



(51) International Patent Classification:

C02F 3/32 (2023.01) C02F 103/04 (2006.01)
C02F 3/34 (2023.01) C02F 103/08 (2006.01)
C02F 3/10 (2023.01) C02F 103/24 (2006.01)
C12N 1/12 (2006.01) C02F 103/26 (2006.01)
C12N 1/20 (2006.01) C02F 103/32 (2006.01)
C12P 39/00 (2006.01) C02F 103/34 (2006.01)
C02F 103/02 (2006.01) C02F 103/36 (2006.01)

(21) International Application Number:

PCT/EP2024/052158

(22) International Filing Date:

30 January 2024 (30.01.2024)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

23166094.5 31 March 2023 (31.03.2023) EP

(71) Applicant: SONY SEMICONDUCTOR SOLUTIONS CORPORATION [JP/JP]; 4-14-1 Asahicho, Atsugi-shi, Kanagawa 243-0014 (JP).

(71) Applicant (for AL only): SONY EUROPE B.V. [GB/GB]; The Heights, Brooklands, Weybridge Surrey KT13 OXW (GB).

(72) Inventors: ROCCUZZO, Sebastiana; c/o Sony Europe B.V., Zweigniederlassung Deutschland, Stuttgart Technology Center, Hedelfinger Str. 61, 70327 Stuttgart (DE). KHODABAKHSHISHALAMZARI, Elham; c/o Sony Europe B.V., Zweigniederlassung Deutschland, Stuttgart Technology Center, Hedelfinger Str. 61, 70327 Stuttgart (DE). ROSSELLI, Silvia; c/o Sony Europe B.V., Zweigniederlassung Deutschland, Stuttgart Technology Center, Hedelfinger Str. 61, 70327 Stuttgart (DE). STAHL, Simon; c/o Sony Europe B.V., Zweigniederlassung Deutschland, Stuttgart Technology Center, Hedelfinger Str. 61, 70327 Stuttgart (DE). ROBERTS, Anthony; c/o Sony Europe B.V., Zweigniederlassung Deutschland, Stuttgart Technology Center, Hedelfinger Str. 61, 70327 Stuttgart (DE). NELLES, Gabriele; c/o Sony Europe B.V., Zweigniederlassung Deutschland, Stuttgart Technology Center, Hedelfinger Str. 61, 70327 Stuttgart (DE). FONSECA DEICHMANN, Vitor Angelo; c/o Sony Europe B.V., Zweigniederlassung Deutschland, Stuttgart

Technology Center, Hedelfinger Str. 61, 70327 Stuttgart (DE).

(74) Agent: ENGELHARD, Markus; BOEHMERT & BOEHMERT ANWALTSPARTNERSCHAFT MBB, Pettenkoferstraße 22, 80336 München (DE).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: DESALINATION OF WATER USING MICROALGAL-BACTERIAL CONSORTIA, AND THEIR APPLICATIONS FOR WATER REUSE

(57) Abstract: The field of the disclosure lies in the desalination of salty water. The present disclosure relates to a method for the desalination of salty water. The present disclosure also relates to a device for the desalination of salty water. The present disclosure further relates to a closed system comprising a lower part and an upper part, wherein salty water and microalgae and/or a microalgae-bacteria consortium are located in the lower part of the closed system, and a root area of a crop is located in the upper part of the closed system. Moreover, the present disclosure relates to uses of a device as defined herein, or a closed system as defined herein.



DESALINATION OF WATER USING MICROALGAL-BACTERIAL CONSORTIA, AND THEIR APPLICATIONS FOR WATER REUSE

BACKGROUND

[0001] The field of the DISCLOSURE lies in the desalination of salty water.

[0002] The present disclosure relates to a method for the desalination of salty water.

[0003] The present disclosure also relates to a device for the desalination of salty water.

[0004] The present disclosure further relates to a closed system comprising a lower part and an upper part, wherein salty water and microalgae and/or a microalgae-bacteria consortium are located in the lower part of the closed system, and a root area of a crop is located in the upper part of the closed system.

[0005] Moreover, the present disclosure relates to uses of a device or a closed system as defined herein.

DESCRIPTION OF THE RELATED ART

[0006] The “background” description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description which may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0007] Decline of freshwater resources has been recognized as one of the main environmental problems on global level. In addition to the increasing extent of primary salinization due to climate change, secondary salinization caused by human interventions is also a significantly increasing problem, therefore, the development of various chemical-free, biological desalination and removal procedures will become increasingly important.

[0008] The treatment of wastewaters with high salt content presents a complicated task for wastewater treatment professionals. Due to the large salt content, saline wastewaters can be introduced neither into surface waters nor into general wastewater treatment systems without pre-treatment. Also, composition of saline wastewaters could be very variable. Coexistence of salts, heavy metals, or nonmetallic compounds usually leads to complicated interactions with each other and with living organisms, affecting their salt tolerance.

[0009] Salt removal operations by physico-chemical processes, such as reverse osmosis, ion exchange or electrodialysis exist but these are rather expensive. Biological methods for the desalination of salty water represent a promising option, because technically valuable microorganisms can be used to assist in desalination of water thanks to the variety of enzymes and secondary metabolites they produce. Microalgae can play a significant role in biological methods for the desalination of salty water.

[0010] However, microalgae require specific conditions for growth. Moreover, the presence of salt in water can greatly influence algal productivity and therefore the efficiency of desalination of salty water to acceptable standards for its safe re-use. Thus, biological desalination of salty water and reuse of salty water faces many complex challenges. Moreover, so far existing algae-based desalination processes cannot remove salt completely via a single step process. Also, most of the current algae-based desalination systems have a long contact time. Currently used systems mostly rely on the use of suspended cells in cultivation systems, which have main limitations in terms of overheating, difficulties in scale-up and higher construction costs.

[0011] Most of the technologies for salty water desalination, e.g., thermal and membrane-based systems, require several and extensive pretreatments steps of chlorine disinfection, antiscalant dosing, and antifoam agent dosing and usually generate secondary waste.

SUMMARY

[0012] In the following, the elements of the invention will be described. These elements are listed with specific embodiments, however, it should be understood that they may be combined in any manner and in any number to create additional embodiments. The variously described examples and preferred embodiments should not be construed to limit the present invention to only the explicitly described embodiments. This description should be understood to support and encompass embodiments which combine two or more of the explicitly described embodiments or which combine the one or more of the explicitly described embodiments with any number of the disclosed and/or preferred elements. Furthermore, any permutations and combinations of all described elements in this application should be considered disclosed by the description of the present application unless the context indicates otherwise.

[0013] The present disclosure provides a method for the desalination of salty water, the method comprising the following steps:

- a. contacting the salty water with microalgae, wherein the salty water comprises bacteria, optionally wherein the microalgae is a suspension of microalgae in an aqueous solution, a paste, a gel, or capsules, or wherein the microalgae are microalgae growing on or in a supportive medium, such as a mesh, a membrane, or a foam;
 - b. culturing the microalgae in the salty water;
 - c. removing a part of the culture from step b., and
 - d. separating the part of the culture of step c. into desalinated water and a microalgae biomass,
- wherein the conditions during the contacting in step a. and/or the culturing in step b. allow a microalgae-bacteria consortium to be established, and wherein the contacting of the salty water with the microalgae in step a. and/or the removing of the part of the culture in step c. is carried out in form of a batch modus, a fed batch modus, a repeated fed batch and harvesting modus, an adaptive modus, such as a fast track adaptive evolution modus, and/or in a titration modus, preferably wherein the contacting of the salty water with the microalgae in step a. and/or the removing of the part of the culture in step c. is carried out in form of a repeated fed batch and harvesting modus, a fast-track adaptive evolution modus, or in a titration modus, and wherein the bacteria and/or the microalgae are halotolerant, optionally wherein the bacteria, the microalgae, and/or the microalgae-bacteria consortium are able to take up salt from the salty water, and/or is able to metabolize salts.

[0014] The present disclosure provides a device for the desalination of salty water, wherein the device is in particular for use in a method as defined herein, comprising:

- (i) at least one salty water collection tank;
- (ii) optionally, at least one pH preconditioning unit;
- (iii) at least one salty water dosing unit;
- (iv) at least one algae starter tank;
- (v) at least one salty water processing tank for combining microalgae with salty water comprising bacteria, and/or for culturing the microalgae in the salty water comprising

the bacteria under conditions to allow a microalgae-bacteria consortium to be established within the at least one salty water processing tank, and

- (vi) optionally, at least one separation unit for separating the content of the processing tank into desalinated water and a microalgae biomass,

wherein the salty water from the at least one salty water dosing unit is supplied to the at least one salty water processing tank in a batch modus, a fed batch modus, a repeated fed batch and harvesting modus, an adaptive modus, such as a fast-track adaptive evolution modus, and/or in a titration modus, preferably wherein the salty water from the at least one salty water dosing unit is supplied to the at least one salty water processing tank in a repeated fed batch and harvesting modus, a fast-track adaptive evolution modus, or in a titration modus.

[0015] The present disclosure provides a closed system comprising a lower part and an upper part, wherein salty water and microalgae and/or a microalgae-bacteria consortium is located in the lower part of the closed system, and a root area of a crop is located in the upper part of the closed system, wherein the microalgae and/or the microalgae-bacteria consortium and the root area of the crop are in direct contact or wherein the microalgae and/or the microalgae-bacteria consortium and the root area of the crop are separated by a mesh and/or an interlayer and/or a membrane, optionally wherein the microalgae and/or the microalgae-bacteria consortium is embedded in the mesh and/or interlayer and/or membrane, or wherein inactivated microalgae cells are used as a membrane to enhance the binding capacity of the microalgae-bacteria consortium, and/or lower the nutrient requirement of the crop, further optionally wherein the bacteria, the microalgae, and/or the microalgae-bacteria consortium is embedded in a protective matrix, such as a biofilm, a membrane matrix, and/or an encapsulation matrix.

[0016] The present disclosure provides the use of a device as defined herein, or a closed system as defined herein, in a method as defined herein, or for the desalination of salty water, for the irrigation of a plant, such as a crop, for the removal of nutrients and/or metals from salty water, for manufacturing processes, such as for supplying water for semiconductor fabrication plants, for example cooling water for manufacturing processes and/or water for the air conditioning of semiconductor fabrication plants, and/or for supplying water for industrial processes, such as for the cleaning of machinery in industrial processes.

[0017] As used herein, the term “comprising” is to be construed as encompassing both “including” and “consisting of”, both meanings being specifically intended, and hence individually disclosed embodiments in accordance with the present disclosure. Where used herein, “and/or” is to be taken as specific disclosure of each of the two specified features or components with or without the other. For example, “A and/or B” is to be taken as specific disclosure of each of (i) A, (ii) B and (iii) A and B, just as if each is set out individually herein. In the context of the present disclosure, the terms “about” and “approximately” denote an interval of accuracy that the person skilled in the art will understand to still ensure the technical effect of the feature in question. The term typically indicates deviation from the indicated numerical value by $\pm 20\%$, $\pm 15\%$, $\pm 10\%$, and for example $\pm 5\%$. As will be appreciated by the person of ordinary skill, the specific such deviation for a numerical value for a given technical effect will depend on the nature of the technical effect. For example, a natural or biological technical effect may generally have a larger deviation than one for a man-made or engineering technical effect. As will be appreciated by the person of ordinary skill, the specific deviation for a numerical value for a given technical effect will depend on the nature of the technical effect. For example, a natural or biological

technical effect may generally have a larger deviation than one for a man-made or engineering technical effect. Where an indefinite or definite article is used when referring to a singular noun, e.g. "a", "an" or "the", this includes a plural of that noun unless something else is specifically stated.

[0018] The foregoing paragraphs have been provided by way of general introduction and are not intended to limit the scope of the following claims. The described embodiments, together with further advantages, will be best understood by reference to the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] A more complete appreciation of the disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

[0020] Figure 1 shows a schematic representation of the general method for the desalination of salty water according to the present disclosure.

[0021] Figure 2 shows a schematic representation of the Repeated Fed-Batch and Harvesting Modus.

[0022] Figure 3 shows a schematic representation of the Fast-Track Adaptive Evolution Modus of the Microalgal-Bacterial Consortium.

[0023] Figure 4 shows a schematic representation of the Titration Modus for Titration-like addition of salty water.

[0024] Figure 5 shows a schematic representation of hydroponic cultures and integrated hydroponic systems in a floating oasis working principle according to the present disclosure with hydroponics floating growing units (farms) directly on the sea (figure 5a), with figures 5b and 5c showing embodiments of the schematic representation of hydroponic cultures and integrated hydroponic systems according to the present disclosure for simultaneous carbon fixation, desalination and crops growth bio-stimulation.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0025] As discussed above, the present disclosure provides a method for the desalination of salty water, the method comprising the following steps:

- a. contacting the salty water with microalgae, wherein the salty water comprises bacteria, optionally wherein the microalgae is a suspension of microalgae in an aqueous solution, a paste, a gel, or capsules, or wherein the microalgae are microalgae growing on or in a supportive medium, such as a mesh, a membrane, or a foam;
 - b. culturing the microalgae in the salty water;
 - c. removing a part of the culture from step b., and
 - d. separating the part of the culture of step c. into desalinated water and a microalgae biomass,
- wherein the conditions during the contacting in step a. and/or the culturing in step b. allow a microalgae-bacteria consortium to be established, and wherein the contacting of the salty water with the microalgae in step a. and/or the removing of the part of the culture in step c. is carried out in form of a batch modus, a fed batch modus, a repeated fed batch and harvesting modus, an adaptive modus, such as a fast-track adaptive evolution modus, and/or in a titration modus, preferably wherein the contacting of the salty

water with the microalgae in step a. and/or the removing of the part of the culture in step c. is carried out in form of a repeated fed batch and harvesting modus, a fast-track adaptive evolution modus, or in a titration modus, and wherein the bacteria and/or the microalgae are halotolerant, optionally wherein the bacteria, the microalgae, and/or the microalgae-bacteria consortium are able to take up salt from the salty water, and/or are able to metabolize salts.

