Blue-Green Algae, Meaning, Characteristics, Conditions, Formation

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Blue-Green Algae, scientifically known as **cyanobacteria**, are **among the oldest life forms on Earth** and are believed to have **played a crucial role in the formation of Earth's oxygen-rich atmosphere through photosynthesis.** Despite their common name, they are not true algae but **photosynthetic bacteria (prokaryotes).**

Under favourable environmental conditions, cyanobacteria multiply rapidly to form Harmful Algal Blooms (HABs), which degrade water quality, produce toxins, threaten aquatic biodiversity and pose serious risks to human and animal health.

Blue-Green Algae Meaning

Blue-Green Algae (Cyanobacteria) are **photosynthetic bacteria** found in freshwater, marine and brackish water ecosystems. They use sunlight, carbon dioxide and nutrients to produce food, and many species can also fix atmospheric nitrogen, enabling them to survive in nutrient-poor environments.

Blue-Green Algae Characteristics

Blue-Green Algae possesses several unique biological and ecological characteristics.

- **Prokaryotic Organisms**: They are bacteria and lack a true nucleus and membrane-bound organelles.
- **Photosynthetic Nature**: Contain chlorophyll-a and phycobilin pigments, giving them a blue-green colour.
- **Nitrogen Fixation**: Many species convert atmospheric nitrogen into usable forms through specialised cells called heterocysts.
- **Wide Distribution**: Found in freshwater, marine, brackish waters, wetlands and moist soils.
- **Bloom Formation**: Multiply rapidly under favourable conditions, forming dense surface blooms.
- **Toxin Production**: Certain species produce cyanotoxins that are harmful to humans, livestock, pets and wildlife.
- **Ancient Organisms**: Among the earliest photosynthetic organisms responsible for the Great Oxygenation Event.

Conditions Favouring Blue-Green Algal Blooms

Blue-Green Algal Blooms develop when environmental conditions favour rapid growth and multiplication of cyanobacteria.

- **Warm Water Temperatures**: Blooms are most common during summer and early autumn when water temperatures are high.
- **Abundant Sunlight**: Longer daylight hours accelerate photosynthesis and growth.
- **Nutrient Enrichment**: Excess nitrogen and phosphorus from fertilisers, sewage and urban runoff stimulate rapid multiplication.
- **Calm or Slow-Flowing Water**: Stagnant lakes, reservoirs and ponds provide favourable conditions for bloom formation.
- **Stable Water Column**: Reduced mixing allows cyanobacteria to remain near the water surface where sunlight is abundant.
- **Climate Change**: Rising temperatures and intense rainfall events increase nutrient runoff and extend bloom seasons.

Causes of Blue-Green Algal Blooms

The increasing frequency and intensity of Blue-Green Algal Blooms are primarily driven by nutrient pollution and environmental changes.

- **Eutrophication**: Excessive enrichment of water bodies with nitrogen and phosphorus triggers rapid cyanobacterial growth.
- **Agricultural Runoff**: Fertilisers and livestock waste wash nutrients into rivers and lakes, promoting bloom formation.
- **Untreated Sewage**: Domestic and industrial wastewater adds nutrient-rich organic matter, creating favourable conditions for cyanobacteria.

- **Urban Stormwater Runoff**: Rainwater carries detergents, chemicals and organic waste into water bodies, increasing nutrient loading.
- **Industrial Effluents**: Nutrient-rich discharges degrade water quality and accelerate bloom development.
- **Climate Change**: Rising temperatures, prolonged dry spells and intense rainfall increase water temperatures and nutrient runoff, extending bloom seasons.
- **Water Flow Modification**: Dams, reservoirs and reduced river flows create stagnant waters where cyanobacteria can multiply rapidly.
- **Land Use Changes**: Deforestation, **soil erosion** and urbanisation increase sediment and nutrient runoff, enhancing eutrophication and bloom formation.

Harmful Algal Blooms (HABs)

A **Harmful Algal Bloom (HAB)** occurs when toxin-producing cyanobacteria multiply rapidly and accumulate in large numbers, severely affecting water quality and aquatic ecosystems. However, not all blooms are toxic, and harmful blooms cannot be identified by appearance alone.

Typical characteristics include:

- Water turning green, blue-green or greenish-brown.
- Surface scums resembling paint, pea soup or floating foam.
- Blooms may persist from a few days to several weeks, depending on environmental conditions.
- Some blooms release cyanotoxins such as microcystins, anatoxins, cylindrospermopsins and saxitoxins, which can contaminate drinking water and threaten public health.
- Bloom decomposition consumes dissolved oxygen, often causing fish kills and creating dead zones.

Impacts of Harmful Algal Blooms (HABs)

Harmful Algal Blooms (HABs) adversely affect aquatic ecosystems, public health and economic activities by degrading water quality, releasing toxins and disrupting ecosystem functioning.

Ecological Impacts

- **Oxygen Depletion**: Bloom decomposition reduces dissolved oxygen, leading to fish mortality.
- **Loss of Biodiversity**: Dense blooms suppress aquatic plants and disrupt aquatic food chains.
- **Reduced Light Penetration**: Surface blooms block sunlight, limiting photosynthesis by submerged vegetation.
- **Ecosystem Imbalance**: Alters nutrient cycling and the structure of aquatic ecosystems.

