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(54) Title: CONTROLLED BIOSECURE AQUATIC FARMING SYSTEM IN A CONFINED ENVIRONMENT

(57) Abstract: The present invention relates generally to improving the bio security and the stability of intensive recirculating aquatic farming systems for instance by hard and soft sensing and control of the pH and alkalinity in an aquatic farming system and in response thereto optimal pH and alkalinity normalisation and nitrogen removal. This control is aimed at reduce toxicity in particular nitrogen toxicity on the living organism and at preventing biosystem collapse. Yet more particularly the invention concerns a control system to restore the biosystem' s homeostasis of intense recirculating aquatic farming systems. The system of present invention to control the pH is particularly suitable for an aquatic farming system that needs a normo-pH suitable for the integration intensive recirculating farming of aquatic animals with the farming of soilless hydroponics crop farming. The present invention relates generally to a controlled farming system for energy efficient farming in a confined space that is monitored and controlled by a hard and soft sensing system whereby the controlled farming system comprises reactors and storage containers, which are interconnected and/or are communicating with the confined space, which comprises the farming system. In particular embodiment the energy, biomass and molecule flows in the internal environment of the reactors, the storage containers and the confined space comprising the reactors and storage containers are controlled for energy efficient farming of aquatic organisms and crops and the minimal waste of energy and material in the external environment. More particularly the present invention concerns a system and method for farming of crops and aquatic animals with improved control of the systems components for optimal use of the biomass and energy input and less energy and biomass waste output.

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CONTROLLED BIOSECURE AQUATIC FARMING SYSTEM IN A CONFINED ENVIRONMENT

Background and Summary

BACKGROUND OF THE INVENTION

A. Field of the Invention

Intro: The present invention relates generally to a controlled farming system, in particular an intensive and recirculating aquatic farming system (IRAFS) in a confined space. More particularly present invention concerns a system and method for farming of crops or aquatic multicellular consumer organism (e.g. animals) with improved control of the systems components for optimal use of the biomass and energy input and less energy and biomass waste output. Such recirculating farming systems are for aquatic multicellular consumer organism (e.g. aquatic animals) or for (soil less) crops (recirculating hydroponics) or a combination thereof and they are in a confined space whereby the farming system is monitored and controlled by a hard and soft sensing system for energy efficient and bio secure farming of aquatic organisms or crops in such a confined space. In a particular embodiment the present invention relates to improving the bio security and the stability of an aquatic farming system, in particular an intensive recirculating farming system for aquatics animals or hydroponics plant, by a control system that controls reactors to restore the biosystem's homeostasis.

Several documents are cited throughout the text of this specification. Each of the documents herein (including any manufacturer's specifications, instructions etc.) are herby incorporated by reference; however, there is no admission that any document cited is indeed prior art of the present invention.

B. Description of the Related Art

Aquatic farming systems can integrate the interaction of condominiums each of diverse organisms and the recirculation of water or watery media at least in part and at

least between some of the condominiums. The bulk of the aquaculture waste produced by aquatic animal, which constitutes metabolic wastes and uneaten feed, can for instance be bioremediated by condominiums of other organisms.

In the current recirculating aquaculture systems or the current recycling closed systems for the cultivation of aquatic multicellular consumer organism (e.g. animals) aerobic nitrifying bioreactors are for instance used to transform ammonium to nitrate. Such aerobic biological water filtration (aerobic BOD removal and nitrification) is commonly used to prevent the accumulation of nitrogen compounds, as ammonium and nitrite, which have a deleterious impact on water quality and the growth of aquatic animals (e.g. fish growth). Aerobic biological water filtration mainly digest dissolved organic material and oxidizes ammonium-ions via nitrite to nitrate (two-step nitrification) by heterotrophic bacteria like *Nitrosomona sp., Nitrospria sp.* and *Nitrobacter sp.*

Various such aerobic biological water filtration technologies have been developed whereof the moving bed biofilters (MBB) have received growing attention because these allow to have more specific surface area at the same volume, they need low maintenance due to self-cleaning (no back wash needed), the water column is well supplied with oxygen, and the filter media does not act like a suspended solids trap.

However even if nitrate is usually mentioned as the least toxic form in comparison to ammonium and nitrite, high concentrations can reduce immune response and influence osmoregulation in aquatic animals (e.g. fish or shrimp). This posses serious capacity limitation. Nitrate nitrogen is usually removed in the drain and part of the water is replaced by clean water. Modern recirculating aquaculture systems combine aerobic nitrification with mechanical removal of the particulate and colloidal organic matter of the solved nitrogen compounds to remediate the toxic ammonia to less toxic nitrates. In general at least 10% of the water has to be replaced by daily fresh water input. The recirculating aquaculture systems aquatic animal farming thus produces different organic waste streams that are typically of higher temperature, loaded with high organic and nutrient loads. Approximately 3 to 10 kg of phosphorus and 39 to 55

kg of nitrogen are released to the environment for every metric ton of fish that is produced (*Bureau et al. N.AM J. Aquaculture: 65 (1): 33 – 38*).

Moreover there is a growing concern about the pressure of such open and closed recirculation aquaculture system on the environment. For instance nutrient enrichment of the outer environment is a major concern. This is enhanced by the dependency of the current finfish and shrimp culture on fish meal and fish oil. The commercial finfish feed with about 20-30% protein needs for the production of 1 kg fish live weight about 1 – 3 kg feed dry weight of fish meal (*Naylor et al. 2000 Nature 405, 1017-1024*). As the fish meal and oil that are derived from the capture and processing of wild pelagic fish stocks is a primary source of protein and dietary lipids in the feeds for predator fish, there is a general concern on its impact on ocean diversity depletion and on the sustainability. Feed and energy contribute to major costs in intensive aquatic animal farming systems.

Bacterial bioreactors and units with aquatic animals can eventually used to deliver irrigating water to soilless aquatic plants or terrestic plants with their roots in aquatic medium. But greenhouse hydroponics crop culture, on the other hand, and in particular the soilless culture re -uses only a part of its heated culture water. Generally 50% of the first culture water is drained (waste drain) to avoid salt and mineral accumulation by recirculation. But the current aquaculture bioremediation systems do not deliver a watery drain medium that as such can be used for efficient integration of aquatic animal and soilles crop culture. The integration of aquatic animal farming in intensive aquaculture with soilless aquatic plants or terrestic plants culture with recirculation of the culture water to the aquatic animal has been found to be difficult and is so far not commercially successful.

There is thus an urgent need in the art for a system for the production of useful biomass in a controllable manner with minimal biomaterial input and energy consumption. Present invention provides such system by a controlled biomass input (for instance aquatic animal feed without or with low fishmeal diets), by a controlled energy production and by controlled energy and biomass redistribution through a controlled exchange of organic matter, CO_2, nitrogen, O_2 and heat between the

connected bioreactors of this farming system and between the farming system and the drain (e.g. the drain storage tank) and by solving the biosecurity problems that are inherent at intensive aquaculture in recirculating systems and its integration with soilless crop culture.

Applications of the reduction of nitrate nitrogen by the process of denitrification has been proposed for the commercial aquaculture but is still connected with biotechnological problems resulting in bio-insecure system and is hardly available since biological denitrification does not appear to be as self-regulating or consistent as a nitrifying biological filter due to the necessity of an exogenous carbon source, since denitrification is as a multi-level process, with a first step which is the reduction of nitrate to nitrite and afterwards follows the reduction of nitrite to molecular nitrogen. As necessary hydrogen donor methanol is used most widely because of its appropriate costs, availability and it can fed easily and accurately. The correct dosage is the crucial step, otherwise toxic compounds like nitrite nitrogen or hydrogen sulphide can be formed. The quantity required for denitrification has to be calculated on basis of the influent nitrate, nitrite and dissolved oxygen concentrations. This level of complexity prevents that denitrification is commonly used in recycling closed systems aquaculture. There is a clear need in the art for improving nitrogen removal of the culture water of aquatic organisms. The current recycling closed systems for the cultivation of aquatic multicellular consumer organism (e.g. aquatic animals) provide also removal techniques, such as sedimentation, filtration and flotation, for the removal of particulate wastes (faeces, uneaten feed, and bacteria flocs) and reduction of load of suspended organic solids and in particular to very fine organic particles, which generally will impact negatively the water quality in such systems with insufficient bioreactor digestion. Depending of the organism of culture the systems can also be provided with an ozone or UV disinfection units. UV disinfection is generally used in recirculating farming systems for aquatic multicellular consumer organism (e.g. aquatic animals) or recirculating hydroponics for (soilless).

SUMMARY OF THE INVENTION

In accordance with the purpose of the invention, as embodied and broadly described herein, the invention is broadly drawn to an energy efficient controlled farming system in a confined environment. The fluid in this system may be a gas, a liquid or a combination of both. The gas is can be an atmospheric gas and the liquid is preferably water or a watery medium, which can carry various other organic and inorganic compounds. The controlled biomass farming system is designed for processes of redistribution of energy and biomass in a controllable manner. The present invention 1) solves the problems of the related art of the high cost of intensive agriculture systems in confined environments such as land based in indoor aquaculture recirculating systems and of the greenhouse crop culture, in particular the hydroponics and 2) prevents the well known occasional event biosystem collapse in such farming systems in particular if indoor recirculating aquaculture is integrated with hydroponics crops culture. Moreover, it solves the problem of the negative impact of these systems on the outer environments. The farming system of present invention comprises a bioenergy producing bacterial bioreactor system, which is integrated in the farming system for bioremediation of organic and inorganic compounds in the farming system.

The controlled farming system comprises reactors, e.g. bioreactors for bioremediation and/or energy production (e.g. biofermentor, biogasification reactor or microbial fuel cell) and physicochemical reactors (e.g. photocatalytic or electrochemical), where under at least some are bioreactors and storage containers, which are interconnected and exchange fluids, energy and biomass with other bioreactors or with the confined environment in a controlled or controllable manner. The flows or transport of the energy, biomass or molecule in the internal environment of the reactors, in the storage containers and eventually also in the confined space (which comprise the reactors and storage container) are at least in a particular embodiment, controlled for energy efficient farming of aquatic multicellular consumer organism (e.g. aquatic animals) and crops with a minimal waste of energy and material in the external environment.

pH control: The pH is an important abiotic factor for biocatalysts operations, electrochemical and photocatalytic operations and the survival and function of plants,

animals and microbial. Hard and soft sensing can be also used to monitor and control the pH and alkalinity and to obtain optimal pH and/or alkalinity in particular in the aquatic organism farming units by activation of reactor actuators, such as a photocatalytic reactor, bioreactor and nitrogen removal in the aquatic farming system. This pH and alkalinity control is aimed at reducing toxicity, in particular nitrogen toxicity, on the living organism and at preventing bio system collapse. The system of present invention to control the pH, alkalinity and solved nitrogen is particularly suitable for an aquatic farming system that needs a normo-pH suitable for the integration intensive recirculating farming of aquatic multicellular consumer organism (e.g. animals) with the farming of soilless hydroponics crop farming.

Components included in the recirculation system are in an embodiment a specific coating used to enhance the biosecurity and or biosafety. The biosafety for farmed organisms can be further enhanced by an antimicrobial and in particular an antibiofilm forming coat on the insight surface of fluid transport tools (piping) or at least in part of the fluid transport tools (pipings) between different reactors of the farming system. This antimicrobial and in particular antibiofilm forming coat is a layer in side the fluid transport systems that contacts the fluids in particular the watery fluids that pass such transport piping. This coating enhances the disinfection activity of photolytic systems such as the UV lamp disinfectors or the photocatalytic (near UV or UV-VIS) systems or the hybrid photocatalytic ultrasound/photocatalyis microbial cell destruction systems. Less living or viable micro organisms (in particular bacteria) pass the photolytic disinfection system, in particular the US disinfectors, which can be demonstrated by plating on a nutrient bottom. Reduced uncontrolled biofilm forming on places of low liquid velocity and hydrodynamic forces in zones between the diverse bioreactors and consequent biofilm detachments can be demonstrated. Photolytic disinfection systems or surface treatments. Biofilm organised organism (flocs) passing the photolytic systems might be at the basis of higher survival than for planktonic microbial. Such coat can be further foreseen by a zero-valent iron capable of adsorbing waterborne viruses. This extra safety control system is efficient for preventing bio system collapse.

This biomass farming system comprising in a particular embodiment separate bioreactor units in a shared confined environment or in different fluid flow interconnected confined environments with a fluid input and fluid output, whereby the biomass farming system comprises

1) an aquaculture system for the culture of aquatic multicellular consumer organism such as aquatic vertebrate animals or such as aquatic invertebrate animals, and further 2) at least one bacterial bioreactors system comprising condominiums of producers bacteria and condominiums of consumer bacteria in a same or separate bioreactor, and 3) an heat pump system, characterised in that the heat pump system is connected by a loop with a drain of the farming system, for instance a container keeping the drain water, to flow heat between drain and the farming system (for instance to move heat from drain to farming system) and whereby the bacterial reactor system is producing the energy that drives the heat pump system. In one aspect of the invention, this further comprises 4) a photocatalytic bioreactor system comprising at least one bioreactor of living photosynthetic producer organisms (belonging to the *Plantae* (e.g. herbs, grasses, vines)). The bacterial bioreactors system comprises an energy production system (bioenergy system) bioreactor, whereby the energy is used to drive actuators of the system.

For instance the bioreactor system hereby comprise a least one circuit to feed electricity generated by the bio-electrochemical bacteria assisted biotransformation system or electricity generated by a gas fired electricity/heating or cooling generator (CHP unit), e.g. a Stirling engine or a Dash Micro CHP, that is fired by the energy rich gas from a biofermentor, to at least one of the systems actuators (for instance a pump actuator to move system fluids or the chemoelectric reactor or the radiation source (for instance the lamp, the microwave generator or the ultrasound generator) of a photocatalytic reactor). Such bacterial bioreactors energy production system (bioenergy system) comprises in a particular embodiment an anaerobic bioreactor with methanogenic reaction function that produces energy rich that drives a heat pump preferably a reverse cycle heat pump for regaining the heat from the drain into the controlled biomass farming system. In the anaerobic bioreactor system the degradation of organic matter by anaerobic respiration releases electrons that for

disposal are accepted or 1) by an anode and distributed by an electric circuit to produce electricity or 2) by molecule electron acceptors such as CO_2, or NO_3^- to produce energy rich gas or a combination of both. Power to drive the actuator of the aquatic farming system is directly generated by the anaerobic bioreactor system or indirectly by burning its gas in a CHP system.

In case the electron acceptor is an anode connected by a circuit to a cathode bioelectricity can be produced. In case of molecule electron acceptors such as CO_2, or NO_3^- energy riches gasses can be collected such as CH_4, methane, (gas energy content = 55,525 kJ/kg at 25°C (25 °C & 1 atm) and N_2. A suitable bioreactor for the production of energy rich gasses is the high rate anaerobic reactor up flow anaerobic sludge blanket (UASB) the anaerobic sequencing batch reactor (ASBR), the fluidized expanded bed reactor, the static granular bed reactor (SGBR), the anaerobic membrane reactor, the anaerobic expanded-bed reactor (EBR) and the granular bed baffled reactor (GRABBR).

Such bacterial reactor system can receive the solved and particulate waste material. In a preferred embodiment of present invention the organic material is first collected in a collection tank that feeds the gasification bioreactor. Such collection tank can function as a concentration tank or as a buffer tank. In a particular embodiment the organic matter particles are first fluidized for instance by ultrasound or before the organic and inorganic matter is fed into the gasification bioreactor. Moreover before the organic and inorganic matter is fed into the gasification bioreactor it is preferably partially mineralized in a photocatalyst reactor hybrid ultrasonic/ photocatalytic or hybrid microwave/ photocatalytic.

The gaseous products such as CH_4 of the gasification bioreactor is transported to a gas collection container and transported to a heat burner that drives the gas driven heat pump system. The bacterial bioreactors system is an energy production system (bioenergy system) that produces the gas that drives a gas driven heat pump system preferably a reverse cycle heat pump for regaining the heat from the drain into the controlled biomass farming system. This heat pump preferably is a reversible absorption heat pump such as a reversible air-water absorption heat pump. The

reversed absorption heat pump is in a preferred embodiment connected in a variable flow control system (as outlined for instance in fig 10 and fig. 11). The farming system can have a closed container for collecting of rain and or ground water (water input tank or clean water basin). The reversed absorption heat pump system with variable flow control system can distribute heat between the water input tank, that farming system and the drain. In a preferred embodiment the variable flow control system is a indoors with outdoors mixed system that is connecting at least one heat releasing or heat extracting unit with the outer environment for instance with the bottom under frost line and/or the air of the out environment. The farming system can have a closed container for collecting of rain and or ground water (water input tank). The reversed absorption heat pump system with variable flow control system can distribute heat between the water input tank, that farming system and the drain. In a preferred embodiment the variable flow control system is a indoors with outdoors mixed system that is connect an heat releasing or heat extracting unit with the outer environment for instance with the bottom under frost line and/or the air of the out environment. If drive energy is gas it is particularly energy efficient in maintaining the fluids of the different units at a desired temperature. Not only produces farming system its own drive energy but it also has a considerable lower energy loss. Electrically-driven heat pumps for heating buildings typically supply 100 kWh of heat with just 20-40 kWh of electricity. But the efficiency of electric power plants is only about 25-40%.

In a particular function such gasification bioreactor is foreseen with an in situ pH sensor for monitoring the pH. In a particular embodiment the bioreactor systems are constructed to exchange watery fluid and gas fluid in a controlled manner under control of a monitoring and control system. The system can for instance comprise a hard sensing tool to produce a signal indicative of an abiotic parameter such as pH, and temperature and a controller to control at least one programmable actuator to adapt these abiotic parameters. For instance the system comprises at least one programmable actuator adapted to deliver a pH regulator agent to said system at an administration rate and at least one programmable heat and/or cool actuator to cool or heat the system. In an embodiment at least one of the following parameters

dissolved oxygen, conductivity, alkalinity, reduced nitrogen ad oxidized nitrogen and whereby the system is further analysed in situ and modulated by a programmable actuator.

In particular embodiment wherein the electron acceptor is an anode that is connected by a circuit to a cathode this controlled biomass farming system in confined environment with controlled biomass input and output and energy input and output comprises a controlled biotransformation system for bioremediation or redistribution of nutrients and energy in a controlled manner between bioreactors of living organisms. Such biotransformation system comprises at least one pump actuator to move the system fluids and at least three bioreactor systems of communicating fluids where under

1) at least one heterotrophic aquatic animal assisted biotransformation unit;

2) at least one of living photosynthetic producer organisms (belonging to the Plantae (e.g. herbs, grasses, vines)) assisted biotransformation for instance an autotrophic plant assisted biotransformation unit, and

3) at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with a) at least one heterotrophic (chemo organotrophic) bio-electrochemical bacteria assisted biotransformation unit to reduce nitrogen and decrease cBOD and to produce bioelectricity that drives actuators of the farming system b) at least one autotrophic (chemolithotrophic) bio-electrochemical bacteria assisted biotransformation unit to oxidize nitrogen and decrease nBOD and to produce bioelectricity that drives actuators of the farming system or at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with both types autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria in one condominium or bioreactor to reduce nitrogen and decrease cBOD and to produce bioelectricity that drives actuators of the farming system

For instance such bioreactor with both condominium of autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria can be an up flow sludge blanket filter (USBF) bioreactor) with an anoxic and an aerated compartment and up flow sludge

blanket filtration with automatic or continued removal of poor settling active sludge flocs or sludge granule and automatic or continued distribution of well settling active sludge flocs or sludge granule to the anoxic zone. Such USBF fuel cell operates a process of up flow sludge blanket filtration which has a substantially higher specific rate of separation that the conventional sedimentation USBF technology and uses up flow sludge blanket filtration in a prism or cone shaped clarifier. The activated sludge flocs or granules that have been generated by high shear in the aerated unit will enter the clarifier at the bottom and, as it rises, upward velocity decreases until the flocs of cells become stationary, effectively filtering out colloid, very fine particles, the flocs with poor settling capacity or the bacterial granules with poor settling capacity, while descending to the bottom of the clarifier and are transferred back into the anoxic zone of the sludge flocs or sludge (bio)granules that become large and heavy. Furthermore such USBF fuel cell operates aeration, nitrification, denitrification, clarification and sludge thickening and stabilization without need of different dedicated vessels. All these processes can be integrates into one bioreactor and can be operates inside one compact bioreactor.

In particular embodiment this controlled biomass farming system in confined environment with controlled biomass energy input and output and energy input and output comprises a controlled biotransformation system for bioremediation or redistribution of nutrients and energy in a controlled manner between bioreactors of living organisms, whereby the biotransformation system comprises at least one pump actuator to move the system fluids and at least three bioreactor systems of communicating fluids where under

1) at least one heterotrophic aquatic animal assisted biotransformation unit;

2) at least one of living photosynthetic producer organisms (belonging to the Plantae (e.g. herbs, grasses, vines)) assisted biotransformation for instance an autotrophic plant assisted biotransformation unit and

3) at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with a) at least one heterotrophic (chemo organotrophic) bio-electrochemical bacteria assisted biotransformation unit to reduce nitrogen and decrease cBOD and b) at least one autotrophic (chemolithotrophic) bio-electrochemical bacteria assisted

biotransformation unit to oxidize nitrogen and decrease nBOD or at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with both types autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria in one condominium or bioreactor whereby the system is further characterised in that the bio-electrochemical bacteria assisted biofilters are bioelectricity producers that are connected by a circuit to drive one or more heat pump system on the bioelectricity from the bio-electrochemical bacteria assisted biofilter or bioremediation system and further characterised in that heat pump system is connected by a loop with a drain of the farming system, for instance a container keeping the drain water, to flow heat between drain and the farming system (for instance to move heat from drain to farming system) and whereby the bacterial reactor system is producing the energy that drives the heat pump system.

In a process scheme according to the present invention photocatalytic are used to enhance the biosafety and productivity. Such aspect of the invention is that the controlled biomass farming system further comprises a system for photocatalytic oxidation of water from or to the aquaculture system. Such system of photocatalytic oxidation is particular suitable for preventing unwanted algae growth, for oxidizes the organic matter, for reducing BOD and for destroying unwanted microbiological organisms and delivers the minerals free of toxic metabolites as a nutrient to the (photo)autotrophic micro organisms and plants. Such systems is preferably placed above the aquaculture system in a confined environment (e.g. a greenhouse) for solar driven photocatalytic oxidation or on the roof of the confined environment of the aquaculture system (e.g. a building) to receive solar radiation. The photocatalytic oxidation system can also be incorporated in a lamp (e.g. UV, near UV or UV-VIS light) radiated fluid flow through case or container that receives fluid from the aquaculture system and/or the photocatalytic bioreactor system (combi photocatalytic oxidation / UV lamp) witch lamps can be system actuators that receive drive current generated by the system. After photocatalytic oxidation suspended solids can be removed by mechanical filtration to further reduce BOD, COD, Chemicals and TSS. In a particular embodiment of present invention such photcatalytic bioreactor is used

to mineralise organic molecules in fluids before presenting to the bioreactors and/or before presenting to cultured crops in particular to the hydroponics culture, the soilless (photo)autotrophic crop culture or the suspended unicellular (photo)autotrophic crops.

Control of Photocatalysis versus biofiter: In a preferred condition the bioreactor operation is integrated with a physicochemical (e.g. photocatalysis or electrochemical) operation whereby a bioreactor, a physicochemical reactor and a control system operationally connected to 1) a sensing means that feeds signals into the control system whereby the sensing means are for analysing physical quantities in reactor or reactor output (physicochemical reactor and/or bioreactor) and for converting such it into a signal which when operational is be fed into the control system and 2) to an actuator system of said physicochemical reactor to feed a control system into said actuator system to control the physicochemical reaction. The control system can operate as a feed back system but can also comprise a model, preferably an adaptive model to control said the physicochemical reaction directly and indirectly the biofiltration operations. Physical measurements of the sensors that are converted into an input signal for the control system are for instance measurements of oxidizable species (RX_{ad}) of intermediates (from for instance a OH or end products quantities (e.g. he $HO^{\bullet}$ / oxidizable species (RX_{ad}) ratio) produced by the physicochemical reactor and/or measurements of intermediates or end products quantities produced by the bioreactor, the quantity of mineralization or organic material in a fluid, or the measurement of the toxicity level of intermediate or end products or of the mixture of intermediates (for instance from a $OH^{\bullet}_{ad} + RX_{ad}$ → intermediate reaction) and end products, or the quantity of super oxide anions $HO2^{\bullet}$ or of reactive hydroxyl radicals ($OH^{\bullet}$) produced or the $OH^{\bullet}$ / oxidizable species (RX_{ad}) ratio produced by said the catalytic physicochemical reactor output or entering in said bioreactor , the quantity of oxidizable species and or oxidized species or the quantity of oxygen or the quantity of superoxide radial. Whereby factors that determine the model are reactor volume of the physicochemical reactor and bioreactor , concentration of the chemical species to be oxidized, the catalyst concentration, time in the physicochemical reactor, catalytic

physicochemical reaction rate, mixing and circulation rates of the fluids, in case of a photocatalytic physicochemical reactor the irradiation and/or the irradiation volume.

It is also possible to sense quantities of primary active species (ecb^-, hvb^+, •OH, HO_2•, O_2•$^-$ and H_2O_2) . Quantities of the ferric ion, Fe_3^+ photoxidation rate modifier can be sensed for feeding a signal into a controller to control the levels of the ferric ion below a certain threshold for instance a value below 5 ppm and above 0.5 ppm.

In another embodiment of present invention the bacterial bioreactors system is an energy production system (bioenergy system) that drives a heat pump preferably a reverse cycle heat pump for regaining the heat from the drain into the controlled biomass farming system. For instance in a particular embodiment the bacterial reactor system that produces the energy to drive the heat pump system comprises an anaerobic bioreactor (fig 2) or aerobic bioreactor (fig 3) or the combination of both (fig 5) comprising a condominium of bioelectrical bacteria whereby the degradation of organic matter on release electrons that for disposal are accepted by an electrode (anode) and distributed by an electric circuit. Such bacterial reactor system can receive the solved and particulate material. In a preferred embodiment of present invention the organic material is first collected in a collection tank that feeds the gasification bioreactor. Such collection tank can function as a concentration tank or as a buffer tank. Yet another embodiment is the fluidization of the organic matter particles for instance by ultrasound before the organic and inorganic matter is fed into the gasification bioreactor. Preferably the organic materials in the fluid of this collection tank is mineralized by photocatalysis. If the organic material is mineralized by the photoctalytic reaction or reactor higher yields of bioenergy production (bioelectricity) are obtained in the bioelectrical reactor (MFC). The electrical circuit of the bioelectrical reactor delivers the energy that drives the heat pump system. The bacterial bioreactors system is an energy production system (bioenergy system) that produces the electricity that drives a heat pump system preferably a reverse cycle heat pump for regaining the heat from the drain into the controlled biomass farming system. This heat pump preferably is a heat pump that preferably operates in a reversible manner for instance a reversible absorption heat pump such as a reversible

air-water absorption heat pump (described in EP 1558881). The reversed absorption heat pump is in a preferred embodiment connected in a variable flow control system.

In this electrochemical bacteria assisted biotransformation system the autotrophic bacteria assisted biotransformation unit can be a nitrifying bacterial fuel cell comprising autotrophic bio-electrochemical bacteria and the heterotrophic bio-electrochemical bacteria assisted biotransformation unit can be a denitrifying bacterial fuel cell. Hereby one or both of the denitrifying bacterial fuel cell and the nitrifying bacterial fuel cell can be flow through fuel cells whereby the water of the farming systems flows through the bacterial fuel cell(s) . In a particular embodiment the autotrophic bio-electrochemical bacteria assisted biotransformation unit comprises *Nitrosomonas europea.* In yet a particular embodiment of present invention the heterotrophic bio-electrochemical bacteria assisted biotransformation comprises *Geobacter sulfurreducens*, *Shewanella oneidensis*, *Rhodoferax ferrireducens* or a combination thereof. The electricity produced by the bioelectrical energy system generates electrical energy to at least one of the actuators of the system for instance to a pump actuator of the system or to a heat pump that transports heat from the drain to bioreactors of the farming system. The controller of the system furthermore can control the fluid flows between the bioremediation units.

In another embodiment of present invention the bacterial bioreactors system is an energy production system (bioenergy system) that drives a heat pump preferably a reverse cycle heat pump for regaining the heat from the drain into the controlled biomass farming system. For instance in a particular embodiment the bacterial reactor system that produces the energy to drive the heat pump system comprises an anaerobic bioreactor or aerobic bioreactor or the combination of both (Fig 5) comprising a condominium of bacteria whereby the degradation of organic matter on release electrons that for disposal are accepted by molecule electron acceptors such as CO_2, or NO_3^- energy riches gasses can be produced in a gasification bioreactor and can be collected such as CH_4, methane, (gas energy content = 55,525 kJ/kg at 25°C (25 °C & 1 atm) and N_2 for burning and driving heat pump systems. Such bacterial reactor system can receive the solved and particulate material. In a preferred embodiment of present invention the organic material is first collected in a collection

tank that feeds the gasification bioreactor. Such collection tank can function as a concentration tank or as a buffer tank. Yet another embodiment is the fluidization of the organic matter particles for instance by ultrasound before the organic and inorganic matter is fed into the gasification bioreactor. Preferably the organic materials in the fluid of this collection tank is mineralized by photocatalysis, eventually by ultrasound or a combined ultrasound photocatalysis mineralization. If the organic material is mineralized by the photoctalytic reaction or reactor with higher yields of bioenergy production (energy rich gas) are obtained in the gasification tank). Gasification tank delivers the energy rich gas to a burner that drives the heat pump system. The gasification system is an energy production system (bioenergy system) that produces the electricity that drives a heat pump system preferably a reverse cycle heat pump for regaining the heat from the drain into the controlled biomass farming system. This heat pump preferably is an absorption heat pump or a Vuilleumier heat pump that preferably operates in a reversible manner for instance a reversible absorption heat pump such as a reversible air-water absorption heat pump (described in EP 1558881). The reversed absorption heat pump is in a preferred embodiment connected in a variable flow control system.

In a particular aspect of present invention the bacterial bioreactors system is an up flow anaerobic sludge blanket reactor or an up flow aerobic sludge blanket reactor or a combination of both. Particularly interesting is a bacterial bioreactors system to filter the water of the farming system while generating floc particles or generating biogranules. Floc particles are for instance agglutinated microbial for instance by bacterial enzyme rich polysaccharide slime. They may comprise condominiums of different microbial, such heterotrophic bacteria, alga (e.g. dinoflagellates & diatoms), fungi, ciliates, flagellates, rotifers, nematodes, metazoans). The average floc diameter is generally 0.2 mm to 2 mm. Particularly interesting is that the flocs have 25% to 56 % proteins and about 25 % to 29% organic carbons and high levels of amino acids that can be processed in useful feed biomass to be redistributed in the farming systems in feed for the aquatic multicellular consumer organism (e.g. aquatic animals). The formation aerobic and anaerobic granules can be enhanced under aerobic or anaerobic conditions by subjecting bacterial sludge shear conditions and

eventually a substrate. Such biogranules have a diameter of 2 to 8 mm. Such biogranules formed under aerobic conditions are composed of an inner denitrifying microbial zone and an outer nitrifying zone. In an embodiment of present invention such biogranules are used to inoculate biofilters. Premineralization or photocatalysis enhances the bioremedciation activity of the floc or biogranule reactor.

In yet another embodiment the biogranules are produced in separate controlled biofloculation units inoculated with selected bacteria for inoculating biofilters or selected probiotic bacteria to protect the faming system against the invasion of unwanted microbials. Such probiotic bacteria can for instance be bacterial of the bacillus species such as the bacteria of the group consisting of *Bacillus licheniformis (B. licheniformis), B. subtilis, B. polymixa, B. laterosporus* and *B. circulans* that are facultative anaerobes and can contribute to nitrification and denitrification and bacillus species that are probiotic for the aquatic organisms and can protect the farming systems against invasion of food spoiler microbials or against pathogens that are known to be pathogens (for instance food born pathogens) to animals such as aquatic animals or to mammalian which consume the aquatic multicellular consumer organisms (e.g. aquatic animals) or the crops of the farming system of present invention. In an embodiment of present invention such biogranules are used to remove nitrogen and phosphate and in an embodiment of present invention such biogranules are sterilized and used as a raw material in designer feed to protect the aquatic organisms against pathogens.

In a particular embodiment the controlled a farming system comprising a controller to control the programmable pH actuator to normalize the pH between 5,5 and 8 (preferably between 6 – 7.5) and to control the heat and/or cool actuator to normalize the temperature between 15 – 30°C (preferably between 20 – 25°C). A particular useful pH regulator agent is an alkalis of the group consisting of calcium bicarbonate, calcium carbonate, calcium hydroxide, magnesium bicarbonate, magnesium carbonate, magnesium hydroxide, sodium bicarbonate, sodium carbonate and sodium hydroxide.

As displayed in the general schematic view of Fig. 1. an embodiment of present invention concerning the fluid communication between separate systems and units of the controlled farming system of present invention. As displayed left under in Fig 1 a bacterial assisted unit of chemo organotrophic bacteria (heterotrophs) derives carbon and energy of oxidation of organic compounds and decrease cBOD (by concerting it in carbon dioxide, water, ammonium ions, phosphate ions and sulphate ions) and increase the alkalinity/pH. The unit is assisted by bio-electrochemical bacterial heterotrophs that generate bioelectricity. As displayed right upper in Fig 1 a condominium of autotrophic bacteria oxidize nBOD (that oxidize ammonium and nitrite ions). The bioelectricity drives actuators of the IRAFS. In an embodiment the mineralized nutrients are delivered to a mixing unit or mixing tank (167) that delivers the water to an hydroponics or soilless plant culture. Also the water storage (168), the drain water tank (159) that receives the (dirty) water of the hydroponics culture, the soilless crop culture system or the crop greenhouse culture (163)) and the clean water tank (157) that stores ground water, rain water or other clean water, are connected with a transport piping or irrigation system to a mixing unit or mixing tank (167). There water supply to the mixing unit or mixing tank (167) is under control of a multiple switch valve (160) to control their water flow towards the mixing unit or mixing tank (167). After the switching valve (160) before of after the mixing unit or mixing tank (167) there is a sterilization and/or mineralization unit (165), preferably a flow through sterilization unit that comprises a UV radiation source (166) to radiate the passing through water or eventually an ozonation system as a germicidal treatment or a that comprises a photocatalyst with a near UV, near UV or UV- VIS radiation source (166) depending on the type of photocatalyst. The photocatalysts mineralization and sterilization combined ultrasound photocatalysis or combined microwave photocatalyst function. The hydroponics culture, the soilless crop culture system or the crop greenhouse culture (163) comprises chemical (nutrient) stock solution tank(s) (162), of which one a acid stock solution tank (162) and another base stock solution tank (162), that all have an transport pipe that passes dosing or reservoir pumps (159) for comprising a desired nutrient solution, pH and alkalinity for instance in the diluter (161) or in the mixing unit or mixing tank (167). The diluter (161) or the mixing unit or mixing tank (167) have an irrigation or transport piping to

the plant growing troughs (164). The plant growing troughs (164) are connected by a transport piping or irrigation with a drain pit (165) that is connected by a transport piping or irrigation with the drain storage tank (158). The system is be controlled by a liquid control system that controls the (nutrient) dosing or reservoir pump, the nutrient solution pH, the nutrient electric conductivity, nutrient solution and condensate water levels.

As displayed in Fig. 2 another embodiment of present invention is a condominium of chemo organotrophic bacteria (heterotrophs) in a bioelectricity (bioelectricity generating) reactor unit or microbial fuel cell (MFC) in a setup to generate current to drive the heat pumps system for transporting heat from one reactor unit of the IRAFS or to transfer heat of the drain that otherwise would be lost into the IRAFS or to drive specific actuators in the controlled farming system.

As displayed in Fig. 3 the IRAFS can comprise a nitrification bacterial fuel cell for addition of oxygen to nitrogen while generating bioelectricity. Within the anode chamber reduced substrates (such as reduced nitrogen), ammonium and nitrite ions are oxidized resulting in a decrease of nBOD with the generation of oxidized nitrogen species and in the generation of electrons and protons. The bioelectricity is used to drive specific actuators of the IRAFS for instance the heat pumps system for transporting heat from one reactor unit of the IRAFS or to transfer heat of the drain that otherwise would be lost into the IRAFS or to drive specific actuators in the controlled farming system.

As displayed in Fig. 4 an embodiment of present invention is a fluid communication system between separate systems and units of the controlled farming system, IRAFS of present invention whereby the both autotrophic bacteria nitrifying and chemo organotrophic bacteria (heterotrophs) denitrifying bacterial condominiums are produce current to drive the heat pump system or specific actuators (for instance the sensors , pumps or controllers) in the controlled agriculture system. The bioelectricity is used to drive specific actuators of the IRAFS for instance the heat pumps system for transporting heat from one reactor unit of the IRAFS or to transfer heat of the drain that otherwise would be lost into the IRAFS or to drive specific

actuators in the controlled farming system. As displayed left under in fig 1 a bacterial assisted unit of chemo organotrophic bacteria (heterotrophs) drives carbon and energy of oxidation of organic compounds and decreases cBOD (by concerting it in carbon dioxide, water, ammonium ions, phosphate ions and sulphate ions) and increase the alkalinity/pH. The unit is assisted by bio-electrochemical bacterial heterotrophs that generate bioelectricity. As displayed right upper in fig 1 concerns a condominium of autotrophic bacteria that oxidize nBOD (that oxidize ammonium and nitrite ions) and decrease the alkalinity/pH.

As displayed in Fig. 5 a certain embodiment of present invention of a combined anaerobic denitrifying / aerobic nitrifying bacterial fuel cell sharing the cathode. The cathode can be subjected to active or passive aeration.

As displayed in Fig. 9 the IRAFS farming system can in an embodiment comprise one or more drainage water collection system (drain storage tank) to collect the drainage water from the recirculating aquaculture system (RAS) and/or the greenhouse horticulture system (GCS). This drainage water collection system is a heat source or sink of the recirculating aquaculture system (RAS) and/or the greenhouse culture system (GCS) or of the IRAFS.

As displayed in Fig. 10 in a particular embodiment of present invention the IRAFS comprises a reversed absorption heat pumps that is fired by energy rich gas of the gasification bioreactor that is integrated in the IRAFS. To transport and deliver heat to the various reactor systems of the IRAFS, such reversed absorption heat pumps connected in a variable flow control system and achieve the desired temperature Tx in the various reactors of the IRAFS. Such temperature and heat flow system control system is important to reduce heat loss but also since aquatic animals and plants can need a different temperature regime and can need a different temperature regime in day and night time..

In a preferred embodiment such IFARS with variable flow control system comprises at least one clean water (ground water and/or rain water) collection or storage tank (400), at least one drain water collection or storage tank with drain water of the

hydroponics or a soilless plant culture unit (e.g. the greenhouse culture system (GCS)) (401), a gasification bioreactor (402), aquatic animal farming system in particular the fish culture (e.g. the recirculating aquaculture system (RAS) or recirculating aquatic animal farming system (403) which can comprise bioreactor units and drain organic waste into the gasification bioreactor or its confined environment or building (404), a hydroponics or a soilless plant culture unit (405) (e.g. the greenhouse culture system (GCS)) or its greenhouse (406), evaporators (407) to absorb heat and condensers (408) to release heat, the reverse switch system(s) (409) and the gas fired heat pump drive system (411). 410 is a place under the frost line ground water. Moreover the IRAFS systems can comprise one or more drainage water collection system to collect the drainage water from the recirculating aquaculture system (RAS) and/or the greenhouse culture system (GCS). This drainage water collection system is a heat source or sink for the recirculating aquaculture system (RAS) and/or the greenhouse culture system (GCS) or the IRAFS. At least one thermal loop comprising at least one of the compressor and working fluid expansion means (for instance an expansion valve) components and at least two heat exchangers each of the evaporator and condenser type connected in the form of a closed circuit for circulating a volatile liquid (working fluid or refrigerant), circulates through the components. At least one evaporator type heat exchanger of the closed loop is in contact with a drainage water collection system. When operational the liquid working fluid temperature in the evaporator is kept lower than the temperature of the drainage water collection system causing heat to flow from the drainage water collection system to the working fluid, and the working fluid evaporates. During operation vapour from the evaporator is compressed (e.g. by a compressor or thermally in an extra solution circuit comprising an absorber, a solution pump and a generator absorber) to a higher pressure and temperature and consequently the hot vapour then enters a condenser heat exchanger which is contact with the RAS or GCS, where it condenses and gives off useful heat to the RAS and/or GCS. Consequently the high-pressure working fluid is expanded again to the evaporator pressure and temperature for instance by asses an in the expansion valve. The working fluid is returned to its original state and once again enters the evaporator. The thermal loop between the drainage water collection system and the RAS and/or GCS can comprise a reversing valve and force the heat flow in

the other direction. Heat is then transferred in the opposite direction, from the RAS and/or GCS that is cooled, to the drainage water collection system. In a particular embodiment the drainage water collection system is contacted with at least one condenser heat exchanger of a closed loop and the RAS and/or GCS with at least one evaporator type heat exchanger.

In a particular embodiment of present invention the IFARS comprises an heat pump system driven by bioenergy generated by at least one of its bioreactors whereby the heat pump system variable flow control system as displayed in Fig. 11. The heat pump system with variable flow control system comprises heat transfer switches with reversible operation in heating mode or in cooling mode. The different components are expansion valves (304), 4 way switch valve (308), two switch valves (309), condenser (301), evaporator (302), compressor (303), drain water container (300), Rain water / groundwater or clean water tank (305), aquatic animal culture tank or tanks (306), hydroponics or soilless crop culture unit(s) (307) and under frost line ground (water) (308). Similarly heat can be transferred from the soilless crop culture unit(s) (307) to the aquatic animal culture tank or tanks (306) this is particularly suitable in a day and night regime. In a particular embodiment the optimal or desired temperature for crop growth is maintained different from the optimal or desired temperature of the aquatic multicellular consumer organisms (e.g. aquatic animals). For instance the optimal temperature for crops in the soilless crop culture unit difference between day and night (for instance 25.5 °C at day and 17.7 °C 's at night. In the aquatic animal culture units the temperate is generally kept equal and stabilized. Controlled heat transfer maintains these different temperature regimes.

In a particular embodiment of present and as displayed in Fig. 12 a removal apparatus for suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD)) for instance a screening apparatus for mechanical removal of the suspended organic solids, particulate organic matter and colloidal organic matter ((coBOD) colloidal BOD and (pBOD) particulate BOD or for instance a microscreen apparatus for removal of the suspended solids, which in this picture is displayed as a side view of an incline belt screen filter (132) with a screen belt (143), or such combined with an installation for the removal of settleable solids for instance gravity separation

(sedimentation) or alternatively a centrifuging or hydrocycloning apparatus can be used for removal of the suspended organic solids, particulate organic matter and colloidal organic matter or combined with a foam fractionation apparatus are used to remove organic matter. All these are foreseen of an input to receive the (dirty) water (148) and an out put (149) to return the (clean) water to the aquatic farming system and furthermore they are foreseen to deliver the waste (142) to a waste collection tank (133). The water collection tank (133) is provide with a transport line (e.g. transport pipe (141) and pump (135)) to deliver the waste to an input (131) of a gasification tank (134) as for instance displayed in fig. 13 or in fig. 14. Such gasification tank (134) can optionally be foreseen of a closed loop (146 & 147) to recirculate its supernatant out put. The gasification tank (134) furthermore comprises on or more out put and distribution line (transport pipe) (136) to transport the energy rich gas to the heat pump firing drive system (441, 216, 204). This distribution line (transport pipe) (136) can optionally distribute the gas first towards a deshydratation unit (150) and the deshydratation unit that can be connected by a distribution line (transport pipe) (151) with a gas storage unit (152) which is connected by a distribution line (transport pipe) (153) with the heat pump firing drive system (441, 216, 204).

In an embodiment of present invention the IRAFS comprises a photocatalyst bioreactor (as displayed in Fig. 15) the photocatalyst bioreactor has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and/or nBOD for instance from the from the aquatic animal farming units. The photoctalyst unit is foreseen with a radiation unit (103) to radiate the photocatalytic material (104). Alternatively the photcatalytic material is exposed to sun light for instance by having tubings with the photocatalytic material or photoctalytic plates of the photocatalytic apparatus exposed to sun light. The photocatalytic material can eventually receive reflected light from a reflector or the photocatalytic unit of the photocatalytic apparatus can be placed above the aquatic animal farming unit in a green house or can be placed on on the roof of the building of the aquatic animal farm. An output and transport piping (107) provides the water wherein the organic load has been mineralized to the feed distributor (134) of a gasification unit (134) for instance a

gasification tank comprising a sludge bed (140), with (bio)granules (144), rising vapour bubbles (139), baffle (138), gas solid separator (145), a feed distributor (134, effluent collection (137). The gasification unit is provided with switch valves (154) to release its processed water via an out put or transport piping (155) or to return the water via a transport piping (99b) to the photocatalytic reactor unit (100). The gasification tank (134) furthermore comprises on or more out put and distribution line (transport pipe) (136) to transport the energy rich gas to the heat pump firing drive system (441, 216, 204). This distribution line (transport pipe) (136) distribute the gas first towards a deshydratation unit (150) and the deshydratation unit can be connected by a distribution line (transport pipe) (151) with a gas storage unit (152) which is connected by a distribution line (transport pipe) (153) with the heat pump firing drive system (441, 216, 204).

In a particular embodiment of present invention the IRAFS comprises (as displayed in Fig. 16) a photocatalytic reactor (100) and a radiation source (103) for UV light, near UV light, UV-VIS light or solar light depending on the type of photocatalyst and the photocatalyst function and optionally with function enhancement by microwave or ultrasound radiation for oxidizing and mineralizing of the complex organic molecules and presentation of the photocatalytic material (104) to an aerobic bioreactor that enhances a larger part of ammonium removal through oxidizing ammonium directly into N_2, or ammonium into NO_2^- or to reduce NO_3^- into NO_2^- depending on the photocatalyst and/or the reaction time. The photocatalytic reactor can deliver such treated water to a pretank unit (101) automatically monitoring toxicity in such pretank unit to detect or measure quantities of toxicity of the photocatalytic end product and eventual intermediates of photocatalytic processing by a toxicity sensor (for instance such sensor described in this application) and subsequently at the detection of the photocatalytic function is an aspect of this invention. In particular for the processing of such data and the control of the photocatalytic actuator function.. By in situ hard sensors with a signal output that is representative for ammonium, nitrite and/or nitrate the ammonium to nitrite proportion can be controlled in the pretrank (101) in a particular embodiment. Furthermore the oxygen and carbon dioxide levels in the water of this pretank unit (101) and in a particular embodiment the toxicity can be

sensed in situ. Suitable sensor for this function are described in this application. This bioreactor is preferably a (bio)granule (144) producing bioreactor foreseen of turbulence or shear force creation means for instance a stirrer (105) for inducing biofilm forming into (bio)granules (144). The photocatalytic reactor is for seen with a transport pipe input (99) to receive water load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the aquatic farming system. A transport piping connects the out put (107) eventually over a pump (108) of the photocatalytic reactor with pretank unit (101) such as an aeration or oxygenation unit (101) which is connected with a transport piping (110) with the aerobic bioreactor (102). A loop (106) eventually with pump (111) allows under control of a valve system (154) to return water treated in the bioreactor via a transport piping (99a) to the photocatalytic reactor input (99) or to the aeration or oxygenation unit (101). This photocatalytic aerobic bioreactor system can release the photocatalyst / aerobic bioreacted water via an output (112) into the aquatic animal farming system or into the storage tanks of the soilless plant culture or hydroponics. The photocatalytic reactor can also been foreseen with a transport pipe or irrigation output (98) to transport water to other units for instance to the plant hydroponics or soilless crop culture unit (Fig. 19). In a particular embodiment the pretank (101) and the photocatalytic reactor (100) are one.

COD in the aquatic environment can be quantified by measuring the amount of electrons captured at a nanostructured thin-layer photoelectrochemical TiO2 electrode of Zhang, SQ et al. (Zhang, SQ; et al. Source Sensors and actuators B-Chemical 141 (2):634-640 2009). During the exhaustive photoelectrocatalytic degradation of organic species in the thin-layer cell and combined with a microelectrochemical system and a laptop computer, the UV-LED PeCOD system enables end-users to perform on-site COD analysis in a simple, rapid, sensitive and accurate manner. Under the optimal conditions, the system can achieve a practical detection limit of 0.2 ppm COD with a linear range of 0-300 ppm COD

Total organic carbon (TOC) measurements or monitored by gas chromatography-mass spectrometry (GC-MS) allows to evaluate the mineralization efficiency of a photocatalysis reactor.

In another embodiment of present invention the IRAFS system comprises a photocatalytic reactor (as displayed in Fig. 17) for oxidizing and mineralizing of the complex organic molecules or for ammonium directly into N_2, or ammonium into NO_2^- or to reduce NO_3^- into NO_2^- depending on the photocatalyst and/or the reaction time and for presentation of the photocatalytic material to an bioreactor system aerobic bioreactor and anaerobic bioreactor that can be tuned to enhance a larger part of ammonium removal through oxidizing ammonium directly into N_2. While not wishing to be bound by theory, it is believed that this ammonium/NO_2^- relationship is important to drive an aerobic biofilter into an annamox operation.

This bioreactor is preferably a (bio)granule (144) producing bioreactor foreseen of turbulence or (hydrodynamic) shear force creation means for instance a stirrer (105) for inducing biofilm forming into (bio)granules (144). A floc or sludge bioreactor is also a suitable. The photocatalytic reactor is foreseen with a transport pipe input (98) to receive water load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the aquatic farming system. A transport piping connects the out put (125) eventually over a pump (129) of the photocatalytic reactor with a pretank (118) for instance an aeration or oxygenation unit (118) and eventually in situ sensors provides information of measured quantities of mineralization and of toxicity of contaminants or intermediates. By in situ hard sensors with a signal output that is representative for ammonium, nitrite and/or nitrate the ammonium to nitrite proportion can be controlled in the pretrank (118) in a particular embodiment. Furthermore the oxygen and carbon dioxide levels in the water of this pretank unit (118). This pretank (118) is connected with a transport piping (126) with the aerobic bioreactor (119), preferably a granule aerobic bioreactor that is foreseen of a turbulence or a shearing means (123) to force biofilm forming microorganisms to form (bio)granules. A loop (100) eventually with pump (130) allow under control of a valve system (154) to return water treated in the bioreactor via a transport piping (99a) to the photocatalytic reactor input (99) or to the pretank or the aeration or oxygenation unit (118). This photocatalytic aerobic bioreactor system can release the photocatalyst / aerobic bioreacted water via an output (127) into anaerobic bioreactor, preferably an anaerobic granule bioreactor

(120) foreseen of a turbulence or shear force means to force the biofilm forming microorganisms to form granules (144b). This anaerobic bioreactor can release the water that has been photocatalytic, aerobic bioreactor and anaerobic bioreactor processed via an output or an output transport piping (131) into the aquatic animal farming system or into the storage tanks of the soilless plant culture or hydroponics. The anaerobic bioreactor is foreseen with a loop of a transport pipeline (100) and eventually a pump (130) under control of a switch valve system back into the photocatalytic unit (117). In a particular embodiment the photocatalytic bioreactor (117).

In a particular embodiment of present invention the IRAFS (as displayed in Fig. 18) comprises photocatalyst reaction unit to pretreat the water that is loaded with organic materials and to oxidize complex organic molecules, suspended organic solids, particulate organic matter and colloidal organic matter ((coBOD) colloidal BOD and/or (pBOD) particulate BOD and/or solved nBOD, cBOD into mineral molecules for instance for organic phosphorus, nitrogen and carbon mineralization or partial mineralization. The photocatalytic unit (100) is provided with a radiation source (103) to radiate the photocatalytic material (104), for instance a UV lamp (103) or alternatively collector sun light or a photocatalytic surface that is exposed to sun light. The photocatalytic unit (100) comprises an output transport piping or irrigation means (107) to transport its processed water to the input system ((135) lowest 134 in fig 18 = 135) to feed a gasification unit (134) or to feed the aerobic biofilter (119). This output transport piping or irrigation means (107) is provided with a switch valve that allows to return the processed water via a transport piping or irrigation means (147b) to the photocatalytic reactor unit. The photocatalytic reactor unit can be foreseen with a gas transport piping (136) to transport the gas fluids generating in the photocatalytic reactor unit. The photocatalytic unit (100) comprises an alternative output (156) under control of a valve (154) that can provide processed water to other units for instance to the aquatic animal farming units. The gasification unit (134) is preferably foreseen of a shear force tool or (136) to force the microorganisms into biogranules (144). The gasification unit is for seen with at least one gas collection unit (145) to collect the energy rich gas ((139 = gas bubble) and a transport piping (136) to

transport the gas fluid to eventual an dehydratation unit (150) and over a gas storage unit (152) via the transport piping (153) or directly via the transport piping (153) to an gas driven heat pump system. The watery fluid out put(s) (137) of the gasification tank (134) is or are connected via a transport piping or irrigation system (118) with an oxygenation or aeration unit (147) which is connected with a transport piping or irrigation system (126) to deliver the aerated or oxygenated water to an aerobic biofilter (119) is preferably an aerobic (bio)granule biofilter foreseen with a shear forces or water disturbance tool (123) to force the microbials into (bio)granules. This aerobic biofilter is connected by a transport piping or irrigation unit (127) to deliver its processed water into an anaerobic biofilter unit (120) which is preferably an anaerobic (bio)granule biofilter foreseen with a shear forces or water disturbance tool (124) to force the microbials into (bio)granules. This anaerobic biofilter unit (120) has an output and output transport piping or irrigation tool (131) to transport its processed water to the aquatic farming animal system or to the crop hydroponics or the soilless plant culture system. The anaerobic biofilter unit (120) comprises further a transport piping or irrigation unit (127) to recirculate its processed watery fluid to aeration tank (147).

In an embodiment of present invention (as displayed in Fig. 19) the IRAFS comprises a nutrient feeding and recirculating system of the plant hydroponics or soilless crop culture (greenhouse) whereby processed water of the other reactor units is delivered to a mixing unit or mixing tank (167) for proper mixing and dosing before the nutrients are delivered to the crops. A water collection unit can receive water of a transport piping (98 or 156) directly from a photocatalytic reaction unit or of a transport piping (131) indirectly from a photocatalytic reaction for instance of a photocatalyst / aerobic bioreactor / anaerobic bioreactor unit (17 or 18 (whereby at least one of the anaerobic bioreactors is a gasification tank) and eventually an other anaerobic is an anaerobic microbial fuel cell (with heterotrophic bioelectrochemical bacteria for anaerobic denitrification), or of a transport piping (112) of a photocatalyst / aerobic bioreactor system (Fig. 16) which comprises a photocatalytic reactor input (99), an aerobic bioreactor unit (autotrophic bioelectrochemical bacteria for aerobic nitrifying bacterial fuel cell) (102) and eventually a separate aeration or oxygenation unit (101) the

transport piping (112) to release the photocatalysed and aerobic bioreacted water into a storage tank (168) or in one of the tanks (157, 158 or 167) of the photocatalyst / aerobic bioreactor system (Fig. 16). The water storage (168) that receives water from the photocatalytic reactors (fig 15, 16, 17, 18, 21, 22, 23 or 24) , the drain water tank (159) (that receives the (dirty) water of the hydroponics culture, the soilless crop culture system or the crop greenhouse culture (163)) and the clean water tank (157) that stores ground water, rain water or other clean water, are connected with a transport piping or irrigation system to a mixing unit or mixing tank (167). There water supply to the mixing unit or mixing tank (167) is under control of a multiple switch valve (160) to control their water flow towards the mixing unit or mixing tank (167). After the switching valve (160) before of after the mixing unit or mixing tank (167) there is a sterilization unit 165), preferably a flow through sterilization unit that comprises a UV radiation source (166) to radiate the passing through water or eventually an ozonation system as a germicidal treatment . The hydroponics culture, the soilless crop culture system or the crop greenhouse culture (163) comprises chemical (nutrient) stock solution tank(s) (162), of which one acid stock solution tank (162) and another base stock solution tank (162), that all have an transport pipe that passes dosing or reservoir pumps (159) for comprising a desired nutrient solution , pH and alkalinity for instance in the diluter (161) or in the mixing unit or mixing tank (167). The diluter (161) or the mixing unit or mixing tank (167) have an irrigation or transport piping to the plant growing troughs (164). The plant growing troughs (164) are connected by a transport piping or irrigation with a drain pit (165) that is connected by a transport piping or irrigation with the drain storage tank (158). The system will be controlled by a liquid control system that controls the (nutrient) dosing or reservoir pump, the nutrient solution pH, the nutrient electric conductivity, nutrient solution and condensate water levels.

As displayed in Fig. 20 (which provides A) a view of a transverse section of a transport fluid pipe between the different units such as the rain water / groundwater or clean water tank (305), the aquatic animal culture tank or tanks (306), the hydroponics or soilless crop culture unit(s) (307) the soilless crop culture unit(s) (307) and the bioreactor units and B) a 3D side view of such transport pipe (113)) in an

embodiment of present invention the outer layer of the liquid transport piping (114) is inside coated by or contacting another antimicrobial layer (116), in particularly a bactericidal layer. Such layer prevents biofilm forming. Suitable coatings have been provided in this application. The antimicrobial layer (116) van also be provided with virucidal properties. In a particular embodiment of present invention at least some of the water storage tanks have been coated inside by the same antimicrobial coating. 115 is the inner lumen of the transport pipe. Instead of in the coating or the second layer the antimicrobial material can be incorporated in material of the piping or the tanks itself.

In a particular embodiment of present invention the IRAFS comprises a photocatalyst reactor (as displayed in Fig. 21) that is connected by its processed water output with a transport piping (125) to a microbial fuel cell unit. The photocatalytic reactor unit (100) has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved cBOD and/or nBOD for instance from the from the aquatic animal farming units. The photoctalyst further comprises a radiation unit (122) to radiate the photocatalytic material (121). This radiation unit can be an UV lamp, near UV or UV-VIS lamp but alternatively the photcatalytic material is exposed to sun light for instance by having tubings with the photocatalytic material or photoctalytic plates of the photocatalytic apparatus exposed to sun light. The photocatalytic material can eventually receive reflected light from a reflector or the photocatalytic unit of the photocatalytic apparatus can be placed above the aquatic animal farming unit in a green house or can be placed on on the roof of the building of the aquatic animal farm. The photocatalytic reactor (117) is for oxidizing and mineralizing of the complex organic molecules and presentation of the photocatalytized molecules to enhance the productivity of a microbial fuel cell. An output and transport piping (125) provides the water wherein the organic load has been mineralized from the photocatalytic reactor (117) to the microbial fuel cell (511 and 501). The microbial fuel cell can be an aerobic microbial fuel cell (511) for instance inoculated with aerobic bacteria (e.g. aerobic nitrifies or aerobic bioelectrichemical autotrophes) such as *Bacillus subtilis*, an anaerobic microbial fuel cell (501) or both (as displayed in Fig.

21). The microbial fuel cell receives water from a transport piping (125) of the photocatalytic reaction unit eventually over a pump (129). The aerobic microbial fuel cell (511) is preceded by an aeration or oxygenation unit (118) that is connected with its output via a transport piping or irrigation system with the aerobic microbial fuel cell (511) (e.g. with anaerobic bioelectrochemical heterotrophes or anaerobic denitrifyers). In case there is no aerobic microbial fuel cell than the anaerobic fuel cell receives water that has been processes in the photocatalytic reactor (117) from the transport piping or irrigation system of the photocatalytic reactor (117). The anode chamber of the microbial fuel cells or the oxygenation or aeration chamber can recycle the processed water back to the photocatalytic reactor unit (100) via a transport piping such as 99b. The output of this hybrid photocatalytic / microbial fuel cell system can release its processed water via a transport piping or irrigation system (131) into water storage (168) or other storage tanks or the mixing tanks (167) of a hydroponics culture, soilless crop culture system or crop greenhouse culture (163). The microbial full cells are provided with an external circuit that comprises a load (502 or 512), with a separator (505 or 510), with the anodes (503 or 516) in their anodes chamber and with the cathodes (504 or 517) in their cathode chamber.

In an particular embodiment of present invention (as displayed in Fig. 22 A the IRAFS comprises a photocatalytic reactor (117) that receives watery fluid loaded with organic molecules or organic matter from an input transport piping (99) or irrigation system (99). The photocatalytic reactor comprises a photocatalytic material (121) UV radiation source (122) or receives sun light radiation. The output for the photocatalytic processed watery fluid is connected with a transport piping (125) or irrigation system (125) which eventually passes a pump (129) and which is connected with a multitubular or multi column microbial fuel cell (525) or a reactor in which micro-organisms generate current (525) so that the photocatalytic water flows over anodic material (521) able to host microbials and able to accept electrons in a series of tubes that are 3 dimensionally surrounded by a cation exchange membrane (526). Such anodic material (521) comprises an electric conductive material (for instance conductive graphite pellets or (macro)porous graphite). The cation exchange membrane (526) is three dimensionally surrounded by a cathodic material (520) and is

separating the cathode from the anode. This cathodic material (520) can be ferricyanide catholyte fluid that overflow the out surface of the cation exchange membrane (526) which ferricyanide catholyte fluid is for instance pumped by a pump (129b) over the outer surface of the cation exchange membrane (526) of the multitubular or multi column microbial fuel cell (525) and can be recycled in a loop (528) and eventually passing an aeration or oxygenation unit (524) provided with an aerator (128). The multitubular or multi column microbial fuel cell (525) is provided with at least one external circuit that comprises a load (522). The multitubular or multi column microbial fuel cell (525). The external circuit (128) is able to receive electrons from the anode and to transport the electrons to the cathodic material (520). The anode is able to accept electrons from the microbials and the cathode is able to transfer the electrons from the external circuit to an electron acceptor or sink.

In a particular embodiment the IRAFS of present invention comprises a combined photocatalyst reactor (100) / gasification unit (134) that is connected by its processed water output (137) with a transport piping (155) to deliver its processed water to a microbial fuel cell unit (as displayed in Fig. 23). The photocatalytic reactor unit (100) has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the from the aquatic animal farming units. The photoctalyst unit is foreseen with a radiation unit (103) to radiate the photocatalytic material (104). Alternatively the photcatalytic material is exposed to sun light for instance by having tubings with the photocatalytic material or photoctalytic plates of the photocatalytic apparatus exposed to sun light. The photocatalytic material can eventually receive reflected light from a reflector or the photocatalytic unit of the photocatalytic apparatus can be placed above the aquatic animal farming unit in a green house or can be placed on on the roof of the building of the aquatic animal farm. An output and transport piping (107) provides the water wherein the organic load has been mineralized to the feed distributor (135 (the lowest 134 in fig 23 is 135)) of a gasification unit (134) for instance a gasification tank comprising a sludge bed (140), with (bio)granules (144), rising vapour bubbles (139), baffle (138), gas solid separator (145), a feed distributor (135 (the lowest 134 in fig 23 is 135)),

effluent collection (137)) . The gasification unit is provided with switch valves (154) to release its processed water via an out put or transport piping (155) or to return the water via a transport piping (99b) to the photocatalytic reactor unit (100). The out put (137) of the combined photocatalyst reactor (100)/ gasification unit (134) is connected via a transport piping or irrigation tool (155) with the microbial fuel cell reactor wherein microbials provide electrons, an anode is provided to accept electrons from the microbials which are transorted by a circuit (502, 512) to the cathode which is able to transfer the electrons from the external circuit to an electron acceptor or sink. The photocatalytic reactor (100) is for oxidizing and mineralizing of the complex organic molecules and presentation of the photocatalytized molecules to the gasification unit (134) and a microbial fuel cell (511, 501) to enhance their productivity. An output and transport piping (155) provides the water wherein the organic load has been mineralized and passed the gasification unit (134) to the microbial fuel cell (501 and/or 511). The microbial fuel cell can be an aerobic microbial fuel cell (511) for instance inoculated with aerobic bacteria (e.g. aerobic nitrifiers or aerobic bioelectrichemical autotrophes) such as *Bacillus subtilis*, an anaerobic microbial fuel cell (501) or both as in Fig. 23. The gasification tank receives water from a transport piping (107) from the photocatalytic reaction unit 100), eventually over a pump (108). The aerobic microbial fuel cell (511) is preceded by an aeration or oxygenation unit (118) that is connected with its output via a transport piping (126) or irrigation system with the aerobic microbial fuel cell (511) (e.g. with anaerobic bioelectrochemical heterotrophes or anaerobic denitrifyers). In case there is no aerobic microbial fuel cell than the anaerobic fuel cell receives water that has been processes in the photocatalytic reactor (100) and gasification unit (134) from the transport piping or irrigation system of the combined photocatalytic reactor (100) / gasification unit (134). The anode chamber of the microbial fuel cells or the oxygenation or aeration chamber can recycle the processed water back to the photocatalytic reactor unit (100) via a transport piping such as 99b. The output of this hybrid photocatalytic / microbial fuel cell system can release its processed water via a transport piping or irrigation system (131) preferably into water storage (168), the mixing tank (167) or other storage tanks of the hydroponics culture, soilless crop culture system or crop greenhouse culture (163).

In a particular embodiment (as displayed in Fig. 24) the IRAFS of present invention comprises a combined photocatalyst reactor / gasification unit that is connected by its processed water output with a transport piping (125) to deliver its processed water to a tubular microbial fuell cell. The photocatalytic reactor unit (100) has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and/or nBOD for instance from the from the aquatic animal farming units. The photoctalyst untis for ween with a radiation unit (103) to radiate the photocatalytic material (104). Alternatively the photcatalytic material is exposed to sun light for instance by having tubings with the photocatalytic material or photoctalytic plates of the photocatalytic apparatus exposed to sun light. The photocatalytic material can eventually receive reflected light from a reflector or the photocatalytic unit of the photocatalytic apparatus can be placed above the aquatic animal farming unit in a green house or can be placed on on the roof of the building of the aquatic animal farm. An output and transport piping (107) provides the water wherein the organic load has been mineralized to the feed distributor (134) of a gasification unit (134) for instance a gasification tank comprising a sludge bed (140), with (bio)granules (144), rising vapour bubbles (139), baffle (138), gas solid separator (145), a feed distributor (134), and effluent collection (137)). The gasification unit is provided with switch valves (154) to release its processed water via an out put or transport piping (155) or to return the water via a transport piping (99b) to the photocatalytic reactor unit (100). The transport piping (155) is connected with a transport piping (125) or irrigation system (125) which eventually passes a pump (129) and which is connected with a multitubular or multi column microbial fuel cell (525) or a reactor in which micro-organisms generate current (525) so that the photocatalytic water flows over anodic material (521) able to host microbials and able to accept electrons in a series of tubes that are 3 dimensionally surrounded by a cation exchange membrane (526) Such anodic material (521) comprises an electric conductive material (for instance conductive graphite pellets or (macro)porous graphite). The cation exchange membrane (526) is three dimensionally surrounded by a cathodic material (520) and is separating the cathode from the anode. This cathodic material (520) can further comprise a catholyte fluid, for instance a ferricyanide catholyte fluid that overflows

the out surface of the cation exchange membrane (526). The catholyte fluid is for instance pumped by a pump (129b) over the outer surface of the cation exchange membrane (526) of the multitubular or multi column microbial fuel cell (525) and can be recycled in a loop (528) and eventually passing an aeration or oxygenation unit (524). 522 is the load of the external circuit (522). The multitubular or multi column microbial fuel cell (525) furthermore comprises an external circuit (128) able to receive electrons from the anode and to transport the electrons to the cathodic material (520). The anode is able to accept electrons from the microbials and the cathode is able to transfer the electrons from the external circuit to an electron acceptor or sink.