[0026] The present disclosure discloses a novel biological method for the desalination of salty water.

[0027] Having put focus on how clean water, food and feed can be sustainably produced, the inventors have developed a simple yet elegant, sustainable and environmentally friendly solution with methods offering simultaneous desalination of salty water streams and their reuse in agriculture applications, i.e. irrigation.

[0028] Biological methods for the desalination of salty water represent a promising option, because technically valuable microorganisms can be used to assist in desalination of water thanks to the variety of biosorption, bioaccumulation, osmoregulation mechanisms and adjusted metabolism via the enzymes and secondary metabolites they produce. Microalgae can play a significant role in biological methods for the desalination of salty water thanks to their biosorption and bioaccumulation mechanisms modulated via morphological adaptation and/or osmoregulation and/or ion exchange (uptake/release of ions) and/or re-establishment of homeostasis and metabolism. However, microalgae require specific conditions for growth. Moreover, the presence of salt in water can greatly influence algal productivity and therefore the efficiency of salty water desalination to acceptable standards for its safe re-use. Thus, biological salty water desalination and reuse of salty water faces many complex challenges.

[0029] According to the methods of the present disclosure, salty water is supplied in a way ensuring that the microalgae and bacteria can efficiently adapt to the presence of salt in the salty water. Thereby, a stable, specialized, and/or adapted microalgae-bacteria consortium can be established that can effectively and timely remove and/or degrade salt of the salty water.

[0030] In one embodiment, the presence of microalgae and bacteria in the consortium promotes each other's growth.

[0031] Of note, after a "scale-up phase" (also referred to as "germination" or "warming-up" phase) of culturing the microalgae in the salty water (step b.), the density of microalgae in the culture is increasing exponentially. Thus, the methods of the present disclosure are also advantageous, because due to the simultaneous microalgae biomass production, less external nutrient substrates need to be added to supply the bacteria and/or the microalgae-bacteria consortium with sufficient nutrients. This further reduces the costs of the methods according to the present disclosure compared to state-of-the-art-methods.

[0032] In one embodiment, a part of the culture from step b. of the method is removed, wherein the part is at least 0,01% of the culture, at least 0,1% of the culture, at least 0,5% of the culture, at least 1% of the culture, at least 10% of the culture, at least 20% of the culture, at least 30% of the culture, at least 40% of the culture, at least 50% of the culture, at least 60% of the culture, at least 70% of the culture, at least 80% of the culture, at least 90% of the culture, or around 100% of the culture. Thus, the term "a part" of the culture can also refer to the entire culture.

[0033] The part of the culture that is removed can then be added to a subsequent batch or to a separation unit, which separates the part of the culture that is removed into clean water and microalgae biomass.

[0034] In one embodiment, the culturing in step b. of the method is carried out in at least two separate batches, optionally wherein the contacting in step a. of the method and/or the removing of the part of

the culture in step c. is carried out periodically and/or stepwise increasingly from one batch to a subsequent batch, such as from a first batch to a second batch, from the second batch to a third batch, from the third batch to a fourth batch, and so on.

[0035] In one embodiment, in the contacting in step a. of the method, the salinity of the salty water is between around 20 g/L and around 50 g/L salt, preferably between around 30 g/L and around 40 g/L salt, more preferably between around 33 g/L and around 37 g/L salt, and most preferably around 35 g/L salt.

[0036] In one embodiment, the salinity of the salty water is adjusted prior to the contacting in step a. of the method to around 1 g/L to around 20 g/L, preferably to around 5 g/L to around 15 g/L, more preferably to around 8 g/L to around 12 g/L, and most preferably to around 10 g/L.

[0037] In one embodiment, the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the repeated fed-batch and harvesting modus.

[0038] In one embodiment, when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the repeated fed-batch and harvesting modus, an amount of a liquid is added to the culture comprising salty water and the microalgae in the contacting of step a. of the method of a subsequent batch, such as the second batch, the third batch, or the fourth batch, that equals the amount of the part of the culture that is removed in step c. of the method of the previous batch, such as the first batch, the second batch, or the third batch, optionally wherein the liquid is salty water, further optionally wherein the amount of the liquid that is added to the culture comprising salty water and microalgae in the contacting in step a. of the subsequent batch that equals the part of the culture that is removed in step c. of the method of the previous batch is increasing from batch to batch, such as is doubled from one batch to the subsequent batch. In this embodiment, the amount of the liquid that is added to the culture comprising salty water and microalgae in the contacting in step a. of the subsequent batch is added “stepwise increasingly”.

[0039] In one embodiment, the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the fast-track adaptive evolution modus.

[0040] In one embodiment, when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the fast track adaptive evolution modus, the part of the culture that is removed in step c. of the method of a previous batch, such as the first batch, the second batch, or the third batch, is added in the contacting of step a. to the salty water of the subsequent batch, such as the second batch, the third batch, or the fourth batch, wherein the salinity in the culture that is added in the contacting of step a. to the salty water of the subsequent batch, such as the second batch, the third batch, or the fourth batch, is increasing compared to the salinity in the culture of the previous batch, such as the first batch, the second batch, or the third batch.

[0041] Microalgae–bacteria co-cultures can show a wide range of relationships other than symbiosis, including commensalism, parasitism, competition, amensalism or neutralism, which might alter their efficacy. Also, these associations are dynamic and can evolve over time. By increasing the initial inoculation ratio slowly from batch to batch, a robust and stable microalgae-bacteria consortium can be assembled, because microalgae and bacteria can slowly acclimatize to the novel conditions in a fast-

track evolutionary adaptation to the salinity of the added water, wherein an accelerated evolution-like mechanism is enabled. The robust and stable microalgae-bacteria consortia thereby established can treat salty water efficiently and effectively.

[0042] In one embodiment, the concentration of microalgae in the culture of a subsequent batch is lower than in the previous batch.

[0043] In one embodiment, the concentration of salt in the culture of a subsequent batch is higher than in the previous batch.

[0044] In one embodiment, when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the fast track adaptive evolution modus, the part of the culture that is removed in step c. of the method of a previous batch that is added in the contacting of step a. to the salty water of the subsequent batch is not increasing from batch to batch, i.e. an equal or an almost equal amount of the culture is removed in step c. of the method of a previous batch compared to the amount that is added in the contacting of step a. to the salty water of the subsequent batch.

[0045] In one embodiment, the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the titration modus.

[0046] In one embodiment, when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the titration modus, the salty water is titrated to a culture comprising the microalgae in step a. of the method. In this embodiment, the salty water is supplied in a titration-like modus, in order to give the microalgae-bacteria consortium sufficient time to slowly adapt and react. Thereby, microalgae have sufficient time to acclimate to the titrated salty water, including pollutants and bacteria. This modus can prevent and/or lower a fast consortium response against the addition of the salty water, which then allows and/or enhances a fast desalination of the salty water. In this embodiment, the microbial consortium is established based on both spatial and temporal “segregation”, which allows algae and bacteria to slowly adapt to the new conditions.

[0047] In one embodiment, when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the titration modus, the algae culture is preferably supplied at an optimal starting density, such as a density within a range of between 1 and 3 g/L. In general, an optimal algae starting density according to the present disclosure is a high density, because a high algae starting density allows the microalgal-bacterial consortium to withstand the new environmental conditions of the added salty water, comprising high contents of salts that might hinder the microalgal-bacterial consortium to be stable established.

[0048] In one embodiment, the microalgae-bacteria consortium established during the contacting in step a. and/or the culturing in step b. of the method is a liquid culture.

[0049] In one embodiment, the microalgae-bacteria consortium established during the contacting in step a. and/or the culturing in step b. is not a biofilm microbial consortium.

[0050] In one embodiment, establishing the microalgae-bacteria consortium during the contacting in step a. and/or the culturing in step b. of the method does not require an organic fish emulsion fertilizer.

[0051] In one embodiment, the bacteria are Ammonia oxidizing bacteria, Nitrite oxidizing bacteria, Ammonia oxidizing archaea, Complete ammonia oxidizer, and/or bacteria belonging to a bacterial

species selected from *Nitrosomonas* spp., *Nitrosospira* spp., *Nitrosococcus* spp., *Nitrobacter* spp., and *Candidatus* spp.

[0052] In one embodiment, the bacteria are halotolerant and/or halophilic.

[0053] In one embodiment, the bacteria are found in saline and/or hypersaline environments.

[0054] In one embodiment, the bacteria are acclimated to sustain even higher salinity levels than those found in their habitat.

[0055] In one embodiment, the bacteria are not separately grown and/or precultured (precultivated).

[0056] In one embodiment, the microalgae are a microalgal culture comprising *Chlorophyceae*, *Eustigmatophyceae*, *Dunaliella salina*, *Dunaliella tertiolecta*, *Synechococcus* spp., *Synechocystis* spp., *Scenedesmus* spp., and/or *Nannochloropsis* spp., such as *Nannochloropsis oculata*, *Nannochloropsis gaditana*, *Nannochloropsis oceanica*.

[0057] In one embodiment, the microalgae are halotolerant and/or halophilic.

[0058] In one embodiment, the microalgae are found in saline and/or hypersaline environments.

[0059] In one embodiment, the microalgae are acclimated to sustain even higher salinity levels than those found in their habitat.

[0060] In one embodiment referring to the contacting in step a. of the method, the microalgae are present in an algal cultivation medium, such as 3N-BBM + V medium, BBM + V medium, Spirul medium, AD medium, MAD Medium, BG11 medium, AD7 medium, Chu-10 medium, Johnson medium, or f/2 medium. In one embodiment, the microalgae are supplied at an optimal starting density, such as a starting density within a range of between 1 and 3 g/L.

[0061] In one embodiment, the method further comprises the step:

- e. embedding the bacteria, the microalgae, and/or the microalgae-bacteria consortium in a protective matrix, such as a biofilm, a membrane matrix, and/or an encapsulation matrix, optionally wherein the bacteria and/or the microalgae are salt metabolizing bacteria and/or salt metabolizing microalgae.

[0062] The additional step e. of the method allows to protect bacteria and/or microalgae from negative effects triggered by a high salt content, i.e., to acclimate to sustain higher salinity levels than those found in their habitat.

[0063] In one embodiment, a living microalgae-bacteria consortium is embedded in the mesh and/or interlayer and/or membrane.

[0064] According to the present disclosure, any kind of mesh and/or interlayer and/or membrane can be used that can separate the microalgae and/or the microalgae-bacteria consortium and the root area of the crop. An example of a mesh and/or an interlayer and/or a membrane that could be used for the present disclosure, without being limited thereto, is a semi-permeable membrane and/or a dialysis membrane.

[0065] In one embodiment, the salty water comprises between around 20 g/L and 50 g/L salt, preferably between around 30 g/L and around 40 g/L salt, more preferably between around 33 g/L and around 37 g/L salt, and most preferably around 35 g/L salt, optionally wherein the salty water comprises water from the sea or the ocean, from the food industry, from the chemical industry, from agriculture, from the textile industry, or from the leather industry.

[0066] In one embodiment, the desalination reduces the salt content in the salty water to no more than 40 g/L, preferably to no more than 30 g/L, even more preferably to no more than 20 g/L, even more preferably to no more than 10 g/L, and most preferably to no more than 5 g/L, or wherein the salt is

almost completely removed, optionally wherein the desalination reduces the amount of nutrients and/or metals in the salty water.

[0067] In one embodiment, a pretreatment of the salty water is performed, optionally wherein the pretreatment is an adjustment of the pH, and wherein the pH is adjusted to a pH of 7.0 to 9.0, preferably to a pH of 7.5 to 8.5, more preferably to a pH of 7.8 to 8.2, even more preferably to a pH of 7.9 to 8.1, and most preferably to a pH of around 8.0. The person of skill is well aware of methods for preadjusting the pH, such as by addition of an acid like HCl or CO₂ injections.

[0068] In the studies used for present disclosure, the pH of the culture is around pH 8.

[0069] In one embodiment, the method does not comprise a preliminary sterilization, filtration, and/or coagulation-flocculation of the salty water. Thus, in the method of the present disclosure, no primary and/or secondary conventional pretreatment steps are required, such as a preliminary sterilization, filtration, and/or coagulation-flocculation of the salty water. Accordingly, the method of the present disclosure is a single-step method, wherein salty water is directly desalinated in a continuous process from entry as “salty water” to exit as “desalinated water”.

[0070] In one embodiment, the desalinated water of step d. of the method is used for the irrigation of plants, such as crops, for manufacturing processes, such as in semiconductor fabrication plants, for example as cooling water and/or for the air conditioning of semiconductor fabrication plants, and/or for industrial processes, such as for the cleaning of machinery in industrial processes, optionally wherein the microalgae biomass of step d. of the method is used as a crop and/or as a fertilizer. In this embodiment, the desalinated water of step d. of the method is reused, for example in agricultural applications, such as in irrigation, or in production factories, in semiconductor fabs or in labs. The desalination of salty water according to the present disclosure maximizes the sustainable use of resources.

[0071] The sustainable use of resources of the present disclosure is further enhanced by the simultaneous production of microalgal and/or crops biomass.

