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Eutrophication and Identification of Algae in Freshwater Lakes of Udaipur, Rajasthan Along with Algal Engineering

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ABSTRACT: Harmful algal blooms, dead zones, and fish kills are the results of a process called eutrophication — which occurs when the environment becomes enriched with nutrients, increasing the amount of plant and algae growth to estuaries and coastal waters. Eutrophication is the process by which an entire body of water, or parts of it, becomes progressively enriched with minerals and nutrients, particularly nitrogen and phosphorus. It has also been defined as "nutrient-induced increase in phytoplankton productivity".[1]:459 Water bodies with very low nutrient levels are termed oligotrophic and those with moderate nutrient levels are termed mesotrophic. Advanced eutrophication may also be referred to as dystrophic and hypertrophic conditions.[2] Eutrophication can affect freshwater or salt water systems. In freshwater ecosystems it is almost always caused by excess phosphorus.[3] In coastal waters on the other hand, the main contributing nutrient is more likely to be nitrogen, or nitrogen and phosphorus together. This depends on the location and other factors.[4][5]

When occurring naturally, eutrophication is a very slow process in which nutrients, especially phosphorus compounds and organic matter, accumulate in water bodies.[6] These nutrients derive from degradation and solution of minerals in rocks and by the effect of lichens, mosses and fungi actively scavenging nutrients from rocks.[7] Anthropogenic or "cultural eutrophication" is often a much more rapid process in which nutrients are added to a water body from a wide variety of polluting inputs including untreated or partially treated sewage, industrial wastewater and fertilizer from farming practices. Nutrient pollution, a form of water pollution, is a primary cause of eutrophication of surface waters, in which excess nutrients, usually nitrogen or phosphorus, stimulate algal and aquatic plant growth. A common visible effect of eutrophication is algal blooms. Algal blooms can either be just a nuisance to those wanting to use the water body or become harmful algal blooms that can cause substantial ecological degradation in water bodies.[8] This process may result in oxygen depletion of the water body after the bacterial degradation of the algae.[9]

KEYWORDS: eutrophication, algal blooms, ecosystems, aquatic, nutrients, pollution, oxygen depletion

I. INTRODUCTION

Algae is an informal term for a large and diverse group of photosynthetic eukaryotic organisms. It is a polyphyletic grouping that includes species from multiple distinct clades. Included organisms range from unicellular microalgae, such as *Chlorella*, *Prototheca* and the diatoms, to multicellular forms, such as the giant kelp, a large brown algae which may grow up to 50 metres (160 ft) in length. Most are aquatic and lack many of the distinct cell and tissue types, such as stomata, xylem and phloem that are found in land plants. The largest and most complex marine algae are called seaweeds, while the most complex freshwater forms are the *Charophyta*, a division of green algae which includes, for example, *Spirogyra* and stoneworts.in freshwater lakes of Udaipur we found these algae:-

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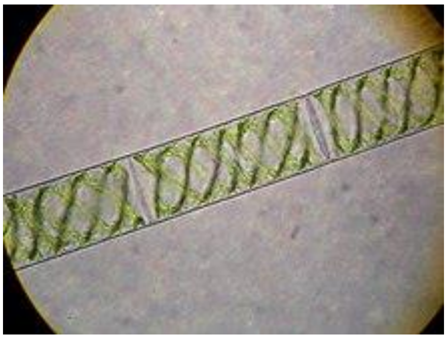
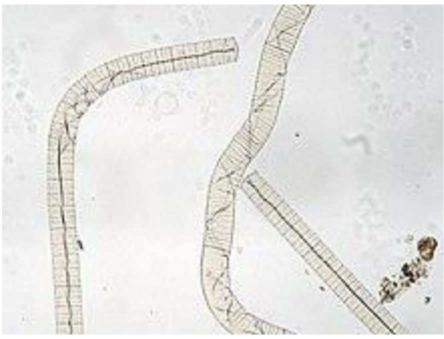
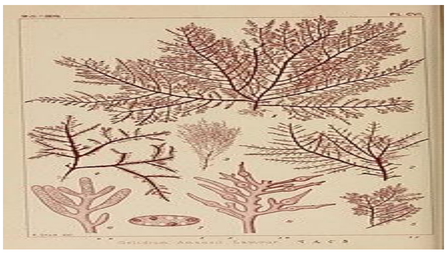