The combined gasification / MFC system is used for bioremediation and production of energy to drive actuators of the IRAFS. 500 kg of fish in weight produces 550 m^3 biogas per year (biogas/a), ca. 3500 kWh_{th} or at least 200 – 500 (800) m^3 biogas/a, depending on the energy content of the biogas with a energy content 6.0 – 6.5 kWh m^{-3} or a fuel equivalent 0.60 – 0.65 L oil/m^3 biogas. The energy efficiency (лMFC), the ratio of power produced by the MFC over a time interval divided by the heat of combustion of the organic substrate is up to 50% when easily biodegradable substrates are used. In comparison the electric energy efficiency for thermal conversion of methane is <40%. But treated materials leaving the gasification or the MFC process still have energy content and can be reused or used in other energy extracting processes.

Some embodiments of the invention are set forth in claim format directly below:

1. A biomass farming system with controlled fluid flow input and/or fluid output for producing useful biomass comprising a bioreactor system with various bioreactor units in a shared confined environment or different confined environments that are connected

<u>whereby the farming system comprises</u>

- a distribution lines and at least one pump actuator to flow system fluids between selected bioreactor systems

- at least one water input container (clean water basin) for collecting or storing of rain water, surface water, municipal tap water and/or ground water

- a drain such as a drain removal system or line to optionally a drain storage container

- an heat pump system

characterised in that the bioreactor units comprise

- at least one aquaculture system for the culture of aquatic multicellular consumer (heterotrophic) organism (aquatic animals) comprising the drain and further comprising a suspended solids (SS), colloidal BOD (coBOD) or particulate BOD (pBOD) removal apparatus with an out put and a transport line connected to one or more collection containers or directly to the gasification bacterial bioreactor system, and further

- at least one collection tank or basin with connected with the removal apparatus and transport line of the aquaculture system to receive solids (TSS), colloidal BOD (coBOD), particulate BOD (pBOD) from the aquaculture system and/or to receive sludge from the bacterial bioreactor system, and further

- at least one bacterial bioreactor system comprising condominiums of producers bacteria and condominiums of consumer bacteria in a same or separate bioreactor and comprising an input to receive solved and particulate organic and inorganic material from the aquaculture system, and further

- gasification bioreactor connected with the removal apparatus and transport line of the removal apparatus or with the one or more collection containers to receive the removed material from the aquaculture system and the gasification bioreactor further comprising a gas collection means and a gas distribution line to transport the energy rich gaseous products toward to a gas burn driver of the heat pump system.

2. The farming system of any of the previous embodiment, whereby the gasification bioreactor comprises a methanogenic reaction function for producing the energy rich gaseous product (e.g. methane).

3. The farming system of any of the previous embodiments whereby the gas collection container is in the gas transport line between gasification bioreactor and the gas burn driver of the heat pump system.

4. The farming system of any of the previous embodiments whereby the heat pump system is connected by a loop with the drain of the farming system to flow heat between drain and the farming system.

5. The farming system of any of the previous embodiments whereby the heat pump system is connected by a heat extracting component with the drain of the farming system to flow heat between drain and the farming system for regaining the heat from the fluid drain into biomass farming system or for instance to move heat from drain to farming system).

6. The farming system of any of the previous embodiments whereby the drain is a drain water tank or basin with out put to the outer environment.

7. The farming system of any of the previous embodiments whereby the loop of the heat pump system is connected with the water input tank, the farming system and the drain to distribute heat between the water input tank or basin, the farming system and the drain.

8. The farming system of any of the previous embodiments whereby the heat pump is a reverse cycle heat pump.

9. The farming system of any of the previous embodiments whereby the reversed absorption heat pump is connected in a variable flow control system.

10. The farming system of any of the previous embodiments whereby the variable flow control system being connected with the water input container, one or more other units of the farming system and the drain.

11. The farming system of any of the previous embodiments whereby the reverse cycle heat pump is a reversible absorption heat pump.

12. The farming system of any of the previous embodiments whereby the reversible absorption heat pump is a reversible air-water absorption heat pump.

13. The farming system of any of the previous embodiments whereby the reversible absorption heat pump is a reversible water-water absorption heat pump.

14. The farming system of any of the previous embodiments whereby the reverse cycle heat pump is integrated variable flow control system

15. The farming system of any of the previous embodiments whereby the variable flow control system is a mixed indoors with outdoors system that connects an heat releasing component or heat extracting component in the outer environment with a confined environment that comprises the biomass farming system.

16. The farming system of any of the previous embodiments whereby the outer environment is the bottom under frost line.

17. The farming system of any of the previous embodiments whereby the outer environment is the air outside the confined farming environment.

18. The farming system of any of the previous embodiments whereby the operating system of the heat pump system comprises at least one pump and at least one heat pump actuator to drive the heat pump system.

19. The farming system of any of the previous embodiments whereby the pump actuator is a gas burner to drive the heat pump by heat.

20. The farming system of any of the previous embodiments whereby the operating system of the heat pump system comprises a in situ temperature sensors in the water input container (clean water basin), in the bioreactor units of farming system and in the drain connected to a signal processor to feeds the input signals from the temperature sensor network system into the signal processor and a controller that controls the heat pump system to adapt the temperature.

21. The farming system of any of the previous embodiments whereby the signal processor comprises a mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of living organisms in relating to the temperature (and eventually the time period of the day) and a controller that controls the heat pump system to adapt the temperature.

22. The farming system of any of the previous embodiments whereby the mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of a specific aquatic animal species in relating to the temperature (and eventually the time period of the day) and a controller.

23. The farming system of any of the previous embodiments whereby the mathematical model that is described on the relationship of a plurality of temperature

variables and a plurality of comfort, stress or welfare variables of a plurality of a specific plant species in relating to the temperature (and eventually the time period of the day) and a controller.

24. The farming system of any of the previous embodiments whereby the mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of a particular bacterial condominium in relating to the temperature (and eventually the time period of the day) and a controller.

25. The farming system of any of the previous embodiments whereby the signal processor comprises an adjuster to adjust the controller to control the heat pump system or an extra heating means to maintain the temperature between 15 – 30°C, preferably between 20 – 25°C.

26. The biomass farming system of any of the previous embodiments, whereby the bioreactor units are interconnected.

27. The biomass farming system of any of the previous embodiments, with controlled biomass and energy input and output.

28. The biomass farming system of any of the previous embodiments, whereby the collection tank or basin is liquefying tank or basin provided (with liquefying actuators (e.g. ultrasonars)).

29. The biomass farming system of any of the previous embodiments, whereby the aquatic animals are vertebrate animals.

30. The biomass farming system of any of the previous embodiments, whereby the aquatic animals are invertebrate animals.

31. The biomass farming system of any of the previous embodiments , whereby the at least one bacterial bioreactors system comprises a fluid input to receive organic and inorganic material form collection tank or basin that receives organic and inorganic material form the aquaculture system.

32. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises a reactor of the group consisting of an anaerobic reactor up flow anaerobic sludge blanket (UASB), an anaerobic sequencing batch reactor (ASBR), a fluidized expanded bed reactor, a static granular bed reactor

(SGBR), an anaerobic membrane reactor, an anaerobic expanded-bed reactor (EBR) and a granular bed baffled reactor (GRABBR).

33. The biomass farming system of any of the previous embodiments , whereby the biofilter comprises a shear for subjecting the autotrophic (chemolithotrophic) bacteria and heterotrophic (chemo organotrohic) bacteria to fluid shear and inducing biogranuation

34. The biomass farming system of any of the previous embodiments , whereby the biogranulate operated biofilter further comprises means for filtering out colloid, very fine particles, the flocs with poor settling capacity or the bacterial granules with poor settling capacity.

35. The biomass farming system of any of the previous embodiments , whereby both condominium of autotrophic (chemolithotrophic) bacteria and heterotrophic (chemo organotrohic) bacteria are in an up flow sludge blanket filter (USBF) bioreactor) with an anoxic and an aerated compartment and up flow sludge blanket filtration with automatic or continued removal device of poor settling active sludge flocs or sludge granule and automatic or continued distribution well settling active sludge flocs or sludge granule to the anoxic zone.

36. The biomass farming system of any of the previous embodiments, whereby the biofilter comprises a shear for subjecting the autotrophic (chemolithotrophic) bacteria and heterotrophic (chemo organotrohic) to fluid shear and inducing biogranulation.

37. The biomass farming system of any of the previous embodiments , whereby the biogranulate operated biofilter further comprises means for filtering out colloid, very fine particles, the flocs with poor settling capacity or the bacterial granules with poor settling capacity.

38. The biomass farming system of any of the previous embodiments , whereby both condominium of autotrophic (chemolithotrophic) bacteria and heterotrophic (chemo organotrohic) bacteria are in an up flow sludge blanket filter (USBF) bioreactor) with an anoxic and an aerated compartment and up flow sludge blanket filtration with automatic or continued removal device of poor settling active sludge flocs or sludge granule and automatic or continued distribution well settling active sludge flocs or sludge granule to the anoxic zone.

39. The biomass farming system of any of the previous embodiments, whereby gasification the bacterial reactor system is connected with the farming unit to receive molecular electron acceptors, such as CO_2, or NO_3^-, and a gas collection and a gas distribution system to collect the energy riches gasses produced after electron acceptation, such as CH_4 and N_2.

40. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises at least on bioelectric bioreactor.

41. The biomass farming system of any of the previous embodiments , whereby the bacterial bioreactor system is a bioelectricity producer integrated operational system that connects and drives farming systems actuator with the bioelectricity.

42. The biomass farming system of any of the previous embodiments , whereby the bacterial reactor system that produces the energy to drive system actuators comprises an anaerobic bioreactor

43. The biomass farming system of any of the previous embodiments , whereby the bacterial reactor system that produces the energy to drive system actuators comprises aerobic bioreactor

44. The biomass farming system of any of the previous embodiments , whereby the bacterial reactor system that produces the energy to drive system actuators comprises the bioreactor that combines an aerobic and anaerobic zone.

45. The biomass farming system of any of the previous embodiments , whereby the bacterial reactor system comprises a condominium of bioelectrical bacteria that degradates molecular or organic nitrogen compounds releasing electrons.

46. The biomass farming system of any of the previous embodiments , whereby the bacterial reactor system further comprise at least one anode connected with a least one electric circuit to accept and distribute the electrons.

47. The biomass farming system of any of the previous embodiments , whereby each electrical circuit is connected to at least one of the systems actuators to drive it by electricity generated by the bio-electrochemical bacteria assisted biotransformation system.

48. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with a) at least one heterotrophic (chemo

organotrophic) bio-electrochemical bacteria assisted biotransformation unit to reduce nitrogen and decrease cBOD.

49. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises at least one autotrophic (chemolithotrophic) bio-electrochemical bacteria assisted biotransformation unit to oxidize nitrogen and decrease nBOD or at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with both types autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria in one condominium or bioreactor.

50. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with a) at least one heterotrophic (chemo organotrophic) bio-electrochemical bacteria assisted biotransformation unit to reduce nitrogen and decrease cBOD and b) at least one autotrophic (chemolithotrophic) bio-electrochemical bacteria assisted biotransformation unit to oxidize nitrogen and decrease nBOD.

51. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with both types autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria in one condominium or bioreactor.

52. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises a shear for subjecting the autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria to fluid shear and inducing biogranulation.

53. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a biogranulate operated biofilter further comprises means for filtering out colloid, very fine particles, the flocs with poor settling capacity or the bacterial granules with poor settling capacity.

54. The biomass farming system of any of the previous embodiments, whereby in the bacterial reactor system both condominium of autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical

bacteria are in an up flow sludge blanket filter (USBF) bioreactor) with an anoxic and an aerated compartment and up flow sludge blanket filtration with automatic or continued removal device of poor settling active sludge flocs or sludge granule and automatic or continued distribution well settling active sludge flocs or sludge granule to the anoxic zone.

55. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a biotransformation system assisted by electrochemical bacteria assisted or a biotransformation unit assisted by autotrophic bacteria is a nitrifying bacterial fuel cell comprising autotrophic bio-electrochemical bacteria

56. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a biotransformation unit assisted by the autotrophic bio-electrochemical bacteria that comprises *Nitrosomonas europea.*

57. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a nitrifying bacterial fuel cell is a flow through fuel cells accepting water of the farming systems flows

58. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a biotransformation unit assisted by heterotrophic bio-electrochemical bacteria can be a denitrifying bacterial fuel cell.

59. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a biotransformation system assisted by heterotrophic bio-electrochemical bacteria comprises *Geobacter sulfurreducens, Shewanella oneidensis, Rhodoferax ferrireducens* or a combination thereof.

60. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system whereby the denitrifying bacterial fuel cell is a flow through fuel cells accepting water of the farming systems flows.

61. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is an electrochemical bacteria assisted biotransformation system or combined nitrifying/denitrifying bacterial fuel cell comprises an anode chamber with heterotrophic bio-electrochemical bacteria, an anode chamber with autotrophic bioelectrochemical bacteria in contact with a common cathode chamber isolated by a selective hydrogen ion permeable separator.

62. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system, whereby the anode chamber with heterotrophic bio-electrochemical bacteria and the anode chamber with autotrophic bioelectrochemical bacteria are flow through fuel cells accepting water flows of the farming systems.

63. The farming system of any of the previous embodiments further comprising at least one photocatalytic bioreactor

64. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by the living photosynthetic producer organisms.

65. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by living photoauto-heterotrophic organisms.

66. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by the living photosynthetic producer organisms belonging to the Plantae (e.g. herbs, grasses, vines)).

67. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic Chlorophytes.

68. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic spermatophytes.

69. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic embryophytes.

70. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic Pteridophytes.

71. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic Bryophytes.

72. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic macrophytes.

73. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic microphytes.

74. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is connected by an irrigation delivery system (tubing or piping) with at least one chemical stock solution container, container of aquaculture drain water and container with drain from the gasification container or a combination thereof.

75. The farming system of any of the previous embodiments , whereby a conductivity sensor network of sensors in the chemical stock solution container, in the aquaculture drain water and the gasification bioreactor drain is connected with a computer comprising a controller or with an electronic controller to process the sensor signals in to a signal that activates actuator for mixing the fluid (of the water of the aquaculture system, the clean water, the drain water of the gasification tank and/or the chemical stock solution water or injecting the fluids in to an irrigation system to the photocatalytic bioreactor.

76. The farming system of any of the previous embodiments , whereby the controller is provided with a mathematical model to compute that the irrigation to the photocatalytic bioreactor is water with an EC of less than 0.5 mScm-1 and a sodium concentration of less that 0.5 mmol l^{-1}.

77. The farming system of any of the previous embodiments , whereby the farming system further comprises an operating system comprising a in situ pH sensors in the water input container (clean water basin) and in bioreactor units of farming system connected to a signal processor to feeds the input signals from the pH sensor network system into the signal processor which signal processor comprises a mathematical model that is described on the relationship of a plurality of pH variables and a plurality of comfort, stress or welfare variables of a plurality of living organisms in relating to the pH and a controller that controls a at least one programmable actuator to adapt the pH.

78. The farming system of any of the previous embodiments , whereby the signal processor comprises an adjuster to adjust the controller to control the programmable pH actuator to maintain the pH between 5,5 and 8 preferably between 6 – 7.5.

79. The farming system of any of the previous embodiments , whereby the programmable actuator is a delivery pump to deliver a pH regulator agent (for instance an agent of the group consisting of an alkalis of the group consisting of calcium bicarbonate, calcium carbonate, calcium hydroxide, magnesium bicarbonate, magnesium carbonate, magnesium hydroxide, sodium bicarbonate, sodium carbonate and sodium hydroxide) to said system to adapt pH.

80. The use of the farming system of any of the previous embodiments for processes of redistribution of organic and inorganic nutrients and energy into useful biomass.

81. The use of the system of any of the previous embodiments for useful biomass farming a controlled bioremediation or redistribution of nutrients and energy between bioreactors of living organisms

82. The use of the farming system of any of previous embodiments with the bacteria assisted bioelectricity producing biofilters connected by a circuit to one or more heat pump system to drive said heat pumps connected by a loop with a drain (drain water tank or basin) of the farming system by bioelectricity from the bio-electrochemical bacteria assisted biofilter to flow heat between drain and the farming system (for instance to move heat from drain to farming system).

Some other embodiments of the invention are set forth in claim format directly below:

1. A biomass farming system with controlled fluid flow input and/or fluid output for producing useful biomass comprising a bioreactor system with various bioreactor units in a shared confined environment or different confined environments that are connected whereby the farming system comprises 1) a distribution line or distribution lines and at least one pump actuator to flow system fluids between selected bioreactor systems, 2) at least one water input for instance a water input container (clean water basin) for collecting or storing of rain water, surface water, municipal tap water and/or ground water, 3) a drain for drain water removal for instance a drain removal line to optionally a drain storage container, 4) an heat pump system with condenser and evaporator heat exchangers, 5) at least one bacterial bioreactor system and whereby the bioreactor system with various bioreactor units comprises a) at least one gasification bioreactor, b) at least one aquaculture system for the culture of aquatic multicellular consumer (heterotrophic) organism (aquatic animals) with at least one suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD) removal apparatus and c) at least one bioreactor unit comprising at least one condominiums of bacteria

characterised in that

the at least one aquaculture system for the culture of aquatic multicellular consumer (heterotrophic) organism (aquatic animals) comprises a drain for drain water removal for instance a drain removal line to optionally a drain storage container, and further the at least one suspended solids (SS), colloidal BOD (coBOD) and/or particulate

BOD (pBOD) removal apparatus comprises an out put and a transport line or transport pipe directly connected to a gasification bacterial bioreactor system for transport of the solids directly to the gasification bacterial bioreactor or indirectly connected to a gasification bacterial bioreactor system via the collection containers which collection containers are connected with a transport line or transport pipe connected to the gasification bacterial bioreactor system for gasification bacterial bioreactor to the gasification bacterial bioreactor, and further the at least one bacterial bioreactor system comprises condominiums of producers bacteria and condominiums of consumer bacteria in a same or separate bioreactor and comprising an input to receive solved and particulate organic and inorganic material from the aquaculture system, and further the gasification bioreactor further comprising a gas collection means and a gas distribution line to transport the energy rich gaseous products toward to gas burner that produces the drive energy to drive actuators of the biomass farming system

2. The farming system of any of the previous embodiments, whereby the gas burner is a gas burn driver of the heat pump system.
3. The farming system of any of the previous embodiments, whereby the gas burner is a CHP system that generates current into a circuit to drive the actuator of the aquatic farming system.
4. The biomass farming system of any of the previous embodiments, whereby gasification the bacterial reactor system is connected with the farming unit to receive molecular electron acceptors, such as CO_2, or NO_3^-, and a gas collection and a gas distribution system to collect the energy riches gasses produced after electron acceptation, such as CH_4 and N_2
5. The farming system of any of the previous embodiment, whereby the gas collection means of the gasification bioreactor is connected with the gas burn driver of the heat pump system via a gas distribution line with a gas dehumidifier and a gas storage unit or tank.
6. The farming system of any of the previous embodiments whereby the gas collection container is in the gas transport line between gasification bioreactor and the gas burn driver of the heat pump system.
7. The farming system of any of the previous embodiment, whereby a photocatalytic reactor unit (100) which has an input piping (99) that recieves (organic rich) water

with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the from the aquatic animal farming units and which comprises at least one fluid transport pipe connected with or which irrigate the bacterial bioreactor system

58. The farming system of any of the previous embodiment, whereby a photocatalytic reactor unit (100) which has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the from the aquatic animal farming units and which photocatalytic unit (100) comprises an output transport piping or irrigation means (107) to transport its processed water to the input system of an aerobic biofilter (119).

9. The farming system of any of the previous embodiment, whereby a photocatalytic reactor unit (100) for oxidizing and mineralizing of the complex organic molecules which photocatalytic unit (100) comprises an output transport piping or irrigation means (107) to transport its processed water to the input system of a microbial fuel cell for the presentation of the photocatalytized molecules to enhance the productivity of a microbial fuel cell.

10. The farming system of embodiment 7, whereby the radiation unit and the photocatalyst material of the photocatalyst reactor is functionalised for oxidizing and mineralizing of to convert complex organic molecules to CO_2, water and mineral acids and a transport pipe to transport such CO_2 and/or mineral acids to the condominiums of producers bacteria.

11. The farming system of embodiment 7, further comprising a unit with photoautotrophic organisms (e.g. aquatic plants) whereby the radiation unit and the photocatalyst material of the photocatalyst reactor is functionalised for oxidizing and mineralizing of to convert complex organic molecules to CO_2, water and mineral acids and comprises an output and a transport pipe to transport such CO_2 and/or mineral acids to the unit with photoautotrophic organisms.

12. The farming system of embodiment 7, whereby the radiation unit and the photocatalyst material of the photocatalyst reactor is functionalised for CO2 reduction ($CO_2 + 2H_2O \rightarrow CH_4 + 2O_2$) in to hydrocarbons and comprises an output and a

transport pipe to transport such hydrocarbons to the condominiums of consumer bacteria.

13. The farming system of any of the previous embodiments whereby the heat pump system is connected by a loop with a drain of the farming system to flow heat between drain and the farming system.

14. The farming system of any of the previous embodiments whereby the operating system of the heat pump system comprises a in situ temperature sensors in the water input container (clean water basin), in the bioreactor units of farming system and in the drain connected to a signal processor to feeds the input signals from the temperature sensor network system into the signal processor and a controller that controls the heat pump system to adapt the temperature.

15. The farming system of any of the previous embodiments whereby the signal processor comprises a mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of living organisms in relating to the temperature (and eventually the time period of the day) and a controller that controls the heat pump system to adapt the temperature.

16. The farming system of any of the previous embodiments whereby the mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of a specific aquatic animal species in relating to the temperature (and eventually the time period of the day) and a controller.

17. The farming system of any of the previous embodiments whereby the mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of a specific plant species in relating to the temperature (and eventually the time period of the day) and a controller.

18. The farming system of any of the previous embodiments whereby the mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of a particular bacterial condominium in relating to the temperature (and eventually the time period of the day) and a controller.

19. The farming system of any of the previous embodiments whereby the signal processor comprises an adjuster to adjust the controller to control the heat pump system or an extra heating means to maintain the temperature between 15 – 30°C, preferably between 20 – 25°C.

520. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises at least on bioelectric bioreactor

21. The biomass farming system of any of the previous embodiments , whereby the bacterial bioreactor system is a bioelectricity producer integrated operational system that connects and drives farming systems actuator with the bioelectricity

1022. The farming system of any of the previous embodiments, further comprising photocatalyst reactor with a radiation unit and photocatalyst material that functionalised for photocatalytic denitrification

23. The farming system of any of the previous embodiments, further comprising photocatalyst reactor with a radiation unit and photocatalyst material that functionalised for to sterilize or disinfect and in particular to destroy microbial pathogens in floc communities

24. The farming system of any of the previous embodiments, further comprising photocatalyst reactor with a radiation unit and photocatalyst material that functionalised for to reduce metals

2025. The farming system of any of the previous embodiments, further comprising photocatalyst reactor with a radiation unit and photocatalyst material that functionalised for water splitting $H2O \rightarrow ½\ O_2 + H_2$ whereby the photocatalyst reactor is further foreseen with transport pipe and eventual hydrogen storage tank to provide hydrogen in a controllable to the aerobic and or anaerobic bioreactor to enhance the growth of hydrogen consuming bacteria such the methanogenic bacteria the aerobic and/or anaerobic granule bioreactor.

26. The farming system of any of the previous embodiments, further comprising photocatalyst reactor with a radiation unit and photocatalyst material that functionalised for water splitting $H_2O \rightarrow ½\ O_2 + H_2$ whereby the photocatalyst reactor is further foreseen with transport pipe and eventual to provide oxygen in a controllable to the aerobic bioreactor with producer bacteria or to the consumer aquatic organism.

27. The farming system of any of the previous embodiments, whereby the photocatalytic reactor can deliver such treated water to a pretank unit (101) and by in situ hard sensor with a signal output that is representative for a measure of ammonium, nitrite and/or nitrate the ammonium to nitrite proportion can be controlled in the pretrank (101) before the water is transferred to bioreactor to set or maintain said bioreactor in an annamox mode.

28. The farming system of any of the previous embodiments, whereby the photocatalytic reactor can deliver such treated water to a pretank unit (101) and by in situ hard sensor with a signal output that is representative for a measure of the oxygen and carbon dioxide levels in the water of this pretank unit (101) and accordingly controlled before the water is transferred to the bioreactor to set or maintain said bioreactor in an annamox mode

29. The farming system of any of the previous embodiments, whereby the photocatalytic reactor can deliver such treated water to a pretank unit (101) and by in situ hard sensor with a signal output that is representative for a measure of toxicity in the water of this pretank unit (101) and accordingly controlled by photocatalytic mineralization of said toxic compounds or intermediates before the water is transferred to the bioreactor to guarantee the biofilter stability

30. The farming system of any of the previous embodiments, whereby the bioreactor is a (bio)granule (144) producing bioreactor foreseen of turbulence or shear force creation means for instance a stirrer (105) for inducing biofilm forming into (bio)granules (144).

31. The farming system of any of the previous embodiments, with a photocatalyst reactor whereby the photocatalyst reactor is a reactor type of the group consisting of falling Film Reactor (FFR), Fiber Optic Cable Reactor (FOCR), Multiple Tube Reactor (MTR), Packed Bed Reactor (PBR), Rotating Disk Reactor with Controlled Periodic Illumination (RDR-CPI), Spiral Glass Tube Reactor (SGTR), Tube Light Reactor (TLR) and Photo CREC Water I.

32. The farming system of any of the previous embodiments, with a photocatalyst reactor sonophotocatalysis function whereby the photocatalyst reactor is combined with ultrasound irradiation (e.g. at a frequency of between 15 to 250 kHz, for instance 215 kHz).

33. The farming system of any of the previous embodiment, whereby the bacterial bioreactor system comprises an aerobic (digester) granule bioreactor
34. The farming system of any of the previous embodiment, whereby the bacterial bioreactor system comprises an anaerobic (digester) granule bioreactor
535. The farming system of any of the previous embodiment, whereby the bacterial bioreactor system comprises an aerobic (digester) granule bioreactor and an anaerobic (digester) granule bioreactor in series.
36. The farming system of any of the previous embodiment, whereby the at least one collection tank or basin which is connected with the removal apparatus and transport line of the aquaculture system to receive solids (TSS), colloidal BOD (coBOD), particulate BOD (pBOD) from the aquaculture system is further provides with a transport line or pipe input to receive sludge from the bacterial bioreactor system.
37. The farming system of any of the previous embodiments, whereby the gasification bioreactor comprises a methanogenic reaction functions for producing the energy rich gaseous product (e.g. methane).
38. The farming system of any of the previous embodiments whereby the heat pump system is connected by a heat extracting component with the drain of the farming system to flow heat between drain and the farming system for regaining the heat from the fluid drain into biomass farming system or for instance to move heat from drain to farming system)
39. The farming system of any of the previous embodiments whereby the drain is the drain water tank or basin with out put to the outer environment
40. The farming system of any of the previous embodiments whereby the loop of the heat pump system is connected with the water input tank, the farming system and the drain to distribute heat between the water input tank or basin, the farming system and the drain.
41. The farming system of any of the previous embodiments whereby the heat pump is a reverse cycle heat pump
42. The farming system of any of the previous embodiments whereby the reversed absorption heat pump is connected in a variable flow control system.

43. The farming system of any of the previous embodiments whereby the variable flow control system being connected with the water input container, one or more other units of the farming system and the drain.

44. The farming system of any of the previous embodiments whereby the reverse cycle heat pump is a reversible absorption heat pump.

45. The farming system of any of the previous embodiments whereby the reversible absorption heat pump is a reversible air-water absorption heat pump.

46. The farming system of any of the previous embodiments whereby the reversible absorption heat pump is a reversible water-water absorption heat pump.

1047. The farming system of any of the previous embodiments whereby the reverse cycle heat pump is integrated variable flow control system

48. The farming system of any of the previous embodiments whereby the variable flow control system is a mixed indoors with outdoors system that connects an heat releasing component or heat extracting component in the outer environment with a confined environment that comprises the biomass farming system.

49. The farming system of any of the previous embodiments whereby the outer environment is the bottom under frost line.

50. The farming system of any of the previous embodiments whereby the outer environment is the air outside the confined farming environment.

2051. The farming system of any of the previous embodiments whereby the operating system of the heat pump system comprises at least one pump and at least one heat pump actuator to drive the heat pump system.

52. The farming system of any of the previous embodiments whereby the pump actuator is a gas burner to drive the heat pump by heat

2553. The biomass farming system of any of the previous embodiments, whereby the bioreactor units are interconnected

54. The biomass farming system of any of the previous embodiments, with controlled biomass and energy input and output

55. The biomass farming system of any of the previous embodiments, whereby the collection tank or basin is liquefying tank or basin provided (with liquefying actuators (e.g. ultrasonars or a recirculation loop through permanent magnets))

56. The biomass farming system of any of the previous embodiments, whereby the aquatic animals are vertebrate animals

57. The biomass farming system of any of the previous embodiments , whereby the aquatic animals are invertebrate animals

558. The biomass farming system of any of the previous embodiments , whereby the at least one bacterial bioreactors system comprises a fluid input to receive organic and inorganic material form collection tank or basin that receives organic and inorganic material form the aquaculture system

59. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises a reactor of the group consisting of an anaerobic reactor up flow anaerobic sludge blanket (UASB), an anaerobic sequencing batch reactor (ASBR), a fluidized expanded bed reactor, a static granular bed reactor (SGBR), an anaerobic membrane reactor, an anaerobic expanded-bed reactor (EBR) and a granular bed baffled reactor (GRABBR).

1560. The biomass farming system of any of the previous embodiments , whereby the biofilter comprises a shear for subjecting the autotrophic (chemolithotrophic) bacteria and heterotrophic (chemo organotrohic) bacteria to fluid shear and inducing biogranulation

61. The biomass farming system of any of the previous embodiments , whereby the biogranulate operated biofilter further comprises means for filtering out colloid, very fine particles, the flocs with poor settling capacity or the bacterial granules with poor settling capacity

62. The biomass farming system of any of the previous embodiments , whereby both condominium of autotrophic (chemolithotrophic) bacteria and heterotrophic (chemo organotrohic) bacteria are in an up flow sludge blanket filter (USBF) bioreactor) with an anoxic and an aerated compartment and up flow sludge blanket filtration with automatic or continued removal device of poor settling active sludge flocs or sludge granule and automatic or continued distribution well settling active sludge flocs or sludge granule to the anoxic zone.

3063. The biomass farming system of any of the previous embodiments, whereby the biofilter comprises a shear for subjecting the autotrophic (chemolithotrophic) bacteria and heterotrophic (chemo organotrohic) to fluid shear and inducing biogranulation.

64. The biomass farming system of any of the previous embodiments , whereby the biogranulate operated biofilter further comprises means for filtering out colloid, very fine particles, the flocs with poor settling capacity or the bacterial granules with poor settling capacity.

565. The biomass farming system of any of the previous embodiments , whereby both condominium of autotrophic (chemolithotrophic) bacteria and heterotrophic (chemo organotrohic) bacteria are in an up flow sludge blanket filter (USBF) bioreactor) with an anoxic and an aerated compartment and up flow sludge blanket filtration with automatic or continued removal device of poor settling active sludge flocs or sludge granule and automatic or continued distribution well settling active sludge flocs or sludge granule to the anoxic zone.

66. The biomass farming system of any of the previous embodiments , whereby the bacterial reactor system that produces the energy to drive system actuators comprises an anaerobic bioreactor

1567. The biomass farming system of any of the previous embodiments , whereby the bacterial reactor system that produces the energy to drive system actuators comprises aerobic bioreactor

68. The biomass farming system of any of the previous embodiments , whereby the bacterial reactor system that produces the energy to drive system actuators comprises the bioreactor that combines an aerobic and anaerobic zone

69. The biomass farming system of any of the previous embodiments , whereby the bacterial reactor system comprises a condominium of bioelectrical bacteria that degradates molecular or organic nitrogen compounds releasing electrons

70. The biomass farming system of any of the previous embodiments , whereby the bacterial reactor system further comprise at least one anode connected with a least one electric circuit to accept and distribute the electrons.

71. The biomass farming system of any of the previous embodiments , whereby each electrical circuit is connected to at least one of the systems actuators to drive it by electricity generated by the bio-electrochemical bacteria assisted biotransformation system

72. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises at least one bio-electrochemical bacteria assisted

biofilter or bioremediation system with a) at least one heterotrophic (chemo organotrophic) bio-electrochemical bacteria assisted biotransformation unit to reduce nitrogen and decrease cBOD

73. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises at least one autotrophic (chemolithotrophic) bio-electrochemical bacteria assisted biotransformation unit to oxidize nitrogen and decrease nBOD or at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with both types autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria in one condominium or bioreactor

74. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with a) at least one heterotrophic (chemo organotrophic) bio-electrochemical bacteria assisted biotransformation unit to reduce nitrogen and decrease cBOD and b) at least one autotrophic (chemolithotrophic) bio-electrochemical bacteria assisted biotransformation unit to oxidize nitrogen and decrease nBOD

75. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with both types autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria in one condominium or bioreactor

76. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system comprises a shear for subjecting the autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria to fluid shear and inducing biogranulation

77. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a biogranulate operated biofilter further comprises means for filtering out colloid, very fine particles, the flocs with poor settling capacity or the bacterial granules with poor settling capacity.

78. The biomass farming system of any of the previous embodiments, whereby in the bacterial reactor system both condominium of autotrophic (chemolithotrophic) bio-

electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria are in an up flow sludge blanket filter (USBF) bioreactor) with an anoxic and an aerated compartment and up flow sludge blanket filtration with automatic or continued removal device of poor settling active sludge flocs or sludge granule and automatic or continued distribution well settling active sludge flocs or sludge granule to the anoxic zone.

79. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a biotransformation system assisted by electrochemical bacteria assisted or a biotransformation unit assisted by autotrophic bacteria is a nitrifying bacterial fuel cell comprising autotrophic bio-electrochemical bacteria

80. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a biotransformation unit assisted by the autotrophic bio-electrochemical bacteria that comprises *Nitrosomonas europea.*

81. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a nitrifying bacterial fuel cell is a flow through fuel cells accepting water of the farming systems flows

82. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a biotransformation unit assisted by heterotrophic bio-electrochemical bacteria can be a denitrifying bacterial fuel cell.

2083. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is a biotransformation system assisted by heterotrophic bio-electrochemical bacteria comprises *Geobacter sulfurreducens, Shewanella oneidensis, Rhodoferax ferrireducens* or a combination thereof.

84. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system whereby the denitrifying bacterial fuel cell is a flow through fuel cells accepting water of the farming systems flows.

85. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system is an electrochemical bacteria assisted biotransformation system or combined nitrifying/denitrifying bacterial fuel cell comprises an anode chamber with heterotrophic bio-electrochemical bacteria, an anode chamber with autotrophic bioelectrochemical bacteria in contact with a common cathode chamber isolated by a selective hydrogen ion permeable separator.

86. The biomass farming system of any of the previous embodiments, whereby the bacterial reactor system, whereby the anode chamber with heterotrophic bio-electrochemical bacteria and the anode chamber with autotrophic bioelectrochemical bacteria are flow through fuel cells accepting water flows of the farming systems.

587. The farming system of any of the previous embodiments further comprising at least one photocatalytic bioreactor

88. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by the living photosynthetic producer organisms.

89. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by living photoauto-heterotrophic organisms and in particular assisted by the photoautotrophic organism (e.g. green plants and photosynthetic bacteria are photoautotrophs).

90. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by the living photosynthetic producer organisms belonging to the Plantae (e.g. herbs, grasses, vines)).

91. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic Chlorophytes.

92. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic spermatophytes.

2093. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic embryophytes.

94. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic Pteridophytes.

95. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic Bryophytes.

96. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic macrophytes.

97. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is assisted by autotrophic microphytes.

3098. The farming system of any of the previous embodiments, whereby the photocatalytic bioreactor is connected by an irrigation delivery system (tubing or piping) with at

least one chemical stock solution container, container of aquaculture drain water and container with drain from the gasification container or a combination thereof.

99. The farming system of any of the previous embodiments , whereby a conductivity sensor network of sensors in the chemical stock solution container, in the aquaculture drain water and the gasification bioreactor drain is connected with a computer comprising a controller or with an electronic controller to process the sensor signals in to a signal that activates actuator for mixing the fluid (of the water of the aquaculture system, the clean water, the drain water of the gasification tank and/or the chemical stock solution water or injecting the fluids in to an irrigation system to the photocatalytic bioreactor

100. The farming system of any of the previous embodiments , whereby the controller is provided with a mathematical model to compute that the irrigation to the photocatalytic bioreactor is water with an EC of less than 0.5 mScm-1 and a sodium concentration of less that 0.5 mmol l-1.

101. The farming system of any of the previous embodiments , whereby the farming system further comprises an operating system comprising a in situ pH sensors in the water input container (clean water basin) and in bioreactor units of farming system connected to a signal processor to feeds the input signals from the pH sensor network system into the signal processor which signal processor comprises a mathematical model that is described on the relationship of a plurality of pH variables and a plurality of comfort, stress or welfare variables of a plurality of living organisms in relating to the pH and a controller that controls a at least one programmable actuator to adapt the pH.

102. The farming system of any of the previous embodiments, whereby the signal processor comprises an adjuster to adjust the controller to control the programmable pH actuator to maintain the pH between 5,5 and 8 preferably between 6 – 7.5.

103. The farming system of any of the previous embodiments, whereby the programmable actuator is a delivery pump to deliver a pH regulator agent (for instance an agent of the group consisting of an alkalis of the group consisting of calcium bicarbonate, calcium carbonate, calcium hydroxide, magnesium bicarbonate, magnesium carbonate, magnesium hydroxide, sodium bicarbonate, sodium carbonate and sodium hydroxide) to said system to adapt pH.

104. The farming system of any of the previous embodiment, whereby the photocatalyst reactor is provided with a Ru (bpy)3 2+ photocatalyst or another suitable photocatalyst for visible light decomposition of aqueous NH4+/NH_3 to N2 and H2.

5105. The farming system of any of the previous embodiment, whereby the actuators that receive energy are of the group of sensors, pumps, chemoelectric reactors, valves lamp, the microwave generator, ultrasound generator, programmable actuator adapted to deliver a pH regulator agent to said system, programmable heat and/or cool actuator to cool or heat the system.

10106. The use of the farming system of any of the previous embodiments for processes of redistribution of organic and inorganic nutrients and energy into useful biomass.

107. The use of the system of any of the previous embodiments for useful biomass farming a controlled bioremediation or redistribution of nutrients and energy between
15 bioreactors of living organisms.

108. The use of the farming system of any of previous embodiments with the bacteria assisted bioelectricity producing biofilters connected by a circuit to one or more heat pump system to drive said heat pumps connected by a loop with a drain (drain water tank or basin) of the farming system by bioelectricity from the bio-
20 electrochemical bacteria assisted biofilter to flow heat between drain and the farming system (for instance to move heat from drain to farming system).

109. The farming system of any of the previous embodiment, whereby the chemo organotrophic bacteria (heterotrophs) bioelectricity (bioelectricity generating) reactor unit or microbial fuel cell (MFC) in a setup to generate current to drive the heat
25 pumps system or specific actuators in the controlled farming system.

110. The farming system of embodiment 107, whereby the chemoorganotrophic bioreactor or the anaerobic liquefier bioreactor is a microbial fuel cell.

111. The farming system of embodiment 108, whereby the cathode of the chemoorganotrophic bioreactor is sparged with dissolved oxygen obtained from a
30 water splitting reactor.

112. The farming system of any of the previous embodiments, whereby a nitrification bacterial fuel cell is incorporated in the aerobic autotrophic nitrifying

bioreactor for addition of oxygen to nitrogen while generating bioelectricity whereby the anode chamber reduced substrates (such as reduced nitrogen), ammonium and nitrite ions are oxidized resulting in a decrease of nBOD with the generation of oxidized nitrogen species and in the generation of electrons and protons.

5113. The farming system of embodiment 110, whereby the both autotrophic bacteria nitrifying and chemo organotrophic bacteria (heterotrophs) denitrifying bacterial condominiums are designed to producing current to drive the heat pump system or specific actuators in the controlled agriculture system.

114. The farming system of any of the previous embodiments, comprising a combined anaerobic denitrifying / aerobic nitrifying bacterial fuel cell sharing the cathode, whereby the cathode can be subjected to active or passive aeration

115. The farming system of any of embodiment 112, whereby oxygen for the autotrophic bioelectrochemical bacterial cell can be obtained from the electrochemical and photocatalytic water splitting actuators.

15116. The farming system of any of the previous embodiments, whereby a controlled fluid communication for atmospheric gas, whereby mineral carbon CO_2 produced by the units of consumer aquatic organisms and the units of consumer microbial organism is transported by a transport line to the bioreactors that are assisted by autotrophic organisms (e.g. the autotrophic microbials or the photoautotrophic organisms).

117. The farming system of any of the previous embodiments, comprising a controlled fluid communication for atmospheric gas that transports the oxygen production by the plant bioreactor or photoautotrophic bioreactor and in particular the bioreactor with photoautotrophic organism (e.g. green plants and photosynthetic bacteria are photoautotrophs is transported to the reactor with producer bacteria.

118. The farming system of any of the previous embodiments, whereby the recirculating aquatic farming system comprises one or more drainage water collection system (drain storage tank) to collect the drainage water from the recirculating aquaculture system (RAS) and/or the greenhouse horticulture system (GCS), these drainage water collection system is a heat source or sink of the recirculating aquatic farming system and heat is collected by an evaporation heat exchanger and transported by the heat pump to a condensing heat exchanger.

119. The farming system of any of the previous embodiments, whereby the recirculating aquatic farming system comprises a greenhouse culture system (and an aquatic animal farming unit.

120. The farming system of any of the previous embodiments 1 – 119 , the system comprising at least one clean water (ground water and/or rain water) collection or storage tank (400), at least one drain water collection or storage tank with drain water of the hydroponics or a soilless plant culture unit (e.g. the greenhouse culture system (GCS)) (401), a gasification bioreactor (402), aquatic animal farming system in particular the fish culture (e.g. the recirculating aquaculture system (RAS) or recirculating aquatic animal farming system (403) which can comprise bioreactor units and drain organic waste into the gasification bioreactor or its confined environment or building (404), a hydroponics or a soilless plant culture unit (405) (e.g. the greenhouse culture system (GCS)) or its greenhouse (406), evaporators (407) to absorb heat and condensers (408) to release heat, the reverse switch system(s) (409) and the gas fired heat pump drive system (411), whereby the system comprises a reversed absorption heat pumps that is fired by energy rich gas of the gasification bioreactor of present invention and whereby the reversed absorption heat pumps connected in a variable flow control system to control the temperature of the aquatic animal farming system in particular the aquatic animal culture (Tf), the temperature of a gasification bioreactor unit (Tb), the temperature (Tp) of the hydroponics or a soilless plant culture unit by realising or extracting heat at the aquatic animal farming system, the gasification bioreactor unit, the hydroponics or a soilless plant culture unit, the E rain water/ground water or clean water storage unit, the drain water tank and the ground (410), a place the under the frost line ground water.

121. The farming system of embodiment 120, whereby the systems further comprises one or more drainage water collection system to collect the drainage water from the recirculating aquaculture system (RAS) and/or the greenhouse culture system (GCS).

122. The farming system of any of the embodiment 120 to 121, whereby the drainage water collection system is a heat source or sink for the recirculating aquaculture system and/or the greenhouse culture system and/or the integrated system of both.

123. The farming system of any of the embodiment 120 to 122, whereby the thermal loop between the drainage water collection system and the RAS and/or GCS can comprising a reversing valve and force the heat flow in the other direction and heat is then transferred in the opposite direction, from the RAS and/or GCS that is cooled, to the drainage water collection system.

124. The farming system of any of the embodiment 120 to 123, whereby the system comprises heat transfer switches of the heat pump system with reversible operation in heating mode or in cooling mode and whereby the different components are of the group consisting of expansion valves (304), 4 way switch valve (308), two switch valves (309), condenser (301), evaporator (302), compressor (303), drain water container (300), Rain water / groundwater or clean water tank (305), aquatic animal culture tank or tanks (306), hydroponics or soilless crop culture unit(s) (307) and under frost line ground water (308).

125. The farming system of any of the embodiment 120 to 124, whereby the heat is transferred from the soilless crop culture unit(s) (307) to the aquatic animal culture tank or tanks (306) for a suitable in a day and night regime

126. The farming system of any of the embodiment 120 to 125, whereby the optimal or desired temperature for crop growth is maintained different from the optimal or desired temperature of the aquatic multicellular consumer organisms (e.g. aquatic animals).

127. The farming system of any of the embodiment 120 to 1264, whereby the optimal temperature for crops in the soilless crop culture unit difference between day and night (for instance 25.5 °C at day and 17.7 °C 's at night and the aquatic animal culture units the temperate is generally kept equal and stabilized.

25128. The farming system of any of the previous embodiments, 1 to 119 whereby the system further comprises a solid removal apparatus for instance a screening apparatus (e.g. a incline belt screen filter (132) with a screen belt (143)) for mechanical removal of the suspended organic solids, particulate organic matter and colloidal organic matter ((coBOD) colloidal BOD and (pBOD) particulate BOD (removal apparatus for suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD)) whereby this solid removal apparatus is foreseen of an input to receive the (dirty) water (148) and an out put (149) to return the (clean) water to the aquatic farming

system and is furthermore foreseen to deliver the waste (142) to a waste collection tank (133) whereby the water collection tank (133) is provide with a transport line (e.g. transport pipe (141) and pump (135)) to deliver the waste to an input (131) of a gasification tank (134) and whereby the gasification tank (134) furthermore comprises on or more out put and distribution line (transport pipe) (136) to transport the energy rich gas to the heat pump firing drive system (441, 216, 204) with gasification heat pump mechanism or to a gas fired electricity/heating or cooling generator (CHP unit) that delivers current to the systems actuators.

129. The farming system of embodiment 128, whereby the distribution line (transport pipe) (136) distribute the gas first towards a deshydratation unit (150) and the deshydratation unit is connected by a distribution line (transport pipe) (151) with a gas storage unit (152) which is connected by a distribution line (transport pipe) (153) with the heat pump firing drive system (441, 216, 204).

130. The farming system of any of embodiments 128 to 129, whereby the gasification tank (134) is foreseen of a closed loop (146 & 147) to recirculate its supernatant out put.

131. The farming system of any of embodiments 128 to 130, whereby the heat pump firing drive system (441, 216, 204) comprises a gasification heat pump mechanism with he condenser (201) to release heat into its environment and an evaporator (203) extracts heat from the environment and whereby the gas heater (204) receives energy rich gas from the gasification tank transport piping (153), heats the condenser (203) and drives the heat pump.

132. The farming system of any of the embodiments 128 to 131, whereby an extra pump pumps the lubricant fluid through the condenser (203) towards and expansion valve (206) to an absorber (202)

133. The farming system of any of embodiments 128 to 132, whereby the generator is connected by a loop with the evaporator (200).

134. The farming system of any of embodiments 128 to 133, whereby the loop passes through an heat exchanger loop (201a) in the condenser (201) through an expansion valve (206) in the evaporator heat exchanger loop (200a) of the evaporator (200)

135. The farming system of any of embodiments 128 to 135, whereby a pipe loop with a heat exchanger in the absorber (202) and a heat exchanger in the condenser (203) connects the absorber with the condenser (201) and has an open end (202a) in the absorber (202).

5136. The farming system of any of embodiments 1 to 129, whereby the system further comprises a photocatalyst bioreactor with an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and/or nBOD for instance from the from the aquatic animal farming units.

10137. The farming system of embodiment 136, whereby the photoctalyst unit is foreseen with a radiation unit (103) to radiate the photocatalytic material (104).

138. The farming system of any of embodiments 136 to 137, whereby the radiation unit is radiating solar light, UV light, near UV light, UV-VIS light or VIS light.

139. The farming system of any of embodiments 136 to 138, whereby the
15 photocatalytic material can eventually receive reflected light from a reflector

140. The farming system of any of embodiments 136 to 139, whereby an output and transport piping (107) provides the water wherein the organic load has been partially mineralized to the feed distributor (134) of a gasification unit (134) for instance a gasification tank comprising a sludge bed (140), with (bio)granules (144),
20 rising vapour bubbles (139), baffle (138), gas solid separator (145), a feed distributor (134, effluent collection (137))

141. The farming system of any of embodiments 136 to 140, whereby the gasification unit is provided with switch valves (154) to release its processed water via an out put or transport piping (155) or to return the water via a transport piping
25 (99b) to the photocatalytic reactor unit (100).

142. The farming system of any of embodiments 136 to 141, whereby the gasification tank (134) furthermore comprises on or more out put and distribution line (transport pipe) (136) to transport the energy rich gas to the heat pump firing drive system (441, 216, 204).

30143. The farming system of any of embodiments 136 to 142, whereby the distribution line (transport pipe) (136) distribute the gas first towards a deshydratation unit (150) and the deshydratation unit can be connected by a distribution line

(transport pipe) (151) with a gas storage unit (152) which is connected by a distribution line (transport pipe) (153) with the heat pump firing drive system (441, 216, 204).

144. The farming system of any of embodiments 136 to 143, whereby an output and transport piping provides the water wherein the organic load has been partially mineralized to a (photo)autotrophic organisms bioreactor the (photo)autotrophic organisms bioreactor is provided with switch valves (to release its processed water via an out put water to return the water via a transport piping to the photocatalytic reactor unit.

145. The farming system of any of embodiments 136 to 144, whereby the system comprises a photocatalytic reactor (100) and a radiation source (103) for reducing CO_2 into hydrocarbons at the photocatalytic material (104)) and presenting such to an anaerobic denitrification bioreactor.

146. The farming system of any of embodiments 136 to 145, whereby the system comprises a photocatalytic reactor (100) and a radiation source (103) for oxidizing and mineralizing of the complex organic molecules) at the photocatalytic material (104)) and presenting such to an aerobic bioreactor (102) which enhances a larger part of ammonium removal through oxidizing ammonium directly into N_2, or ammonium into NO_2^- or to reduce NO_3^- into NO_2^- depending on the photocatalyst and/or the reaction time.

147. The farming system of any of the embodiments 1 to 129, whereby the photocatalytic reactor is foreseen with a transport pipe input (99) to receive water load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the aquatic farming system and whereby the transport piping connects the out put (107) eventually over a pump (108) of the photocatalytic reactor with pretank unit (101) such as an aeration or oxygenation unit (101) which is connected with a transport piping (110) with the aerobic bioreactor (102).

148. The farming system of embodiment 147, whereby a loop (106) eventually with pump (111) allows under control of a valve system (154) to return water treated in the bioreactor via a transport piping (99a) to the photocatalytic reactor input (99) or to the aeration or oxygenation unit (101).

149. The farming system of any of any of the embodiments 147 to 148, whereby a photocatalytic aerobic bioreactor system can release the photocatalyst / aerobic bioreacted water via an output (112) into the aquatic animal farming system or into the storage tanks of the soilless plant culture or hydroponics.

5150. The farming system of any of any of the embodiments 147 to 149, whereby the photocatalytic reactor is foreseen with a transport pipe or irrigation output (98) to transport water to other units for instance to the plant hydroponics or soilless crop culture unit

151. The farming system of any of any of the embodiments 147 to 151, whereby
10 the pretank (101) and the photocatalytic reactor (100) are one.

152. The farming system of any of any of the embodiments 147 to 151, whereby depending on the photocatalytic material the radiation source can be a solar light collector, UV source, near UV source, UV-VIS source, VIS source.

153. The farming system of any of the embodiments 1 to 129, comprising a
15 photocatalytic reactor for oxidizing and mineralizing of the complex organic molecules or for ammonium directly into N_2, or ammonium into NO_2^- or to reduce NO_3^- into NO_2^- depending on the photocatalyst and/or the reaction time and for presentation of the photocatalytic material to an bioreactor system aerobic bioreactor and anaerobic bioreactor that can be tuned to enhance a larger part of ammonium
20 removal through oxidizing ammonium directly into N2.

154. The farming system of embodiment 153, whereby the photocatalytic reactor is foreseen with a transport pipe input (98) to receive water load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the aquatic farming system.

25155. The farming system of any of the embodiments 153 to 154, whereby the transport piping connects the out put (125) eventually over a pump (129) of the photocatalytic reactor with a pretank (118) for instance an aeration or oxygenation unit (118) and whereby in situ hard sensors with a signal output that is representative for ammonium, nitrite and/or nitrate the ammonium to nitrite proportion can be
30 controlled in the pretrank (118) and whereby optionally the oxygen and carbon dioxide levels in the water of this pretank unit (118) and whereby this pretank (118)

is connected with a transport piping (126) with the aerobic bioreactor (119), preferably a granule aerobic bioreactor, flocs or sludge bioreactor.

156. The farming system of any of the embodiments 153 to 155, whereby furthermore a loop (100) eventually with pump (130) allow under control of a valve system (154) to return water treated in the bioreactor via a transport piping (99a) to the photocatalytic reactor input (99) or to the pretank or the aeration or oxygenation unit (118) and whereby this photocatalytic aerobic bioreactor system can release the photocatalyst / aerobic bioreacted water via an output (127) into anaerobic bioreactor, preferably an anaerobic granule bioreactor (120) foreseen of a turbulence or shear force means to force the biofilm forming microorganisms to form granules (144b).

157. The farming system of any of the embodiments 153 to 156, whereby this anaerobic bioreactor can release the water that has been photocatalytic, aerobic bioreactor and anaerobic bioreactor processed via an output or an output transport piping (131) into the aquatic animal farming system or into the storage tanks of the soilless plant culture or hydroponics. The anaerobic bioreactor is foreseen with a loop of a transport pipeline (100) and eventually a pump (130) under control of a switch valve system back into the photocatalytic unit (117). In a particular embodiment the photocatalytic bioreactor (117).

158. The farming system of any of the embodiments 1 to 129, comprising a photocatalyst reaction unit to pretreat the water that is loaded with organic materials and to oxidize complex organic molecules, suspended organic solids, particulate organic matter and colloidal organic matter ((coBOD) colloidal BOD and/or (pBOD) particulate BOD and/or solved nBOD, cBOD into mineral molecules for instance for organic phosphorus, nitrogen and carbon mineralization or partial mineralization, disinfection and/or metal reduction.

159. The farming system of any of the embodiments 158, whereby the photocatalytic unit (100) is provided with a radiation source (103) to radiate the photocatalytic material (104), for instance a UV lamp (103), UV-VIS, Near UV, VIS depending on the type of photocatalyst, or alternatively collector sun light or a suitable photocatalytic surface that is exposed to sun light.

160. The farming system of any of the embodiments 158 to 159, whereby the photocatalytic unit (100) comprises an output transport piping or irrigation means

(107) to transport its processed water to the input system (135) to feed a gasification unit (134) and whereby the output transport piping or irrigation means (107) is provided with a switch valve that allows to return the processed water via a transport piping or irrigation means (147b) to the photocatalytic reactor unit.

5161. The farming system of any of the embodiments 158 to 160, whereby the photocatalytic reactor unit comprises a gas transport piping (136) to transport the gas fluids generating in the photocatalytic reactor unit.

162. The farming system of any of the embodiments 158 to 161, whereby the photocatalytic unit (100) comprises an alternative output (156) under control of a valve (154) that provides processed water to other units for instance to the aquatic animal farming units.

163. The farming system of any of the embodiments 158 to 162, whereby the gasification unit is for seen with at least one gas collection unit (145) to collect the energy rich gas ((139 = gas bubble) and a transport piping (136) to transport the gas fluid to eventual an dehydratation unit (150) and over a gas storage unit (152) via the transport piping (153) or directly via the transport piping (153) to an gas driven heat pump system.

164. The farming system of any of the embodiments 158 to 163, whereby the watery fluid out put(s) (137) of the gasification tank (134) is or are connected via a transport piping or irrigation system (118) with an oxygenation or aeration unit (147) which is connected with a transport piping or irrigation system (126) to deliver the aerated or oxygenated water to an aerobic biofilter (119)

165. The farming system of any of the embodiments 158 to 164, whereby the aerobic biofilter is connected by a transport piping or irrigation unit (127) to deliver its processed water into an anaerobic biofilter unit (120) which is preferably an anaerobic (bio)granule biofilter foreseen with a shear forces or water disturbance tool (124) to force the microbial into (bio)granules.

166. The farming system of any of the embodiments 158 to 165, whereby the anaerobic biofilter unit (120) has an output and output transport piping or irrigation tool (131) to transport its processed water to the aquatic farming animal system or to the crop hydroponics or the soilless plant culture system.

167. The farming system of any of the embodiments 158 to 166, whereby the anaerobic biofilter unit (120) comprises further a transport piping or irrigation unit (127) to recirculate its processed watery fluid to aeration tank (147).

168. The farming system of any of the embodiments 158 to 167, whereby the anaerobic biofilter unit (120) wherein in the bacterial reactions can be carried out over several different temperature ranges depending on the tolerance of the bacteria, ranging from moderate or room-level temperatures (15-35°C) to both high temperatures (50-60°C) tolerated by thermophiles and low temperatures (<15°C) where psychrophiles can grow.

169. The farming system of any of the embodiments 1 to 129, whereby a recirculation system of the plant hydroponics or soilless crop culture (greenhouse) is incorporated in the aquatic farming system that further comprises a water collection unit that can receive water of a transport piping (98 or 156) directly from a photacatalytic reaction unit or of a transport piping (131) indirectly from a photacatalytic reaction for instance of a photocatalyst / aerobic bioreactor / anaerobic bioreactor unit (17 or 18) and whereby at least one of the anaerobic bioreactors is a gasification tank and eventually an other anaerobic is an anaerobic microbial fuel cell with heterotrophic bioelectrochemical bacteria for anaerobic denitrification), or of a transport piping (112) of a photocatalyst / aerobic bioreactor system

170. The farming system of embodiment 169, whereby the photacatalytic reaction unit comprises a photocatalytic reactor input (99), an aerobic bioreactor unit (autotrophic bioelectrochemical bacteria for aerobic nitrifying bacterial fuel cell) (102) and eventually a separate aeration or oxygenation unit (101) and whereby the transport piping (112) releases the photocatalysed and aerobic bioreacted water into a storage tank (168) or in one of the tanks (157, 158 or 167) of the photocatalyst / aerobic bioreactor system.

171. The farming system of any of the embodiments 169 to 170, whereby the water storage (168) which receives water from the photocatalytic reactors and the drain water tank (159) which receives the (dirty) water of the hydroponics culture, the soilless crop culture system or the crop greenhouse culture (163)) and the clean water tank (157) ,that stores ground water, rain water or other clean water, are connected with a transport piping or irrigation system to a mixing unit or mixing tank (167).

172. The farming system of any of the embodiments 169 to 171, whereby the water supply to the mixing unit or mixing tank (167) is under control of a multiple switch valve (160) to control their water flow towards the mixing unit or mixing tank (167) and whereby after the switching valve (160) before of after the mixing unit or mixing tank (167) there is a mineralization and/or sterilization unit (165), preferably a flow through sterilization unit that comprises a UV radiation source or UV source, near UV source, UV-VIS source, VIS source or solar light source (166) depending on the photocatalyst material and can be assisted by ultrasound or microwave source to radiate the passing through water or eventually an ozonation system as a germicidal treatment.

173. The farming system of any of the embodiments 169 to 172, whereby the photocatalytic reactor depending on the photocatalyst material and on the radiation source (166), e.g. UV, Near US, VIS light or Sun light, can for obtaining a sterilisation and / or mineralization function.

174. The farming system of any of the embodiments 169 to 173, whereby the photocatalytic mineralization and/or sterilization unit (165) function is intensified or enhanced function by an hybrid photocatalyst / ultrasound function or an hybrid photocatalyst / microwave function.

175. The farming system of any of the embodiments 169 to 174, whereby the hydroponics culture, the soilless crop culture system or the crop greenhouse culture (163) comprises chemical (nutrient) stock solution tank(s) (162), of which one a acid stock solution tank (162) and another base stock solution tank (162), that all have an transport pipe that passes dosing or reservoir pumps (159) for composing a desired nutrient solution , pH and alkalinity for instance in the diluter (161) or in the mixing unit or mixing tank (167) and whereby the diluter (161) or in the mixing unit or mixing tank (167) receives minerals from the photocatalytic unit and whereby such diluter (161) or the mixing unit or mixing tank (167) have a an irrigation or transport piping to the plant growing troughs (164) and whereby the plant growing troughs (164) are connected by a transport piping or irrigation with a drain pit (165) that is connected by a transport piping or irrigation with the drain storage tank (158), such system being controlled by a liquid control system that controls the (nutrient) dosing

or reservoir pump, the nutrient solution pH, the nutrient electric conductivity, nutrient solution and condensate water levels.

176. The farming system of any of the embodiments 1 to 129, whereby the transport fluid pipe (114) between the different units such as the rain water / groundwater or clean water tank (305), the aquatic animal culture tank or tanks (306), the hydroponics or soilless crop culture unit(s) (307) the soilless crop culture unit(s) (307) and/or the bioreactor units comprises an outer layer of the liquid transport piping (114) which is coated in the inside or on the inner lumen of the piping (115) of the transport pipe (114) by an antimicrobial layer in particularly a virucidal and/or a layer prevents biofilm forming (116)

177. The farming system of embodiment 176, whereby at least some of the water storage tanks have been coated inside by a by an antimicrobial layer in particularly a virucidal layer and/or a layer prevents biofilm forming (116)

178. The farming system of any of the embodiments 176 to 177, whereby the photocatalyst reactor is connected by its processed water output with a transport piping (125) to a microbial fuel cell unit and whereby the photocatalytic reactor unit (100) has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved cBOD and/or nBOD for instance from the from the aquatic animal farming units and whereby the photocatalytic reactor (117) which is for oxidizing and mineralizing of the complex organic molecules and presentation of the photocatalytized molecules to enhance the productivity of a microbial fuel cell comprises an output and transport piping (125) that provides the water wherein the organic load has been mineralized from the photocatalytic reactor (117) to the microbial fuell celles (511 and 501).

179. The farming system of any of the embodiments 176 to 178, whereby the microbial fuel cell is an aerobic microbial fuel cell (511) for instance inoculated with aerobic bacteria (e.g. aerobic nitrifiers or aerobic bioelectrochemical autotrophes) such as *Bacillus subtilis*, or an anaerobic microbial fuel cell (501) or both and whereby the microbial fuel cell receives water from a transport piping (125) of the photocatalytic reaction unit eventually over a pump (129) and whereby such aerobic microbial fuel cell (511) is preceded by an aeration or oxygenation unit (118) that is

connected with its output via a transport piping or irrigation system with the aerobic microbial fuel cell (511)

180. The farming system of any of the embodiments 1 to 129, comprising a photocatalytic reactor (117) that receives watery fluid loaded with organic molecules or organic matter from an input transport piping (99) or irrigation system (99) and whereby the output for the photocatalytic processed watery fluid is connected with a transport piping (125) or irrigation system (125) which eventually passes a pump (129) and which is connected with a multitubular or multi column microbial fuel cell (525) or a reactor in which micro-organisms generate current (525) so that the photocatalytic water flows over anodic material (521) able to host microbial and able to accept electrons in a series of tubes that are 3 dimensionally surrounded by a cation exchange membrane (526) and whereby such anodic material (521) comprises an electric conductive material and whereby the cation exchange membrane (526) is three dimensionally surrounded by a cathodic material (520) and is separating the cathode from the anode and whereby the multitubular or multi column microbial fuel cell (525) is provided with at least one external circuit that comprises a load (522) able to receive electrons from the anode and to transport the electrons to the cathodic material (520) whereby the anode is able to accept electrons from the microbial and the cathode is able to transfer the electrons from the external circuit to an electron acceptor or sink.

181. The farming system of any of the embodiments 1 to 129, comprising a combined photocatalyst reactor (100) / gasification unit (134) that is connected by its processed water output (137) with a transport piping (155) to deliver its processed water to a microbial fuel cell unit and whereby the photocatalytic reactor unit (100) has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the from the aquatic animal farming units and whereby the output and transport piping (107) provides the water wherein the organic load has been mineralized to the feed distributor (135) of a gasification unit (134) for instance a gasification tank comprising a sludge bed (140), with (bio)granules (144), rising vapour bubbles (139), baffle (138), gas solid separator (145), a feed distributor (135 (the lowest 134 in fig 23 is 135)), effluent collection (137)) and whereby the

gasification unit is provided with switch valves (154) to release its processed water via an out put or transport piping (155) or to return the water via a transport piping (99b) to the photocatalytic reactor unit (100).

182. The farming system of embodiment 181, whereby the out put (137) of the combined photocatalyst reactor (100)/ gasification unit (134) is connected via a transport piping or irrigation tool (155) with the microbial fuel cell reactor wherein microbials provide electrons, an anode is provided to accept electrons from the microbial which are transorted by a circuit (502, 512) to the cathode which is able to transfer the electrons from the external circuit to an electron acceptor or sink.

183. The farming system of any of the embodiments 181 to 182, whereby the photocatalytic reactor (100) is for oxidizing and mineralizing of the complex organic molecules and presentation of the photocatalytized molecules to the gasification unit (134) and a microbial fuel cell (511, 501) to enhance their productivity and whereby output and transport piping (155) provide the water wherein the organic load has been mineralized and passed the gasification unit (134) to the microbial fuel cell (501 and/or 511).