[0072] In one embodiment, the microalgae biomass separated from the part of the culture of step c. of the method has a biomass density [cells/ml] of at least $2 \cdot 10^6$ cells/ml, preferably at least $3 \cdot 10^6$ cells/ml, more preferably at least $4 \cdot 10^6$ cells/ml, even more preferably at least $5 \cdot 10^6$ cells/ml, even more preferably at least $6 \cdot 10^6$ cells/ml, even more preferably at least $7 \cdot 10^6$ cells/ml, and most preferably at least $7.5 \cdot 10^6$ cells/ml. The biomass density [cells/ml] in the microalgae biomass separated from the part of the culture of step c. of the method can depend on the duration of cultivation. In one embodiment, the cultivation duration is 1 week.

[0073] In one embodiment, the microalgae biomass separated from the part of the culture of step c. of the method has an optical density (OD) between 0.1 and 0.2.

[0074] In one embodiment, in the removing a part of the culture in step c. of the method, older cells and/or accumulated nutrients are removed from the culture, optionally wherein the removal of older cells increases the light utilization in the culture, and/or enhances the nutrient and salt uptake from the salty water. Importantly, the removal of older cells increases the light utilization in the culture by reducing the likelihood of self-shading effects of older cells in the culture. The removal of older cells and/or accumulated nutrients from the culture maintains a vigorous growth of the microalgal-bacterial consortium in the culture.

[0075] In one embodiment, the method does not generate secondary waste.

[0076] In one embodiment, the method does not comprise the use of chemicals, or only comprises the use of a chemical for the adjustment of the pH or the injection of CO₂ but no additional chemical.

[0077] In one embodiment, the method further comprises one or more steps selected from:

- f. monitoring the quality of the process and/or the content of salt in the water,
- g. supplying air and/or carbon dioxide to the culture,
- h. drying the microalgae biomass separated in step d. of the method, and
- i. extracting metals from the microalgae biomass of step d. of the method.

[0078] In one embodiment, the method further comprises the growing of a crop, and wherein the microalgae-bacteria consortium and the crop are in direct contact or wherein the microalgae-bacteria consortium and the crop are separated by a mesh and/or an interlayer and/or a membrane, such as a semi-permeable membrane, optionally wherein the microalgae and/or the microalgae-bacteria consortium is embedded in the mesh and/or interlayer and/or membrane, or wherein inactivated microalgae cells are used as mesh and/or interlayer and/or membrane to enhance the binding capacity of the microalgae-bacteria consortium, and/or lower the nutrient requirement of the crop.

[0079] In one embodiment, inactivated microalgae cells are used as mesh and/or interlayer and/or membrane. The inactivated microalgae cells can also be referred to as “spent algae biomass”.

[0080] In one embodiment, the membrane is a selective membrane.

In one embodiment, microalgae and crop roots can either be in direct contact, wherein symbiotic associations can be established and maintained. This allows simultaneous water bioremediation and desalination and crop growth stimulation in a *hydroponics* design, such as a *Syneco-hydroponics* design. The term *Syneco*, as used herein, refers to an ecosystem that is self-sustained.

[0081] In an alternative embodiment, microalgae and crops root are separated by a mesh and/or interlayer.

[0082] In one embodiment, the microalgae-bacteria consortium and the crops are separated by a mesh and/or interlayer, wherein the mesh and/or the interlayer and/or membrane prevents the movement of at least one salt, such as a salt comprising at least one sodium ion, at least one chloride ion, at least one bicarbonate ion, at least one fluoride ion, at least one bromide ion, at least one potassium ion, at least one dichromate ion, at least one calcium ion, at least one bisulfate ion, at least one copper ion, at least one nitrogen ion, such as an ammonia ion, a nitrate ion, or a nitrite ion, at least one phosphate ion, such as PO₄³⁺, at least one phosphite ion, and/or at least one sulfate ion, from the salty water to the crop, and wherein the mesh allows the diffusion of at least one crop-growth promoting compound and/or desalinated water to the crop, optionally wherein the at least one crop-growth promoting compound is released by the microalgae-bacteria consortium, and/or the at least one salt is metabolized and/or degraded by the microalgae-bacteria consortium.

[0083] In one embodiment, the mesh and/or interlayer and/or membrane is an internal mesh and/or interlayer and/or membrane.

[0084] In one embodiment, the mesh and/or the interlayer and/or the membrane is a stacked repetitive configuration of sequential meshes and/or sequential interlayers and/or sequential membranes.

[0085] When coculture systems, such as cocultures of microalgae and bacteria, are difficult to operate due to different conditions required for growth of strains, product inhibition, substrate competition, and so on, a spatially segregated design with a submerged mesh and/or interlayer and/or membrane, can overcome the issues of the incompatibility of the members of the consortium, while also helping the

exchange of beneficial metabolites only. Importantly, the mesh and/or interlayer and/or membrane allows only for the mixture of clean water and growth promoting compounds to reach the upper part of the closed system, where the crop roots are located, i.e., allows a selective diffusion of clean water and beneficial compounds.

[0086] The microalgae-bacteria consortium metabolizes and/or degrades salt of the salty water, thereby preventing salt and/or an amount of the salt to reach the roots of the crop.

[0087] In one embodiment, the mesh and/or interlayer and/or membrane allows the at least one crop to grow under ideal conditions by reducing product inhibition, reducing substrate competition, and/or improving the required growth conditions of different strains.

[0088] In one embodiment, any of the steps a. to i. of the method is repeated by a certain amount, such as once, twice, three times, four times, five times, six times, seven times, and so on.

[0089] As discussed above, the present disclosure provides a device for the desalination of salty water, wherein the device is in particular for use in a method according to the present disclosure, comprising:

- (i) at least one salty water collection tank;
- (ii) optionally, at least one pH preconditioning unit;
- (iii) at least one salty water dosing unit;
- (iv) at least one algae starter tank;
- (v) at least one salty water processing tank for combining microalgae with salty water comprising bacteria, and/or for culturing the microalgae in the salty water comprising the bacteria under conditions to allow a microalgae-bacteria consortium to be established within the at least one salty water processing tank, and
- (vi) optionally, at least one separation unit for separating the content of the processing tank into desalinated water and a microalgae biomass,

wherein the salty water from the at least one salty water dosing unit is supplied to the at least one salty water processing tank in a batch modus, a fed-batch modus, a repeated fed-batch and harvesting modus, an adaptive modus, such as a fast track adaptive evolution modus, and/or in a titration modus, preferably wherein the salty water from the at least one salty water dosing unit is supplied to the at least one salty water processing tank in a repeated fed-batch and harvesting modus, a fast track adaptive evolution modus, or in a titration modus.

[0090] In one embodiment, the device does not require the presence of a separation unit if microalgae and crops are in direct contact. In other embodiments, a separation unit for separating the content of the processing tank into desalinated water and a microalgae biomass is beneficial.

[0091] In one embodiment, the device comprises

- (i) at least one salty water collection tank;
- (ii) at least one pH preconditioning unit;
- (iii) at least one salty water dosing unit;
- (iv) at least one algae starter tank;
- (v) at least one salty water processing tank for combining microalgae with salty water comprising bacteria, and/or for culturing the microalgae in the salty water comprising the bacteria under conditions to allow a microalgae-bacteria consortium to be established within the at least one salty water processing tank, and

- (vi) at least one separation unit for separating the content of the processing tank into desalinated water and a microalgae biomass.

[0092] In one embodiment, the pH is adjusted in the at least one pH preconditioning unit to a pH of 7.0 to 9.0, preferably a pH of 7.5 to 8.5, more preferably a pH of 7.8 to 8.2, even more preferably to a pH of 7.9 to 8.1, and most preferably to a pH of around 8.0.

[0093] In one embodiment, the at least one salty water dosing unit is an automatic salty water dosing, such as a timed salty water pump.

[0094] In one embodiment, the bacteria are Ammonia oxidizing bacteria, Nitrite oxidizing bacteria, Ammonia oxidizing archaea, Complete ammonia oxidizer, and/or bacteria belonging to a bacterial species selected from *Nitrosomonas spp.*, *Nitrosospira spp.*, *Nitrosococcus spp.*, *Nitrobacter spp.*, and/or *Candidatus spp.*

[0095] In one embodiment, the bacteria are halotolerant and/or halophilic.

[0096] In one embodiment, the bacteria are found in saline and/or hypersaline environments.

[0097] In one embodiment, the bacteria are acclimated to sustain even higher salinity levels than those found in their habitat.

[0098] In one embodiment, the conditions inside the device allow bacteria to establish symbiotic relationships with microalgae and/or crops.

[0099] In one embodiment, the microalgae are a microalgal culture comprising *Chlorophyceae*; *Eustigmatophyceae*, *Dunaliella salina*, *Dunaliella tertiolecta*, *Synechococcus spp.*, *Synechocystis spp.*, *Scenedesmus spp.*, and/or *Nannochloropsis spp.*, such as *Nannochloropsis oculata*, *Nannochloropsis gaditana*, and/or *Nannochloropsis oceanica*.

[00100] In one embodiment, the microalgae are halotolerant and/or halophilic.

[00101] In one embodiment, the microalgae are found in saline and/or hypersaline environments.

[00102] In one embodiment, the microalgae are acclimated to sustain even higher salinity levels than those found in their habitat.

[00103] In one embodiment, the device additionally comprises one or more of:

- (vii) a sensor for process monitoring;
- (viii) a unit for supplying air and/or carbon dioxide;
- (ix) a sensor for monitoring the water quality of the process and/or the content of salt in the water;
- (x) a drying unit, and
- (xi) an extraction unit, optionally wherein the extraction unit is for extracting metals.

[00104] In one embodiment, the desalinated water is used for the irrigation of plants, such as crops, in manufacturing processes, such as in semiconductor fabrication plants, for example as cooling water and/or for the air conditioning of semiconductor fabrication plants, and/or for industrial processes, such as for the cleaning of machinery in industrial processes, optionally wherein the microalgae biomass is used as crop and/or as fertilizer.

[00105] As discussed above, the present disclosure provides a closed system comprising a lower part and an upper part, wherein salty water and microalgae and/or a microalgae-bacteria consortium is located in the lower part of the closed system, and a root area of a crop is located in the upper part of the closed system, wherein the microalgae and/or the microalgae-bacteria consortium and the root area of the crop are in direct contact or wherein the microalgae and/or the microalgae-bacteria consortium

and the root area of the crop are separated by a mesh and/or an interlayer and/or a membrane, or wherein the microalgae and/or the microalgae-bacteria consortium is embedded in mesh and/or interlayer and/or membrane, or wherein inactivated microalgae cells are used as a membrane to enhance the binding capacity of the microalgae-bacteria consortium, and/or lower the nutrient requirement of the crop, further optionally wherein the bacteria, the microalgae, and/or the microalgae-bacteria consortium is embedded in a protective matrix, such as a biofilm, a membrane matrix, and/or an encapsulation matrix.

[00106] In one embodiment, the microalgae and/or the microalgae-bacteria consortium and the root area of the crop are separated by a mesh and/or an interlayer and/or a membrane, wherein the mesh and/or interlayer and/or membrane prevents the movement of at least one salt, such as a salt comprising at least one sodium ion, at least one chloride ion, at least one bicarbonate ion, at least one fluoride ion, at least one bromide ion, at least one potassium ion, at least one dichromate ion, at least one calcium ion, at least one bisulfate ion, at least one copper ion, at least one nitrogen ion, such as an ammonia ion, a nitrate ion, or a nitrite ion, at least one phosphate ion, such as PO_4^{3+} , at least one phosphite ion, and/or at least one sulfate ion, from the salty water from the lower part of the closed system to the root area of the crop in the upper part of the closed system, and wherein the mesh and/or interlayer allows for diffusion of a crop-growth promoting compound and/or clean water to the upper part of the closed system, optionally wherein the crop-growth promoting compound is released by the microalgae-bacteria consortium, and/or a salt is metabolized and/or degraded by the microalgae-bacteria consortium.

[00107] In one embodiment, the mesh and/or interlayer and/or membrane and/or the microalgae-bacteria consortium reduces crop toxicity, evaporation, product inhibition, and/or substrate competition, and/or increases light utilization, water utilization, nutrient utilization, and/or carbon fixation of the crop, thereby enhancing the crop growth and/or yield. Moreover, the aeration of the crop is improved.

[00108] In one embodiment, the closed system is a reactor.

[00109] In one embodiment, the closed system is a microalgae-bacteria consortium reactor.

[00110] In one embodiment, carbon dioxide (CO_2), and/or illumination is supplied naturally and/or artificially, optionally wherein the artificial illumination is an LED illumination.

[00111] In one embodiment, carbon dioxide (CO_2), and/or illumination is supplied naturally, such as by the atmosphere and/or by sunlight.

[00112] In one embodiment, the light intensity and/or LED illumination is 50 to 150 $\mu\text{mol}/\text{m}^2\text{xs}$, preferably 60 to 100 $\mu\text{mol}/\text{m}^2\text{xs}$, such as around 60 $\mu\text{mol}/\text{m}^2\text{xs}$ or around 150 $\mu\text{mol}/\text{m}^2\text{xs}$.

[00113] In one embodiment, a photoperiod is used, such as a 16:8 light to dark cycle.

[00114] In one embodiment, constant light is used, i.e., light to dark cycle is 24:0.

[00115] In one embodiment, the contact time of crop roots located in the upper part of the closed system and salty water and microalgae and/or a microalgae-bacteria consortium located in the lower part of the closed system, is between 5 and 22 days.

[00116] In one embodiment, the closed system is installed *in-situ*, such as on the sea or the ocean, or wherein the closed system is installed where secondary desalination streams are produced.

