Applicant: - CHANDIGARH UNIVERSITY

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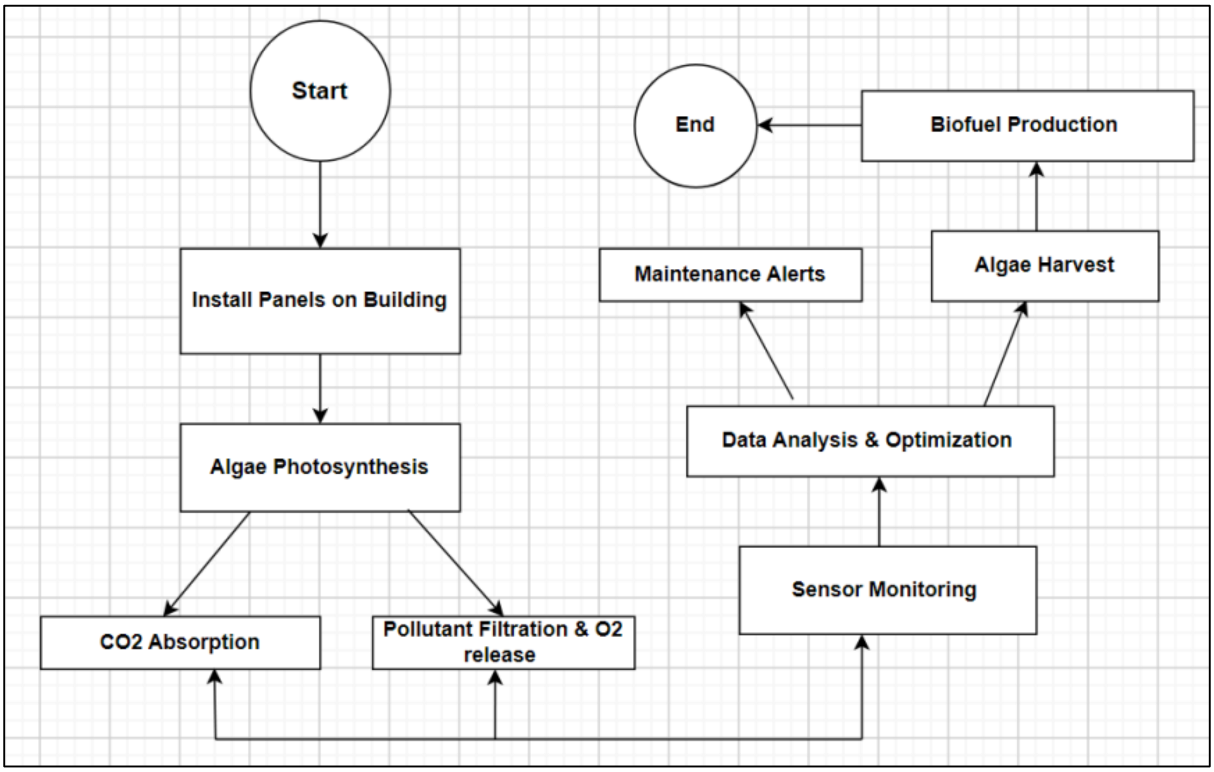

FIG. 1

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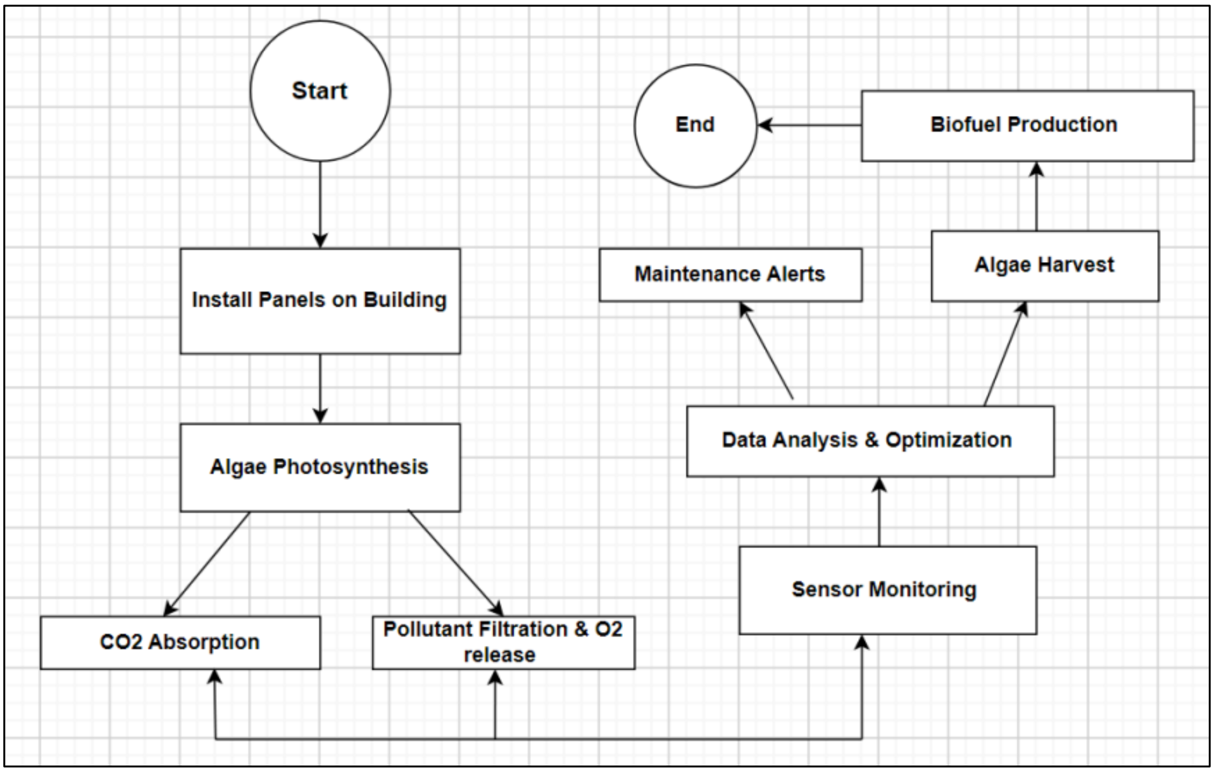