184. The farming system of any of the embodiments 181 to 183, whereby the output of this hybrid photocatalytic / microbial fuel cell system can release its processed water via a transport piping or irrigation system (131) preferably into water storage (168), the mixing tank (167) or other storage tanks of the hydroponics culture, soilless crop culture system or crop greenhouse culture (163).

185. The farming system of any of the embodiments 1 to 129, comprising a combined photocatalyst reactor / gasification unit that is connected by its processed water output with a transport piping (125) to deliver its processed water to a tubular microbial fuell cell and whereby the photocatalytic reactor unit (100) has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and/or nBOD for instance from the from the aquatic animal farming units and whereby the photoctalyst unites foreseen with a radiation unit (103) to radiate the photocatalytic material (104).- and whereby an output and transport piping (107) provide the water wherein the organic load has been partially mineralized to the feed distributor (134) of a gasification unit (134) for instance a gasification tank comprising a sludge bed

(140), with (bio)granules (144), rising vapour bubbles (139), baffle (138), gas solid separator (145), a feed distributor (134), effluent collection (137))

186. The farming system of embodiment 185, whereby the gasification unit is provided with switch valves (154) to release its processed water via an out put or transport piping (155) or to return the water via a transport piping (99b) to the photocatalytic reactor unit (100) aned whereby the transport piping (155) is connected with a transport piping (125) or irrigation system (125) which eventually passes a pump (129) and which is connected with a multitubular or multi column microbial fuel cell (525) or a reactor in which micro-organisms generate current (525) so that the photocatalytic water flows over anodic material (521) able to host microbial and able to accept electrons in a series of tubes that are 3 dimensionally surrounded by a cation exchange membrane (526)

187. The farming system of any of the embodiments 184 to 186, comprising a nitrification bacterial fuel cell for addition of oxygen to nitrogen while generating bioelectricity whereby the oxygen is generated at a radiated (near UV, UV – VIS, preferably visible light or solar light radiation) photo anode in water to produce gaseous oxygen and hydrogen : $H_2O + 2h^+ \rightarrow 2H^+ + ½\ O_2$ and whereby the H^+ is transported to the anode chamber with electrochemical bacteria (heterotrophic nitrifiers) and oxygen is transported to the cathode chamber.

188. The farming system of any of the embodiments 185 to 187, whereby within the anode chamber reduced substrates (such as reduced nitrogen), ammonium and nitrite ions are oxidized resulting in a decrease of nBOD with the generation of oxidized nitrogen species and in the generation of electrons and protons.

189. The farming system of any of the embodiments 1 to 129, comprising a photocatalytic reactor (700) with a photocatalytic material for down hill or up hill photocatalysis, whereby the photocatalyst material is immobilized on a substrate, for instance of amorphous silica or glass plates, or whereby the photocatalyst are suspended particles photocatalytic reactor with micro particles , preferably with a magnetic core (704) and a silica layer (703) which are coated by photocatalytic Nan particles for instance for down hill or up hill photocatalysis whereby such system comprises photocatalyts for O_2 and H_2 generation and photocatalysts that use the O_2 for H_2O_2 generation and/or for photocatalytic oxidation of the organic material or to

convert (oxidize) organic molecules into CO2, water and minerals (mineralization) for instance for use into atmospheric and water based nutrients for the producer organism bioreactors, e.g. the plants or the producer bacteria).

190. The farming system of any of the embodiments 1 to 129, comprising a photocatalytic reactor (700) with a photocatalytic material for down hill or up hill photocatalysis, whereby the photocatalyst material is immobilized on a substrate, for instance of amorphous silica or glass plates, or whereby the photocatalyst are suspended particles photocatalytic reactor with micro particles, preferably with a magnetic core (704) and a silica layer (703) which are coated by photocatalytic Nan particles for instance for down hill or up hill photocatalysis whereby such system comprises photocatalytic material (suitable photocatalyst have been described in this application) for water into H_2 and O_2 and/or photocatalytic material H_2O and C_2O into hydrocarbons for the consumer organism e.g. to fuel anaerobic bacteria bioreactor or the fuel driven farming system actuators.

15191. The farming system of any of the previous embodiments, whereby CO2 produced by consumer organisms is transported to the producer organism.

192. The farming system of any of the previous embodiments, whereby CO2 produced by consumer organisms photocatalysed to hydrocarbons such as methanol as a necessary hydrogen donor for the chemo heterotrophic microbial bioreactor and thus to fuel the chemo heterotrophic microbial bioreactor.

193. The farming system of any of the previous embodiments, whereby oxygen required by the aquatic animals and the aerobic producer bacteria is obtainable from the electrochemical and photocatalytic water splitting actuators.

194. The farming system of any of the previous embodiments, comprising a photocatalytic reactor with a mixture of particles that function microphotoelectodes whereof a portion of the first microphotoelectodes if radiated (e.g. under visible light or near infrared) perform water splitting $H_2O \rightarrow H_2 + \frac{1}{2} O_2$ and another portion of the second microphotoelectodes perform OH• radicals generation if radiated (e.g. under visible light or near infrared) and oxidize organic adsorbed pollutants (RXad) onto the surface and whereby the molecular oxygen produced by the first microphotoelectodes acts as an acceptor species in the electron-transfer reaction.

195. The farming system of any of the previous embodiments, comprising a photocatalytic reactor comprising different units, first init(s) with an OH• radicals generation and adsorbed pollutants (RXad) and eventual metal reduction function (down hill photocatalysis function) and second unit(s) with a water splitting function (up hill photocatalysis).

196. The farming system of any of the previous embodiments, whereby the system is in situ monitored by hard sensors and on-line analyzers for water analysis and water process monitoring to produce a signal indicative for the measure of a selected biotic or abiotic parameter and control and automatically monitoring the fluid systems of the aquatic farm systems to detect and measure abiotic and biotic parameters; and subsequently at the detection of an unwanted shift van be controlled by a soft sensor system in operational contacts with a programmable actuator adapted to regulate said biotic or abiotic parameter.

197. The farming system of any of the previous embodiments, whereby the system uses a model-based predictive controller based on an adaptive dynamic reactor model to predict a future response of said bioreactors to said interaction physicochemical and/or electrochemical reactors as a function of time and compensates effects of external disturbance on said bioreactors by adjusting said operation rate of said physicochemical and/or electrochemical reactors regulators to achieve a normo status in culture units of the aquatic organisms.

198. The farming system of any of embodiment 197, whereby parameter settings are adapted by the incoming signal to more closely approximate the dynamic behaviour of the biofilters and hereby the controller pro-actively compensates a future effect of known current or future disturbances by using said adaptive dynamic model in order to minimise deviation from normo biofilter function and in such way protects the aquatic organisms culture units.

199. The farming system of any of the previous embodiments, whereby in situ aqueous sensor comprises any of the sensing of the group consisting of oxygen, conductivity, alkalinity, reduced nitrogen ad oxidized nitrogen

30200. The farming system of any of the previous embodiments, whereby in situ aqueous sensor comprises any of the physical measurements of the sensors that are converted into an input signal for the control system are for instance measurements of

oxidizable species (RX_{ad}) of intermediates (from for instance a OH or end products quantities (e.g. he $HO^{\bullet}$ / oxidizable species (RX_{ad}) ratio) produced by the physicochemical reactor and/or measurements of intermediates or end products quantities produced by the bioreactor, the quantity of mineralization or organic material in a fluid, or the measurement of the toxicity level of intermediate or end products or of the mixture of intermediates (for instance from a $OH^{\bullet}_{ad} + RX_{ad}$ → intermediate reaction) and end products, or the quantity of super oxide anions $HO2^{\bullet}$ or of reactive hydroxyl radicals ($OH^{\bullet}$) produced or the $OH^{\bullet}$ / oxidizable species (RX_{ad}) ratio produced by said the catalytic physicochemical reactor output or entering in said bioreactor , the quantity of oxidizable species and or oxidized species or the quantity of oxygen or the quantity of super oxide radial.

201. The farming system of any of the previous embodiments, whereby in situ aqueous sensor comprises any of the sensing of the group consisting of NH4+/NH3 sensing, simultaneous determination of nitrate and nitrite , pH and the electrical conductivity (EC) , phosphate sensing, continuous NH4+ measurement, NH4+ & NO3- , in situ total solids , the biological oxygen demand, the total oxygen demand (TOC), toxicity monitor , flow of liquid , salinity , electrical conductivity, alkalinity, individual ions like K+, Ca_2+, NO_3−, SO_4^{2-}, NH_4^+ , Na^+ and Cl^-.

202. The farming system of any of the previous embodiments, whereby the system comprises in-situ measurements sensors of gases of the group of sensing consisting of H_2, H_2S, CH_4, N_2, O_2, He and CO_2, $O2/CO_2$ and carbon monoxide (CO) levels in a gas or atmosphere that as been stored in a separate buffer tanks or in the atmosphere in the confined environment(s), the reactors of the gas fluid transport lines.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description. It is to be understood that both

the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention.

Particular and preferred aspects of the invention are set out in the accompanying independent and dependent claims. Features from the dependent claims may be combined with features of the independent claims and with features of other dependent claims as appropriate and not merely as explicitly set out in the claims.

Thus, the claims following the detailed description are hereby expressly incorporated into this detailed description, with each claim standing on its own as a separate embodiment of this invention.

Detailed Description

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

The following detailed description of the invention refers to the accompanying drawings. The same reference numbers in different drawings identify the same or similar elements. Also, the following detailed description does not limit the invention. Instead, the scope of the invention is defined by the appended claims and equivalents thereof.

Definitions used in this application

A photocatalyst is a substance that is activated by absorption of a photon and that helps accelerate a reaction without being consumed. Factors that influence its photocatalytic activity are for instance structure, particle size, surface properties, preparations, spectral activation, and resistance to mechanical stress.

Direct (solar) radiation for the meaning of this application is the solar radiation that reaches ground level without being absorbed or scattered. Diffuse (solar) radiation for the meaning of this application is the solar which has been dispersed before reaching the ground is called. Global radiation is the sum of direct (solar) radiation and diffuse (solar) radiation

A photocatalyst is defined as a substance that is activated by the absorption of a photon and helps accelerate a reaction, without being consumed.

Photocatalytic processes are divided into two groups: homogeneous photocatalytic oxidation, e.g. UV/hydrogen peroxide; and heterogeneous photocatalytic oxidation, such as UV/semiconductor photocatalysis. In the heterogeneous process, hydroxyl radicals (one of the most oxidative chemical species) are produced from the redox reaction between photo-excited electrons and electron acceptors on the surface of the semiconductor photocatalyst. Heterogeneous photocatalysis couples low-energy ultraviolet light with semiconductors acting as photocatalysts. The process is catalytic and allows the semiconductor to remain active for long periods of time. Three components must be present in order for the heterogeneous photocatalytic reaction to take place: an emitted photon (in the appropriate wavelength), a catalyst surface (usually a semi-conductor material) and a strong oxidizing agent (in most cases oxygen). The heterogeneous photocatalytic process is initiated when a photon with energy equal to or greater than the band gap energy (Ebg) of the photocatalyst reaches the photocatalyst surface, resulting in molecular excitation. Ebg is defined as the difference between the filled valence band and the empty conduction band of the photocatalyst, in the order of a few electron volts. This molecular excitation results in the generation of mobile electrons in the higher energy conduction band (Ecb) and positive holes in the lower energy valence band (Evb) of the catalyst.

In this process, electron hole pairs that are generated by the band-gap excitation carry out in situ degradation of the organic molecules whereby a complete mineralization is obtainable to carbon dioxide, water, and mineral acid.

Semiconductors are electrical solids. Electrical solids are divided into three groups depending on their ability to conduct electricity: metals; insulators; and semiconductors. Metals are good thermal and electrical conductors due to their chemical bonding structure. Insulators are poor conductors as they are covalently bonded non-metals. Lying between these two groups are semiconductors, whose band structure can, under certain circumstances, allow electrical and thermal conductivity. semiconductors have been of interest since the 1950's due to their unique optical and

electronic properties. In an isolated atom, electrons occupy various discrete energy levels which are closely spaced. In a crystal, these energy levels are modified into millions of separate levels, collectively termed an energy band. A semiconductor contains two energy bands known as: the valence band (the highest occupied band (VB)); and the conduction band (the lowest unoccupied band (CB)). At normal temperatures, due to thermal promotion, a metal possesses electrons in the CB, whereas an insulator possesses no electrons in the CB. A semiconductor falls between these two categories. Fig 27 A shows the relative positions of the conduction and valence bands, with the corresponding area between them known as the band gap, in which no electron energy levels exist. Most of the semiconductors which have been investigated as photocatalysts for water treatment have been metal oxides (e.g. TiO2, ZnO, SnO2, WO3) and chalcogenides (CdS, ZnS, CdSe). Metal chalcogenides possess narrower band gaps, which make them sensitive to visible irradiation; however they are subject to photocorrosion. The photocatalysts' effectiveness for oxidation of organics in water treatment is dependent on the oxidation potential of the VB and the reduction potential of the CB. Typical Semi conductor photocatalysts for oxidation purpose are TiO2 (rutile) with band gap energy of 3.0 and with (eV) Wavelength (nm) of 413; TiO2 (anatase) with band gap energy of 3.2 and with (eV) Wavelength (nm) of 388; ZnO with band gap energy of 3.2 and with (eV) Wavelength (nm) of 388; ZnS with band gap energy of 3.6 and with (eV) Wavelength (nm) 335; CdS with band gap energy of 2.4 and with (eV) Wavelength (nm) 516; Fe_2O_3 with band gap energy of 2.3 and with (eV) Wavelength (nm) 539 and WO_3 with band gap energy of 2.8 and with (eV) Wavelength (nm) 443. Depending on the radiation source and the photocatalytic reactor function the process can be run with any of these photocatalysts.

TiO_2 semiconductor: Metal oxide semiconductors have been found to be the most suitable photocatalysts given their photo corrosion resistance and their wide band gap energies. TiO_2 is an inexpensive metal oxide semiconductors photocatalyst (100–200 dollars per tonne) and allows photocatalytic operations at low lamp wattage or solar energy. TiO_2 as catalyst is active, inexpensive, no hazardous, stable, and reusable. TiO_2 possesses high photocatalytic efficiency. The light required to activate the

catalyst is low-energy UV-A ($\lambda < 380$ nm) of intensity around 1-5Wm^{-2} for photo excitation. It is also possible to use solar light as an alternative and TiO_2 can be functionalized for this. The CB of TiO_2 is sufficiently negative for the reduction of O2, while the VB is sufficiently positive for the oxidation of OH making it an excellent semiconductor for the oxidation of organics in water. Adherence of the catalyst to the supporting substrate is can be in accordance with immobilisation techniques such as electrophoretic deposition and sol-gel related methods, among others. The reduction potentials of $SrTiO_3$, WO_3 and ZnS could also be used for the photocatalytic oxidation of organic pollutants; however it is often found that TiO_2 is the most efficient semiconductor for the treatment of water containing organic pollutants. Properties of TiO_2 preparations, such as crystalline phase, grain size, surface area and volume can be controlled by synthetic procedures. Although the final properties of the TiO_2 are dependent upon its synthesis, it has been established that post-synthetic treatments such as hydrothermal processing and microwave irradiation have significant effects on crystallinity and grain size. Three morphological forms of TiO2 exist: anatase, rutile and brookite. Brookite exhibits low stability and is usually ignored for practical applications. The anatase and rutile forms are commonly available in industrial TiO_2 products, with anatase most often used for catalytic purposes due to its larger photoreactivity than rutile. Anatase is thermodynamically stable up to 800 °C, above which a phase transformation to rutile occurs. The backward transition is not observed on cooling due to the high activation energy required. Both anatase and rutile exist as a tetragonal crystal lattice, each Ti atom is coordinated to six O atoms and each O atom is coordinated to three Ti atoms. The two principal catalytic phases of TiO_2, anatase and rutile, have numerous structural and functional differences. Commercially available anatase is typically less than 50 nm in size with the particles possessing a band gap of 3.2 eV, corresponding to a UV wavelength of 387 nm. The adsorptive affinity of anatase for organic compounds is higher than that of rutile and anatase exhibits lower rates of recombination in comparison to rutile due to its 10-fold greater rate of hole trapping. In contrast, the thermodynamically stable rutile phase generally contains particles larger than 200 nm with a smaller band-gap of 3.0 eV with excitation wavelengths that extend into the visible spectrum at 410 nm. Despite this, anatase is generally regarded as the more

photochemically active phase, due to the combined effect of lower rates of recombination and higher surface adsorptive capacity. There are several TiO_2 synthesis methods in the art such as vapour phase oxidation, hydrolysis of TiCl4 and titanium alcoholates delivering TiO_2 with different structures, crystallinities and impurities resulting in different properties. Photocatalytic activity is influenced by crystal structure, porosity, surface area, particle size distribution and surface hydroxyl density. These factors influence the production of electron-hole pairs, surface adsorption and desorption, as well as the redox process. Advantages of using TiO_2 as a photocatalyst include its insolubility in water and its non-toxicity. In addition, the photocatalytic process does not require the addition of consumable chemicals and a waste sludge is not produced. Anatase TiO_2 has a band gap energy of 3.2 eV equivalent to light of λ 387 nm or less. Since TiO_2 absorbs near-UV light, the exploitation of solar energy is a real possibility. A small but significant proportion of light between 300 – 400 nm of the solar spectrum reaches the earth's surface and could be utilised for the photocatalytic treatment of water. Many investigators have reported the solar photocatalytic degradation of pollutants in aqueous solution. Irradiation of TiO_2 particles with photons of energy equal to or greater than the band gap energy, results in the promotion of an electron from the VB to the CB of the particle. The outcome of this process is a region of positive charge, termed a hole (h+) in the VB and a free electron (e-) in the CB. This electron-hole pair can either recombine inside the semiconductor particle or move to the surface where they can react with adsorbed molecules. Once diffusing to the TiO_2 particle surface, the positively charged hole can directly oxidise organic products; or react with surface bound hydroxyl groups (OH-) or adsorbed water molecules to form hydroxyl radicals (OH•). The presence of oxygen consumes trapped electrons by reacting to form superoxide ions, preventing recombination. The final product of the reduction may also be OH• radicals and the hydroperoxyl radical HO_2 . Reactions involving the electron and hole should proceed simultaneously to prevent the accumulation of electrons in CB and prevent the recombination of electrons and holes. Therefore the efficient removal of electrons is essential to promote photocatalytic oxidation. Hydroxyl radicals have long been known as strong, indiscriminate oxidizing agents. During photocatalysis they can react with organic compounds and bacterial species

adsorbed onto, or very close to the semiconductor surface resulting in degradation (total oxidation of pollutant results in production of carbon dioxide and water). TiO_2 has been produced in various forms. TiO_2 particles can be loaded with metals and metal oxides such as vanadium oxide, platinum, manganese oxide, palladium and ruthenium. Metals on TiO_2 ease the separation of charges with electrons collected in metal particles. TiO2 and activated carbon composites can have excellent activity for NOx conversion due to the strong TiOi photocatalytic activity and activated carbon adsorption, while the addition of metal oxides such as Fe_2O_3, CO_3O_4 and NiO to the TiO_2-activated carbon composite catalyst increases the activity.

Degussa P25. Degussa P25 is TiO_2 produced by vapour phase oxidation characterised by a narrow particle size distribution, high photoactivity, minimal impurities (99.5% pure TiO_2) and containing up to 25% rutile in anatase or a , which has a composition ratio of 75:25 anatase: rutile, and crystallites, which are non-porous and cubic with rounded edges. Degussa P25 has an average particle size of ~ 21 nm, a specific area of 50 ± 15 m2 g-1. The high activity of Degussa P25 is thought to be due to a more positive CB potential in rutile compared to anatase. This allows photogenerated electrons to pass from anatase to rutile preventing recombination within the anatase. The lower activity of rutile can be a result of its lower over-potential for the reduction of oxygen Degussa P25 is a mixed phase semiconductor, whereby negative charges produced on rutile by visible light are stabilised through electron transfer to lower energy anatase lattice trapping sites (et) allowing electrons to reach the surface. Transfer of the photogenerated electron to anatase lattice trapping sites allows holes that would have been lost to recombination to also reach the surface via lattice trapping sites (ht). Degussa P25 can be immobilized on amorphous silica and glass plates.

BOD means for present application 'biological oxygen demand' or 'biochemical oxygen demand; For the meaning of present invention C = 'carbon', d = 'day', dw = 'dry weight', fw = 'fresh weight' , K_2O = 'potassium monoxide', mM = 'milliMole' (A chemical unit of concentration), N = 'nitrogen' (An element, existing predominantly in compounds with other elements, such as oxygen and hydrogen, in the environmental systems) NH_3 = 'ammonia', or 'non-ionised ammonia' (Inorganic

nitrogen compound), NH_3-N = 'nitrogen as ammonia' (The amount of nitrogen present in the form NH_3 NH_4 'ionised ammonia' / 'ammonium' (Inorganic nitrogen compound. More accurately written NH_4^+), NH_4-N = 'nitrogen as ionised ammonia / ammonium' (The amount of nitrogen present in the form NH_4^+), NO_2 = 'nitrite' Inorganic nitrogen compound. (More accurately written NO_2^-), NO_2-N = 'nitrogen as nitrite' (The amount of nitrogen present in the form NO_2), NO_3 = 'nitrate' (Inorganic nitrogen compound. More accurately written NO_3^-), NO_3-N = 'nitrogen as nitrate' (The amount of nitrogen present in the form NO_3^-), TAN = 'total ammonia nitrate' (The total amount of nitrogen present in the NH_3 and NH_4^+ forms), TN, = Total N 'total nitrogen' (The total amount of nitrogen present.), P '= phosphorous', PAH = 'Polycyclic Aromatic Hydrocarbons', PCB = 'Polychlorinated Biphenyl', PO4 = 'phosphate' (More accurately written PO_4^{3-}), PO_4-P = 'phosphorous as phosphate' (The amount of phosphorous present as phosphate), TP, = Total P 'total phosphorous' (The total amount of phosphorous present.), Urea-N = 'urea nitrogen' The amount of nitrogen present as urea and TSS = total suspended solids, cBOD = 'Carbonaceous Biological Oxygen Demand', coBOD = colloidal BOD, pBOD = particulate BOD and nBOD = nitrogenous Biological Oxygen Demand, $\upsilon \sim$ = Wave number, λ = Wavelength, μm = Micrometer, Abs = Absorbance, AFM = Atomic Force Microscopy, APO = Advanced photocatalytic oxidation as = Asymmetric vibration, ATP = Adenine tri-phosphate, ATR = Attenuated total reflectance, BET = Brunauer-Emmett-Teller, BJH = Baret-Joyner-Halenda ca. = Approximately, CB = or cb Conduction band, CFU = Colony Forming Unit cm-1 = Wavenumber, CoA = Co-enzyme A, CV = Cyclic voltammogram, DI = Distilled water, Dp = Particle diameter, e- = Electron, EAP = Electrochemically-assisted photocatalysis, Ebg = Band gap, Er = Reference potential, Es S = ample potential, et = Lattice trapping site for electrons, eV = Electron volt, FTIR = Fourier transform infrared, FWHM = Full width half maximum, Lattice = trapping sites or holes, hv = Photon of light/energy, ip = In-plane vibration, MW = Microwave, nm = Nanometer, O2·- = Superoxide, OH• = Hydroxyl radical, Ox. = Oxidation, PCA = Principal Component Analysis, ppm = Parts per million, R or RH Organic pollutant, Red. = Reduction, rpm = Revolutions per minute and s = Symmetric vibration

Actinomycete = Filamentous bacteria, mold like bacteria, acute = having a sudden onset and short course, adsorb = the taking up of one substance at the surface of an organism, aerobic = the use of free molecular oxygen for cellular respiration, aggregate Crowded or massed into a dense cluster, alkalis = chemical compound that releases alkalinity in water, amino acid = a group of organic acids in which a hydrogen atom of the hydrocarbon (alkyl), radical is exchanged for the amino group; used in the production of proteins, ammonification = the release of amino groups or ammonia from organic-nitrogen compounds by microbial activity, anaerobic = an environment where free molecular oxygen is not used by bacteria for the degradation of substrate, anoxic = an environment where bacteria use nitrite ions or nitrate ions aqueous , assimilatory = a general term for all the metabolic processes that permit the build up of nutrients utilized by organisms, atom = the smallest particle of an element that can take part in a chemical reaction, bacillus = a rod-shaped bacterium or a genus in the family *Bacillaceae*, bactericide = a substance capable of killing bacteria, bio augmentation = the addition of commercially prepared cultures of organotrophs and nitrifying bacteria to a wastewater treatment process to improve operational conditions, brackish water = water having less salt than seawater, but undrinkable, ultraviolet radiation short wavelengths of electromagnetic radiation in the range of 100 to 400 nm,

The following symbols have been further used: C = Carbon, $CaCO_3$ = Calcium carbonate, $Ca(HCO_3)_2$ = Calcium bicarbonate, $Ca(OH)_2$ = Calcium hydroxide, $C_6H_{12}O_6$ =Glucose, CO_2 = Carbon dioxide, CO_3^{2-} = Carbonate, -COOH = Carboxylic acid (carboxyl) group, H = Hydrogen, H^+ =Hydrogen ion, HCO^{-3} = Bicarbonate ion, H_2CO_3 = Carbonic acid, HNO_2 = Nitrous acid, N = Nitrogen, N_2 = Molecular nitrogen, $-NH_2$ = Amino group, NH_3 = Ammonia, NH_4^+ = Ammonium ion, NH_2CONH_2 = Urea, NH_2OH = Hydroxylamine, NH_4OH = Aqua ammonia, NO = Nitric oxide, N_2O = Nitrous oxide, NO_2^-= Nitrite ion, NO_3^-= Nitrate ion, NOH = Nitroxyl, Na_2CO_3 = Sodium carbonate, $NaHCO_3$ = Sodium bicarbonate, $NaHSO_3$ =Sodium bisulfite, NaOH = Sodium hydroxide, O_2 = Free molecular (dissolved) oxygen, OCl^- = Hypochlorite ion, OH- = Hydroxyl ion, PO_4^{2-} = Phosphate

The Hydraulic retention time (HRT) is a measure of the average length of time that a soluble compound remains in a constructed reactor.

"A drain" is in present invention in the meaning of this invention is a pipe or channel that carries off waste fluid, preferably waste water or waste atmosphere from the agriculture system of present invention or it can be the container (the drain storage tank) that contains the waste fluid before its is released from the confined agriculture environments. Eventually some of this drain water can be used to mix it again with water from the clean water basin.

"Chemoautotrophic" bacteria in the meaning of present invention are bacteria that grow by consuming inorganic nitrogen compounds. Many species of nitrifying bacteria have complex internal membrane systems that are the location for key enzymes in nitrification: ammonia monooxygenase which oxidizes ammonia to hydroxylamine, and nitrite oxidoreductase, which oxidizes nitrite to nitrate.

"Photoautotrophic organisms" in the meaning of present invention are organisms, typically a plant, that obtain energy from sunlight as its source of energy to convert inorganic materials into organic materials for use in cellular functions such as biosynthesis and respiration. In order to capture light as source of energy, photoautotrophs carry out photosynthesis, converting energy from sunlight, carbon dioxide and water into organic materials. Photoautotrophs provide nutrition for many forms of life. They include the plants, algae and certain protists bacteria.

"Photoheterotrophs" (or photoorganotrophs) are heterotrophic organisms which use light for energy, but cannot use carbon dioxide as their sole carbon source. Consequently, they use organic compounds from the environment to satisfy their carbon requirements. They use compounds such as carbohydrates, fatty acids and alcohols as their organic "food". Examples are purple non-sulfur bacteria, green non-sulfur bacteria and heliobacteria .

"Anoxygenic" for the present invention is in the meaning of not producing oxygen, especially to describe certain forms of bacterial photosynthesis. The term "anoxygenic" is most often used to describe the form of photosynthesis in purple

bacteria, green sulfur bacteria, green non-sulfur bacteria, and heliobacteria. In this kind of photosynthesis, the electron flow is cyclic with all electrons used in photosynthesis eventually being transferred back to the single reaction centre and oxygen is not produced.

Crops (e.g. plant crops) are in the meaning of this invention of multicellular or unicellular photosynthetic producer organisms for instance plants that are cultured for a particular use for instance for gaining useful biomass. Crops can be chemoautotrophic or photoautotrophic organisms.

Plants photoautotrophic (multicellular or unicellular) organisms belonging to the Plantae.

Glycogen accumulating organisms (GAO are organisms that use energy from glycolysis to accumulate substrate (e.g. glucose) fermentations products (e.g. acetate in the form of poly-hydroxy-butyrate (PHB).

"Polyphosphate accumulating organisms" (PAO) use energy stored in poly-P to store exogenous substrate in the form of poly-hydroxy-butyrate (PHB).

"Activated sludge" concerns the active biological material produced by activated sludge plants and which affects all the purification processes. This activated sludge, which in healthy sludge (healthy activated sludge) which is a brown floc, is largely composed of saprotrophic bacteria but also has an important protozoan flora mainly composed of amoebae, *Spirotrichs, Peritrichs* including *Vorticellids* and a range of other filter feeding species. Other important constituents include motile and sedentary Rotifers. In poorly managed sludge activation, on the other hand a range of mucilaginous filamentous bacteria can develop including *Sphaerotilus natans* which produces a sludge that is difficult to settle and can result in the sludge blanket decanting over the weirs in the settlement tank to severely contaminate the final effluent quality. This material is often described as sewage fungus but true fungal communities are relatively uncommon.

By "nanoparticle" is meant particles having nanometric dimensions, and nanoparticles may have, for example, dimensions in the order of a few nanometres to several hundred nanometres. The nanoparticles may be of a similar size to or smaller size than any given target virus or viruses.

Biofilm for the meaning of this invention is a community of microbials forming at a phase boundary generally, but not always, at a liquid:solid interface. Spatially and temporally heterogeneous. May have specific mechanisms for attachment to surface. Generates EPS for adhesion, protection and to facilitate community interactions.

Bacterial colony for the meaning of this invention is a group of organisms growing on a surface, often fed with nutrient from below and incorporating gas exchange from above. May be a clone formed from a single cell. Shows recognizable pattern, limited morphogenesis and spatial and temporal heterogeneity.

A floc for the meaning of present invention is a loosely associated mixed community of microbials showing irregular radial symmetry and temporal and spatial heterogeneity.

Anaerobic (digester) granules for the meaning of present invention is a reasonably symmetrical radially organized microbial community showing spatial differentiation and metabolic co-operation, often leading to the oxidation of organic substrates, leading in the end to gas such as energy rich methane or as N_2.

Aerobic (digester) granules for the meaning of present invention is a reasonably symmetrical radially organized microbial community, preferably with diameter: 2-8 mm, formed in an aerobic environment and showing spatial differentiation and metabolic co-operation with phosphate removal and anoxic growth in the corn, nitrification in a middle zone and heterotrophic growth in an outer layer.

EXAMPLES

Components of the aquatic farm systems of the present invention

The system of present invention can be in situ monitored by the following hard sensors and on-line analyzers for water analysis and water process monitoring to produce a signal indicative for the measure of a selected biotic or abiotic parameter and control and automatically monitoring the fluid systems of the aquatic farm systems to detect and measure abiotic and biotic parameters; and subsequently at the detection of an unwanted shift van be controlled by a soft sensor system in operational contacts with a programmable actuator adapted to regulate said biotic or abiotic parameter. Several commercially available hard sensors have been identified as particularly suited for the monitoring of the aquatic farm systems of the present invention. The physical arrangement of hard sensor and the soft sensor controller can take many forms including but not limited to the few arrangements described herein.

An aspect of the invention uses a model-based predictive controller based on an adaptive dynamic reactor model to predict a future response of said bioreactors to said interaction physicochemical and/or electrochemical reactors as a function of time and compensates effects of external disturbance on said bioreactors by adjusting said operation rate of said physicochemical and/or electrochemical reactors regulators to achieve a norm status in culture units of the aquatic organisms. The parameter settings are here by adapted by the incoming signal to more closely approximate the dynamic behaviour of the biofilters. Hereby the controller pro-actively compensates a future effect of known current or future disturbances by using said adaptive dynamic model in order to minimise deviation from norm biofilter function and in such way protects the aquatic organisms culture units.

Where the fluid systems are liquid good candidates are of hard sensor, in particular for integration in the sensor network of present invention but are not limited to, are:

Aqueous NH_4^+/NH_3 can be measured using a gas sensing electrode for instance model 95 – 12 Therma Orian, Beverly, MA.

In Situ, reagent less UV spectrophotometry with simultaneous determination of nitrate and nitrite are available for nitrogen cycling in waters. For instance the in situ UV spectrophotometric sensor (ProPS, TriOS GmbH, Oldenburg, Germany) can be used

for the real time, in situ, high resolution simultaneous mapping of nitrate/nitrite (linearity 0.01 – 6 mg N L−1, RSD's NO_3-N 4–10%, NO_2-N 7–14%) in fresh and estuarine waters.

A particular aspect of present invention is a in situ monitoring by the following sensors. In Situ, reagentless UV spectrophotometry with simultaneous determination of nitrate and nitrite are available for nitrogen cycling in waters. For instance the in situ UV spectrophotometric sensor (ProPS, TriOS GmbH, Oldenburg, Germany) can be used for the real time, in situ, high resolution simultaneous mapping of nitrate/nitrite (linearity 0.01 – 6 mg N L−1, RSD's NO_3-N 4–10%, NO_2-N 7–14%) in fresh and estuarine waters.

Conventional pH probe connected to a pH amplifier (e.g. Crison pH Rocon 18) can be used to monitor the pH and the electrical conductivity (EC) with an EC sensor (e.g. Models EC250 & EC350 Stevens-Greenspan) and with dissolved oxygen sensor (Stevens-Greenspan Dissolved Oxygen Sensor). It is particularly suitable to monitor and adjust O_2, pH and electrical conductivity in the injection of acid, base and/or various nutrient mixes in nutrient reservoir tank to the photocatalytic bioreactor. It is also particularly suitable to monitored and adjusted O_2, pH and electrical conductivity in the intensive recirculating system for the culture of aquatic multicellular consumer organism such as aquatic vertebrate animals or aquatic invertebrate animals by in situ analysis and controlled activating of actuators such as injectors of acid, base and/or various nutrient mixes in nutrient reservoir tank to the photocatalytic bioreactor.

A phosphate sensor, for instance the Helios Phosphate Process Buoy (Envitech Ltd), measures phosphate through direct immersion in aeration basins or final effluent. The Stip Helios phosphate process buoy measures phosphate through direct immersion in aeration basins or final effluent. The buoy is filled by the hydrostatic pressure of the water, and emptied by air pressure. This eliminates the need for pumps in the waste water. Valves contact only air, reagents and calibration standards, assuring a high level of reliability. The buoy is equipped with a filtration cell, in which wastewater is separated from sludge and solids before it is fed into the reaction cell. During the phosphate measurement, a low volume of reagent is accurately regulated to assure

high measuring accuracy with low reagent consumption. The buoy automatically calibrates itself daily using the standard addition method, and at the same time compensates for variability in the wastewater. The Helios Phosphate Process Buoy measures phosphate through direct immersion in aeration basins or final effluent. The buoy is filled by the hydrostatic pressure of the water, and emptied by air pressure. This eliminates the need for pumps in the wastewater. Valves contact only air, reagents, and calibration standards, assuring a high level of reliability. The Phosphate Buoy is equipped with a filtration cell, in which wastewater is separated from sludge and solids before it is fed into the reaction cell. During the phosphate measurement, a low volume of reagent is accurately regulated to assure high measuring accuracy with low reagent consumption. The buoy automatically calibrates itself daily using the standard addition method, and at the same time compensates for variability in the wastewater. On the other had the On-Line PO_4 measurement Spectron (Envitech Ltd) is a spectrophotometric analyser for quasi continuous on-line measurement of Phosphate in wastewater. For monitoring and control, the Spectron is equipped with signal outputs of 0-20 or 4-20 mA. A built-in graphical display shows concentration data and other important information, which are stored for the last 14 days. An optional diskette drive provides long-term data storage. The Spectron (Ptotal) is a spectrophotometric analyser for quasi continuous measurement of phosphorus in wastewater. The sample is thermally digested. Then specific reagents are added, which form an intense yellow complex with phosphorus with concentration dependent absorbance between 380 and 480 nm. The analyser is equipped with a diode array spectrophotometer that operates from 380 to 780 nm, and automatically calibrates itself daily using two standards. Both these Spectron analysers have a bypass which is the fast feed loop to the analyser. The peristaltic pump transfers a portion of the sample to the measuring cell, where it is mixed with reagents delivered by the reagent pumps. As the sample and reagent streams mix, they form the yellow colour complex, which is analysed between 380 and 480 nm. In a particular embodiment the farming system comprises at least one ammonia and/or nitrate sensor for sensing ammonium and/or nitrate in the liquids. For instance the AmNiSys ammonia and nitrate measuring system (Envitech Ltd) AmNiSys is a specification ammonia and nitrate

measuring system with true continuous reading for use in wastewater applications which also can accommodate fluorescent DO measurement.

The completeness of the nitrification can also be followed in situ by an ammonium probe (e.g. the "NH_4D sc Ammonium Probe") combined with colorimetric or spectrophotometric nitrite ion and nitrate ion analysis. On the other hand, the GENION 1 (Envitech Ltd) is an on-line analyzer for continuous NH_4^+ measurement using a gas-selective electrode. The analyzer automatically calibrates itself daily using a standard. The bypass is the fast feed loop to the analyzer. The peristaltic pump transfers a portion of the sample to the measuring cell. In the mixing cell wastewater and dilution water are combined. Oil and fat are separated by the rotation of the agitator. The rotating slit is the inlet to the measuring cell and the only flow restriction inside the system. The slit is continuously cleaned by the rotary motion of the axle. In the measuring cell, the NH_4^+ concentration of the wastewater is maintained at a constant, low level. The desired value of the electrode is thus also maintained at a high-sensitivity bias point. The actual value is calculated from the NH_4^+ concentration and the dilution ratio. The measuring point corresponds to the calibration point. Another possibility is the Isco-Stip in-situ process boys for NH_4^+ & NO_3^- (Envitech Ltd). This Process Buoys measure nitrate and ammonium through direct immersion in aeration basins or final effluent. The buoy is filled by the hydrostatic pressure of the water, and emptied by air pressure. This eliminates the need for any pumps in the wastewater. Valves contact only air, reagents, and calibration standards, assuring a high level of reliability. For ammonia measurement the Isco-Stip Process Buoy PBS 1 (NH_4^+) is equipped with a purgeable cell, in which, wastewater is separated from sludge and solids before it is fed into the reaction cell. During the ammonium measurement, the necessary pH value is accurately regulated to assure high measuring accuracy with low reagent consumption. The buoy automatically calibrates itself daily using the standard addition method, and at the same time compensates for variability in the water.

In situ total solids are measured by a spectroscopic sensor, stip-scan of Envitech ltd) with Nitrate , SAC (UV 254) , COD , TOC, Sludge Volume , Sludge Index and Total Solids. The spectroscopic sensor, Stip-scan of Envitech Ltd uses a light spectrum

from 190 to 720 nm with settlement phase can be used for on-line measurement of Total Solids and SVI (Sludge Volume Index) with simultaneous accurate and reliable in-situ measurement of a wide range of parameters such as NO3, SAC(UV 254), COD, and TOC with accommodation the interfering effects of turbidity, colour and "overlapping" absorption spectra.

The biological oxygen demand is measured by a BIOX-1010 apparatus, which is an on-line analyser for continuous BOD measurement (Envitech Ltd). It operates by continuously pumping sampled water through a sample bypass. The peristaltic pump built into BIOX continuously feeds a small stream of wastewater from the sample bypass to the bioreactor. Before it reaches the bioreactor, this wastewater stream is diluted with oxygen-saturated dilution water supplied by a gear pump. Another suitable sensor is the PHOENIX-1010 (Envitech Ltd). It is a does continuous rapid COD measurement which is a procedure for quick analysis of Chemical Oxygen Demand. In the PHOENIX-1010 analyser, this procedure uses ozone for oxidation and thus operates with one of the most powerful oxidizing agents available. The analysis lag time between sample entering the intake and data output is 3 to 15 minutes for a measurement range of 10 to 1500 mg/litre COD. The analyzer automatically calibrates itself each day.

The total oxygen demand (TOC) is analysed in situ for instance by the STIP-toc (Envitech Ltd) is an analytical apparatus that functions as a high temperature TOC analyzer without ultra- or fine filtration. A large sample stream is taken in via an automatically self-cleaning coarse filter in the sample bypass. In the stripping cell, inorganic carbon is removed through acidification and sparging. In the rotating slit filter, a sub stream for analysis is split off directly before the furnace. In the furnace the analysis stream is thermally and catalytically oxidized. After the evolved gas mixture is dried and neutralized, it is measured as CO_2 in the IR detector, and reported as TOC. The system automatically calibrates itself daily with two TOC standards (two point calibration. The Isco-STIP-toc (Envitech Ltd), on the other hand, functions as a high-temperature TOC analyser without ultra or fine filtration. Isco-STIP-toc (Envitech Ltd) is a TOC analysers that functions as a high-temperature TOC analyser without ultra or fine filtration.

In situ Toxicity monitor is used to monitor microbial effects. A suitable sensor is the STIPTOX-adapt (W) (Envitech Ltd), which is a toxicity analyser with immobilized turbulent- bed biology. As in the BIOX-1010, the microbes grow on the inner surface of small hollow cylinders. Like the activated sludge of a treatment plant, the microbial population in the bioreactor is adapted to the conditions of the wastewater. So long as the wastewater is not toxic to the adapted biology, the organisms in the bioreactor take up dissolved oxygen. A toxic impact inhibits the respiration of the organisms, causing an increase in the dissolved oxygen level. If the respiration rate decreases by more than about 20%, an additional dilution of the wastewater is triggered, and is regulated such that the overall depression of microbial activity does not exceed 20%. This protects the microbes and provides the mechanism for toxicity measurement. The mixing ratio of wastewater and dilution water, together with the oxygen difference, are used to calculate the toxicity reading. In an embodiment of present invention the photocatalytic detoxification efficiency and removal of toxic intermediates is sensed in situ by an online toxicity sensor. New reliable and continuous monitors which can provide (near) real-time information on water quality are available. They can be used for control of the water output of a the photocatalytic bioreactor. The chemical analytical monitoring systems identify and quantify specific water contaminants, biomonitoring on the other had gives an indication of the total quality, including the effects of unknown toxic substances. The TOXcontrol, a biological toxicity monitor using luminescent bacteria (Biesbosweg 2 • 5145 PZ Waalwijk), the s::can spectrolyser(™), a submersible UV-VIS spectrophotometer probe (Meßtechnik GmbH), is used to biomonitor and sense the a broad range of quantities of intermediates at low concentrations in the reactor output to guarantee full mineralization. Continuous measurement of acute toxicity in water can be done by a solid state microrespirometer such as the microrespirometer described by Fco. Javier Del Campo et al Sensors and Actuators B: Chemical Volume 126, Issue 2, 1 October 2007, Pages 515-521 which consists of a naturally developed biofilm of *Pseudomonas aeruginosa* over a Nafion modified array of gold microdisc electrodes. They system warns against the presence of toxic substances in the environment where it is placed. MicroLAN BV (Waalwijk, the Netherlands) or microLAN US (Wilmington Delaware, US) combines biomonitor using luminescent bacteria (Vibrio

fischeri) with s::can UV-VIS sensor technology in an integrated system for on-line monitoring and for global effect monitoring for instance the aquatic toxicity. A microbial fuel cell based biosensor generates electrical current as a direct linear measure of metabolic activity of the electrochemically active microorganisms. The microorganisms gain energy from the anodic over potential and a direct control of the over potential allows to detect a toxic event and prevents false positives (Stein, NE et al. Bioelectrochemistry 78 (1): 87 – 91 2010). Solid state microrepspirometers are available for the continued measurement of acute toxicity events in water (Del Campo, F.J. Sensor and actuators B – Chemical 126515 – 521 2007). The photoluminescence biosensors incorporate a biological component coupled to a transducer which translates the interaction between the analyte and the biocomponent into a signal that can be processed and reported (Reardon, KF et al. Optical sensor systems in biotechnology 11699- 123 , 2009) These sensor are particularly suitable for sensing toxicity in an aqueous environment.

On-Line PO_4 is measured online by the Spectron (Envitech Ltd), which is a spectrophotometric analyser for quasi continuous on-line measurement of Phosphate in wastewater. For monitoring and control, the SPECTRON is equipped with signal outputs of 0-20 or 4-20 mA. A built-in graphical display shows concentration data and other important information, which are stored for the last 14 days. An optional diskette drive provides long-term data storage. The SPECTRON (Ptotal) (Envitech Ltd) is a spectrophotometric analyser for quasi continuous measurement of phosphorus in wastewater. The sample is thermally digested. Then specific reagents are added, which form an intense yellow complex with phosphorus with concentration dependent absorbance between 380 and 480 nm. The analyser is equipped with a diode array spectrophotometer that operates from 380 to 780 nm, and automatically calibrates itself daily using two standards. For both systems a bypass is the fast feed loop to the analyser. The peristaltic pump transfers a portion of the sample to the measuring cell, where it is mixed with reagents delivered by the reagent pumps. As the sample and reagent streams mix, they form the yellow colour complex, which is analysed between 380 and 480 nm

The flow of liquid in and from the separate reactors is measured by a flow meter. A flow meter is an instrument used to measure linear, nonlinear, mass or volumetric flow rate of a liquid or a gas. Water flows can be read from permanent flow meters (e.g. type: Bürkert, mod. 8035). Where the fluid systems are gas the flow can be measured by measuring the gravimetric flow rate of that gas with a mass flow meter.

Salinity meters are used to assess the salinity in the watery fluids and the nutrient solutions of the aquatic farming system. There are several types of electronic meters commonly available for measuring the salinity of water or a nutrient solution. The two most popular meters are electroconductivity (EC) and Total Dissolved Solids (TDS) meters. Essentially, an EC meter measures the ability of an aqueous solution to carry an electric current. It does this by measuring the electric current between two electrodes (the electricity flows by ion transport). A nutrient-rich solution will have a higher electroconductivity than a solution with less ionic salts. Microprocessor technology scales the measurement of electroconductivity into either milliSiemens/cm (mS/cm) or microSiemens/cm (mS/cm). EC meters are favoured by commercial growers, simply because they give the best estimate of the strength of a nutrient solution. TDS is the concentration of a solution as the total weight of dissolved solids. These meters are widely used by hobbyists, and actually measure the electroconductivity of a solution. They do this by measuring the electric current between two electrodes. A greater concentration of nutrients will cause the electric current to flow faster than a solution with a lower concentration. Microprocessor technology uses an in-built conversion factor to scale the readout in so-called parts per million (ppm). In situ salinity measurements in can be done with a fibre-optic probes based on a multi-channel axial optical fibre spectrograph (N D´ıaz-Herrera et al. Meas. Sci. Technol. 17 (2006) 2227–2232)

Electrical conductivity and pH. The EC and pH sensors are the simplest form of direct measurement in electrolyte solutions. The EC sensors are used in equipment for the processing of molecular nutrient measure using three equidistant ring-shaped electrodes which are mounted inside reactor tanks or inside water transport system e.g. a water pipe at equal distances. The temperature of the fluid is measured and is used to modify the value of the alternating current (AC) voltage applied between the

central electrode and the ground electrodes as a means of temperature compensation. This AC voltage is typically around 1 V. The AC frequency that may range from 400 Hz to 50 kHz AC voltage is used to avoid polarization of the electrodes. The EC is determined by dividing the AC voltage by the electric current measured between the central electrode and the two end-electrodes. The current ranges from 0.1 to 10 mA. Both end electrodes are connected to each other and to the electrical ground terminal to allow the serial or parallel connection of several EC electrodes in one water supply system. The security is enhanced by using two or more distinct EC electrodes in parallel to provide a check on the functioning of both EC sensors against each other.

The pH of a solution indicates how acidic or basic (alkaline) it is. The pH sensor measures the potential across a thin glass bulb or membrane caused by the difference in activity of H_3O^+ ions (protons) in the electrolyte on one side of the membrane and the measurant on the other side. A gel is generally as an electrolyte, which means that the electrolyte needs no further replenishing. In this way, the slow deterioration of the pH sensor is avoided. The lifetime expectancy of these pH sensors

is about one year. Also for the pH sensing, two or sensors are preferably used , so that one sensor is checked against the other.

Sensors for individual ions. There are also sensors for individual ions available in the art. For instance the Ion-selective Electrode (ISE) is a sensor which converts the activity of a specific ion dissolved in a solution into an electrical potential which can be measured by a voltmeter. The sensing part of the electrode is usually made as an ion-specific membrane, along with a reference electrode. ISEs are used to measure the activity of cations and anions in the root environment. ISE sensors are available for most macro-nutrients, like K^+, Ca^{2+}, NO_3^-, SO_4^{2-}, $NH4^+$ and for Na^+ and Cl^-

hard sensors and on-line analyzers for gas fluid analysis and gas process monitoring and control, in particular for in air measurement which are suitable for the system of present invention:

Several continuous in-situ measurements sensors of gases (H_2, H_2S, CH_4, N_2, O_2, He and CO_2) are in the art to monitor the atmosphere in the confined environments of

present invention which can be integrated to pass the signals to a controller. For multiple atmospheric parameters monitoring multi gas analyser are available. For instance the in-situ FTIR Multi Gas Analyser (Gasmet In-Situ Multi Gas Analyser IS-5) for Emission Control Monitoring (Thomson Environmental Systems- The IS-5 from Gasmet Technologies is an in-situ continuous multi gas analyser, utilising proven FTIR technology. The IS-5 is designed for CEM and process control applications. FTIR technology allows for simultaneous quantification of up to 50 different gas components including H_2O, CO_2, CO, SO_2, NO, NO_2, N_2O, HF, HCL, NH_3, VOC's, Hydrocarbons and Formaldehyde. (Libraries are available for 300 different compounds). Speciation of VOC's is also possible.

An O_2/CO_2 analyser (e.g. infra-red gas analyzer and paramagnetic analyzer) can also be used to determine the atmospheric concentrations of CO_2 and O_2. For instance the O_2 analyzer with zirconia sensor (Cambridge Sensotec) is suitable. There are also fast responding multiple gas analyzer: oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO) in the art (e.g. The Rapidox 3100Cambridge Sensotec). To maintain a defined CO_2 concentration (for instance 1000 µl/L. The controller can actuate the opening of a flow controllers for regulating or a gas flow or mass flow controller (FC) or with a controllable gas flow rate (e.g. from Qualiflow Inc. (e.g. F202-FA-44 V), Boorks Instruments, Sierra Instruments, Inc., Senserion or Bronkhorst High-Tech B.V.). Infrared CO_2 sensor provide precise CO_2 control and fast response by actuators opening of doors or FC's.

Some sensors can specifically measure H_2 and N_2 levels in the atmosphere. For instance the Hydrogen Analyser TG-1500XA-has an excellent sensitivity (no response to other flammable or toxic gases and oxygen is not required) for measuring of H_2 in N_2.

The Fluke 975 simultaneously measures, logs and displays temperature (wet bulb and dew point), velocity, humidity, carbon dioxide (CO_2) and carbon monoxide (CO) levels. Absorption-based humidity sensors are available (Honeywell) which provide both temperature and %RH (Relative Humidity) outputs. Such relative humidity/temperature and relative humidity sensors can be configured with integrated

circuitry to provide on-chip signal conditioning. A controller can active an actuator such as an air fan for internally air circulation in the confined environment to prevent gradients or such as a heat exchange coil connected to hot or chilled water for temperature control. A controller can also active a de-ionized water injector for adaptation of the atmospheric humidity for instance at levels of 70% which in case of discontinued or staggered culture of the plants can eventually not been controlled by the water evaporation from the plants.

These above mention in situ sensors can be used to analyse abiotic factors (e.g. O_2, CO_2, N_2) in a gas or atmosphere that as been stored in a separate buffer tanks or in the atmosphere in the confined environment(s).

The pH turned out to an abiotic factor of major importance in the intensive aquatic farming in recirculating water systems. At least one embodiment of present invention provides the monitoring and control of the hydrogen ion concentration in the water in the environment of the aquatic crops or the roots of the corps and/the aquatic animals of the recirculating culture systems. In an aquatic farming systems aside temperature and oxygen, pH turned out to be most important abiotic factor that exerts great effect in a short period on the aquatic organisms or on the plants which make contact with their root system in the recirculating water (e.g. soilless culture or crop hydroponics or aquatic animals) is the hydrogen ion concentration (pH) of their water environment. Hydrogen ions have the ability to move and combine with other ions, this activity (a_H) is the effect of the active effective concentration (C_H e.g; in gm-moles per liter) and the pH (-log (a_H) or – log γ * C_H) express this concentration or activity. The pH has a major impact in the aquatic farming systems by shifting the equilibrium of chemical reactions in or surrounding the organisms. Moreover the living organisms are directly affected by the pH of their watery culture medium for instance by a pH induced shift in the ammonium/ammonia equilibrium. For instance nutrient uptake by plant's root systems is temperature and pH dependent. Control of the pH in the various units or bioreactor of an aquatic farming system is important in the farming performance.

Attempts have been made to use the drain water of recirculating aquaculture systems to irrigate soilless crops in hydroponics culture systems. However these systems are vulnerable to bio collapse. An embodiment of present invention provides solutions to this problem by control and monitoring system that provides a stable compromised hydrogen ion concentration range (normoPH) for the various le farming and bioreactor units with different pH requirements. The present invention provides in an embodiment a monitoring and control systems of the hydrogen ions concentration in the different units of the recirculating farming system and more particularly in water the makes contact with the aquatic animals, the crops (e.g. the roots systems of the soilless corps) and the condominiums of bioremediating microbials (e.g. the nitrifying bacteria and denitrifying bacteria). Present invention foresees in situ pH mentoring and control in the watery environment of the crop.

The optimal pH values recommended in soilless crops culture or hydroponics: However are usually within the range of 5.0–6.0 to obtain optimal nutrient uptake, while pH values between 6.0 and 7.0 will be still adequate for the majority of crops. High pH values (>7.0) in the irrigation water to the soilless plant culture are undesirable, because Ca and Mg carbonates and orthophosphates may precipitate in the irrigation lines and drippers to the crops. In addition, at pH above 7.2 the proportion of $H_2PO_4^-$ species decreases and that of HPO_4^{2-} increases. Since the $H_2PO_4^-$ ion is much more available to plants than HPO_4^{2-}, high pH may induce P-deficient conditions, even if there is adequate total P in the solution, and high substrate pH may reduce micronutrients availability to plants, because of precipitation reactions. For instance, acidic pHs (below 5.0) may be detrimental to root membranes and may increase the Al and Mn concentrations in the substrate solution to toxic levels. Very low pH (e.g. < 4.5) or high pH (e.g. > 9.0) has a direct severe damaging effect on plant roots affecting the plant growth. The main effects of nitrogen source on soilless-grown plants, is, modification of the rhizosphere pH, availability of further nutritional elements, NH_4^+ toxicity and incidence of physiological disorders such as chlorosis and blossom-end rot (BER). The pH and alkalinity of the watery culture medium in an aquatic farming system for instance in an aquaculture or in a crop hydroponics is thus a major concern for productive and cost effective farming.

In particular when recirculating aquaculture systems are integrated with soilless crops in hydroponics culture systems.

On the other hand, that the rate of nitrification by nitrifying bacteria at a *pH of 5.0 to 6.7* for instance in biofilters is sluggish, increases at a pH of 6.7 to 7.2 but is optimal and more constant at a pH 7.2 to 8.0. Many aerobe nitrifying biofilters, and in particular these that operate as sludge processes, denitrify at a pH close to neutral. Denitrification, on the other hand, for instance in the Denitrifying biofilter: can occur over a wide range of pH values or is relatively insensitive to acidity but may be slowed at low pH. For instance a range of pH values acceptable for proper flock formation by facultative anaerobes and denitrification is 6.5 to 8.5. But to ensure acceptable enzymatic activity of facultative anaerobe and nitrifying bacteria, the pH in the anaerobic tank is preferably maintained at a pH value greater than 7.0. The optimal pH range for denitrification is 7.0 to 7.5. Present invention foresees in situ pH mentoring and control in the watery environment of the condominiums of microbials that generate the bioremediation and generate the energy to drive the systems actuators (e.g. the systems heat pump system).

Aberrant pH in the aquatic environment of an organism induces stress. Stress in a complex organism such as plant or aquatic animal is generally defined as the disturbance of the internal equilibrium (homeostasis) of the organism. Stress on multiple organisms in a condominium can be defined as the disturbance of the equilibrium which such condominium controls and stress on a biosystem of different interacting condominiums can be controlled as disturbance of the equilibrium between this interacting condominiums. Stress on an organism is the first step towards disease occurrence. Stress reduces the resistance of these organisms and makes them more susceptible to diseases which eventually lead to a collapse of the condominium of these organisms and of the biosystem which the condominium of organism controls. Therefore, the extent of stress and the ability of these complex organisms such as aquatic organisms (e.g. fish) and plants to resist and maintain homeostasis are most important for survival and growth. Stressful conditions adversely affect these complex organisms and make them more susceptible to different diseases, presumably due to immunosuppressant. The pH can change the toxicity of molecules in the aquatic

medium on these living organisms and pH in particular affects the ammonium toxicity. For instance un-ionized NH_3 as a percent of total ammonia is temperature and pH dependent (table 1), while the ammonia toxicity to freshwater fish and the ammonia toxicity on the plant roots is temperature and pH dependent as well (table 2). Ammonia can be analysed using a Sension II pH/ISE meter combined with an ammonia electrode. There is a need in the art for NH_4^+ monitoring and control systems and to solve the problem of uncontrolled fluctuations in ammonium toxicity. Present invention provides an ammonium/ammonia removal system that is independent of the bacterial process is such solution in present invention.

Since systems normo-pH is around neutral pH, the in situ pH sensing is particularly useful to monitor recirculating aquatic farming systems to control and maintain such normo-pH. PH electrodes offer a great sensitivity and range ability in the farming process management. The sensor can track a minute change of 0.000000005 in hydrogen ions concentration at pH 7. Conventional pH probes connected to a pH amplifier (e.g. Crison pH Rocon 18) can be used to monitor the pH. The pH sensor measures the potential across a thin glass bulb or membrane caused by the difference in activity of H_3O^+ ions (protons) in the electrolyte on one side of the membrane and the measurant on the other side. The pH can be measured with a standard combination type of sensor and includes a measuring electrode and a reference electrode in the same sensor body. A gel can be used as an electrolyte, which means that the electrolyte needs no further replenishing. In this way, the slow deterioration of the pH sensor is avoided. The lifetime expectancy of these pH sensors is about one year. Two sensors can be used, so that one sensor is checked against the other. .In an embodiment op present invention pH is continued sensed in different reactor unit to feed sensor signals in the processes of a controller to control the pH per bioreactor unit in the farming system or maintain systems normo-pH.

Considering that the optimal pH values recommended in soilless culture are usually within the range of 5.0–6.0. But, nevertheless, pH values between 6.0 and 7.0 are adequate for the majority of crops. Furthermore considering that the rate of nitrification by nitrifying bacteria is at an acceptable rate at pH of 6.7 to 7.2 but optimal and constant at a pH 7.2 to 8.0 it is understandable that a tight control of

hydrogen ions for systems normo-pH is important in the culture water at least in the water that passes from the aquaculture to the hydroponics system or visa versa. A a pH in the watery environment of aquatic animals around 7, preferably pH 6 to 8, more preferably pH 6,5 to 7,5 is suitable for biosecure farming of aquatic animals. Almost all freshwater fish inhabit waters with a pH from 5.0-9.0, with the majority of these inhabiting water with a slightly acidic to slightly basic pH (6-7.5) and freshwater shrimps such *Macrobranchium* species have an optimal pH range of 6.5 and 9.5. A tight control of hydrogen ions in the culture water that passes from the aquaculture to the hydroponics system or visa versa is thus important. There is thus a need in the art to have a proper pH monitoring and a tight pH controller to create a system biosystem normo-pH for the optimal functioning of the biofilters (nitrifying / denitrifying) or other bioreactor in a recirculating aquatic farming system or of a tight controlled pH in separate culture units such as in the aquatic multicellular consumer organisms (e.g. aquatic animals) farming units with its biofilters (aquaculture normo-pH) and in the irrigation water to the plants or plant roots (crop normo-pH). The present invention obtains such tight controlled pH by a controlled integration of different bioreactor units. The control system of present invention can also be used to maintain a different normo-pH in the aquaculture unit (aquaculture normo-pH or slightly acidic to slightly basic pH (6-7.5)) than the plant normo-pH (range of 5.0–6.0) at the root of the plants in the soilless or hydroponics crop culture. Such systems normo-pH, is a pH value between 6- 8, preferably 6.5 to 7.5 and most preferably 7.7 to 7.2. This is very difficult to maintain only by driving on biological systems in an uncontrolled manner. Because there is a major impact of a pH out the ranges of systems normo-pH or system normo-hydrogen ion activity on the toxicity and the stress in the condominiums of different organisms leading to a disturbance of the equilibrium of the biosystem that these condominiums control, there is thus a need in the art to have a proper pH control for the optimal functioning of the nitrifying biofilters or bioreactor in a recirculating aquatic farming system and there is in particular a need for a tight control of pH (hydrogen ion activity) to maintain a condition of system normo-pH or systems normo-hydrogen ion activity in recirculating aquatic farming systems of aquatic vertebrate or invertebrate animals and hydroponics or soilleness plant culture that are connected via bioreactor bacterial loop of nitrifying bacterial

and denitrifying bacterial condominiums and that exchange water. This is very important to prevent collapse of homeostasis in single organism or in the condominiums of organisms of the recirculating farming system.

Nitrification bio filters are commonly used in recirculating aquatic animal farming systems. They are however not a common practice in soilless crop culture. By in an embodiment of present invention integrating the recirculating aquatic animal farming systems with recirculating soilless crop culture we face new problems of biosecurity and maintaining biosystem equilibrium. The pH monitoring and control was found important to realise such integration of nitrifying biofilters in this integration. The pH or concentration of hydrogen ions has an effect on the condominiums of aerobic nitrifying microbials and function of such in the aerobic nitrifying reactor unit or the aerobic nitrifying zone of a nitrifying reactor unit. Such nitrifying bioreactor or nitrifying zone in bioreactors are generally used to convert the ammonia and nitrite ions (that are at relatively low concentrations toxic for aquatic vertebrate and invertebrate animals but also for the photosynthetic cyanobacteria and plants) to less toxic nitrate nutrients. It can be operational run a ammonium oxidation in two consecutive stages: ammonium to nitrate oxidation $NH_4^+ + 1.5\ O_2 \rightarrow NO_2^- + 2H^+ + H_2O$ (e.g. by *Nitrosomonas europaea*) and nitrite to nitrate $NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$ (e.g. by *Nitrobacter winogradskyi* e.g. strain Nb-255) whereby dissolved oxygen is removed from the water by the bacteria and added to the ammonium ions and nitrite ions. These processes are generally energy consuming by the need of continued aeration or oxygenation. Optimal temperature range for nitrification is about 28°C to 32 °C while at 16 °C the nitrification is approximately 50% of nitrification rate at 30 °C. The pH of the medium has been reported to be another most important influencing factor in nitrification processes, and the tendency for nitrification rates to decrease under acid conditions, is generally recognised. An acidic pH causes low concentrations of carbonates, and a lack of the carbon sources required for microbial growth could be the direct cause of the reduction of nitrification rates. A drop in pH may shut down the nitrifying biofiltering operation resulting into an accumulation of ammonium and/or nitrite. Similar to the effect of temperature, NO_2-oxidising bacteria were found to be more sensitive to acidic conditions than the NH_4^+ oxidisers, and

accumulation of toxic levels of nitrogen dioxide ($NO2^-$) under low pH has been reported. The pH has a direct impact on the oxidation process of NH_4^+ to NO_2^-, as H^+ is a product of this reaction, and consequently, accumulation of free protons in the solution inhibits further oxidation of NH_4^+. Moreover there are direct effects of pH on microbial activity, or the size or composition of populations of microbials. Changes in pH frequently induce changes in additional vital features, for example membrane permeability, nutrient availability and element toxicity. There is a need in the art for pH monitoring and pH control systems of the nitrification bio filters that are integrated in recirculating aquatic farming systems with bioreactor units or condominiums of organisms that affect the pH in the watery medium that is fed to the nitrification bio filters. Moreover there is a need in the art for pH monitoring and pH control systems of the other than condominiums of organisms that are integrated in recirculating aquatic farming systems with nitrifying bioreactor units or nitrifying condominiums of organisms and that receive aquatic medium from such nitrification bio filters or of such nitrifying condominiums of organisms. Nitrifying condominiums of organisms affect the pH in the watery medium that is fed to the nitrification bio filters. For instance the there is an effect of the aerobic nitrifying reactor unit on the pH and alkalinity: Furthermore, alkalinity is lost during aerobic nitrification. This loss occurs through the use of alkalinity as a carbon source by nitrifying bacteria and the destruction of alkalinity by the production of hydrogen ions (H^+) and nitrite ions during nitrification. Hydrogen ions are produced when ammonium ions are oxidized to nitrite ions. Alkalinity loss during nitrification, thus occurs through the use of alkalinity as a carbon source by nitrifying bacteria. But significantly more alkalinity is lost through the oxidation of ammonium ions namely the destruction of alkalinity by carbon dioxide (CO_2) consumption for autotrophic growth, the production of hydrogen ions (H^+) and nitrite ions by the process. Significantly more alkalinity is lost through the oxidation of ammonium ions than through the use of alkalinity as a carbon source. When hydrogen ions are produced during the oxidation of ammonium ions, nitrous acid (HNO_2) also is produced. Nitrous acid destroys alkalinity. The amount of nitrous acid and nitrite ions produced is dependent on the pH of the aerobic bioreactor. Approximately 7.14 mg (theoretical) of alkalinity as $CaCO_3$ are destroyed per milligram of ammonium ions oxidized. As

alkalinity is lost (e.g. activated sludge process) and the pH of the aerated nitrification tank drops below 6.7, a significant decrease occurs in nitrification. Therefore it is important to maintain an adequate amount or residual buffer of alkalinity in the aeration tank to provide pH stability and ensure the presence of inorganic carbon for nitrifying bacteria. It is important for successful nitrification for instance in an activated sludge process that it can be adequately buffered with alkalinity to counteract its tendency to become more acidic over time through nitrification. This poses a limiting factor on the water recirculation and forces the farmers of aquatic animals in recirculating systems to quickly remove particulate and colloidal BOD. Current recirculating aquaculture systems depends currently on fast mechanical removal of the particulate and colloidal organic matter to reduce the biofiltering needs and combine this with aerobic nitrification of the solved nitrogen compounds to remediate the toxic ammonia to less toxic nitrates. And furthermore at least 10% of the culture water is replaced by clean water daily. This release of nitrate waste has a negative impact in the environment. Present invention, solves this problem by combining condominiums of organisms in the recirculating aquatic farming systems to solve this problem of nitrate environmental waste by controlling biosystem equilibrium in a biosystem of recirculating fluids between communicating condominiums of organisms that remediate the nitrate into useful biomass or energy. However it is demonstrated that a monitoring and control of the pH in the condominiums of the communicating bioreactors (e.g; microbial biofilters, the aquatic animal unit and the soilless crop unit) is important to increase biosecurity and to avoid biosystems collapse.