[00117] Such a “floating oasis” configuration (i.e. *in-situ* installment) offers many advantages, such as

- no preliminary sterilization and filtration of the salty water is needed
- optimized use of illumination and aeration
- simultaneous desalination of salty water and crops growth.

[00118] As discussed above, the present disclosure provides the use of a device according to the present disclosure, or a closed system according to the present disclosure, in a method according to the present disclosure, or for the desalination of salty water, for the irrigation of a plant, such as a crop, for the removal of nutrients and/or metals from salty water, for manufacturing processes, such as for supplying water for semiconductor fabrication plants, for example cooling water for manufacturing processes and/or water for the air conditioning of semiconductor fabrication plants, and/or for supplying water for industrial processes, such as for the cleaning of machinery in industrial processes.

[00119] Note that the present technology can also be configured as described below.

- (1) A method for the desalination of salty water, the method comprising the following steps:
 - a. contacting the salty water with microalgae, wherein the salty water comprises bacteria, optionally wherein the microalgae is a suspension of microalgae in an aqueous solution, a paste, a gel, or capsules, or wherein the microalgae are microalgae growing on or in a supportive medium, such as a mesh, a membrane, or a foam;
 - b. culturing the microalgae in the salty water;
 - c. removing a part of the culture from step b., and
 - d. separating the part of the culture of step c. into desalinated water and a microalgae biomass,wherein the conditions during the contacting in step a. and/or the culturing in step b. allow a microalgae-bacteria consortium to be established, and wherein the contacting of the salty water with the microalgae in step a. and/or the removing of the part of the culture in step c. is carried out in form of a batch modus, a fed batch modus, a repeated fed batch and harvesting modus, an adaptive modus, such as a fast track adaptive evolution modus, and/or in a titration modus, preferably wherein the contacting of the salty water with the microalgae in step a. and/or the removing of the part of the culture in step c. is carried out in form of a repeated fed batch and harvesting modus, a fast track adaptive evolution modus, or in a titration modus, and wherein the bacteria and/or the microalgae are halotolerant, optionally wherein the bacteria, the microalgae, and/or the microalgae-bacteria consortium are able to take up salt from the salty water, and/or are able to metabolize salts.
- (2) The method according to (1), wherein the culturing in step b. of the method is carried out in at least two separate batches, optionally wherein the contacting in step a. of the method and/or the removing of the part of the culture in step c. is carried out periodically and/or stepwise increasingly from one batch to a subsequent batch, such as from a first batch to a second batch, from the second batch to a third batch, from the third batch to a fourth batch, and so on.
- (3) The method according to (1) or (2), wherein in the contacting in step a. of the method, the salinity of the salty water is between around 20 g/L and around 50 g/L salt, preferably between around 30 g/L and around 40 g/L salt, more preferably between around 33 g/L and around 37 g/L salt, and most preferably around 35 g/L salt.
- (4) The method according to any one of (1) to (3), wherein when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the repeated fed-batch and harvesting modus, an amount of a liquid is added to the culture comprising salty water and the microalgae in the contacting of step a. of the method of a subsequent batch, such as the second batch, the third batch, or the fourth batch, that equals the amount of the part of the culture that is removed in step c. of the method of the previous batch, such as the first batch, the second batch, or the third batch, optionally wherein the liquid is salty water, further

optionally wherein the amount of the liquid that is added to the culture comprising salty water and microalgae in the contacting in step a. of the subsequent batch that equals the part of the culture that is removed in step c. of the method of the previous batch is increasing from batch to batch, such as is doubled from one batch to the subsequent batch.

(5) The method according to any one of (1) to (3), wherein when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the fast-track adaptive evolution modus, the part of the culture that is removed in step c. of the method of a previous batch, such as the first batch, the second batch, or the third batch, is added in the contacting of step a. to the salty water of the subsequent batch, such as the second batch, the third batch, or the fourth batch, wherein the salinity in the culture that is added in the contacting of step a. to the salty water of the subsequent batch, such as the second batch, the third batch, or the fourth batch, is increasing compared to the salinity in the culture of the previous batch, such as the first batch, the second batch, or the third batch.

(6) The method according to any one of (1) to (3), wherein when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the titration modus, the salty water is titrated to a culture comprising the microalgae in step a. of the method.

(7) The method according to any one of (1) to (6), wherein the bacteria are Ammonia oxidizing bacteria, Nitrite oxidizing bacteria, Ammonia oxidizing archaea, Complete ammonia oxidizer, , and/or bacteria belonging to a bacterial species selected from *Nitrosomonas spp.*, *Nitrospira spp.*, *Nitrosococcus spp.*, *Nitrobacter spp.*, and *Candidatus spp.*

(8) The method according to any one of (1) to (7), wherein the microalgae are a microalgal culture comprising *Chlorophyceae*, *Eustigmatophyceae*, *Dunaliella salina*, *Dunaliella tertiolecta*, *Synechococcus spp.*, *Synechocystis spp.*, *Scenedesmus spp.*, and/or *Nannochloropsis spp.*, such as *Nannochloropsis oculata*, *Nannochloropsis gaditana*, and/or *Nannochloropsis oceanica*.

(9) The method according to any one of (1) to (8), wherein in the contacting in step a. of the method, the microalgae are present in an algal cultivation medium, such as 3N-BBM + V medium, BBM + V medium, Spirul medium, AD medium, MAD Medium, BG11 medium, AD7 medium, Chu-10 medium, Johnson medium or f/2 medium, optionally wherein the microalgae are supplied at an optimal starting density, such as a starting density within a range of between 1 and 3 g/L.

(10) The method according to any one of (1) to (9), wherein the method further comprises the step:
e. embedding the bacteria, the microalgae, and/or the microalgae-bacteria consortium in a protective matrix, such as a biofilm, a membrane matrix, and/or an encapsulation matrix, optionally wherein the bacteria and/or the microalgae are salt metabolizing bacteria and/or salt metabolizing microalgae.

(11) The method according to any one of (1) to (10), wherein the salty water comprises between around 20 g/L and 50 g/L salt, preferably between around 30 g/L and around 40 g/L salt, more preferably between around 33 g/L and around 37 g/L salt, and most preferably around 35 g/L salt, optionally wherein the salty water comprises water from the sea or the ocean, from the food industry, from the chemical industry, from agriculture, from the textile industry, or from the leather industry, further optionally wherein the desalination reduces the salt content in the salty water to no more than 40 g/L, preferably to no more than 30 g/L, even more preferably to no more than 20 g/L, even more preferably

to no more than 10 g/L, and most preferably to no more than 5 g/L, or wherein the salt is almost completely removed, further optionally wherein the desalination reduces the amount of nutrients and/or metals in the salty water.

(12) The method according to any one of (1) to (11), wherein the desalinated water of step d. of the method is used for the irrigation of plants, such as crops, for manufacturing processes, such as in semiconductor fabrication plants, for example as cooling water and/or for the air conditioning of semiconductor fabrication plants, and/or for industrial processes, such as for the cleaning of machinery in industrial processes, optionally wherein the microalgae biomass of step d. of the method is used as crop and/or as fertilizer.

(13) The method according to any one of (1) to (12), wherein in the removing a part of the culture in step c. of the method, older cells and/or accumulated nutrients are removed from the culture, optionally wherein the removal of older cells increases the light utilization in the culture, and/or enhances the nutrient and/or salt uptake from the salty water.

(14) The method according to any one of (1) to (13), wherein the method does not generate secondary waste, and/or wherein the method does not comprise the use of chemicals.

(15) The method according to any one of (1) to (14), wherein the method further comprises one or more steps selected from:

- f. monitoring the quality and/or the salt content of the process,
- g. supplying air and/or carbon dioxide to the culture,
- h. drying the microalgae biomass separated in step d. of the method, and
- i. extracting metals from the microalgae biomass of step d. of the method.

(16) The method according to any one of (1) to (15), wherein the method further comprises the growing of a crop, and wherein the microalgae-bacteria consortium and the crop are in direct contact or wherein the microalgae-bacteria consortium and the crop are separated by a mesh and/or an interlayer and/or a membrane, optionally wherein the microalgae and/or the microalgae-bacteria consortium is embedded in a membrane, or wherein inactivated microalgae cells are used as membrane to enhance the binding capacity of the microalgae-bacteria consortium, and/or lower the nutrient requirement of the crop.

(17) The method according to (16), wherein the microalgae-bacteria consortium and the crop are separated by a mesh and/or an interlayer and/or a membrane, wherein the mesh prevents the movement of at least one salt, such as a salt comprising at least one sodium ion, at least one chloride ion, at least one bicarbonate ion, at least one fluoride ion, at least one bromide ion, at least one potassium ion, at least one dichromate ion, at least one calcium ion, at least one bisulfate ion, at least one copper ion, at least one nitrogen ion, such as an ammonia ion, a nitrate ion, or a nitrite ion, at least one phosphate ion, such as PO_4^{3-} , at least one phosphite ion, and/or at least one sulfate ion, from the salty water to the crop, and wherein the mesh allows the diffusion of at least one crop-growth promoting compound and/or desalinated water to the crop, optionally wherein the at least one crop-growth promoting compound is released by the microalgae-bacteria consortium, and/or the at least one salt is metabolized and/or degraded by the microalgae-bacteria consortium.

(18) A device for the desalination of salty water, wherein the device is in particular for use in a method according to any one of (1) to (17), comprising:

- (i) at least one salty water collection tank;

- (ii) optionally, at least one pH preconditioning unit;
- (iii) at least one salty water dosing unit;
- (iv) at least one algae starter tank;
- (v) at least one salty water processing tank for combining microalgae with salty water comprising bacteria, and/or for culturing the microalgae in the salty water comprising the bacteria under conditions to allow a microalgae-bacteria consortium to be established within the at least one salty water processing tank, and
- (vi) optionally, at least one separation unit for separating the content of the processing tank into desalinated water and a microalgae biomass,

wherein the salty water from the at least one salty water dosing unit is supplied to the at least one salty water processing tank in a batch modus, a fed batch modus, a repeated fed batch and harvesting modus, an adaptive modus, such as a fast-track adaptive evolution modus, and/or in a titration modus, preferably wherein the salty water from the at least one salty water dosing unit is supplied to the at least one salty water processing tank in a repeated fed batch and harvesting modus, a fast-track adaptive evolution modus, or in a titration modus.

(19) The device according to (18), wherein the device additionally comprises one or more of:

- (vii) a sensor for process monitoring,
- (viii) a unit for supplying air and/or carbon dioxide,
- (ix) a sensor for monitoring the water quality and/or the salt content of the water,
- (x) a drying unit, and
- (xi) an extraction unit, optionally wherein the extraction unit is for extracting metals.

(20) The device according to (18) or (19), wherein the bacteria are Ammonia oxidizing bacteria, Nitrite oxidizing bacteria, Ammonia oxidizing archaea, Complete ammonia oxidizer, and/or bacteria belonging to a bacterial species selected from *Nitrosomonas spp.*, *Nitrosospira spp.*, *Nitrosococcus spp.*, *Nitrobacter spp.*, and/or *Candidatus spp.*

(21) The device according to any one of (18) to (20), wherein the microalgae are a microalgal culture comprising *Chlorophyceae*, *Eustigmatophyceae*, *Dunaliella salina*, *Dunaliella tertiolecta*, *Synechococcus spp.*, *Synechocystis spp.*, *Scenedesmus spp.*, and/or *Nannochloropsis spp.*, such as *Nannochloropsis oculata*, *Nannochloropsis gaditana*, and/or *Nannochloropsis oceanica*.

(22) The device according to any one of (18) to (21), wherein the desalinated water is used for the irrigation of plants, such as crops, in manufacturing processes, such as in semiconductor fabrication plants, for example as cooling water and/or for the air conditioning of semiconductor fabrication plants, and/or for industrial processes, such as for the cleaning of machinery in industrial processes, optionally wherein the microalgae biomass is used as crop and/or as fertilizer.

(23) A closed system comprising a lower part and an upper part, wherein salty water and microalgae and/or a microalgae-bacteria consortium is located in the lower part of the closed system, and a root area of a crop is located in the upper part of the closed system, wherein the microalgae and/or the microalgae-bacteria consortium and the root area of the crop are in direct contact or wherein the microalgae and/or the microalgae-bacteria consortium and the root area of the crop are separated by a mesh and/or an interlayer and/or a membrane optionally wherein the microalgae and/or the microalgae-bacteria consortium is embedded in the mesh and/or interlayer and/or membrane, or wherein inactivated microalgae cells are used as a membrane to enhance the binding capacity of the microalgae-bacteria

consortium, and/or lower the nutrient requirement of the crop, further optionally wherein the bacteria, the microalgae, and/or the microalgae-bacteria consortium is embedded in a protective matrix, such as a biofilm, a membrane matrix, and/or an encapsulation matrix.

(24) The closed system according to (23), wherein the microalgae and/or the microalgae-bacteria consortium and the root area of the crop are separated by the mesh and/or interlayer and/or membrane, wherein the mesh and/or interlayer and/or membrane prevents the movement of at least one salt, such as a salt comprising at least one sodium ion and/or at least one chloride ion, at least one bicarbonate ion, at least one fluoride ion, at least one bromide ion, at least one potassium ion, at least one dichromate ion, at least one calcium ion, at least one bisulfate ion, at least one copper ion, at least one nitrogen ion, such as an ammonia ion, a nitrate ion, or a nitrite ion, at least one phosphate ion, such as PO_4^{3+} , at least one phosphite ion, and/or at least one sulfate ion, from the salty water from the lower part of the closed system to the root area of the crop in the upper part of the closed system, and wherein the mesh and/or interlayer and/or membrane allows for diffusion of a crop-growth promoting compound and/or clean water to the upper part of the closed system, optionally wherein the crop-growth promoting compound is released by the microalgae-bacteria consortium, and/or a salt is metabolized and/or degraded by the microalgae-bacteria consortium.