FIG. 1

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No. of Sheets: 2
Sheet No. 2

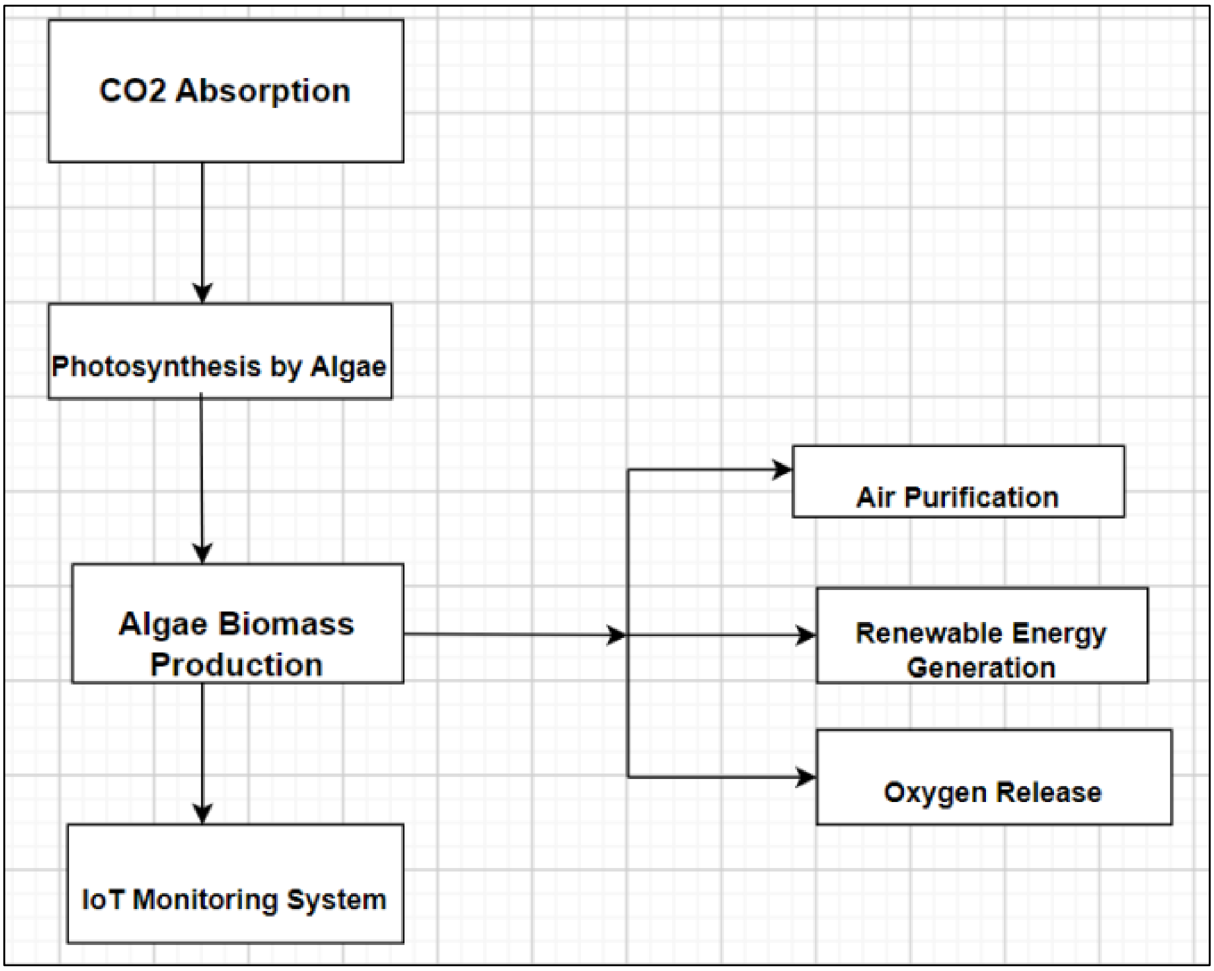

FIG. 2

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FORM 2

THE PATENTS ACT, 1970

(39 of 1970)