Health Impacts

- **Human Health Risks**: Exposure may cause skin irritation, eye irritation, vomiting, diarrhoea, headaches and respiratory problems.
- **Unsafe Drinking Water**: Cyanotoxins contaminate drinking water and require advanced treatment, as boiling does not destroy these toxins.

- **Animal Mortality**: Livestock, pets and wildlife may suffer poisoning after consuming contaminated water.

Economic Impacts

- **Higher Water Treatment Costs**: Additional treatment is required to remove cyanotoxins from drinking water.
- **Loss to Fisheries**: Fish mortality and contamination reduce commercial and inland fish production.
- **Decline in Tourism**: Recreational activities such as swimming and boating decline during bloom events.
- **Agricultural Losses**: Livestock deaths and contaminated irrigation water reduce agricultural productivity.

Blue-Green Algae in India

India has witnessed increasing occurrences of harmful cyanobacterial blooms due to rapid urbanisation, nutrient pollution and climate change. For example:

- **Bellandur Lake, Bengaluru (Karnataka)**: One of India's most polluted urban lakes, Bellandur experiences recurring cyanobacterial blooms driven by untreated sewage and nutrient-rich wastewater. Dense blooms are often accompanied by toxic foam and occasional lake fires caused by accumulated pollutants.
- **Hussain Sagar Lake, Hyderabad (Telangana)**:Excess nutrient loading from sewage and urban runoff has resulted in frequent cyanobacterial blooms, deteriorating water quality and reducing dissolved oxygen.
- **Vembanad Lake (Kerala)**: India's longest lake has reported periodic cyanobacterial blooms linked to agricultural runoff, sewage discharge and eutrophication.
- **Yamuna River (Delhi Stretch)**: High nutrient pollution from untreated sewage promotes eutrophic conditions, encouraging cyanobacterial growth and worsening water quality.
- **Loktak Lake (Manipur)**: Nutrient enrichment from surrounding catchments has increased the risk of algal proliferation, threatening the lake's unique wetland ecosystem.

Impact of Climate Change on Blue-Green Algal Blooms

Climate change is acting as a threat multiplier by increasing the frequency, duration and geographic spread of Blue-Green Algal Blooms and aggravating their ecological and public health impacts.

- **Longer Bloom Seasons**: Rising temperatures extend the period suitable for cyanobacterial growth.
- **Increased Nutrient Runoff**: Extreme rainfall and floods transport larger quantities of nitrogen and phosphorus into water bodies.
- **Greater Water Stress**: Droughts and reduced river flows increase water stagnation, favouring bloom persistence.
- **More Frequent Harmful Blooms**: Warmer conditions enhance the production of cyanotoxins and increase the likelihood of Harmful Algal Blooms (HABs).
- **Expansion to New Regions**: Rising temperatures enable cyanobacterial blooms to occur in areas previously less vulnerable.
- **Threat to Water Security**: More frequent blooms degrade freshwater quality, affecting drinking water, fisheries and aquatic biodiversity.

Monitoring and Prevention

As Blue-Green Algal Blooms cannot be completely eliminated, management focuses on early detection, nutrient reduction and ecosystem-based prevention.

- **Water Quality Monitoring**: Regular monitoring of chlorophyll, cyanobacteria, dissolved oxygen, nitrogen and phosphorus enables early bloom detection.
- **Remote Sensing & GIS**: Satellite imagery and drones help track bloom formation and spread in large water bodies.
- **Nutrient Pollution Control**: Reduce nitrogen and phosphorus inputs from agriculture, sewage and industrial effluents to prevent eutrophication.
- **Wastewater Management**: Treat municipal and industrial wastewater before discharge into rivers and lakes.
- **Sustainable Agricultural Practices**: Promote balanced fertiliser use, precision farming and vegetative buffer strips to minimise nutrient runoff.
- **Ecosystem Restoration**: Rejuvenate wetlands, maintain environmental flows and conserve riparian vegetation to improve water quality.
- **Public Awareness**: Issue health advisories and restrict recreational and drinking water use during confirmed Harmful Algal Blooms.

Government Initiatives

India has launched several programmes to improve water quality, reduce nutrient pollution and conserve aquatic ecosystems, thereby lowering the risk of harmful algal blooms.

- **National Water Quality Monitoring Programme (NWMP)**: CPCB monitors the quality of rivers, lakes and reservoirs across the country.
- **Namami Gange Programme / National Mission for Clean Ganga (NMCG)**: Reduces sewage discharge, improves wastewater treatment and rejuvenates the Ganga ecosystem.
- **National Plan for Conservation of Aquatic Ecosystems (NPCA)**: Supports restoration and conservation of lakes and wetlands.
- **Wetlands (Conservation and Management) Rules, 2017**: Regulate activities that degrade wetlands and promote their sustainable management.
- **AMRUT**: Expands urban sewerage networks and wastewater treatment infrastructure.
- **Jal Shakti Abhiyan**: Promotes water conservation, watershed management and protection of water bodies.
- **Atal Bhujal Yojana**: Encourages community-led groundwater management, helping reduce pressure on freshwater ecosystems.