(25) The closed system according to (23) or (24), wherein the mesh and/or interlayer and/or membrane and/or the microalgae-bacteria consortium reduces crop toxicity, evaporation, product inhibition, and/or substrate competition, and/or increases the light utilization, water utilization, nutrient utilization, and/or carbon fixation of the crop, thereby enhancing the crop growth and/or yield.

(26) The closed system according to any one of (23) to (25), wherein the closed system is a reactor, optionally wherein the reactor is a microalgae-bacteria consortium reactor.

(27) The closed system according to any one of (23) to (26), wherein air, carbon dioxide (CO_2), and/or illumination is supplied naturally and/or artificially, optionally wherein the artificial illumination is an LED illumination.

(28) The closed system according to any one of (23) to (27), wherein the closed system is installed *in-situ*, such as on the sea or the ocean, or wherein the closed system is installed where secondary desalination streams are produced.

(29) Use of a device according to any one of (18) to (22), or a closed system according to any one of (23) to (28), in a method according to any one of (1) to (17), or for the desalination of salty water, for the irrigation of a plant, such as a crop, for the removal of nutrients and/or metals from salty water, for manufacturing processes, such as for supplying water for semiconductor fabrication plants, for example cooling water for manufacturing processes and/or water for the air conditioning of semiconductor fabrication plants, and/or for supplying water for industrial processes, such as for the cleaning of machinery in industrial processes.

[00120] The term “salty water”, as used herein, is meant to refer to any water that contains a certain amount of salt and that cannot be reused for certain applications containing this amount of salt, i.e., the salty water needs to be desalinated prior allowing the reuse of the water in certain applications, such as agricultural applications. The term “salty water” can be used for water comprising water from the sea or the ocean, from the food industry, from the chemical industry, from agriculture, from the textile industry, or from the leather industry. The term “salty water”, as used in some embodiments herein, shall refer to water comprising between around 20 g/L and 50 g/L salt, preferably between around 30

g/L and around 40 g/L salt, more preferably between around 33 g/L and around 37 g/L salt, and most preferably around 35 g/L salty.

[00121] The term “salty” and “saline” are sometimes used interchangeably. For example, the terms “salty water” and “saline water” can be used interchangeably herein.

[00122] According to the present disclosure, the term „desalinated water“ refers to water separated from the part of the culture of step c. of the method of the present disclosure. In accordance with the present disclosure, the term „desalinated water“ shall refer to water that can be reused in agricultural applications, such as in irrigation, or in production factories. In one example, the „desalinated water“ is water that can be reused in agricultural applications, such as in irrigation, or in production factories, compatible with EU standards.

[00123] The term “a”, as used herein, is meant to refer to “at least one”. For example, the term “a lower part” and “an upper part” shall refer to “at least one lower part” and “at least one upper part”.

[00124] The term “bacteria”, as used herein, is meant to refer to at least one bacterium. The term “bacteria” shall include bacterial monocultures and mixed cultures.

[00125] The term “microalgae”, as used herein, is meant to refer to at least one microalga. The term “microalgae” shall include algal monocultures and mixed cultures, and shall include various media in which the microalgae can be contained, such as in an aqueous solution, or a paste, or a gel, or capsules, or microalgae growing on or in a supportive medium, such as a mesh, membrane, or foam.

[00126] The term “separating”, as used herein, shall refer to taking a culture or a part of the culture into desalinated water and a microalgae biomass, i.e. dividing a culture or a part of the culture into desalinated water and a microalgae biomass.

[00127] The term “periodically”, as used herein, is meant to refer to performing something at regular intervals and/or occasionally, such as after 6 hours, after 1 day, after 3 days, after 10 days, and so on.

[00128] The term “crop”, as used herein, is meant to refer to any plant. The terms “crop” and “plant” are sometimes used interchangeably in the present disclosure. The term “crop”, as used herein, includes feed, such as food or supplements for human consumption or feed for animal consumption, and also ornamental plants.

[00129] The term “device”, as used herein, shall also refer to an apparatus or a desalination facility. The term “device”, “apparatus”, and “desalination facility” are sometimes used interchangeably in the context of the present disclosure.

[00130] The term “removing”, as used herein, shall refer to taking a part of a culture, such as an effluent, or harvesting a part of a culture. Specifically, the term “removing” as used for step c. of the method, refers to taking a part of the culture, which can then be harvested or used for inoculation of a different culture, such as for inoculation of a subsequent batch of culture.

[00131] The term “biological desalination” of salty water, as used herein, shall refer to the bioremediation of salty water. The terms “biological desalination” and “bioremediation” of salty water, as used herein, are sometimes used interchangeably.

[00132] The term “inactivated microalgae cells”, as used herein, can also be referred to as “spent algae biomass”. The “inactivated microalgae cells”, or “spent algae biomass”, can be used as mesh and/or interlayer and/or membrane in some embodiments of the present disclosure.

[00133] The term “floating oasis” as used herein, shall refer to an *in-situ* installment of a device and/or a system as used herein. According to the present disclosure, the term “floating oasis” or “*in-situ*

installment” can also be referred to as hydroponics “floating growers”, “floating farms”, or “floating gardens”.

[00134] The main advantages of the methods and devices for the desalination of salty water of the present disclosure are as follows:

- efficient and timely desalination methods of salty water compatible with EU standards for reuse in agricultural applications, such as in irrigation, or in production factories
- optimization of cultivation conditions of microalgae and bacteria to maximize desalination of salty water while also promoting algal biomass and crops growth
- environmentally friendly, effective and sustainable solution for the biological desalination of salty water, especially in coastal communities, who have limited access to quality water resources
- enabling competitiveness in remote areas impacted by water shortages
- maximizing sustainable use of resources by simultaneously desalinating water and enhancing the production of microalgal and/or crops biomass
- skipping primary and secondary conventional desalinations of salty water, such as preceding sterilization, filtration, and/or coagulation-flocculation steps
- overcoming the problem of time-consuming screening procedures and artificially assembling and pairing microalgae and bacteria to enable the stable association of microalgae-bacteria consortia
- no need to separately grow and/or preculture (precultivate) bacteria prior to culturing them with microalgae, thus allowing a directed adaptive evolutionary approach
- enable microalgae and bacteria to withstand new environmental conditions of added salty water
- enable microalgae and bacteria to develop enhanced specific traits, including higher resistance to multiple stresses, such as hypersalinity
- overcoming problems caused by the presence of salt in water that can greatly influence algal biomass productivity and therefore the efficiency of salty water desalination to acceptable standards for its safe re-use
- enable different growth environmental conditions for different members in a microalgae-bacteria consortium, thereby overcoming instability and low efficiency of many coculture systems, as well as strain incompatibility issues
- no need to generate secondary waste when water is desalinated.

[00135] The methods, devices, systems, as well as their uses disclosed herein fulfill the requirements responsible for the above advantages.

EXAMPLES

EXAMPLE 1:

[00136] In the schematic representation shown in Figure 1, the general method for desalination of salty water according to the present disclosure is depicted. In Figures 1 to 4, the abbreviation “SW” refers to salty water. Of note, the Salty water Dosing Unit and Process Tanks could be organized in different ways to enable a batch modus, a fed-batch modus, a repeated fed-batch and harvesting modus (Figure 2), an adaptive modus, such as a fast-track adaptive evolution modus (Figure 3), and/or a titration modus (Figure 4).

EXAMPLE 2:

[00137] In the schematic representation shown in Figure 2, the Repeated Fed-Batch and Harvesting Modus is shown. A fed-batch modus ensures that the effluent is properly treated and reaches the limits for recycling/reuse. Periodic harvesting can increase the salty water desalination performance because accumulated nutrients from the system are removed, and also vigorous growth of the microalgal-bacterial consortium in the system is maintained (as older cells are removed). This leaves healthy, productive microalgal-bacterial cultures, where self-shading effects are avoided and therefore light utilization is optimized. Overall, a fed-batch process with period-stepwise increasing harvesting increases the efficiency of the nutrient and salt uptake from the salty water.

EXAMPLE 3:

[00138] In the schematic representation shown in Figure 3, the fast-track adaptive evolution modus is shown. A good microbial consortium design must match ecological and evolutionary principles, which can be achieved by a fast-track adaptive evolution modus, i.e. a gradient increase of salty water combined with an adaptive evolution approach with optimization of initial inoculation ratios. This implies the application of selective pressure as driving force for the selection of microorganisms with enhanced phenotypes, thus allowing the development of new biological functions and performance. The obtained consortium produces higher microalgal biomass and also results in better desalination of salty water compared to the original consortium.

EXAMPLE 4:

[00139] In the schematic representation shown in Figure 4, the titration modus is shown. Of note, the pH regulation unit for salty water is an optional feature. As shown in Figure 4, in this configuration, the microbial consortium is established based on both spatial and temporal “segregation”. The salty water – whose only pretreatment relies on eventual pH adjustment – is supplied in a titration-like modus, in order to give sufficient time for the microalgal-bacterial consortium to adapt and react. At the same time, also the algae cells are optimally provided, so that the initial density inside the Microalgal-Bacteria Consortium-Reactor is high enough to withstand the new environmental conditions of the added salty water. Thus, the titration-like addition of salty water and the provision of algae cells at an ideal density enables a fast consortium response against salty water inactivation.

EXAMPLE 5:

[00140] In the schematic representation shown in Figure 5, hydroponic cultures and integrated hydroponic systems according to the present disclosure are shown, which allow simultaneous carbon fixation, salty water desalination and crops growth bio-stimulation. When coculture systems are difficult to operate due to different growth features of strains, product inhibition, substrate competition, and so on, a spatially segregated design (Figure 5 B, left side) with semi-permeable submerged membrane and/or mesh and/or interlayer can overcome the issues of the incompatibility of members of the consortium, while also helping the exchange of beneficial metabolites only. Figure 5 C shows another hydroponic tank setup according to the present disclosure with an interlayer to let only water and beneficial metabolite flow through. In this setup, a tank for the microalgae-bacteria consortium is acclimated/adapted to the lowest salinity, while another tank for the microalgae-bacteria consortium is acclimated/adapted to a medium salinity, and yet another tank for the microalgae-bacteria consortium is acclimated/adapted to the highest salinity.

[00141] Thus, the foregoing discussion discloses and describes merely exemplary embodiments of the present disclosure. As will be understood by those skilled in the art, the present disclosure may be

embodied in other specific forms without departing from the spirit or essential characteristics thereof. Accordingly, the disclosure of the present disclosure is intended to be illustrative, but not limiting of the scope of the disclosure, as well as other claims. The disclosure, including any readily discernible variants of the teachings herein, define, in part, the scope of the foregoing claim terminology such that no inventive subject matter is dedicated to the public.

Claims

1. A method for the desalination of salty water, the method comprising the following steps:
 - a. contacting the salty water with microalgae, wherein the salty water comprises bacteria, optionally wherein the microalgae is a suspension of microalgae in an aqueous solution, a paste, a gel, or capsules, or wherein the microalgae are microalgae growing on or in a supportive medium, such as a mesh, a membrane, or a foam;
 - b. culturing the microalgae in the salty water,
 - c. removing a part of the culture from step b., and
 - d. separating the part of the culture of step c. into desalinated water and a microalgae biomass,wherein the conditions during the contacting in step a. and/or the culturing in step b. allow a microalgae-bacteria consortium to be established, and wherein the contacting of the salty water with the microalgae in step a. and/or the removing of the part of the culture in step c. is carried out in form of a batch modus, a fed batch modus, a repeated fed batch and harvesting modus, an adaptive modus, such as a fast track adaptive evolution modus, and/or in a titration modus, preferably wherein the contacting of the salty water with the microalgae in step a. and/or the removing of the part of the culture in step c. is carried out in form of a repeated fed batch and harvesting modus, a fast track adaptive evolution modus, or in a titration modus, and wherein the bacteria and/or the microalgae are halotolerant, optionally wherein the bacteria, the microalgae, and/or the microalgae-bacteria consortium are able to take up salt from the salty water, and/or are able to metabolize salts.
2. The method according to claim 1, wherein the culturing in step b. of the method is carried out in at least two separate batches, optionally wherein the contacting in step a. of the method and/or the removing of the part of the culture in step c. is carried out periodically and/or stepwise increasingly from one batch to a subsequent batch, such as from a first batch to a second batch, from the second batch to a third batch, from the third batch to a fourth batch, and so on.
3. The method according to claim 1 or 2, wherein in the contacting in step a. of the method, the salinity of the salty water is between around 20 g/L and around 50 g/L salt, preferably between around 30 g/L and around 40 g/L salt, more preferably between around 33 g/L and around 37 g/L salt, and most preferably around 35 g/L salt.
4. The method according to any one of claims 1 to 3, wherein when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the repeated fed batch and harvesting modus, an amount of a liquid is added to the culture comprising salty water and the microalgae in the

contacting of step a. of the method of a subsequent batch, such as the second batch, the third batch, or the fourth batch, that equals the amount of the part of the culture that is removed in step c. of the method of the previous batch, such as the first batch, the second batch, or the third batch, optionally wherein the liquid is salty water, further optionally wherein the amount of the liquid that is added to the culture comprising salty water and microalgae in the contacting in step a. of the subsequent batch that equals the part of the culture that is removed in step c. of the method of the previous batch is increasing from batch to batch, such as is doubled from one batch to the subsequent batch.