A solution in the art to rebuild alkalinity is the addition of alkalis for alkalinity addition to control pH. Such alkalis are for instance the compounds of the group consisting of sodium bicarbonate ($NaHCO_3$ Baking soda), Calcium carbonate ($CaCO_3$ Calcite), KOH, limestone, whiting chalk, sodium carbonate (Na_2CO_3 Soda ash), calcium hydroxide ($Ca(OH)_2$ Lime), Sodium hydroxide and 50% NaOH (Caustic soda). Hydroponics greenhouse systems are generally foreseen with stock solution of nutrient/fertilizer which are provided with an extra acid or base solution for pH correction. An extra amount of an acid or base solute can be used to control pH of the

batch of nutrient solution in the mixing tank diluter/dispenser units wherein the concentrated fertilizers are diluted to a nutrient solution to be taken up by the plant. But such hydroponics greenhouse do generally not have microbial nitrifying bioreactors and only recycle a part of there drain water to avoid the negative effects of mineral accumulation crop root. Furthermore the addition of alkalis is limited. Sodium, for instance, is an element that is at higher concentration damaging to the plant, the sodium concentration in the water to the plant roots should be less than 0.5 mmol l^{-1}. It has been shown that high salinity and high sodium concentration displace calcium from membrane-binding sites, and so cause malfunctioning and alteration of the membrane permeability and selectivity in plants. Since the addition of chemicals such as sodium bicarbonate ($NaHCO_3$ Baking soda), calcium carbonate ($CaCO_3$ Calcite), KOH, limestone, whiting chalk, sodium carbonate (Na_2CO_3 Soda ash), calcium hydroxide ($Ca(OH)_2$ Lime), sodium hydroxide and 50% NaOH (Caustic soda) in the aquatic medium of the soilless crop bioreactor from stock solutions to rebuild alkalinity can have negative effects on the condominiums of other organisms in the aquatic recirculating systems this will limit the water reuse. There is a need in the art for other pH control actuator that those based on the addition of alkalis. Present invention solves such problem by the integration of communicating condominiums of bioremediating microbials that do not build of the alkalis and aid to the control of a normo-pH.

pH fluctuations in the aquatic recirculating farming systems can result in a biosystems collapse. On the other hand condominiums of living organism in the watery medium or the plants that contact the watery medium with their roots will in the aquatic farming system each modify the pH and/or alkalinity of their watery environment. Instability of a certain condominium of microbial in the aquatic farming system will have a major impact on the pH and/or alkalinity affecting the other condominiums and eventually rendering them instable as well or inducing them to collapse. For instance such nitrification can be disturbed by several factors. A relatively small increase of inhibitory compounds can cause dramatic changes in the growth of nitrifying bacteria. There are several forms of inhibition (short-term (acute) or long-term (chronic) loss of enzymatic activity) and toxicity (permanent loss of

enzymatic activity or irreversible damage) to cellular structure that may occur during nitrification, resulting significantly lower the rate of reproduction of nitrifying bacteria, resulting in a ''washout'' of the population through the loss of bacteria in the secondary effluent or sludge wasting. Free ammonia, for instance, inhibits *Nitrosomonas* and *Nitrobacter*. It can inhibit *Nitrosomonas* at concentrations as low as 10 mg/l. and *Nitrobacter* at concentrations as low as 0.1 mg/l. The accumulation of nitrite ions is due to partial inhibition of enzymatic activity within nitrifying bacteria. This inhibition prevents the rapid oxidation of nitrite ions to nitrate ions. This can occur by operational factors responsible for this inhibition such deficiencies in key nutrients, excess ammonium ion concentration as well as excess cBOD, inhibitory and toxic wastes, the pH changes and temporary low dissolved oxygen level and ultraviolet radiation or harmful light. Nitrite ions in relatively low concentrations may be toxic to many aquatic organisms, including bacteria. With decreasing pH, nitrite ions are more easily converted to free nitrous acid. The conversion of nitrite ions to free nitrous acid and its accumulation are a function of nitrite ion concentration and aeration tank pH. Nitrous acid further destroys the alkalinity. There is a need in the art for pH monitoring and control systems and systems to prevent nitrite ions accumulation and to avoid biofilter wash out. This is especially the case if the farming systems are designed to integrate aquaculture with plant hydroponics or soilless crop culture.

Another condominium of bacteria with anoxic respiration with reduction of nitrite ions and nitrate ions (oxygen removed from the ions), mostly facultative anaerobes (for instance in anaerobic respiration bioreactor) for instance denitrifying bacteria can compensate lost alkalinity or in part restore alkalinity. These organisms have the enzymatic ability to use free molecular oxygen, nitrite ions, or nitrate ions to degrade cBOD. Denitrifying bacteria degrade cBOD using nitrite ions and nitrate ions in the absence of free molecular oxygen. These bacteria degrade cBOD in order to obtain energy for cellular activity and carbon for cellular synthesis (growth and reproduction). Alkalinity is for instance produced when organic nitrogen compounds are deaminated and nitrate ions are destroyed during denitrification. The hydroxyl ion (OH^-) and some of the carbon dioxide produced during denitrification are returned to

the activated sludge process as alkalinity. The present invention provides control systems to balance aerobic nitrification and anaerobic denitrification or anoxic respiration with reduction of nitrite ions and nitrate ions. In an embodiment of present invention the recirculating aquatic farming comprises in situ hard sensors, preferably continued sensors, that produce a signal indicative of pH, aqueous NH_4^+/NH_3, aqueous nitrate or aqueous nitrite in a microbial condominium, preferably microbial condominium in biogranules, and preferably comprising microbials of the group consisting of Brocadia, Kuenenia, Anammoxoglobus, Scalindua and Planctomycetes whereby their output signals are processed online in a processor that controls a programmable actuator adapted to regulate the proportion of aqueous nitrate versus aqueous nitrite and a control system is adapted to regulate the rate of removal of addition of H_4^+/NH_3, aqueous nitrate or aqueous nitrite. In a preferred embodiment a model-based predictive controller based on an adaptive dynamic microbial condominium model can predict a future response of said condominium's pH to said administration or removal rate of said aqueous NH_4^+/NH_3, aqueous nitrate or aqueous nitrite as a function of time and compensates effects of external disturbance on said condominiums' pH by adjusting said administration rate of said aqueous NH_4^+/NH_3, aqueous nitrate or aqueous nitrite to achieve a status of normo-PH and maintained alkalinity in said microbial condominium and the parameter settings are adapted by the incoming signal to more closely approximate the dynamic nitrogen behaviour of the microbial condominium. The programmable actuator can be an inflow controller of clean water, water of the aquatic animal farming unit, water of the soilless crop farming unit water that has been processed in a photocatalytic unit. The control system can furthermore comprise a continuous feedback of said condominiums' pH that is under control and the controller can be feedback controller based on an adaptive dynamic condominium model. In the most preferred embodiment the control system strives to nitrite/ammonium ratio of 1 or equimolar amounts of NH_4^+/NH_3 and nitrite in to watery environment of the condominium of bacteria for instance by partial ammonium removal, nitrate to nitrite reduction (e.g. photochemical-induced reduction), or partial nitrification of ammonium to nitrite to achieve optimal maintenance of the alkalinity. External disturbance can be one selected from the group of disturbances consisting of: increased or decreased input of inhibitory compounds,

toxicity, bacterial washout, deficiency of essential nutrients, change in nutrient intake, temperature change, nitrous oxide (N_2O), microbial contaminants, redox potential change, change in carbon availability and excess in cBOD. The adaptive dynamic condominium model can be based on a low-order (N)ARX-model or it can be based on a state-space model. Furthermore prefiltered input and output variables (i.e. instrumental variables) can be used to estimate the model parameters. In a particular embodiment this system is configured to maintain H4+/NH_3 and nitrite in to watery environment of the condominium of bacteria in about equal amounts to enhance anaerobic oxidation of ammonium. The system is configured to maintain normo-pH in the reciculating aquatic farming system. Loss of pH and a shift from systems normo-pH (systems normo-hydrogen ion activity) in integrating recirculating aquatic farming systems of aquatic vertebrate or invertebrate animals with hydroponics or soilless plant culture with a bacterial loop of nitrifying bacterial and denitrifying bacterial condominiums can occur due to denitrification malfunction.

In an additional embodiment of present invention the security of the biosystem is further improved and secured by an in situ measurement of nitrous oxide to predict pH collapse. The nitrous oxide can be measured in the gas exit of a nitrifying bioreactor or of a bioreactor with an anoxic or anaerobic zone. In a particular embodiment of present invention nitrous oxide is in situ sensed. For instance a nitrous oxide sensor to quantify nitrous oxide in a nitrous oxide, oxygen and nitrogen gas mixture or directly into the water environment of such bioreactor.

The signal produced by the nitrous oxide sensor indicative for instability in the microbial condominium for instance by external disturbance can be processed online in a processor that controls the programmable actuator adapted to adaptive dynamic microbial condominium model can predict a future response of said condominium's pH to said administration or removal rate of said aqueous NH_4^+/NH_3, aqueous nitrate or aqueous nitrite as a function of time and to compensate the effects of external disturbance on said condominiums' pH. Nitrous oxide sensors are available in the art. For instance the Unisense nitrous oxide microsensor is a miniaturized Clark-type nitrous oxide sensor with a guard cathode designed reliable and fast measurements at high spatial resolution. The Unisense nitrous oxide microsensor is equipped with an

oxygen front guard making it insensitive to oxygen. In situ measurements of nitric oxide in exhaust of a denitrifying bioreactor is possible using a sensor based on a widely tuneable external-cavity GaN diode laser (Thomas N. et al. Applied Optics, Vol. 46, Issue 19, pp. 3946-3957) or by microsensors (Andersen K, Kjaer T, Revsbech NP (2001) An oxygen insensitive microsensor for nitrous oxide. Sensor Actuat B-Chem 81:42–48). The production and release of nitrous oxide usually occurs under strongly fluctuating conditions or when denitrifying bacteria are adversely affected. The amount of nitrous oxide released is relatively small. Nitric oxide is not ordinarily released from the bacterial cells and is this indicative for biofilter instability. The Unisense N_2O sensor can directly measure levels of dissolved N_2O in aqueous environments and is not sensitive to O_2. In an embodiment op present invention N_2O is continued sensed to feed sensor signals in the processes of a controller warn for bioreactor instability and to react to control the pH per bioreactor unit in the farming system or to maintain systems normo-pH.

The alkalinity rebuild is important because much alkalinity is lost in the activated sludge process during nitrification. Approximately 50% of the alkalinity lost during nitrification is returned during denitrification. The amount of alkalinity produced or returned to an activated sludge process during denitrification is 3.57 mg as CaCO3 per milligram of nitrate ions that are reduced to molecular nitrogen. The amount of alkalinity produced or returned to an activated sludge process during denitrification is 3.57 mg as $CaCO_3$ per milligram of nitrate ions that are reduced to molecular nitrogen. This amount of alkalinity that is returned during denitrification is approximately one-half the amount of alkalinity that is lost during nitrification. The net alkalinity change in an activated sludge process through bacterial activity is a function of organic-nitrogen compounds deaminated, ammonium ions converted to nitrite ions, ammonium ions assimilated into new cells or Mixed Liquor Volatile Suspended Solids (MLVSS), and nitrate ions destroyed during denitrification. Denitrification removes nitrogen from the wastewater by converting it to insoluble gases that escapes to the atmosphere. This nitrogen-containing gas is insoluble in wastewater and escapes to the atmosphere. When nitrite ions and nitrate ions are reduced to ammonium ions inside the bacterial cell, the nitrogen in the ammonium

ions is incorporated into cellular material. This reduction of nitrogen is termed "assimilatory" nitrite or nitrate reduction. Assimilatory nitrite reduction and assimilatory nitrate reduction do not remove nitrogen from the wastewater. Condominiums of denitrification can thus be used in a controlled manner to compensate at least the alkalinity destruction by the nitrifying bacterial condominiums if the stability of such bacterial system is controllable. The stability of such cooperating nitrifying and denitrifying bacterial system is critical and difficult to guarantee in recirculating aquatic farming systems wherein the equilibrium is multifactorial. There are several operational factors that strongly influence denitrification such as the presence of substrate (cBOD), the absence of free molecular oxygen, the presence of an adequate and active population of denitrifying bacteria, pH, temperature, nutrients, and redox potential, whereby the an important factor is the presence of substrate or readily available carbon and the absence of free molecular oxygen. Besides molecular nitrogen, nitrous oxide (N_2O) is produced during denitrification from nitrite ions and nitrate ions. Nitrous oxide also is produced and released by denitrifying bacteria. Nitrous oxide sensor to quantify nitrous oxide in a nitrous oxide, oxygen and nitrogen gas mixture or directly into the water environment of such bioreactor that nitrous oxide sensors are available in the art. For instance the Unisense nitrous oxide microsensor is a miniaturized Clark-type nitrous oxide sensor with a guard cathode designed reliable and fast measurements at high spatial resolution. The Unisense nitrous oxide microsensor is equipped with an oxygen front guard making it insensitive to oxygen. In situ measurements of nitric oxide in exhaust of a denitrifying bioreactor is possible using a sensor based on a widely tuneable external-cavity GaN diode laser (*Thomas N. et al. Applied Optics, Vol. 46, Issue 19, pp. 3946-3957*) or by microsensors (*Andersen K, Kjaer T, Revsbech NP (2001)* An oxygen insensitive microsensor for nitrous oxide. Sensor Actuat B-Chem 81:42–48). The production and release of nitrous oxide usually occurs under strongly fluctuating conditions or when denitrifying bacteria are adversely affected. The amount of nitrous oxide released is relatively small. Nitric oxide is not ordinarily released from the bacterial cells and is this indicative for biofilter instability. The Unisense N_2O sensor can directly measure levels of dissolved N_2O in aqueous environments and is not sensitive to O_2. An embodiment of present invention foresees

in situ measurement of nitrous oxide and to feed the signals of said sensor to a controller to predict aerobic biofilter collapse. Moreover the present invention optimally uses the integration of aerobic nitrification and denitrification to save on oxygenation cost and maintain the alkalinity. The production and release of nitrous oxide usually occurs under strongly fluctuating conditions or when denitrifying bacteria are adversely affected. Since in the system of present invention, at least one bioreactor with condominiums of denitrifying bacteria is introduced to compensate at least in part the alkalinity reducing effect of the condominiums of denitrifying bacteria we hypothesized that the increase of nitrous oxide in said the denitrifying bioreactor is a sentinel or early warning before the denitrifying bioreactor loses its compensatory alkalinity rebuilding effect. An embodiment of present invention integrates such in situ nitric oxide sensor in a sensor network of the aquatic pH, nitrate, nitrite and ammonium to control actuators that control ammonium, nitrate and nitrite proportions.

It is a particular embodiment of present invention to have the nitrifying condominiums which decline alkalinity and reduce pH are compensated by the alkalinity building up and pH increasing activity of the denitrifying condominiums. This can be achieved under control of a hard and soft sensing system. These condominiums can be in different bioreactor units or can be in different zone of the same bioreactor system. For instance present invention provides a security ammonium removal system to reduce the ammonium-ion toxicity and to maintain the pH at systems normo-pH by switching on alternative ammonium removal. Moreover an embodiment of present invention the pH monitoring system is organised to maintain a dual pH regime of an aquaculture normo-pH and a crop normo-pH in the plant culture unit for instance in the hydroponics or soilless plant culture. A sensor network with hard sensors (pH sensors) monitor the different bioreactor (plant culture, aquatic animal culture, microbial nitrification / denitrification) and balance their pH and alkalinity effects towards normo-PH (system normo-pH or aquaculture normo-pH in combination with crop normo-pH).

Particularly suitable for the recirculating intensive aquatic farming system (IRAFS) of present invention is a bioreactor systems that integrates nitrification and denitrification processes. The hard sensors can measure N_2O, NH_4^+/NH_3, NO_2^- and NO_3^- and feed a signal representative for the measurement to a processor with a model based controller to activate if required the bioreactor system to transfer ammonium and nitrite directly into N_2 while preserving the alkalinity (e.g. by modulating the ammonium / nitrite proportion in the water to be treated). Using the biofilm forming capability of various microorganisms and under hydrodynamic shear force, turbulence or an up flow gas velocity of more than 1.2 cm/s biogranules (diameter: 2-8 mm) are formed in an aerobic or anaerobic conditions, e.g. in the granular sludge blanket bioreactor. Even in the presence of molecular oxygen, the biogranules will comprise an outer zone of heterotrophic growth (COD + $O_2 \rightarrow CO_2 + H_2O$), hereunder a nitrification zone ($NH_4 + O_2 \rightarrow NOx$) and in the core an anoxic zone capable of phosphate removal (COD + NOx + $PO_4^{3-} \rightarrow N_2 + CO_2 + H_2O$ + poly-P). The turbulence is preferably carried out by rotors instead of direct aeration to form more stable biogranules. Aeration or oxygenation is preferably done in a separated tank that feeds its water into the tank or bioreactor with the biogranulation process. The bioreactor with the microbial granules can be up flow sludge blanket reactor (AUSB) whereby the reactor contents are kept in turbulence for instance by a rotor. Poor settable granules being removed in a discontinued a sequencing batch reactor (SBR) with settling periods or a continued process.

If the pH in the aquatic farming systems drops to a critical level or of the norm-pH and the denitrification can not cope with the acidifying nitrification process, the system of present invention with control the bioreactor to work on direct transformation of ammonium ions in N_2 The farming system of present invention can in an embodiment be foreseen with alternative ammonium removal systems to response to a change in for instance ammonium toxicity, pH and a change in NO_2 production in the bioreactor units. Such ammonium removal systems can be alternative microbial roots or can be non microbial physical systems with and actuator that responds to a signal from a controller. An embodiment of invention provides a

hard sensing means for sensing NO_2. NO_2 is indicative for an unstable denitrification process and adds to acidification and alkalinity breakdown by the aerobic nitrification process. Moreover NH_4^+/NH_3 and NO_2^- are preferably in situ measured to control adequate ammonium and nitrite to N_2 conversion.

Nitrification is operationally run by an ammonium oxidation in two consecutive stages: ammonium to nitrate oxidation $NH_4^+ + 1.5\ O_2 - NO_2^- + 2H^+ + H_2O$ (e.g. by *Nitrosomonas europaea*) and nitrite to nitrate $NO_2^- + 0.5\ O_2 - NO_3^-$ (e.g. by *Nitrobacter winogradskyi* e.g. strain Nb-255) whereby dissolved oxygen is removed from the water by the bacteria and added to the ammonium ions and nitrite ions. During the nitrification process nitrogen and oxygen is used as an electron donor. In the nitrification process the destruction of alkalinity by the production of hydrogen ions (H+) and nitrite ions during nitrification. Hydrogen ions are produced when ammonium ions are oxidized to nitrite ions. Alkalinity loss during nitrification thus occurs through the use of alkalinity as a carbon source by nitrifying bacteria. But significantly more alkalinity is lost through the oxidation of ammonium ions namely the destruction of alkalinity by carbon dioxide (CO_2) consumption for autotrophic growth, the production of hydrogen ions (H^+) and nitrite ions by the process. Significantly more alkalinity is lost through the oxidation of ammonium ions than through the use of alkalinity as a carbon source. When hydrogen ions are produced during the oxidation of ammonium ions, nitrous acid (HNO_2) also is produced. Nitrous acid destroys alkalinity. The amount of nitrous acid and nitrite ions produced is dependent on the pH of the aerobic bioreactor. Approximately 7.14 mg (theoretical) of alkalinity as $CaCO_3$ are destroyed per milligram of ammonium ions oxidized. As alkalinity is lost (e.g. activated sludge process) and the pH of the aerated nitrification tank drops below 6.7, a significant decrease occurs in nitrification resulting in a possible collapse. It could be demonstrated that such alkalinity loss can drastically be decreased or prevented in the IRAFS by bioreactor systems that combine nitrification and denitrification in particular if such can be switched to a mode at least in part of direct ammonium and nitrite to N2 conversion. In an embodiment of present invention the aquatic farming system is provided with a unit that switch to an anaerobic ammonium oxidation instead. Hard sensors that measure a pH drop and /or measure

an increase in nitrous acids in the nitrification bioreactor can activate an actuator to switch that bioreactor operates on a mode of partial nitrification or anaerobic ammonium oxidation. Aerobic oxidation of ammonium is switched to ammonium oxidation under of conditions limited molecular oxygen (O2). For instance a sensor that picks up a signal of NO_2 increase will provide a signal to a computer compressor with a controller or to a controller to provide signals to activate such activator. One such actuation is preventing that nitrite and oxygen are available as electron acceptors. Under this lower pH anaerobic ammonium oxidation can be induced by imposed CO_2 and O_2 limitation such that the nitrite is used as a oxidant to ammonia forcing the bioreactor to operate in partial nitrification with the direct transformation of ammonium ions in N_2 or simultaneously transforming nitrite and ammonium into in N_2 (NH_4^+ NO_2^- → $N_2 + 2H_2O$). Van Cleemput, O., and L. Baert. and Smith, D. H., and F. E. Clark demonstrated that NH_4^+ and NO_2^- under low pH and under an NO atmosphere (to prevent decomposition of nitrite) have been demonstrated to produce N_2 from ammonium and nitrite been confirmed (*Van Cleemput, O., and L. Baert. 1984. Plant Soil 76:233–241 and Smith, D. H., and F. E. Clark. 1960. Soil Sci.90:86–92*) a process of anaerobic ammonium oxidation that dad also been suggested by Engelbert Broda (1977) Mulder, Arnold described anaerobic ammonium ion oxidizing microorganisms (*US5078884 A (1992)*) in which ammonium ion is used as electron donor in the denitrification whereby for the ammonium ion oxidation no extra carbon-source is necessary to achieve denitrification and of course less oxygen is required than for aerobic ammonium oxidation. Van de Graaf et al confirmed in a denitrifying fluidized bed reactor that this direct conversion of ammonium to dinitrogen gas without oxygen and with nitrite as the electron acceptor ($NH_4^+ + NO_2^- \rightarrow 2H_2O + N_2$) is a bacterial process (Van de Graaf et al Microbiology, Apr. 1995, p. 1246–1251). Important nitrogen losses (40 – 70 %) hde been observed earlier in rotating biological contactor bt Baumgarten and Seyfried, 1996 (*Baumgarten and Seyfried, 1996 G. Baumgarten and C.F. Seyfried, Water Science and Technology 34 (7–8) (1996), pp. 445–453*) under low dissolved oxygen conditions, which were not due to heterotrophic denitrification but due to direct biological conversion of ammonia to nitrogen in (micro)aerobic conditions (aerobic deammonification), probably because there are both aerobic conditions in the outer biofilm and anoxic conditions at the core

of the biofilm. If ammonium is first partially oxidized to nitrite, then the remaining ammonium can be further transformed into dinitrogen (N_2) by *planctomycete* like bacteria (bacterial of the phylum plantomycetes) such as the genera *Planctomyces* and *Pirellula*, growing in anaerobic zones of a treatment system. Such bioreactor can host for instance *Brocadia, Kuenenia, Anammoxoglobus* and/or *Scalindua*. The anaerobic ammonium oxidation is a method comprising converting a part of ammonium to nitrite by nitrite-type nitrification reaction using ammonium oxidizing bacteria, with ammonium as an electron donor and nitrite as an electron acceptor, and simultaneously denitrifying the nitrite and the remaining ammonium using anaerobic ammonium oxidizing bacteria without requiring an addition of extra organic substance (such as methanol). The anaerobic ammonium oxidation requires only a small amount of oxygen in nitrification reaction, does not require an organic substance (such as methanol) in denitrification reaction, and thus can be operated at a considerably reduced running cost, advantageously. Present invention demonstrates that a proper amount of nitrite can be maintained by reducing nitrate to nitrite for instance by heterotrophic denitrifying bacteria or by a catalyst e.g. Pt–Cu/Al_2O_3, molybdenum-mediated atom transfer or Ag/TiO_3. If nitrate is produced into nitrite for instance by such reduction than the ammonium and nitrite under anoxic or anaerobic condition can easily been denitrified into dinitrogen gas. An embodiment of present invention provides in a IRAFS such in a catalytic reactor in a water unit that feeds its water to the microbial bioreactor. Another useful system, which can be combined with the photocatalytic reduction of nitrate to nitrite is an aerobic bioreactor for partial oxidation of ammonium into nitrite (partial nitrification of ammonium under aerobic oxidation conditions or nitrite-type nitrification reaction using aerobic ammonium oxidizing bacteria) preferably with oxygenation and stirring or fluidizing . This aerobic bioreactor is provided with an outflow of NO_2-N and NH_4-N (preferably in equal proportions) to a second bioreactor with limited oxygen wherein nitrite acts as the electron acceptor for oxidation of ammonium to dinitrogen gas ($NH_4^+ + NO_2^- \rightarrow 2H_2O + N_2$). For the second reaction of limited oxygen the microbial can be enrichment in a biofilm system to prolong the sludge age or the bioreactor can drive on granular sludge for instance in a sequencing batch reactors (SBR) or in gas-lift-loop reactors. Alternatively the partial oxidation of ammonium into nitrite (partial

nitrification) and the anaerobic or anoxic oxidation of ammonium and nitrite to dinitrogen (N_2) gas can be in a multiple gas lift reactor with a serious of gas lift components. The partial nitrification (nitrite-type nitrification reaction) is carried out by immobilized autotrophic nitrifying bacteria in the aerobic zone part and in the second anaerobic zones part immobilized ammonium oxidizing bacteria. Anaerobic ammonium oxidation converts ammonium and nitrite further into dinitrogen. In an embodiment of present invention the first bioreactor is replaced by a photocatalytic reactor to convert ammonium and nitrite into dinitrogen. Alternatively the bioreactor actuator is single-stage aerobic bioreactor with intermeshing aerobic, anoxic, and anaerobic zones with completely autotrophic nitrogen removal over nitrite, The intermeshing aerobic, anoxic, and anaerobic zones provide habitat for the coexistence of different microbial communities (stoichiometry: NH_4^+ 0.85 $O_2 \rightarrow$ 0.435 N_2 + 0.13 NO_3^- + 13 H_2O + 1.4 H^+). Changes caused by the NH_4^+-limitation are completely reversible, and the system can re-established itself as soon as the ammonium limitation is removed even enduring periods of up to one month of ammonium limitation without irreversible damage. The process can be achieved in both continuous (the continuously-aerated SBBR.) and intermittent aeration pattern (the intermittently-aerated sequential batch biofilm reactor (SBBR)). In an embodiment of present invention the system comprises a first aeration tank, that delivers water to the first aerobic bioreactor for partial oxidation of ammonium into nitrite which provides NO_2-N and NH_4-N in near to in equal proportions to the second bioreactor with limited oxygen, whereby the first and second bioreactor are respectively a aerobic and an anaerobic biogranulation tank. In such embodiment of present invention anaerobic ammonium oxidation is induced in bioreactor wherein the biofilm forming microbial are under turbulence self granulating into biogranules or biofilm granules. The anaerobic ammonium oxidation system comprises a first tank wherein the level of molecular oxygen and the level of CO_2 is regulated for instance by aeration and optionally the pH is adjusted this first tank is connected by a discharge pipe to a second tank, the biograulation tank wherein self granulation of the bacteria is enhanced by turbulence or shear, for instance by a rotor. A pre-tank tank feeds water with a controllable dissolved oxygen, CO_2 content and pH towards the biogranulation bioreactor. For aerobic granulation oxygen-containing gas is fed to the first reactor

which is connected with the bioreactor with the biogranules. The second tank or biogranule bioreactor reactor can from time to time partly be emptied by discharging the top part or can remove floating biogranules in a continued process. These tanks can connected in a recircualting loop so that the first tank receives supernatant from the second biogranulation tank for a series of recirculations. Depending on the oxygen supply to the first tank the biogranulation tank can 1) in case of sufficient oxygen supply operate as an aerobic granular biofilter with phosphate removal and anoxic growth (COD + Nox + $PO_4^{3-} \rightarrow N_2 + CO_2 + H_2O$ + poly-P) in the core of the granular biofilm, with nitrification in a layer on the core ($NH_4 + O_2 \rightarrow NOx$) and heterotrophic growth (COD + $O_2 \rightarrow CO_2 + H_2O$) on the outer layer or 2) under of conditions imposed molecular oxygen (O_2) and CO_2 limitation so that the nitrite is used as a oxidant to ammonia and a lower pH (preferably less than 7.3) there will occur partial nitrification in a layer of the biofilm granules and aerobic oxidation of ammonium is at least in part switched to anaerobic ammonium oxidation. The oxygen limitation in the bacterial condominiums of autotrophic nitrification and denitrification results in a direct NH_4^+ to N_2 transformation. The system is provided with a transport line or piping for transporting water of the first water treatment (pH adjustment, CO_2 stripping, and/or oxygenation) tank to the biofilm granulation tank (tank for granulation suspended microorganisms with stirring, shearing or turbulence forces) and the biofilm granulation tank can be for seen with a transport line or piping for transporting supernatant water back to the first water treatment tank or to a third biogranulation tank that operates under anaerobic condition. A discharge line can discharge supernatant water of a biogranulation tank or return water to another tank in the system. Valves are activated by actuators that receive signals from a controller that receives input signals from a network of in situ hard sensors comprising sensors of the group consisting of a pH sensor, a NO_2 sensors, an ammonium sensors, a nitrite sensor and a nitrate sensor.

In a particular embodiment of the recirculating intensive aquatic farming system (RIAFS) of present invention the ammonium oxidation ($NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$) activity by condominiums of autotrophic micro-organisms is obtained by combining condominiums of autotrophic micro-organisms with photocatalysis for nitrate to

nitrite reduction. This ammonium removal is obtained with adequate alkalinity rebuild. The nitrates in the water that will be transferred to the anaerobic condominiums of autotrophic micro-organisms (e.g. bioreactor 102) are converted (reduced) to nitrites by contacting at least part of the nitrates with at least a metal catalyst and radiation from a radiation source to produce such nitrite, where after at least some of the ammonium and nitrite are converted to nitrogen gas under anaerobic conditions by autotrophic micro-organisms. Direct ammonium to nitrogen gas with carbon dioxide production this mixed or hybrid catalytic / microbial process results in an alkalinity rebuild.

Moreover the catalytic nitrate removal decreases the need for water replacement in the recirculating aquatic animal farming systems by at least 10% clean water combined with coBOD /pBOD removal as is currently the practice. Such metal catalyst can for instance be a metal selected from the group of zinc, iron, silver, iron tin, nickel, manganese, palladium, platinum, magnesium, and alloys or mixtures thereof and preferably of the group consisting of copper, silver, mercury, palladium, platinum and alloys or mixtures thereof on a TiO_2 surface for instance TiO_2 P25 with a surface area of $49m^2/g$ and primary crystal size 30 nm (Degussa) or TiO_2 Hombikat UV 100 with a surface area of 250 m^2 g^{-1} primary crystal size <10 nm (Sachtleben Chemie) and most preferred metal catalyst is Ag/TiO_2. Sufficient mixing (or fluid bed, trickle bed or fixed bed processing) to achieve effective contact of the catalyst metal with the primary reduction metal is used. For example, in batch processes, a metallic powder which has been coated with catalyst metal may be mixed with the nitrate solution in a stirred reactor tank. Alternatively, the nitrate solution may be passed through a bed of dispersed metal. In another method, the nitrate solution may be contacted with a solid non-dispensed metal structure, such as metal sheets, spheres or cylinders. Alternatively in an embodiment of present invention a photocatalyst reactor which have a liquid transport pipe connected with or which irrigate the aerobic and/or anaerobic bioreactor, such as the aerobic (digester) granule bioreactor or as the anaerobic digester) granule bioreactor, is foreseen by a Ru (bpy)3 2+ photocatalyst or another suitable photocatalyst for visible light or UV decomposition of aqueous NH_4^+/NH_3 to N_2 and H_2. Such photocatalyst reactor can be further foreseen with

another transport pipe and eventual hydrogen storage tank to provide hydrogen in a controllable to the aerobic and or anaerobic bioreactor. This is particular suitable to enhance the growth of hydrogen consuming bacteria such the methanogenic bacteria the aerobic and/or anaerobic granule bioreactor.

One of the disadvantages of IRAFS is the disadvantages that stem from the very nature of recirculation water with a permanent risk of disease outbreaks. To control disease outbreaks recirculating aquaculture, crop hydroponics or IRAFS are equipped with disinfection units that mostly are based in UV radiation. They are equipped with Ultra-violet radiation units. Ultra-violet radiation (UV radiation) is electromagnetic radiation with a wavelength between 200 and 400 nm. Wavelengths between 200 and 280 nm (UV-C), with an optimum at 254 nm, have a strong killing effect on micro-organisms, because it minimizes the multiplication of DNA chains. However As ultraviolet (UV) radiation is used mainly for the treatment of surfaces thin films and clear water. The Sun, on the other hand emits most of its radiation in a wavelength band between 100 nm and 4000 nm. The energy dose of the radiation is expressed in mJ/cm2 (=mWs/cm2), at which mW is the quantity of UV-C energy, is the duration of the energy and cm2 is the area to which the energy attenuated. From experiments it is known that different levels of radiation are needed for different organisms so as to achieve the same level of efficacy a dose which varies from 100 mJ/cm2 for eliminating bacteria and fungi to 250 mJ/cm2for eliminating viruses. Relatively high doses are needed to compensate for variations in water turbidity and variations in penetration of the energy into the solution due to low turbulence around the UV lamp or variations in output from the UV lamp. For commercial purpose, the high dosages are recommended. The systems are never 100 bio secure. The UV lamps radiate is generally in a housing or a container that is provided with an inlet and an outlet to receive water of the aquatic faming system. In general this housing or container is a flow through unit. In an embodiment of present invention is provided with photo catalysis material in at least one such UV unit that receives water from the farming system is provided with a photocatalyst material. The UV unit can be provided with a photocatalytic material that allows the oxidation of ammonium ion to nitrite or nitrate and the reduction of nitrate and nitrite to N_2 or the nitrate to nitrite reduction. In a

particular embodiment such photocatalytic material is titanium (IV) oxide for instance as powder surfaces (TiO_2 particles) or plates. Other suitable photo-catalyst material is for instance Fe/TiO_2, TiO_2 and Fe/TiO_2 can by a sol gel synthesis method be produced as a mesoporous material. Variation in the pore size is possible via different assembling strategies that are available in the art using a variety of organic molecules as nano-size templating materials or self assembling surfactant or amphotheric copolymers to synthesize mesoporous TiO_2, Fe/TiO_2, Cr/TiO_2, Mg/TiO_2, Ag/TiO_2 or $CoTiO_2$ with different pore sizes. These mesoporous materials can be in the form of films or membranes. TiO_2 films and membranes can be prepared through methods employing surfactant molecules as a pore directing agent along with a novel acetic acid-based sol-gel route. The sol is composed of polyethylene glycol sorbitan monolaurate surfactant, acetic acid, titanium tetraisopropoxide, and isopropanol.. Under UV radiation ammonium ion in the presence of air or pure oxygen is converted to either nitrite or nitrate. On the other TiO_2 doped with altervalent cation, Fe_3^+, Cr_3^+, Co_2^+ and Mg_2^+ is a material that under UV radiation induces reduction of nitrite and nitrate ions. Ag/TiO_2 is particularly suitable for nitrate to nitrite reduction. Such photocatalyst material is in a particular embodiment such Ag/TiO_2 and is position in the housing in such manner that it receives UV radiation when the lamp is operational. Is Ag /TiO_2 preferably in the form of TiO_2-Ag porous nanocomposites which can be films (e.g. thin-film) membranes or a suspension of TiO_2-Ag particles. When by irradiation with UV Ag/TiO_2 induces reduction of nitrate to N_2 or nitrate to nitrite and Total-N removal. In an embodiment of present invention such photocatalyst reactor is used to affect the ammonium / nitrite proportion is used to force a bioreactor into an ammonium + Nitrite conversion to N_2. An Ag/TiO_2 catalyst with homogeneously dispersion of coated silver clusters, Ag/TiO_2 (P25, Degussa, Japan; anatase 79%, rutile 21%) can be prepared by a pH-controlled photocatalytic process (*F. Zhang, N. et al. , Langmuir 19 (2003), p. 8230*). Optionally formic acid is added as a hole scavenger. This photocatalyst when irradiation by sunlight is capable of reducing nitrate at 100 % N selectivity to N_2 without generating considerable amounts of ammonium or NO_2^-. In an embodiment of present invention a photocatalyst photochemical reactor comprising such photocatalysts either in suspension or in film or membrane is used for removing nitrate to achieve a proper NH_4^+/NH_3 versus nitrate

proportion to feed into an aerobic ammonium oxidation bioreactor. TiO_2 doped with altervalent cations, Fe^{3+}, Cr^{3+}, Co^{2+} and Mg^{2+} to improve the charge separation by means of a permanent electric field van for instance be synthesized by a method described by Ranjit K.T. and Viswanathan B. (*Journal of Photochemistry and Photobiology A: Chemistry, Volume 107, Number 1, 15 July 1997 , pp. 215-220(6)*) These photocatalystic materials either as film, membrane or particle suspension can be used for nitrite and nitrate ion reduction towards ammonia under UV or sunlight radiation. On the other hand a Ru (bpy)3 2+ photocatalyst can be used for visible light decomposition of aqueous NH_4+/NH_3 to N_2 and H_2. $[Ru(bpy)3]^{2+}$ ions have been know for their electrochemiluminescence and been used to develop sensors for a variety of analytes that range from metal ions and small molecules to DNA, peptides, and proteins. Synthesis of $[[Ru(bpy)_3]^{2+}$ -doped silica nanoparticles (RuSi) has for instance been described (*L. Wang, C. Y. et al Nano Lett. 2005, 5, 37 and L. H. Zhang, S. J. Dong, Anal. Chem. 2006, 78, 5119*). In a particular embodiment of present invention such photo catalyst is used to change the NH_4^+/NH_3 versus NO_2^- and NO_3^- proportions in water that is presented or irrigated to the microbial bioreactors or water that is presented or irrigated to soilless plant or hydroponics culture. A platinized TiO_2 photocatalyst is particularly suitable for present invention. TiO_2 (ST-01, average size 7 nm, from Ishihara Sangyo Co.Ltd.) can be used to produce such platinized TiO_2 by photochemical reducing tetrachloroplatinate in a TiO_2–water suspension in the presence of 2 wt% methanol. This platinized TiO_2 photocatalyst material can be in a suspension of particles, in a films or membrane. Under radiation for example UV or solar light radiation such platinized TiO_2 photocatalyst will photo decompose aqueous NH_4^+/NH_3 into nitrogen (N_2) and hydrogen (H_2). The photocatalyst material of present invention is also used for water splitting with UV light so that hydrogen produced via water splitting using the photocatalysist to boost the biofilter activity by delivering hydrogen to a biofilter reactor unit. Hydrogen into contact with the microbial community stimulates hydrogenotrophic methanogens to convert hydrogen to methane. In an embodiment of present invention a photo catalyst photochemical reactor is used to feed hydrogen (H_2) obtainable from platinized TiO_2 photocatalyst into such anaerobic denitrification bioreactor or into the bioreactor. Furthermore Ga1−xZnx)(N1−xOx) actually functions as a suitable photocatalyst for hydrogen

production from water. Oxynitrides, such as TaON, Ta_3N_5, and $LaTiO_2$ N, can be obtained by heating a corresponding metal oxide powder under a flow of NH_3. (Ga1−xZnx)(N1−xOx), loading of cocatalysts (typically metal or metal oxide nanoparticles) for instance with RuO2 modification or nanoparticles of Rh2−yCryO3 (to obtain (Ga1−xZnx)(N1−xOx))) achieves overall water splitting under visible light with a proper quantum efficiency. Metal-free polymeric photocatalyst for visible-light-driven H_2 production from water are available. For instance the graphitic carbon nitrides (g-C3N4) with graphitic planes constructed from tri-s-triazine units connected by planar amino groups have such properties (XinchenWang et al. Nature Materials. Vol 8 2009. The carbon nitrides can for instance be prepared by heating cyanamide (Aldrich, 99% purity) to temperatures between 673 and 873 K (ramp: 2:2 K min_1) for 4 h.

In an embodiment of present invention A IRAFS is provided with at least such UV lamp unit that is provided with an ammonium oxidizing photocatalyst and at least one UV lamp unit with a nitrate and/or nitrite reducing photocatalyst. Sensor that sense for pH, NH_4, NO_3^- and or NO_2^- will provide a signal to a controller that is connected to provide an activation signal to such UV unit. For instance in case that the nitrification bioreactor fails photocatalytic ammonium oxidation can be switched on. In case that the denitrificating biofilter fails the photocatalytic NO_3^- and NO_2^- reduction can be switched on to a non bacterial system for removing nitrogen from the watery culture medium of the aquatic farming system provide a real time optimization of TN, ammonium, nitrate and nitrite in case of failure of the bioreactor biofiltering system. Moreover these photocatalytic systems provide a capacity to interact with and optimize the bioreactor systems. Alternative to the UV lamp solar photochemical processes can be used. They generally use only high-energy short-wavelength photons and sunlight at wavelengths over 600 nm is normally not useful for the photocatalysis. For instance, TiO_2 photocatalysis uses UV or near-UV sunlight (300 to 400 nm) the high-wavelength photons are used to reach a specific temperature and to store, collect, and distribute solar energy in the farming system by converting this higher wavelength solar radiation to heat and transferring this to water that is then pumped to the aquatic farming system. Water is pumped through tubes that that can

for instance contact with a flat-plate or step-plate photo reactor (non concentrating photo-reactor) for instance mounted above the aquatic animal farming or aquaculture system or on the roof of the farming building. The latter is a photocatalyst material that absorbs sunlight and optimally insulated on the front with layers of glass and air; the glass allows visible light to fall on the photocatalyst material but also traps the resulting heat, which is then transferred to the water that returns to the aquatic farming system. Alternatively, the fluid is pumped through an evacuated glass tube or a volume of space wit the photocatalytic material onto which a large volume of sunlight has been focused (and hence concentrated) by reflecting mirrors for instance line focusing parabolic through concentrators (concentrating photo-reactor). They may be provided with sun tracking systems. After photo catalysis and picking up heat from the collector, water is pumped to a (insulated) storage tank, (where it can be used immediately or stored for later use) or to the aquatic farming system.

Photocatalysis mineralizes carboneous organic substances into carbon dioxide and inorganic and nitrogen containing molecules in NO_3^- and NH_4^+ (equation organic molecules + $O_2 \rightarrow CO_2 + H_2O$ + minerals (e.g. NH_4^+/NH_3^-, NO_2^- or NO_3). Also photocatalyst material suitable for present invention is a semiconductor solid surfaces that are photoexcitated by UV light, near UV, UV-VIS or solar light depending on the type of photocatalyst. As a result, mobile electrons and positive surface charges are generated resulting in excited electron-hole pairs. These excited sites and electrons accelerate oxidation and reduction reactions. In particular suitable is a wide band gap semiconductor like titanium dioxide such as polycrystalline TiO_2 catalyst to be irradiated. Such material is used for the photocatalytic mineralization of organic species so that minerals instead of organic species are delivered to the bioreactor units and/or the soilless crop culture systems. Since UV lamp system are commonly used before the biofilter units in recirculating aquaculture systems to prevent microbial contamination, an hybrid UV lamp / photocatalyst system for hydrogen production to deliver hydrogen to the biofilter units does not necessary need extra energy input. The UV light, near UV or solar light irradiating source and the photocatalyst can be integrated in a rector unit such as a multiple tube reactor, a tube light reactor, a rotating tube reactor, and a Taylor vortex reactor. In an embodiment of present

invention aqueous NH_4^+/NH_3 in the water effluents of the aquatic farming system is transformed into N_2 gas by biological and chemical inert photoactivatable material for photocatalysis such as the semiconductor CdS or the semiconductor oxide, ZnO, MgO, WO_3, Fe_2O_3, TiO_2 and under UV light or solar radiation in a photochemical reactor to induce absorption of a photon with energy equal to, or greater than the band gap of the semiconductor (ca. 3.2 eV for anatase). Particularly suitable is the anastase TiO_2 (density of 3.9 g/ml) Degussa TiO_2 P 25 (closely approximating to 25% rutile, 75% anatase) with a specific area of 50 ± 15 m^2/g. The radiation source can come from a UV lamp or from solar light. The photochemical reactor can be an immersion well (in case a UV lamp is used that has to be surrounded by the solution to be irradiated) or flat or trapped wall or tubular photoreaction and the photocatalyst can a suspension or a thin film. In a particular embodiment NH_4^+/NH_3 into N_2 volatilization photochemical reaction system is activated by on switching of a pump, valves and/or an UV radiation tool whereby the to be treated water is contacted with said the photacatalyser under simultaneous radiation. The switch of/on of the photocatalyst actuator is controlled by a control or that receives input signals from sensors in bioreactors or in the drain water of a bioreactor. A signal that is indicative of an instability or disruption in the bioreactor functions such an unacceptable decrease in alkalinity or abbreviation of the pH from norm-pH, can switch on the photocatalytic NH_4^+/NH_3 transformation to compensate the alkalinity loss that is function of aerobic nitrification. For every 1 mg/l of aerobic oxidized ammonium approximately 7.14 mg/l of alkalinity is required. This NH_4^+/NH_3 volatilization photoreactors have preferably their outlet connected with the irrigation or piping towards the bioreactor units.

These photocatalytic systems add to the biosecurity of the IRAFS by destroying bacteria, viruses and algae and easily oxidize carbon atoms into CO_2. Several non biodegradable organic compounds can be mineralized by photocatalysis. By treating the water upstream of the bioreactor units by a photocatalysis process less biofilter collapse can be recorded. The microorganisms in a bioreactor are sensitive to inhibitory or toxic organic compounds. This can for instance cause dramatic changes in the growth of nitrifying bacteria. Nitrifying bacteria cannot so easy acclimate

(gradual repair or replacement of enzymes damaged by inhibitory compounds) as often to an inhibitory event as can organotrophs. For instance the inhibitory threshold concentration of some organic compounds have been documented: Allyl alcohol 20.0, Aniline 8.0, Chloroform 18.0, Mercaptobenzothiazole 3.0, Phenol 6.0, Skatol 7.0, Thioacetamide 0.5 and Thiourea 0.1 mg/l. Photacatalysis removes or destroys organic compounds even non biodegradable compounds that are biocidal, inhibitory or toxic to nitrifying bacteria are removed in the inlet water in the aerobic nitrification. Another reason for decreases bioreactor collapse and the increased biosecurity in the IRAFS is that an input of photodisinfected water from the photochemical reactor into the bioreactor system can prevent inoculation with unwanted micro organisms. Bioreactors and the IRAFS are less vulnerable to invasion of unwanted organisms. It is particularly suitable to have the water photo disinfected before entering the bioreactors to prevent unwanted contamination of the bioreactor units but also to have the water photo disinfected before entering the before the aquatic animal farming system. Photocatalysis removes or destroys organic compounds even non biodegradable compounds that are carcinogenic, mutagenic, endocrine disrupting and that for instance could accumulate in the adipose tissue of the farmed aquatic animals. Moreover photacatalysis kills waterborne pathogens. It is therefore a preferred embodiment of present invention to have such photochemical reactor upstream of the bioreactor units and upstream of the aquatic animal farming systems. In an embodiment of present invention the aquatic farming system comprises a photochemical reactor for NH4+/NH_3 volatilization, photodisinfected and organic compounds such as alcohols, carboxylic acids, phenolic derivatives, or chlorinated aromatics, into harmless products e.g. carbon dioxide, water, and simple mineral acids upstream from the bioreactor system comprising a nitrification bioreactor and denitrification bioreactor (or a hybrid nitrification/denitrification bioreactor) or in a loop with the bioreactor system for receiving and providing watery medium. Furthermore this photochemical reactor downstream from a coBOD / pBOD removal unit (for instance a micro sieve drum filter) and upstream of the aquatic farming animal system in a second loop.

In a specific embodiment of present invention the first water treatment tank is connected with a tank for reducing nitrate to nitrite whereby the nitrate reduction tank feeds water into first water treatment tank. Reducing nitrate to nitrite can for instance by heterotrophic denitrifying bacteria wherein the nitrate reduction treatment is carried out by the nitrate comprising liquid into contact with a catalyst that reduces the nitrate as a nitrogen component to nitrite catalyst. Suitable catalysts are e.g. Pt–Cu/Al_2O_3, Pd—Cu catalyst or catalysts of molybdenum-mediated atom transfer. Photocatalytic nitrate to nitrite reduction can be activated to deliver water loaded with ammonium nitrite approaching equimolar amounts to for an anaerobic bacterial bioreactor into ammonium and nitrite to dinitrogen conversion. This photocatalytic nitrate to nitrite reduction can be carried out in a pre-treatment unit or tank before the water is delivered to the microbial bioreactor. In yet another specific embodiment of present invention the first water treatment tank is an aerobic biofilter for partial nitrification by controlled operating conditions such as dissolved oxygen between 0.5 - 1 mg O_2/l), solids retention time at 1-2 d, temperature at 25-37°C and pH at 7.5-8.0. This bioreactor is controlled to reduce ammonium and reduce nitrite and preferably to approach an ammonium/nitrite proportion of 1. The pre-treatment system is provided with a transport line or piping for transporting water of this first water treatment to the biofilm granulation tank (tank for granulation suspended microorganisms with stirring, shearing or turbulence forces).

The time of photocatalytic treatment affects if organic nitrogen is released as NH_4^+/NH_3, NO_3^- or NO_2^- and so will do the selected photocatalyst. Since plant productivity is intimately linked to nutrient uptake and pH regulation the nutrients derived from the aquatic animal farming system is preferably presented in the irrigation to a soilless crop culture or hydroponics are preferably in a mineral form. Hydroponics greenhouse systems are generally foreseen with stock solution of nutrient/fertilizer which are provided with an extra acid or base solution for pH correction. An extra amount of an acid or base solute can be used to control pH of the batch of nutrient solution in the mixing tank diluter/dispenser units wherein the concentrated fertilizers are diluted to a nutrient solution to be taken up by the plant. Furthermore such hydroponics can comprise a buffer tank, nutrient reservoir pump,

growing troughs, collecting trough, condensed water tank, acid stock solution, base stock solution tank, nutrient stock solution tank, In one embodiment, after mineralization on the photocatalytic reactor or the photocatalytic / photochemical reactor wherein transformation of organic matter to minerals (mineralization) water of this photochemical is flows the hydroponics system for pH adjustment, nutrient completion and mixing with clean and or drain water for irrigation to the (soilless) crop. The computer systems used in hydroponics that guarantee the accurate delivery of minerals to the plant crops can be used to control the integration of mineral delivery from the photocatalytic reactor or the photocatalytic / photochemical reactor. In an embodiment of present invention up flow of the soilless crop culture or up flow of the bacterial bioreactor units photocatalysis mineralizes carboneous organic substances into carbon dioxide and inorganic and nitrogen containing organic and inorganic molecules in NO_3^- and NH_4^+. Water irrigation from the aquatic farming system towards the soilless crop culture unit or the hydroponics system preferably undergoes photocatalytic mineralization in the photocatalytic reactor , photocatalytic / photochemical reactor or photochemical reactor unit. Preferably there is such photochemical reactor upstream of the soilless crop culture unit or the hydroponics system or upstream of a water collection tank for mixing water with drain water, stock nutrient; pH adjusting compounds and/or clean water under control of nutrient mixing and nutrient injection software before irrigation of the soilless crop culture unit or the hydroponics system. Optionally the same photochemical reactor is upstream connected via a loop with and the aquatic animal farming system and the soilless crop culture unit or the hydroponics system and the microbial bioreactor system.

Since time of photocatalytic treatment will affect if organic nitrogen is released as NH_4^+/NH_3, NO_3^- or NO_2^- and so will do the selected photocatalyst water from the photo catalytic, the photoreaction can present NH_4^+/NH_3, NO_3^- or NO_2^- in a controllable manner, the proportions of the different nitrogen compounds are further adjustable by controlled mixing of the different sources before irrigation to the crops. This is important to plant root nutrient uptake and plant root exudation. If Nitrogen (N) is only presented as NO_3^- salts in the nutrient solution to the plant roots the plant anion uptake exceeds cation uptake and the plant roots will extrude anion equivalents

back into the solution to maintain electroneutrality. Further addition of H^+ is than necessary to maintain pH and overall nutrient availability. If NH_4^+ would be presented to the plant roots as the main N source than the cation uptake would exceed anion uptake. H+ ions will be extruded by the plant roots decreasing the solution pH and base addition would be necessary to maintain overall nutrient availability and stable pH. The ionic balance in plants is highly dependent on the uptake of N and K. N as two charge options NH_4+ and NO_3- but the only charge option for K is the K^+ cation.. NH_4^+ is a key ion to help to maintain electro neutrality. . High levels of NH_4^+ can inhibit the uptake of K^+, Mg_2^+ Ca_2^+ (plants have generally a high requirement at Ca_2^+. According to Beusichem et al (1988) up to 70% of the anions and cations can be presented as NH_4^+ or NO_3^-. In an embodiment of present invention such plant root exudation are integrated in the control system as a sentinel to provide signals to the controller or the computer processor which contains a controller. In an embodiment of present invention pH sensors are integrated to monitor acidification of the rhizosphere and feed signals into the controller to maintain crop normo-pH. Nitrate or NH_4 uptake by plant roots changes the pH of the medium (*Marschner, H. and Römheld, V. (1996). Root-induced changes in the availability of micronutrients in the rhizosphere. In Plant Roots, the Hidden Half, 2nd edn (Y. Waisel, A. Eshel, and U. Kafkafi, eds). New York: Marcel Dekker, pp. 557–579 and Marschner, H., Römheld, V., Horst, W.J. and Martin, P. (1986)). Root-induced changes in the rhizosphere: Importance for the mineral nutrition of plants. Z. Pfanzenennaehr Bodenk., 149, 441–459*). On the other hand, the plant roots are a source and sink of organic compounds and plant hormones and play a function in carbohydrate storage, to enable the following year's propagation, roots become the main carbon (C) storage organ for the plant. The effects of root-mediated pH changes in the rhizosphere are well documented. They are caused by excretion of ions (mainly H^+, OH^- and organic bases or acids) which balance the electric charge, following cation or anion uptake by roots, root respiration, carbon exudation or redox processes. Accumulation of soluble organic acid excreted from roots in the presence of an inert medium may induce a pH decrease because the adsorption reactions are negligible and the ligand acts as weak acid, whereas, in contrast, the quantities of OH^- released following ligand adsorption onto a substrate with a high surface charge may be significant and much higher than

that of H+ added via ligand dissolution. Root-secreted chemicals mediate multi-partite interactions in the rhizosphere, where plant roots continually respond to and alter their immediate environment (*Dayakar V. Badri and Jorgee M. Vivanco Plant, Cell & Environment Volume 32 Issue 6, Pages 666 – 681, 2009*). Pollution stress by phytotoxic compounds, for instance aluminium stress for instance by external Al3+ concentration affect the plant root exudation e.g. by increased secretion of electrolytes, of sugars increase and of amount of secreted amino acids (*Ping Wang et al. J. Agric. Food Chem., 2006, 54 (26), pp 10040–10046*). It was hypothesized that a sudden switch plant root exudation is indicative for a pH/nitrogen toxicity effect in the integrating recirculating aquatic farming systems of aquatic vertebrate or invertebrate animals with hydroponics or soilleness plant culture with a bacterial loop of nitrifying bacterial and denitrifying bacterial condominiums. Fibre optic sensor reported to monitor different soluble analytes are available such as a polyimide-coated fiber Bragg gratings (FBG) or a glucose-selective surface plasmon resonance sensor (as for instance the surface plasmon resonance sensor based e.g. Nanogold-plasmon-resonance-based glucose sensing based on concanavalin A and sugars glucose selectively in the range of 0.1~50 mmol/l) or the surface plasmon resonance sensor based on bacterial glucose/galactose-binding protein and can be used to monitor plant root exudation. .

Components included in the recirculation system are photocatalytic reactor used for photocatalytic water splitting, oxidation, degradation of products or disinfection depending on the type of catalyst and the radiation source.

Depending on the type of photocatalyst Visible light, solar light, UV or near UV can be used to activate the photocatalyst to induce mineralization or degradation. Visible light induced photocatalytic degradation, decomposition, mineralization or advanced oxidation (e.g. under aerated conditions) of aqueous organic molecules in particular to convert (oxidize) organic molecules into CO2, water and minerals (mineralization – complete mineralization) can be in various photoreactor types, photocatalyst arrangements, light sources, and operation conditions for photocatalytic degradation, decomposition or mineralization of organic molecules. For instance degradation,

decomposition, mineralization or advanced oxidation is carried out under LED (light-emitting diode) lights of the wavelength of 450-475 nm is carried out with TiO2 and/or ZnO functionalized or sensitized by conjugated polymer poly(fluorene-co-thiophene (Qiu, RL; et al. Reaction kinetics and catalysis letter 94 (1):183-189 2008). This photocatalytic degradation, decomposition, mineralization or advanced oxidation can result in detoxification when toxic organic compounds are removed and no toxic intermediates are produced or left by an incomplete process. The total organic carbon (TOC) measurements allows to evaluate the mineralization efficiency and various toxicity assay (e.g. Daphnia magna or Artemia salina sentinels) are available in the art to monitor the detoxification process and the degradation of reaction by-products and without restriction good candidates have been mentioned in this application. Components included in the recirculation system are photocatalytic reactor used for photocatalytic oxidation (in presence of oxygen). Photocatalytoc oxidation and complete mineralizing converting organic molecules to CO2, water, and mineral acids can be by a suitable photocatalysist such as TiO2 and its variants. Moreover metal cations reduction is obtainable whereby photogenerated electron e^-_{cb} reduces inorganic metal ions with a reduction potential that is less negative than the reduction potential of the conduction band such as the pairs Ni(II)/Ni(0), Pb(II)/Pb(0), Fe(III)/Fe(0), Cu(II)/Cu(I), Cu(II)/Cu(0), Cu(I)/Cu(0), Fe(III)/Fe(II), Ag(I)/Ag(0), and Hg(II)/Hg(0); organic oxidation and inorganic reduction has a synergic effect on photocatalytic oxidation. Fe^{3+} ion concentrations below 10 ppm promote higher TiO_2 oxidation rates than those obtained in the unpromoted PC reaction (maximum value at 5 ppm of Fe^{3+} ions). However high Fe^{3+} ion concentrations considerably reduce the photo-oxidation rate. Symbolically overall photocatalytic reaction is expressed by the equation: $R + Cat + h\nu \rightarrow P + Cat$ where R and P are reactants and reaction products, respectively, present in the gas or liquid phase, Cat is the solid photoadsorbent (photocatalyst), and hn is the symbol of photons able to be absorbed by the photocatalyst. Photon absorption by photocatalyst is regarded as the first stage of photo excitation of heterogeneous system; the photo excitation pathways of wide band gap solids may involve photo generation of excitons and/or free charge carriers, depending on photocatalyst features such as fundamental absorption band, extrinsic/intrinsic defect absorption bands, or UV-induced colour

centre bands. Independently of photo excitation type, photon absorption has two main effects: (i) it changes the characteristics of photocatalyst surface and (ii) it generates active photo adsorption centres. A typical case of the first effect is that band gap irradiation induces superhydrophilicity (photoinduced superhydrophilicity, PSH) on the TiO_2 surface, which shows hydrophobic features under dark conditions. This PSH is accompanied by photocatalytic activity, as both phenomena have a common ground, so that the surface-adsorbed compounds may be either photo oxidized or washed away by water. The second important effect is that irradiation absorption generates active states of the photo adsorption centres with trapped electrons and holes.

Ultrasound (US) and/or microwave (MW) irradiation on the photocatalyst can induce degradation, decomposition or mineralization of aqueous organic molecules or in combination with UV/VIS radiation or UV radiation it strongly enhances the process. The photocatalytic degradation, decomposition or mineralization of aqueous organic molecules can be enhanced by light and microwave radiation for instance UV/VIS radiation + microwave photolysis or UV radiation + microwave photolysis. For instance by internal lamps (classical UV lamp) or by powered quartz mercury electrodeless discharge lamps in a microwave field. Moreover heterogeneous photocatalytic degradation or organic molecules (e.g. onTiO2 photocatalysist) can be combined with ultrasound irradiation e.g. at a frequency of between 15 to 250 kHz, for instance 215 kHz , whereby sonolysis with photocatalysis is called sonophotocatalysis. Ultrasonic (US) irradiation on a photocatalytic material such as TiO2 results in sonocatalytic microbial inactivation by the generation of hydroxyl (OH) radicals during US irradiation (Shimizu, N; et al; BIOCHEMICAL ENGINEERING JOURNAL 48 (3):416-423 2010). For instance the CeO2/TiO2, SnO2/TiO2, ZrO2/TiO2 and F-Si-comodified TiO2 composites, carbon nanotube/TiO2 and nanosized Au doped -TiO2 nanoparticles photocatalyists are particularly suitable for sonocatalytic degradation of organic molecules under ultrasonic irradiation.

Bacterial bioreactors and units with aquatic multicellular consumer organism (e.g. aquatic animals) are eventually used to deliver irrigating water to soilless plants

(aquatic plants or terrestic plants with their roots in aquatic medium. This form of integration can eventually aid to redistribution of organic, inorganic material and energy in a more cost effective manner on condition that biosystems could be biostable and no biosystem collapses (which is a major cost factor) would occur at least not a regular basis. Since high density and highly productive land-based recirculation systems can have a great potential of production of aquatic organisms near the urban consumer societies, there is a need in the art. The idea of integrating plant culture with aquatic animal culture, however, did not result in a cost effective and commercial applicable solution, despite decades of R&D trials. In recirculating aquatic farming systems (aquatic farming systems for aquatic multicellular consumer organism (e.g. aquatic animals) or recirculating hydroponics for (soilless) crops) the recirculating fluids are passed through a UV radiation unit to disinfect. However system collapse is still a major cost burden in the current recirculating aquatic farming systems. Present invention provides cost effective and bio securities solution for the intensive recirculating aquaculture systems and provides biosecure energy efficient aquatic farming systems in a confined environment suitable for integration in soilless or hydroponics plant culture. Despite these tools, in particular the aquatic animal intense farming recirculating systems, are not brake through on large commercial scale. Aquaculture in water intense recirculating aquaculture systems exists for some decades now. However, an expansion of its commercial use has been clearly hindered by high operational costs and the tremendous cost of a biosystem collapse. According to Gruttierez – Wing and Malone the cost for water treatment in a recirculation systems of the art is as high as 5.9 €/kg annual production (*Gruttierez – Wing and Malone 2006 Aquaculture Engineering 34(3), 163 171*).

Moreover, in the intense recirculating intense aquatic animal farming systems of the art the water quality is still more unstable and water quality fluctuations, such as temporary increases in ammonia or nitrite, can result in disease and significant losses of the culture organisms. These environmental fluctuations often lead to suppressed immune systems and greater susceptibility to pathogens (i.e., disease-causing organisms, such as bacteria, parasites, fungi, and viruses) and disease outbreaks. Recirculating systems favour the growth of many disease-causing organisms and

spread of disease. There are a number of reasons for this tendency, including higher densities of fish when compared to other culture systems; build up of sediment and subsequently pathogens in tanks, sumps, or filtration components (especially mechanical and biological filters), and slower turn over of water. Over time, pathogens can become concentrated (i.e., present in high numbers).

Most pathogens are considered opportunistic, causing disease only in fish with suppressed immune systems. However, if pathogens become sufficiently numerous they can also cause disease in healthy fish. In addition, the continuous flow of water throughout a system can spread pathogens rapidly, despite the ultraviolet sterilization or ozone. Ultraviolet sterilization or ozonation are basically only surface treatments. Bacteria, parasites, fungi and viruses can all become concentrated in recirculating systems. Bacteria that typically increase in number in recirculating systems include *Aeromonas spp., Vibrio spp., Mycobacterium spp., Streptococcus spp.*, and *Flavobacterium columnare (Columnaris disease)* (UF/IFAS Fact Sheets FA-14 Aeromonas Infections, FA-31 *Vibrio* Infections of Fish and VM-96 *Mycobacteriosis* in Fish; UF/IFAS Circular 57 Streptococcal Infections of Fish; and SRAC Publication No. 479b Columnaris Disease, respectively). Parasites that tend to thrive and spread relatively easily in recirculating systems include *Trichodina, Ichthyophthirius, Costia* and monogeneans (UF/IFAS Circulars 716 Introduction to Freshwater Fish Parasites and 920 *Ichthyophthirius multifiliis* (White Spot) Infections in Fish; and UF/IFAS Fact Sheet FA-28 Mongenean Parasites of Fish, respectively). Closed systems can also foster the spread of fungi and viruses (UF/IFAS Fact Sheets VM-97 Fungal Diseases of Fish and FA-29 Introduction to Viral Diseases of Fish, respectively). A combination of decreased immunity of the aquatic organisms and accumulation of pathogenic microbials can lead to a biosystem collapse. There is a clear need to improve biosecurity which leads to disease outbreak to make intense recirculating culture of aquatic organisms a profitable business. The combination of light and ultrasound enhances the rate of inactivation of *E. coli* in a TiO2 suspension reactor (Stevenson, M.; Bullock, K.; Lin, W. Y.; Rajeshwar, K. *Res. Chem. Intermed.* 1997, *23*, 311-323). There are various photoreactor types, photocatalyst arrangements, light sources, and operation conditions for photocatalytic sterilisation. An ultraviolet light

emitting diode (UV-LED) illuminator or a fluorescent lamp light source radiation on a TiO2 photocatalytic films (for instance obtained by the low-pressure metal-organic chemical vapour deposition) is used to sterilize against bacterial pathogens. Ultraviolet radiation refers to electromagnetic radiation in the 200- 400 nm wavelength range. UVA covers from 315 to 400 nm, UVB from 280 to 315 nm and UVC from 200 to 280 nm. Radiation at UVB and UVC wavelengths has no toxic properties and is invariably harmful to living cells. By damaging the DNA, it can induce deleterious processes such as mutagenesis, carcinogenesis and cell death. Disinfection of secondary wastewater effluents compared to stream and river water by UV requires higher doses (50 – 60 mW cm^{-2}) due to the higher concentration of micro-organisms and increased micro-organism resistance. Uneconomically viable values exceeding 100 mW cm^{-2} are required to inactivate protozoan pathogens such as *Cryptosporidium* and *Giardia.* Typical waterborne pathogens with high health significance are bacteria such as Campylobacter jejuni, C. coli, Pathogenic E. coli, Salmonella typhi, other salmonellae, Shigella spp. and Vibrio cholera, viruses such as Adenoviruses , Enteroviruses, Hepatitis A, Enterically transmitted non-A, non-B hepatitis viruses, Hepatitis E, Norwalk virus and Rotavirus and Protozoa such as Antamoeba histolytica, Giardia intestinalis and Cryptosporidium parvum. Some gram-positive bacteria, under extreme environmental conditions produce specialised structures called endospores. Endospores are formed internal to the bacterial membrane, during the process of sporulation. Sporulation represents a dormant stage within the bacterial lifecycle. Endospores are highly durable dehydrated cells with thick walls and additional layers, which are much more complex than that of vegetative cells. The durability of endospores allows them to survive for many years until conditions become favourable for germination, at which time the endospore converts back to a vegetative cell. Endospores can survive extreme heat, lack of water and exposure to many toxic chemicals and radiation. There is thus a need in better disinfection tools than the conventional chemical, radiation and heating water treatments.