1. *Spirogyra* (common names include water silk, mermaid's tresses, and blanket weed) is a genus of filamentous charophyte green algae of the order Zygnematales, named for the helical or spiral arrangement of the chloroplasts that is characteristic of the genus. *Spirogyra* is very common in relatively clear eutrophic water, developing slimy filamentous green masses. In spring *Spirogyra* grows under water, but when there is enough sunlight and warmth they produce large amounts of oxygen, adhering as bubbles between the tangled filaments. The filamentous masses come to the surface and become visible as slimy green mats. *Spirogyra* has a cell wall, nucleus, pyrenoid, and spiral chloroplasts.



2. *Oscillatoria* is a genus of filamentous cyanobacterium which is often found in freshwater environments, such as hot springs, and appears blue-green. *Oscillatoria* reproduces by fragmentation, facilitated by dead cells which separate a filament into separate sections, or hormogonia, which then grow. *Oscillatoria* uses photosynthesis to survive and reproduce. Each filament of oscillatoria consists of trichome which is made up of rows of cells. The tip of the trichome oscillates like a pendulum. In reproduction, it takes place by vegetative means only. Usually the filament breaks into a number of fragments called hormogonia. Each hormogonium consist of one or more cells and grow into a filament by cell division in one direction.



3. *Gelidium* is a genus of thalloid red algae comprising 134 species. Its members are known by a number of common names. Branching is irregular, or occurs in rows on either side of the main stem. *Gelidium* produces tetraspores. Many of the algae in this genus are used to make agar. *Chaetangium* is a synonym

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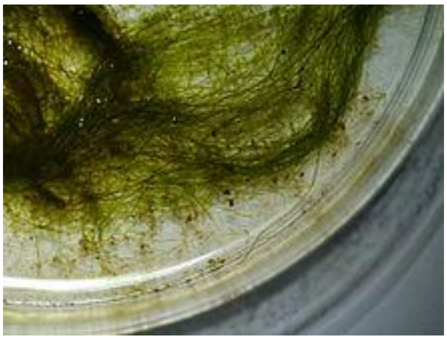

4. *Vaucheria* is a genus of Xanthophyceae or yellow-green algae known as water felt. *Vaucheria* exhibits apical growth from the tip of filaments forming mats in either terrestrial or freshwater environments.[3][4] Its filaments form coenocytes with a large central vacuole pushing against the surrounding cytoplasm; the vacuole extends along the entire filament except for the growing tip.[4] The chloroplasts are located on the periphery of the cytoplasm with the nuclei aggregating toward the center near the vacuole
5.

6. *Fucus spiralis* is olive brown in colour and similar to *Fucus vesiculosus* and *Fucus serratus*. It grows to about 30 cm long and branches somewhat irregularly dichotomous and is attached, generally to rock, by a discoid holdfast. The flattened blade has a distinct mid-rib and is usually spirally twisted without a serrated edge, as in *Fucus serratus*, and it does not show air-vesicles, as *Fucus vesiculosus*.