5. The method according to any one of claims 1 to 3, wherein when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the fast track adaptive evolution modus, the part of the culture that is removed in step c. of the method of a previous batch, such as the first batch, the second batch, or the third batch, is added in the contacting of step a. to the salty water of the subsequent batch, such as the second batch, the third batch, or the fourth batch, wherein the salinity in the culture that is added in the contacting of step a. to the salty water of the subsequent batch, such as the second batch, the third batch, or the fourth batch, is increasing compared to the salinity in the culture of the previous batch, such as the first batch, the second batch, or the third batch.
6. The method according to any one of claims 1 to 3, wherein when the contacting of the salty water with the microalgae in step a. of the method and/or the removing of the part of the culture in step c. of the method is carried out in form of the titration modus, the salty water is titrated to a culture comprising the microalgae in step a. of the method.
7. The method according to any one of claims 1 to 6, wherein the bacteria are Ammonia oxidizing bacteria, Nitrite oxidizing bacteria, Ammonia oxidizing archaea, Complete ammonia oxidizer, and/or bacteria belonging to a bacterial species selected from *Nitrosomonas spp.*, *Nitrosospira spp.*, *Nitrosococcus spp.*, *Nitrobacter spp.*, and *Candidatus spp.*
8. The method according to any one of claims 1 to 7, wherein the microalgae are a microalgal culture comprising *Chlorophyceae*, *Eustigmatophyceae*, *Dunaliella salina*, *Dunaliella tertiolecta*, *Synechococcus spp.*, *Synechocystis spp.*, *Scenedesmus spp.*, and/or *Nannochloropsis spp.*, such as *Nannochloropsis oculata*, *Nannochloropsis gaditana*, and/or *Nannochloropsis oceanica*.
9. The method according to any one of claims 1 to 8, wherein in the contacting in step a. of the method, the microalgae are present in an algal cultivation medium, such as 3N-BBM + V medium, BBM + V medium, Spirul medium, AD medium, MAD Medium, BG11 medium, AD7

medium, Chu-10 medium, Johnson medium, or f/2 medium, optionally wherein the microalgae are supplied at an optimal starting density, such as a starting density within a range of between 1 and 3 g/L.

10. The method according to any one of claims 1 to 9, wherein the method further comprises the step:
 - e. embedding the bacteria, the microalgae, and/or the microalgae-bacteria consortium in a protective matrix, such as a biofilm, a membrane matrix, and/or an encapsulation matrix, optionally wherein the bacteria and/or the microalgae are salt metabolizing bacteria and/or salt metabolizing microalgae.
11. The method according to any one of claims 1 to 10, wherein the salty water comprises between around 20 g/L and 50 g/L salt, preferably between around 30 g/L and around 40 g/L salt, more preferably between around 33 g/L and around 37 g/L salt, and most preferably around 35 g/L salt, optionally wherein the salty water comprises water from the sea or the ocean, from the food industry, from the chemical industry, from agriculture, from the textile industry, or from the leather industry, further optionally wherein the desalination reduces the salt content in the salty water to no more than 40 g/L, preferably to no more than 30 g/L, even more preferably to no more than 20 g/L, even more preferably to no more than 10 g/L, and most preferably to no more than 5 g/L, or wherein the salt is almost completely removed, further optionally wherein the desalination reduces the amount of nutrients and/or metals in the salty water.
12. The method according to any one of claims 1 to 11, wherein the desalinated water of step d. of the method is used for the irrigation of plants, such as crops, for manufacturing processes, such as in semiconductor fabrication plants, for example as cooling water and/or for the air conditioning of semiconductor fabrication plants, and/or for industrial processes, such as for the cleaning of machinery in industrial processes, optionally wherein the microalgae biomass of step d. of the method is used as crop and/or as fertilizer.
13. The method according to any one of claims 1 to 12, wherein in the removing a part of the culture in step c. of the method, older cells and/or accumulated nutrients are removed from the culture, optionally wherein the removal of older cells increases the light utilization in the culture, and/or enhances the nutrient and/or salt uptake from the salty water.
14. The method according to any one of claims 1 to 13, wherein the method does not generate secondary waste, and/or wherein the method does not comprise the use of chemicals.
15. The method according to any one of claims 1 to 14, wherein the method further comprises one or more steps selected from:

- f. monitoring the quality and/or the salt content of the process,
 - g. supplying air and/or carbon dioxide to the culture,
 - h. drying the microalgae biomass separated in step d. of the method, and
 - i. extracting metals from the microalgae biomass of step d. of the method.
16. The method according to any one of claims 1 to 15, wherein the method further comprises the growing of a crop, and wherein the microalgae-bacteria consortium and the crop are in direct contact or wherein the microalgae-bacteria consortium and the crop are separated by a mesh and/or an interlayer and/or a membrane, optionally wherein the microalgae and/or the microalgae-bacteria consortium is embedded in the mesh and/or interlayer and/or membrane, or wherein inactivated microalgae cells are used as membrane to enhance the binding capacity of the microalgae-bacteria consortium, and/or lower the nutrient requirement of the crop.
17. The method according to claim 16, wherein the microalgae-bacteria consortium and the crop are separated by a mesh and/or an interlayer and/or a membrane, wherein the mesh and/or interlayer and/or membrane prevents the movement of at least one salt, such as a salt comprising at least one sodium ion, at least one chloride ion, at least one bicarbonate ion, at least one fluoride ion, at least one bromide ion, at least one potassium ion, at least one dichromate ion, at least one calcium ion, at least one bisulfate ion, at least one copper ion, at least one nitrogen ion, such as an ammonia ion, a nitrate ion, or a nitrite ion, at least one phosphate ion, such as PO_4^{3-} , at least one phosphite ion, and/or at least one sulfate ion, from the salty water to the crop, and wherein the mesh and/or interlayer and/or membrane allows the diffusion of at least one crop-growth promoting compound and/or desalinated water to the crop, optionally wherein the at least one crop-growth promoting compound is released by the microalgae-bacteria consortium, and/or the at least one salt is metabolized and/or degraded by the microalgae-bacteria consortium.
18. A device for the desalination of salty water, wherein the device is in particular for use in a method according to any one of claims 1 to 17, comprising:
- (i) at least one salty water collection tank;
 - (ii) optionally, at least one pH preconditioning unit;
 - (iii) at least one salty water dosing unit;
 - (iv) at least one algae starter tank;
 - (v) at least one salty water processing tank for combining microalgae with salty water comprising bacteria, and/or for culturing the microalgae in the salty water comprising the bacteria under conditions to allow a microalgae-bacteria consortium to be established within the at least one salty water processing tank, and

- (vi) optionally, at least one separation unit for separating the content of the processing tank into desalinated water and a microalgae biomass,

wherein the salty water from the at least one salty water dosing unit is supplied to the at least one salty water processing tank in a batch modus, a fed batch modus, a repeated fed batch and harvesting modus, an adaptive modus, such as a fast track adaptive evolution modus, and/or in a titration modus, preferably wherein the salty water from the at least one salty water dosing unit is supplied to the at least one salty water processing tank in a repeated fed batch and harvesting modus, a fast track adaptive evolution modus, or in a titration modus.

19. The device according to claim 18, wherein the device additionally comprises one or more of:

- (vii) a sensor for process monitoring,
- (viii) a unit for supplying air and/or carbon dioxide,
- (ix) a sensor for monitoring the water quality and/or the salt content of the water,
- (x) a drying unit, and
- (xi) an extraction unit, optionally wherein the extraction unit is for extracting metals.

20. The device according to claim 18 or 19, wherein the bacteria are Ammonia oxidizing bacteria, Nitrite oxidizing bacteria, Ammonia oxidizing archaea, Complete ammonia oxidizer, and/or bacteria belonging to a bacterial species selected from *Nitrosomonas spp.*, *Nitrospira spp.*, *Nitrosococcus spp.*, *Nitrobacter spp.*, and/or *Candidatus spp.*

21. The device according to any one of claims 18 to 20, wherein the microalgae are a microalgal culture comprising *Chlorophyceae*, *Eustigmatophyceae*, *Dunaliella salina*, *Dunaliella tertiolecta*, *Synechococcus spp.*, *Synechocystis spp.*, *Scenedesmus spp.*, and/or *Nannochloropsis spp.*, such as *Nannochloropsis oculata*, *Nannochloropsis gaditana*, and/or *Nannochloropsis oceanica*.

22. The device according to any one of claims 18 to 21, wherein the desalinated water is used for the irrigation of plants, such as crops, in manufacturing processes, such as in semiconductor fabrication plants, for example as cooling water and/or for the air conditioning of semiconductor fabrication plants, and/or for industrial processes, such as for the cleaning of machinery in industrial processes, optionally wherein the microalgae biomass is used as crop and/or as fertilizer.

23. A closed system comprising a lower part and an upper part, wherein salty water and microalgae and/or a microalgae-bacteria consortium is located in the lower part of the closed system, and a root area of a crop is located in the upper part of the closed system, wherein the microalgae and/or the microalgae-bacteria consortium and the root area of the crop are in direct contact or wherein the microalgae and/or the microalgae-bacteria consortium and the root area of the crop

are separated by a mesh and/or an interlayer and/or a membrane, optionally wherein the microalgae and/or the microalgae-bacteria consortium is embedded in the mesh and/or interlayer and/or membrane, or wherein inactivated microalgae cells are used as a membrane to enhance the binding capacity of the microalgae-bacteria consortium, and/or lower the nutrient requirement of the crop, further optionally wherein the bacteria, the microalgae, and/or the microalgae-bacteria consortium is embedded in a protective matrix, such as a biofilm, a membrane matrix, and/or an encapsulation matrix.

24. The closed system according to claim 23, wherein the microalgae and/or the microalgae-bacteria consortium and the root area of the crop are separated by a mesh and/or interlayer and/or membrane, wherein the membrane prevents the movement of at least one salt, such as a salt comprising at least one sodium ion and/or at least one chloride ion, at least one bicarbonate ion, at least one fluoride ion, at least one bromide ion, at least one potassium ion, at least one dichromate ion, at least one calcium ion, at least one bisulfate ion, at least one copper ion, at least one nitrogen ion, such as an ammonia ion, a nitrate ion, or a nitrite ion, at least one phosphate ion, such as PO_4^{3-} , at least one phosphite ion, and/or at least one sulfate ion, from the salty water from the lower part of the closed system to the root area of the crop in the upper part of the closed system, and wherein the membrane allows for diffusion of a crop-growth promoting compound and/or clean water to the upper part of the closed system, optionally wherein the crop-growth promoting compound is released by the microalgae-bacteria consortium, and/or a salt is metabolized and/or degraded by the microalgae-bacteria consortium.
25. The closed system according to claim 23 or 24, wherein the mesh and/or interlayer and/or membrane and/or the microalgae-bacteria consortium reduces crop toxicity, evaporation, product inhibition, and/or substrate competition, and/or increases the light utilization, water utilization, nutrient utilization, and/or carbon fixation of the crop, thereby enhancing the crop growth and/or yield.
26. The closed system according to any one of claims 23 to 25, wherein the closed system is a reactor, optionally wherein the reactor is a microalgae-bacteria consortium reactor.
27. The closed system according to any one of claims 23 to 26, wherein air, carbon dioxide, and/or illumination is supplied naturally and/or artificially, optionally wherein the artificial illumination is an LED illumination.
28. The closed system according to any one of claims 23 to 27, wherein the closed system is installed *in-situ*, such as on the sea or the ocean, or wherein the closed system is installed where secondary desalination streams are produced.

29. Use of a device according to any one of claims 18 to 22, or a closed system according to any one of claims 23 to 28, in a method according to any one of claims 1 to 17, or for the desalination of salty water, for the irrigation of a plant, such as a crop, for the removal of nutrients and/or metals from salty water, for manufacturing processes, such as for supplying water for semiconductor fabrication plants, for example cooling water for manufacturing processes and/or water for the air conditioning of semiconductor fabrication plants, and/or for supplying water for industrial processes, such as for the cleaning of machinery in industrial processes.

