that all of these toxins will be produced by an algal bloom derived from cyanobacteria, rather these toxins may be produced based on the available scientific literature. Confirmation of the presence of any of these potential toxins can only be done by scientific test.

Table 1: Toxins that can be produced by cyanobacteria and their potential symptoms/impacts on humans

| Toxin | Potential Symptoms/impacts in humans from exposure |
|---|---|
| Microcystin | • Abdominal pain;<br>• Headache;<br>• Sore throat;<br>• Vomiting and nausea;<br>• Dry cough;<br>• Diarrhea;<br>• Blistering around the mouth; and<br>• Pneumonia.[7] |
| Cylindrospermopsin | • Nausea;<br>• Vomiting; |

[7] Health Effects from Cyanotoxins, United States Environmental Protection Agency website, 26 September 2023

| | |
|---|---|
| | • Bloody diarrhea;<br>• Abdominal pain;<br>• Kidney damage;<br>• Protein or blood in urine;<br>• Dehydration;<br>• Fever;<br>• Headache[8]. |
| Anatoxin | • Dizziness;<br>• Drowsiness;<br>• Incoherent speech;<br>• Tremor;<br>• Fasciculations;<br>• Hypersalivation;<br>• Diarrhea;<br>• Ataxia;<br>• Motor weakness;<br>• Respiratory and muscular paralysis. |
| Guanitoxin, formerly known as anatoxin-a(S) | • Numbness or tingling in fingers and toes;<br>• Dizziness;<br>• Drowsiness;<br>• Incoherent speech;<br>• Salivation;<br>• Convulsions;<br>• Respiratory paralysis leading to death (established in experimental animals) |
| Saxitoxin | • Numbness or tingling around mouth;<br>• Numbness spreading to arms and hands; |

[8] Cyanobacteria (Harmful Algae) Bloom Guidance, A resource for local public health authorities, Oregon Health Authority, 2020

| | |
|---|---|
| | • Muscle soreness;<br>• Muscle weakness;<br>• Paralysis;<br>• Difficulty breathing[9];<br>• Respiratory failure and death can occur from paralysis.[10] |
| Nodularin (Heptatoxin) | • Nausea, vomiting, or diarrhea;<br>• Bad taste in mouth;<br>• Blisters in mouth;<br>• Acute jaundice and/or hepatitis;<br>• Blood in urine or dark urine;<br>• Malaise, lethargy;<br>• Headache and fever;<br>• Loss of appetite;<br>• Elevated liver enzymes;<br>• Kidney damage;<br>• Anorexia. |
| Lyngbyatoxins | contact dermatitis, eye and ear irritation, respiratory irritation[11] |

Whilst death is mentioned as a possible outcome from exposure to a number of toxins identified in table 1, it is important to note the following comment from the Association of State and Territorial Health Officials in the United States[12]

[9] Luděk Bláha, Pavel Babica, and Blahoslav Maršálek, oxins produced in cyanobacterial water blooms – toxicity and risks, National Library of Medicine, 2009

[10] Case Definition: Saxitoxin, Emergency Preparedness and Response, Centers for Disease Control website, 26 September 2023

[11] Luděk Bláha, Pavel Babica, and Blahoslav Maršálek, oxins produced in cyanobacterial water blooms – toxicity and risks, National Library of Medicine, 2009

[12] Cyanobacterial Blooms and associated illnesses - A Clinician Toolbox for Physicians and Healthcare Providers, Association of Stated and Territorial Health Officials, USA

> *Although there have been **no documented human deaths** due to cyanotoxin exposure in the United States, people can become ill from coming into contact with cyanobacteria.*

As well as the scientifically established impacts on human health set out in table 1, there remains ongoing study into other potential impacts on human health. One such area relates to the fact that 95% of cyanobacteria can produce an amino acid called Beta-N-methylamino-L-alanine, or BMAA. Some research involving animals showed that BMAA has harmful effects on the brain. The Association of State and Territorial Health Officials in the United States however notes that:

> *…further research is needed to understand the possible link between BMAA and brain diseases in humans, such as ALS, Alzheimer's, Parkinson's and dementia[13].*

Indeed, a 2017[14] critical review of the link between BMAA and neurodegenerative disease in humans concluded that the hypothesis of a causal BMAA neurodegenerative disease relationship is not supported by existing data.

In terms of actual verifiable illness figures, the Centres for Disease Control (CDC One Health Harmful Algal Bloom System (OHHABS)) report for 2021, recorded a total of 117 people with illnesses resulting from contact with an algal bloom across the USA. Nearly all (89%) of the 117 people who became ill reported water and 7% reported air as a source of exposure (multiple sources were reported in 1% of illnesses). People sought care in 86 (74%) instances; over half (59%) called a poison control centre, and 8% of illnesses resulted in an emergency department visit (Table 1). No deaths were reported.

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[13] ibid

[14] N. Chernoff, D. J. Hill, D. L. Diggs, B. D. Faison, B. M. Francis, J. R Lang, M. M. Larue, T.-T. Le, K. A. Loftin, J. N. Lugo, J. E. Schmid & W. M. Winnik (2017) A critical review of the postulated role of the non-essential amino acid, β-N-methylamino-L-alanine, in neurodegenerative disease in humans, Journal of Toxicology and Environmental Health, Part B, 20:4, 183-229, DOI: 10.1080/10937404.2017.1297592

Furthermore, toxins were detected in over 50% of the harmful algal bloom (HAB) events.

### 1.2.2 Animal health impacts

Similarly, to the situation presented in table 1, in section 1.2.1 of this paper, the toxins produced by a blue-green algal bloom can adversely impact the health of animals.

The US Centers for Disease Control (CDC) produces guidance for veterinarians in terms of what symptoms to look out for in relation to animals that come into contact with blue-green algae and these include[15]:

- Excess drooling, vomiting, diarrhea, foaming at mouth
- Jaundice, hepatomegaly
- Blood in urine or dark urine
- Malaise
- Stumbling
- Loss of appetite
- Photosensitization in recovering animals
- Abdominal tenderness
- Progression of muscle twitches
- For saxitoxin exposure, high doses may lead to respiratory paralysis and death if artificial ventilation is not provided

Veterinarians are also advised that monogastric animals such as dogs, cats, horses and pigs appear to be less sensitive than ruminants or birds; however, the dose-response curve is very steep in dogs—up to 90% of a lethal dose may elicit no clinical signs.