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THE PATENTS RULES, 2003

COMPLETE SPECIFICATION

(See Section 10; rule 13)

MODULAR ALGAE BIO-REACTOR PANELS FOR URBAN BUILDING

APPLICANT(S)

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NATIONALITY: Indian

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The following specification particularly describes the invention, and how it is to be performed.

FIELD OF THE INVENTION

The present invention relates to the domain of environmental sustainability and urban ecology in aspects relating to air pollution, carbon sequestration, and renewable energy generation. The system introduces the Modular Algae Bio-reactor Panel System for potential installation and integration with buildings and their associated infrastructure, in that it harnesses algae's natural carbon dioxide capture and release of oxygen and production of biomass for biofuels. The system incorporates IoT-enabled monitoring, automated water and nutrient supply, and optional photovoltaic cells, ensuring optimal performance with minimal maintenance. The invention promotes sustainable urban living by merging environmental remediation with architectural innovation.

BACKGROUND OF THE INVENTION

The rapid pace of urbanization and industrialization has significantly contributed to environmental challenges, particularly air pollution and climate change. Carbon dioxide (CO_2), a major greenhouse gas, is one of the primary contributors to global warming. As urban centers expand and industries grow, the concentration of CO_2 in the atmosphere continues to rise, leading to severe health, environmental, and economic consequences. Governments, industries, and researchers around the world are working to create measures of reducing those emissions and helping the earth.

Conventional carbon capture methods using chemical absorption, underground storage, and mechanical filters are promising but with their disadvantages. These methods are expensive and require great infrastructure with minimal adaptability to different environments. Besides, they do not hold potential for generating any useful resources and complementing existing urban environments in a manner that would make them popular for any widespread dissemination. As a result, there is an increasing demand for solutions that not only capture CO_2 effectively but are also cost-efficient, sustainable, and multifunctional.

Microalgae have emerged as a promising alternative for carbon capture due to their natural ability to absorb CO_2 during photosynthesis. Algae are among the fastest-growing photosynthetic organisms, capable of sequestering significant amounts of CO_2 while producing oxygen. Furthermore, the biomass generated by algae being utilized in various applications, including biofuel production, pharmaceuticals, food supplements, and bio-based materials. Despite these advantages, current algae-based systems face challenges such as scalability, operational efficiency, and seamless integration into urban environments.

Prior art **US2015004685A1** titled “High Efficiency Continuous Micro Algae Bioreactor” discloses a process, providing a continuous photosynthetic bioreactor for carbon sequestration. An on-site bioreactor directly decreases the concentration of carbon dioxide in the emissions of fossil fuel consuming units. In this process, an algal medium is maintained in a bioreactor. Light is provided through artificial means where nutrients are added in a cross flow pattern and waste products are removed as they are created, allowing for maximum growth of the algae.

Another prior art **IN202421037404A** titled **“**A SYSTEM FOR PURIFYING THE AIR IN URBAN ENVIRONMENTS USING MICROALGAE-BASED AIR PURIFICATION AND METHOD THEREOF**”** discloses a scalable remedy for urban air pollution and climate change. The system consists of a photobioreactor vessel containing water and microalgae, which is powered by natural sunlight to facilitate photosynthesis. The process transforms carbon dioxide into oxygen, which is subsequently discharged into the atmosphere via a bubble column. The system is designed for urban environments where space and pollution constraints prevent conventional tree planting, this system is compact enough to be installed on rooftops, parking lots, and shopping centres.

With an ever-growing interest to integrate algae-based bioreactor systems into the urban infrastructure over the last decade, such bioreactor systems address carbon dioxide emissions at the same time as generating biomass. Most current designs are big, cumbersome to maintain, and unsuitable for large-scale application in densely populated areas. Currently, there has been a constraint on the development of these systems due to lack of modularity and adaptability towards the dynamic space of an urban environment.

The present invention aims to address these challenges by introducing a compact, modular, and efficient algae-based bioreactor system that easily being integrated into the urban environment which is being done in the form of building facades, rooftops, and public spaces to capture local CO_2 emissions. The modularity of the system allows it to be adapted to different scales and applications, which makes it ideal for residential, commercial, and industrial use. The system also includes advanced monitoring and automation technologies to make it more efficient and easier to maintain.