Components included in the recirculation system are in an embodiment a photocatalytic reactor used for water splitting. There are several photocatalysts

developed in last years for water splitting reaction under visible light. The properties required by photocatalysts for water splitting are band edge potentials suitable for water splitting, band-gap energy around 2.0–2.2 eV, and stability under reaction conditions. Water decomposition is obtainable by photoelectrochemical or photocatalytic technologies using near-infrared and visible light or solar electromagnetic radiation. This process mimics photosynthesis by converting water into H_2 and O_2 using inorganic semiconductors that catalyze the overall water-splitting reaction, equated as $H_2O \rightarrow ½\ O_2 + H_2$ The reaction involves the standard Gibbs free energy change (DG0) greater than 237 KJ mol_1, equivalent to 2.46 eV per molecule (1 eV=96.1 KJ mol_1). This energy is equivalent to the energy of photons with wavelengths shorter than 500 nm. However, direct water splitting cannot be achieved directly by sunlight because the water molecule cannot be electronically excited by sunlight photons. But this is achieved in an indirect way by a two-electron stepwise process whereby the photocatalytic surfaces capable of absorbing solar energy to generate electrons and holes that can respectively reduce and oxidize the water molecules adsorbed on photocatalysts. when a photo semiconductor absorbs light photons with energies greater than its band-gap energy (Eg). This absorption creates excited photoelectrons in the conduction band (CB) and holes in the valence band (VB) of the semiconductor, as schematically depicted in fig. 28 III. Photon energy is converted in chemical energy (hydrogen). the surface of the semiconductor, the photoinduced electrons and holes reduce and oxidize adsorbed water to produce gaseous oxygen and hydrogen according the equations of oxidation : $H_2O + 2h^+ \rightarrow 2H^+ + ½\ O_2$, reduction : $_2H+ + 2e \rightarrow H_2$. From the perspective of band positions and resistance to reactions at the solid/liquid interface semiconductors suitable for water splitting are $KTaO_3$, $SrTiO_3$, TiO_2, ZnS, and SiC. One of the strategies for inducing visible-light response in TiO_2 was the chemical doping of TiO_2 with metal ions with partially filled d-orbitals (V, Cr, Fe, Co, Ni, etc.). TiO_2 codoped with a combination of Sb^{5+} and Cr^{3+} is active for O_2 evolution under visible-light irradiation (> 440 nm) from an aqueous solution using $AgNO_3$ as sacrificial reagent Visual light response has been increased for TiO_2 by doping it with Sb, C, Ta or Cr for TiO_2 and $SrTiO_3$ and by doping ZnS with Cu or Ni. Semiconductor mixing (composite) is another strategy for developing photocatalysts with visible-light response from photocatalysts with a wide

band gap. Also specific semicondotor composites are used for VIS light photocatalysis. This strategy is based on the coupling of a wide band-gap semiconductor with a narrow band semiconductor with a more negative CB level. In this way, CB electrons can be injected from the small band-gap semiconductor into the large band semiconductor, thereby extending the absorption capacity of the mixed photocatalyst. Suitable semiconductor composites are CdS-TiO_2, CdS-$K_4Nb_6O_{17}$, $Ca_2Fe_2O_4$ and $PbBi_2Nb_{1.9}W_{0.1}O_9$. Specific semiconductor alloys extend the visible light response of wide band-gap photocatalysts involves making solid solutions between wide and narrow band-gap semiconductors such as the semiconductor alloys GaN-ZnO, ZnO-GeO, ZnS-CdS, ZnS-AgInS2, and CdS-CdSe. The deposition of noble metals (e.g., Pt, Rh) or metal oxides (e.g., NiO, RuO2) onto photocatalyst surfaces is an effective way of enhancing photocatalyst activity. The co catalyst improves the efficiency of photocatalysts. Nitrogen substitution on Sr2Nb2O7 oxides also enables the absorption of the oxynitride in the visible range as a result of the mixing of N 2p with O 2p states near the VB.

Components included in the recirculation system are photocatalytic reactor used for photocatalytic denitrification. Photocatalytic denitrification of water with 96% conversion of nitrate ions can be achieved by using silver modified titanium dioxide obtained by the sol-gel method. Silver particles are photo precipitated. With a electron donor (e.g. formic acid) it is possible to substantially intensify the process and reduce the yield of a by-product—NH_4^+ (A.V. Lozovskii, I.V. Stolyarova, R.V. Prikhod'ko, V.V. Goncharuk, 2009, published in Khimiya i Tekhnologiya Vody, 2009, Vol. 31, No. 6, pp. 631–642.).

Photocatalytic reaction can be enhanced. Various methods of attempting to post-synthetically enhance the overall efficiency of the photocatalytic process have been investigated. These modifications include doping with transition metals to increase electrical conductivity, loading with metal nanoclusters, annealing the catalyst at elevated temperatures to improve crystallinity and particle size, using electron acceptors other than O_2 and electrochemically-assisting the mechanism by the application of a positive bias. The most important modification to date is the reduction of the TiO_2 particle size to within the nanometre range which has been shown to

significantly increase its catalytic activity. This is due to the higher surface-to-volume ratio, and as such it is routine to use nanometre-sized particles.

Reactor performance is enhanced by dispersing the TiO_2 nanoparticles in water, because of higher surface contact of the nanoparticles with the target compounds. However, the difficulty in separating unsupported particles from water for reuse is limiting commercially viable industrial reactors. Therefore, a need to employ supported catalysts is realised where a thin layer of nanometre-sized TiO2 particles can be formed on a supporting surface. These can be particle or fixed supports,74,85 with the majority of research performed in the former case. TiO2, for example, has been fixed onto tubes, glass plates, fibres, membranes, or photo reactor walls. However, catalytic activity approximately five to six times lower is usually seen (compared with the powdered form). This is due to: a reduced surface-to volume ratio (from binding with the supporting surface); catalyst agglomeration (surface clumping) during fixation; and the mass transfer limit for the organic compounds.87 Film thickness is also of great importance: if the film is too thin, not enough light will be absorbed and if too thick, the holes are generated too deep in the catalyst layer.88 These problems can be overcome by employing a nanoporous TiO2 film to ensure maximum light absorption and also by bringing the pollutant close to the TiO2 surface. When TiO_2 was coated onto rotating disks, rotating mesh sheets and narrow light tubes, improved catalytic performance was noted, due to increased mass transfer.89-91 As a result of the large length scales used in these structures, the catalytic performance did not approach those employing suspended nanoparticle catalysts. Reduction of O_2 by CB electrons was the rate limiting step in all cases where the molecules in the solution can be quickly oxidised by hydroxyl radicals or directly by holes. The efficiency of a TiO_2 immobilised system with a suspension system, with O_2 as an electron acceptor in both cases, and reported that both systems were comparable (Dijkstra, M. F. J.; Michorius, A.; Buwalda, H.; Panneman, H. J.; Winkelman, J. G. M.; Beenackers, A. A. C. M. *Catal. Today* **2001**, *66*, 487-494.) Therefore, efficient mass transfer in a reactor can produce immobilized TiO_2 photocatalytic degradation rates to within those seen using suspension systems In a aligned nanotube, nonrod, nanoribbos, or nanowire structure versus ordinary porous

structure such photocatalyst layer, e.g. TiO_2 layer, becomes a better light harvester and electron transporters. Such TiO2 nanotubes can be well produced from bulk crystalline titanium metal (Gong D, Grimes CA, Varghese OK, Hu WC, Singh RS, Chen Z,Dickey EC (2001) J Mater Res 16:3331; Ghicov A, Tsuchiya H, Macak JM, Schmuki P (2005) Electrochem Commun 7:505, Elsanousi A, Zhang J, Fadlalla HMH, Zhang F, Wang H, Ding XX, Huang ZX, Tang CC (2008) J Mater Sci 43:7219 and Jaroenworaluck A, Regonini D, Bowen CR, Stevens R, Allsopp D (2007) J Mater Sci 42:6729).

Several heterogeneous photocatalysis reactors are good candidates for the aquatic farming system present invention. Heterogeneous photocatalysis reactors need optimal light distribution inside the reactor providing high surface areas for catalyst per unit reactor volume, high surface area per unit volume of reaction liquid inside the reactor , with optimal surface-to-volume ratio while eliminating the prospect of light loss by absorption and scattering in the reaction medium. The volume of heterogeneous photocatalytic reactor can be expressed as $VR = Q \cdot C_{in}.X / \kappa .\chi$ where Q is the volumetric flow rate ($m^3\ s^{-1}$), Cin is the inlet pollutant concentration (mol m^{-3}), X is the fractional conversion desired, κ is illuminated catalyst surface area in contact with reaction liquid inside the reactor volume ($m^2\ m^{-3}$), and $\chi$is the average mass destruction rate (mol $m^{-2}\ s^{-1}$). χ is a reaction-specific parameter as it expresses the performance of catalyst for the breakdown of a specific model component, while κ is a reactor-specific parameter representing the amount of catalyst inside a reactor that is sufficiently illuminated so that it is active and is in contact with the reaction liquid. A multiple tube reactor (MTR), a distributive-type photocatalytic reactor design with hollow tubes in which catalyst is fixed to a structure in the form of glass slabs (plates), rods, or tubes inside the reactor allows for high values of κ and will eliminate light passage through the reaction liquid. This is advantageous because when light approaches the catalyst through the bulk liquid phase, some radiation is lost due to absorption in the liquid. For instance κ (m^{-1}) of 2000 achieved and the reactor and can be scaled-up with small VR. Tube light reactor (TLR) photocatalytic reactor is based on such on the MTR. The distributive-type photocatalytic reactor design with hollow tubes and narrow diameter fluorescent tube lamps of low wattage

emitting lights in the wavelength of interest (λ<365 nm) whereby the catalyst is deposited on the outer surface of the low wattage lamps allowing for allowing for large surface area for catalyst per unit reactor volume. The lamps can be in various shapes and lengths and can be placed inside a reactor to form a variety of different configurations allowing for uniform light distribution along the length of the tubes (Periyathamby, U., and Ray, A.K., Chem. Eng. Technol. 22, 881 (1999 and Ajay K. Ray, Antonie A.C.M. Beenackers Catalysis Today 40 (1998) 73±83)). Furthermore the immersion type heterogeneous photocatalytic reactor with lamp(s) immersed within the reactor (Ray, A.K., and Beenackers, A.A.C.M. European patent, WO1997037936 (1996).) has a κ (m^{-1}) of 2667 and can be scale-up with small VR.

Several commercially available lamps have been identified as particularly suited for the process. A semiconductor light source, LEDs, emitted low-intensity red light. versions are available across the visible, ultraviolet and infrared wavelengths, with very high brightness. The ultraviolet light-emitting diode (UV-LED), can used as alight source for the photocatalytic decomposition of organic materials aqueous media by the UV-LED/TiO2 process (Chen, HW; et al. Source JOURNAL OF CHEMICAL TECHNOLOGY AND BIOTECHNOLOGY 82 (7):626-635 2007). Artificial UV lamps can power photocatalytic processes. The band gap of TiO2 anatase is 3.2 eV and the irradiation portion that can participate in the photocatalytic reaction is the one below 388 nm. Artificial UV sources are made of different metals including mercury, sodium, zinc/cadmium and rare gases (neon, argon). The mercury emission lines are usually in the desired range of energy for driving the photochemical reactions. Artificial UV lamps can be grouped in low pressure mercury lamp, medium pressure mercury lamp and high pressure mercury lamp categories. Solar light can also activate TiO_2 given that the TiO_2 activation spectrum overlaps with the solar spectrum. LEDs can be used to drive the photocatalytic process with a low level of energy (e.g. 3 - 5 voltages) and thus at high energy efficiency LED to absorb light energy exceeding band gap (WO2001064318 A1).

Photocatalytic oxidation and complete mineralizing converting organic molecules to CO_2, water, and mineral acids can be by a suitable photocatalysist such as TiO_2 and its

variants. In an embodiment of present invention CO_2 generated by this process is delivered to the bioreactor with plants or to the aerobe bioreactor with autotrophic microorganisms In a particular embodiment the CO_2 is photocatalysed to hydrocarbons such as methanol to fuel the chemoheterotrophic microbial bioreactor.

The process and farming system can be designed to utilize CO2 reduction. TiO_2 nanotube arrays formed by anodic oxidation of titanium have very high surface areas comparable to porous titania nanoparticle films, and proven photocatalytic properties. While the TiO_2 band gap, 3.0 and 3.2 eV for rutile and anatase, respectively, restricts excitation wavelengths to less than $\approx$ 400 nm, we have succeeded in incorporating nitrogen into the nanotubes in situ during anodization, with a subsequent heat treatment resulting in crystallized nanotubes with N 2p states formed above the titania

valence band shifting the absorption edge of titania to ~540 nm. These nitrogen-

doped titania nanotube arrays, with platinum and/ or copper nanoparticles dispersed upon the top of the nanotube array surface, have been used to convert carbon dioxide and water vapour into hydrocarbons under natural (outdoor) sunlight according to the equation $CO_2 + {}_2H_2O \rightarrow CH_4 + 2O_2$ (Oomman K. et al; Nano Lett., 2009, 9 (2), 731-737). Titania has been used for such photocatalytic processes due to its powerful oxidation properties, superior charge transport properties, and corrosion resistance. Its e photocatalytic carbon dioxide conversion rates can be enhanced by (i) employing high surface area titania nanotube arrays, with a wall thickness low enough to facilitate efficient transfer of photogenerated charge carriers to the surface species; (ii) modifying the titania band gap to absorb and utilize the visible portion of the solar spectrum where the bulk of the solar energy lies; (iii) distributing cocatalyst nanoparticles on the nanotube array surface to adsorb the reactants and help the redox process. TiO_2 nanotube arrays formed by anodic oxidation of titanium have very high surface areas, comparable to porous titania nanoparticle films, and proven photocatalytic properties (Mor, G. K.; Carvalho, M. A.; Varghese, O. K.; Pishko, M.

V.; Grimes, C. A. J. Mater. Res. 2004, 19, 628) While the TiO2 band gap, 3.0 and 3.2 eV for rutile and anatase, respectively, restricts excitation wavelengths to less than ≈ 400 nm, incorporating nitrogen into the nanotubes in situ during anodization, with a subsequent heat treatment resulting in crystallized nanotubes with N 2p states formed above the titania valence band shifts the absorption edge of titania to ~540 nm. These nitrogen-doped titania nanotube arrays, with platinum and/or copper nanoparticles dispersed upon the top of the nanotube array surface, can been used to convert carbon dioxide and water vapour into hydrocarbons under natural (outdoor) sunlight. The nitrogen-doped titania nanotube arrays are synthesized by anodizing titanium foil in an electrolyte consisting of 0.3 M ammonium fluoride (NH4F) in 2 vol % water containing ethylene glycol at 55 V. (Paulose, M.; Shankar, K.; Yoriya, S.; Prakasam, H. E.; Varghese, O. K.; Mor, G. K.; Latempa, T. A.; Fitzgerald, A.; Grimes, C. A. J. Phys. Chem. B 2006, 110, 16179). Nanotube array samples up to ≈130 μm in length are prepared by changing the anodization duration. The debris from the anodization bath redepositing on top of the original nanotubes can be removed by ultrasonic agitation and/or critical point drying (CPD) according to Paulose, M.; Prakasam, H. E.; Varghese, O. K.; Peng, L.; Popat, K. C.; Mor, G. K.; Desai, T. A.; Grimes, C. A. J. Phys. Chem. C 2007, 111, 14992. The nitrogen-doped titania flow-through nanotube array are loaded into a membrane or photoelectrode for high rate photocatalytic conversion of CO_2 and water vapour into hydrocarbon fuels under UV, near UV and violet, blue or green light radiation. Luisa F. et al use electrodeposited silver particles over TiO2 thin film for CO_2 reduction in aqueous solution. The TiO2 thin films were supported on transparent conductive glass plates were modified by silver particles (250 nm diameter) deposited by electrochemical double pulse from an aqueous solution of silver nitrate (Luisa F. Cueto, Gerardo T. Martínez, Genaro Zavala, Eduardo M. Sánchez Journal of Nano Research (Volume 9) Pages 89-100 February, 2010). Photocatalytic reduction of CO2 in the presence of H2 as the reductant can be over gallium oxide, Ga2O3 (Teramura, K.; Tsuneoka, H.; Shishido, T.; Tanaka, T.

Chem. Phys. Lett. 2008, 467, 191). Nanostructured Cobalt Oxide Clusters in Mesoporous Silica allow the direct conversion of carbon dioxide and water to methanol. The metal oxide nanocluster catalysts for water oxidation is driven efficiently by visible-light-absorbing binuclear charge-transfer chromophores (H. Han, H. Frei, J. Phys. Chem. C 2008, 112, 16156) The organocatalyst, N-heterocyclic carbenes (NHCs) such as IMes (1,3-bis-(2,4,6 trimethylphenyl)imidazolylidene) are stable, even in the presence of oxygen and efficiently catalyze a reduction reaction carbon dioxide reduction at room temperature hydrogen bonds with carbon dioxide into methanol (Siti Nurhanna Riduan et al ANGEWANDTE CHEMIE-INTERNATIONAL EDITION Volume: 48 Issue: 18 Pages: 3322-3325 Published: 2009) the reaction CO2 + 2e- → CO + ½O2, which involves a free energy change of about 257 kJ/mol (1.33 eV per electron). The CO, thus formed, reacts with atomic hydrogen to form hydrocarbons

Typical intermediates produced by primary active species (ecb−, hvb+, •OH, HO2•, O2•−, and H2O2) during photocatalytic degradation are for instance (i) aromatic compounds, (ii) carboxylic acids, (iii) nitrogen-containing straight chain compounds, and (iv) inorganic species (ammonium and nitrate ions).

Generally UV light with a wave length lower than 388 nm can be absorbed by TiO2 generating a pair of charges e^-_{cb} / h^+_{vb} (photogenerated electron e^-_{cb} / photogenerated hole h^+_{vb}) . reduction of the e^-_{cb} / h^+_{vb} recombination results in more hydroxyl radicals production and a better oxidation efficiency .

Effective retardation of recombination of the e-cb-h+vb pair, can be obtained if the the electron- and hole-sinks is physically adsorbed or chemically attached to the surface of the semiconductor

The addition of some metals in particular those metal cations with a reduction potential that is less negative than the reduction potential of the conduction band can synergistically enhance the photocatalytic oxidation. The relative low cost of Fe ions and its Fenton's reaction with H_2O_2 to produce hydrol radicals m²akes this an interesting dopant in semiconductors, in particular TiO_2 for instance a TiO_2 doped

with wetness impregnation or thermal plasma until 0.5wt % of Fe. Fe-TiO_2-doped catalysts can for instance be prepared by a 48-h period of mixing of the solution containing the catalyst and Fe ions. After mixing, the catalyst can be dried at 393K for 24 h and then calcined at 773K. An other suitable dopant is Ag. Ag-doped TiO_2 xerogels can be synthesized in a single step through the simultaneous hydrolysis and condensation of Ti(IV) isopropoxide with an alkoxysilane-functionalized silver complex Whereby the silver is present in the form of metallic nanoparticles and silicon is distributed in the TiO2 matrix and attached by Si–O–Ti bonds. TiO2 doped with silver and silica can for instance be synthesized from a suspension of silver nitrate powder, AgNO3, in half of the 2-methoxyethanol used as solvent, and adding N-[3-(2-aminoethyl) aminopropyl] trimethoxysilane H2NCH2CH2NH(CH2)3Si(OCH3)3 97% (EDAS, Aldrich, produced by Dow Corning). Such mixture can be stirred until the complete dissolution of the silver salt. Titanium (IV) tetraisopropoxide (TTIP) 98% (Janssen Chimica) is consequently added and the water in the remaining half of the 2-methoxyethanol volume is added to the mixture under vigorous stirring. Such solution is closed tightly and heated to 70 °C for 24 h (gelation and aging). In all gels, the hydrolysis ratio, i.e., the molar ratio H = [H2O]/([TTIP] + 3/4[EDAS]), and the dilution ratio, i.e., the molar ratio R = [2-methoxyethanol]/([TTIP] + [EDAS]) is kept constant at values of 2.2 and 20, respectively. introduction of silver through an alkoxysilane complex automatically introduces a few percents of silica in the TiO2-based material. That low amount of silica modifies dramatically the behaviour of the xerogels when heated at high temperature. Indeed, while exhibiting a high surface area after washing, all samples (with and without silica) lose a large proportion of their surface when heated. Well crystallized anatase materials with a significant porosity and doped with Ag is obtained through the synthesis method. This amorphous TiO2-based xerogel with very high surface area with enhanced thermal stability and photoactive under UV/Vis light, biologically and chemically inert, photostable is suitable for semiconductor heterogeneous photocatalysis. Doping the photocatalyst with dyes to increase the photocatalytic efficiency by increasing the photocatalyst activity. Doping the photocatalyst with metals to increase the photocatalytic efficiency.

Due to the large band gap of 3.1 eV, TiO3 allows only a relative small fraction of the solar spectrum to be used. Visible light photocatalysis can be obtained. One of the strategies for insuring visible light response in Ti03 is chemical doping of TiO3 with metal ions with partial filled d-orbitals such as V, Cr, Fe, Co and Ni for instance by ion-implantation. Visible-light response improvement of TiO2 can be obtained in TiO2-N, TiO2-S or TiO2-C by doping of TiO2 anions such as N, C or S as substitutes for oxygen in the TiO2 lattice. For these anion-doped TiO2 photocatalysts, the mixing of the p states of doped anion (S, N or C) with the O 2p states shifts the VB edge upward and narrows the band-gap energy of TiO2. Required by photocatalysts for water splitting have been identified (band edge potentials suitable for water splitting, band-gap energy around 2.0–2.2 eV. For overall water splitting, among the semiconductors KTaO3, SrTiO3, TiO2, ZnS, CdS, and SiC fulfil the thermodynamic requirements from the perspective of band positions. Ion doping has been carried out for enhancing the visible-light response of wide band-gap photocatalysts (UV-active). Examples include Sb- or Ta- and Cr-doped TiO2 and SrTiO3, ZnS doped with Cu or Ni, or C-doped TiO2. The replacement of cations in the crystal lattice of a wide band-gap semiconductor may create impurity energy levels within the band gap of the photocatalyst that facilitates absorption in the visible range. Insertion of dopants into the photocatalyst structure can be carried by advanced ion-implantation technique which more effective than chemical methods for controlling the insertion. Semiconductor mixing (composite) can be used for photocatalysts with visible-light response from photocatalysts with a wide band gap which is based on the coupling of a wide band-gap semiconductor with a narrow band semiconductor with a more negative conduction band (CB) level. Such visible light composite photocatalyst can be of the group consisting of: CdS-TiO2, CdS-K4Nb6O17 and Ca2Fe2O4-PbBi2Nb1.9W0.1O9. Another approach to extend to visible light response of wide band-gap photocatalysts involves making solid solutions between wide and narrow band-gap semiconductors with a similar lattice structure, such alloys can be of the group consisting of GaN-ZnO, ZnO-GeO, ZnS-CdS, ZnS-AgInS2 and CdS-CdSe. The deposition of noble metals (e.g., Pt, Rh) or metal oxides (e.g., NiO, RuO2) onto photocatalyst surfaces is an effective way of enhancing photocatalyst activity. The co catalyst improves the efficiency of photocatalysts.

Photocatalytic reactors can comprise immobilized catalyst (e.g. TiO_2, TiO_2/Pt , ZnO) anchored on a support via physical surface forces or chemical bonds on activated carbon, fiber optic cables, fibreglass, glass, glass beads, glass wool, membranes, quartz sand, zeolites, Silica gel, stainless steel, Teflon for instance on the reactor wall surrounding the light source. The fibres which anchor the photocatalyst van be structures into a textile or fabric or they can be incorporated into a membrane. The photocatalyst coated beads or particles can be incorporated into membrane. Such substrates can be integrated in immobilized reactor designs such as the know designs of the group consisting of the falling Film Reactor (FFR), Fiber Optic Cable Reactor (FOCR), Multiple Tube Reactor (MTR), Packed Bed Reactor (PBR), Rotating Disk Reactor with Controlled Periodic Illumination (RDR-CPl), Spiral Glass Tube Reactor (SGTR), Tube Light Reactor (TLR) and Photo CREC Water I. For any of these reactors TiO2 may be replaced by an alternative photocatalysts.

The Falling Film Reactor (FFR) of the art comprises an immobilized TiO_2 coating on the internal wall of a column, a descending film of water and a lamp placed in the central section of the column. This reactor configuration may only provide a limited active catalyst surface per unit reactor volume. The Fiber Optic Cable Reactor (FOCR) is a design with fiber optic cables bringing irradiation to the supported photocatalysis (e.g. TiO_2). This system can allow the irradiation of a remotely located photocatalyst with minimum scattering and uniform irradiation. A typical FOCR includes Degussa P25 immobilized on quartz optical fibbers and a Xe arc UV-radiation lamp (310-375 nm). The Multiple Tube Reactor (MTR) is a design with a cylindrical vessel (5-6 cm of diameter) containing 54 hollow quartz glass tubes (diameter 0.6 cm) externally coated with photocatalyst. The MTR resembles a shell and tube heat exchanger with the water to be treated flowing in the shell side of the MTR. The irradiation is distributed in hollow tubes for instance via an aluminium reflector. The MTR provides a large activated photocatalyst area per unit reactor volume. The Packed Bed Reactor (PBR) is an annular packed unit irradiated by a

central lamp. Several variations of the PBR are reported such as TiO2 coated glass mesh, TiO2 coated glass wool, and TiO2 coated glass beads. The Rotating Disk Reactor with Controlled Periodic Illumination (RDR-CPI) contains immobilized TiO_2 films placed on the surface of a rotating disk. The disk is attached to a power-driven shaft that rotates at a rate of 20-100 rpm. An arrangement of lamps are used to irradiate the disk surface. The rotating hydrodynamics provides good reagent access to the catalyst surface. The Spiral Glass Tube Reactor (SGTR) consists of a TiO_2-coated spiral tube wrapped around a lamp. The Tube Light Reactor (TLR) comprises a stainless steel flat top plate and an inner welded plate characterize the TLR. Several U-shaped Ti02-coated lamps are placed around the welded plate. The assembly is enclosed in a rectangular stainless steel vessel. Possible advantages of the TLR are a high catalyst surface area per unit volume and favourable scaling-up possibilities. The Photo-CREC Water I is an annular reactor with a lamp placed at the reactor centerline. This configuration allows high TiO_2 loading of the glass mesh, good catalyst irradiation and uniform contact of the circulating water. The Photo-CREC-Water I reactor was originally proposed by de Lasa and Valladares (de Lasa, H. I., and Valladares, J., 1997, Photocatalytic reactor, US Patent No. 5,683,589. 1997), and Valladares (1995). Modifications were introduced to the original design by Serrano and de Lasa (Serrano, B., and de Lasa, H., 1997, Photocatalytic degradation of water organic pollutants. Kinetic modelling and energy efficiency. Ind. Eng. Chem. Res. 36:4705-4711. 1997). an annular channel with multiple (16) baskets positioned at 45° angles characterizes the Photo-CREC-Water I. The Photo-CREC reactor is configured with stainless steel spacers placed between the baskets. These spacers secure the basket in position and ensure minimum loss of light. The near-UV lamp is located in the central channel, providing 15 W of monochromatic light (365 nm). Water is circulated in a downward flow, with the only exception being the start-up of the run when an upward flow evacuates the air pockets. Water exiting the reactor is discharged into an oxygenator. This unit is equipped with a perforated pipe air distributor and a magnetic stirrer securing water saturation with oxygen. A variable-flow Gilson pump completes the experimental system. This pump is used to return the water to the upper section of the photoreactor unit, closing in this way the cycle of water oxygenation and recirculation. The reactor comprises a mesh with

photocatalyst, such as TiO_2 (TiO_2-mesh - catalyst loading (16.5 wt %)) or TiO_2 activated cabon composite on the impregnated fiberglass mesh) mounted on the inner face of each of the conical baskets. Such immobilized photocatalyst anchored on fiberglass mesh, do not require particle recovery. The TiO2 or TiO2 activated cabon composite on such fiberglass mesh can be loaded with metals such as platinum, palladium and ruthenium or with metal oxides such as Fe2O3, Co3O4, or NiO to increase phoytocatalytic activity. The fiberglass mesh can also comprise multiple semi conductor materials with a varying band gap energy (eV) and this a different excitation wave length. For instance TiO2 (rutile) has eV of 3.0 and a excitation wavelength requirement of 413 nm (UV), TiO2 (anatase) has eV of 3.2 and a excitation wavelength requirement of 388 nm (near violet UV), ZnO has eV of 3.2 and a excitation wavelength requirement of 388 nm (near violet UV), ZnS has eV of 3.6 and a excitation wavelength requirement of 335 nm (UV), CdS has eV of 2.4 and a excitation wavelength requirement of 516 nm (green light), Fe2O3 has as eV of 2.3 and a excitation wavelength requirement of 539 nm (green light) and W03 has as eV of 2.8 and a excitation wavelength requirement of 443 nm (violet light).

The radiation source can be UV radiation for instance UV-A from 315 to 400 nm (near ultraviolet range) , UV-B from 280 to 315 or UV-C from 200 to 280 nm. The UV-C spectrum (200 to 280 nanometres) is the most lethal wavelength for microorganisms, because it disrupts the bonds in the between the atoms in the chemicals in microorganisms. This range of wavelengths, with 264 nanometres being the peak germicidal wavelength, is known as the Germicidal Spectrum. Generally only a 4-5% portion of the sunlight that reaches the earth is in the 300- 400 nm near ultraviolet range and activates TiO2. UV-A from 315 to 400 nm (near ultraviolet range) can excite TiO2 (anatase), ZnO and ZnS. Wavelength converters or spectral converter can to improve the spectral mismatch. Any chelates with suitable absorption and donor properties and able to form kinetically stable 1:1 chelates with lanthanide metal ions would could act for wavelength conversion. A class of such chelates and methods for making them are disclosed in European Patent Application No. 0,195,413.

Eu chelate is a light-emitting material that can be incorporated in a wave length conversion film due to the high PL quantum efficiency by the ultraviolet excitation. Though the typical transition of trivalent Eu ion generates red emission. Eu chelate, such as Eu(TTA)3phen [TTA: thenoyltrifluoronacetone, phen: 1,10-phenanthroline], improves the absorption coefficient per each Eu ion, and reduces the concentration quenching due to the inter-molecular interaction. For instance near-UV is converted to red wavelength by a transparent (in the visible region) thick film containing 38.8 wt% of YVO4:Bi3+,Eu3+ nanoparticles of 10.8 ± 1.6 nm in size (nanoparticle film shows a high transparency(transmittance at 619 nm is ~ 96% irrespective of the film thickness) (Satoru Takeshita et al. Material research Society, 2010 Spring Meeting, Volumes 1245 – 1274). A wave length converting film including the sol–gel glass encapsulated Eu(TTA)3phen, which has the high luminance red emission with the near violet excitation.

Barium ferrite (Alfa Aesar) particles are coated with silica using a Stöber technique [Watson, S., Scott, J., Beydoun, D., & Amal, R. (2005). Studies on the preparation of magnetic photocatalysts, Journal of Nanoparticle Research, 7, 691–705.]. Specifically, 4000 mg of BaFe12O19 are dispersed in 500 ml of 0.51:0.79:15:0.037 mol ratio of H20:NH4OH:EtOH: TEOS. The particles were stirred for 24 h with a PTFE overhead mixer at 475 rpm. The resulting particles were dried at 65°C for 24 h resulting in a total mass of ~ 4.40 g. The silica-coated barium ferrite particles and 18.9 g titanium dioxide (Degussa P25) were then dispersed in an acid catalyzed silica sol-gel [Byrne, H.E., Kostedt, W.L, IV, Stokke, J.M., & Mazyck, D.W. (2009). Characterization of HF-catalyzed silica gels doped with Degussa P25 Titanium Dioxide, Journal of Non-Crystalline Solids, 355, 525–530.]. The was prepared with 113 ml of Nanopure water (18.2 MX/cm), 225 ml ethanol, 156 ml TEOS, 18 ml 1 M HNO3, and varying volumes of 3% hydrofluoric acid. The volume ratio of HNO3 to HF was used to denote the three types of HSAMP explored in this work. For example, HSAMP8 indicates that a volume ratio of 8:1 and a volume of 2.25 ml HF. The gelation time varied by hydrofluoric acid concentration between 7 and 24 h. This time was determined as the time necessary to reach a viscosity such that visible particle movement was negligible and the vortex near the overhead mixer paddles was no

longer apparent. The gel was then poured into plastic specimen containers, sealed and aged at 25°C for 48 h then 60°C for another 48 h. To dry the gel and evaporate residual ethanol, the aged gel was dried in a PTFE container with a small hole on the top. The drying followed a 3°C ramp to 103°C, held for 18 h, then followed another 3°C ramp to 180°C and was held for 6h. After drying, the xerogel was heat treated with a 5°C ramp to 450°C, held for 1 h and cooled naturally. The resulting xerogel was ground with a mortar and pestle and wet sieved to retain the 45–90 μm fraction. The powder is dried at 180°C and stored under vacuum until use. The solar spectrum at 1.5 atmosphere mass according to the ASTM standard comprises 922 W. M^{-2} where under about 40% near IR or 375 W. M^{-2} , 55% visible light or 504 W. M^{-2} and 5% UV or 43 W. M^{-2}.

Heterogeneous photocatalysis for remediation comprising a photon emitter in a proper wavelength to emit photons with energy edual or g-higher than the ban gap energy of said catalyst in catalyst surface , a catalyst surface (e.g. a semi-conductor material) and a strong oxidation agent (e.g. oxygen). Light with photon energies greater than the band gap can be absorbed by the crystal, exciting electrons from the filled valence band to the empty conduction band (illus. a). The state in which an electron is removed from the filled valence band is known as a hole. It is analogous to a bubble in a liquid. The hole can be thought of as being mobile and having positive charge. The excited electrons and holes rapidly lose energy (in about 10^{-12} s) by the excitation of lattice phonons (vibrational quanta). The excited electrons fall to near the bottom of the conduction band, and the holes rise to near the top of the valence band, and then on a much longer time scale (of 10^{-9} to 10^{-6} s) the electron drops across the energy gap into the empty state represented by the hole. This is known as electron-hole recombination. An energy approximately equal to the band gap is released in the process. Electron-hole recombination is radiative if the released energy is light and nonradiative if it is heat.

An embodiment of present invention comprises a controlled aquatic farming or water treatment system with a photocatalytic reactor that comprises different for instance an array of different photocatalytic surfaces. Such reactor comprises multiple photocatalysts and metal contacts for reacting multiple fluid analytes in water,

analyte mixtures in water and intermediates in water produced by the other photocatalytic surface. In a particular embodiment such photocatalytic reactor is a particulate suspension system (fig 27) which photocatalytic reactor comprises a mixture of particles that function microphotoelectodes whereof a portion of the first microphotoelectodes if radiated (e.g. under visible light or near infrared) perform water splitting H_2O → H_2 + ½ O_2 and another portion of the second microphotoelectodes perform OH• radicals generation if radiated (e.g. under visible light or near infrared) and oxidize organic adsorbed pollutants (RXad) onto the surface, whereby the molecular oxygen produced by the first microphotoelectodes acts as an acceptor species in the electron-transfer reaction. In a particular embodiment photoreactor comprises different units , first init(s) with a OH• radicals generation and adsorbed pollutants (RXad) and eventual metal reduction function (down hill photocatalysis function) and second unit(s) with a water splitting function (up hill photocatalysis).

It is a particular embodiment of present invention to have the nitrifying condominiums which decline alkalinity and reduce pH been compensated by the alkalinity building and pH increasing activity of the denitrifying condominiums. These condominiums can be in different bioreactor units or can be in different zone of the same bioreactor system. Present invention provides a security ammonium removal system to reduce the ammonium-ion toxicity and to maintain the pH at systems normo-pH by switching on ammonium removal. In an embodiment of present invention the pH monitoring system is organised to maintain a dual pH regime of an aquaculture normo-pH and a crop normo-pH in the plant culture unit for instance in the hydroponics or soilless plant culture. A sensor network with hard sensors (pH sensors) monitor the different bioreactor (plant culture, aquatic animal culture, microbial nitrification / denitrification) and balance their pH and alkalinity effects towards normo-PH (system normo-pH or aquaculture normo-pH in combination with crop normo-pH). Ammonium removal can be by various from the aqueous or watery farming medium can be by various types of actuators. For instance by ion-exchange using packed bed zeolite (e.g. Clinoptilolite) reactor can be activated as a response of a reduced hydrogen activity under the systems normo-pH or

the systems normo-hydrogen ion activity. A continuous ammonium removal system based on an ion-exchange medium (zeolite) has for instance been fully disclosed in US7264732 B2. Or the one step anaerobic ammonium oxidation process can be boosted or switched on . This system is under control pH measurements if there is a risk of a downwards pH shift for systems normo-pH for instance in the units that host the aquatic animals or in the water that irrigates the soilleness crop culture units. NH_4^+ and NO_2^- under low pH and under an NO atmosphere (to prevent decomposition of nitrite) have been demonstrated to produce N_2 from ammonium and nitrite been confirmed (*Van Cleemput, O., and L. Baert. 1984. Nitrite: a key compound in N loss processes under acid conditions. Plant Soil 76:233–241 and Smith, D. H., and F. E. Clark. 1960. Volatile losses of nitrogen from acid or neutral soils or solutions containing nitrite and ammonium ions. Soil Sci.90:86–92*). Van de Graaf et al Applied and environmental Microbiology, Apr. 1995, p. 1246–1251 confirmed in a denitrifying fluidized bed reactor that this direct conversion of ammonium to dinitrogen gas without oxygen and with nitrite as the electron acceptor ($NH_4^+ + NO_2^- \rightarrow 2H_2O + N_2\uparrow$ or) is a bacterial process. If ammonium is first partially oxidized to nitrite, then the remaining ammonium be further transformed into dinitrogen by planctomycete like bacteria growing in anaerobic zones of a treatment system. Alternatively the actuator is single-stage aerobic bioreactor with intermeshing aerobic, anoxic, and anaerobic zones with completely autotrophic nitrogen removal over nitrite, which can occur in a system . The intermeshing aerobic, anoxic, and anaerobic zones provide habitat for the coexistence of different microbial communities (stoichiometry: $NH_4 + 0.85\ O_2 \rightarrow 0.435\ N_2 + 0.13\ NO_3^- + 13\ H_2O + 1.4\ H^+$). Changes caused by the NH_4^+-limitation are completely reversible, and the system can re-established itself as soon as the ammonium limitation was removed even enduring periods of up to one month of ammonium limitation without irreversible damage. The process can be achieved in both achieved in both continuous (the continuously-aerated SBBR) and intermittent aeration pattern (the intermittently-aerated sequential batch biofilm reactor (SBBR)).

Another ammonium removal reactor is a bioreactor based on oxygen limited autotrophic nitrification – denitrification for direct NH_4^+ to N_2 transformation.

Important nitrogen losses (40 – 70%) have been observed earlier in rotating biological contactor (*Baumgarten and Seyfried 1996*) under low dissolved oxygen conditions, which were not due to heterotrophic denitrification but due to direct biological conversion of ammonia to nitrogen in (micro)aerobic conditions (aerobic deammonification), probably because their are both aerobic conditions in the outer biofilm and anoxic conditions at the core of the biofilm. Another ammonium removal reactor is an air stripper with surfaces to improve contact between water / gas for instance a packed bed air stripper to remove ammonia (NH_3) from water. Ammonia nitrogen exists in both dissolved gas form (NH_3) and in true solution (NH_4^+) in a dynamic equilibrium : $NH_3 + H2O \leftrightarrow NH_4^+ + OH^-$ which is controlled by solubility that varies with temperature and pH. In general at a temperature of 20°C and a pH of 7 or below, only ammonium ions are present. As the pH increases above 7, the chemical equilibrium is gradually shifted to the left in favour of the ammonium gas formation. At a pH of about 11.5- 12 only the dissolved gas is present. However the ammonium stripping can efficiently been achieved by stripping ammonia from the farming water by a two steps process steam at atmospheric pressure and condensing said steam comprising stripped ammonia and second step comprising rectifying said condensed steam comprising ammonia to at least 20% by weight of aqueous ammonia, said second step advantageously being carried out at a pressure above atmospheric pressure. A one step process for stripping ammonia from liquids has been described in US7416644 B2. The stripper system is connected to an evaporator. In the evaporator aqueous liquid is heated at a pressure below atmospheric pressure whereby vapour is developed at a temperature below 100° C. The vapour from the evaporator is directed to the liquid medium containing ammonia and this results in ammonia being stripped from the liquid and transferred to the vapour phase. The vapour phase is condensed in a first condenser at a low pressure, and the liquid thus obtained is further treated in a stripper unit at a higher pressure.

The vast majority of micro-organisms live and grow in aggregated forms such as biofilms, flocs ('planktonic biofilms') and sludge. This form of growth is lumped in the somewhat inexact but generally accepted expression 'biofilm'. The feature which

is common to all these phenomena is that the micro-organisms are embedded in a matrix of extracellular polymeric substances (EPS) which are responsible for morphology, structure, coherence, physico-chemical properties and activity of these aggregates (*Wingender, J. & Flemming, H.-C. (1999). Autoaggregation in flocs and biofilms. In Biotechnology, vol. 8, pp. 63–86. Edited by J. Winter. Weinheim: VCH*). Granulation is a process in which microorganisms aggregate to form a spherical, dense biomass. Granules have been grown successfully in either anaerobic or aerobic. Environments. The formation of aerobic granules seems to be independent of the characteristics of the organic substrate (*Jiang, H. L., Tay, J. H., and Tay, S. T. L. 2002. Aggregation of immobilized activated sludge cells into aerobically grown microbial granules for the aerobic biodegradation of phenol. Lett Appl Microbiol 35: 439–445*).We use water shear forces for instance stirring in aerobic or anaerobic biofiltering bioreactor units to form biogranules and hypothesized that these biogranules can be used as inert biotics to up-regulate the host defence mechanisms of the cultured fish against pathogenic microorganisms that host its water reuse environment. This is translated in a higher prophylactic disease resistance against pathogens that host the recirculating system than the classic immune stimulants such as beta-glucans suggesting a specific mechanism. Sterilized biogranules of bacterial biofilter units of the IRAFS can be reintroduced in the IRAFS as food biomass for the aquatic animals, in particular the fish of the IRAFS. Biogranules can be simply sterilized by heat. For large scale production the biogranules products of the anaerobic and/or aerobic biogranulator are preferably properly packed, eventually dehydrated, cooled and sterilized by gamma rays from radioactive nuclides or X-rays emitted by high-energy electron beams which are suitable sources of ionizing energy and are commonly used for food irradiation and which can penetrate substantial thicknesses of solid materials. Gamma rays food irradiation is carried out in gamma-Ray Facilities for instance in a MDS Nordion Pallet™ gamma-ray irradiator loaded with Co-60 for large pallet loads of low-density packages MDS Nordion Centurion™ gamma-ray facilities for treating thinner packages of high-density products or the Gray*Star Genesis™ gamma-ray facility, which irradiates products under water are suitable for sterilizing such biogranular biomass. X-Ray food irradiation is for instance done in X-Ray facilities such as the Palletron™ system (MDS Nordion &

IBA). Alternatively food irradiation by energetic electrons in sterilizing electron beam accelerators such as the microwave linear accelerators (linacs) such as the Circe™ Sband Systems (Linac Technologies S.A. France), the L-band systems (Iotron Industries Canada Inc.) or the IMPELA™ linac is used for the sterilization of the packed biogranules products. The present invention in a particular concerns in a particular embodiment the use of biogranlution units that are integrated in a recirculating aquatic animal culture system for the production of a feed ingredient. The biogranules are collected by a collections means, they are sterilized by a sterilization means, dehydrated and used as a feed additive. This feed reduces loss caused by diseases in recirculating aquatic animal farming systems, in particular the recirculating fish culture. It furthermore concerns the use of sterilized microorganism granules, microgranules comprising microorganism (biogranules) from a granular sludge bioreactor of a recirculating aquatic animal farming system that comprises said granular sludge bioreactor in the manufacture of a medicinal feed to protect said aquatic multicellular consumer organisms (e.g. aquatic animals) against pathogens that host their environment. In a certain embodiment these biogranules comprise aerobic microorganisms. In yet another embodiment of present invention these biogranules comprise anaerobic microorganisms. The aerobic or anaerobic granule bioreactors can be inoculated or further be inoculated by specific facultative anaerobes (aerobic (O_2) or anaerobic) such as *Bacillus Pseudomonas,* which is particularly suitable for cBOD removal, denitrification and floc formation. Such sterilized microorganism granules, microgranules comprising *Bacillus Pseudomonas* from a granular sludge bioreactor of a recirculating aquatic animal farming system that comprises said granular sludge bioreactor in the manufacture of a medicinal feed to protect said aquatic multicellular consumer organisms (e.g. aquatic animals) against pathogens that host their environment.

Several type bioreactor units can be integrated in the intensive recirculating aquatic farming system or IRAFS of present invention. For instance suitable soilless crops for culture in the IRAFS of present invention are photoauto-heterotrophic which can be raised in the photoauto-heterotrophic bioreactor. In particular suitable is *Rhodospirillum rubrum* (e.g. the ATCC25903 or ATCC11170) of which the cultures

do not produce toxins and which delivers an edible biomass that is a suitable complementary food source for animal and human. The R. rubrum biomass produced in the photoauto-heterotrophic bioreactor(s) of the IRAFS of present invention can be reintroduced in the IRAFS as feed additive for the aquatic animals that are cultured in the IRAFS. A particular photoheterotrophic bioreactor integrated in the system of present invention is a plant culture unit for instance a soilless horticulture in a protected or confined space such as greenhouse, preferably in a greenhouse that receives water of the aquatic organism's culture system (e.g. the aquatic animals). A very suitable plant culture unit to be integrated in the system is based on the nutrient film technique (NFT). This provides a thin film of nutrient solution through channels that comprise the root zone (alternatively other techniques may be used such as static aerated technique, intermediate irrigation and root misting). The NFT can further comprise a buffer tank, nutrient reservoir pump, growing troughs, collecting trough, condensed water tank, acid stock solution, base stock solution tank, nutrient stock solution tank, sterilization loop bypass pump, U.V. system, liquid filter and ozonation system as a germicidal treatment The photoheterotrophic bioreactor system will be controlled by a liquid control system that controls the nutrient reservoir pump, the nutrient solution pH, the nutrient electric conductivity, nutrient solution and condensate water levels. Water from the other bioreactor (e.g. the aquatic animal farming unit) is delivered to this photoheterotrophic bioreactor via the liquid control system. The air composition such as O_2, CO_2, N_2 and Volatile Organic Compounds such as ethylene is monitored and controlled. Such photo reactive bioreactors need solar or man made lightening. Lightening systems or radiation providing sources that are suitable for present invention can be incandescent lamps, fluorescent lamps, high intensity discharge lamps (metal halide, high pressure sodium lamps) light emitting diodes and microwave lamps (MW). HPS lamps (e.g. PL2000 600 W HPS) are useful for plant growth because of their PAR efficiency, long rated life and light intensity drop is slow as the lamp ages. Metal halide (MH) lamps for instance PL2000 400 W MH with Hortilux Maxima Reflector emit in the spectrum almost continuously over the 400 and 700 nm waveband which resembles the spectrum of daylight. But they have a shorter rated life than HPS lamps. A combination of MH and HPS is

preferably. The radiation is controllable by a lightening control system e.g. Schneider PLC

The nitrifying bioreactor is dedicated to degrading ammonium from other compartments into nitrate which can be made available to the photobioreactors as a nitrogen source. With increasing pH ammonium ions are converted to ammonia. Ammonia and nitrite ions are at relatively low concentrations toxic for aquatic vertebrate and invertebrate animals and for the photosynthetic cyanobacteria and plants. Such nitrifying bioreactor an be operational run a ammonium oxidation in two consecutive stages: ammonium to nitrate oxidation $NH_4^+ + 1.5\ O_2 \rightarrow NO_2^- + 2H^+ + H_2O$ (e.g. by *Nitrosomonas europaea*) and nitrite to nitrate $NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$ (e.g. by *Nitrobacter winogradskyi* e.g. strain Nb-255) whereby dissolved oxygen is removed from the water by the bacteria and added to the ammonium ions and nitrite ions. Among the autotrophic ammonia/nitrite oxidizers are the chemolithotrophs (autotrophs) that absorb cBOD. For instance ammonia oxidizing microbials can be of the genera of the group consisting of *Nitrosomonas, Nitrosococcus, Nitrosospira, Nitrosolobus and Nitrosovibrio* or nitrite oxidizer of the group of genera consisting of *Nitrobacter, Nitrococcus, Nitrospira and Nitrospina.* The inorganic carbon source for these organisms, in particular for the autotrophic nBOD-oxidising, such as the NH_4^+ oxidisers (*Nitrosomonas, Nitrococcus, Nitrocysis, Nitrosolubus, Nitrospira*) and the NO_2^- oxidisers (*Nitrobacter, Nitrococcus and Nitrospira*) is inorganic carbon CO_2 for the syntheses of their cellular material which can be solved as carbonic acid (H_2CO_3): $CO_2 + H_2O \rightarrow H_2CO_3$, which can disassociate in bicarbonate (HCO_3^-) and H^+: $H2CO3 \leftrightarrow H^+ + HCO_3^-$. Suitable organisms for inoculation or growing in this aerobic bioreactor are selected bacteria from the group consisting of *Arthrobacter, Bacillus, Nitrobacter, Nitrosomonas, Proteus, Pseudomonas and Vibrio.* It can be also *Actinomycetes* organisms selected from the group consisting of Mycobacterium, *Nocardi* and *Streptomyces* or it can be Protozoa of the group consisting of *Epistylis* and *Vorticella* or it can be fungal organisms such as fungi of the group of the *Aspergillus.* By using CO_2 as carbon substrate and ammonium ions and nitrite as energy substrate the nitrifying bacteria decrease the alkalinity and the pH in their environment, the aerated bioreactors. Present invention provides solution for

biofiltration without destroying the alkalinity or without drastically affecting the alkalinity. Eventually the chemolithoautotrophic ammonia oxidizers (CAO) and chemolithoautotrophic nitrite oxidizers (CNO) can be used to inhabit the nitrifying bioreactor for NH_4^+ and NO_2^- oxidation to nitrate at condition that is controlled to be permanently at a slightly acid conditions. The system is preferably operated at 15° - 30°C and pH 6.4 – 8. The nitrifying bacteria are generally chemoautotrophic bacteria that grow by consuming inorganic nitrogen compounds. Many species of nitrifying bacteria have complex internal membrane systems that are the location for key enzymes in nitrification: ammonia monooxygenase which oxidizes ammonia to hydroxylamine, and nitrite oxidoreductase, which oxidizes nitrite to nitrate. The operation can, however, be improved if beside the nitrifying chemoautotrophs such bioreactor can be hosting organotrophs (cBOD oxidizing bacteria or heterotrophs) which are able to remove soluble cBOD, particulate BOD (pBOD) and colloidal BOD (coBOD). The autotrophic nitrifying bacteria generally reduce the nBOD in the activated sludge process. But for adequate nBOD reduction, the cBOD must be reduced to a relatively low concentration (e.g.< 40 mg/l). This can be adequately obtained by organotrophs which oxidize organic wastes through aerobic respiration or anaerobic respiration. Such organotrophs can be of the group of the strict aerobes consisting of *Actinobacter*, *Arthrobacter, Micrococcus, Nocardia* and *Thiothrix* or they van be facultative anaerobes of the group consisting of the A*chromobacter, Actinyces, Aerobacter, Bacillus, Beggiatoa, Cormynebacterium, Enterobacter, Escherichia, Flavaobacterium*, *Klebsiella, Proteus, Pseudomonas, Spaerotillus* and *Zoogloe*, which use free molecular oxygen or another molecule comprising oxygen to oxidize organic waste but with preference free molecular oxygen since they obtain in this way larger quantities of energy and produce more offspring. This aerobic reactor may contain floc formation initiators of the group consisting of *Achromobacter, Aerobacter, Bacillus, Escherichia, Flavobacterium* and *Pseudumonas* whereby he formed flocs will contain organotrophs and autotrophic nitrifiers for improved cBOD and nBOD removal.

A preferred nitrifying bioreactor is the aerated activated sludge bioreactor (e.g. an aerated fluidized microbead reactor) or another preferred reactor is a USBF reactor

with an anoxic and an aerated aerobic zone for nitrification conversion oxidation reduced ammonium ion NH_4^+ into NO_2^- and into NO_3^- waste substrate conversion to simple substrates CO_2, H_2O, NH_4^+, NO_2^-, NO_3^-, SO_4^{2-}, PO_4^{2-} and bacterial cells.

A liquefier bioreactor can be integrated in the IRAFS to improve its operations. In a specific embodiment of present invention the aerobic nitrifying bioreactor receives water that is loaded with material from a liquefier bioreactor or that has been pre-treated in this liquefier bioreactor. This can improve the efficiency of the nitrifying bioreactor because macromolecules and polymers have been degraded. Such liquefier bioreactor for hydrolysis (macromolecular hydrolysis by hydrolytic fermentative bacteria), acidogenesis (production fermentation products), actenogenesis (degradation of volatile fatty acids and alcohols by actenogenic bacteria) and methanolgenesis (conversion of the fermented products into methane by methanogenic and acetoclastic bacteria). Such water from the liquefier bioreactor can further be mineralized in the photocatalytic reactor (assisted with or without a ultrasound or microwave function) before it is presented to the aerobic bioreactor or to the photo(auto/hetero)trophic bioreactor and in particular for the photoautotrophic bioreactor comprising organism (e.g. green plants and photosynthetic bacteria are photoautotrophs). Such bioreactor can be operational after inoculation with selected strains from faeces and with *Fibrobacter* to enhance the degradation of fibres. Such liquefier bioreactor is anaerobic or at least a reactor that comprises an anoxic zone. In a particular embodiment the liquefier bioreactor produces energy rich gas that is transported by a gas transport line to the firing system that drives a heat pump system for redistributing the heat in the IRAFS for instance from the final drain upstream to a bioreactor unit. Particularly interesting for integration in the farming system of present invention is a reactor hosting a heterogeneous community of heterotrophic organisms, denitrifier organisms, nitrifier organisms, for instance the biofloc and/or biogranule bioreactor that is integrated in the IRAFS. For instance the IRAFS can integrate a biofloc based bioreactor. Such biofloc based bioreactor is a reactor hosting a heterogeneous community of heterotrophic organisms, denitrifier organisms, nitrifier organisms and poly-P (polyphosphate) /PHB (poly-hydroxy-butyrate) /glycogen accumulating organisms in a biofloc motive. Such heterogeneous

communities can host floc forming bacteria (e.g. *Zoogloea* such as *Zoogloea ramigera*), filamantous bacteria and algae and can be enhanced by abiotic factors such as light, shear rate and temperature and C/N ratios of approximately 5 – 15, preferably 5 – 12 and most preferably approximating 10. Glycogen accumulating organisms (GAO) are organisms that use energy from glycolysis to accumulate substrate (e.g. glucose) fermentations products (e.g. acetate) in the form of poly-(beta) hydroxy-butyrate (PHB). A wide range of microorganisms (e.g. *Alcaligenes eutrophus* and *Pseudomonas oleovarians* accumulate poly-P-beta-hydroxybutyrate (PHB). Polyphosphate accumulating organisms (PAO) use energy stored in poly-P to store exogenous substrate in the form of poly-hydroxy-butyrate (PHB). Such Floc comprise generally 70-80% organic matter including heterotrophic bacteria, algae (dinoflagellates & diatoms), fungi, ciliates, flagellates, rotifers, nematodes, metazoans and detritus. Their composition changes rapidly and frequently through the cycle. Floc particles are agglutinated by bacterial enzyme-rich polysaccharide slime. Average floc diameter is 0.2mm up to 2mm by end of cycle. Flocs have 25% to 56% protein, 25% to 29% organic carbon and have high levels of amino acids. The bio-flocs derivable from this system have a suitable nutritional value to supplement the feed of the aquatic organisms and to be reprocessed into animal feed for the aquatic organisms of another unit of the culture system. In present invention it is demonstrated that such reintroducing of this biomass in the IRAFS via feed to the aquatic animal farming unit, and in particular to the cultured fish, can improve the biosecurity by enhancing the a specific and specific immunity protecting the animals against pathogen microbials that are hosted by the IRAFS.

An alternative embodiment of the invention takes advantage of the fact that extracellular polymers produced by microbial can be used to produce biofilm condominiums of microbial in the form of biogranules (Biogranulation): Another approach of treatment of organic loaded water is by inducing the phenomenon of microbial self-aggregation into biogranules in a biogranule bioreactor that is integrated in the IRAFS. Such biogranule reactors are preferably used in the biofilters of the framing system of present invention. Furthermore a separate biogranule bioreactor can be used to generate granules of selected bacteria that are used to

inoculate the biofilters by designer biogranules of selected microorganisms and to deliver such living biogranules as probiotics to prevent an invasion of unwanted pathogens in to the farming systems and into the aquatic multicellular consumer organisms (e.g. aquatic animals). In a particular embodiment of present invention sterilized and mineralized nutrients derived from the waste of the other units of the IRAFS are fed into such biogranule bioreactor to produce the probiotic biogranules by forcing under shear biofilm forming into biogranules. Biogranulation is a controllable process. It was demonstrated that in airlift reactors, biofilms are formed on suspended carrier particles. These biofilm-on-carrier pellets are subject not only to the turbulence and liquid shear that affect fixed-support biofilms but also to particle collisions. The formation of natural, mixed-population, suspended biofilm pellets was investigated by. Heijnen, J. J., et al. (*Heijnen, J. J., et al 1992. Formation of biofilms in a biofilm air-lift suspension reactor. Wat. Sci. Tech. 26: 647–654*). Gjaltema, A. et al (1997) further studied the influence of carrier type on adhesion and biofilm formation of pure and mixed cultures (*Gjaltema, A., et al. 1997. Adhesion and biofilm development on suspended carriers in airlift reactors: Hydrodynamic conditions versus surface characteristics. Biotechnol. Bioeng. 55, pp. 880–889*). Gjaltema, A. et al. (1997) using suspended carriers (standard, roughened, hydrophobic and positively charged glass beads, sand and basalt grains) in laboratory airlift reactors. The results clearly show that in airlift reactors hydrodynamic conditions and particle collisions control biofilm formation. Increased surface roughness of the carriers promoted biofilm accumulation on suspended carriers, whilst the physico-chemical characteristics of the carrier surface proved to be less important. The influences of reactor conditions (substrate loading rate and shear) and microbial characteristics (yield and growth rate) on the structure and biofilms on the formation of biofilms in Biofilm Airlift Suspension (BAS) reactors had been described In case of a right balance smooth and stable biofilms can be obtained (*M.C.M. van Loosdrecht et al. Biofilm structures Water Science and Technology Volume 32, Issue 8, 1995, Pages 35-43*). Granular sludge was initially used in upflow anaerobic sludge blanket (UASB) reactors (*Lettinga G., et al . (1980) Use of the UASBR concept for biological WWT, especially for anaerobic treatment. Biotech. & Bioeng., 22,' 699-734.*). Wirtz R. and Dague R. developed a wash out strategies for the poor settling granules in

anaerobic sequencing batch reactors. (*Wirtz R., Dague R. (1996) Enhancement of granulation and start-up in the anaerobic sequencing batch reactor. Wat. Env. Res. 68, 883-892.*). Van Loosdrecht M., et al. used granular sludge in biofilm airlift suspension reactors (van Loosdrecht M., et al. (1995) Biofilm structures. War. Sci. Tech., 32(8), 35--43.). Wirtz R and Dague R. (1996) hypothesized that granulation is benefited by a low hydraulic retention time (HRT), causing poor-settling biomass to wash out, and a high organic loading rate, ensuring sufficient new biomass growth. This has been confirmed *Bossier P* and *Verstraete W* who demonstrated for instance that microbial aggregation into good settling sludge is essential for the well-functioning of activated sludge systems treating waste water. Not only can the well settling sludge easier been separated from the bad settling sludge. But moreover there were advantages of better resistance to antibiotics and sometimes higher metabolic activity. Part of the micro-organisms (Up to 25%) in activated sludge system growing at the expense of incoming organic material either fail to aggregate or do not aggregate into settling flocs, because of lack strong or appropriate signals (*Bossier P and Verstraete W (1996) Triggers for microbial aggregation in activated sludge? Appl Microbiol Biotechnol 45:1–6*). This makes it obvious that separation strategies of poor settler and good settler in for instance sequencing batch or discontinued processing with a settling phase and a shearing phase would benefit anaerobic systems but also aerobic systems. The anaerobic (digester) granules are multilayer and have a microbiological composition which is different in each layer (Guiot, S.R., Pauss, A., & Costerton, J.W. (1992). Water Sci. Technol., 25, 1–10). The inner layer mainly consists of methanogens that may act as nucleation centres necessary for the initiation of granule development. H_2-producing and H_2-utilizing bacteria are dominant species in the middle layer, and a mixed species including rods, cocci, and filamentous bacteria takes predominant position in the outermost layer. To convert a target organic to methane, the spatial hydrogen consuming methanogenic bacteria rapidly scavenge the hydrogen and keep the level of hydrogen partial pressure extremely low. This provides a thermodynamically favourable condition for the hydrogen-producing acetogenic bacteria to break down the aforementioned organic compounds into acetate, H_2, and CO_2. The microbial self aggregation in which microbial cells are organized into dense and fast settling granules with a diameter from 0.5 to 10 mm is

of practical importance in both anaerobic and aerobic biological waste treatment. In the aerobic granular sludge reactors and the aerobic granular sludge reactors biogranulation is provided an advantage towards floc formation that the easy settling biogranules can be separated from the more difficult settling floc (*Bossier P and Verstraete W (1996) Triggers for microbial aggregation in activated sludge? Appl Microbiol Biotechnol 45:1–6*). Moreover, in the aerobic granular sludge reactors bacterial communities of ammonium oxidizing bacteria growth on the oxygen rich part of the granule surface and heterotrophic organisms growth in the inner anoxic zone to reduce nitrate to N_2 and remove phosphate (*L. Tijhuis, J. L. et al., Biotechnol. Bioeng. 1995, 47, 585.)* Beside in methanogens granulation occurs for acidifying bacteria (*Beeftink H. H. (1987) Anaerobic Bacterial Aggregates. Ph.D. thesis, University of Amsterdam, The Netherlands*) aerobic nitrifying bacteria (*De Beer, D., et al. S.P.P., 1993. Microelectrode measurements in nitrifying aggregates. Appl. Env. Microbiol. 59, pp. 573–579*), in denitrifying bacteria (*Van der Hoek J. P. (1988) Granulation of denitrifying sludge. In: Granular aerobic sludge, ed. G. Lettinga, A. J. B. Zehnder, J. T. C. Grotenhuis and L. W. Hulshoff Pol. Pudoc, Wageningen, The Netherlands, pp. 203–210*) and in aerobic heterotrophs (*Tijhuis, L., et al., 1994. Formation and growth of heterotrophic aerobic biofilms on small suspended particles in airlift reactors. Biotechnol. Bioeng. 44, pp. 595–608*; *Van Benthum, W.A.J., et al. 1996. Formation and detachment of biofilms and granules in a nitrifying biofilm airlift suspension reactor. Biotechnol. Prog. 12 6, pp. 764–772*). D. De Beer, J et al successfully generated biogranulation of nitrifying bacteria in a two phase (liquid solid) fluid bed nitrifying reactor under aeration conditions and without need of addition of carrier material (D. De Beer, J et al Appl Environ Microbiol. 1993 February; 59(2): 573-579). All these observations on aerobic biofilms have been done in a continuously operated system.