The CDC's One Health Harmful Algal Bloom System (OHHABS) report for 2021[16] recorded animal health impacts from algal blooms reported from across the USA. At least 2,715 animal cases of illness occurred and were reported to OHHABS for 2021, including a large wildlife mortality event in Washington

[15] Cyanobacterial Blooms: Information for Veterinarians, Harmful Algal Bloom (HAB)-Associated Illness, Centers for Disease Control website, 26 September 2023

[16] Summary Report – One Health Harmful Algal Bloom System (OHHABS), United States, 2021, Centers for Disease Control website

involving at least 2,000 bats. Most wildlife cases were classified as confirmed (76%), domestic pet cases as probable (67%), and livestock cases as suspect (60%). Significantly, 92% of ill animals died.

In terms of animal impacts in relation to the human food chain, there appears to be a lack of definitive evidence in terms of human health risks from consuming animals exposed to blue-green bacteria and any associated toxins. The general approach advocated in many jurisdictions appears to be precautionary in nature, particularly in relation to fish. By way of example, the Oregon Department of Fish and Wildlife within the USA makes the following observations in relation to fish caught from water affected by an algal bloom[17]:

> *Eating fish caught from affected waters is an unknown health risk. There have been no reports of people becoming sick from eating fish caught during a bloom, but there has been no definitive research regarding the risk to human health.*
>
> *It is known that some cyanobacterial toxins (called cyanotoxins) have been found to accumulate in fish tissues, and particularly in the internal organs such as the liver and kidneys. Toxin accumulation studies suggest that the muscle (fillet) tissue is less affected by cyanotoxins.*

## 2 Lough Neagh's current state – key indicators

There follows an overview of the existing evidence base for the current state and status of the water within Lough. Emphasis is given to those areas which can either contribute to or be impacted by an algal bloom.

### 2. 1 Water quality

In Northern Ireland (NI), water quality is reported under the Water Framework Directive (WFD). The WFD and its monitoring and reporting criteria are transposed in NI through the Water Environment (Water Framework Directive)

[17] Fishing during blue-green algae (cyanobacterial) blooms, Oregon Department of Fish and Wildlife website, 26 September 2023

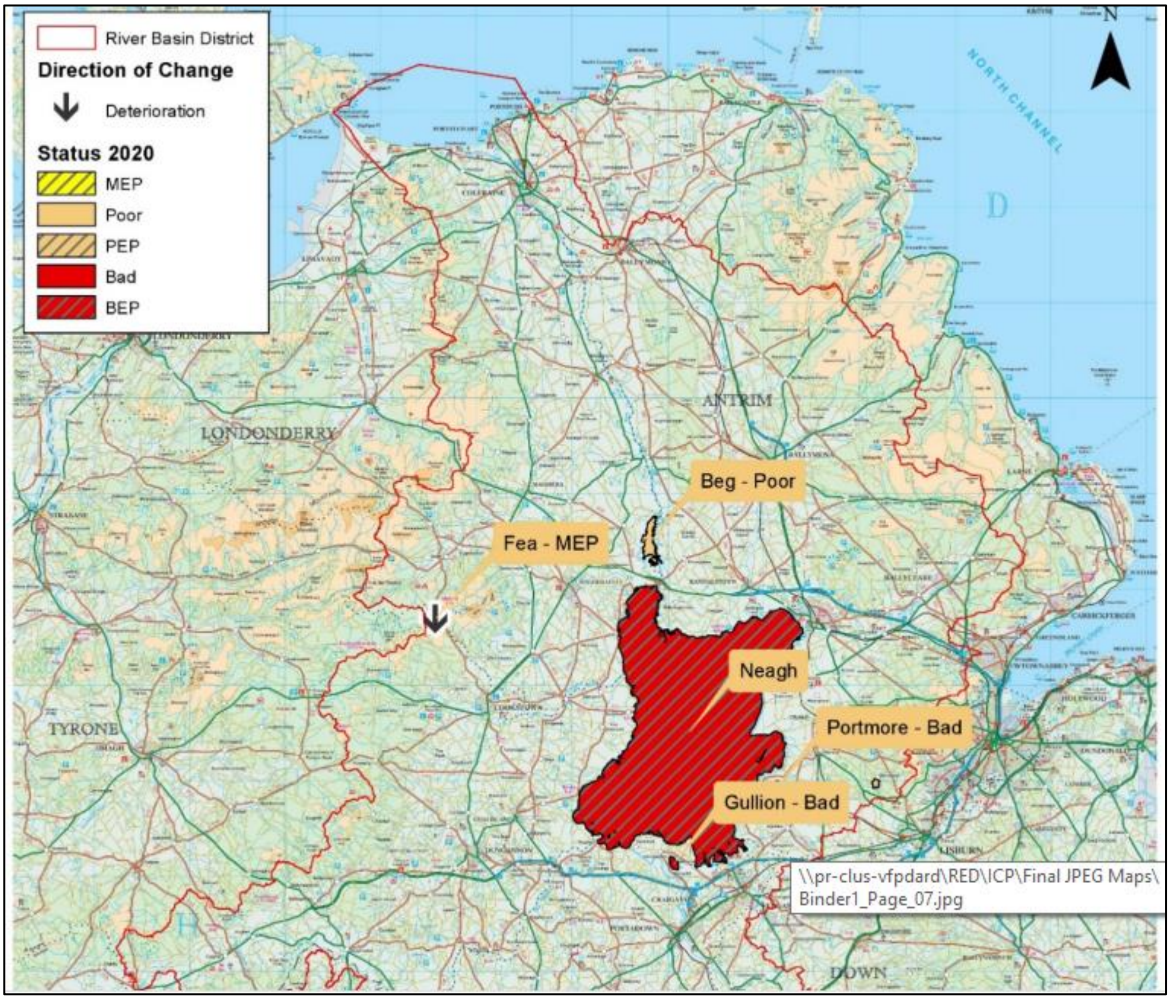
Regulations (Northern Ireland) 2017. The Water (Amendment) (Northern Ireland) (EU Exit) Regulations 2019 ensure that the WFD has continued to operate in NI post EU exit.

The WFD requires the assessment of both ecological and chemical conditions of all surface waters in NI, to give a combined overall status which may range from: bad; poor; moderate; good; and high.[18]

According to the consultation for the new round of River Basin Management Plans 2021-2027, as of 2020, Lough Neagh is in poor status, as shown by the dark red area in the map below.