II. DISCUSSION

These 5 species were identified in freshwater lake of Udaipur. Algae tend to cause eutrophication also. Eutrophication is characterized by excessive plant and algal growth due to the increased availability of one or more limiting growth factors needed for photosynthesis such as sunlight, carbon dioxide, and nutrient fertilizers. Eutrophication occurs naturally over centuries as lakes age and are filled in with sediments .However, human activities have accelerated the rate and extent of eutrophication through both point-source discharges and non-point loadings of limiting nutrients, such as nitrogen and phosphorus, into aquatic ecosystems (i.e., cultural eutrophication), with dramatic consequences for drinking water sources, fisheries, and recreational water bodies .For example, aquaculture scientists and pond managers often intentionally eutrophy water bodies by adding fertilizers to enhance primary productivity and increase the density and biomass of recreationally and economically important fishes via bottom-up effects on higher trophic levels. However, during the 1960s and 1970s, scientists linked algal blooms to nutrient enrichment resulting from anthropogenic activities such as agriculture, industry, and sewage disposal .The known consequences of cultural eutrophication include blooms of blue-green algae (i.e., cyanobacteria) tainted drinking water supplies, degradation of recreational opportunities, and hypoxia. The estimated cost of damage mediated by eutrophication in the U.S. alone is approximately $2.2 billion annually . The most conspicuous effect of cultural eutrophication is the creation of dense blooms of noxious, foul-smelling phytoplankton that reduce water clarity and harm water quality .Algal blooms limit light penetration, reducing growth and causing die-offs of plants in littoral zones while also lowering the success of predators that need light to pursue and catch prey .Furthermore, high rates of photosynthesis associated with eutrophication can deplete dissolved inorganic carbon and raise pH to extreme levels during the day. Elevated pH can in turn ‘blind' organisms that rely on perception of dissolved chemical cues for their survival by impairing their chemosensory abilities. When these dense algal blooms eventually die, microbial decomposition severely depletes dissolved oxygen, creating a hypoxic or anoxic ‘dead zone' lacking sufficient oxygen to support most organisms.

Death of fish due to hypoxia by eutrophication in Udaipur lake.

Algal engineering for bioremediation, bioenergy production, and biomedical applications

Algae have received substantial consideration as a potential feedstock for extensive applications in the environmental sector, biofuel production, and biomedical engineering. Rapid climate changes, shrinking natural resources, and food crises are on the rise globally. The release of untreated industrial wastewaters containing vast amounts of carbon, nitrogen (N), and phosphorus (P) causes severe pollution and environmental damage. Hence, the recovery of such nutrients is required through a suitable sustainable process. Microalgae-based technologies have gained significant attention compared to other techniques due to their sustainable and cost-effective treatment strategies for removing wastewater nutrients. Algal biomass could potentially be used for bioenergy production and high-value bioproducts. High operational costs and low yield are the main limitations for developing microalgae-based biorefineries. Therefore, most researchers focus on an integrated approach for the cultivation of a suitable algal strain and its downstream processing. Algal biomass production for use as a biofuel is not feasible from a techno-economic perspective. A biorefinery concept could be a more suitable approach for bio-oil extraction, and the remaining biomass could be used for several biomedical applications.

III. **RESULTS**

Algae is an abundant and widely varied group of aquatic organisms capable of producing oxygen through photosynthesis and thereby harvesting energy from sunlight to grow and produce a range of biochemicals.That capability and related characteristics can make algae a useful component in the development of advanced systems for effectively treating wastewater, producing cleaner energy and new biofuels, reducing harmful carbon dioxide emissions and improving decontamination and pollution control techniques.Engineers and scientists say the chemical components in algae can also strengthen materials used to build transportation systems and other public infrastructure — while sequestering carbon in the process to substantially boost the sustainability of both natural and built environments. Among ways being explored to combine biology and engineering to remedy a range of growing global environmental problems, algae-based solutions look especially promising.The encouraging viewpoint stems from progress in research that is revealing how the properties of algae can be harnessed to become the driving force for a slew of productive biotechnological pursuits.Some of the research findings have been the result of efforts based at the Arizona Center for Algae Technology and Innovation, or AzCATI, embedded in the **Ira A. Fulton Schools of Engineering at Arizona State University.**