By applying modern design principles to the system, it reduces carbon footprint in the city while allowing cities to act as sustainability bases. Since integrating such systems without changing the previously laid infrastructure leaves only minor interruption but maximum environment impact, using algae-based bioreactors adds circular economy characteristics. This also reduces reliance on non-renewable resources as the waste carbon dioxide is reused for by-product synthesis.

The disclosed invention is one of the groundbreaking solutions to one of the most pressing environmental challenges of our time. Combining the natural benefits of microalgae with cutting-edge technology and adaptable design, the invention represents a significant step toward creating sustainable, self-sufficient urban ecosystems. This approach addresses not only the need for CO_2 reduction but also aligns with global goals for cleaner air, renewable energy, and sustainable urban development.

OBJECTS OF THE INVENTION

The principal object of the present invention is to provide an efficient capture system of carbon dioxide (CO_2) emissions in urban and industrial environments, thereby reducing atmospheric greenhouse gas concentrations.

The other objective of the invention is to utilize microalgae as a natural medium for CO_2 capture through photosynthesis, hence ensuring an environmentally sustainable solution.

The other objective of the invention is to design system that being scaled up and down depending on the requirements for the different urban spaces and industrial facilities.

The other objective of the invention is to create a system that seamlessly integrates into what already exists in the city's infrastructure, such as building facades, rooftops, and public spaces with minimum modification.

Another object of this invention is to minimizing the space, energy, and water required by the bioreactor system while maximizing its absorption of CO_2.

Another object of the present invention is to enable the production of valuable biomass as a byproduct which can be used further for biofuels, pharmaceuticals, food supplements, and other bio-based products.

Another object of the present invention is to ensure the system economically viable for mass deployment by lowering operational and maintenance costs.

Another object of the present invention is to incorporate high-tech automation and monitoring systems in order to facilitate ease of operation and minimize human intervention.

Another object of the present invention is to contribute to a circular economy by converting waste CO_2 into valuable byproducts, thereby reducing reliance on non-renewable resources.

Another object of the present invention is to develop a system adaptable to diverse geographic and climatic conditions, ensuring global applicability.

Another object of the present invention is to design the bioreactor in an aesthetically pleasing manner, making it suitable for public and private spaces without disrupting the aesthetic value of urban landscapes.

Another object of the present invention is to promote long-term environmental sustainability by reducing carbon emissions and supporting renewable resource generation.

Another object of the present invention is to meet international environmental standards and regulations for carbon emissions and promote adherence to sustainability goals.

Another object of the present invention is to ensure the system being scaled for applications ranging from small residential units to large industrial complexes, addressing diverse emission sources.

Final objective of this invention is to provide a versatile, sustainable, and scalable algae-based bioreactor system that captures carbon dioxide emissions, integrates seamlessly into urban and industrial spaces, and transforms waste CO_2 into valuable byproducts, thereby addressing global environmental challenges while promoting economic and ecological benefits.

The foregoing, and other objects, features, and advantages of the present invention becomes readily apparent upon further review of the following detailed description of the preferred embodiment as illustrated in the accompanying drawings.

SUMMARY OF THE INVENTION

The present invention refers to an innovative algae-based bioreactor system designed for carbon dioxide (CO_2) capture and utilization. The system utilizes microalgae as a natural medium for absorbing CO_2 from urban and industrial emissions through photosynthesis. The invention is integrated with a modular design, allowing the bioreactor to adapt to varying spatial and operational requirements, making it suitable for installation on building facades, rooftops, and public spaces which provides a sustainable and effective remedy in combating climate change through the mitigation of carbon emissions from urban activities and industries.

In one embodiment, the bioreactor system comprises panels, which are transparent and semi-transparent, with suspended microalgae in a nutrient-rich aqueous solution. Such panels are placed in locations of high emissions, capturing the CO_2 from the ambient air and directly from industrial exhaust streams. The bioreactor is designed with monitoring and control devices that automate it to optimize conditions for the algae's growth and maximize efficiency of CO_2 capture and conversion.

Another embodiment has a modular design that is being scaled and customized for different applications. For example, the system is being scaled down to be used in residential settings, and scaled up to industrial facilities and urban landscapes. This modularity ensures wide applicability and allow for the attainment of specific carbon reduction targets depending on the source and intensity of emissions.

Another enhancing feature of the system is the ability to generate valuable byproducts such as algal biomass that is being used for biofuel production, pharmaceuticals, food supplements, and many more high-value applications. The capture of CO_2 into marketable resources not only solves environmental problems but also presents an economic motive for adoption.

In another embodiment, the system is integrated seamlessly with existing urban infrastructure without diminishing the aesthetic value of the environment. The bioreactor panels are designed to blend with modern architectural styles, thereby making them appropriate for use in urban areas such as commercial buildings, residential complexes, and public spaces. Incorporation of energy-efficient components ensures that the operation of the system is sustainable and cost-effective over time.