[18] DAERA (2021) Water Framework Directive Statistics Report December 2021 https://www.daera-ni.gov.uk/sites/default/files/publications/daera/NI%20Water%20Framework%20Directive%20Statistics%20Report%202021.pdf

Figure 1: Map showing the 2020 surface water status for lake water bodies with improvements & deteriorations in relation to 2015




Source: DAERA Draft RBMP 2021-2027 consultation

Most recent figures, for 2021, are reported in DAERA's WFD Statistics Report 2021. However, this gives the status of the Neagh Bann River Basin District[19] (NB RBD) for 2021, but does not appear to provide specific data for Lough Neagh. However, the 2021 status of Lough Neagh may be inferred from this report as follows.

According to DAERA's 2021 WFD Statistics report, new priority substances were added to the monitoring requirements for assessing chemical status. These additions are known as ubiquitous, persistent, bioaccumulative, toxic

[19] The Neagh Bann river basin district (NB RBD) covers an area of around 5740 km2. Lough Neagh, located in the centre of the district is the main lake, with other smaller ones include Lough Fea, Portmore, Ross and Beg. For more information see Neagh Bann River Basin District | Department of Agriculture, Environment and Rural Affairs (daera-ni.gov.uk)

(uPBT), or 'forever' chemicals. These have been detected in all monitored stations and resulted in failures. Therefore, failures have been applied to all surface water bodies in NI, including lakes. According to the 2021 WFD Statistics report, this means that no lakes in NI will meet overall good status, when ecological and chemical status are combined.[20]

One of the additional chemicals is cypermethrin. Cypermethrin is a broad-spectrum insecticide used in a range of agricultural, public health, and domestic applications. For arable farming, cypermethrin is one of the most widely used pesticides in terms of the total land area treated[21].

Seven out of the 10 lakes in NI that failed due to this chemical, are based in the NB RBD.

In summary, the status of lakes in the NB RBD in 2021 include:

- In 2015 and 2018, five (24 %) of the 21 lake water bodies were classified as good overall status. In 2021, no lakes achieved good overall status.
- In 2015 and 2018, five (24 %) of the 21 lake water bodies in Northern Ireland were classified as good or high for ecological status and 16 (76 %) lake water bodies were classified as 'moderate or worse'. In 2021, three (14 %) lakes were classified as good ecological status with 18 lakes (86 %) classified as 'moderate or worse'.[22]
- The Neagh Bann RBD has 10 lake water bodies, two (20 %) achieved good ecological status in 2015 and 2018, with two (20%) classed as bad. In 2021, one (10 %) water body achieved good ecological status, with three (30%) classed as bad.[23]
- In 2015, 2018 and 2021, all 21 (100 %) lake water bodies were classified as good chemical status when excluding both uPBT substances and cypermethrin.
- 11 (52 %) achieved good chemical status and 10 (48 %) failed to achieve good chemical status when excluding uPBT substances. These figures include cypermethrin failures showing 10 lakes displaying failure levels due to the

[20] DAERA (2021) Water Framework Directive Statistics Report December 2021 https://www.daera-ni.gov.uk/sites/default/files/publications/daera/NI%20Water%20Framework%20Directive%20Statistics%20Report%202021.pdf p. 2&5

[21] Cypermethrin M. Falah and S. Burr (2023) (Science Direct)

[22] DAERA (2021) Water Framework Directive Statistics Report December 2021 https://www.daera-ni.gov.uk/sites/default/files/publications/daera/NI%20Water%20Framework%20Directive%20Statistics%20Report%202021.pdfp.18/19

[23] Ibid Table 4a p.20

insecticide. All 21 (100 %) lakes failed to achieve good chemical status when uPBT substances and cypermethrin failures are included.

- In the Neagh Bann RBD, 10 (100 %) lakes achieved good chemical status when excluding both uPBT substances and cypermethrin. 3 (30 %) lake water bodies achieved good chemical status and seven (70 %) failed to achieve good chemical status when excluding uPBT substances and including the cypermethrin failures (showing 7/10 lakes in NI failing due to the insecticide, located in the Neagh Bann Basin). When the chemical status includes uPBT substances and cypermethrin failures, all 10 (100 %) lakes failed to achieve good chemical status.[24]

### Considerations

- 2020 data shows Lough Neagh in poor status. The 2021 report states that no lakes in NI will achieve 'good' status, due to the new measurement additions.
- Of the 10 lakes that failed due to the insecticide cypermethrin, seven of them are in the NB RBD. Will the NB RBD be targeted in relation to addressing this in the new RBMPs?
- Does the Department have projected time frames for achieving 'good overall status' in Lough Neagh? And are these likely to be longer due to the new chemical elements for monitoring?

## 2.2 Nutrients

According to the UK Environment Agency (2022), phosphorus and nitrogen are the main nutrients involved in eutrophication, with phosphorus the main cause of eutrophication in freshwaters.[25]

That being said, the US EPA, explains that phosphorus is a critical nutrient required for all life. It plays a major role in the formation of DNA, cellular energy, and cell membranes (and plant cell walls) and is therefore a common ingredient in commercial fertilisers.

[24] Ibid p.22/23

[25] UK EA (December 2022) Phosphorus and freshwater eutrophication: challenges for the water environment

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1171043/Phosphorus-challenges-for-the-water-environment.odt

However, too much of the nutrient can have negative impacts on aquatic ecosystems:

*Phosphorus is usually considered the "limiting nutrient" in aquatic ecosystems, meaning that the available quantity of this nutrient controls the pace at which algae and aquatic plants are produced. In appropriate quantities, phosphorus can be used by vegetation and soil microbes for normal growth. However, in excess quantities, phosphorus can lead to water quality problems such as eutrophication and harmful algal growth. Some aquatic resources, such as wetlands, naturally serve as sinks for phosphorus found in sediments or dissolved in water. However, since phosphorus generally occurs in small quantities in the natural environment, even small increases can negatively affect water quality and biological condition[26].*

### 2.2.1 Key nutrient Levels

Figures 2 and 3 show the nitrate and phosphorus concentrations in Lough Neagh from 1995 to 2022. Figure 2 shows a steady increase in nitrate in Lough Neagh from 2017 to 2022. Figure 3 shows how phosphorus levels haven't changed much since the early 2000s, albeit with a bit of a drop from 2010 to 2015. There has also been a recorded increase in phosphorous since 2015.