But anaerobic systems based on microbial granules were already operated in a discontinued mode to separate the well settling biogranules form the poor settling biogranules. Formation of anaerobic microbial granules was already observed in case of up flow anaerobic sludge blanket (UASB) reactor in 1980's. The granular sludge

was already used been used in up flow anaerobic sludge blanket (UASB) reactors (*Lettinga G., et al . (1980) Use of the UASBR concept for biological WWT, especially for anaerobic treatment. Biotech. & Bioeng., 22,' 699-734.*). Nearly 6000 industrial wastewater treatment plants based on this technology are in operation world wide. It has been later developed in a discontinued more by the anaerobic sequencing batch reactors (*Wirtz R., Dague R. (1996)* Enhancement of granulation and start-up in the anaerobic sequencing batch reactor. Wat. Env. Res. 68, 883-892 and in biofilm airlift suspension reactors (van Loosdrecht M., et al (1995) Biofilm structures. War. Sci. Tech., 32(8), 35--43.). However, anaerobic granulation technology has the following disadvantages: 1) requires long start-up period (2 to 4 months) 2) relatively high operation temperature (30 to 35°C for mesophilic UASB reactors), 3) unsuitable for low-strength organic wastewater 4) not suitable for nutrient (nitrogen and phosphorous) removal. And in order to overcome these drawbacks, Mishima, K and Nakamura developed microbial granules in aerobic up flow sludge blanket reactor (AUSB) and demonstrated that the granules had excellent settleability. The sludge produced in the aerobic AUSB process formed granules (diameter: 2-8 mm), mixed-liquor suspended solids in the AUSB reactor was maintained at 8200 mg/L. showing excellent settleability suitable for a discontinued process with a settling phase as for the anaerobic processes. experiential results for municipal sewage treatment using the Aerobic Up flow Sludge Blanket (AUSB) process (*Mishima, K and Nakamura, M. self-immobilization of aerobic activated-sludge - a pilot –study of the aerobic up flow sludge blanket process in municipal sewage treatment 15th Biennial conf. of the international assoc. on water pollution research and control, Jul. 29-Aug O3, 1990 Kyoto Japan. and Mishima, K. and Nakamura, M. (1991). Self immobilization of aerobic activated sludge-a pilot study of the aerobic up flow sludge blanket process in municipal sewage treatment. Water Sci. Technol., 23, 981–990*). Akiyoshi Ohashi et al. tested biological aerated filter (BAF) under a range of substrate loadings and C/N influent ratios until stable nitrification (*Akiyoshi Ohashi et al. Influence of substrate c/n ratio on the structure of multi-species biofilms consisting of nitrifiers and heterotrophs Water Science and Technology Volume 32, Issue 8, 1995, Pages 75-84).* Later Morgenroth et al., (1997) cultivated aerobic microbial granules in a sequencing batch reactor (SBR). In these sequencing batch reactors (SBR) aerobic granules can

also be formed (*Morgenroth, E., et al 1997. Aerobic granular sludge in a sequencing batch reactor. Water Res. 31 12, pp. 3191–3194*). A. Gjaltema, N. et al Adhesion and Biofilm Development on Suspended Carriers in Airlift Reactors: Hydrodynamic Conditions versus Surface Characteristics Biotechnology and Bioengineering, Vol. 55, No. 6, September 20, 1997. Sung S. et al (*Laboratory studies on the anaerobic sequencing batch reactor, in Water Environment Research, 67, (3) p 294, 1995*) had already obtained bacterial granules in the anaerobic systems and developed it into a technology of short (10-30 minutes) clarification with removal of the upper part the poor-settling sludge (granules). They developed a process for obtaining of a granule form bacterial growth in a bioreactor with a substrate containing phase whereby in a first phase the substrate is transformed by the bacteria will the liquid phase is mixed under the formation and growth on an in the liquid phase suspended solid phase which comprises the bacteria. In a second step of their process the mixing in the reactor is stopped to allow of the a part of the solid phase and in a third phase the reactor is partially emptied by removal of the upper phase of the reactor which consequently is filled with fluid (water) that contains substrate. Hereafter the steps 1 – 3 are repeated. The process of Morgenroth et al (*Morgenroth et al "Aerobic granular sludge in a sequencing batch reactor" Water research Elsevier science publishers, Amsterdam Nl vol 31, no. 12, 1 December 1997 (1997-12-01), pages 3191-3194*) discloses culturing of granules in a sequencing batch reactor (SBR) under aerobic conditions, similarly to the steps under anaerobic conditions (*Sung S. et al Laboratory studies on the anaerobic sequencing batch reactor, in Water Environment Research, 67, (3) p 294, 1995*). In the sequencing batch reactor (SBR) granules are cultured under aerobic conditions and to enhance the growth of granular sludge the SBR operated with very short sedimentation and draw phases resulting in the washout of slow settling biomass. Fast settling granules are retained in the reactor and thus had an advantage over flocs with a slower settling velocity. It was demonstrated that after 40 days of operation the granules are the dominant form of microbial aggregates. Granules taken from the reactor can be stored for weeks without disintegrating. Furthermore, Beun J J et al.: *(Beun J J et al.: "Aerobic granulation in a sequencing batch airlift reactor" Wat. Res vol. 36, no. 3, February 2002 (2002-02), pages 702-712 and Wat. Res. Vol. 33, No. 10, pp. 2283±2290, 1999 (online 24 July 1998)* described the use of sludge

granules N-Removal in a granular sludge sequencing batch airlift reactor and wash-out of flocculated sludge. A suitable method is wherein for the treatment of (waste) water comprising an organic nutrient, wherein the water is brought into contact with microorganisms comprising sludge particles, an oxygen comprising gas is fed to the sludge particles, and furthermore the method comprises the settling of the sludge particles and the discharge of organic nutrient-depleting (waste) water. This can be done in steps for instance by a first step whereby the (waste) water is fed to the sludge granules, an oxygen- comprising gas is introduced in a second step and in a third step the sludge granules that settle more slowly are discharged from the reactor and the sludge granules that settle more quickly remain in the reactor. Alternatively the method concerns treatment of (waste) water comprising an organic nutrient and wherein the waste water is brought into contact with microorganisms-comprising sludge particles and whereby an oxygen-comprising gas is fed to the sludge particles that the settling of the sludge and the discharge of organic nutrient-depleted waste water can be improved by feeding in a first step sludge granules to this water under anaerobic conditions and after the supply of the water to be treated an oxygen-comprising gas is introduced in a second step and in a third step, a settling step, the sludge granules are allowed to settle and part of the sludge particles that do not settle are removed. Granular sludge demonstrates high settling velocities leading to good solid-liquid separation, high biomass retention, high activity, and an ability to withstand high loading rates. Some define granules as spherical biofilm (*Grotenhuis J., Smit M., van Lammeren A., Stams A. and Zehnder A. (1991b) Localization and quantification of extracellular polymers in methanogenic granular sludge. Appl. Microb. and Biotech., 36, 115-119., EI-Mamouni R., Leduc R., Costerton J. and Guiot S. (1995) Influence of the microbial content of different precursory nuclei on anaerobic granulation dynamics. J. of Biotech. 39(3), 239-249.*). Granular methanogenic sludge can remain well conserved under unfed conditions for several years (*Kosaric N. and Blasczyzk R. (1990) Microbial aggregates in anaerobic WWT. Advances in Biochem. Eng. and Biotech. 42, 28-55*). Although buoyant densities of granules are equal to densities of discrete bacterial cells, granules show much better settling properties because of their larger size (*Guiot S., Pauss A. and Costerton J. (1992) A structured model of the anaerobic granule consortium. Wat. Sci. Tech.*

25(7), 1-10.). This has been confirmed. Aerobic granular sludge (AGS) technology improved sludge settling and behaviour in activated sludge systems. The main advantage is that aerobic granular sludge (AGS) can settle very fast in a reactor or clarifier because AGS is compact and has strong structure. It also has good settle ability and a high capacity for biomass retention (*A. Nor Anuar et al. , Settling behaviour of aerobic granular sludge Water Science & Technology Vol 56 No 7 pp 55–63 2007*). It was generally thought that the up flow velocity in a UASB creates a selective pressure to which the organisms have two responses: to be washed out or to bind together and form easily settle ability granules (*Guiot S., Pauss A. and Costerton J. (1992) A structured model of the anaerobic granule consortium. Wat. Sci. Tech. 25(7), 1-10*). Other sources point to the methanogenic microorganisms found in granules which exhibit natural tendencies to aggregate as being the cause of granule formation (*Kosaric N. and Blasczyzk R. (1990) Microbial aggregates in anaerobic WWT. Advances in Biochem. Eng. and Biotech.42, 28-55.; Fang, Chui and Li (1994) Microbial structure and activity of UASB granules treating different wastewaters. Wat.Sci. Tech., 30(12), 87-96)*. Extracellular polymers (ECP) bridge the bacterial cells together and hold granules together (*Ross W. (1984) The phenomenon of sludge pelletization in the anaerobic treatment of a maize processing plant.Water SA, 10(4), 197-204.; Shen C., Kosaric N. and Blaszczyk R. (1993) The effect of selected heavy metals on anaerobic granules & their extracellular polymeric substance (EPS). War. Res., 27(1), 25-33.*). The composition of the substrate is an important factor for granule formation (*Dolfing J., et al (1987) Production of granular methanogenic sludge on laboratory scale. In: Microbial Aspects of Granular Methanogenic Sludge, Jan Dolfing, Ph.D. Thesis, Agricultural University, Wageningen, The Netherlands*). They concluded through parallel experiments with different substrates in up flow and batch reactors that the formation of granules is initially a purely biological phenomenon, influenced by the choice of substrates. They also conclude that although the growth of granules in batch reactors is possible, it is more favourable in up flow systems. Lettinga G et al. recommended the use of wastewater containing carbohydrates for forming granules ((Lettinga G et al (1980) Use of the UASBR concept for biological WWT, especially for anaerobic treatment. Biotech. & Bioeng., 22,' 699-734) . Van der Hock J. (1987) hypothesizes that calcium may create a matrix

for the granulation of sludge (*van der Hock J. (1987) Granulation of denitrifying sludge. In: Proc. of the Gasmat Workshop: Granular Anaerobic Sludge; Microbiology and Technology, Lettinga G., Zehnder A., Grotenhuis J., and Hulshoff Pol L. (Eds) Pudoc, Wageningen, The Netherlands, 203-210).* Granular sludge demonstrates high settling velocities facilitating efficient solid-liquid separation. With high biomass retention and biological activity a granular sludge reactor can be operated at high volumetric loading rates. In the past anaerobic treatment concepts have been developed and implemented which make use of granular sludge. It has been shown that granular sludge can be obtained under aerobic process conditions. The aerobic granular sludge reactor is operated as a sequenced batch reactor (Granulated Sequenced Batch Reactor - GSBR). The SBR concept is necessary to achieve process conditions for the formation of aerobic granular sludge. Batch feeding of the reactor induces a high substrate concentration at the beginning of a treatment cycle. Due to a high concentration gradient substrate can diffuse deeply into the granules preventing starvation of bacteria within the granules. With insufficient feeding (diffusion gradient) the bacteria at the centre of the granules will be starved and weakened which eventually leads to the disintegration of the granules. In general the size of the granules will increase until the formation of stable granules is limited by substrate diffusion. Less stable granules are susceptible to shear forces and will be reduced in size or disintegrate. Weakened biomass in the granule centre will also decrease the granule density and inhibit settling processes, causing washout. Thus, a dynamic equilibrium will eventually be reached between substrate concentration and the average diameter of granules. Unlike bacteria found in anaerobic granular sludge, aerobic bacteria in general do not tend to naturally form granules. In order to achieve granulation under aerobic process conditions, short settling times are used to introduce a strong selective advantage for well-settling sludge (granules). Poor-settling biomass will be washed out under these conditions. Accordingly, appropriate settling and decanting times in each treatment cycle are chosen. Alternatively poor - settling sludge sludge can be removed under a continued process as for instance in the Liquid-Solid Circulating Fluidized-Bed Bioreactor described by Nabin Chowdhury et al. (*A Novel Liquid-Solid Circulating Fluidized-Bed Bioreactor for Biological Nutrient Removal from Municipal Wastewater Chem. Eng. Technol. 2009, 32, No. 3,*

364–372). High shear forces under turbulent flow conditions give selective advantage to the formation of stable granules. Both, an air-lift reactor and a bubble column reactor seem capable of achieving sufficiently turbulent flow conditions while maintaining the oxygen supply. A bubble column reactor enables a better process control of the nitrogen removal (denitrification). In turn it will be possible to significantly lower the energy demand of the process. Research has shown that nitrogen removal rates of more than 80% seem feasible. Nitrification is taking place in the outer, aerobic layer of the granules. Denitrification will occur in the anoxic core of the granules with the necessary carbon source being supplied by substrate diffused into the granules. Similar to conventional applications of the SBR concept one treatment cycle in the AGSR has four, more or less well-defined phases: Filling - Mixing/Aerating - Settling - Decanting. Phase 1 and 2 - Filling and mixing/aerating: Continuous mixing and aeration are achieved through injection of oxygen-rich gas. Turbulent flow conditions are created giving the granule forming bacteria a selective advantage. Phase 3 - Settling: The allowed settling times corresponds to settling velocities of 10 to 15 m/h, causing poor-settling biomass to be washed out and the granules to be retained in the reactor. Phase 4 - Decanting: In the third phase the reactor is emptied through outlets at the middle of the tank. The selected volume exchange ratio (hydraulic retention time) determines the amount of effluent that is drawn off. The added value of biogranulation lies in the use of aerobic granules that settle more rapidly than the other sludge in water treatment. Alternatively the suspended microorganisms can be granulated into biogranules in container with a shear creating agitator, whereby the reacted water is provided into the granulation tank from a separate aeration tank preferably in the form of upward streams to induce a an upward streams and an agitation power. In contrast to aeration carried out directly in the granulation tank there is no requirement of an additional solid-liquid separation apparatus for the poorly settling bacterial flocs. These biogranule biofiltering system as a whole can be made more compact and required less space and as a result the costs are reduced and the energy consumption can be lower. The biogranules derivable form this system have a suitable nutritional value to supplement the diet of the aquatic organisms and to be reprocessed into animal feed in the farming

system of present invention for instance for the aquatic organisms of another unit of the culture system.

In an anaerobic reactor, microorganisms release phosphorus out of their cells. In an anoxic tank, NO_3^- and NO_2^- are reduced into N2 gas by denitrification microorganisms. In an aerated biofilter unit, organic matters are removed and the phosphorous released from the anaerobic reactor is removed by phosphorous-removing microorganisms that take in the phosphorous overly, and nitrogen is oxidized by nitrogen oxidizing microorganisms. Granulating suspended microorganisms to thereby form granulated activated sludge can simultaneously remove nitrogen and phosphorous because such biogranulated suspended microorganisms in the aerobic condition full of dissolved oxygen, growing aerobic microorganisms on the surface of the activated sludge as well as growing anaerobic microorganisms within the granular activated sludge. The nitrogen and phosphorous can be removed by cultivating microorganisms in one biological reaction tank because these biogranules the aerobic microorganisms inhabit on the surface of the granulated activated sludge where the chances for contacting the dissolved oxygen are relatively high, while anaerobic microorganisms inhabit in the inside of the granulated activated sludge where oxygen exists scarcely or anaerobic condition is maintained. Present invention demonstrates that organic waste bioremediation in biogranule bioreactors that receive aerated water can remove ammonium, nitrite and nitrate from the IRAFS without destroying its alkalinity. The Nitrate to N_2 conversion achieved allow less dirty by clean water replacement in the IRAFS which saves on energy and results on less polluting NO_3^- output in the environment. Moreover demonstrable the alkalinity can be maintained by shifting towards a direct ammonium + nitrate to N_2 conversion.

The drain water can only partially be re-used for non halo tolerant embryophytes. High salinity water (EC \ 2 mS cm^{-1}), for instance from the drain of the IRAFS, can lead to growth depression in the photocatalytic bioreactor if such photocatalytic

bioreactor assisted by non halo tolerant embryophytes (e.g. an hydroponics crop or flower culture unit). The classic practices of irrigating essential nutrient and essential minerals to such a photocatalytic bioreactor or photoauto-heterotrophic bioreactor and in particular for the photoautotrophic bioreactor comprising organism (e.g. green plants and photosynthetic bacteria are photoautotrophs) is to provide the irrigation system that irrigates clean water towards the photocatalytic bioreactor assisted by non halo tolerant embryophytes with soluble fertilizers (fertigate) whereby a diluter/dispenser actuator under control of pH and EC sensing combines the irrigated clean water (e.g. from a rain water storage tank or basin) or irrigated clean water already premixed with drain water from this photocatalytic bioreactor with chemical solutes from at least one stock solution tank or basin and eventually acid from a acid storage tank or basin or base form a base storage tank or basin. All solutes are finally mixed in a mixing tank which is connected with a transport line or irrigation means with the photocatalytic bioreactor assisted to irrigate the non halo tolerant embryophytes (e.g. an hydroponics crop or flower culture unit). Such photocatalytic bioreactor assisted by non halo tolerant embryophytes is in a particular embodiment of present invention irrigated with water from a water input container (clean water basin), from an aquatic animal farming unit (aquaculture system), from a water collection tank or basin or from the water collection tank or basin of the gasification unit of from the chemical stock solution tank or basin. In a particular embodiment of present invention of present invention prevents that high salinity water (EC\ 2mS cm^{-1} or higher) is provided to such photocatalytic bioreactor. Moreover in embodiment of present invention the organic and inorganic molecules from the other bioreactor such as the biofilters or the aquatic animal farming are liquefied or from their collection tanks is further mineralized by a photocatalytic reactor before it is delivered to the mixing tank to irrigate the non halo tolerant embryophytes or non halo tolerant crops. Sensors control the pH and conductivity and feed their measurement signals into a processor with a controller to control the actuators (pumps or valves) of the units that deliver water to the mixing tank to provide water with desired salinity nutrients and pH to the photocatalytic organism. This way considerably less nutrients from the stock solutions is used. Water from aquaculture (aquatic animal farming unit) drain storage container (permeate or clarified), water from the gasification biofilter drain

container and eventually drain water of the drain storage tank of the IRAFS system is mixed in the mixing tank which provides the water to irrigate to the photocatalytic reactor. For optimal control this sensor network of electrical conductivity sensor and pH sensor is connected with a computer comprising a controller or with an electronic controller to process the sensor signals into a signal that activates actuator for mixing the fluid and eventually adding clean water from the clean water storage tank or container. The control can adjusted on disturbance parameters and can be adapted to the needs of the photosynthetic producer organisms. The actuators such as system pumps, measuring pumps and flow sensors are under control of the controller to provide a fluid with proper pH, EC in the irrigation pipe or supply line to the photosynthetic producer organisms. Furthermore sensors for individual ions of selected of the group consisting of K^+, Ca_2^+, NO_3^-, SO_4^{2-}, NH_4^+, Na^+ and Cl^-, pH and EC are connected with a computer comprising a controller or with an electronic controller to process the sensor signals in to a new signal that activates specific actuators for providing individual basic or acid fertiliser solutions for instance of the group consisting of $Ca(NO3)_2$, NH_4NO_3, KH_2NO_3, $MgSO_4$ and KNO3 and of micronutrients.

Moreover the irrigation delivery system to photocatalytic bioreactor and or the photocatalytic bioreactor is provided with in situ oxygen, temperature sensing with transducers to convert this abiotic sensing into electrical signals towards a computer or electronic controller to control the oxygenation and heat pump or heating devices. Moreover if the photocatalytic bioreactor an embryophyte assisted it photocatalytic bioreactor is provided with moisture sensor for instance a tensiometer to measure the moisture tension or a dielectric capacitance of the time domain reflectometry type or the frequency domain reflectometry type and optionally a evapotranspiration sensor such sensors being provided with transducers to transfer this in electrical signals that can be sensed by a computer or electronic controller.

High salinity water (EC \ 2 mS cm-1) is important for growth autotrophic halophiles. High salinity water (EC \ 2 mS cm-1) is the end product of an IRAFS that basically operates on freshwater organisms. In the soilless or hydroponics green water house farming such high salinity water poses serious limitation and recirculation, results in

high water consumption and release of salts and nutrients in the environment. A tank or basin that receives drain water from a photocatalytic bioreactor assisted by non halo tolerant embryophytes is irrigated to a second the photocatalytic bioreactor that is assisted by halo tolerant photocatalytic micro organisms or by halo tolerant halophiles for further for effective biological treatment of saline wastewater, to remove salt and BOD of the drain water of the first photocatalytic bioreactor and to produce hydrogen to enhance the growth and activity of a methanogens of the gasification tank and/or the anaerobic biofilter units or the aerobic zone in a biofilter unit of the IRAFS. This second photocatalytic bioreactor is an aerobic photocatalytic bioreactor assisted by halo tolerant organisms. Preferably this second photocatalytic bioreactor is an activated sludge type bioreactor in an aerated tank or basin. This reactor can operate in fed-batch operation. The activated sludge type bioreactor can be provided with an immersed porous device to withdraw the permeate, for instance immersed hollow fibre membranes. In a particular embodiment the first photocatalytic bioreactor is assisted by the salt-tolerant organism (*Halobacter halobium*) or *Halobacter halobium* incorporated in the activated sludge. If the second photocatalytic bioreactor assisted by halo tolerant photocatalytic microorganisms, in particular the *Halobacteriaceae* which are aerobic heterotrophs such as *Halobacterium halobium,* is provided with an immersed anode and electrode it is a bio-photoelectrochemical reactor for providing current to electricity driven actuators of the IRAFS. *Halobacterium halobium*, pumps protons across the membrane upon illumination. Hydrogen gas production can be enhanced electrochemically by leading a current through two electrodes. In an embodiment of present such bio-photoelectrochemical reactor can be provided by an hydrogen collection device and a transport pipe to transport the hydrogen to the methanogens of the gasification tank and/or the anaerobic biofilter units or the aerobic zone in a biofilter unit. The photocatalytic bioreactor assisted by halo tolerant photocatalytic microorganisms comprises a H_2 acceptor and distribution system to provide hydrogen to the anaerobic bioreactors to activate the organisms that drive chemoautotrophically on hydrogen + carbon dioxide, for example, methanogens growing autotrophically with hydrogen as electron donor to enhance the methanogenic reactions of reduction of CO_2 with hydrogen and the lithoautotroph (e.g. *Acetohalobium arabaticum*) that grow as a hydrogen + carbon dioxide or on

carbon monoxide. In yet another embodiment of present invention the aerobic photocatalyticbioreactor is a bio-photochemical reactor assisted by photosynthetic halotolerant bacteria, in particular the *Halobacter halobium*, whereby the halotolerant bacteria are in an anode chamber with an input to receive cBOD form drain water preferably of the first photocatalytic bioreactor in contact with a cathode chamber that can receive light to activate light-dependent translocation of protons in a created electrochemical gradient and is isolated by a selective hydrogen ion permeable separator, for instance a cation exchange membrane which receives electron acceptor molecules for instance O_2 and whereby the aerobic photocatalyticbioreactor further comprises a least one electric circuit between the two electrodes to accept and distribute the electrons from the anode chamber to the cathode chamber. The an anode chamber with autotrophic bioelectrochemical bacteria in contact with a common cathode chamber isolated by a selective hydrogen ion permeable separator

Such biomass produced in the photocatalytic bioreactor can be fed into the anaerobic liquefier bioreactor to produce the energy rich gas stream for driving actuators of the system such as gas fearing of the heat pump or generating current into a circuit to the electricity driven actuators

Aquaculture in water intense recirculating aquaculture systems exists for some decades now. There are also proposals to integrate recirculating aquaculture systems with soilless plant culture or crop hydroponics (photoauto-heterotrophic crops) and in particular for the photoautotrophic organism (e.g. green plants and photosynthetic bacteria are photoautotrophs). However, an expansion of its commercial use has been clearly hindered by the problem with current recirculating aquatic farming systems that they favour the growth of water borne human or aquatic animal pathogens (e.g. Enterobacteriaceae) and many disease-causing organisms and spread of disease. Typical pathogens in recirculating systems are microbials of the group consisting off *Aeromonas spp., Vibrio spp., Mycobacterium spp., Streptococcus spp., Flavobacterium columnare, Aeromonas spp, Streptococcal spp, Ichthyophthirius multifiliis*. A continuous flow of water throughout a system can spread pathogens rapidly. There is growing consumer awareness against the use of antibacterial chemical additives to control such. Attempts to reduce such without the addition of

antimicrobial medication is for instance ozonation and ultraviolet sterilization with ultraviolet (UV) sterilizers that typically consist of UV-producing lamps encased in a glass or quartz sleeve in a flow through unit to let the water passing over the lamps. The lamps emit ultraviolet light (a wavelength of approximately 254 nm is considered optimal) that penetrates cells and damages genetic material (DNA and RNA). This systems are energy consuming, do not remove the stressor that for instance cause suppressed immune systems in and are at the basis of disease outbreak (Most pathogens are considered opportunistic, causing disease only in fish with suppressed immune systems) and dot not remove pathogen reservoirs for instance floc communities comprising such pathogens can be formed in the recirculation systems out of control of the sterilisation zones. For instance microbial biofilms impact myriad environments spot in the recirculation systems, from the irrigation systems or water pipes to the units holding the farming multicellular consumer organisms (e.g. aquatic animals) or photoauto-heterotrophic organisms and in particular the photoautotrophic organism (e.g. green plants and photosynthetic bacteria are photoautotrophs). Low shear and slower turn over of water spots are an ideal substrate for facultative pathogens and uncontrolled biofilm forming. Pathogenic microorganisms may be incorporated into biofilms found in aquaculture systems, causing recurring exposure to potential disease agents and such biofilms can become pathogen reservoirs that host a variety of microbials such as bacteria, parasites, fungi and viruses. Biofilms afford bacteria with protection from a wide array of environmental insults, as diverse as antibiotics, predators, and irradiation by UV. Over time, pathogens can become concentrated (i.e., present in high numbers) or become sufficiently numerous that they can pass the ultraviolet (UV) sterilizers unit, in particular when the water is turbid or when biofilm parts that detached or biofilm flocs pass the UV sterilizers. Since UV has a shallow penetration in opaque materials microbials in biofilm flocs may well be protected against UV radiation. Typical UV radiation sources cannot provide enough photon energy to produce ionization in most materials. In general the type of material substrate (Buna-N rubber, polyvinyl chloride (PVC), chlorinated PVC, glass, fiberglass, and stainless steel) for the biofilm had no significant ($P > 0.05$) effect on the effectiveness of the sanitizers (Robin K. King; et al. . . Journal of Applied Aquaculture, 1545-0805, Volume 20, Issue 2, 2008, Pages 79 – 92). There is thus a

clear need in the art to control unwanted biofilm forming and to improve the efficiency of ultraviolet (UV) sterilizers in order to enhance the bio security of water recirculating aquaculture systems. Moreover, significant mortalities from viral outbreaks is a worst scenario in intensive aquaculture systems. The state of the art aquaculture systems provide sterilizer (ultra violet light filter or ozonation or ultra violet light ozonation) units which are instance flown through by placing these units the water transport line to the bioreactor units, to the aquaculture systems or to the hydroponics crop culture system. Ultra violet light filter or ozonation or ultra violet light ozonation particularly destroy bacteria and other microorganisms if the water is not too loaded by organic materials such as pBOD and coBOD. However this treatments does not prevent regular virus outbreaks in recirculating aquaculture systems with mass mortalities and closing of the entire facility as only solution.

In an embodiment of present invention antiviral coatings comprising metal, metal oxide and ceramic nanoparticles (nanometre catalysts) and nanoparticles of a compound of general formula MnXy, where M is (i) a metal selected from the group consisting of Calcium (Ca), Aluminium (Al), Zinc (Zn), Nickel (Ni), Tungsten (W) or Copper (Cu); or (ii) a non-metal selected from the group consisting of Silicon (Si), Boron (B) or Carbon (C); in which n is equal to 1, 2 or 3, and X is (iii) a non-metal selected from the group consisting of Oxygen (O), Nitrogen (N), or Carbon (C); or (iv) an anion selected from the group consisting of orthophosphate (PO_4^{3-}), hydrogen phosphate (HPO^{2-}), dihydrogen phosphate (H_2PO_4), carbonate (CO_3), silicate (SiO_4^{2-}), sulphate (SO_4^{2-}), nitrate (NO_3), nitrite (NO_2); in which y is equal to 0, 1, 2, 3 or 4; which strong antiviral properties are applied on the inner wall of water or drain water storage tanks and on the water distribution lines or pipes between the different bioreactor units. Accordingly there is a need to reduce reduction of viral load or to prevent the development of viral loads and consequently to prevent transmission of virus particles in intensive recirculating aquaculture or hydroponics systems. Nanoparticles for use on the inner wall of water or drain water storage tanks and on the water distribution lines or pipes between the different bioreactor units according to the present invention may have an average particle size of up to about 100 nm, up to about 200 nm, up to about 300 nm, or up to about 500 nm. Preferably the average

particle sizes may be in ranges of from about 1 nm to about 90 nm, suitably from about 5 nm to about 75 nm or from about 20 nm to about 50 nm. Particularly preferred average particle size ranges are of from about 20 nm to about 50 nm. Preferred specific surface area of said particles may be in the range of from 150 m^2/g to about 1450 m2/g, preferably, from 200 m2/g to about 700 m2/g, suitable values may comprise 150m^2/g, 640m^2/g, 700m^2/g. The voids in the particles may be of the order of from 0.1 to about 0.8 ml/g, suitably of from 0.2 to about 0.7 ml/g, preferably about 0.6 ml/g. Such nanoparticles metal or metal oxide such as silver, titanium dioxide, zinc oxide and carbon (nanometre catalysts) and oxides and/or hydroxides of calcium and/or magnesium with virucidal properties can be prepared which have been prepared according to Fang et al (*Virologica Sinica, 20, 70-74 (2005)*). Such catalysts are supported nanometre-sized catalytic crystal particle compositions of metals wherein the exposed faces of the nanometre-sized catalyst particles comprise predominantly crystal planes. Also Bentonite, which is a colloidal clay material and dolomite which is calcined and partly hydrated is a suitable antiviral component that can be overflown or contacted with water of the IRAFS to prevent biosystem collapse in particular in the aquatic farming units. Nanoparticles of bentonite have also been prepared and have been reported to have a virucidal activity.

The inner wall of water or drain water storage tanks and on the water distribution lines or pipes between the different bioreactor units may be of a material that incorporates antiviral or virucidal nanoparticles or is coated by a coating that incorporates antiviral or virucidal nanoparticles in the form of dry powders, in the form of liquids, in the form of sol-gels or in the form of polymers, as well in the form of nanotubes. The inner wall of water or drain water storage tanks and on the water distribution lines or pipes between the different bioreactor units may be of a material that incorporates antiviral or virucidal nanoparticles or is coated by a coating that incorporates antiviral or virucidal nanoparticles that are or agglomerated or in free association. The inner wall of water or drain water storage tanks and on the water distribution lines or pipes between the different bioreactor units may be of a material that incorporates antiviral or virucidal nanoparticles or is coated by a coating that incorporates antiviral or virucidal nanoparticles which comprise single element M for the case where y is

equal to 0 in the general formula MnXy and X is therefore not present, or the nanoparticles may comprise a compound as defined above where y has the value 1, 2 or 3 and x varies accordingly with respect to the value of y in conformity with the respective valencies of the elements M and X present in the formula. Alternatively, the inner wall of water or drain water storage tanks and on the water distribution lines or pipes between the different bioreactor units may be of a material that incorporates antiviral or virucidal nanoparticles or is coated by a coating that incorporates antiviral or virucidal nanoparticles of a single element where y is equal to 0 may be doped with one or more elements selected from the group consisting of Silicon (Si), Boron (B), Phosphorous (P), Arsenic (As), Sulphur (S) or Gallium (Ga); alloyed with one or more elements selected from the group consisting of Aluminium (Al), Manganese (Mn), Magnesium (Mg), Nickel (Ni), Tin (Sn), copper (Cu), Titanium (Ti), Tungsten (W), Silver (Ag) or Iron (Fe). For example, mixed nanoparticles may be composed of different elements as follows: C-P-Ag-Zn, C-P-Cu-S, C-P-Cu-Ni-S, C-Si-Ag-Zn, C-Si-Cu-S, C-Si-Cu-Ni, C-Cu-Zn-W, C-Cu-Zn-Ag, C-Cu-Zn-W-Ag, C-W-Ti-B, C-W-Ti-N, C-Ti-N, Si-N, Ti-N, Al-N, B-N, Al-B. The inner wall of water or drain water storage tanks and on the water distribution lines or pipes between the different bioreactor units may also be of a material that incorporates or is coated a coating that incorporates such antiviral nanoparticels which further comprise at least one of the following oxides : TiO_2, Cu_2O, CuO, ZnO, NiO, Al2O_3, FeO, Fe_2O_3, Fe_3O_4, CoO, Co_3O_4, or Si_2O_3, or a combination thereof. Suitable materials of the inner wall of water or drain water storage tanks and on the water distribution lines or pipes between the different bioreactor units for preventing a viral outbreak in the recirculating systems are materials that incorporate or are coated with a coating that incorporates compounds of the general formula MnXy may be oxides, carbonates, silicates, carbides, nitrides and/or phosphates, for instance , aluminium oxide (Al_2O_3), silicon dioxide, (SiO_2), zinc oxide (ZnO), aluminium phosphate (i.e. aluminium phosphate (AlPO), aluminium hydrogen phosphate ($Al_2(HPO_4)3$), aluminium dihydrogen phosphate ($Al(H_2PO_4)_3$), calcium oxide (CaO), calcium carbonate ($CaCO_3$), calcium silicate ($CaSiO_4$), calcium phosphate (i.e. calcium phosphate ($Ca_3(PO_4)2$), calcium hydrogen phosphate ($CaHPO_4$), or calcium dihydrogen phosphate ($Ca(H_2PO_4)$), silicon nitride (Si_3N_4), silicon carbide (SiC), boron nitride

(BN), tungsten carbide (WC), titanium carbide (TiC) or titanium carbonitride ($TiC_{0.5}N_{0.5}$) or a mixed composition thereof eventually as layered (core/shell) particles comprising an inner core and an outer shell and eventually comprising nanoparticles further comprising one or more of titanium dioxide (TiO2), zinc oxide (ZnO) and titanium dioxide (TiO2). Several techniques are available in the art to produce nanoparticles or nanoparticle materials. Sol-gel processing is a wet chemical synthesis approach that can be used to generate nanoparticles by gelation, precipitation, and hydrothermal treatment. Size distribution of semiconductor, metal, and metal oxide nanoparticles can be manipulated by either dopant introduction or heat treatment. Better size and stability control of quantum-confined semiconductor nanoparticles can be achieved through the use of inverted micelles, polymer matrix architecture based on block copolymers or polymer blends, porous glasses, and ex-situ particle-capping techniques. Other nanoparticle synthesis techniques include sonochemical processing, cavitation processing (e.g. using a piston gap homogeniser), microemulsion processing, and high- energy ball milling. In sonochemistry, an acoustic cavitation process can generate a transient localized hot zone with extremely high temperature gradient and pressure. Such sudden changes in temperature and pressure assist the destruction of the sonochemical precursor (e.g. organometallic solution) and the formation of nanoparticles. In hydrodynamic cavitation, nanoparticles are generated through creation and release of gas bubbles inside the sol-gel solution. By rapidly pressurizing in a supercritical drying chamber and exposing to cavitational disturbance and high temperature heating, the sol- gel solution is mixed. The erupted hydrodynamic bubbles are responsible for nucleation, growth, and quenching of the nanoparticles. Particle size can be controlled by adjusting the pressure and the solution retention time in the cavitation chamber. Microemulsions can be used for synthesis of metallic, semiconductor, silica, barium sulphate, magnetic, and superconductor nanoparticles. By controlling the very low interfacial tension (10^{-2} to 10^{-3} mN/m but preferably ~10^{-3} mN/m) through the addition of a co surfactant (e.g., an alcohol of intermediate chain length), these micro emulsions are produced spontaneously without the need for significant mechanical agitation. The technique is useful for large-scale production of nanoparticles using relatively simple and inexpensive hardware. High energy ball milling has been used for the generation of

magnetic, catalytic, and structural nanoparticles. It is often important to achieve the controlled generation of monodispersed nanoparticles with size variance so small that size selection by centrifugal precipitation or mobility classification is not necessary. Among all the synthesis techniques discussed above, gas- phase synthesis is one of the best techniques with respect to size monodispersity, typically achieved by using a combination of rigorous control of nucleation-condensation growth and avoidance of coagulation by diffusion and turbulence as well as by the effective collection of nanoparticles and their handling afterwards. The stability of the collected nanoparticle powders against agglomeration, sintering, and compositional changes can be ensured by collecting the nanoparticles in liquid suspension. Surfactant molecules have been used to stabilize the liquid suspension of metallic nanoparticles. Alternatively, inert silica encapsulation of nanoparticles by gas-phase reaction and by oxidation in colloidal solution has been shown to be effective for metallic nanoparticles. Approaches have been developed for the generation of monodisperse nanoparticles that do not require the use of a size classification procedure. Monodispersed gold colloidal nanoparticles with diameters of about 1 nm can be prepared by reduction of metallic salt with UV irradiation in the presence of dendrimers. Poly(amidoamine) dendrimers with surface amino groups of higher generations have spherical 3-D structures, which may have an effective protective action for the formation of gold nanoparticles. One production method that is suitable for the production of these materials is the Tesima® process (described in WO 01/78471 and WO 01/58625) where a high temperature DC plasma is used to generate plasma within an inert gas envelope. The nanoparticles can also be prepared by a process which comprises the generation of plasma within an inert gas envelope and the insertion into the plasma of a substance and/or liquid comprising an element or elements or compounds of said element or elements, or a mixture thereof, followed by the gas cooling of the resultant vapour upon exit from the plasma. Materials (either pre-produced feedstock or mixed feedstock), or liquids, can be placed into the plasma causing them to vaporise very rapidly. The resultant vapour then exits the plasma where it is then cooled by quantities of cold gas. These gases can be either inert (such as argon or helium) or can be air, or can have trace components to develop the chemistry/morphology/size that is required. The rapid cooling (greater than 100,000 degree a second) then freezes the

particle for subsequent cooling and collection using a combination of techniques that can include solid or fabric filters, cyclones and liquid systems. The materials can also be collected directly into containers under either inert gas or into various liquids. For the present invention the nanoparticles have to be suitably be formulated in an appropriate carrier to manufacture articles or coatings to be placed between the different bioreactor units of the farming system of present invention, preferably in the distribution lines. The coating process may be by any generally suitable means, such as for example, spray coating, electro-spray coating, dipping, plasma coating. The articles between the different bioreactor units may be fluid filters. The filter may be prepared from any suitable natural or artificial material as described above in relation to the second aspect of the invention. The filters may be prepared from any suitable fibre or fabric, such as natural or artificial fibres. Natural fibres include cotton, wool, cellulose (including paper materials), silk, hair, jute, hemp, sisal, flex, wood, bamboo. Artificial fibres include polyester, rayon, nylon, Kevlar®, lyocell (Tencell®), polyethylene, polypropylene, polyimide, polymethyl methacrylate, Poly (Carboxylato Phenoxy) Phosphazene PCPP, fibre glass (glass), ceramic, metal, carbon.

Drawing Description

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given herein below and the accompanying drawings which are given by way of illustration only and thus are not limitative of the present invention.

Fig. 1. is a general schematic view showing an embodiment of present invention concerning the fluid communication between separate systems and units of the controlled farming system of present invention. Left upper in fig 1 concerns the aquaculture consumer animals culture unit and left under in fig 1 concerns the chemoorganothropic bioreactor or anaerobic liquefier bioreactor, a bacterial assisted unit of chemo organotrophic bacteria (heterotrophs) that derive carbon and energy of oxidation of organic compounds and decrease cBOD (by concerting it in carbon dioxide, water, ammonium ions, phosphate ions and sulphate ions) and increase the

alkalinity/pH. The unit can be assisted by bio-electrochemical bacterial heterotrophs that generate bioelectricity. Right upper in fig 1 concerns, the autotrophic (nitrifying) bioreactor a condominium of autotrophic bacteria that oxidize nBOD (that oxidize ammonium and nitrite ions). Right under concerns the photoautotrophic bioreactor to produce useful biomass for consumption or for feeding it into the energy producing chemo organic bioreactor. The in fig. 1 two upper reactors can receive oxygen from an electrochemical or photocatalytic water splitting actuator.

Fig. 2 is a display of the chemo organotrophic bacteria (heterotrophs) bioelectricity (bioelectricity generating) reactor unit or microbial fuel cell (MFC) in a setup to generate current to drive the heat pumps system or specific actuators in the controlled farming system. This can be incorporated in the chemoorganotrophic bioreactor or the anaerobic liquefier bioreactor. Oxygen in the anode chamber will inhibit electricity generation, so the system must be designed to keep the bacteria separated from oxygen (the catholyte in this example). This separation of the bacteria from oxygen can be achieved by placing a membrane that allows charge transfer between the electrodes, forming two separate chambers: the anode chamber, where the bacteria grow; and the cathode chamber, where the electrons react with the catholyte. The cathode is sparged with air to provide dissolved oxygen for the reaction. The two electrodes are connected by a wire containing a load (i.e. , the device being powered), but also a resistor can be used as the load. In principle, the membrane is permeable to protons that are produced at the anode, so that they can migrate to the cathode where they can combine with electrons transferred via the wire and oxygen, forming water. The current produced by an MFC can be by monitoring the voltage drop across the resistor using either (a) a voltmeter (intermittent sampling) or (b) a multimeter or potentiostat hooked up to a computer for essentially continuous data acquisition. The development of processes that can use bacteria to produce electricity represents a fantastic method for bioenergy production as the bacteria are self-replicating, and thus the catalysts for organic matter oxidation are self-sustaining. Virtually any biodegradable organic matter can be used in the MFC, including volatile acids, carbohydrates, proteins, alcohols, and even relatively recalcitrant materials like cellulose. The production of molecular nitrogen (N_2) is an indicator of denitrification

of nitrite ions and nitrate ions but there are secondary indicator such as the fact that denitrification returns the alkalinity resulting in an increase in alkalinity/pH. This return to alkalinity can be used to compensate for the alkalinity loss in the nitrifying aerobic bioreactor units. *Shewanella putrefaciens, Geobacter sulfurreducens, Geobacter metallireducens* and *Rhodoferax ferrireducens* have electrochemically active redox enzymes on their outer membranes that transfer the electrons to the external materials and therefore, do not require exogenous chemicals to accomplish electron transfer to the electrodes.

Fig. 3 displays nitrification bacterial fuel cell for addition of oxygen to nitrogen while generating bioelectricity. This can be incorporated in the aerobic autotrophic nitrifying bioreactor of Fig. 1 (see fig 4). Within the anode chamber reduced substrates (such as reduced nitrogen), ammonium and nitrite ions are oxidized resulting in a decrease of nBOD with the generation of oxidized nitrogen species and in the generation of electrons and protons. The nitrification is indicated by the production of nitrite and nitrate ions or can be suspected by physical indicators such as an increase in the liquor oxygen demand or an decrease in the dissolved oxygen by the dissolved oxygen consumption of the nitrifying bacteria during the oxidation of the ammonium ions and nitrite ions and a decrease of the liquor alkalinity/pH by the production of the nitrite ions. The drop occurs through the use of the alkalinity as a carbon source by nitrifying bacteria and the destruction of the alkalinity by the production of hydrogen ions and the nitrite ions during the nitrification. Defining the form of nitrification needs however the measure of the concentrations of the specific ammonium, nitrite and nitrate ions. The oxidation of the reduced nitrogen results in a decrease of the negative charge and an increase of the positive charge due to the loss of the electrons. Oxygen is provided to the cathode through a gas diffusion layer (for instance porous carbon) . The two electrodes are connected by a wire containing a load (i.e., the device being powered) or a resistor. The both chambers are separated by a separation means (e.g. a membrane) that permeable to protons that are produced at the anode, so that they can migrate to the cathode where they can combine with electrons transferred via the wire to the cathode where oxygen is reduced to water.

The gas diffusion layer sticked to the cathode can for instance be Teflon treated carbon paper or Teflon treated woven cloth

Fig. 4 is a general schematic view showing an embodiment of a fluid communication between separate systems and units of the controlled farming system of present invention whereby the both autotrophic bacteria nitrifying (right upper) and chemo organotrophic bacteria (heterotrophs) denitrifying bacterial condominiums (left under) are designed to producing current to drive the heat pump system or specific actuators in the controlled agriculture system. Left under in fig 1 concerns a bacterial assisted unit of chemo organotrophic bacteria (heterotrophs), the chemo organotrophic bioreactor, that derive carbon and energy of oxidation of organic compounds and decrease cBOD (by converting it in carbon dioxide, water, ammonium ions, phosphate ions and sulphate ions) and increase the alkalinity/pH. The unit is assisted by bio-electrochemical bacterial heterotrophs that generate bioelectricity. Right upper in fig 1 concerns a condominium of autotrophic bacteria, the aerobic autotrophic bioreactor, that oxidize nBOD (that oxidize ammonium and nitrite ions) and decrease the alkalinity/pH. The CO_2 produced by consumer organisms is transported to the producer organism or is CO2 is photocatalysed to hydrocarbons such as methanol as a necessary hydrogen donor for the hemoheterotrophic microbial bioreactor and thus to fuel the chemoheterotrophic microbial bioreactor. Oxygen required by the aquatic animals and the aerobic producer bacteria is obtainable from the electrochemical and photocatalytic water splitting actuators.

Fig. 5 displays a certain embodiment of present invention of a combined anaerobic denitrifying / aerobic nitrifying bacterial fuel cell sharing the cathode. The cathode can be subjected to active or passive aeration. Oxygen for the autotrophic bioelectrochemical bacterial cell can be obtained from the electrochemical and photocatalytic water splitting actuators.

Fig. 6 is a schematic view of controlled fluid communication more particularly the exchange of nutrient loaded water

Fig. 7 is a schematic view of controlled fluid communication, more particular gas fluid communication or gas in liquid fluid communication. . Mineral carbon CO_2 production by the units A and D. The dotted lines demonstrate the transport to the bioreactors that are assisted by autotrophic organisms (tank B and C)

Fig. 8 is a schematic view of controlled gas fluid communication and more particularly the oxygen production by the plant bioreactor or photoauto-heterotrophic bioreactor and in particular the bioreactor with photoautotrophic organism (e.g. green plants and photosynthetic bacteria are photoautotrophs). The arrow demonstrates the transport of the oxygen fluid.

Fig. 9 is a graphic scheme that demonstrates that the farming system comprises one or more drainage water collection system (drain storage tank) to collect the drainage water from the recirculating aquaculture system (RAS) and/or the greenhouse horticulture system (GCS). This drainage water collection system is a heat source or sinks of the recirculating aquaculture system (RAS) and/or the greenhouse culture system (GCS) or of the IRA. In an embodiment, heat is collected by an evaporation heat exchanger and transported by the heat pump to a condensing heat exchanger.

Fig. 10 provides a scheme of the use reversed absorption heat pumps fired by energy rich gas of the gasification bioreactor of present invention. The reversed absorption heat pumps connected in a variable flow control system. Tf = temperature of the aquatic animal farming system in particular the fish culture (e.g. the recirculating aquaculture system (RAS)) which can comprise bioreactor units and drain organic waste into the gasification bioreactor, Tb = temperature of a gasification bioreactor unit for instance a sludge blanket bioreactor or a granule bioreactor, Tp = temperature hydroponics or a soilless plant culture unit (e.g. the greenhouse culture system (GCS)), Tr =temperature of the rain water/ground water or clean water storage, Tg = ground temperature, Td = temp drain water tank, Q = heat, Q- = heat extracted and Q+ = heat released. The system comprises at least one clean water (ground water and/or rain water) collection or storage tank (400), at least one drain water collection or storage tank with drain water of the hydroponics or a soilless plant culture unit (e.g. the greenhouse culture system (GCS)) (401), a gasification

bioreactor (402), aquatic animal farming system in particular the fish culture (e.g. the recirculating aquaculture system (RAS) or recirculating aquatic animal farming system (403) which can comprise bioreactor units and drain organic waste into the gasification bioreactor or its confined environment or building (404), a hydroponics or a soilless plant culture unit (405) (e.g. the greenhouse culture system (GCS)) or its greenhouse (406), evaporators (407) to absorb heat and condensers (408) to release heat, the reverse switch system(s) (409) and the gas fired heat pump drive system (411). 410 is a place the under the frost line ground water. The system comprises one or more drainage water collection system to collect the drainage water from the recirculating aquaculture system (RAS) and/or the greenhouse culture system (GCS). This drainage water collection system is a heat source or sink for the recirculating aquaculture system (RAS) and/or the greenhouse culture system (GCS) or the IRAFS. At least one thermal loop comprising at least one of the compressor and working fluid expansion means (for instance an expansion valve) components and at least two heat exchangers each of the evaporator and condenser type connected in the form of a closed circuit for circulating a volatile liquid (working fluid or refrigerant), circulates through the components. At least one evaporator type heat exchanger of the closed loop is in contact with a drainage water collection system. When operational the liquid working fluid temperature in the evaporator is kept lower than the temperature of the drainage water collection system causing heat to flow from the drainage water collection system to the working fluid, and the working fluid evaporates. During operation vapour from the evaporator is compressed (e.g. by a compressor or thermally in an extra solution circuit comprising an absorber, a solution pump and a generator absorber) to a higher pressure and temperature and consequently the hot vapour then enters a condenser heat exchanger which is contact with the RAS or GCS, where it condenses and gives off useful heat to the RAS and/or GCS. Consequently the high-pressure working fluid is expanded again to the evaporator pressure and temperature for instance by asses an in the expansion valve. The working fluid is returned to its original state and once again enters the evaporator. The thermal loop between the drainage water collection system and the RAS and/or GCS can comprising a reversing valve and force the heat flow in the other direction. Heat is then transferred in the opposite direction, from the RAS and/or GCS that is

cooled, to the drainage water collection system. In a particular embodiment the drainage water collection system is contacted with at least one condenser heat exchanger of a closed loop and the RAS and/or GCS with at least one evaporator type heat exchanger.

Fig. 11 provides function diagram of possible heat transfer switches of the heat pump system with reversible operation in heating mode or in cooling mode. The different components are expansion valves (304), 4 way switch valve (308), two switch valves (309), condenser (301), evaporator (302), compressor (303), drain water container (300), Rain water / groundwater or clean water tank (305), aquatic animal culture tank or tanks (306), hydroponics or soilless crop culture unit(s) (307) and under frost line ground (water) (308). Similarly heat can be transferred from the soilless crop culture unit(s) (307) to the aquatic animal culture tank or tanks (306) this is particularly suitable in a day and night regime. In a particular embodiment the optimal or desired temperature for crop growth is maintained different from the optimal or desired temperature of the aquatic multicellular consumer organisms (e.g. aquatic animals). For instance the optimal temperature for crops in the soilless crop culture unit difference between day and night (for instance 25.5 °C at day and 17.7 °C 's at night. In the aquatic animal culture units the temperate is generally kept equal and stabilized. Controlled heat transfer maintains these different temperature regimes.

Figure. 12 is a graphic display of a screening apparatus for mechanical removal of the suspended organic solids, particulate organic matter and colloidal organic matter ((coBOD) colloidal BOD and (pBOD) particulate BOD (removal apparatus for suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD)) for instance a micro screen apparatus for removal of the suspended solids, which in this picture is displayed as a side view of an incline belt screen filter (132) with a screen belt (143). This can be combined with an installation for the removal of settleable solids for instance gravity separation (sedimentation) or alternatively a centrifuging or hydrocycloning apparatus can be used for removal of the suspended organic solids, particulate organic matter and colloidal organic matter. Suspended non filterable particulate matter can be removed by a foam fractionation apparatus. All these are foreseen of an input to receive the (dirty) water (148) and an out put (149) to return

the (clean) water to the aquatic farming system. Furthermore they are foreseen to deliver the waste (142) to a waste collection tank (133). The water collection tank (133) is provided with a transport line (e.g. transport pipe (141) and pump (135)) to deliver the waste to an input (131) of a gasification tank (134). As displayed in this Fig. the gasification tank (134) is foreseen of a closed loop (146 & 147) to recirculate its supernatant out put. The gasification tank (134) furthermore comprises on or more out put and distribution line (transport pipe) (136) to transport the energy rich gas to the heat pump firing drive system (441, 216, 204). This distribution line (transport pipe) (136) distribute the gas first towards a deshydratation unit (150) and the deshydratation unit can be connected by a distribution line (transport pipe) (151) with a gas storage unit (152) which is connected by a distribution line (transport pipe) (153) with the heat pump firing drive system (441, 216, 204).

Fig. 13 is a schematic view of the gasification heat pump mechanism. The condenser (201) releases heat into its environment and the evaporator (203) extracts heat from the environment. A gas heater (204) receiving energy rich gas from the gasification tank transport piping (153) heats the condenser (203) and drives the heat pump. An extra pump pumps the lubricant fluid through the condenser (203) towards and expansion valve (206) to an absorber (202). The generator is connected by a loop with the evaporator (200). The loop passes through an heat exchanger loop (201a) in the condenser (201) through an expansion valve (206) in the evaporator heat exchanger loop (200a) of the evaporator (200) A pipe loop with an heat exchanger in the absorber (202) and an heat exchanger in the condenser (203) connects the absorber with the condenser (201) and has a open end (202a) in the absorber (202).

Fig. 14 provides a scheme of gas driven heat pumps whereby 210 are the expansion valves, 211 is a solvent pump, 213 is an evaporator that releases heat in the environment for instance the aquatic animal farming system, 212 is a condenser that extracts heat from the environment, 215 is the separator, 214 is an absorber that releases heat in the environment for instance the aquatic animal farming system. Heating induces vapour (for instance ammonia) to escape of a micro porous materials for instance zeolites whereby the condenser transfer heat to its environment. After the expansion valve the vapour (or instance ammonia is absorbed in the micro porous

materials for instance zeolites whereby the heat exchanger of the evaporator extract heats from its environment.

Fig. 15 provides a schematic view of a photocatalyst bioreactor with an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and/or nBOD for instance from the from the aquatic animal farming units. The photoctalyst unit is foreseen with a radiation unit (103) to radiate the photocatalytic material (104). Alternatively the photcatalytic material is exposed to sun light for instance by having tubings with the photocatalytic material or photoctalytic plates of the photocatalytic apparatus exposed to sun light. The photocatalytic material can eventually receive reflected light from a reflector or the photocatalytic unit of the photocatalytic apparatus can be placed above the aquati nimal farming unit in a green house or can be placed on on the roof of the building of the aquatic animal farm. An output and transport piping (107) provides the water wherein the organic load has been mineralized to the feed distributor (134) of a gasification unit (134) for instance a gasification tank comprising a sludge bed (140), with (bio)granules (144), rising vapour bubbles (139), baffle (138), gas solid separator (145), a feed distributor (134, effluent collection (137)) . The gasification unit is provided with switch valves (154) to release its processed water via an out put or transport piping (155) or to return the water via a transport piping (99b) to the photocatalytic reactor unit (100). The gasification tank (134) furthermore comprises on or more out put and distribution line (transport pipe) (136) to transport the energy rich gas to the heat pump firing drive system (441, 216, 204). This distribution line (transport pipe) (136) distribute the gas first towards a deshydratation unit (150) and the deshydratation unit can be connected by a distribution line (transport pipe) (151) with a gas storage unit (152) which is connected by a distribution line (transport pipe) (153) with the heat pump firing drive system (441, 216, 204). Bacterial reactions can be carried out over several different temperature ranges depending on the tolerance of the bacteria, ranging from moderate or room-level temperatures (15-35°C) to both high temperatures (50-60°C) tolerated by thermophiles and low temperatures (<15°C) where psychrophiles can grow.

Fig. 16 is a drawing that displays a photocatalytic reactor (100) and a radiation source (103) for oxidizing and mineralizing of the complex organic molecules and presentation of the photocatalytic material (104) to an aerobic bioreactor that enhances a larger part of ammonium removal through oxidizing ammonium directly into N_2, or ammonium into NO_2^- or to reduce NO_3^- into NO_2^- depending on the photocatalyst and/or the reaction time. The photocatalytic reactor can deliver such treated water to a pretank unit (101). By in situ hard sensor with a signal output that is representative for Ammonium, nitrite and/or nitrate the ammonium to nitrite proportion can be controlled in the pretrank (101) in a particular embodiment. Furthermore the oxygen and carbon dioxide levels in the water of this pretank unit (101). This bioreactor is preferably a (bio)granule (144) producing bioreactor foreseen of turbulence or shear force creation means for instance a stirrer (105) for inducing biofilm forming into (bio)granules (144). The photocatalytic reactor is for seen with a transport pipe input (99) to receive water load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the aquatic farming system. A transport piping connects the out put (107) eventually over a pump (108) of the photocatalytic reactor with pretank unit (101) such as an aeration or oxygenation unit (101) which is connected with a transport piping (110) with the aerobic bioreactor (102). A loop (106) eventually with pump (111) allows under control of a valve system (154) to return water treated in the bioreactor via a transport piping (99a) to the photocatalytic reactor input (99) or to the aeration or oxygenation unit (101). This photocatalytic aerobic bioreactor system can release the photocatalyst / aerobic bioreacted water via an output (112) into the aquatic animal farming system or into the storage tanks of the soilless plant culture or hydroponics. The photocatalytic reactor can also been foreseen with a transport pipe or irrigation output (98) to transport water to other units for instance to the plant hydroponics or soilless crop culture unit (Fig. 19). In a particular embodiment the pretank (101) and the photocatalytic reactor (100) are one. Depending on the photocatalytic material and as explained in this application, the radiation source can be a solar light collector, UV source, near UV source, UV-VIS source, VIS source.

Fig. 17 is a drawing that displays a photocatalytic reactor for oxidizing and mineralizing of the complex organic molecules or for ammonium directly into N_2, or ammonium into NO_2^- or to reduce NO_3^- into NO_2^- depending on the photocatalyst and/or the reaction time and for presentation of the photocatalytic material to an bioreactor system aerobic bioreactor and anaerobic bioreactor that can be tuned to enhance a larger part of ammonium removal through oxidizing ammonium directly into N2. This bioreactor is preferably a (bio)granule (144) producing bioreactor foreseen of turbulence or (hydrodynamic) shear force creation means for instance a stirrer (105) for inducing biofilm forming into (bio)granules (144). The photocatalytic reactor is foreseen with a transport pipe input (98) to receive water load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the aquatic farming system. A transport piping connects the out put (125) eventually over a pump (129) of the photocatalytic reactor with a pretank (118) for instance an aeration or oxygenation unit (118). By in situ hard sensors with a signal output that is representative for ammonium, nitrite and/or nitrate the ammonium to nitrite proportion can be controlled in the pretrank (118) in a particular embodiment. Furthermore the oxygen and carbon dioxide levels in the water of this pretank unit (118). This pretank (118) is connected with a transport piping (126) with the aerobic bioreactor (119), preferably a granule aerobic bioreactor that is foreseen of a turbulence or a shearing means (123) to force biofilm forming microorganisms to form (bio)granules. A loop (100) eventually with pump (130) allow under control of a valve system (154) to return water treated in the bioreactor via a transport piping (99a) to the photocatalytic reactor input (99) or to the pretank or the aeration or oxygenation unit (118). This photocatalytic aerobic bioreactor system can release the photocatalyst / aerobic bioreacted water via an output (127) into anaerobic bioreactor, preferably an anaerobic granule bioreactor (120) foreseen of a turbulence or shear force means to force the biofilm forming microorganisms to form granules (144b). This anaerobic bioreactor can release the water that has been photocatalytic, aerobic bioreactor and anaerobic bioreactor processed via an output or an output transport piping (131) into the aquatic animal farming system or into the storage tanks of the soilless plant culture or hydroponics. The anaerobic bioreactor is foreseen with a loop of a transport pipeline (100) and eventually a pump (130) under

control of a switch valve system back into the photocatalytic unit (117). In a particular embodiment the photocatalytic bioreactor (117). Biogranules can also be in the form of flocs or sludge (biofloc or bio sludge).

Fig. 18 displays a photocatalyst reaction unit to pretreat the water that is loaded with organic materials and to oxidize complex organic molecules, suspended organic solids, particulate organic matter and colloidal organic matter ((coBOD) colloidal BOD and/or (pBOD) particulate BOD and/or solved nBOD, cBOD into mineral molecules for instance for organic phosphorus, nitrogen and carbon mineralization or partial mineralization, disinfection and/or metal reduction.. The photocatalytic unit (100) is provided with a radiation source (103) to radiate the photocatalytic material (104), for instance a UV lamp (103), UV-VIS, Near UV, VIS depending on the type of photocatalyst, or alternatively collector sun light or a suitable photocatalytic surface that is exposed to sun light. Suitable photocatalyst have been explained in this application. The photocatalytic unit (100) comprises an output transport piping or irrigation means (107) to transport its processed water to the input system ((135) lowest 134 in fig 18 = 135) to feed a gasification unit (134). This output transport piping or irrigation means (107) is provided with a switch valve that allows to return the processed water via a transport piping or irrigation means (147b) to the photocatalytic reactor unit. The photocatalytic reactor unit can be foreseen with a gas transport piping (136) to transport the gas fluids generating in the photocatalytic reactor unit.

The photocatalytic unit (100) comprises an alternative output (156) under control of a valve (154) that can provide processed water to other units for instance to the aquatic animal farming units. The gasification unit (134) is preferably foreseen of a shear force tool or (136) to force the microorganisms into granules (144). The gasification unit is for seen with at least one gas collection unit (145) to collect the energy rich gas ((139 = gas bubble) and a transport piping (136) to transport the gas fluid to eventual an dehydratation unit (150) and over a gas storage unit (152) via the transport piping (153) or directly via the transport piping (153) to an gas driven heat pump system. The watery fluid out put(s) (137) of the gasification tank (134) is or are connected via a transport piping or irrigation system (118) with an oxygenation or aeration unit

(147) which is connected with a transport piping or irrigation system (126) to deliver the aerated or oxygenated water to an aerobic biofilter (119) is preferably an aerobic (bio)granule biofilter foreseen with a shear forces or water disturbance tool (123) to force the microbials into (bio)granules. This aerobic biofilter is connected by a transport piping or irrigation unit (127) to deliver its processed water into an anaerobic biofilter unit (120) which is preferably an anaerobic (bio)granule biofilter foreseen with a shear forces or water disturbance tool (124) to force the microbials into (bio)granules. This anaerobic biofilter unit (120) has an output and output transport piping or irrigation tool (131) to transport its processed water to the aquatic farming animal system or to the crop hydroponics or the soilless plant culture system. The anaerobic biofilter unit (120) comprises further a transport piping or irrigation unit (127) to recirculate its processed watery fluid to aeration tank (147). Bacterial reactions can be carried out over several different temperature ranges depending on the tolerance of the bacteria, ranging from moderate or room-level temperatures (15-35°C) to both high temperatures (50-60°C) tolerated by thermophiles and low temperatures (<15°C) where psychrophiles can grow. Instead of biogranules the bioreactor can operate on flocs or sludge.

Fig. 19 displays the nutrient feeding and recirculating system of the plant hydroponics or soilless crop culture (greenhouse) that is incorporated in the IRAFS of present invention. A water collection unit can receive water of a transport piping (98 or 156) directly from a photacatalytic reaction unit or of a transport piping (131) indirectly from a photacatalytic reaction for instance of a photocatalyst / aerobic bioreactor / anaerobic bioreactor unit (17 or 18 (whereby at least one of the anaerobic bioreactors is a gasification tank) and eventually an other anaerobic is an anaerobic microbial fuel cell (with heterotrophic bioelectrochemical bacteria for anaerobic denitrification), or of a transport piping (112) of a photocatalyst / aerobic bioreactor system (Fig. 16) which comprises a photocatalytic reactor input (99), an aerobic bioreactor unit (autotrophic bioelectrochemical bacteria for aerobic nitrifying bacterial fuel cell) (102) and eventually a separate aeration or oxygenation unit (101) the transport piping (112) to release the photocatalysed and aerobic bioreacted water into a storage tank (168) or in one of the tanks (157, 158 or 167) of the photocatalyst / aerobic bioreactor

system (Fig. 16). The water storage (168) that receives water from the photocatalytic reactors (fig 15, 16, 17, 18, 21, 22, 23 or 24) , the drain water tank (159) (that receives the (dirty) water of the hydroponics culture, the soilless crop culture system or the crop greenhouse culture (163)) and the clean water tank (157) that stores ground water, rain water or other clean water, are connected with a transport piping or irrigation system to a mixing unit or mixing tank (167). There water supply to the mixing unit or mixing tank (167) is under control of a multiple switch valve (160) to control their water flow towards the mixing unit or mixing tank (167). After the switching valve (160) before of after the mixing unit or mixing tank (167) there is a mineralization and/or sterilization unit (165), preferably a flow through sterilization unit that comprises a UV radiation source or UV source, near UV source, UV-VIS source, VIS source or solar light source (166) depending on the photocatalyst material and can be assisted by ultrasound or microwave source to radiate the passing through water or eventually an ozonation system as a germicidal treatment. mineralization and/or sterilization unit (165) can comprise a photocatalysts. In the presence of a photocatalyst material and depending on the selected photocatalyst material the radiation source (166) can for obtaining a sterilisation and / or mineralization function radiate also UV-VIS light. Moreover for intensified or enhanced function a mineralization and/or sterilization unit (165) can comprise beside a photocatalyst and a UV, Near US, VIS light or Sun light source further comprise an hybrid photocatalyst / ultrasound function or an hybrid photocatalyst / microwave function. The hydroponics culture, the soilless crop culture system or the crop greenhouse culture (163) comprises chemical (nutrient) stock solution tank(s) (162), of which one a acid stock solution tank (162) and another base stock solution tank (162), that all have an transport pipe that passes dosing or reservoir pumps (159) for composing a desired nutrient solution , pH and alkalinity for instance in the diluter (161) or in the mixing unit or mixing tank (167). The diluter (161) or the mixing unit or mixing tank (167) have an irrigation or transport piping to the plant growing troughs (164). The plant growing troughs (164) are connected by a transport piping or irrigation with a drain pit (165) that is connected by a transport piping or irrigation with the drain storage tank (158). The system will be controlled by a liquid control

system that controls the (nutrient) dosing or reservoir pump, the nutrient solution pH, the nutrient electric conductivity, nutrient solution and condensate water levels.

Figure. 20 provides **A)** a view of a transverse section of a transport fluid pipe between the different units such as the rain water / groundwater or clean water tank (305), the aquatic animal culture tank or tanks (306), the hydroponics or soilless crop culture unit(s) (307) the soilless crop culture unit(s) (307) and the bioreactor units and **B)** a 3D side view of such transport pipe (113). The outer layer of the liquid transport piping (114) is coated by an antimicrobial layer in particularly a virucidal layer. Such layer prevents biofilm forming (116). Suitable coatings have been provided in this application. In a particular embodiment of present invention at least some of the water storage tanks have been coated inside by the same antimicrobial coating. 115 is the inner lumen of the transport pipe. Instead of in the coating the antimicrobial material can be incorporated in material of the piping or the tanks itself.