Overall, this is a versatile and scalable solution to the global problem of CO_2 emissions. Through the natural process of photosynthesis of microalgae linked with advanced engineering and modular design, the system opens up an effective, cost-friendly, and practical eco-friendly carbon capture and utilization approach. The invention is in line with environmental sustainability, circular economy, and climate action objectives by opening up pathways for reducing the carbon footprint of urban and industrial ecosystems.

Various objects, features, aspects, and advantages of the inventive subject matter that become more apparent from the following detailed description of preferred embodiments, along with the accompanying drawing figures in that the same numerals represent like components.

BRIEF DESCRIPTION OF THE DRAWINGS

These, and other features, aspects, and advantages of the present invention that become better understood through the following description, appended claims, and accompanying drawings:

Fig. 1 illustrates a block-diagram of Modular Algae Bio-reactor Panel System according to various embodiments.

Fig. 2 illustrates flow-diagram of the working of the Modular Algae Bio-reactor Panel system according to various embodiments.

DETAILED DESCRIPTION OF THE INVENTION

The present invention has been particularly shown, and described concerning certain preferred embodiment, and specific features thereof. The embodiments set forth hereinbelow are to be taken as illustrative rather than limiting.

The following description includes the preferred best mode of one embodiment of the present invention. It is clear from this description of the invention that the invention is not limited to these illustrated embodiments but that the invention also includes a variety of modifications, and embodiments thereto. Therefore, the present description has been seen as illustrative, and not limiting.

While the invention is susceptible to various modifications, and alternative constructions, it has been understood, that there is no intention to limit the invention to the specific form disclosed, but, on the contrary, the invention is to cover all modifications, alternative constructions, and equivalents falling within the spirit, and scope of the invention as defined in the claims.

In any embodiment described herein, the open-ended terms "comprising," "comprises,”, and the like (that are synonymous with "including," "having”, and "characterized by") be replaced by the respective partially closed phrases "consisting essentially of," consists essentially of, “, and the like or the respective closed phrases "consisting of," "consists of, the like.

As used herein, the singular forms “a,” “an,”, and “the” designate both the singular, and the plural, unless expressly stated to designate the singular only.

System overview

The present invention relates to a scalable, modular algae bioreactor system that captures atmospheric CO_2 by utilizing the carbon fixation capability of microalgae. The bioreactor system consists of transparent/ semi-transparent panels containing microalgae suspended in a nutrient-rich aqueous solution. The system captures CO_2 from ambient air and directly from emission sources and optimizes microalgal growth conditions to enhance carbon fixation and biomass production. The modular design is adaptable to various spatial, operational, and aesthetic requirements.

According to all the embodiments of the present invention, Figure 1 detailed about the system where algae panels are installed on buildings to enable algae photosynthesis, leading to two primary outcomes: CO_2 absorption and pollutant filtration coupled with oxygen release. Sensor monitoring is integrated to track system performance, feeding data into a data analysis and optimization process to enhance efficiency. Based on the analysis, maintenance alerts are issued as needed. The system also involves algae harvesting, which serves as an input for biofuel production. This closed-loop process combines environmental benefits, such as air purification and CO_2 reduction, with renewable energy generation, culminating in a sustainable and efficient solution.

Key Components of the Bioreactor System

1. Bioreactor Panels

The bioreactor panels represent the central framework of the system. These panels come in robust, lightweight materials like polycarbonate and tempered glass. The panels facilitate maximum light penetration to ensure photosynthesis and structural integrity. Microalgae are suspended in a nutrient-rich aqueous medium within a panel that provides all the necessary nutrients and minerals to support algal growth. The panels are sealed to prevent contamination and ensure the optimal growing conditions.

2. Microalgal Medium

The bioreactor uses specially selected microalgae strains, such as *Chlorella vulgaris* or *Spirulina platensis,* known for their high CO_2 uptake and growth rates. These strains are cultivated in a controlled environment with nutrient solutions containing nitrogen, phosphorus, and trace minerals, ensuring optimal growth and productivity.

3. CO_2 Capture Mechanism

The system incorporates an air intake mechanism that are developed to capture the CO_2 of ambient air and direct industrial emissions. In an industrial emission mode, the pretreatment units ensure that the emitted gases are stripped of impurities such as sulfur oxides and nitrogen oxides, thus, exposing the algae to clean CO_2.

4. Light Management System

To maximize photosynthesis, the system uses natural sunlight in combination with energy-efficient LED lights. LEDs are tuned to emit wavelengths that optimize microalgal growth. Sensors and automated systems control light intensity and duration, ensuring efficient energy utilization.

