CLAIMS

1. Desalination device comprising at least one electrochemical cell (10) comprising:

(a) an anode (18) suitable for allowing the electrochemical reaction of oxidation of the OH^- ion and consequent production of oxygen gas and release in solution of protons H^+ wherein said anode (18) is contained in an anode chamber (14; 114) suitable for containing or containing as an anolyte an acidic solution;

(b) a cathode (20) connected through an electrical connection (22) to said anode (18) and suitable to allow the electrochemical reaction of reduction of proton H^+ and consequent production of hydrogen gas and release in solution of OH^- ions wherein said cathode (20) is contained in a cathode chamber (16; 116) suitable to contain or containing as a catholyte a basic solution,;

(c) a system for feeding said anode chamber with said acidic solution;

(d) a system for feeding said cathode chamber with said basic solution;

(e) a cation exchange membrane (28; 128) impermeable for OH^- ions and permeable for cations;

(f) an anion exchange membrane (26; 126) impermeable for H^+ ions and permeable for anions;

wherein said anodic chamber (14; 114) and said cathodic chamber (16; 116) are separated by said cation exchange membrane (28; 128) and said anion exchange membrane (26; 126) which in turn are separated by a third chamber (12; 112) suitable for containing or containing an aqueous solution of chloride salt,

where

(α) said cation exchange membrane (28; 128) is simultaneously a wall or a portion thereof of said cathode chamber (16; 116) and of said third chamber (12; 112) such that from the third chamber (12; 112) to the cathode chamber (16; 116) a passage of salt cations is possible;

(β) said anion exchange membrane (26; 126) is simultaneously a wall or a portion thereof of said anode chamber (14; 114) and of said third chamber (12; 112) such that from the third chamber (12; 112) to the anode chamber (14; 114) a passage of salt anions, is possible; **characterized in that** said electrodes (18, 20) are made of graphite and the desalination device further comprises

(h) a carbonation reactor (50)

wherein the cathode chamber (16) comprises an inlet (38), and an outlet (40) which are connected in circuit in which said carbonation reactor (50) is inserted.

2. Desalination device according to claim 1, **characterized in that**

- said basic solution is an aqueous solution of NaOH;
- said cations are Na+ and said anions are Cl-; and
- said chloride salt is NaCl.

3. Desalination device according to claim 1 or 2, **characterized in that** it is configured to perform the following algorithm:

(i) feeding the anode chamber (14; 114) with an anolyte;

(ii) feeding the cathode chamber (16; 116) with a catholyte,;

(iii) feeding the third chamber (12; 112) with a concentrated chloride salt solution;

(iv) oxidation of OH^- on the anode (18) with the formation of oxygen O_2 and H^+ protons;

(v) reduction of H^+ on the cathode (20) with the formation of H_2 hydrogen and OH^- hydroxide ions.

4. Desalination device according to claim 3, characterized in that said anolyte is water and said catholyte is water or a base produced therein at reduced concentrations.

5. Desalination device according to any one of the preceding claims, **characterized in that** each of said chambers (12, 14, 16; 112, 114, 116) is provided with an inlet (30, 34, 38; 130, 134, 138) and an outlet (32, 36, 40; 132, 136, 140), namely:

(a) that the anode chamber (14; 114) is provided with an inlet (34; 134) for fresh anolyte and an outlet (36; 136) for anolyte enriched with salt anions and oxygen;

(b) that the cathode chamber (16; 116) is provided with an inlet (38; 138) for the fresh catholyte and an outlet (40; 140) for the catholyte enriched in salt cations, and hydrogen; and

(c) that the third chamber (12; 112) has an inlet (30; 130) for an aqueous starting salt solution and an outlet (32; 132) for the reduced concentration salt solution.

6. Desalination device according to any one of the preceding claims, **characterized in that** it further comprises

(g) a gas-liquid separation device,, suitable for recovering the hydrogen produced which is connected to the outlet of the cathode chamber (16; 116).

7. Desalination device according to claim 6, **characterized in that** said gas-liquid separation device is a gas-liquid scrubber.

8. Desalination device according to claim 6 or 7, **characterized in that** said gas-liquid separation device is connected to a fuel cell.

9. Desalination device according to any one of the preceding claims, **characterized in that** said at least one electrochemical cell comprises

(i) a first plate (166) supporting in a first window applied in said first plate said anode chamber (114) of meandering path and having an inlet and an outlet for the anolyte at its ends;

(ii) a second plate (168) supporting in a second window applied to said second plate said central chamber (112) of meandering path and having an inlet and outlet for saline solution at its ends; and

(iii) a third plate (170) supporting in a third window applied in said third plate said cathode chamber (116) of meandering path and having an inlet and outlet for the catholyte at its ends,

(iv) said anion exchange membrane (127) interposed between said first (166) and said second (168) plate;

(v) said cation exchange membrane (128) interposed between said second (168) and said third (170) plate;

(vi) a plate anode disposed alongside said first plate (168) on the opposite side from the position of said anion exchange membrane (127); and

(vii) a plate cathode disposed alongside said third plate (170) on the opposite side with respect to the position of the cation exchange membrane (128);

wherein plates, membranes and electrodes are superimposed in the following order: anode, anode chamber, anion exchange membrane, central chamber, cation exchange membrane, cathode,

wherein each plate is provided with a plurality of second holes divided into three pairs of holes (134, 136; 130, 132; 138, 140) for conveying in separate channels the flows of anolyte, catholyte and saline solution, one hole (134; 130; 138) of each pair provided for inlet of the respective flow into the system and the other hole (136; 132; 140) for exit from the system,

wherein the corresponding holes are arranged so that with the overlapping of the plates

they result aligned to be able to connect them to form separate channels for the respective flows,

in which each flow traverses along the channel formed by the relative overlapping holes the whole system, but only in the plate carrying the chamber to which the relative channel flow is dedicated a communication with the chamber inlet is realized in such a way as to allow the flow to pass through the chamber and enter through the chamber outlet into the corresponding outlet channel formed by the respective set of holes.