Fig. 21 displays a photocatalyst reactor that is connected by its processed water output with a transport piping (125) to a microbial fuel cell unit. The photocatalytic reactor unit (100) has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved cBOD and/or nBOD for instance from the from the aquatic animal farming units. The photoctalyst comprises a radiation unit (122) to radiate the photocatalytic material (121). This radiation unit can be an UV lamp but alternatively the photcatalytic material is exposed to sun light for instance by having tubings with the photocatalytic material or photoctalytic plates of the photocatalytic apparatus exposed to sun light or alternatively the photocatalytic material is exposed to near UV, UV-VIS light, VIS light or other suitable radiation sources described in this application depending on the photocatalytic material. The photocatalytic material can eventually receive reflected light from a reflector or the photocatalytic unit of the photocatalytic apparatus can be placed above the aquatic animal farming unit in a green house or can be placed on on the roof of the building of the aquatic animal farm. The photocatalytic reactor (117) is for oxidizing and mineralizing of the complex organic molecules and presentation of the photocatalytized molecules to enhance the productivity of a microbial fuel cell. An output and transport piping

(125) provides the water wherein the organic load has been mineralized from the photocatalytic reactor (117) to the microbial fuell celles (511 and 501). The microbial fuel cell can be an aerobic microbial fuel cell (511) for instance inoculated with aerobic bacteria (e.g. aerobic nitrifiers or aerobic bioelectrichemical autotrophes) such as *Bacillus subtilis*, an anaerobic microbial fuel cell (501) or both as displayed in Fig. 21. The microbial fuel cell receives water from a transport piping (125) of the photocatalytic reaction unit eventually over a pump (129). The aerobic microbial fuel cell (511) is preceded by an aeration or oxygenation unit (118) that is connected with its output via a transport piping or irrigation system with the aerobic microbial fuel cell (511) (e.g. with anaerobic bioelectrochemical heterotrophes or anaerobic denitrifyers). In case there is no aerobic microbial fuel cell than the anaerobic fuel cell receives water that has been processes in the photocatalytic reactor (117) from the transport piping or irrigation system of the photocatalytic reactor (117). The anode chamber of the microbial fuel cells or the oxygenation or aeration chamber can recycle the processed water back to the photocatalytic reactor unit (100) via a transport piping such as 99b. The output of this hybrid photocatalytic / microbial fuel cell system can release its processed water via a transport piping or irrigation system (131) into water storage (168) or other storage tanks or the mixing tanks (167) of a hydroponics culture, soilless crop culture system or crop greenhouse culture (163). 502 and 512 displays a load of an external circuit. The component 505 and 510 displays a separator. The components 503 and 516 display the anodes in their anodes chamber. 504 and 517 is a picture of the cathodes. The anaerobic fuel cell can be hosted by bacterial reactions can be carried out over several different temperature ranges depending on the tolerance of the bacteria, ranging from moderate or room-level temperatures (15-35°C) to both high temperatures (50-60°C) tolerated by thermophiles and low temperatures (<15°C) where psychrophiles can grow.

Fig. 22 A displays a photocatalytic reactor (117) that receives watery fluid loaded with organic molecules or organic matter from an input transport piping (99) or irrigation system (99). The photocatalytic reactor comprises a photocatalytic material (121) UV radiation source (122) or receives sun light radiation. The output for the

photocatalytic processed watery fluid is connected with a transport piping (125) or irrigation system (125) which eventually passes a pump (129) and which is connected with a multitubular or multi column microbial fuel cell (525) or a reactor in which micro-organisms generate current (525) so that the photocatalytic water flows over anodic material (521) able to host microbials and able to accept electrons in a series of tubes that are 3 dimensionally surrounded by a cation exchange membrane (526). Such anodic material (521) comprises an electric conductive material (for instance conductive graphite pellets or (macro)porous graphite). The cation exchange membrane (526) is three dimensionally surrounded by a cathodic material (520) and is separating the cathode from the anode. This cathodic material (520) can be ferricyanide catholyte fluid that overflow the out surface of the cation exchange membrane (526) which ferricyanide catholyte fluid is for instance pumped by a pump (129b) over the outer surface of the cation exchange membrane (526) of the multitubular or multi column microbial fuel cell (525) and can be recycled in a loop (528) and eventually passing an aeration or oxygenation unit (524) provided with an aerator (128). The multitubular or multi column microbial fuel cell (525) is provided with at least one external circuit that comprises a load (522). The multitubular or multi column microbial fuel cell (525). The external circuit (128) is able to receive electrons from the anode and to transport the electrons to the cathodic material (520). The anode is able to accept electrons from the microbials and the cathode is able to transfer the electrons from the external circuit to an electron acceptor or sink

Fig. 22 B is a follow up of Fig. 22 A. It shows two transfers section of one column or tube of the multitubular microbial fuel cell reactor. The anode material (521) is surrounded by a cation exchange membrane (526) between an outer layer (527) which for contact wit other cathodes in the series of columns or tubes can be a electric conductive layer for instance of graphite. Between the outer layer (527) and the cation exchange membrane (526) is a cathode material (520) which is a solid in a watery medium (in fig 23 B2) that contacts the cation exchange membrane (526) or which is a catholyte fluid (in fig 23 B1).

Fig. 23 displays a combined photocatalyst reactor (100) / gasification unit (134) that is connected by its processed water output (137) with a transport piping (155) to

deliver its processed water to a microbial fuel cell unit. The photocatalytic reactor unit (100) has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the from the aquatic animal farming units. The photoctalyst unit is foreseen with a radiation unit (103) an UV radiator, near –UV radiator, UV-VIS radiator, VIS light radiator depending on the photocatalytic material, to radiate the photocatalytic material (104) and is eventually assisted by an utrasonic or microwave radiator. Alternatively the photcatalytic material is exposed to sun light for instance by having tubings with the photocatalytic material or photoctalytic plates of the photocatalytic apparatus exposed to sun light. The photocatalytic material can eventually receive reflected light from a reflector or the photocatalytic unit of the photocatalytic apparatus can be placed above the aquatic animal farming unit in a green house or can be placed on on the roof of the building of the aquatic animal farm. An output and transport piping (107) provides the water wherein the organic load has been mineralized to the feed distributor (135 (the lowest 134 in fig 23 is 135)) of a gasification unit (134) for instance a gasification tank comprising a sludge bed (140), with (bio)granules (144), rising vapour bubbles (139), baffle (138), gas solid separator (145), a feed distributor (135 (the lowest 134 in fig 23 is 135)), effluent collection (137)) . The gasification unit is provided with switch valves (154) to release its processed water via an out put or transport piping (155) or to return the water via a transport piping (99b) to the photocatalytic reactor unit (100). The out put (137) of the combined photocatalyst reactor (100)/ gasification unit (134) is connected via a transport piping or irrigation tool (155) with the microbial fuel cell reactor wherein microbials provide electrons, an anode is provided to accept electrons from the microbials which are transorted by a circuit (502, 512) to the cathode which is able to transfer the electrons from the external circuit to an electron acceptor or sink. The photocatalytic reactor (100) is for oxidizing and mineralizing of the complex organic molecules and presentation of the photocatalytized molecules to the gasification unit (134) and a microbial fuel cell (511, 501) to enhance their productivity. An output and transport piping (155) provides the water wherein the organic load has been mineralized and passed the gasification unit (134) to the microbial fuel cell (501 and/or 511). The microbial fuel

cell can be an aerobic microbial fuel cell (511) for instance inoculated with aerobic bacteria (e.g. aerobic nitrifiers or aerobic bioelectrichemical autotrophes) such as *Bacillus subtilis*, an anaerobic microbial fuel cell (501) or both as in Fig. 23. The gasification tank receives water from a transport piping (107) from the photocatalytic reaction unit 100), eventually over a pump (108). The aerobic microbial fuel cell (511) is preceded by an aeration or oxygenation unit (118) that is connected with its output via a transport piping (126) or irrigation system with the aerobic microbial fuel cell (511) (e.g. with anaerobic bioelectrochemical heterotrophes or anaerobic denitrifyers). In case there is no aerobic microbial fuel cell than the anaerobic fuel cell receives water that has been processes in the photocatalytic reactor (100) and gasification unit (134) from the transport piping or irrigation system of the combined photocatalytic reactor (100) / gasification unit (134). The anode chamber of the microbial fuel cells or the oxygenation or aeration chamber can recycle the processed water back to the photocatalytic reactor unit (100) via a transport piping such as 99b. The output of this hybrid photocatalytic / microbial fuel cell system can release its processed water via a transport piping or irrigation system (131) preferably into water storage (168), the mixing tank (167) or other storage tanks of the hydroponics culture, soilless crop culture system or crop greenhouse culture (163). 502 and 512 displays a load of an external circuit. The component 505 and 510 displays a separator. The components 503 and 516 display the anodes in their anodes chamber. 504 and 517 is a picture of the cathodes. 500 kg of fish in weight produces 550 m^3 biogas per year (biogas/a), ca. 3500 kWh_{th} or at least 200 – 500 (800) m^3 biogas/a, depending on the energy content of the biogas with a energy content 6.0 – 6.5 kWh m^{-3} or a fuel equivalent 0.60 – 0.65 L oil/m^3 biogas. The energy efficiency (лMFC), the ratio of power produced by the MFC over a time interval divided by the heat of combustion of the organic substrate is up to 50% when easily biodegradable substrates are used. In comparison the electric energy efficiency for thermal conversion of methane is <40%. But treated materials leaving the gasification or the MFC process still have energy content and can be reused or used in other energy extracting processes.

Fig. 24 displays a combined photocatalyst reactor / gasification unit that is connected by its processed water output with a transport piping (125) to deliver its processed water to a tubular microbial fuell cell. The photocatalytic reactor unit (100) has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and/or nBOD for instance from the from the aquatic animal farming units. The photoctalyst untis for ween with a radiation unit (103) to radiate the photocatalytic material (104). The photoctalyst unit is foreseen with a radiation unit (103) an UV radiator, near –UV radiator, UV-VIS radiator, VIS light radiator depending on the photocatalytic material, to radiate the photocatalytic material (104) and is eventually assisted by an utrasonic or microwave radiator. Alternatively the photcatalytic material is exposed to sun light for instance by having tubings with the photocatalytic material or photoctalytic plates of the photocatalytic apparatus exposed to sun light. The photocatalytic material can eventually receive reflected light from a reflector or the photocatalytic unit of the photocatalytic apparatus can be placed above the aquati nimal farming unit in a green house or can be placed on on the roof of the building of the aquatic animal farm. An output and transport piping (107) provides the water wherein the organic load has been mineralized to the feed distributor (134) of a gasification unit (134) for instance a gasification tank comprising a sludge bed (140), with (bio)granules (144), rising vapour bubbles (139), baffle (138), gas solid separator (145), a feed distributor (134), and effluent collection (137)). The gasification unit is provided with switch valves (154) to release its processed water via an out put or transport piping (155) or to return the water via a transport piping (99b) to the photocatalytic reactor unit (100). The transport piping (155) is connected with a transport piping (125) or irrigation system (125) which eventually passes a pump (129) and which is connected with a multitubular or multi column microbial fuel cell (525) or a reactor in which micro-organisms generate current (525) so that the photocatalytic water flows over anodic material (521) able to host microbials and able to accept electrons in a series of tubes that are 3 dimensionally surrounded by a cation exchange membrane (526) Such anodic material (521) comprises an electric conductive material (for instance conductive graphite pellets or (macro)porous graphite). The cation exchange membrane (526) is three dimensionally surrounded by

a cathodic material (520) and is separating the cathode from the anode. This cathodic material (520) can further comprise a chatolyte fluid, for instance a ferricyanide catholyte fluid that overflows the out surface of the cation exchange membrane (526). The catholyte fluid is for instance pumped by a pump (129b) over the outer surface of the cation exchange membrane (526) of the multitubular or multi column microbial fuel cell (525) and can be recycled in a loop (528) and eventually passing an aeration or oxygenation unit (524). 522 is the load of the external circuit (522). The multitubular or multi column microbial fuel cell (525) furthermore comprises an external circuit (128) able to receive electrons from the anode and to transport the electrons to the cathodic material (520). The anode is able to accept electrons from the microbials and the cathode is able to transfer the electrons from the external circuit to an electron acceptor or sink. 500 kg of fish in weight produces 550 m^3 biogas per year (biogas/a), ca. 3500 kWh_{th} or at least 200 – 500 (800) m^3 biogas/a, depending on the energy content of the biogas with a energy content 6.0 – 6.5 kWh m^{-3} or a fuel equivalent 0.60 – 0.65 L oil/m^3 biogas. The energy efficiency (ɲMFC), the ratio of power produced by the MFC over a time interval divided by the heat of combustion of the organic substrate is up to 50% when easily biodegradable substrates are used. In comparison the electric energy efficiency for thermal conversion of methane is <40%. But treated materials leaving the gasification or the MFC process still have energy content and can be reused or used in other energy extracting processes.

Fig. 25 displays nitrification bacterial fuel cell for addition of oxygen to nitrogen while generating bioelectricity. The oxygen is generated at a radiated (near UV, UV – VIS, preferably visible light or solar light radiation) photo anode in water. To generate H_2 and O_2, a photosemiconductor photo anode (of $KTaO_3$, $SrTiO_3$, TiO_2, ZnS, and SiC). in water is excited by light photons (hν). When the photo anode absorbs light photons with energies greater than its band-gap energy (Eg). This absorption creates excited photoelectrons in the conduction band (CB) and holes in the valence band (VB) of the semiconductor. Once the photogenerated electron–hole pairs have been created in the semiconductor bulk, they must separate and migrate to the surface competing effectively with the electron–hole recombination process that consumes the photo charges generating heat. At the surface of the semiconductor, the

photoinduced electrons and holes reduce and oxidize adsorbed water to produce gaseous oxygen and hydrogen : $H_2O + 2h^+ \rightarrow 2H^+ + ½ O_2$.

H^+ is transported to the anode chamber with electrochemical bacteria (heterotrophic nitrifiers) and oxygen is transported to the cathode chamber. Within the anode chamber reduced substrates (such as reduced nitrogen), ammonium and nitrite ions are oxidized resulting in a decrease of nBOD with the generation of oxidized nitrogen species and in the generation of electrons and protons. The nitrification is indicated by the production of nitrite and nitrate ions or can be suspected by physical indicators such as an increase in the liquor oxygen demand or an decrease in the dissolved oxygen by the dissolved oxygen consumption of the nitrifying bacteria during the oxidation of the ammonium ions and nitrite ions and a decrease of the liquor alkalinity/pH by the production of the nitrite ions. The drop occurs through the use of the alkalinity as a carbon source by nitrifying bacteria and the destruction of the alkalinity by the production of hydrogen ions and the nitrite ions during the nitrification. Defining the form of nitrification needs however the measure of the concentrations of the specific ammonium, nitrite and nitrate ions. The oxidation of the reduced nitrogen results in a decrease of the negative charge and an increase of the positive charge due to the loss of the electrons. Oxygen is provided to the cathode through a gas diffusion layer (for instance porous carbon) . The electrodes are connected by a wire containing a load (i.e., the device being powered) or a resistor. The both chambers are separated by a separation means (e.g. a membrane) that permeable to protons that are produced at the anode, so that they can migrate to the cathode where they can combine with electrons transferred via the wire to the cathode where oxygen is reduced to water. The gas diffusion layer sticked to the cathode can for instance be Teflon treated carbon paper or Teflon treated woven cloth

Fig. 26 displays (700) a suspended particles photocatalytic reactor with microparticles, preferably with a magnetic core (704) and a silica layer (703) which are coated by photocatalytic nanoparticles for instance for down hill or up hill photocatalysis; hereby is displayed photon (703) induced electron-hole (704) generation in a photocatalyst particle (702) (for instance Degussa P25 titanium dioxide) and some of the mechanisms involved: a) Ray promotes the formation of the

electron-hole and electron, b) electron-hole is used in the formation of the OH* groups promoting oxidation processes, c) the electron is utilized in a number of reduction processes, d) electron and electron-hole can recombine contributing to process inefficiency. The system can comprise photocatalyts for O_2 and H_2 generation and photocatalysts that use the $O_2$for H_2O_2 generation and/or for photocatalytic oxidation of the organic material or to convert (oxidize) organic molecules into CO2, water and minerals (mineralization) for instance for use into atmospheric and water based nutrients for the producer organism bioreactors, e.g. the plants or the producer bacteria). Alternatively the photocatalyst material is immobilized on a substrate, for instance of amorphous silica or glass plates).

Fig. 27 displays B a suspended particles photocatalytic reactor with C microparticles, photocatalytic nanoparticles (e.g. TiO2) surrounding a silica layer surrounding a supramagnetic core (for instance barium ferrite) to form a magnetic removable photocatalytic material D is the nanoparticular photocatalytic material (i.e. TiO2) with display of a hole induced by a photon. The photocatalytic material displays in **A** a band gap which is assigned an energy value (Ebg) and which corresponds to its width in energy, and is the additional energy (denoted as hv) required for an electron (e-) to move from the VB into the CB. This implies that an electron possessing the required amount of energy can separate from the parent atom and become free to move at random through the crystal structure in the CB. The promotion of an electron to the CB leaves a positive hole (h+) in the VB. Thus the action of promoting an electron from the VB to the CB creates an electron-hole pair. Electrons may be promoted to the CB following absorption of a photon of energy greater than or equal to the Ebg. If an electron recombines with a hole, the conservation of energy demands that the absorbed energy be dissipated as heat or light in B. Such photocatalytic reactor can comprise photocatalytic material (suitable photocatalyst have been described in this application) for water into H_2 and O_2 and/or photocatalytic material H_2O and C_2O into hydrocarbons for the consumer organism e.g; to fuel anaerobic bacteria bioreactor or the fuel driven farming system actuators. Alternatively the photocatalyst material is immobilized on a substrate, for instance of amorphous silica or glass plates).

In a particular embodiment the farming system of present invention comprises at least one thermal loop comprising at least one of the compressor and working fluid expansion means (for instance an expansion valve) components and at least two heat exchangers each of the evaporator and condenser type connected in the form of a closed circuit for circulating a volatile liquid (working fluid or refrigerant), circulates through the components. Hereby at least one evaporator type heat exchanger of the closed loop is in contact with a drainage water collection system (drain storage tank).

When operational the liquid working fluid temperature in the evaporator is kept lower than the temperature of the drainage water collection system causing heat to flow from the drainage water collection system to the working fluid, and the working fluid evaporates. During operation vapour from the evaporator is compressed (e.g. by a compressor or thermally in an extra solution circuit comprising an absorber, a solution pump and a generator absorber) to a higher pressure and temperature and consequently the hot vapour then enters a condenser heat exchanger which is contact with the RAS or GCS, where it condenses and gives off useful heat to the RAS and/or GCS. Consequently the high-pressure working fluid is expanded again to the evaporator pressure and temperature for instance by means of the expansion valve. The working fluid is returned to its original state and once again enters the evaporator. The thermal loop between the drainage water collection system and the RAS and/or GCS can comprising a reversing valve and force the heat flow in the other direction. Heat is then transferred in the opposite direction, from the RAS and/or GCS that is cooled, to the drainage water collection system. In a particular embodiment the drainage water collection system is contacted with at least one condenser heat exchanger of a closed loop and the RAS and/or GCS with at least one evaporator type heat exchanger. Eventually the condenser heat exchanger can be in control with the clean water basin that supplies the rain and/or ground water into the RAS and GCS.

In a preferred embodiment the closed loop thermal system is or the closed loop thermal system thermally driven by heat supply to drive the cycle (for instance waste heat, gas or biomass firing) This heat has been generated from biomass produced in the farming system. The working fluid can comprise an absorbent for instance ammonia (working fluid) and water (absorbent) or water (working fluid) and lithium

bromide (absorbent). In case the working fluid is compressed thermally in a working solution circuit which consists of an absorber, a solution pump, a generator and an expansion valve the low-pressure vapour from the evaporator is absorbed in the absorbent whereby the process generates heat. The solution is consequently pumped to high pressure and then enters the generator, where the working fluid is boiled off with an external heat supply at a high temperature. The working fluid (vapour) is condensed in the condenser while the absorbent is returned to the absorber via the expansion valve. Heat is extracted from the heat source in the evaporator. Useful heat is given off at medium temperature in the condenser and in the absorber. In the generator high-temperature heat is supplied to run the process. The system can be a reversed system and the evaporator can be contacting with the drainage water collection system to extract heat thereof and to release the heat via the condenser to the RAS and/or GCS. Eventually the condenser heat exchanger can be in control with the clean water basin that supplies the rain and/or ground water into the RAS and GCS.

A thermal loop of present invention can comprise multiple evaporators connected to a single condenser or multiple condensers connected to a single evaporators in a multisplit approach or the thermal loop of present invention can be connected to multiple condenser and evaporator heat exchange units and can be operate in a variable refrigerant flow approach under a management and control systems (see Fig. 10).

In a particular embodiment of present invention the thermal loop between the drainage water collection system the RAS and/or GCS works in a mixed mode the ground under the frost line or the outdoor air functioning as a heat source and providing cooling or heating towards the RAS and/or GCS. In a particular systems the thermal loop of present invention integrates a ground heat exchanger in which an heat transfer fluid is permanently contained in its closed system (closed loop system) or in which the heat transfer fluid is part of a larger environment (open loop system), most commonly using ground water or surface water as the heat transfer medium In yet another particular embodiment the thermal loop of present invention integrates a

direct expansion (DX) geothermal heat pump system. Such DX systems may be single or multi-speed.

In a particular embodiment of present invention the thermal loop of present invention or the thermal loop of present invention in a mixed mode with an air to air or ground thermal pump is provided with a desuperheater to captures heat from the hot refrigerant as it leaves the heat pump compressor and transfers it to a separate hot water system.

The aquaculture system can be integrated in the greenhouse horticulture system or can be a system that communicated with water or atmosphere with the greenhouse horticulture system. The aquaculture system can have two or more fish holding units to subject separate fish communities to a different day-night light and or temperature regime than the greenhouse horticulture system. Such separate fish holding units can be connected to the same biofiltering system.

Particular coatings can be used depending in the components of the system. In a corrosive environment for the metal components for instance the metal tubing, in particular the sub-surface metal tubing , the metal tubing in the drainage water collection system a protective heat conductive coating, or to the dissimilar metal connection points can be applied . Such protective coating can be low density polyethylene, for instance low density polyethylene with a wall thickness of 0.01 to 0.015 inches or 0.02 to 0.1 inches and a heat transfer inhibitive coating for the liquid refrigerant transport tubing that need to prevented of heat exchange (for instance a coating of a low density polyethylene with a wall thickness of at least 0.05 inches. Suitable refrigerants are for instance a R-410A or a R-22 refrigerant. The driving energy is heat is produced by firing of the methane or H2 gas from the Bioenergy Systems

In particular embodiment this controlled biomass farming system in confined environment with controlled biomass, energy input and output is a controlled biotransformation system for bioremediation or redistribution of nutrients and energy in a controlled manner between bioreactors of living organisms. The

biotransformation system comprises at least one pump actuator to move the system fluids and at least three bioreactor systems of communicating fluids where under

1) at least one heterotrophic aquatic animal assisted biotransformation unit;

2) at least one of living photosynthetic producer organisms (belonging to the Plantae (e.g. herbs, grasses, vines)) assisted biotransformation for instance an autotrophic plant assisted biotransformation unit and

3) at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with a) at least one heterotrophic (chemo organotrophic) bio-electrochemical bacteria assisted biotransformation unit to reduce nitrogen and decrease cBOD and b) at least one autotrophic (chemolithotrophic) bio-electrochemical bacteria assisted biotransformation unit to oxidize nitrogen and decrease nBOD or at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with both types autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria in one condominium or bioreactor whereby the system is further characterised in that the bio-electrochemical bacteria assisted biofilters are bioelectricity producers that are connected by a circuit to drive one or more heat pump system on the bioelectricity from the bio-electrochemical bacteria assisted biofilter or bioremediation system and further characterised in that heat pump system is connected by a loop with a drain of the farming system, for instance a container keeping the drain water, to flow heat between drain and the farming system (for instance to move heat from drain to farming system) and whereby the bacterial reactor system is producing the energy that drives the heat pump system.

In one aspect of the invention, the invention relates to a controlled biomass farming system, for processes of redistribution of energy and biomass in a controllable manner. This biomass farming system comprising separate bioreactor units in a shared confined environment or in different fluid flow interconnected confined environments with a fluid input and fluid output, whereby the biomass farming system comprises

1) an aquaculture system for the culture of aquatic multicellular consumer organism such as aquatic vertebrate animals or such as aquatic invertebrate animals, and further

2) at least one bacterial bioreactors system comprising condominiums of producers bacteria and condominiums of consumer bacteria in a same or separate bioreactor, and

3) an heat pump system, characterised in that the heat pump system is connected by a loop with a drain of the farming system, for instance a container keeping the drain water, to flow heat between drain and the farming system (for instance to move heat from drain to farming system) and whereby the bacterial reactor system is producing the energy that drives the heat pump system.

In one aspect of the invention, the invention relates to a controlled biomass farming system, for processes of redistribution of energy and biomass in a controllable manner. This biomass farming system comprising separate bioreactor units in a shared confined environment or in different fluid flow interconnected confined environments with a fluid input and fluid output, whereby the biomass farming system comprises

1) an aquaculture system for the culture of aquatic multicellular consumer organism such as aquatic vertebrate animals or such as aquatic invertebrate animals, and further

2) a photocatalytic bioreactor system comprising at least one bioreactor of living photosynthetic producer organisms (belonging to the Plantae (e.g. herbs, grasses, vines)), and

3) at least one bacterial bioreactors system comprising condominiums of producers bacteria and condominiums of consumer bacteria in a same or separate bioreactor, and

4) an heat pump system, characterised in that the heat pump system is connected by a loop with a drain of the farming system, for instance a container keeping the drain water, to flow heat between drain and the farming system (for instance to move heat from drain to farming system) and whereby the bacterial reactor system is producing the energy that drives the heat pump system.

In an embodiment of present invention the bacterial bioreactors system is an energy production system (bioenergy system) that drives a heat pump preferably a reverse cycle heat pump for regaining the heat from the drain into the controlled biomass farming system.

For instance in a particular embodiment the bacterial reactor system comprising a methanogenic reaction function that produces the energy to drive the heat pump system comprises an anaerobic bioreactor for anaerobic respiration whereby the degradation of organic matter on release electrons that for disposal are accepted by an anode and distributed by an electric circuit or by molecule electron acceptors such as CO_2, or NO_3^-. In case of molecule electron acceptors such as CO_2, or NO_3^- energy

riches gasses can be collected such as CH_4, methane, (gas energy content = 55,525 kJ/kg at 25°C (25 °c & 1 atm) and N_2. A suitable bioreactor for the production of energy rich gasses is the high rate anaerobic reactor up flow anaerobic sludge blanket (UASB) the anaerobic sequencing batch reactor (ASBR), the fluidized expanded bed reactor, the static granular bed reactor (SGBR), the anaerobic membrane reactor , the anaerobic expanded-bed reactor (EBR) and the granular bed baffled reactor (GRABBR). Such bacterial reactor system can receive the solved and particulate material. In a preferred embodiment of present invention the organic material is first collected in a collection tank that feeds the gasification bioreactor . Such collection tank can function as a concentration tank or as a buffer tank. Yet another embodiment is the fluidization of the organic matter particles for instance by ultrasound before the organic and inorganic matter is fed into the gasification bioreactor. The gaseous products such as CH_4 of the gasification bioreactor is transported to a gas collection container and transported to a heat burner that drives the gas driven heat pump system. The bacterial bioreactors system is an energy production system (bioenergy system) that produces the gas that drives a drives gas driven heat pump system preferably a reverse cycle heat pump for regaining the heat from the drain into the controlled biomass farming system. This heat pump preferably is a reversible absorption heat pump such as a reversible air-water absorption heat pump. The reversed absorption heat pump is in a preferred embodiment connected in a variable flow control system (as outlined for instance in fig 9). The farming system can have a closed container for collecting of rain and or ground water (water input tank or clean water basin). The reversed absorption heat pump system with variable flow control system can distribute heat between the water input tank, that farming system and the drain. In a preferred embodiment the variable flow control system is a indoors with outdoors mixed system that is connect an heat releasing or heat extracting unit with the outer environment for instance with the bottom under frost line and/or the air of the out environment. In a particular function that gasification bioreactor is foreseen with an in situ pH sensor for monitoring.

In a particular embodiment the bioreactor systems are constructed to exchange watery fluid and gas fluid in a controlled manner under control of a monitoring and

control system. The system can for instance comprises a hard sensing tool to produce a signal indicative of an abiotic parameter such as pH, and temperature and a controller to control at least one programmable actuator to adapt these abiotic parameters. For instance the system comprises at least one programmable actuator adapted to deliver a pH regulator agent to said system at an administration rate and at least one programmable heat and/or cool actuator to cool or heat the system. In an embodiment at least one of the following parameters dissolved oxygen, conductivity, alkalinity, reduced nitrogen ad oxidized nitrogen and whereby the system is further analysed in situ and modulated by a programmable actuator.

In an embodiment of present invention the bacterial bioreactors system is an energy production system (bioenergy system), whereby the energy is used to drive actuators of the system. For instance the system can comprise a least one circuit to feed electricity generated by the bio-electrochemical bacteria assisted biotransformation system to at least one of the systems actuators (for instance a pump actuator to move system fluids).

In particular embodiment this controlled biomass farming system in confined environment with controlled biomass, energy input and output is a controlled biotransformation system for bioremediation or redistribution of nutrients and energy in a controlled manner between bioreactors of living organisms. The biotransformation system comprises at least one pump actuator to move the system fluids and at least three bioreactor systems of communicating fluids where under

1) at least one heterotrophic aquatic animal assisted biotransformation unit;

2) at least one of living photosynthetic producer organisms (belonging to the Plantae (e.g. herbs, grasses, vines)) assisted biotransformation for instance an autotrophic plant assisted biotransformation unit and

3) at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with a) at least one heterotrophic (chemo organotrophic) bio-electrochemical bacteria assisted biotransformation unit to reduce nitrogen and decrease cBOD and b) at least one autotrophic (chemolithotrophic) bio-electrochemical bacteria assisted biotransformation unit to oxidize nitrogen and decrease nBOD or at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with both types

autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria in one condominium or bioreactor

For instance such bioreactor with both condominium of autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria can be an up flow sludge blanket filter (USBF) bioreactor) with an anoxic and an aerated compartment and up flow sludge blanket filtration with automatic or continued removal of poor settling active sludge flocs or sludge granule and automatic or continued distribution well settling active sludge flocs or sludge granule to the anoxic zone. Such USBF fuel cell operates a process of up flow sludge blanket filtration which has a substantially higher specific rate of separation that the conventional sedimentation USBF technology and uses up flow sludge blanket filtration in a prism or cone shaped clarifier. The activated sludge flocs or granules that have been generated by high shear in the aerated unit will enter the clarifier at the bottom and, as it rises, upward velocity decreases until the flocs of cells become stationary, effectively filtering out colloid, very fine particles, the flocs with poor settling capacity or the bacterial granules with poor settling capacity, while descending to the bottom of the clarifier and are transferred back into the anoxic zone of the sludge flocs or sludge (bio)granules that become large and heavy. Furthermore such USBF fuel cell operates aeration, nitrification, denitrification, clarification and sludge thickening and stabilization without need of different dedicated vessels. All these processes can be integrates into one bioreactor and can be operates inside one compact bioreactor.

In particular embodiment this controlled biomass farming system in confined environment with controlled biomass, energy input and output is a controlled biotransformation system for bioremediation or redistribution of nutrients and energy in a controlled manner between bioreactors of living organisms. The biotransformation system comprises at least one pump actuator to move the system fluids and at least three bioreactor systems of communicating fluids where under

1) at least one heterotrophic aquatic animal assisted biotransformation unit;

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3) at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with a) at least one heterotrophic (chemo organotrophic) bio-electrochemical bacteria assisted biotransformation unit to reduce nitrogen and decrease cBOD and b) at least one autotrophic (chemolithotrophic) bio-electrochemical bacteria assisted biotransformation unit to oxidize nitrogen and decrease nBOD or at least one bio-electrochemical bacteria assisted biofilter or bioremediation system with both types autotrophic (chemolithotrophic) bio-electrochemical bacteria and heterotrophic (chemo organotrohic) bio-electrochemical bacteria in one condominium or bioreactor whereby the system is further characterised in that the bio-electrochemical bacteria assisted biofilters are bioelectricity producers that are connected by a circuit to drive one or more heat pump system on the bioelectricity from the bio-electrochemical bacteria assisted biofilter or bioremediation system and further characterised in that heat pump system is connected by a loop with a drain of the farming system, for instance a container keeping the drain water, to flow heat between drain and the farming system (for instance to move heat from drain to farming system) and whereby the bacterial reactor system is producing the energy that drives the heat pump system.

In an embodiment of present invention the bacterial bioreactors system is an energy production system (bioenergy system) that drives a heat pump preferably a reverse cycle heat pump for regaining the heat from the drain into the controlled biomass farming system. For instance in a particular embodiment the bacterial reactor system that produces the energy to drive the heat pump system comprises an anaerobic bioreactor (fig 2) or aerobic bioreactor (fig 3) or the combination of both (fig 5) comprising a condominium of bioelectrical bacteria whereby the degradation of organic matter on release electrons that for disposal are accepted by an electrode (anode) and distributed by an electric circuit. Such bacterial reactor system can receive the solved and particulate material. In a preferred embodiment of present invention the organic material is first collected in a collection tank that feeds the

gasification bioreactor . Such collection tank can function as a concentration tank or as a buffer tank. Yet another embodiment is the fluidization of the organic matter particles for instance by ultrasound before the organic and inorganic matter is fed into the gasification bioreactor. The electrical circuit of the delivers the energy that drives the heat pump system. The bacterial bioreactors system is an energy production system (bioenergy system) that produces the electricity that drives a heat pump system preferably a reverse cycle heat pump for regaining the heat from the drain into the controlled biomass farming system. This heat pump preferably is a reversible absorption heat pump such as a reversible air-water absorption heat pump. The reversed absorption heat pump is in a preferred embodiment connected in a variable flow control system. The farming system can have a closed container for collecting of rain and or ground water (water input tank). The reversed absorption heat pump system with variable flow control system can distribute heat between the water input tank, that farming system and the drain. In a preferred embodiment the variable flow control system is a indoors with outdoors mixed system that is connect an heat releasing or heat extracting unit with the outer environment for instance with the bottom under frost line and/or the air of the out environment.

In a particular embodiment the controlled a farming system comprising a controller to control the programmable pH actuator to normalize the pH between 5,5 and 8 (preferably between 6 – 7.5) and to control the heat and/or cool actuator to normalize the temperature between 15 – 30°C (preferably between 20 – 25°C). A particular useful pH regulator agent is an alkalis of the group consisting of calcium bicarbonate, calcium carbonate, calcium hydroxide, magnesium bicarbonate, magnesium carbonate, magnesium hydroxide, sodium bicarbonate, sodium carbonate and sodium hydroxide.

In this electrochemical bacteria assisted biotransformation system the autotrophic bacteria assisted biotransformation unit can be a nitrifying bacterial fuel cell comprising autotrophic bio-electrochemical bacteria and the heterotrophic bio-electrochemical bacteria assisted biotransformation unit can be a denitrifying bacterial fuel cell. Hereby one or both of the denitrifying bacterial fuel cell and the nitrifying bacterial fuel cell can be flow through fuel cells whereby the water of the farming

systems flows through the bacterial fuel cell(s) . In a particular embodiment the autotrophic bio-electrochemical bacteria assisted biotransformation unit comprises *Nitrosomonas europea.* In yet a particular embodiment of present invention the heterotrophic bio-electrochemical bacteria assisted biotransformation comprises *Geobacter sulfurreducens*, *Shewanella oneidensis*, *Rhodoferax ferrireducens* or a combination thereof. The electricity produced by the bioelectrical energy system generates electrical energy to at least one of the actuators of the system for instance to a pump actuator of the system or to a heat pump that transports heat from the drain to bioreactors of the farming system. The controller of the system furthermore can control the fluid flows between the bioremediation units.

Another aspect of the invention is that the controlled biomass farming system further comprises a system for photocatalytic oxidation of water from or to the aquaculture system. Such system of photocatalytic oxidation is particular suitable for preventing unwanted algae growth, for oxidizes the organic matter, for reducing BOD and for destroying unwanted microbiological organisms. In embodiments of present invention a photocatalytic oxidation reactor is used to increase the biosecurity in farming of aquatic animals and crops, to mineralise organic molecules that are presented or fed bacterial condominiums to increase their efficiency of bioenergy production (bioelectricity in the microbial fuel cell or energy rich gas in the biogasification unit) and to mineralise organic molecules that are presented or fed to the crops. A photocatalytic oxidation of the of the fluids loaded with organic matters before it is fed to the bacterial condominiums for biotransformation or bioenergy production moreover provides more stable biotransformation system for bioremediation or redistribution of nutrients and energy with surprisingly less biosystem collapse. Such systems are preferably placed above the aquaculture system in a confined environment (e.g. a greenhouse) for solar driven photocatalytic oxidation or on the roof of the confined environment of the aquaculture system (e.g. a building) to receive solar radiation. The photocatalytic oxidation system can also be incorporated in a UV lamp radiated fluid flow through case or container (combi photocatalytic oxidation / UV lamp) that receives fluid from the aquaculture system (aquatic animal farming system) and/or the photocatalytic bioreactor system (aquatic crop, soilless plants or

unicellular crops). After photocatalytic oxidation suspended solids can be removed by mechanical filtration to further reduce BOD, COD, Chemicals and TSS.

Table 1. Un-ionized NH_3 as a percent of total ammonia (by temperature and pH). Percent NH_3 of total ammonia

Temp (F)	pH 6.5	pH 7.0	pH 7.5	pH 8.0	pH 8.5
68	.13	.40	1.24	8.82	11.2
77	.18	.57	1.77	5.38	15.3
82	.22	.70	2.17	6.56	18.2
86	.26	.80	2.48	7.46	20.3

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed. It is apparent for the man skilled in the art that various scales of the integrated units can be calculated to obtain optimal performce and integration; For instance GPS-X - World-Class Wastewater Simulation (Hydromantis) and SASSPro V2 (HTI, Inc) simulator modeling software is used for en steady-state and dynamic simulations of the biofilter unites and FLUENT 6.3.26 (Fluent Inc) is applied for the computational fluid dynamics (CFD) simulation of the photocatalytic reactors .

Table 2.Lethal ammonia concentrations at 30°C that are lethal for fish (by pH, and duration of exposure)

pH	duration	Lethal* Ammonia Concentration (mg/l)	
		total	NH_3
6.5	1-hr	14.3	0.036
	4-day	0.73	0.002
7.0	1-hr	11.6	0.093
	4-day	0.74	0.006
7.5	1-hr	7.3	0.181
	4-day	0.74	0.019
8.0	1-hr	3.5	0.26
	4-day	0.47	0.035
8.5	1-hr	1.3	0.26
	4-day	0.17	0.035

*Lethal concentrations are derived from levels at which half of the exposed individuals die.

Claims

51. A biomass farming system with controlled fluid flow input and/or fluid output for producing useful biomass comprising a bioreactor system with various bioreactor units in a shared confined environment or different confined environments that are connected whereby the farming system comprises 1) a distribution line or distribution lines and at least one pump actuator to flow system fluids between selected bioreactor systems, 2) at least one water input for instance a water input container (clean water basin) for collecting or storing of rain water, surface water, municipal tap water and/or ground water, 3) a drain for drain water removal for instance a drain removal line to optionally a drain storage container, 4) an heat pump system with condenser and evaporator heat exchangers, 5) at least one bacterial bioreactor system and whereby the bioreactor system with various bioreactor units comprises a) at least one gasification bioreactor, b) at least one aquaculture system for the culture of aquatic multicellular consumer (heterotrophic) organism (aquatic animals) with at least one suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD) removal apparatus and c) at least one bioreactor unit comprising at least one condominiums of bacteria

characterised in that

the at least one aquaculture system for the culture of aquatic multicellular consumer (heterotrophic) organism (aquatic animals) comprises a drain for drain water removal for instance a drain removal line to optionally a drain storage container, and further the at least one suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD) removal apparatus comprises an out put and a transport line or transport pipe directly connected to a gasification bacterial bioreactor system for transport of the solids directly to the gasification bacterial bioreactor or indirectly connected to a gasification bacterial bioreactor system via the collection containers which collection containers are connected with a transport line or transport pipe connected to the

gasification bacterial bioreactor system for gasification bacterial bioreactor to the gasification bacterial bioreactor, and further the at least one bacterial bioreactor system comprises condominiums of producers bacteria and condominiums of consumer bacteria in a same or separate bioreactor and comprising an input to receive solved and particulate organic and inorganic material from the aquaculture system, and further the gasification bioreactor further comprising a gas collection means and a gas distribution line to transport the energy rich gaseous products toward to gas burner that produces the drive energy to drive actuators of the biomass farming system

2. The farming system of any of the previous claims, whereby the gas burner is a gas burn driver of the heat pump system.

3. The farming system of any of the previous claims, whereby the gas burner is a CHP system that generates current into a circuit to drive the actuator of the aquatic farming system.

4. The farming system of any of the previous claim, whereby a photocatalytic reactor unit (100) which has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and/or nBOD for instance from the from the aquatic animal farming units and which comprises at least one fluid transport pipe connected with or which irrigate the bacterial bioreactor system

205. The biomass farming system of any of the previous claims, whereby gasification the bacterial reactor system is connected with the farming unit to receive molecular electron acceptors, such as CO_2, or NO_3^-, and a gas collection and a gas distribution system to collect the energy riches gasses produced after electron acceptation, such as CH_4 and N_2

256. The farming system of any of the previous claim, whereby the gas collection means of the gasification bioreactor is connected with the gas burn driver of the heat pump system via a gas distribution line with a gas dehumidifier and a gas storage unit or tank.

7. The farming system of any of the previous claims whereby the gas collection container is in the gas transport line between gasification bioreactor and the gas burn driver of the heat pump system.

8. The farming system of any of the previous claim, whereby a photocatalytic reactor unit (100) which has an input piping (99) that recieves (organic rich) water with a load of suspended solids (SS), colloidal BOD (coBOD) and/or particulate BOD (pBOD), solved CBOD and nBOD for instance from the from the aquatic animal farming units and which photocatalytic unit (100) comprises an output transport piping or irrigation means (107) to transport its processed water to the input system of an aerobic biofilter (119).

9. The farming system of any of the previous claim, whereby a photocatalytic reactor unit (100) for oxidizing and mineralizing of the complex organic molecules which photocatalytic unit (100) comprises an output transport piping or irrigation means (107) to transport its processed water to the input system of a microbial fuel cell for the presentation of the photocatalytized molecules to enhance the productivity of a microbial fuel cell.

10. The farming system of claim 4, whereby the radiation unit and the photocatalyst material of the photocatalyst reactor is functionalised for oxidizing and mineralizing of to convert complex organic molecules to CO_2, water and mineral acids and a transport pipe to transport such CO_2 and/or mineral acids to condominiums of producers bacteria.

11. The farming system of claim 4, further comprising a unit with photoautotrophic organisms (e.g. aquatic plants) whereby the radiation unit and the photocatalyst material of the photocatalyst reactor is functionalised for oxidizing and mineralizing of to convert complex organic molecules to CO_2, water and mineral acids and comprises an output and a transport pipe to transport such CO_2 and/or mineral acids to the unit with photoautotrophic organisms.

2512. The farming system of claim 4, whereby the radiation unit and the photocatalyst material of the photocatalyst reactor is functionalised for CO2 reduction ($CO_2 + 2H_2O \rightarrow CH_4 + 2O_2$) in to hydrocarbons and comprises an output and a transport pipe to transport such hydrocarbons to the condominiums of consumer bacteria.

13. The farming system of any of the previous claims whereby the heat pump system is connected by a loop with a drain of the farming system to flow heat between drain and the farming system.

14. The farming system of any of the previous claims whereby the operating system of the heat pump system comprises a in situ temperature sensors in the water input container (clean water basin), in the bioreactor units of farming system and in the drain connected to a signal processor to feeds the input signals from the temperature sensor network system into the signal processor and a controller that controls the heat pump system to adapt the temperature.

15. The farming system of any of the previous claims whereby the signal processor comprises a mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of living organisms in relating to the temperature (and eventually the time period of the day) and a controller that controls the heat pump system to adapt the temperature.

16. The farming system of any of the previous claims whereby the mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of a specific aquatic animal species in relating to the temperature (and eventually the time period of the day) and a controller.

17. The farming system of any of the previous claims whereby the mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of a specific plant species in relating to the temperature (and eventually the time period of the day) and a controller.

18. The farming system of any of the previous claims whereby the mathematical model that is described on the relationship of a plurality of temperature variables and a plurality of comfort, stress or welfare variables of a plurality of a particular bacterial condominium in relating to the temperature (and eventually the time period of the day) and a controller.

19. The farming system of any of the previous claims whereby the signal processor comprises an adjuster to adjust the controller to control the heat pump system or an extra heating means to maintain the temperature between 15 – 30°C, preferably between 20 – 25°C.

20. The biomass farming system of any of the previous claims, whereby the bacterial reactor system comprises at least on bioelectric bioreactor
21. The biomass farming system of any of the previous claims , whereby the bacterial bioreactor system is a bioelectricity producer integrated operational system that connects and drives farming systems actuator with the bioelectricity
22. The farming system of any of the previous claims, further comprising photocatalyst reactor with a radiation unit and photocatalyst material that functionalised for photocatalytic denitrification
23. The farming system of any of the previous claims, further comprising photocatalyst reactor with a radiation unit and photocatalyst material that functionalised for to sterilize or disinfect and in particular to destroy microbial pathogens in floc communities
24. The farming system of any of the previous claims, further comprising photocatalyst reactor with a radiation unit and photocatalyst material that functionalised for to reduce metals
25. The farming system of any of the previous claims, further comprising photocatalyst reactor with a radiation unit and photocatalyst material that functionalised for water splitting $H2O \rightarrow \frac{1}{2} O_2 + H_2$ whereby the photocatalyst reactor is further foreseen with transport pipe and eventual hydrogen storage tank to provide hydrogen in a controllable to the aerobic and or anaerobic bioreactor to enhance the growth of hydrogen consuming bacteria such the methanogenic bacteria the aerobic and/or anaerobic granule bioreactor.
26. The farming system of any of the previous claims, further comprising photocatalyst reactor with a radiation unit and photocatalyst material that functionalised for water splitting $H_2O \rightarrow \frac{1}{2} O_2 + H_2$ whereby the photocatalyst reactor is further foreseen with transport pipe and eventual to provide oxygen in a controllable to the aerobic bioreactor with producer bacteria or to the consumer aquatic organism.
27. The farming system of any of the previous claims, whereby the photocatalytic reactor can deliver such treated water to a pretank unit (101) and by in situ hard sensor with a signal output that is representative for a measure of ammonium, nitrite and/or nitrate the ammonium to nitrite proportion can be controlled in the pretrank (101) before the

water is transferred to bioreactor to set or maintain said bioreactor in an annamox mode.

28. The farming system of any of the previous claims, whereby the photocatalytic reactor can deliver such treated water to a pretank unit (101) and by in situ hard sensor with a signal output that is representative for a measure of the oxygen and carbon dioxide levels in the water of this pretank unit (101) and accordingly controlled before the water is transferred to the bioreactor to set or maintain said bioreactor in an annamox mode

29. The farming system of any of the previous claims, whereby the photocatalytic reactor can deliver such treated water to a pretank unit (101) and by in situ hard sensor with a signal output that is representative for a measure of toxicity in the water of this pretank unit (101) and accordingly controlled by photocatalytic mineralization of said toxic compounds or intermediates before the water is transferred to the bioreactor to guarantee the biofilter stability

1530. The farming system of any of the previous claims, whereby the bioreactor is a (bio)granule (144) producing bioreactor foreseen of turbulence or shear force creation means for instance a stirrer (105) for inducing biofilm forming into (bio)granules (144).

31. The farming system of any of the previous claims, with a photocatalyst reactor whereby the photocatalyst reactor is a reactor type of the group consisting of falling Film Reactor (FFR), Fiber Optic Cable Reactor (FOCR), Multiple Tube Reactor (MTR), Packed Bed Reactor (PBR), Rotating Disk Reactor with Controlled Periodic Illumination (RDR-CPI), Spiral Glass Tube Reactor (SGTR), Tube Light Reactor (TLR) and Photo CREC Water I.

2532. The farming system of any of the previous claims, with a photocatalyst reactor sonophotocatalysis function whereby the photocatalyst reactor is combined with ultrasound irradiation (e.g. at a frequency of between 15 to 250 kHz, for instance 215 kHz).

33. The farming system of any of the previous claim, whereby the bacterial bioreactor system comprises an aerobic (digester) granule bioreactor

34. The farming system of any of the previous claim, whereby the bacterial bioreactor system comprises an anaerobic (digester) granule bioreactor

35. The farming system of any of the previous claim, whereby the bacterial bioreactor system comprises an aerobic (digester) granule bioreactor and an anaerobic (digester) granule bioreactor in series.

36. The farming system of any of the previous claim, whereby the at least one collection tank or basin which is connected with the removal apparatus and transport line of the aquaculture system to receive solids (TSS), colloidal BOD (coBOD), particulate BOD (pBOD) from the aquaculture system is further provides with a transport line or pipe input to receive sludge from the bacterial bioreactor system.

37. The farming system of any of the previous claims, whereby the gasification bioreactor comprises a methanogenic reaction functions for producing the energy rich gaseous product (e.g. methane).

38. The farming system of any of the previous claims whereby the heat pump system is connected by a heat extracting component with the drain of the farming system to flow heat between drain and the farming system for regaining the heat from the fluid drain into biomass farming system or for instance to move heat from drain to farming system)

39. The farming system of any of the previous claims whereby the drain is the drain water tank or basin with out put to the outer environment

40. The farming system of any of the previous claims whereby the loop of the heat pump system is connected with the water input tank, the farming system and the drain to distribute heat between the water input tank or basin, the farming system and the drain.

41. The farming system of any of the previous claims whereby the heat pump is a reverse cycle heat pump

2542. The farming system of any of the previous claims whereby the reversed absorption heat pump is connected in a variable flow control system.

43. The farming system of any of the previous claims whereby the variable flow control system being connected with the water input container, one or more other units of the farming system and the drain.

3044. The farming system of any of the previous claims whereby the reverse cycle heat pump is a reversible absorption heat pump.

45. The farming system of any of the previous claims whereby the reversible absorption heat pump is a reversible air-water absorption heat pump.
46. The farming system of any of the previous claims whereby the reversible absorption heat pump is a reversible water-water absorption heat pump.
547. The farming system of any of the previous claims whereby the reverse cycle heat pump is integrated variable flow control system
48. The farming system of any of the previous claims whereby the variable flow control system is a mixed indoors with outdoors system that connects an heat releasing component or heat extracting component in the outer environment with a confined environment that comprises the biomass farming system.

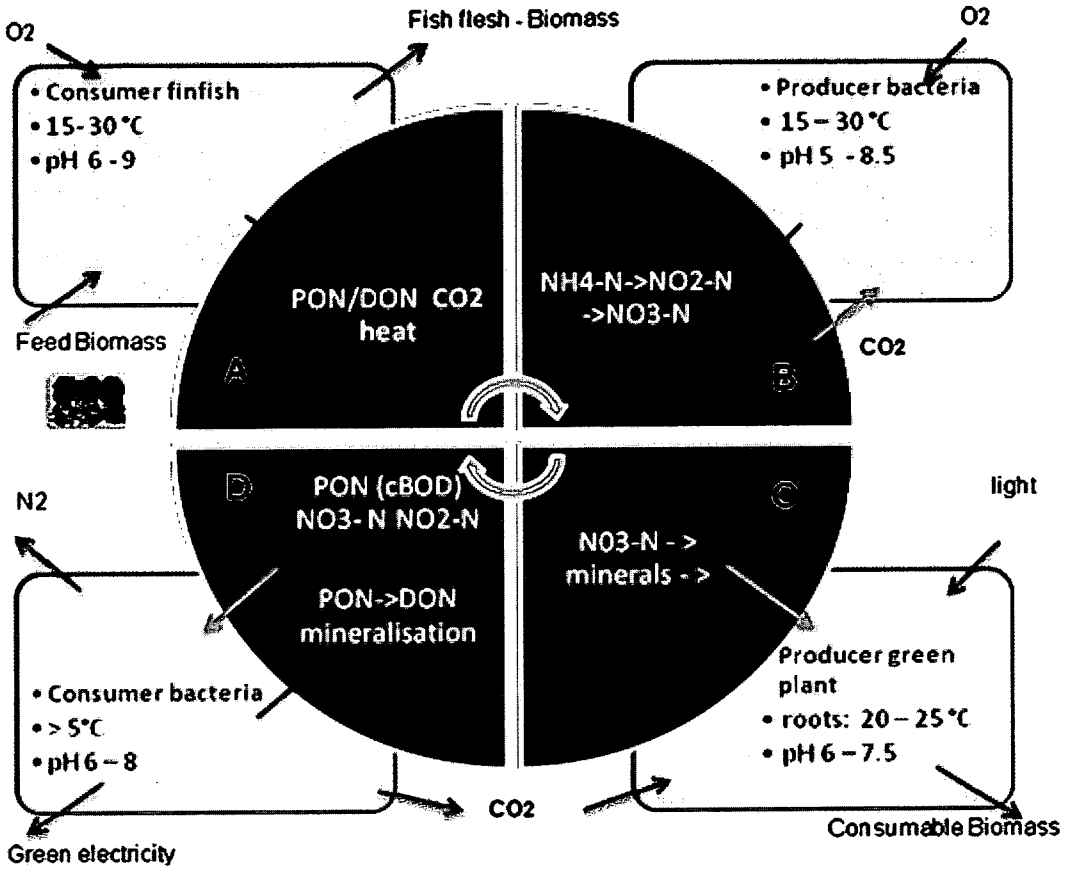
O2
Fish flesh - Biomass
O2
• Consumer finfish
• 15-30 °C
• pH 6 - 9
• Producer bacteria
• 15 – 30 °C
• pH 5 - 8.5
PON/DON CO2
heat
NH4-N->NO2-N
->NO3-N
A
B
Feed Biomass
CO2
N2
light
D
PON (cBOD)
NO3- N NO2-N
C
N03-N - >
minerals - >
PON->DON
mineralisation
Producer green
plant
• roots: 20 – 25 °C
• pH 6 – 7.5
• Consumer bacteria
• > 5°C
• pH 6 – 8
CO2
Consumable Biomass
Green electricity

Fig 1

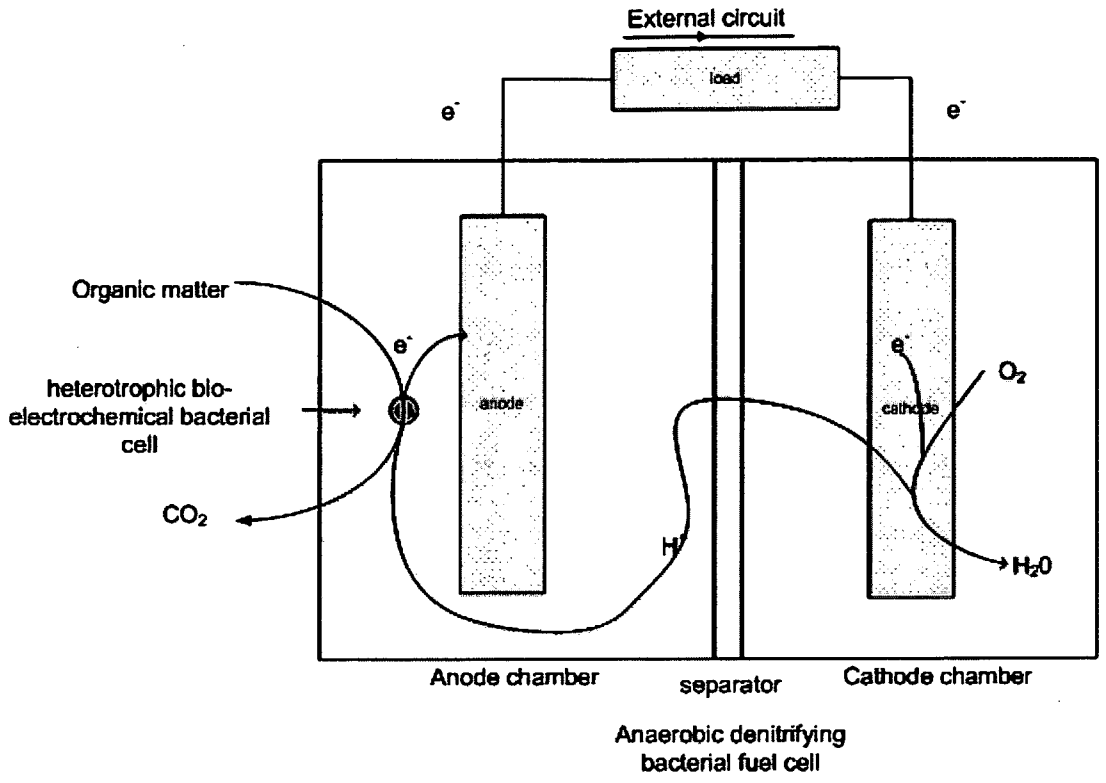
External circuit
load
e⁻
e⁻
Organic matter
heterotrophic bio-electrochemical bacterial cell
CO2
e⁻
anode
e⁻
cathode
O2
H+
H2O
Anode chamber
separator
Cathode chamber
Anaerobic denitrifying bacterial fuel cell

Fig. 2

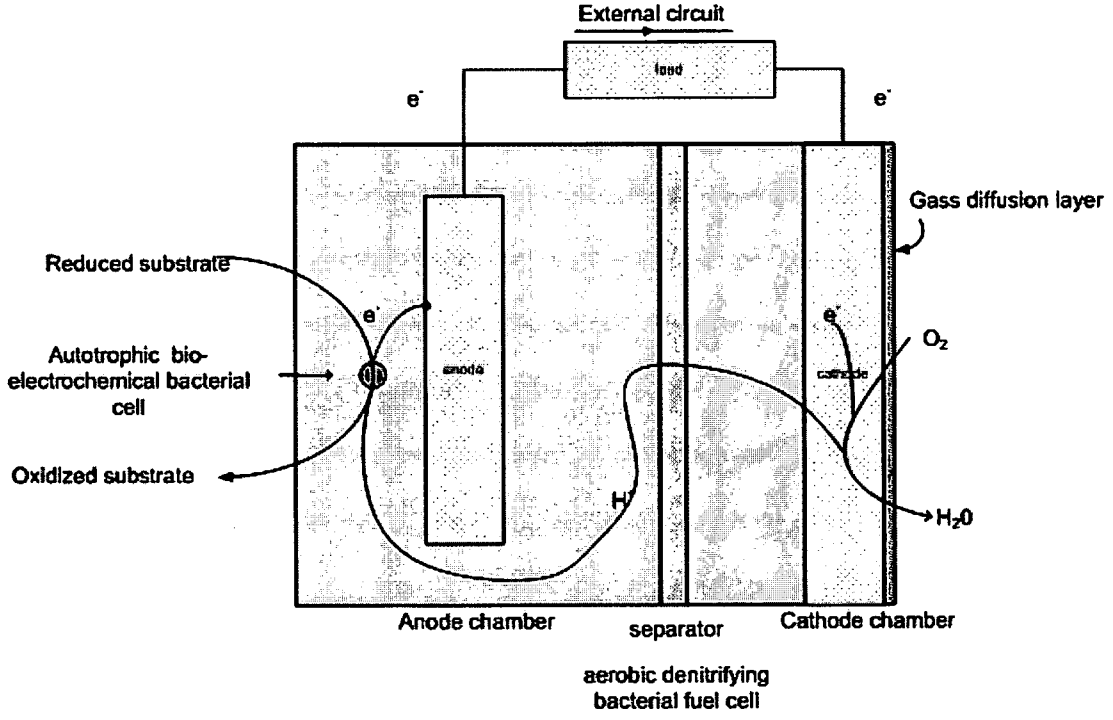
External circuit
load
e⁻
e⁻
Gass diffusion layer
Reduced substrate
Autotrophic bio-electrochemical bacterial cell
Oxidized substrate
e⁻
anode
e⁻
cathode
O2
H+
H2O
Anode chamber
separator
Cathode chamber
aerobic denitrifying bacterial fuel cell