5. Nutrient Delivery System

A closed-loop nutrient delivery system provides the microalgae with the necessary nutrients. The system periodically circulates the nutrient-rich aqueous medium through the panels to prevent stagnation and ensure uniform growth.

6. Monitoring and Control System

The bioreactor is fully fitted with advanced monitoring sensors to measure critical parameters like CO_2 concentration, temperature, pH, dissolved oxygen, and light intensity. These sensors are connected to an automated control system, which adjusts environmental conditions in real time to maximize the efficiency of the bioreactor.

7. Harvesting and Processing Unit

Algal biomass produced during the process is periodically harvested using a separation system, such as centrifugation and filtration. The harvested biomass is then processed into valuable products, including biofuels, animal feed, or pharmaceuticals.

Operation of the System

The bioreactor system uses atmospheric CO_2-laden air, which is drawn into the panels. The gas is then absorbed into the aqueous medium by photosynthetic microalgae through the utilization of light, either natural or artificial, to convert CO_2 and water into oxygen and organic biomass. Under optimal growth conditions, the system automatically controls its temperature, light, and nutrient levels.

When the microalgae have reached a predetermined density, the biomass is harvested using a separation unit. The remaining aqueous medium is recirculated into the system, ensuring sustainability and minimizing waste. The biomass harvested is then further processed and being directed towards high-value products, including biofuels, cosmetics, and food additives.

According to the embodiments of the present invention, Figure 2 detailed about the system where CO_2 absorption and photosynthesis by algae lead to algae biomass production, which contributes to air purification, renewable energy generation, oxygen release, and monitoring through an IoT system.

Steps of the Invention

- Design Phase: In the design stage, the various elements of the invention are conceptualized and selected. Suitable microalgae strains with high growth rates, CO_2 absorption capacity, and suitable biomass output are selected. The materials for the bioreactor panels and other components also be chosen depending on requirements in durability and transparency. It must also have an ability to scale so that it is being used in small-scale applications such as urban deployment and large-scale ones such as in industrial setups.

- Construction and Assembly: After the design, the panels for the bioreactor, filtration systems, nutrient delivery systems, and control systems are put together. The modular panels integrate with the air intake and light management systems to make up the bioreactor units. Wiring and piping are installed very carefully to allow smooth operation. Sensors are installed in the system to monitor the key variables.

- Software Development: The software platform is developed to manage the system's sensors and control the automated processes. The platform includes algorithms for real-time monitoring, environmental optimization, and biomass estimation. It also provides a user-friendly interface for operators to monitor and adjust the system remotely.

- Testing and Calibration: After assembly, the system undergoes various tests to ascertain whether each component works appropriately. Calibration of sensors is also important in ensuring that each gives its actual data value. The control systems are then tested in order to test how the system changes when environmental parameters change.

- Deployment: After successful testing, the system is installed at the designated site. This is being an urban area where CO_2 emissions are high and an industrial facility that generates a large amount of waste CO_2. The installation is done with careful attention to space constraints and local conditions (e.g., sunlight availability).

- Operation and Maintenance: Once it is running, the system needs to be monitored and maintained from time to time. This includes checking the nutrient delivery systems, cleaning filters, and harvesting biomass at the optimal time. It also needs software updates regularly so that the system continues to work efficiently.

- Byproduct Utilization: The harvested microalgae are processed into various valuable byproducts. Depending on the target market, these byproducts include biofuels, animal feed, food supplements, and other high-value compounds. The biomass processing system is designed to convert the algal biomass into these products in an efficient manner, reducing waste and maximizing resource use.

Step-by-Step Explanation of the Invention

1. CO_2 Capture

- Air Intake System: The first step in the system is to capture CO_2 from ambient air and from industrial exhaust gases. This is being achieved by drawing the air in through an intake system, most likely consisting of fans and natural convective air currents. Once the air enters the system, carbon dioxide is captured from the rest of the air stream using either a membrane separation process, amine scrubbing, and other carbon capture technologies. They usually target the selective capture of carbon dioxide from the environment, and thus only the air that reaches the microalgae is supplied with all the CO_2 needed for photosynthesis.

- Impurity Removal: Alongside CO_2 capture, the system also needs to filter out other impurities, particularly nitrogen oxides (NOx) and sulfur oxides (SOx), which is being harmful to both microalgae growth and the system’s functionality. In this regard, filtration systems include particulate filters and chemical scrubbers ensuring that only pure CO_2 enter the bioreactor.

2. Photosynthesis in the Bioreactor Panels

- Bioreactor Design: The bioreactor panels are large, transparent and semi-transparent chambers that hold the microalgae and nutrient solution. Translucency allows light penetration through the panels, which is necessary for photosynthesis. In the panels, microalgae are suspended in an aqueous nutrient-rich medium providing the necessary nutrients for their growth, such as nitrogen, phosphorous, and trace minerals.