[26] Indicators: Phosphorus, National Aquatic Resource Surveys, United States Environmental Protection Agency website, 26 September 2023

Figure 2 : Lough Neagh nitrate levels 1995-2022[27]

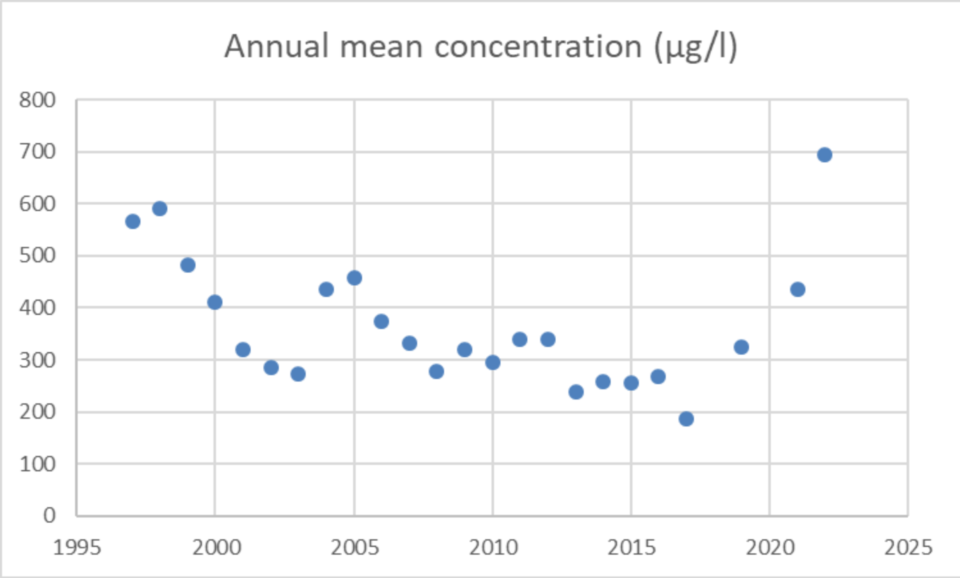
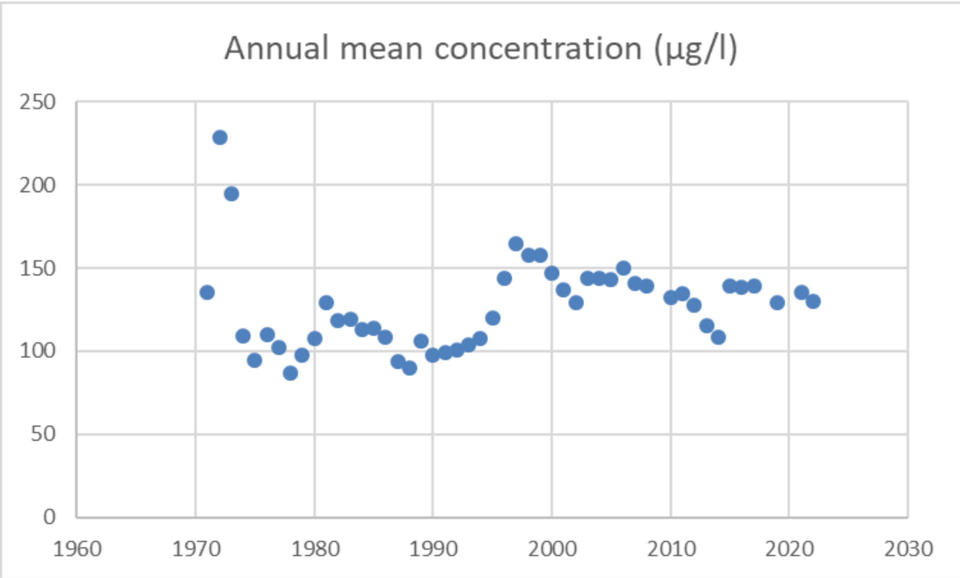



Figure 3: Lough Neagh phosphorus levels 1995-2022[28]




With regards to controlling phosphorus and nitrogen levels in NI, on 11 April 2019 the new Nutrient Action Programme Regulations (Northern Ireland) 2019 (NAP) came into force 2019-2022. The new Regulations replace the Phosphorus (Use in Agriculture) Regulations 2014 and the Nitrates Action

[27] Information provided by DAERA (22/09/23)

[28] ibid

Programme Regulations (Northern Ireland) 2014 as amended. These requirements remain in place in NI post Brexit under the Nitrates Directive. With Phosphorus Regulation included in the NAP, Cross Compliance Standards now apply to the application and use of chemical phosphorus on land[29].

Since 2007 the European Commission has granted NI a derogation from the Nitrates Directive from a land application limit of livestock manure per hectare per year, provided farms meet certain criteria. The Commission renewed the derogation for the duration of the Nutrients Action Programme (NAP) for 2019 - 2022. ***However, considering NI's water quality issues, it may be of interest to find out what will happen to this derogation going forward?***

When considering recovery from high phosphorus concentrations and achieving 'good' status, Rippey et al (2021) looked at four lakes, including Lough Neagh, in their paper: *Timescale of reduction of long-term phosphorus release from sediment in lakes*[30]. The paper explains that recovery timescales are often underestimated because external and internal phosphorus loads are not both considered. It's the reduction in internal loads in sediments that can cause natural delays in recovery.

According to the paper's conclusions, it would take 41 years for Lough Neagh to reduce phosphorus by 75% from internal sediment. For this reason, the paper suggests:

> *Within the context of developing River Basin Management Plans, specifically the timescale of achieving Good Status for lakes, the natural delay in recovery due to the internal P load in some lakes needs to be considered.*[31]

### Considerations

- Will the new RBMPs take internal phosphorus load reduction timeframes into account?

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[29] Nitrates Directive | Department of Agriculture, Environment and Rural Affairs (daera-ni.gov.uk)

[30] Brian Rippey, Julie Campbell, Yvonne McElarney, James Thompson, Mary Gallagher, Timescale of reduction of long-term phosphorus release from sediment in lakes, Water Research, Volume 200, 2021 Timescale_Accepted_Manuscript_PDF.pdf (ulster.ac.uk)

[31] ibid

- The paper highlights it may take 41 years for internal phosphorus to decrease 75%. However, could the timeframe be extended by delays in reducing external loads if sufficient resources aren't available?
- The Rippey et al (2021) paper explains that the WFD status is determined by the deviation of phytoplankton, other aquatic flora, benthic invertebrate fauna and fish fauna from undisturbed conditions. It is not conclusive from the paper whether internal phosphorus reduction of 75% will be required for Lough Neagh to achieve 'good' status, or whether this could be achieved with a smaller, or higher, reductions. Has the department calculated the amount of phosphorus and nitrate reductions (internal and external) needed?
- What will happen to NI's nitrate derogation that was granted under the NAP 2019-2022. Will it be re-applied for and could there be difficulties in getting it due to water quality issues?