10. Desalination device according to claim 9, **characterized in that**

- said anode, cathode or third chamber (112, 114, 116) of meandering path have a thickness with respect to the plane of the meandering path extension not exceeding 6 mm;
- each plate is provided with a plurality of first holes (172) arranged so that as the plates are overlapped, they are aligned so that they can be connected with relative fastening means;
- each plate is provided with a plurality of third holes (146, 147) for collecting gases formed in the anode and cathode chambers respectively (114, 116) and arranged in such a way that with the overlapping of the plates they result aligned to be able to connect them to form separate channels for relative gas flows of the respective anode and cathode chambers.

11. Desalination device according to claim 9 or 10, **characterized in that** it comprises a plurality of three-chamber electrochemical cells which is grouped into a cell stack according to

variant (A) wherein the individual elements follow each other according to the following scheme: $[+AZC-][+AZC-]_n$ with n = 1, 2, ...,;

OR according to

variant (B) in which the individual elements follow each other according to the following scheme: +AZC-CZA+AZC-CZA+.....+AZC- with varying number of AZC- and CZA-groups in which units with three adjacent chambers have the corresponding electrode in common,

wherein for both variants (A) and (B) A is a plate (166) with an anode chamber (114), Z is a plate (168) with a central chamber (112), C is a plate (170) with a cathode chamber (116), the "+" sign an anode and the "-" sign a cathode, an anion exchange membrane (127) is placed

between adjacent chambers A and Z, and a cation exchange membrane (128) is placed between adjacent chambers Z and C; and

wherein for both variants (A) and (B) the chambers of the same type are connected through the relative inlets and outlets of the chambers and corresponding holes in the plates.

12. Desalination device according to any one of the preceding claims, **characterized in that** it comprises a plurality of electrochemical cells in a multipolar configuration in a stack containing the cells with alternating polarity.

13. Desalination device according to any one of the preceding claims, **characterized in that** it comprises pumping systems (42, 44, 64) with adjustable speed for feeding said chambers.

14. A desalination process comprising the following steps:

(a) providing a desalination device according to any one of the preceding claims;

(b1) feeding the anode chamber (14; 114) with an anolyte;

(b2) feeding the cathode chamber (16; 116) with a catholyte;

(b3) feeding of the third chamber (12; 112) with a concentrated chloride salt solution;

(c1) oxidation of OH^- on the anode (18) with the formation of oxygen O_2 and protons H^+;

(c2) reduction of H^+ on the cathode (20) with the formation of hydrogen H_2 and hydroxide ions OH^-;

(d1) in reaction to increased concentration of H^+ ions in the anode chamber (14; 114) passage of salt anions, from the third chamber (12; 112) into the anode chamber (14; 114);

(d2) in reaction to the increased concentration of OH^- ions in the cathode chamber (16; 116) passage of salt cations, from the third chamber (12; 112) into the cathode chamber (16; 116);

wherein the feeding of the cathode chamber (16) and an extraction of its contents take place in a circuit from which hydrogen is diverted and wherein carbonates and bicarbonates (56) are diverted from said carbonation reactor with the effect of buffering the pH of the basic solution which returns to the cathode chamber (16).

15. Desalination process according to claim 13, characterized in that said anolyte is water; said catholyte is water or the base produced therein at reduced concentration, sad salt anions are chlorides and said salt cations are Na+.

16. Process according to claim14 or 15, **characterized in that**

(i) the anode chamber (14; 114) is fed with controlled flow, and that acid solutions containing oxygen are extracted therefrom;

(ii) the cathode chamber (16; 116) is fed with controlled flow with a basic solution or with water and that concentrated basic solutions and hydrogen are extracted therefrom;

(iii) the central chamber (12; 112) is fed at a controlled rate by concentrated salt solutions and that dilute salt solutions are extracted therefrom allowing control of the concentrations of the components of the aqueous solutions contained in the relevant chambers (12, 14, 16; 112, 114, 116).

17. Process according to claim 16, characterized in that the anode chamber is fed with an acid solution or water and that the basic solution is NaOH.

18. Process according to claim 14 to 17, **characterized in that** the feeding of the cathode chamber (16) and the extraction of its contents take place in a circuit from which hydrogen (46) is diverted, feeding a fuel cell, in which the energy produced in the fuel cell can be used to power the desalination device.

19. Process according to any one of claims from 14 to 18, characterized in that the flow of the saline solution to be treated is kept stable within the central chamber of each cell, or through the use of peristaltic metering pumps that are controlled using a Programmable Logic Controller (PLC) by monitoring the conductivity of the solution analysed at the point where it leaves the cell and in that inside the anode and cathode chamber the flow of the anolyte and of the catholyte is kept stable, or through the use of peristaltic metering pumps managed via PLC by monitoring the pH of the same solutions analysed at the point where they exit the cell.

20. Process according to any one of claims 14 to 18, characterized in that the pH of the basic solution is buffered at values between 8.5 and 9.5.

21. Use of the desalination device and process according to any one of the preceding claims for reducing the concentration of chlorides in brackish water, industrial waste, mining, water treatment, or marine waters for one or more purposes selected from the group consisting of:

- production of carbonates and/or bicarbonates;
- removal of CO_2 from the atmosphere;
- production of hydrogen for the purpose of producing energy.