Fig 3

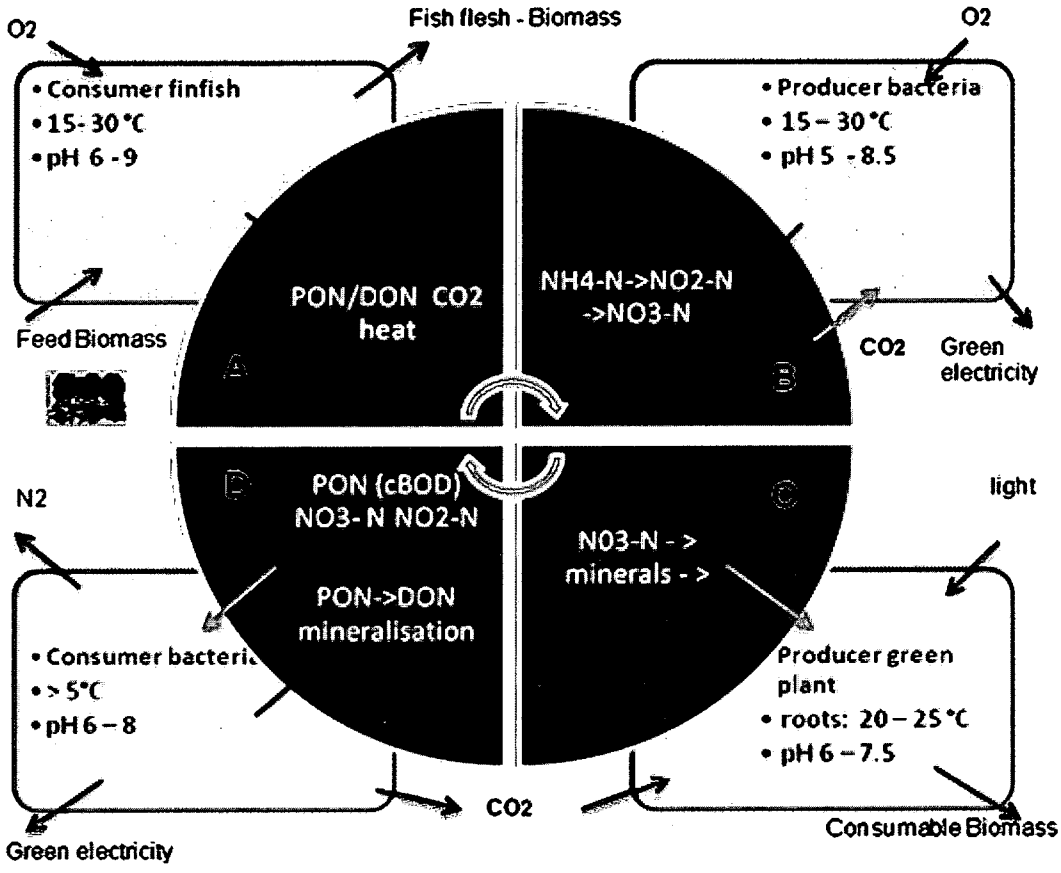

Fig. 4

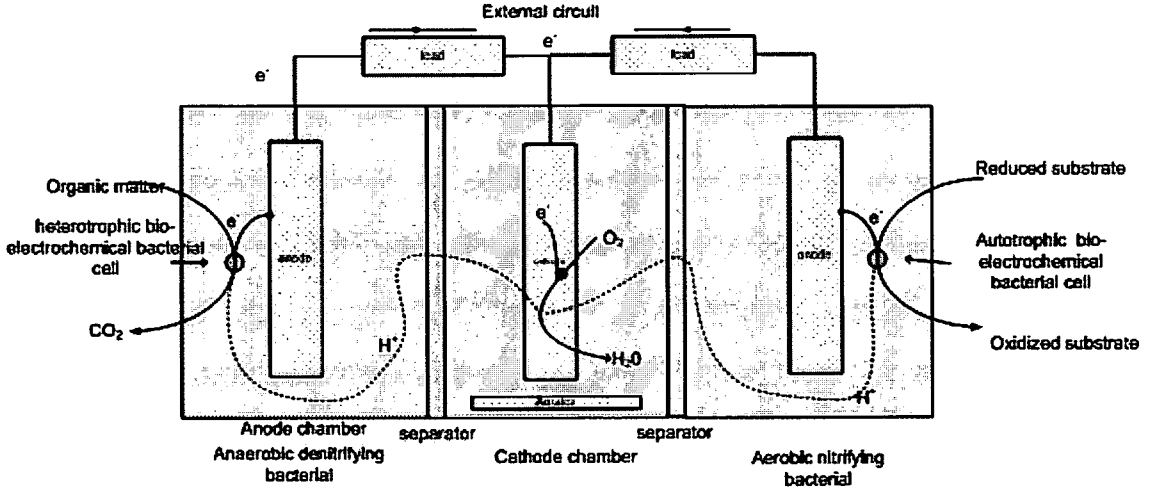

Fig. 5

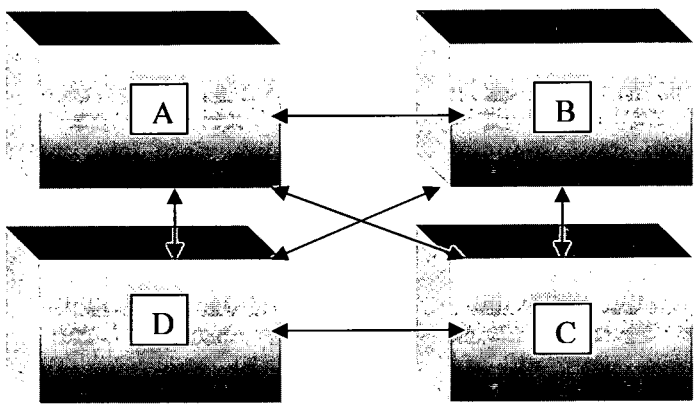

Fig 6

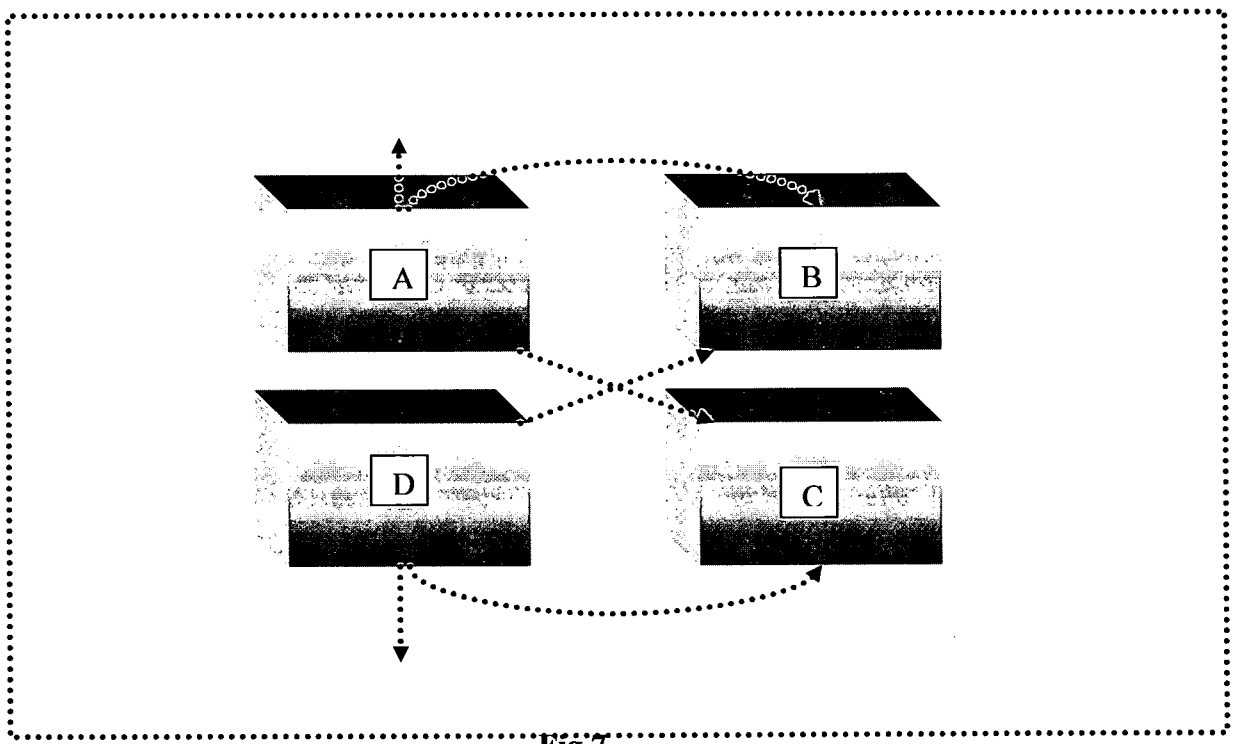

Fig 7

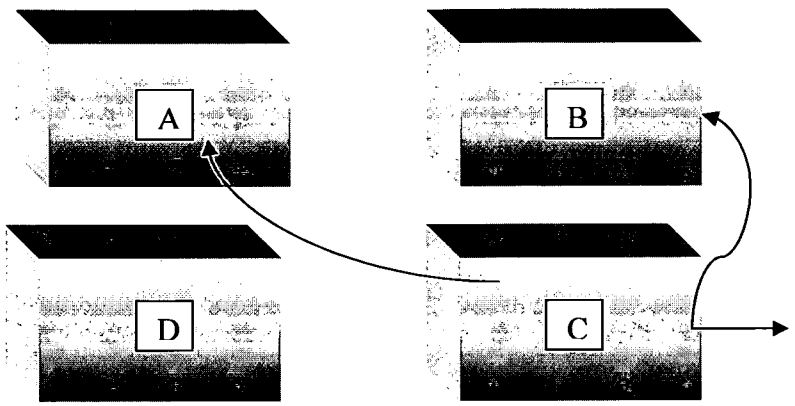

Fig 8

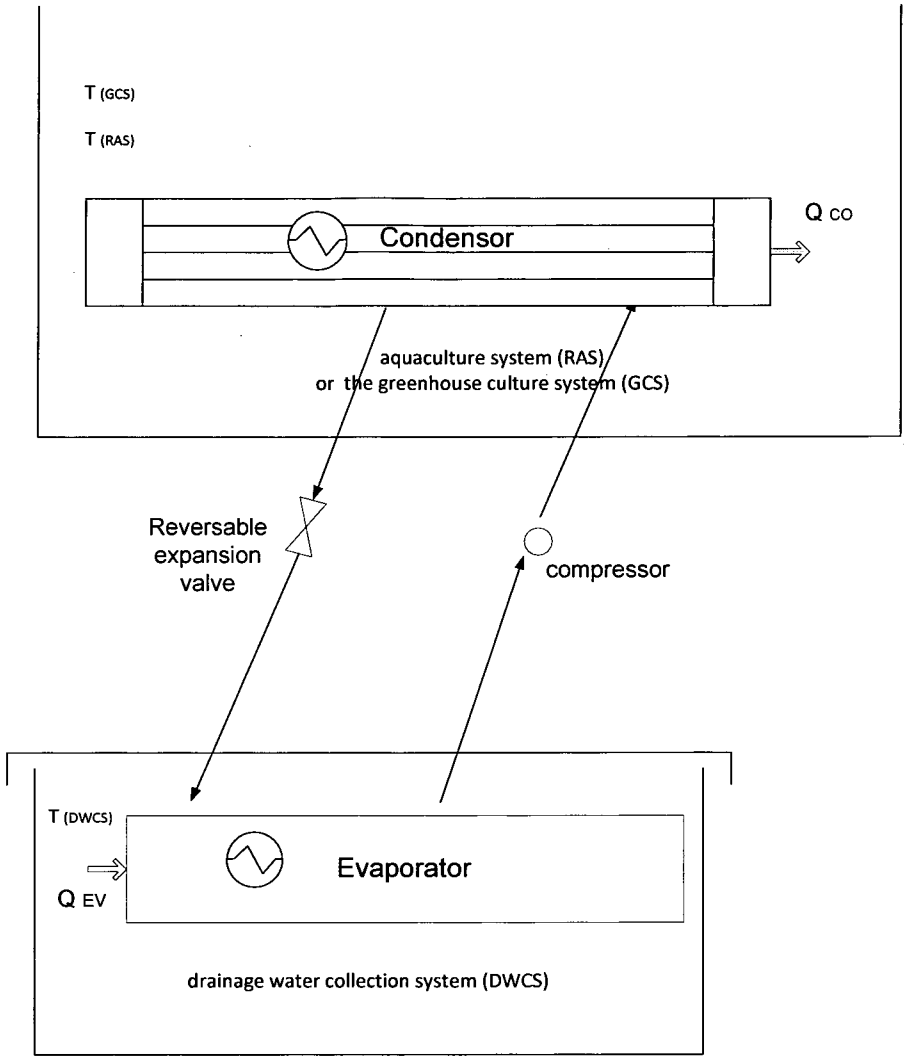
T (GCS)
T (RAS)
Condensor
Q CO
aquaculture system (RAS)
or the greenhouse culture system (GCS)
Reversable
expansion
valve
compressor
T (DWCS)
Q EV
Evaporator
drainage water collection system (DWCS)

Fig 9

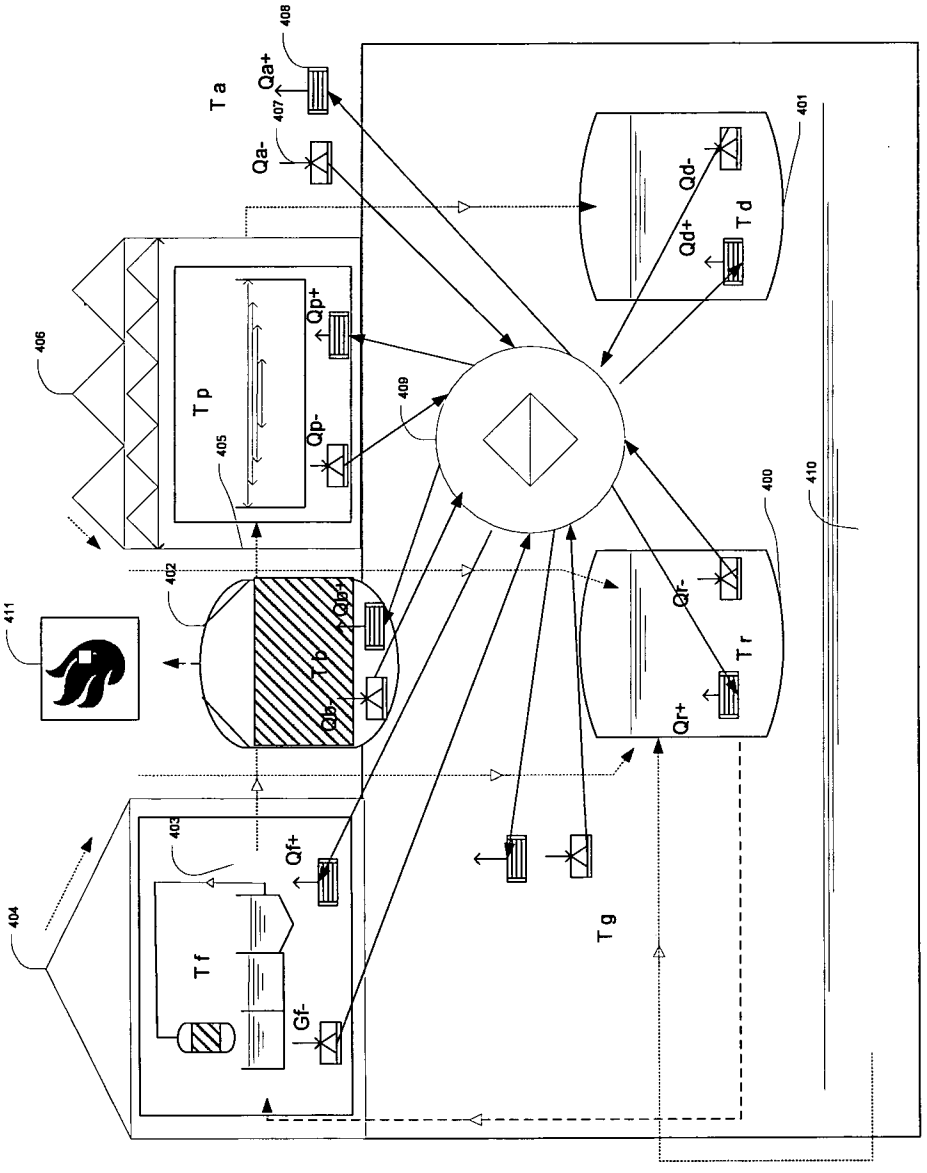
T a
Qa+
Qa-
T p
Qp+
Qp-
T b
Qb+
Qb-
T f
Qf+
Gf-
T d
Qd+
Qd-
T r
Qr+
Qr-
T g
400
401
402
403
404
405
406
407
408
409
410
411

Fig. 10

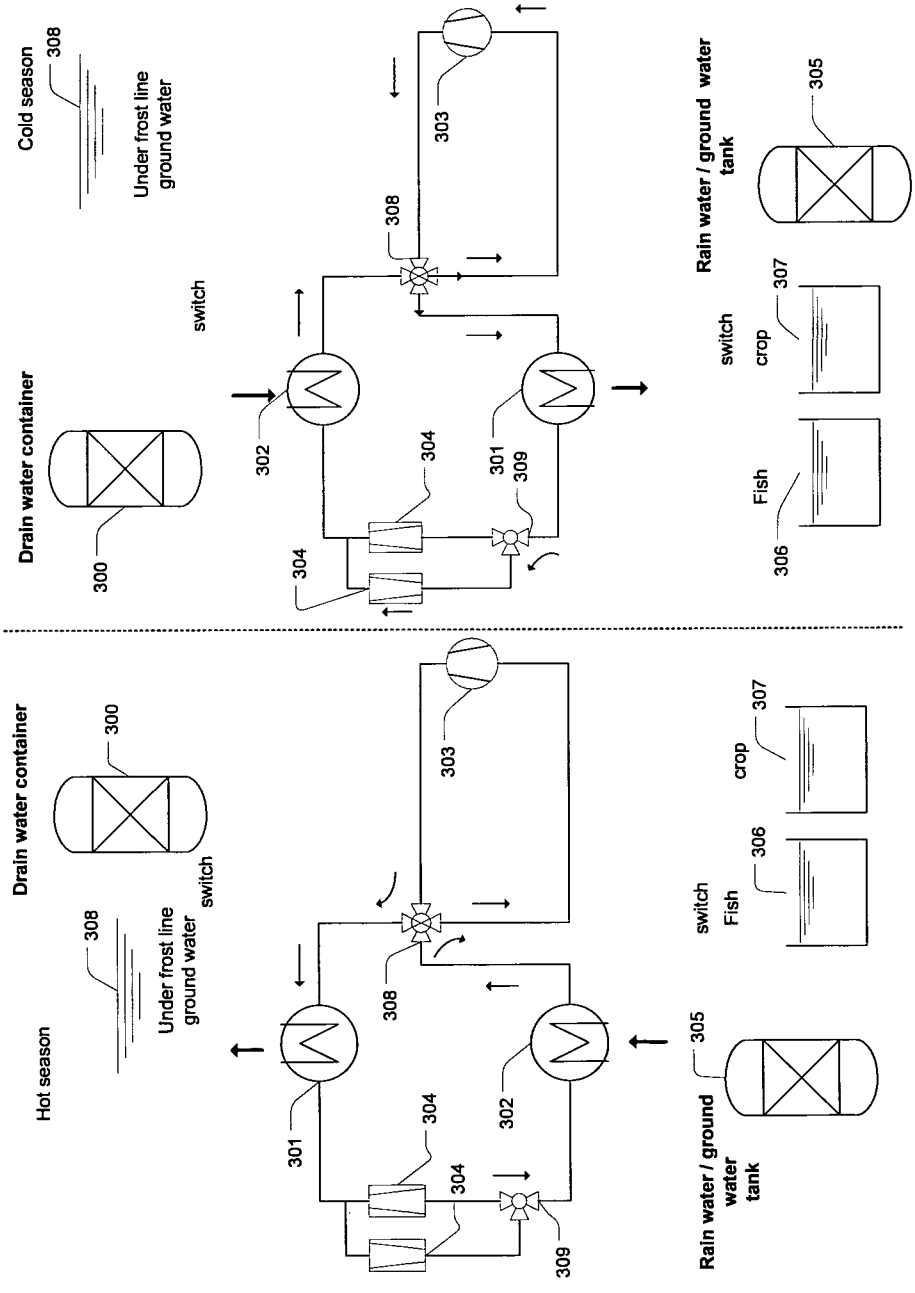
Cold season
308
Under frost line ground water
Drain water container
300
switch
302
304
301
309
303
308
Rain water / ground water tank
305
switch
crop
307
Fish
306
Hot season
308
Under frost line ground water
Drain water container
300
switch
303
308
301
304
304
302
309
305
Rain water / ground water tank
switch
Fish
306
crop
307

Fig. 11

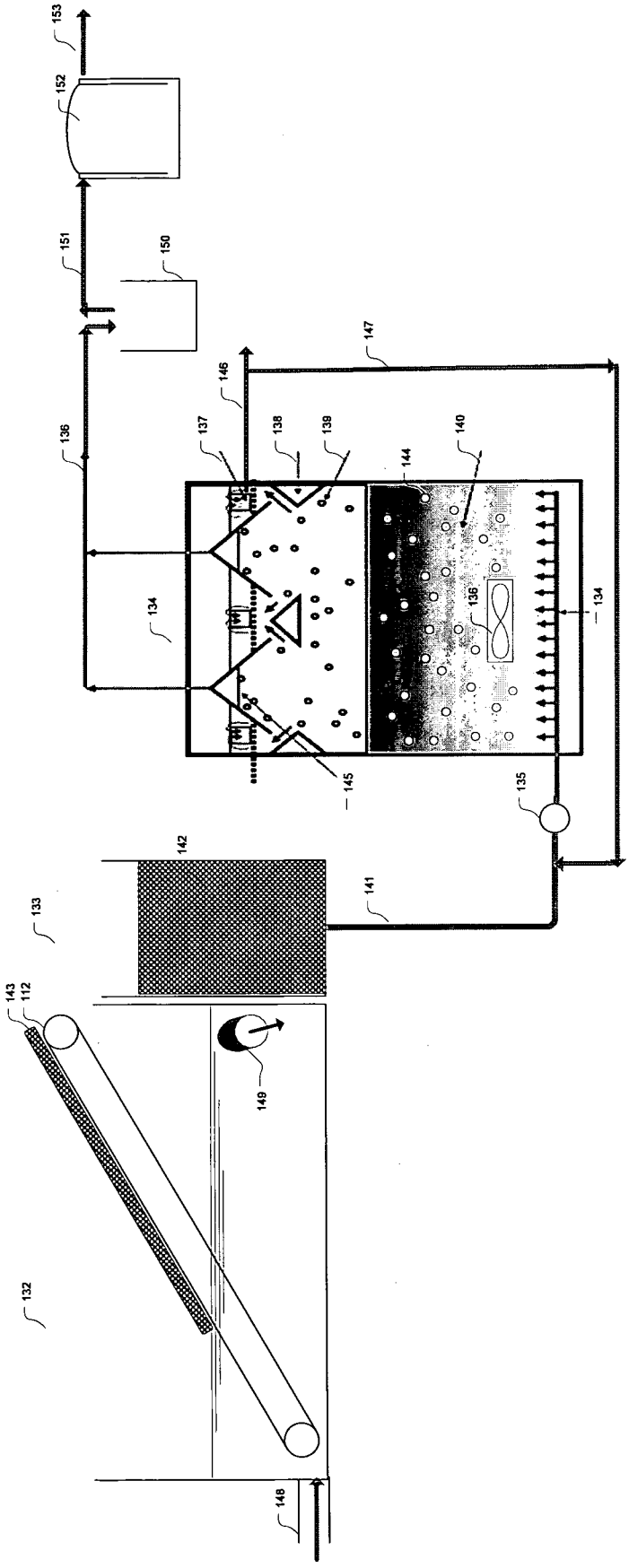
153
152
151
150
147
146
137
138
139
144
140
136
134
136
134
145
135
142
141
133
143
112
149
132
148

Fig. 12

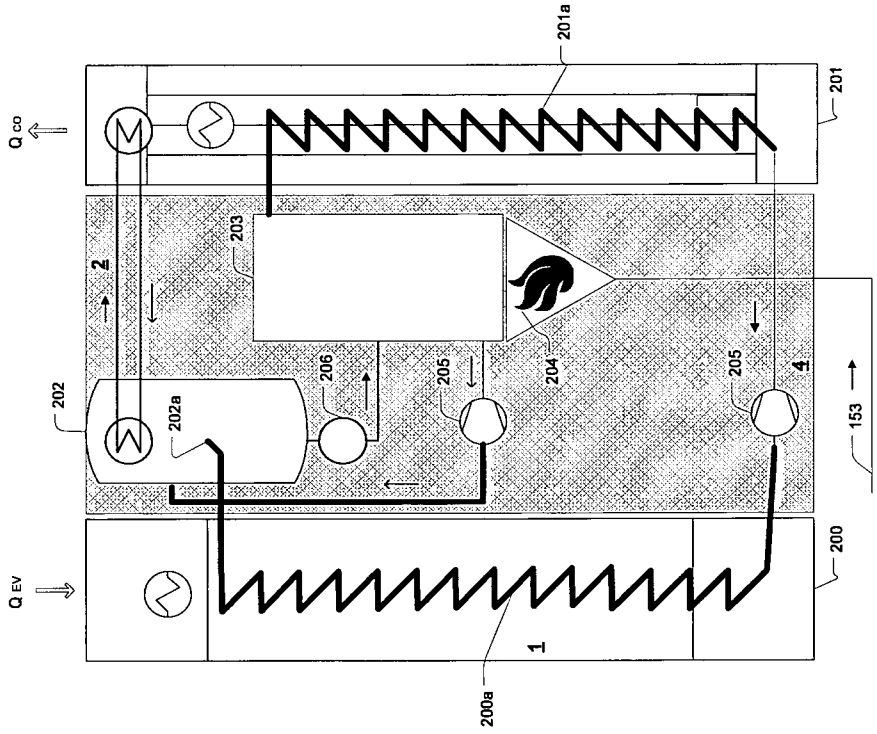

Fig. 13

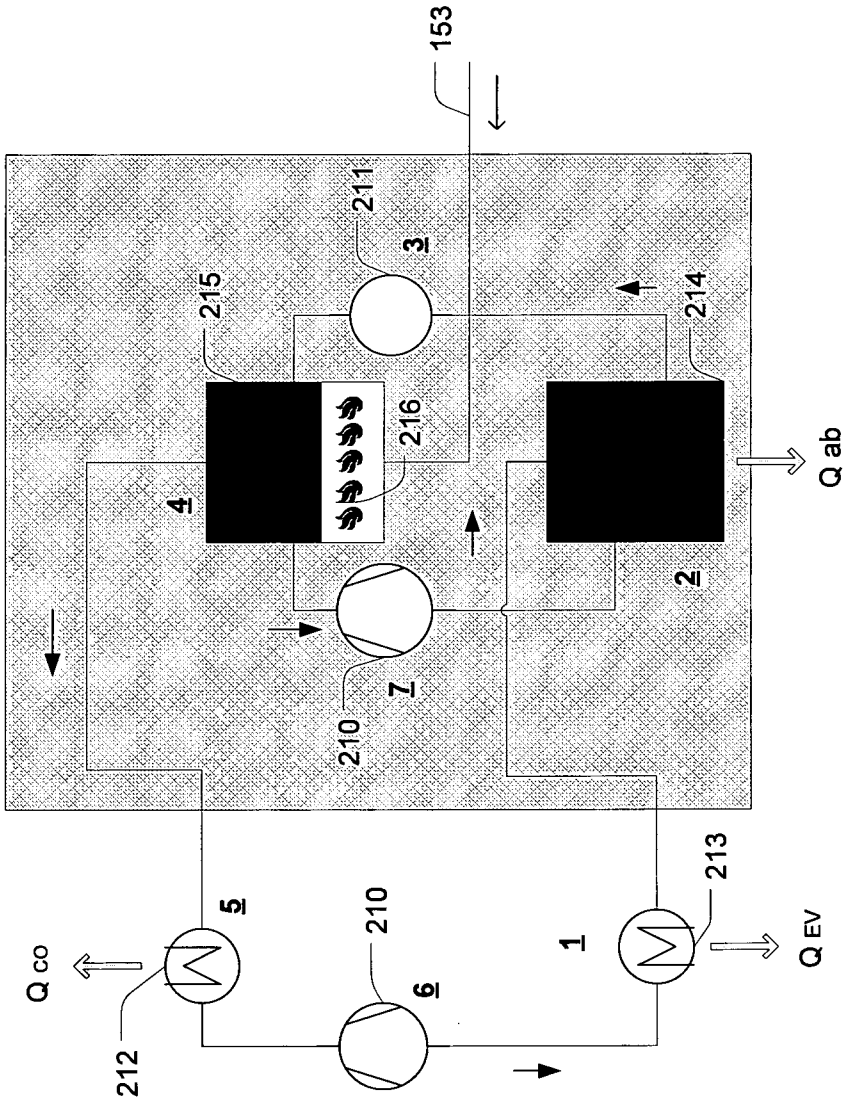

Fig. 14

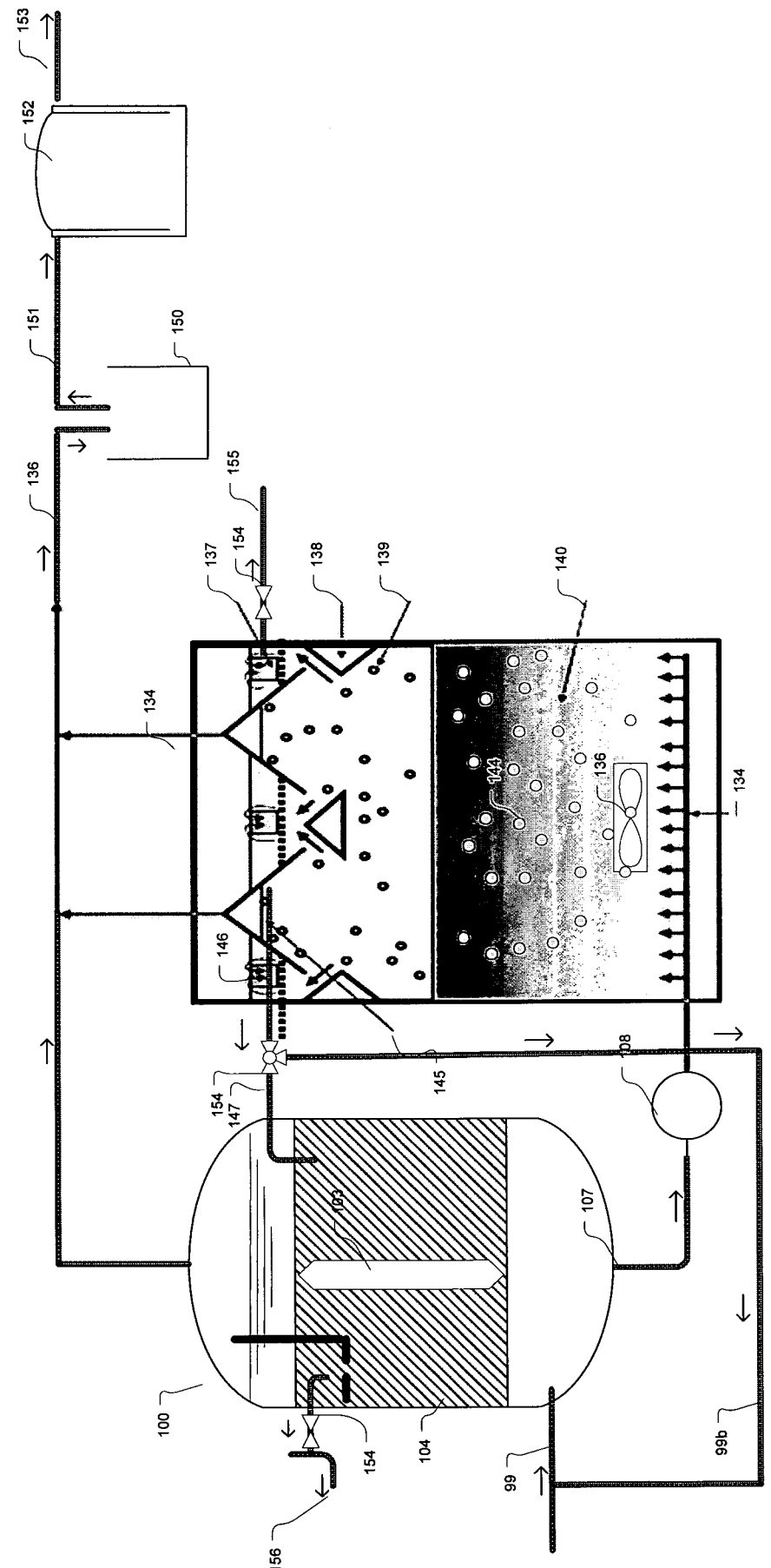
153
152
151
150
136
155
154
137
138
139
140
134
146
143
136
134
154
147
145
108
107
103
100
154
104
99
99b
156

Fig. 15

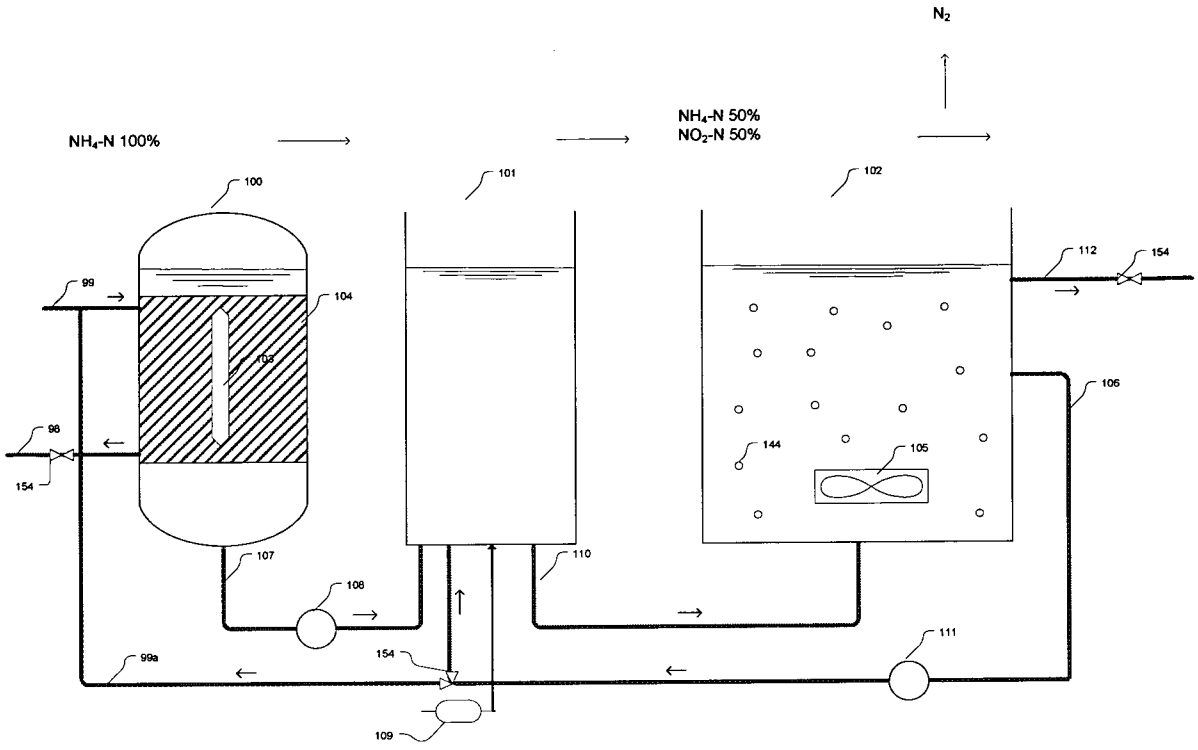
N2
NH4-N 100%
NH4-N 50%
NO2-N 50%
100
101
102
99
104
103
112
154
106
98
154
144
105
107
108
110
111
99a
154
109

Fig. 16

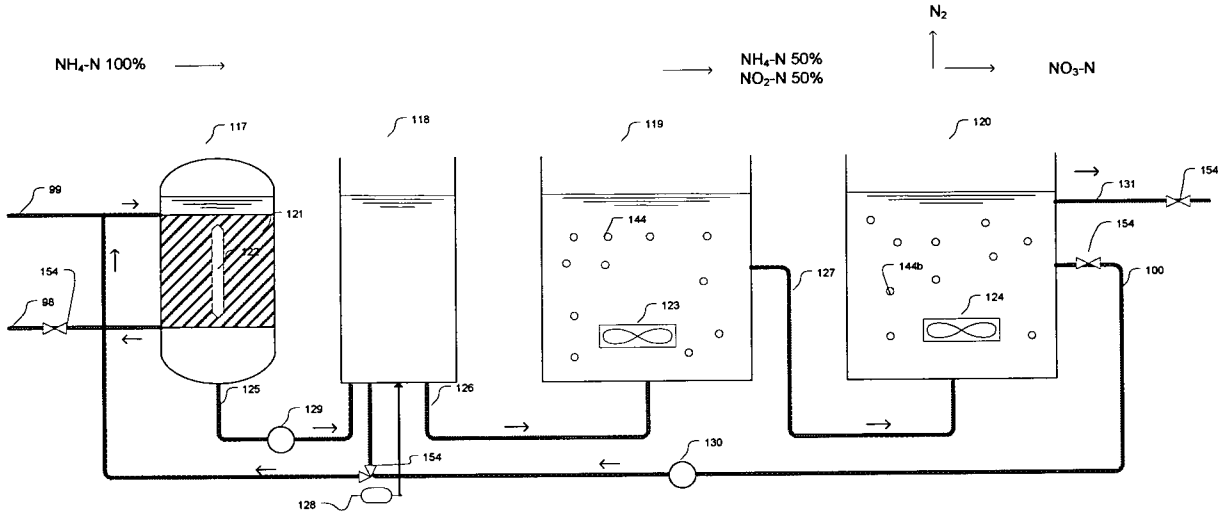
N2
NH4-N 100%
NH4-N 50%
NO2-N 50%
NO3-N
117
118
119
120
99
121
122
131
154
154
144
154
98
144b
127
100
123
124
125
129
126
130
154
128

Fig. 17

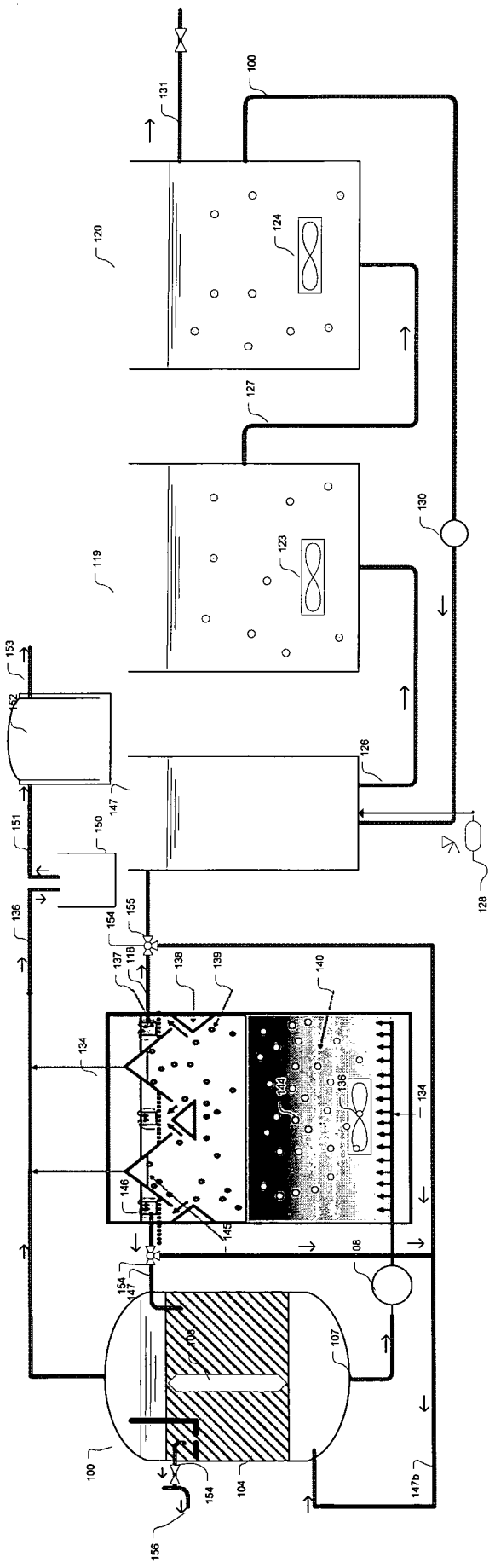
100
131
120
124
127
119
123
130
153
152
126
147
151
150
128
136
154
155
137
118
138
139
140
134
144
146
145
108
107
105
104
147b
156

Fig. 18

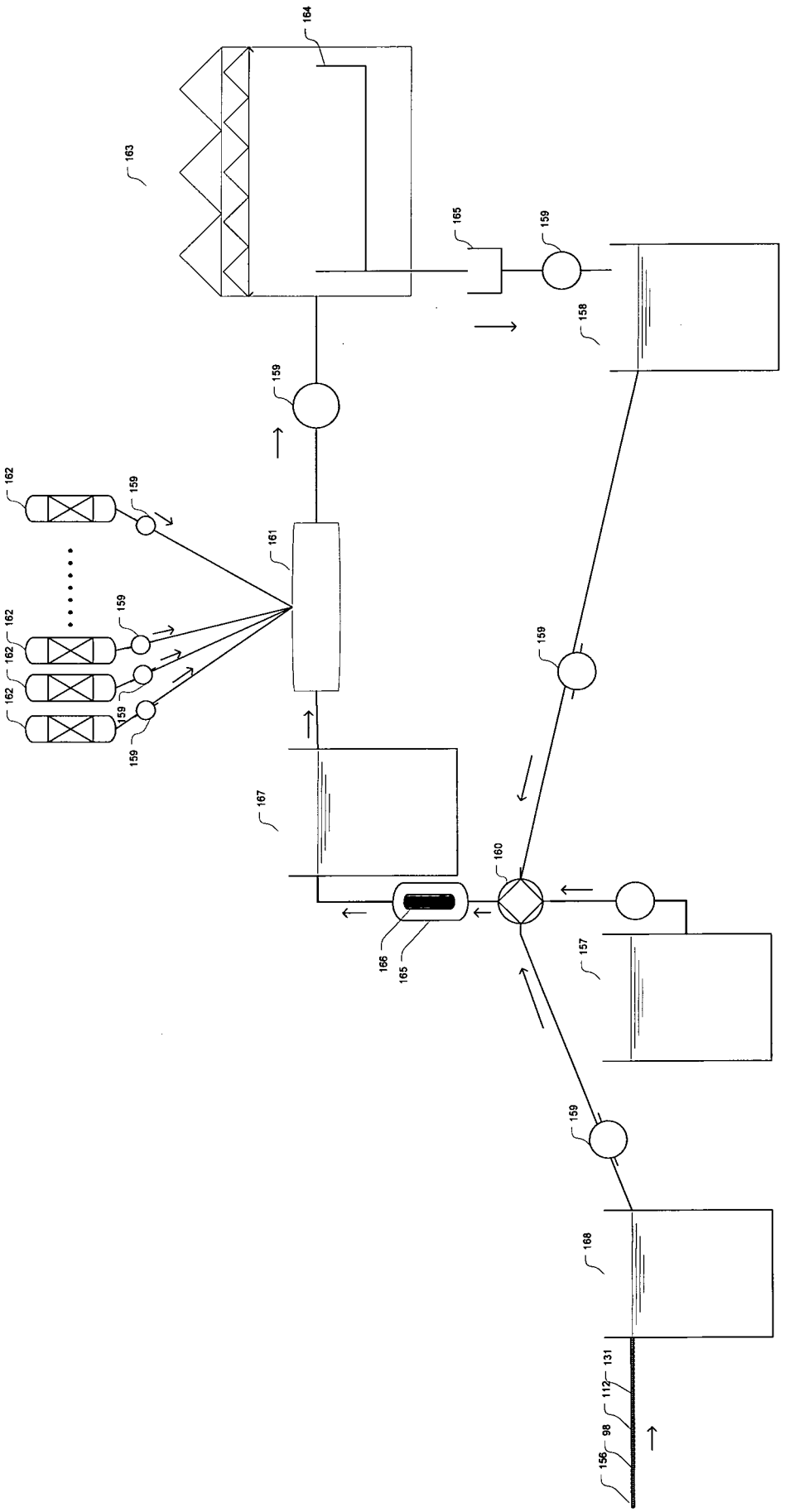
164
163
165
159
158
159
162
159
161
162
159
162
162
159
159
159
167
160
166
165
157
159
168
131
112
98
156

Fig. 19

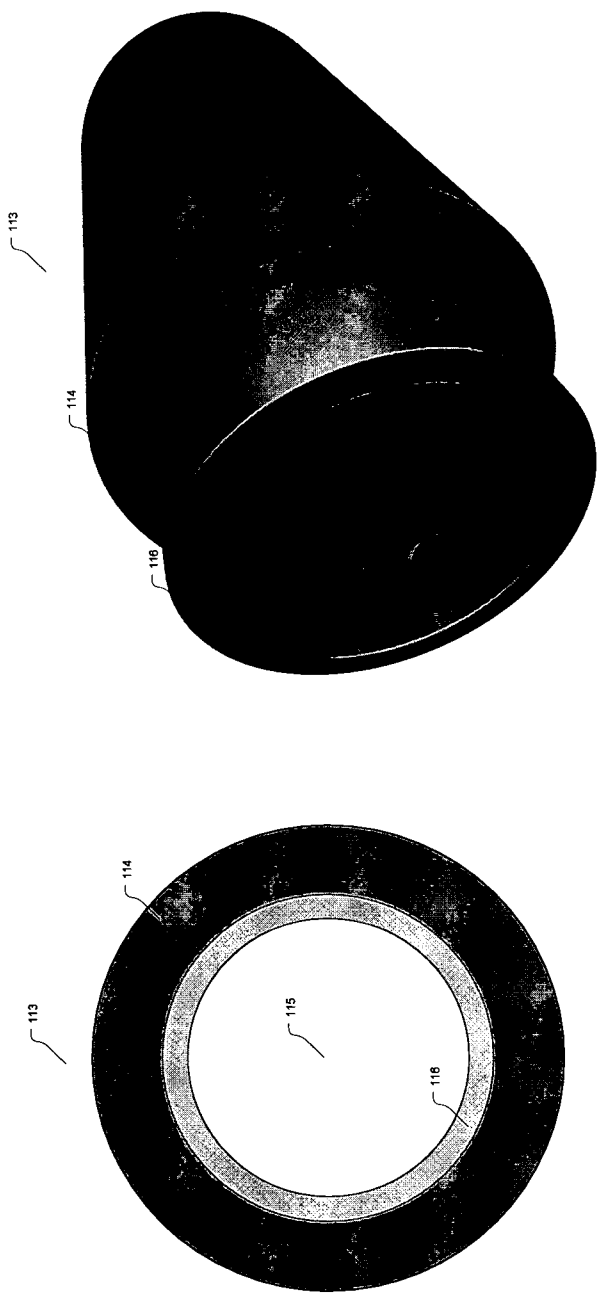

Fig. 20

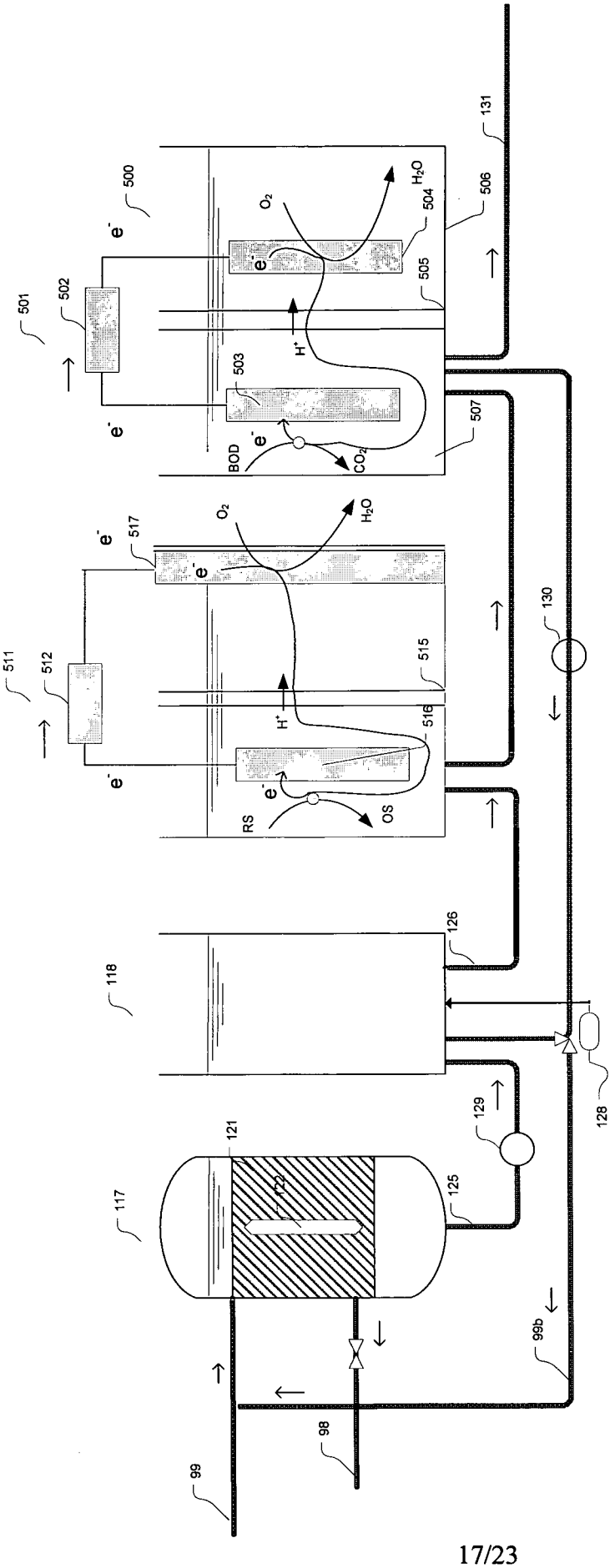
131
500
506
504
505
501
502
503
507
BOD
CO2
H2O
O2
H+
e-
517
511
512
515
516
RS
OS
130
118
126
128
129
121
117
125
99b
98
99

Fig. 21

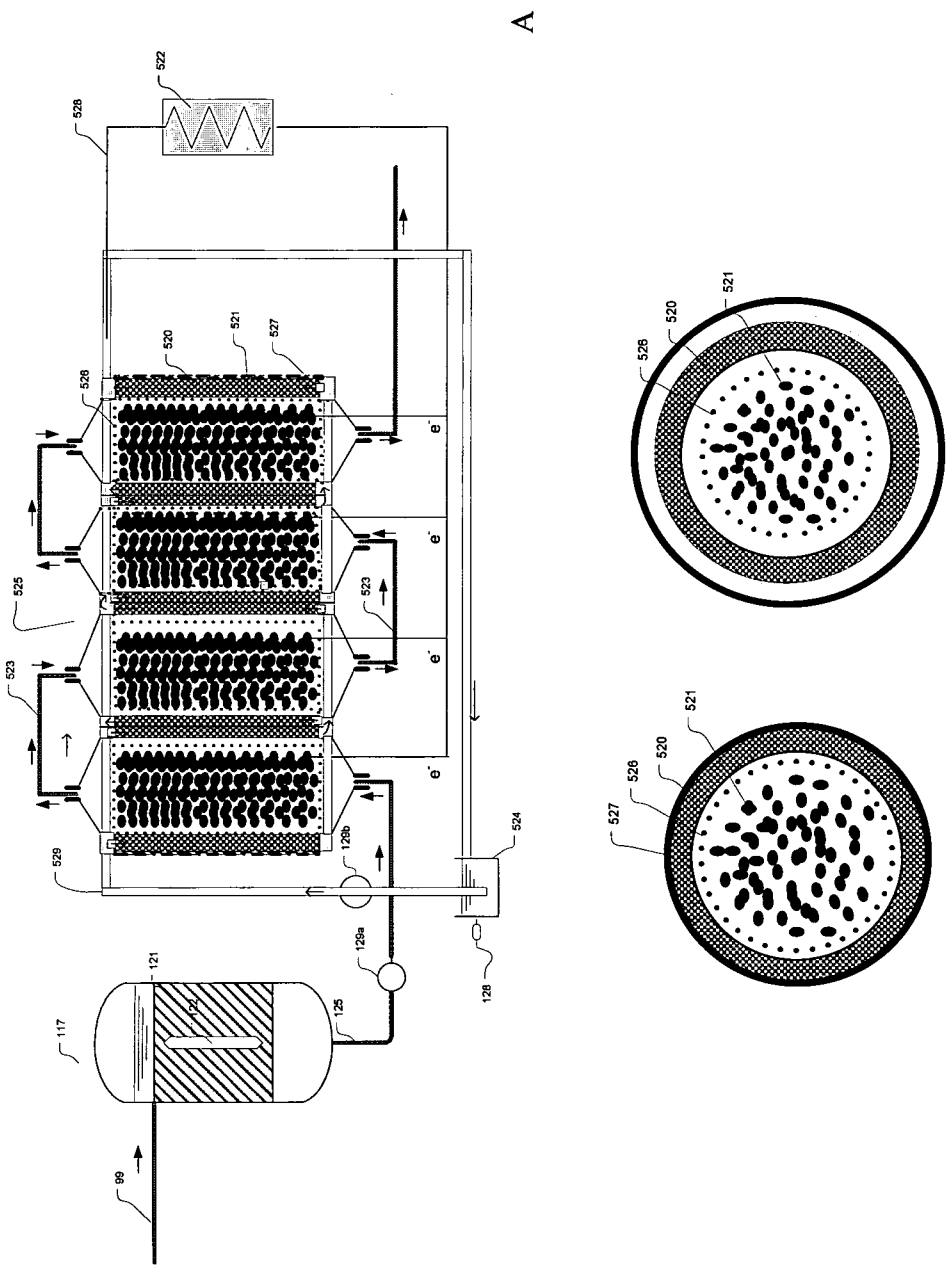
A
522
528
520
521
527
526
525
523
524
529
128b
129a
128
121
117
125
99
e-
B2
B1

Fig. 22 A & B

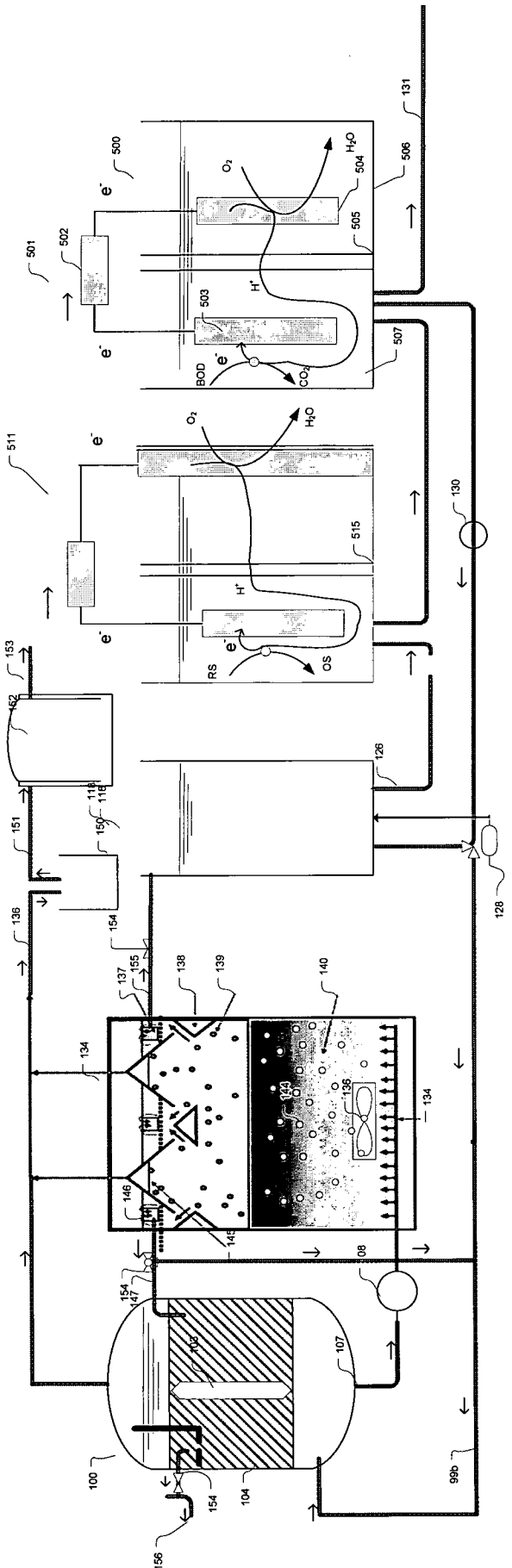
500
501
502
503
504
505
506
507
511
515
131
130
128
126
153
152
151
150
118
136
154
155
137
138
139
140
134
146
145
147
148
107
108
100
104
156
99b
O_2
H_2O
H^+
e^-
BOD
CO_2
RS
OS

Fig. 23

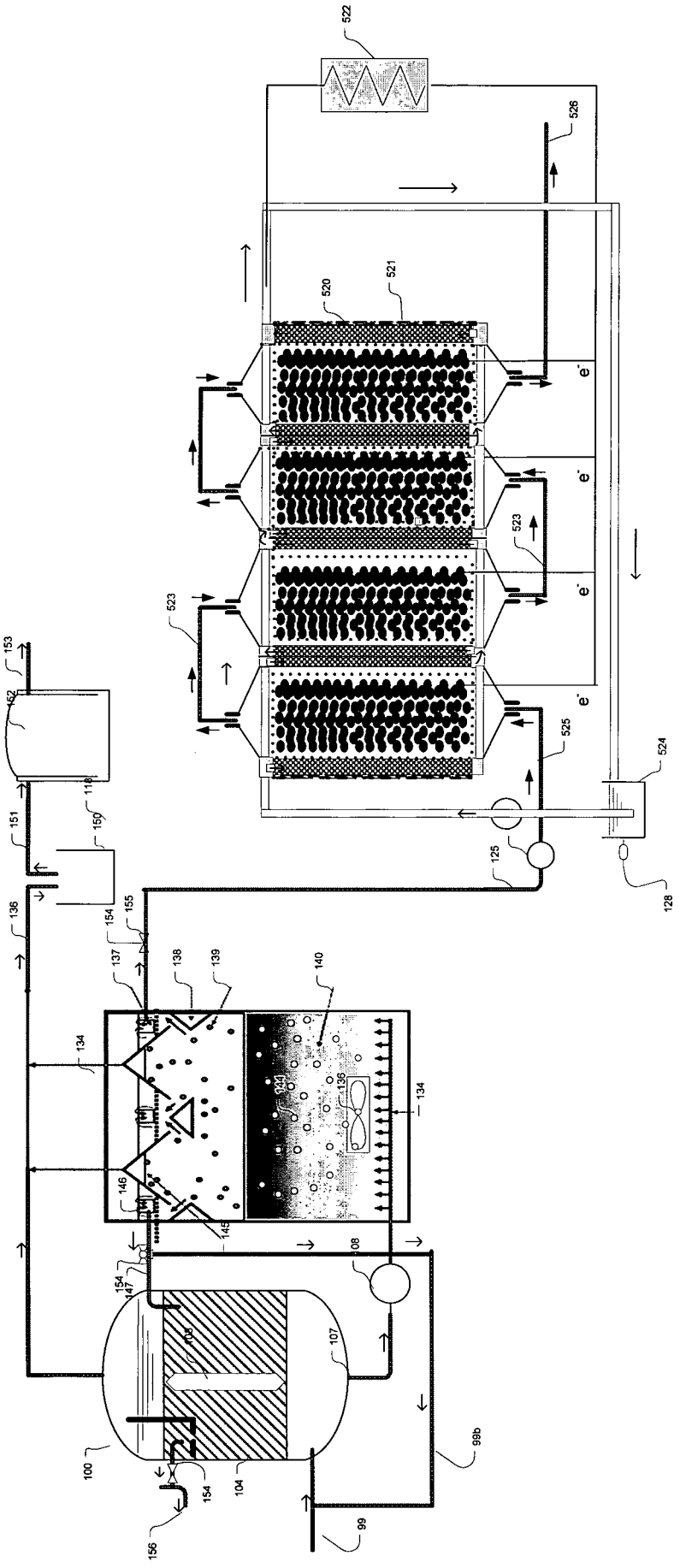
522
526
520
521
523
525
524
125
128
153
152
118
151
150
136
154
155
137
138
139
140
134
144
130
146
145
108
147
107
109
100
104
99b
99
156

Fig. 24

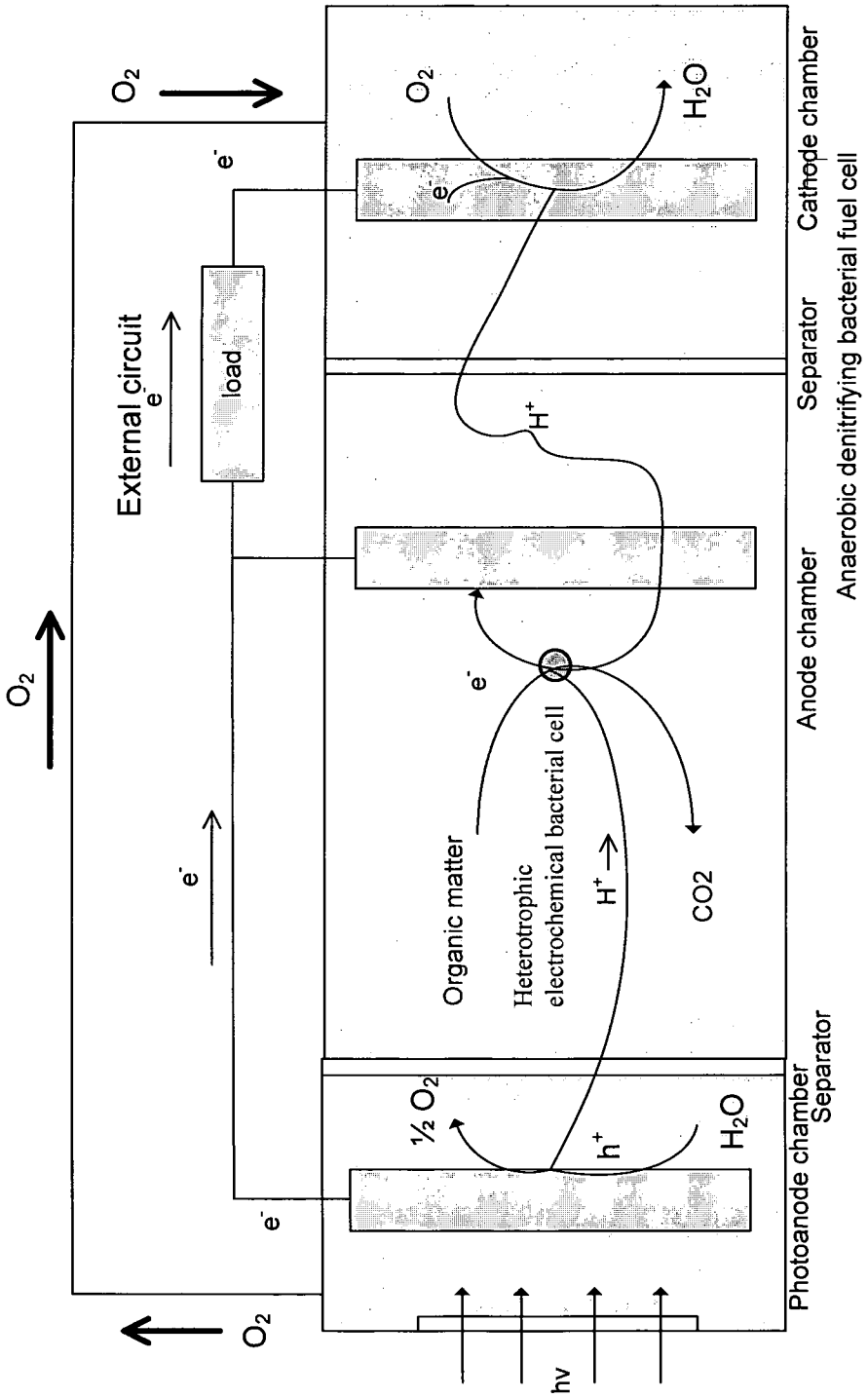
O2
e-
External circuit
load
e-
O2
H2O
Cathode chamber
Separator
H+
Anaerobic denitrifying bacterial fuel cell
Anode chamber
e-
Organic matter
Heterotrophic electrochemical bacterial cell
H+
CO2
e-
½ O2
h+
H2O
Photoanode chamber
Separator
hv
O2
O2

Fig. 25

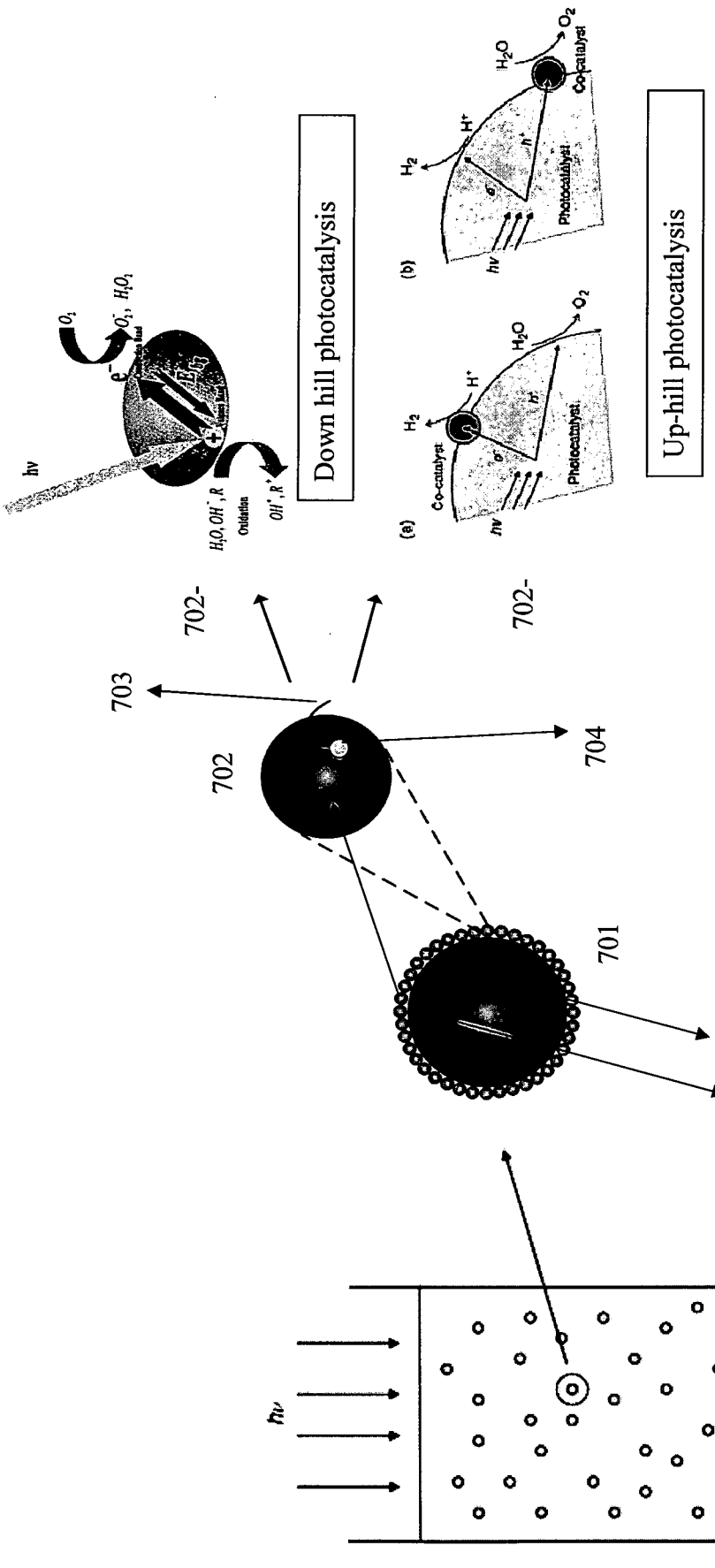
Down hill photocatalysis
Up-hill photocatalysis
Photocatalyst
Co-catalyst
Oxidation
hν
700
701
702
702-
703
704

Fig. 26

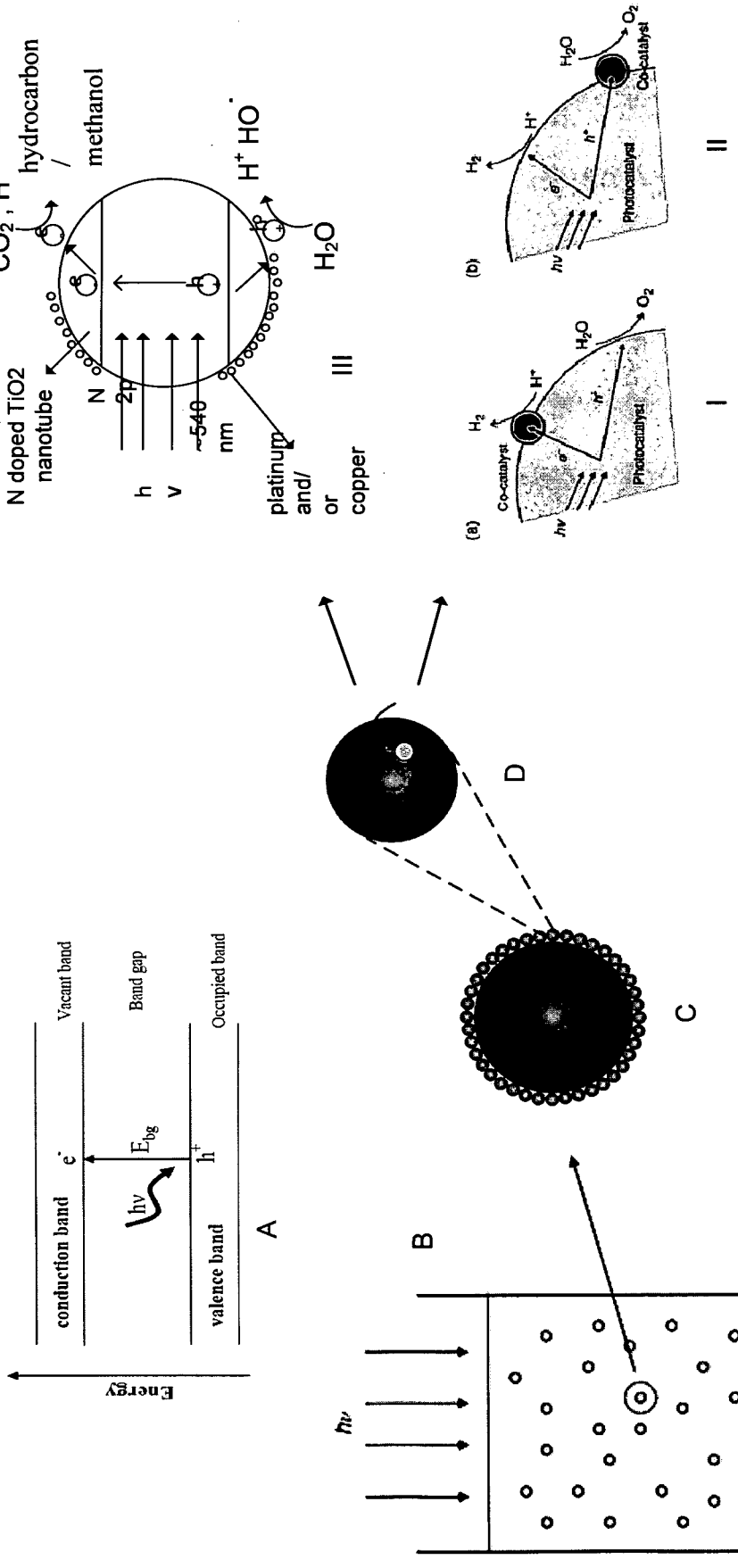
CO2 , H+
hydrocarbon / methanol
H+ HO·
H2O
N doped TiO2 nanotube
N
2p
h v
~540 nm
platinum and/ or copper
III
H2O
O2
H2
H+
e-
h+
Co-catalyst
Photocatalyst
hν
(b)
(a)
II
I
Energy
conduction band
valence band
e-
h+
Ebg
hν
Vacant band
Band gap
Occupied band
A
B
C
D
hν

Fig. 27