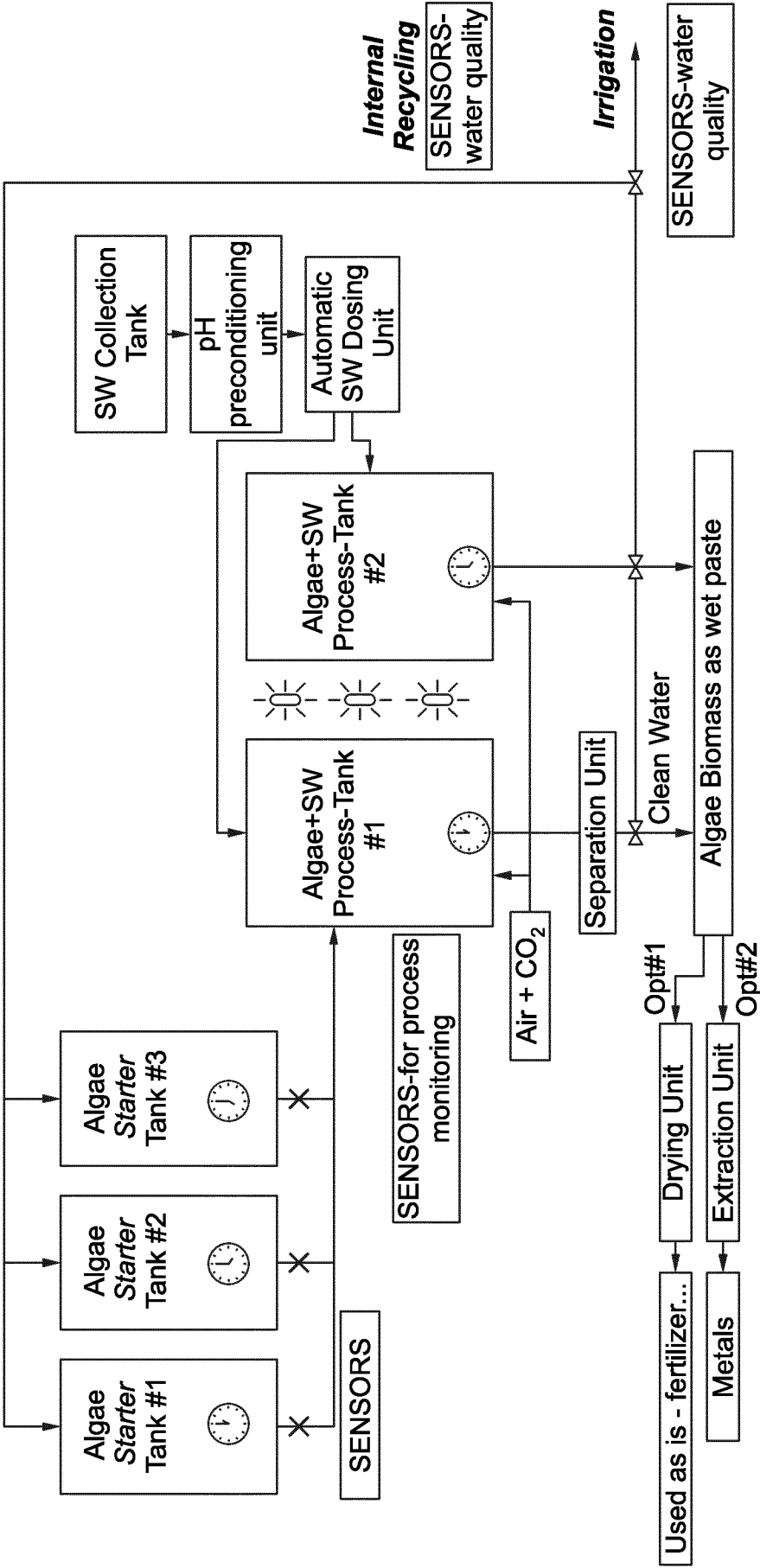


FIG. 1

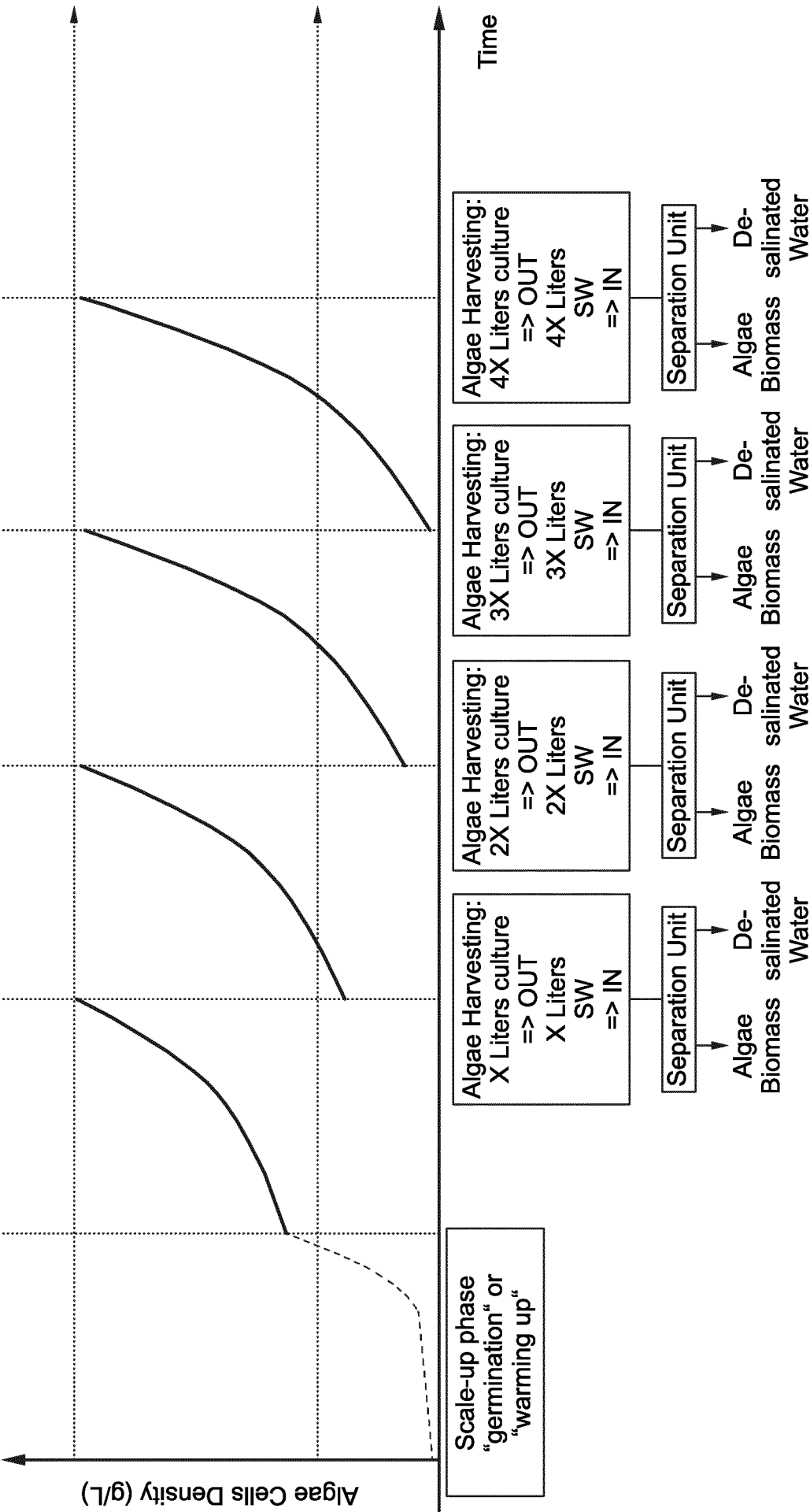


FIG. 2

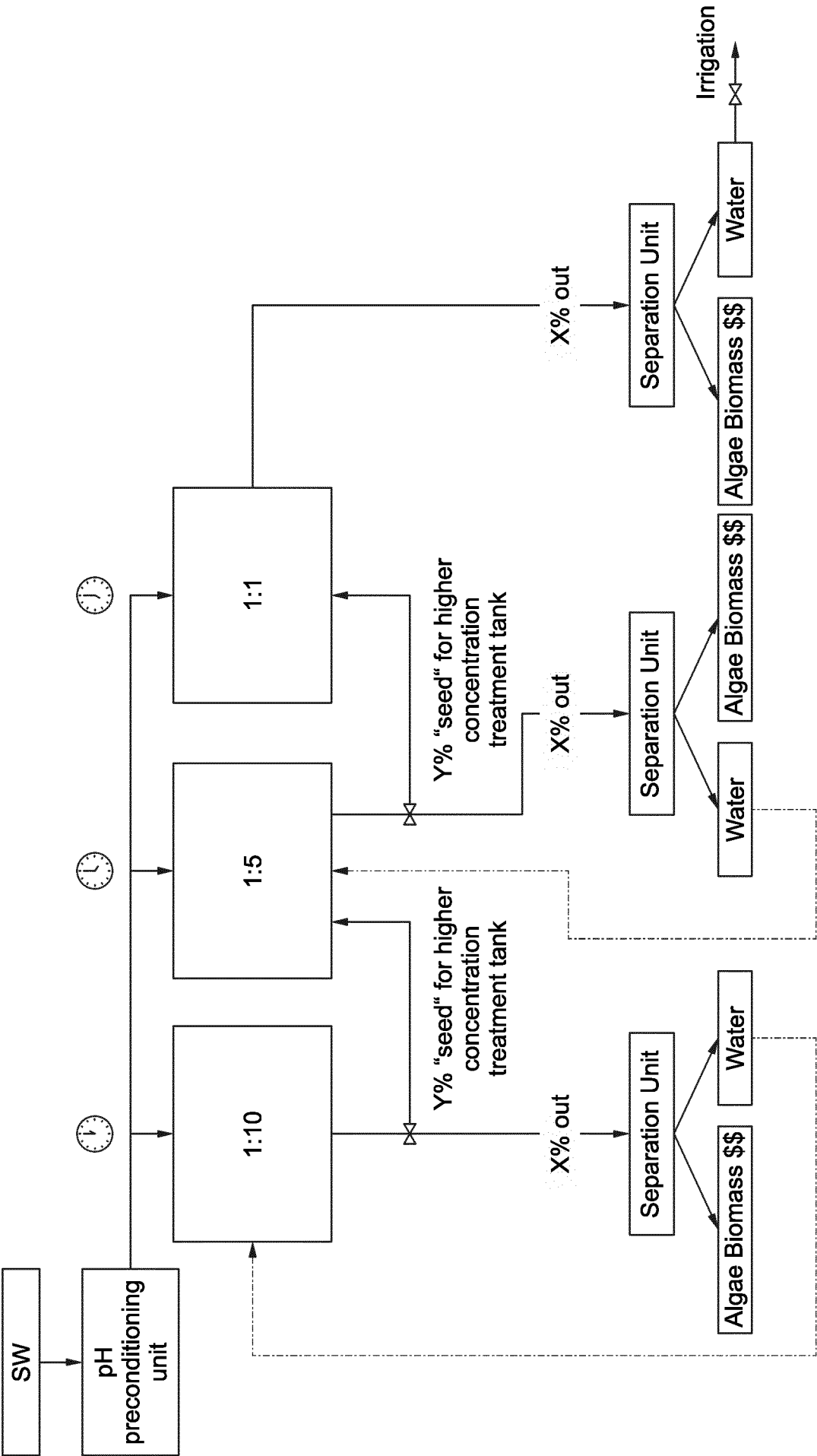


FIG. 3

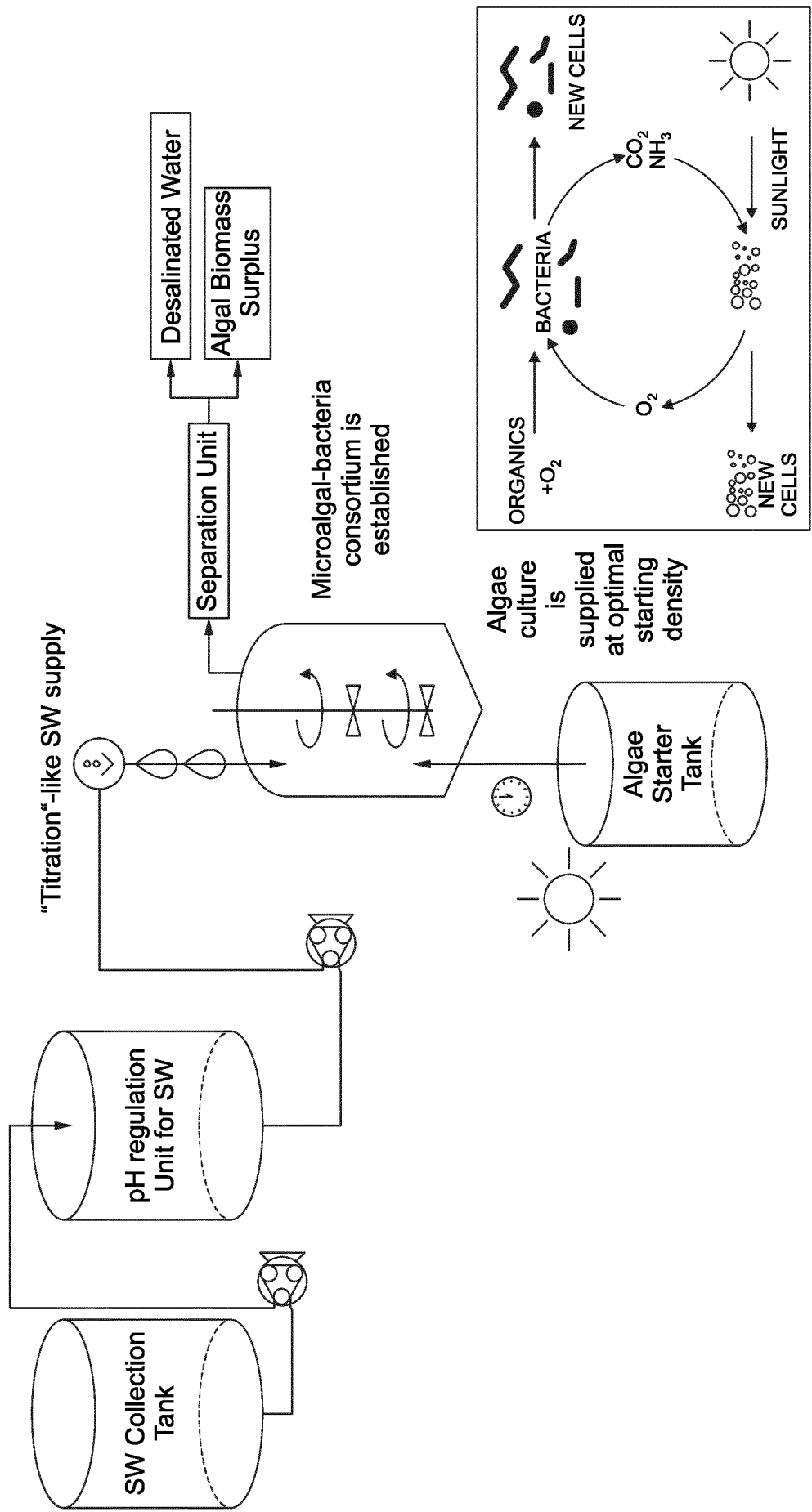


FIG. 4

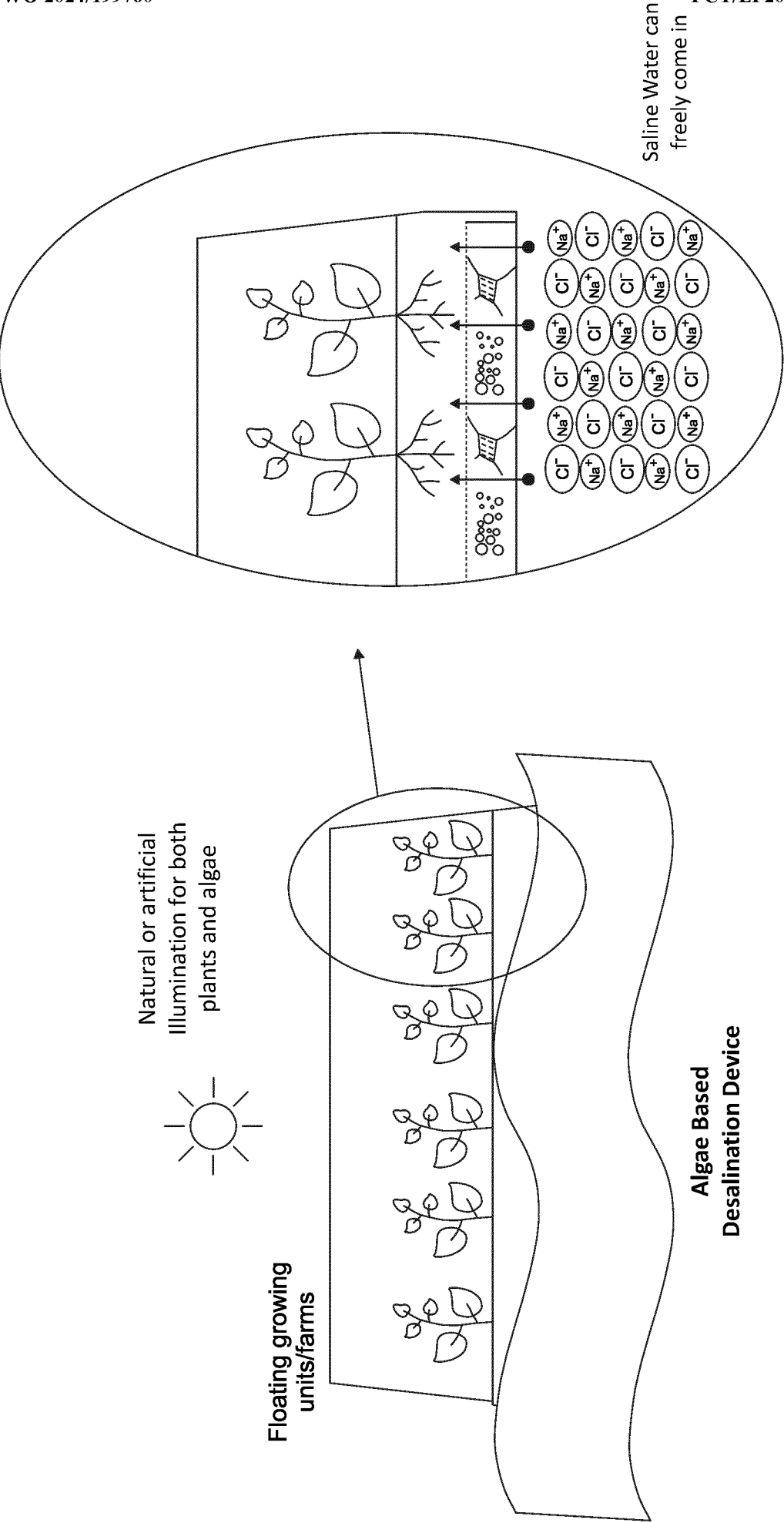


FIG. 5 A

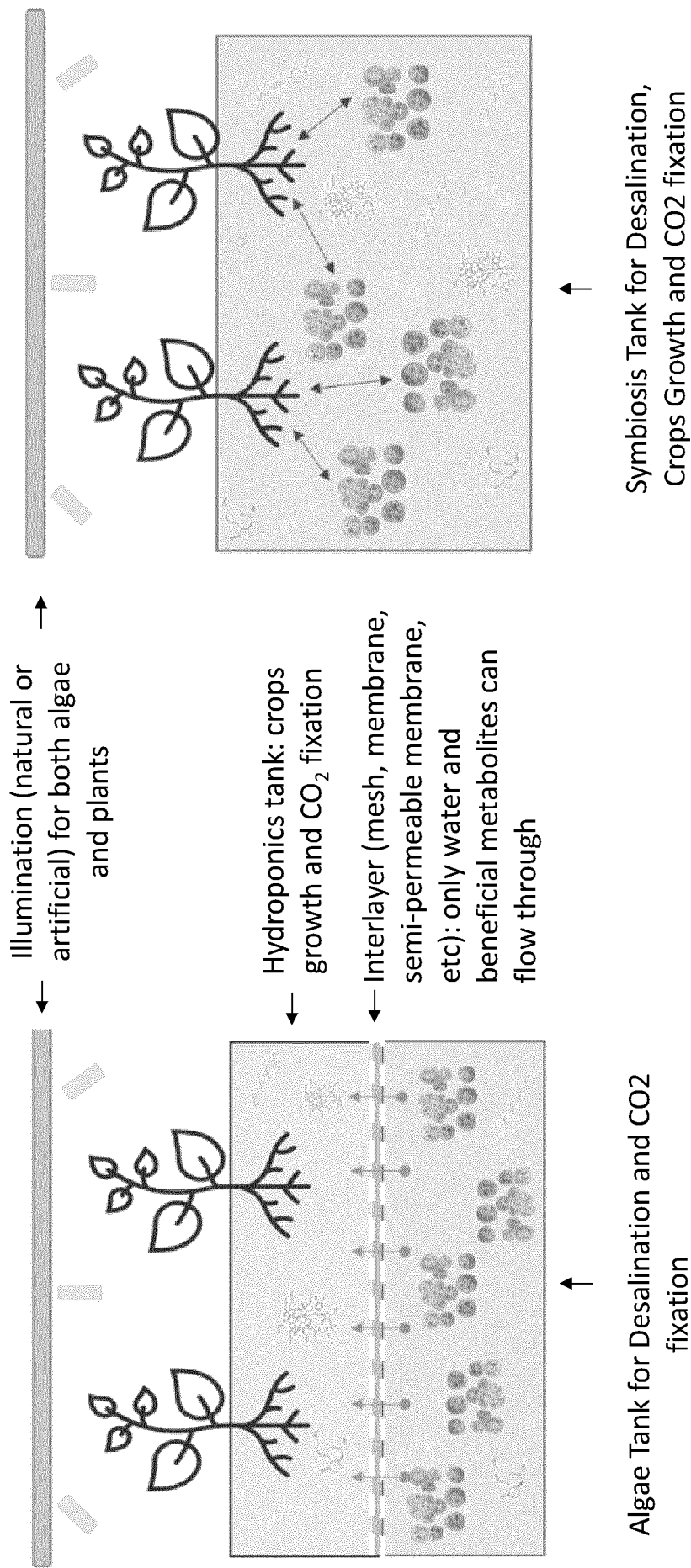
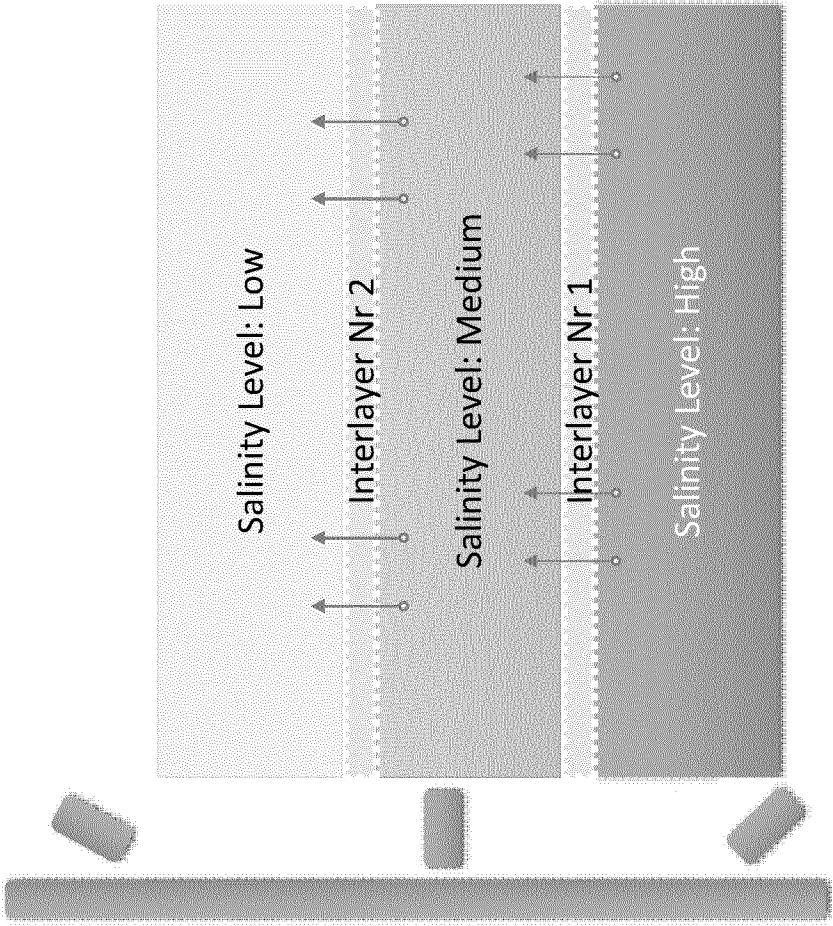


FIG. 5 B

Hydroponics Tank



Illumination (natural or artificial) for both algae and plants

Tank for Algae/Bacteria consortium acclimated/adapted to medium salinity

Interlayer to let only water and beneficial metabolite flow through

Tank for Algae/Bacteria consortium acclimated/adapted to highest salinity

FIG. 5 C

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/052158

A. CLASSIFICATION OF SUBJECT MATTER		
INV.	C02F3/32	C02F3/34
	C12P39/00	C02F3/10
		C12N1/12
		C12N1/20
ADD.	C02F103/02	C02F103/04
	C02F103/08	C02F103/24
	C02F103/26	
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) C02F C12N		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NADI M. H. A. EL: "Desalination Using Algae Ponds under Nature Egyptian Conditions", JOURNAL OF WATER RESOURCES AND OCEAN SCIENCE, vol. 3, no. 6, 8 December 2014 (2014-12-08), pages 69-73, XP093146216, ISSN: 2328-7969, DOI: 10.11648/j.wros.20140306.11	1-22,29
A	abstract pages 70-73	23-28
	----- -/--	
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 27 March 2024		Date of mailing of the international search report 11/04/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Rozanska, Agnieszka

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2024/052158

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Devasya Roopa P: "Batch and Fed Batch Cultivation and Harvesting of Nannochloropsis Gaditana for Environmental Applications", , 7 November 2017 (2017-11-07), pages 1-188, XP093145838, ISBN: 979-8-8454-7089-8 Retrieved from the Internet: URL: https://core.ac.uk/download/pdf/85003269.pdf [retrieved on 2024-03-26]	1-22, 29