#### 2.2.2 Sources of nutrients within Lough Neagh

In terms of sources, the draft RBMP details that the potential main sources for nutrient pressures are agricultural land use (diffuse) and pressures related to sewage infrastructure (point source). Research carried out in 2020 found that over 60 % of phosphorus losses to our water bodies originate from agriculture (diffuse)[32], and over a third can be attributed to sewage impacts (24% from waste water treatment facilities and 12% from septic tanks)[33].

The draft RBMP explains that underfunding for the waste water and sewage network has resulted in capacity issues at over 100 locations across NI. Which becomes a particular problem during storm events with increased risk of flooding form sewers.[34]

### Considerations

- Are there differences in nutrient production from different types of slurry?
- If so, will more targeted approaches be taken within certain sectors?

[32] Doody et al (2020) published an analysis of the Substance Flow Analysis (SFA) for Phosphorus (P) in the Northern Ireland food system as part of the RePhoKUS project. See DAERA draft RBMP p.91 https://www.daerani.gov.uk/sites/default/files/consultations/daera/Draft%203rd%20cycle%20River%20Basin%20Management%20Plan%20for%20Northern%20Ireland%202021-2027_0.PDF

[33] DAERA draft RBMP p.94 https://www.daera-ni.gov.uk/sites/default/files/consultations/daera/Draft%203rd%20cycle%20River%20Basin%20Management%20Plan%20for%20Northern%20Ireland%202021-2027_0.PDF

[34] ibid

- Funding has been mentioned as the main issue related to waste water treatment and sewage infrastructure. It may be if interest to find out from DfI, what funding will be available under the budget to improve the infrastructure?

## 2.3 Water turbidity

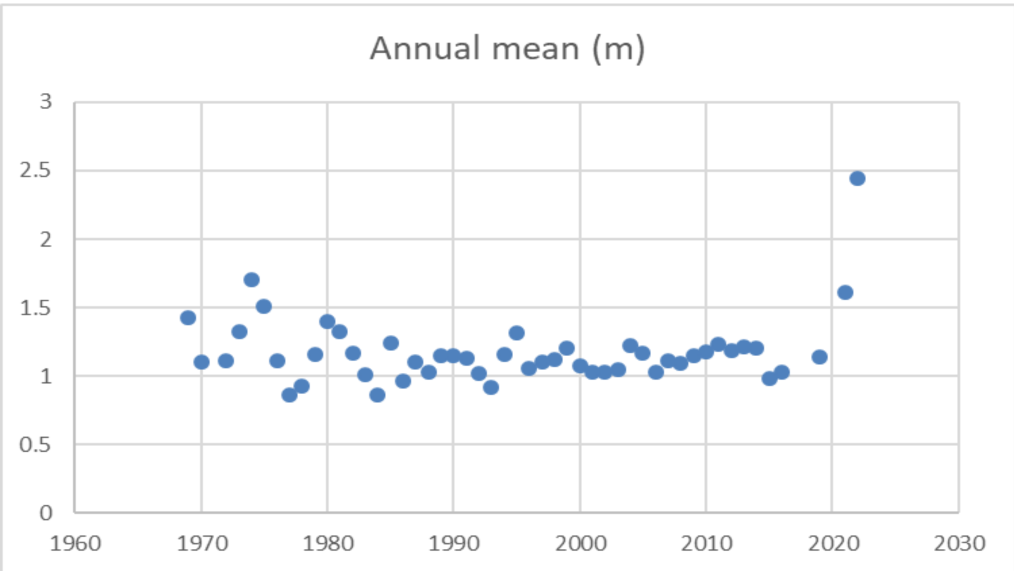
As already referenced in section 1 of this paper, water turbidty (ie level of suspended solids in water) can have either a limiting or enabling impact in relation to the potential for algal blooms. Water turbidity is measured using a secchi disk which is lowered into the water. The depth in metres where the disk can no longer be seen provides an indication of the transparency of the water.

Data provided by DAERA covering the period 1960 to 2022, and presented in figure 4 below, highlights the fact that there has been a marked decrease in water turbidity since 2021. This decrease is in contrast with a relatively stable level of water turbidity for most of the period between 1990 and 2020.

### Considerations

- Has there been any investigation by DAERA or others to determine the key driver/cause for the reduction in water turbidity since 2021? If yes, what conclusions have been drawn?

Figure 4: Water turbidity in Lough Neagh 1960-2022




## 2.4 Water temperature

DAERA data[35], as presented in figures 5 and 6 below highlights the fact that the annual mean temperature of Lough Neagh at both the surface and a depth of 10 metres has been rising over recent years.

