CLAIMS

1. An atmospheric water generation system comprising at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) including:

- at least two successive processing stages (AB/VC; M1-M4; CA/VC) each including an adsorbent structure (AB; CA) comprising an adsorbent material, which adsorbent structure (AB; CA) is coupled to an adjacent vapor chamber (VC) to allow vapor transfer thereto;

- a heating stage (HT; HM) to provide thermal energy to the adsorbent structures (AB; CA);

- a cooling stage (CL; CM) to cause condensation of water vapor in at least a final one of the vapor chambers (VC); and

- a circuit (C, V) to force circulation of moist ambient air through the adsorbent structures (AB; CA) and cause adsorption of water in the adsorbent structures (AB; CA),

wherein the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) is configured to operate in a desorption mode where the heating stage (HT; HM) is operated such that thermal energy provided by the heating stage (HT; HM) causes water adsorbed in the adsorbent structures (AB; CA) to be desorbed into water vapor, which water vapor transits to the adjacent vapor chamber (VC) where the water vapor condenses into a condensate.

2. The atmospheric water generation system according to claim 1, wherein the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) is configured such that latent heat resulting from condensation of the water vapor generated by a preceding processing stage (AB/VC; M1-M3; CA/VC) is transferred to the adsorbent structure (AB; CA) of a following processing stage (AB/VC; M2-M4; CA/VC) to sustain desorption.

3. The atmospheric water generation system according to claim 1, wherein the adsorbent structure includes an adsorbent bed (AB) containing the adsorbent material, which adsorbent bed (AB) is coupled to the adjacent vapor chamber (VC) via a vapor permeable separation wall (10).

4. The atmospheric water generation system according to claim 3, wherein the processing stages (AB/VC) are distributed one after the other in sequence,

wherein the vapor chamber (VC) of a preceding processing stage (AB/VC) is coupled to the adsorbent bed (AB) of a following processing stage (AB/VC) via a heat exchanger plate (20) to cause condensation of the water vapor along a surface of the heat exchanger plate (20),

and wherein the heat exchanger plate (20) is configured such that latent heat resulting from condensation of the water vapor along the surface of the heat exchanger plate (20) on the vapor chamber (VC) side is transferred to the adsorbent bed (AB) of the following processing stage (AB/VC).

5. The atmospheric water generation system according to claim 4, wherein the heating stage includes a heat exchanger device (HT) coupled to the adsorbent bed (AB) of a first one of the processing stages (AB/VC) to supply thermal energy to the adsorbent material contained therein,

and wherein the cooling stage includes a cooling device (CL) coupled to the vapor chamber (VC) of a last one of the processing stages (AB/VC) to cause condensation of the water vapor contained therein.

6. The atmospheric water generation system according to claim 4, wherein the heat exchanger plate (20) is provided with a plurality of protruding heat transfer elements (200a, 200b) extending from the heat exchanger plate (20) into the vapor chamber (VC) of the preceding processing stage (AB/VC) and/or into the adsorbent bed (AB) of the following processing stage (AB/VC).

7. The atmospheric water generation system according to claim 3, further comprising one or more heat transfer tubes (25) extending through at least one of the adsorbent beds (AB) to supply thermal energy to the adsorbent material contained therein.

8. The atmospheric water generation system according to claim 7, wherein the one or more heat transfer tubes (25) is or are fed with water vapor coming from a preceding stage (AB/VC; HM, M1-M3) of the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$),

and wherein each heat transfer tube (25) is configured such that latent heat resulting from condensation of the water vapor along inner walls of the heat transfer tube (25) is transferred to the surrounding adsorbent bed (AB).

9. The atmospheric water generation system according to claim 3, wherein the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) comprises a plurality of processing modules (M1-M4) distributed one after the other in sequence, each processing module (M1-M4) including a plurality of the adsorbent beds (AB) interposed between a plurality of the adjacent vapor chambers (VC),

wherein each processing module (M1-M4) further includes one or more heat transfer tubes (25) extending through each of the adsorbent beds (AB) to supply thermal energy to the adsorbent material contained therein,

wherein the heat transfer tubes (25) of each processing module (M1-M4) are fed with water vapor coming from the vapor chambers (VC) of a preceding module (HM, M1-M3) of the atmospheric water generation unit ($AWGU_1$, $AWGU_2$),

wherein each heat transfer tube (25) is configured such that latent heat resulting from condensation of the water vapor along inner walls of the heat transfer tube (25) is transferred to the surrounding adsorbent bed (AB),

and wherein the vapor chambers (VC) of each processing module (M1-M4) feed water vapor to a following module (M2-M4, CM) of the atmospheric water generation unit ($AWGU_1$, $AWGU_2$).

10. The atmospheric water generation system according to claim 9, further comprising a heating module (HM) located immediately before the plurality of processing modules (M1-M4) and a condenser module (CM) located immediately after the plurality of processing modules (M1-M4),

wherein the heating module (HM) includes a plurality of the adsorbent beds (AB) interposed between a plurality of the adjacent vapor chambers (VC),

wherein the heat transfer tubes (25) of a first one (M1) of the plurality of processing modules (M1-M4) are fed with water vapor coming from the vapor chambers (VC) of the heating module (HM),

and wherein the condenser module (CM) includes a plurality of condensation chambers (CC) that are fed with water vapor coming from the vapor chambers (VC) of a last one (M4) of the plurality of processing modules (M1-M4).