- Photosynthetic Process: The microalgae absorb CO_2 and H_2O and undergo photosynthesis, but with the conversion of these primary materials into O_2 and biomass using natural light and, in some laboratory setups, LED lights. Carbohydrates, proteins, and lipids all constitute this harvested biomass. According to the law of photosynthesis, the rate varies directly with available light and carbon dioxide, thereby making environmental conditions prime.

3. Nutrient and Environment Optimization

- Nutrient Delivery: Microalgae grow optimally using several nutrients in the solutions including nitrogen in ammonium and nitrate, phosphorus, potassium, magnesium, trace elements like iron, and many others. The nutrient is introduced into the bioreactor via automated pumps and valves in the right concentrations. Nutrient solution continuously runs in and out through bioreactor panels to ensure that depletion of medium does not occur as well as mix the medium well.

- Environmental Parameters Monitoring: The system continuously monitors the parameters like temperature, pH, dissolved oxygen, and light intensity to maximize the efficiency of photosynthesis by microalgae. Real-time data is received from sensors placed in the bioreactor, and the control system adjusts the operating conditions; for example, it increases light intensity or adjusts the flow rate of CO_2 so that the best possible environment is given to the microalgae for growth.

4. Biomass Harvesting

- Density Determination: Once the microalgae have reached a certain concentration, that is, a point level of biomass, they are ready to be harvested. Biomass concentration is determined by measuring optical density in the solution and employing other non-invasive monitoring methods, thereby estimating the algal concentration.

- Harvesting Techniques: Once the required concentration of biomass is obtained, the microalgae is being separated from the liquid nutrient medium through a number of methods. The most common methods are centrifugation and filtration. This process includes centrifugation, where at high speeds, one separates the algae from the water using the density difference. Filtration systems work by passing the liquid through mesh and membranes with a fine hole size and capturing the microalgae. Then the separated microalgae are being harvested for further processing.

- Recirculation of Medium: The nutrient solution that remains after the algae are harvested is not wasted. It is generally recycled back into the system for use in subsequent cycles, helping conserve both water and nutrients. The closed-loop system is critical in maintaining resource efficiency.

5. Biomass Processing

- Harvested Biomass Applications: Once the algae have been separated from the medium, the harvested biomass is being converted into valuable byproducts. Common applications for algae biomass include the generation of biofuels (e.g., biodiesel or bioethanol), animal feed high in proteins and omega-3 fatty acids, food supplements, such as spirulina and chlorella, and pharmaceuticals, like antioxidants and other bioactive compounds.

- Biomass Conversion Process: Further steps in the process include drying, oil extraction, and chemical conversion, such as transesterification for biofuels. Biomass further being subjected to fermentation, purification, and extraction of specific compounds for high-value products like pharmaceuticals.

Step-by-Step Functionality of the Software

System Monitoring:

The software monitors and analyzes a large number of sensors spread over the bioreactor system. These sensors continuously update key parameters such as temperature, light intensity, CO_2 concentration, pH levels, and the microalgae culture's health in general. These data are analyzed by the software for monitoring the current status of the system in real time. It also being able to give out historical reports and trend analysis for assistance in evaluating system performance over time.

Automated Control:

The software makes real-time adjustments to numerous system parameters that are determined through sensor inputs. For example, if the temperature is not in the optimal range, the software turns the heating and cooling units on and off. Conversely, if CO_2 concentration goes below the ideal level, then the system automatically increases flow of

CO_2. The software is able to regulate the lighting system so that there is the ideal amount of lighting, especially if the system uses artificial LED lighting.

Data Logging:

The software logs all the actions and data points produced by the system, which then form a comprehensive dataset to be used in analysis, troubleshooting, and performance optimization. The data logs are being reviewed by the operators to identify any irregularities and inefficiencies. This long-term dataset is also useful for scientific studies, as it enables researchers to assess the efficiency and effectiveness of different operational strategies over time.

Alerts and Notifications:

If any of the critical parameters move out of the optimal range, for instance, excessive concentration of CO_2, nutrient imbalance, and failure of the system, the software alerts the operators and system administrators. The alert is being communicated through email, text message, and even mobile application, thereby ensuring that problems are addressed early enough before significant damage is caused to the system.

Biomass Density Estimation:

Based on real-time data from the sensor, the software calculates the density of microalgae, mainly using optical density readings and the latest algorithms in place. In this system, when the required biomass density has been reached, the software reports to the operators that harvesting has to be performed. Biomass growth, therefore, be tracked very closely, allowing accurate timing of the harvesting process for yield and efficiency.

User Interface:

The software includes a graphical user interface (GUI) that displays real-time key operation metrics in graphic format. Operator view some real-time information on system performances, adjust and change settings and check the panels of each bioreactor - lighting and the flow of nutriment status. The interface also allows retrieval of historical information, graphs and performance trends as well.