Figure 5: Average annual temperature (°C) at Lough Neagh surface 1960-2022

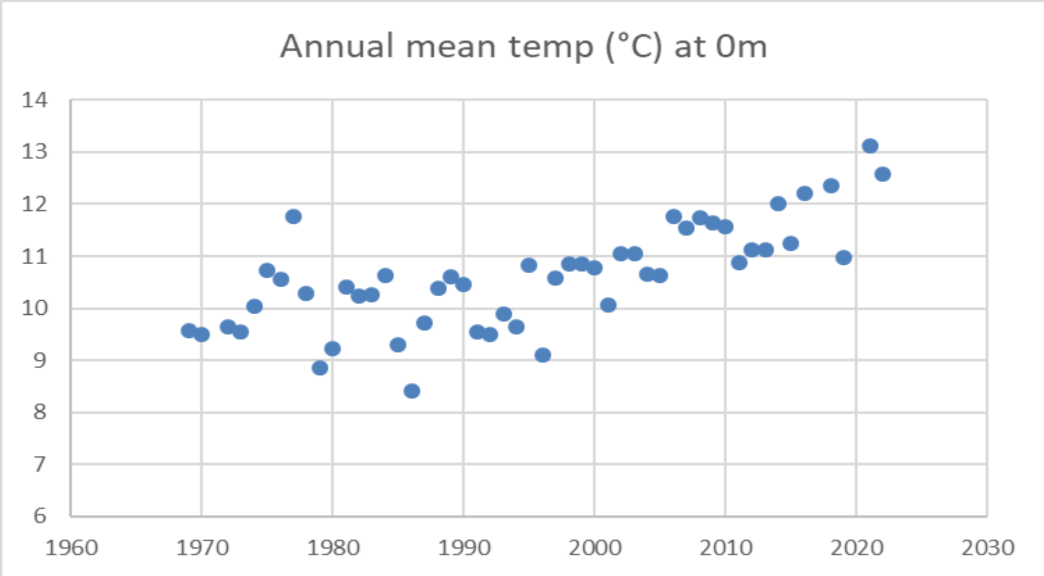
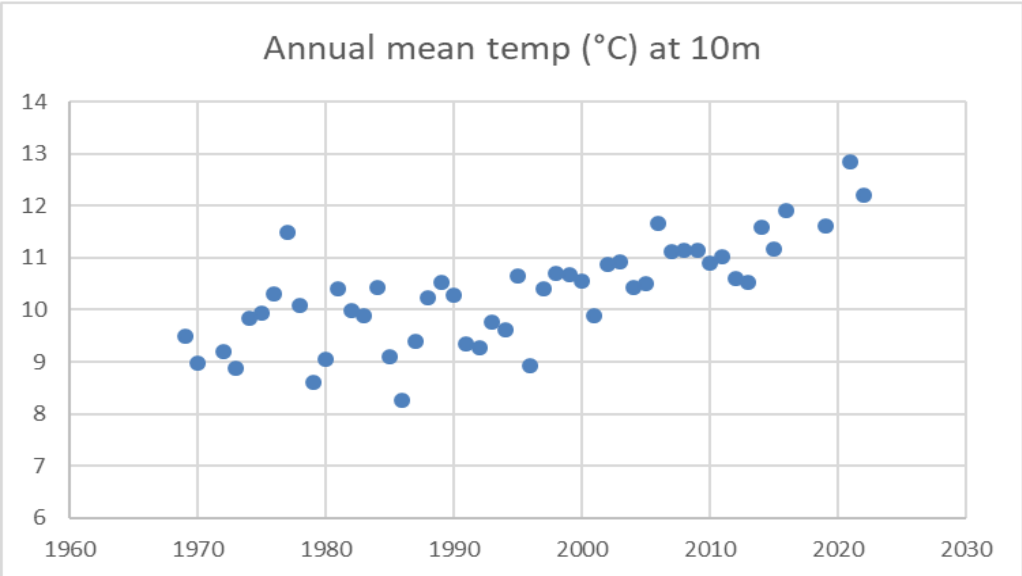



Figure 6: Average annual temperature (°C) at 10 metre depth within Lough Neagh 1960-2022




## Considerations

- Are the increases in water temperature within Lough Neagh a direct consequence of climate change?

[35] DAERA sourced data provided on 22/09/23

- Are there any other factors at play here?

## 2.5 Drinking water

According to NI Water, Lough Neagh supplies 40.7% of the drinking water within Northern Ireland. Water Treatment Works that abstract raw water from Lough Neagh are:

- Dunore Point
- Moyola
- Forked Bridge
- Castor Bay

NI Water released a statement on 15 September 2023 regarding the continued use of Lough Neagh for drinking water:

*We can assure our customers that the water supplied from all our Water Treatment Works, which includes water abstracted from Lough Neagh, is safe to drink and use as normal…*

*…Increased levels of algae can cause an unusual taste and smell to water from your tap but does not pose a risk to health. The taste and smell can be earthy and/or musty. Therefore, while the water from your tap can be used in the normal way, we fully appreciate some customers might notice a difference in the taste and/or odour to their drinking water at this time.*[36]

## 2.6 Angling and eel fishing

Lough Neagh continues to support both a commercial eel fishery and recreational fishing for various species. There has been significant media commentary on the seemingly different approaches being advocated by the Food Standards Agency (FSA) in relation to the both of these activities.

As things stand, the commercial fishery continues to operate normally whilst there is public guidance dissuading people from consuming fish caught recreationally within the Lough.

[36] NI Water [online] https://www.niwater.com/news-detail/12350/Your-water-is-safe-to-drink/ (Accessed 22/09/2023)

This position was affirmed by the Food Standards Agency at a press briefing on 21 September 2023[37]. In seeking to explain their advice the FSA suggested that

> *If there is toxin in a fish it is likely to accumulate in the internal organs which are removed by commercial fisheries but not always by people privately fishing.*

**Considerations**

- What additional steps are the FSA taking or proposing to take in ensuring that fish entering the human food chain, which are caught within Lough Neagh are safe to consume?
- Has there been any testing of either sampled fish organs or meat caught by either the commercial or recreational sectors?

## 3 Potential for redress

The Lough Neagh Partnership was formed in 2003. This is a stakeholder organisation that was established to help manage and protect Lough Neagh. The board of the partnership is made up of elected representatives, landowners, fishermen, farmers and local communities. It has produced a number of publications in relation to the management and protection of Lough Neagh. However what ability this Partnership has in terms of resources and powers to address the issue alone is uncertain.

In 2014 a Lough Neagh Working Group was formed by the then DARD Minister. However, the main focus of this was to look at the potential for bringing Lough Neagh under public ownership[38].

Some potential questions arise from this situation. According to a recent Belfast Live Article, DAERA is forming a Water Quality Steering Group. Is this the same as the ones formed back in 2018 under the different catchment areas of the RBMPs? What will this working group be able deliver beyond those formed

[37] Lough Neagh algae: Panel of government experts say lough not safe to swim in - but is safe for drinking water, Newsletter, 21 September 2023

[38] http://www.niassembly.gov.uk/assembly-business/official-report/reports-13-14/25-november-2013/#AQO%205077/11-15 - oral questions for answer Agriculture and Rural Development – questions 1 and 4

in 2018? What will be its role, membership, what powers will it have and budget?

DAERA's environment, marine and fisheries resource budget was cut by just over £5m[39] for 2022-23 compared to 2021-22. How will this impact water quality monitoring and improvement?

The consultation on the 3RD cycle of RBMPs lists a number of measures, existing and new, that will address water quality in NI. These include sectoral specific measures aimed at diffuse and point source, such as:

- reducing nutrient and pesticide pollution from agriculture;
- improving waste water treatment plants (2021-2017);
- reform and review of point source regulation;
- establishment of a NI Regulators Forum for Chemicals and Pesticides;
- The continuation and establishment of joint working e.g. joint management between DAERA and NI Water on monitoring pollution incidents etc, Water Catchment Partnership (NI Water, DAERA, UFU).

However, the draft RBMP does not specifically mention Lough Neagh, and it may be worth finding out, that in light of the recent events, will the draft RBMP be reviewed with Lough Neagh as a focal point?

In fact, according to the consultation on the 3RD cycle of RBMPs , the NI WFD 2017 Regulations:

> *…set an objective that all water bodies achieve a status of 'good or better' by 2027 apart from where exemptions apply (e.g. Lough Neagh)*.