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AzCATI launched in 2010 with a multimillion-dollar investment from Science Foundation Arizona, a nonprofit with the mission of diversifying Arizona's economy by aligning university research with the needs of industry.The foundation's support financed the development of several acres of algal growth ponds on ASU's Polytechnic campus — located close to biochemical and molecular biology labs with resources available for use in AzCATI's projects, particularly the cultivation of algal biomass for biofuels.Before long, the center became one of the major testbeds for algae biotechnology-derived products, including nutraceuticals, biofuels, food and feed and high-value pharmaceuticals — all from algae biomass. This was possible due in large part to the Department of Energy-funded ATP3 consortium, which is designed to accelerate research and development of algae-based technologies."We've become basically the algae farmers for many public and private ventures that need to make advances in algae cultivation and productivity to reach their goals and our goals," said John McGowen, AzCATI's director of operations and an ASU sustainability scientist. "We collaborate with industry and academics to 'road-test' technology, and use data being generated by our testbed site to contribute to reducing technology risk and helping to propel the success of these enterprises."The center now has longstanding working relationships with major U.S. research facilities, including the National Renewable Energy Laboratory, the Pacific Northwest National Laboratory, Los Alamos National Laboratory and Sandia National Laboratories."Most of the national labs don't have access to their own outdoor testing facilities, so they can come to us," McGowen said. "Recently, through the DOE-funded DISCOVR consortium, we've achieved some of the highest outdoor algae cultivation productivity rates ever."

Expanding engineering of algae research and development

AzCATI is part of ASU's LightWorks, an accelerator that focuses on advancing solar energy generation and other sources of sustainable energy, fuels and related products. The center is also part of the School of Sustainable Engineering and the Built Environment, one of the six Fulton Schools.Through its connection to LightWorks and the school, AzCATI has been able to draw on a broad array of engineering and science resources and expertise, helping the center attract close to $70 million from public agencies, industry and foundations — as well as partnering with startups to obtain small business innovation grants — leading to significant expansion of AzCATI's activities during its first decade.Over that time, the use of algae in products has notably increased. Algae is now an ingredient in foods (for humans and animals), cosmetics, nutritional supplements like omega-3 oils, antioxidants, coloring agents, dyes for fabric, sunblock lotion, printing ink, flour and paper, among many other consumer products.

Beyond those uses, algae is a key ingredient in materials essential to a variety of industries. It's often a key component of bioconcrete, the source of many bioplastics, and a growing source of agricultural biostimulants and fertilizers. Algae is used in aquaculture as feed for fish and shrimp, naturally imparting healthy antioxidants and omega-3 oils, along with appetizing colors, that don't come from typical soymeal.Looking at possibilities for expanding and improving the use of algae-based processes and technology to advance not only economic interests but also the greater societal good is the main thrust of research led by the three Fulton Schools faculty members on AzCATI's leadership team. Each is contributing to innovation in what is called the Algae-Food/Energy/Water Nexus.

Research Professor Peter Lammers studies algae from acidic hot springs, applying his knowledge of molecular biology and environmental chemistry to create large-scale carbon-foundries that will fuel the future carbon economy.Assistant

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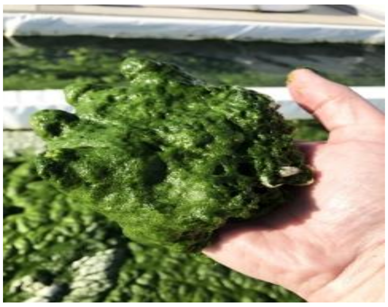
Professor Taylor Weiss concentrates on making biochemical and biophysical advances, using synthetic biology and novel sensors to create and control the production of renewable biochemicals, sustainable agricultural additives, algal biofuels and products to improve human health.Professor Shuguang Deng utilizes chemical engineering principles to develop adsorbents, catalysts and membranes for systems and technologies providing sustainable energy, chemicals, fuels and construction materials.