Integration with IoT:

The software easily being integrated into the Internet of Things (IoT) structure, enabling a remote monitoring and management of the system. For instance, one, view any status from wherever in the globe using a smartphone and computer. IoT integration has also made easier the collection and analysis of data and performance directly from other remote locations in real-time.

Therefore, the present invention provides a novel and efficient system for capturing CO_2 from the environment and converting it into valuable biomass through the cultivation of microalgae. The invention includes a multi-stage process starting with CO_2 capture, followed by optimized photosynthesis within bioreactor panels, and ends with the harvesting and processing of microalgae for a variety of useful byproducts, such as biofuels, animal feed, and pharmaceuticals. The system is designed to be scalable and incorporates advanced software for real-time monitoring and automated control of environmental conditions to ensure optimal algal growth. Moreover, the innovation promotes sustainability through recycling of resources. A closed-loop system of nutrient recirculation with continuous biomass production has been adopted in the invention. Cutting-edge technologies like automated nutrient delivery, air filtration, and light management are incorporated into the system to ensure that it runs efficiently at a range of operational scales. Thus, it offers a holistic approach towards CO_2 mitigation in addition to high-value-product generation that leads towards environmental sustainability and economic viability.

I/We Claim:

1. A Modular Algae Bio-reactor Panel System for capturing carbon dioxide (CO_2) and producing biofuels, comprising:

   a plurality of modular algae cultivation panels, each panel having a transparent, durable, and sunlight-permeable housing containing a culture of live algae;

   an automated water and nutrient supply system configured to provide a consistent and regulated flow of water and nutrients to the algae culture in each panel;

   a plurality of environmental monitoring sensors embedded within each panel, configured to monitor CO_2 levels, temperature, humidity, algae health, and light intensity;

   a control unit to process sensor data and adjust the flow of water and nutrients to optimize algae growth;

   a harvesting mechanism to collect mature algae biomass from the panels for processing into biofuels; and

   a biofuel production module, optionally integrated with the system, for converting harvested algae biomass into renewable biofuels.

2. The Modular Algae Bio-reactor Panel System of claim 1, wherein the panels are scalable and customizable to fit various architectural designs and building sizes.

3. The Modular Algae Bio-reactor Panel System of claim 1, wherein the system comprises an integrated photovoltaic cell array configured to provide energy for operating the water pumps, sensors, and control unit.

4. The Modular Algae Bio-reactor Panel System of claim 1, wherein the environmental monitoring sensors further include chlorophyll fluorescence sensors to assess the health of the algae culture.

5. The Modular Algae Bio-reactor Panel System of claim 1, wherein the system further comprises a water recycling system for reusing water to minimize resource consumption.

6. The Modular Algae Bio-reactor Panel System of claim 1, wherein the harvested algae biomass is processed into biofuels selected from the group consisting of biodiesel, biogas, and ethanol.

7. The Modular Algae Bio-reactor Panel System of claim 1, wherein the system includes wireless communication capabilities to transmit environmental data to a remote monitoring platform for analysis and system optimization.

8. A method for reducing atmospheric CO_2 and producing biofuels using a Modular Algae Bio-reactor Panel System, comprising:

installing a plurality of modular algae cultivation panels on the exterior surfaces of urban buildings and structures;

providing a consistent flow of water and nutrients to the algae culture through an automated supply system to sustain algae growth;

monitoring environmental parameters including CO_2 levels, temperature, humidity, and algae health via integrated sensors;

utilizing the algae's photosynthesis process to absorb CO_2 and produce oxygen while growing biomass;

harvesting the matured algae biomass for biofuel production; and

optionally converting the harvested algae biomass into renewable biofuels.

9. The method of claim 8, wherein the harvesting of algae biomass is performed periodically, based on predetermined growth cycles, and the biomass is stored for further processing into biofuels.

10. The method of claim 8, further comprising integrating the Modular Algae Bio-reactor Panel System with smart city infrastructure for optimizing energy consumption and environmental impact.

Dated this: 13th January, 2025

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ABSTRACT

MODULAR ALGAE BIO-REACTOR PANELS FOR URBAN BUILDING

The present invention relates to a Modular Algae Bio-reactor Panel System for capturing atmospheric carbon dioxide (CO_2) while producing renewable biofuels. The system comprises a plurality of modular algae cultivation panels equipped with environmental monitoring sensors and an automated water and nutrient supply system optimized for algae growth. The panels are installed on the exterior of buildings or structures, using the natural photosynthesis process of algae to absorb CO_2 and produce biomass. The biomass is harvested and converted into biofuels such as biodiesel, biogas, and ethanol. The system further includes an integrated control unit that processes sensor data to regulate environmental conditions, improving algae productivity. This invention is sustainable for urban carbon capture and renewable energy generation, which reduces greenhouse gas emissions and enhance environmental sustainability.

FIG. 1