- Why is Lough Neagh exempted from the time frame?
- If Lough Neagh is an exemption from the timeframe, how will reassurance be given that measures put in place will try to achieve 'good' status in Lough Neagh as soon as possible?
- Does the Department have a likely time frame for Lough Neagh?
- What specific work will be carried out by DAERA to address the immediate problem, and the longer-term goal of improving the water quality in Lough Neagh?

[39] Budget Bill Supporting Memorandum https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1128635/Northern_Ireland_Budget_Bill__Supporting__Memorandum.pdf

# 4 Policy responses to address eutrophic lakes and associated algal blooms

## 5.1 UK

The UK Technical Advisory Group (UKTAG) for the WFD consulted in 2019 on proposed lake nitrogen standards, for use alongside the current phosphorus standards for eutrophication control. These are now being introduced for the new UK river basin management plans[40]. ***Do the new NI RBMPs consider lake nitrogen standards? Is this something that future RBMPs will incorporate and if so when?***

The new environmental land management scheme (ELMS) in England is being introduced between 2021 and 2024 as an important future mechanism for reducing diffuse pollution from agriculture. ***It may be of interest to find out more detail about NI's Environmental Farming Scheme with regards to reducing diffuse pollution from agriculture under the new 2024-2028 tranche.***

A programme of phosphorus reduction trials at sewage treatments works was undertaken by water companies in England, as part of the National Environment Programme of the 2014 Periodic Review. According the UK Environment Agency, these trials and the follow-up experience with the new/improved techniques are helping to determine which technologies, suited to UK conditions, can reliably reduce phosphorus at sewage treatment works to very low levels. ***It may be of interest to find out if NI Water and DfI fed into these trials, or have conducted/plan to conduct anything similar?***

The UK Environment Act requires a set of statutory environmental targets to be set which have been provided for under the UK Environmental Improvement Plan. Targets include:

- Reduce nitrogen, phosphorus and sediment pollution from agriculture into the water environment by at least 40% by 2038, compared to a 2018 baseline,

[40] UK EA (December 2022) Phosphorus and freshwater eutrophication: challenges for the water environment

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1171043/Phosphorus-challenges-for-the-water-environment.odt with an interim target of 10% by 31 January 2028, and 15% in catchments containing protected sites in unfavourable condition due to nutrient pollution by 31 January 2028.

- Reduce phosphorus loadings from treated wastewater by 80% by 2038 against a 2020 baseline, with an interim target of 50% by 31 January 2028.

However, these targets do not apply to NI under the Environment Act. NI has developed its own Environmental Improvement Plan (EIP) in the form of a draft Environment Strategy. However, the draft NI Strategy does not contain binding targets similar to the UK EIP. The draft NI Strategy states the following objectives, without specific detail on targeted amounts:

- Potential new overall Phosphorus & Nitrogen Balance targets, under the RBMPs;
- More sustainable nutrient management on farms - chemical and organic fertilisers are only applied based on soil requirements and intended land use;
- Reduced levels of nitrates and phosphorus in NI waterbodies;
- By 2031 the nutrient surplus in soils has been reduced;
- The draft RBMP lists a number of measures to reduce diffuse pollution from agriculture and point source pollutions from sewage (Tables 44-45 p.115). However, none of these measures appear to mention targets.
- Will similar types of targets to those under the UK EIP be provided for NI? If so, where?

Due to the privatisation of water companies in England, in July 2022 the government announced that a new legal duty will be placed on water companies in England to upgrade wastewater treatment works by 2030 in 'nutrient neutrality' areas to the highest achievable technological levels.

Further details on measures can be found from page 6 of the UK EA (2022) Phosphorus and freshwater eutrophication: challenges for the water environment.

Also, see UK EEA (2021) Nitrates: Challenges for the water environment

## 5.2 Europe

According to the European Environment Agency (EEA), nearly all European countries have taken policy measures for tackling eutrophication, albeit with differing approaches and focuses. For example, some use mandatory legislated incentives to motivate farmers to implement agri-environmental measures. while others use voluntary approaches.

According to the EEA, Denmark uses non-subsidised mandatory measures, in comparison to Finland whose measures voluntary and subsidised. Legislation on reducing nitrate losses date back to 1980s in Denmark and Sweden where both countries aimed at a 50% reduction. Over time these targets have been tightened (see Annex 1[41] for more detail). According to the EEA, both countries have had great success in reducing diffuse nitrate losses from agriculture over the last decade:

> *Danish agriculture it has proven possible to reduce N-leaching by on average 33% and N-concentrations and loads in surface waters with on average 29–32% while maintaining at the same time crop yields and increasing livestock production significantly.*[42]

The EEA attributes this success to over 30 years of implementation of mandatory targets. That being said, according to the EEA, a regulated approach in Finland showed less of an effect on nitrogen losses to aquatic environments[43].

Denmark is also an example where an event was used as a catalyst to address nutrient issues and help change attitudes. According to the EEA:

> *An example from Denmark shows also, that such disaster events can speed up the development of environmental action plans. A main factor that kicked-off the Danish National Action Plans with a regulation aiming at nutrient management in agriculture was a television report, which showed dead lobsters in the Kattegat Sea. The reason for the finding of dead lobsters was attributed to hypoxia resulting from algal blooms triggered by nutrient runoff from agricultural fields. The public awareness increased tremendously and people realised that something had to be done to reduce nutrient losses from agriculture. Against this background the first Danish Action Plan was initiated in 1985.*[44]

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[41] EEA Eutrophication abatement study (ecologic.eu) p.69

[42] Ibid p.73/74

[43] EEA Eutrophication abatement study (ecologic.eu) p.55

[44] Ibid p.56

The EEA also noted the importance of the 'polluter pays principle' approach for eutrophication abatement. Provided it is applied strictly and the financial burden is shared proportionally across sectors depending on their contribution to the problem. The EEA explains how Denmark conducted a quantitative assessment of emissions loads from different sectors. From this they reached an agreement between sectors where efforts made to achieve nutrient reduction were relative.[45]

For more information see the case studies used in the EEA European Topic Centre on Inland, Coastal and Marine Waters study (2016): European assessment of eutrophication abatement measures across land-based sources, inland, coastal and marine waters (S.6 and Annex1)

### 5.3 Global

According to Bhagwatti and Ahmahad (2019), a survey of International Lake Environment Committee (ILEC), (1988–1993)[46], illustrated that 54% of lakes in the Asia Pacific Region were eutrophic, 53% in Europe, 28% in Africa, 84% North America and 41% South America. In China alone, about 51% of lakes were reported as eutrophic. However, this study is dated from 1993 and there may be more up to date figures.