Attracting support from a range of public and commercial sources



Research by Fulton Schools colleagues outside of AzCATI meshes with the center's goals and helps support its ongoing projects.Associate Professor Elham Fini is using an additive derived from algae to boost the resilience and reduce the emissions of asphalt — which is especially important in hot and sunny Arizona.Professors Bruce Rittman and Rolf Halden's work focuses on finding more effective methods of protecting and restoring the health of ecosystems.In his Center for Negative Carbon Emissions, Professor Klaus Lackner is developing carbon capture technology to help pull harmful greenhouse gases out of the atmosphere.Research capabilities in these and related areas over the years have brought AzCATI more than a dozen major projects funded by the U.S. Department of Energy, along with other projects supported by the Small Business Innovation Research programs of the U.S. Department of Agriculture and the National Institutes of Health.Funding has also come from the Department of Energy's Advanced Research Projects Agency-Energy, the Central Arizona Project — the aqueduct and canal system that brings water to much of central and southern Arizona — as well as numerous companies such as Xylem, a major multinational innovator in water technology.

Research collaborators rely on AzCATI's expertise and creativity

Longtime AzCATI collaborators in industry, government agencies and research universities say the center has played an essential role in their research and development success.Matthew Posewitz, a professor of chemistry at the Colorado School of Mines, has been in algae research field for more than 20 years and has worked on algae biofuels and related projects with support from the National Renewable Energy Laboratory and the Department of Energy.

"Some algae technology advances were pioneered at ASU dating back decades ago," Posewitz said, "and the people at AzCATI continue to perform that level of work. They have been consistently at the forefront of algae testbed productivity. We have always been able to rely on the competence and creativity of the people there." Philip Pienkos has that same level of confidence in AzCATI's researchers and technicians."I have always trusted them to do outstanding work and I always will," said the biologist and recently retired emeritus scientist with the National Renewable Energy Lab.His assertion is based on collaborations he was involved in with AzCATI since its early days, finding its leadership especially motivated to make breakthroughs in algae research."Once we decided what it was going to take to accomplish what we wanted to do, we could count on them getting the work done," Pienkos said.He recalls the first project he worked on with AzCATI researchers being an especially rewarding accomplishment. Together they provided the basis for a concept of an algae-based biorefinery, which led to the development of algae-based polyurethane, a plastic material with a plethora of practical uses.Today, Pienkos is in the process of getting his own startup venture off the ground as a platform for commercializing urethane technology.

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IV. CONCLUSIONS

Helping to reverse direction on our unsustainable path

From a big-picture perspective, Lammers and Weiss say, solutions to the environmental threats posed by the increasing amounts of detritus — decomposing waste and debris — that is created by modern civilization lie at the nexus of AzCATI’s endeavors and related ASU research projects.For example, conventional activated sludge treatment of municipal wastewater leads directly to 24 billion tons of carbon emitted as carbon dioxide. The AzCATI team is researching ways of using algae to turn wastewater treatment into a renewable carbon foundry that would replace petroleum as the primary feedstock for industrial carbon commodities. AzCATI’s leaders say that engineering algae can help society change its unsustainable course. Algae-based technologies and systems could provide alternatives to wasteful and unsustainable practices that are causing environmental deterioration.The researchers envision such an advance enabling development of effective and economical methods to clean up the damage that has already been done, while also spurring the development of new products — along with creating new jobs to better support communities and economies in an ever-growing world.

LightWorks Director Gary Dirks, who led the effort to establish AzCATI, says the center is at the leading edge of realizing the full potential of algae-based technology “to turn what is in those waste streams into valuable products.”Such advances can contribute to creating “more sources of fuel, food, raw materials and chemical feedstocks to improve life in the future,” Dirks said. Ram Pendyala, director of the School of Sustainable Engineering and the Built Environment, shares that outlook. AzCATI’s work “will lead to transformative algae-based technologies that fuel our societies and clean our environments in the years ahead,” Pendyala said.

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