A	pages 46-50 pages 55-97 -----	23-28
X	AJENG AARONN AVIT ET AL: "Resource recovery from hydroponic wastewaters using microalgae-based biorefineries: A circular bioeconomy perspective", JOURNAL OF BIOTECHNOLOGY, vol. 360, 19 October 2022 (2022-10-19), pages 11-22, XP093146356, Amsterdam NL ISSN: 0168-1656, DOI: 10.1016/j.jbiotec.2022.10.011 figure 2 pages 13-16 -----	1-29
X	MA RUIYANG ET AL: "Nutritional Profile and Bioremediation of Tropical Marine Aquaculture with an Integrated Microalgae and Bacteria Symbiosis", WATER, AIR, SPRINGER INTERNATIONAL PUBLISHING, CHAM, vol. 233, no. 5, 1 May 2022 (2022-05-01), XP037866400, ISSN: 0049-6979, DOI: 10.1007/S11270-022-05615-8 [retrieved on 2022-05-12]	1-22, 29
A	pages 1-5, 15 -----	23-28
X	US 8 507 254 B1 (ABUHASEL KHALED ALI [US]) 13 August 2013 (2013-08-13) figure 1 ----- -/--	18-22

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2024/052158

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ZHANG BO ET AL: "Adaptive Laboratory Evolution of Microalgae: A Review of the Regulation of Growth, Stress Resistance, Metabolic Processes, and Biodegradation of Pollutants", FRONTIERS IN MICROBIOLOGY, vol. 12, 18 August 2021 (2021-08-18), pages 1-8, XP093145839, Lausanne ISSN: 1664-302X, DOI: 10.3389/fmicb.2021.737248 the whole document -----	1-29
A	Allman Tony: "The Difference Between Batch, Fed-batch and Continuous Processes", , 23 July 2020 (2020-07-23), pages 1-7, XP093145842, Retrieved from the Internet: URL:https://www.infors-ht.com/en/blog/the-difference-between-batch-fed-batch-and-continuous-processes/ [retrieved on 2024-03-26] the whole document -----	1-29

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2024/052158

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 8507254	B1	13-08-2013	NONE