Bhagowati and Ahmad (2019) inform that Lake Erie, in North America, is one of the best examples of lake eutrophication due to manmade problems. The lake is long (388km by 92km) and shallow with an average depth of 19m. The lake is shallow, warm and highly nutrient, the perfect conditions for eutrophication. Bhagowati and Ahmad (2019) list different cases of lake eutrophication around the world and the main causes. Most of which are human induced, which they call cultural eutrophication.[47]

[45] Ibid p.55

[46] ILEC/Lake Biwa Research Institute (Ed.), Survey of the State of the World's Lakes, vols. I–IV, International Lake Environment Committee, Otsu and United Nations Environment Programme, Nairobi (1988–1993)

[47] Table 2 https://www.sciencedirect.com/science/article/pii/S164235931730143X/pdfft?md5=3d70b5abd8908c20852d719a4d97f870&pid=1-s2.0-S164235931730143X-main.pdf

Their conclusions highlight that while the reduction of nutrients from human activities is needed, policy makers and governments should consider the use of ecological modelling and prediction for the eutrophication control and remediation of lakes. They state that more recent restoration of Lake Washington and Erie was possible due to lake modelling. One of the benefits of using modelling is that it can tell how certain interventions are likely to affect the trophic state of a lake. It can also predict the likely timeframe for returning the lake to healthy status.

In 2014, AFBI referred to a modelling tool for lake management called DOLMANT (Development of targeted ecological modelling tools for lake management). It is described as having

> *created a management framework for lakes which included all of the major biological elements in lakes; this has not existed before[..]*
>
> *[..} will inform environmental managers on the benefits of actions designed to improve the fauna and flora of lakes, through nutrient management, implementation of the Water Framework Directive, and applied fisheries management*[48]

It may be of interest to find out what impact this modelling, or similar, has had on the ongoing management of Lough Neagh.

# 6 Practical approaches to address eutrophication and associated algal blooms

There has been considerable study and experimentation when in relation to addressing eutrophication and associated algal blooms. An undoubted driver for much of this work has been the fact that the phenomenon is global in nature.

Table 2 below summarises some of the approaches taken in various jurisdictions to address freshwater lake eutrophication and associated algal blooms.

[48] AFBI research leads to new understanding of lake ecosystems | Agri-Food and Biosciences Institute (afbini.gov.uk)

Table 2: Approaches to address lake eutrophication and algal blooms

| Approach | Summary examples |
|---|---|
| Reducing agricultural runoff through the use of strips of vegetation beside rivers | The use of so-called riparian strips is a natural approach that can significantly reduce nitrate and phosphorous nutrients reaching the waterway. One cited study highlights how a 12 m wide woody-vegetation riparian buffer reduced a 40 mg L−1 TN concentration by >50% and a 34 μg L−1 TP concentration by >66%[49]. |
| Nutrient rich sediment removal from lake bed | A 1982 paper[50] highlights the work undertaken in Lake Trummen in Sweden, a 1km2 lake with a mean depth of 1.6m. The lake experienced regular algal blooms caused by water enriched by sewage and industrial effluent. Suction dredging the upper half-meter of sediments on the lake bed over two years led to significant decreases in nutrient concentrations and associated algal blooms. |
| Use of constructed wetlands to reduce nutrient levels within waterways | A 2006 scientific paper[51] highlights the use of constructed wetlands as way of achieving a 50% decrease in nitrate and phosphorous levels within an agricultural catchment area.<br><br>Constructed wetlands have also been utilised locally within Ireland[52] and Northern Ireland[53] as a means of reducing nutrient levels in waste water outfall and agricultural waste runoff. |

[49] T.R. Aguiar Jr., K. Rasera, L.M. Parron, A.G. Brito d , M.T. Ferreira, Nutrient removal effectiveness by riparian buffer zones in rural temperate watersheds: The impact of no-till crops practices, Agricultural Water Management 149 (2015) 74–80, 2014

[50] Cronberg, Gerturude, Phytoplankton Changes in Lake Trummen induced by restoration, FOLIA LIMNOLOGICA SCANDINAVICA, 1982

[51] Vymazal Jan, Removal of Nutrients in Various Types of Constructed Wetlands, The Science of The Total Environment 380(1-3):48-65, 2007

[52] Dr. Rory Harrington and Colm Ryder, Dúchas, The Heritage Service. The use of Integrated Constructed Wetlands (ICW's) in the management of farmyard runoff and waste water

[53] Stoneyford Integrated Constructed Wetland, NI water website, 26 September 2023.

| Approach | Summary examples |
|---|---|
| Use of selectively toxic microbes to kill zebra mussels | A 2002 US research paper[54] explored the use of a selectively toxic common microbe a means of controlling zebra mussel populations. In lab trials the use of Pseudomonas fluorescens CL0145A proved an effective control. |
| Use of chemicals to control blue green algae | The use of copper sulphate as an algicide is common but is toxic to many other plants and animals. By contrast, the use of hydrogen peroxide has been shown to be effective[55] and selective, without harming other plants or animals. As a downside, application of hydrogen peroxide application needs to be regular and there is some suggested risk of a threat to drinking water toxin contamination due to the rapid die off of cyanobacteria. |
| Use of chemicals to neutralise nutrient effects | The use of lime, aluminium sulphate, iron salts and other chemicals added to lake water is a well-established means of immobilising phosphorus in sediments[56]. This approach can also be deployed in waste water treatment plants. However, these treatments often need to be repeated, are expensive, and may not be effective in some systems. |

It should be noted that a number of the approaches set out in table 2 would be challenging to deliver in Lough Neagh, given the size of the Lough, the biodiversity within and around it, and the potential expense involved. This raises the obvious question as to how many of these approaches have been assessed for potential adoption by the local authorities.

[54] Molloy Daniel, Biological control of zebra mussels, Proceedings of the Third California Conference on Biological Control, University of California, Davis, California. (pp.86-94)

[55] Hans C P Matthijs 1, Petra M Visser, Bart Reeze, Jeroen Meeuse, Pieter C Slot, Geert Wijn, Renée Talens, Jef Huisman, Selective suppression of harmful cyanobacteria in an entire lake with hydrogen peroxide, Water Research, Volume 46, Issue 5, 1 April 2012, Pages 1460-1472

[56] Precipitation and Inactivation Of Phosphorus As A Lake Restoration Technique, National Service Center for Environmental Publications (NSCEP), United States Environmental Protection Agency, 1981