11. The atmospheric water generation system according to claim 7, wherein each heat transfer tube (25) includes a drainage port for drainage of the condensate condensing therein.

12. The atmospheric water generation system according to claim 1, wherein the adsorbent structure includes a coated adsorbent layer (CA) provided on a side of a heat transfer structure (30, 300a, 300b; 40) in the adjacent vapor chamber (VC).

13. The atmospheric water generation system according to claim 12, wherein the processing stages (CA/VC) are distributed one after the other in sequence,

wherein the vapor chamber (VC) of a preceding processing stage (CA/VC) is coupled to the coated adsorbent layer (CA) of a following processing stage (CA/VC) via the heat transfer structure (30, 300a, 300b; 40) to cause condensation of the water vapor along a surface of the heat transfer structure (30, 300; 40),

and wherein the heat transfer structure (30, 300a, 300b; 40) is configured such that latent heat resulting from condensation of the water vapor along the surface of the heat transfer structure (30, 300a, 300b; 40) on the vapor chamber (VC) side is transferred to the coated adsorbent layer (CA) of the following processing stage (CA/VC).

14. The atmospheric water generation system according to claim 13, wherein the heating stage includes a heat exchanger device (HT) coupled to the heat transfer structure (30, 300a, 300b; 40) of a first one of the processing stages (CA/VC) to supply thermal energy to the adsorbent material of the associated coated adsorbent layer (CA),

and wherein the cooling stage includes a cooling device (CL) coupled to the vapor chamber (VC) of a last one of the processing stages (CA/VC) to cause condensation of the water vapor contained therein.

15. The atmospheric water generation system according to claim 13, wherein the heat transfer structure (30, 300a, 300b) includes a heat exchanger plate (30) provided with a plurality of protruding heat transfer elements (300a, 300b) extending from the heat exchanger plate (30) into the vapor chamber (VC) of the preceding processing stage (CA/VC) and/or into the vapor chamber (VC) of the following processing stage (CA/VC) where the coated adsorbent layer (CA) is provided.

16. The atmospheric water generation system according to any one of claims 1 to 15, wherein part or all of the vapor chambers (VC) includes/include a drainage port for drainage of the condensate condensing therein.

17. The atmospheric water generation system according to any one of claims 1 to 15, wherein the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) is further configured to operate in an adsorption mode where the heating stage (HT; HM) is operated such that heating of the adsorbent structures (AB; CA) is stopped or such that the heating stage (HT; HM) is used to cool the adsorbent structures (AB; CA).

18. The atmospheric water generation system according to claim 17, comprising first and second atmospheric water generation units ($AWGU_1$, $AWGU_2$) in side-by-side operation,

wherein the first atmospheric water generation unit ($AWGU_1$) is configured to operate in the desorption mode during a first cycle, while the second atmospheric water generation unit ($AWGU_2$) is configured to operate in the adsorption mode,

and wherein the first atmospheric water generation unit ($AWGU_1$) is configured to be switched to the adsorption mode during a second cycle, while the second atmospheric water generation unit ($AWGU_2$) is configured to be switched to the desorption mode.

19. The atmospheric water generation system according to any one of claims 1 to 15, wherein the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) is coupled to a thermal storage device (TS).

20. The atmospheric water generation system according to any one of claims 1 to 15, wherein the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) is coupled to a thermal energy source (TES) originating from solar energy or industrial waste heat processes.

21. The atmospheric water generation system according to any one of claims 1 to 15, further comprising a low-pressure system to maintain the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) in a partial vacuum condition during desorption.

22. The atmospheric water generation system according to claim 21, wherein the low-pressure system comprises a vacuum pump connected to one or more collection tanks collecting the condensate to reduce overall system pressure in the adsorbent structures (AB; CA) and vapor chambers (VC).

23. An atmospheric water generation method comprising the following steps:

(a) providing at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) including two or more successive processing stages (AB/VC; M1-M4;

CA/VC) each including an adsorbent structure (AB; CA) comprising an adsorbent material, which adsorbent structure (AB; CA) is coupled to an adjacent vapor chamber (VC) to allow vapor transfer thereto;

(b) forcing circulation of moist ambient air through the adsorbent structures (AB: CA) to cause adsorption of water in the adsorbent structures (AB; CA);

(c) supplying thermal energy to the adsorbent structures (AB; CA) to cause water adsorbed in the adsorbent structures (AB; CA) to be desorbed into water vapor, which water vapor transits to the adjacent vapor chamber (VC); and

(d) condensing the water vapor contained in the vapor chamber into a condensate.

24. The atmospheric water generation method according to claim 23, wherein latent heat resulting from condensation of the water vapor generated by a preceding processing stage (AB/VC; M1-M3; CA/VC) is transferred to the adsorbent structure (AB; CA) of a following processing stage (AB/VC; M2-M4; CA/VC) to sustain desorption.

25. The atmospheric water generation method according to claim 23, wherein the adsorbent structure includes an adsorbent bed (AB) containing the adsorbent material, which adsorbent bed (AB) is coupled to the adjacent vapor chamber (VC) via a vapor permeable separation wall (10).

26. The atmospheric water generation method according to claim 25, wherein the processing stages (AB/VC) are distributed one after the other in sequence,

wherein the vapor chamber (VC) of a preceding processing stage (AB/VC) is coupled to the adsorbent bed (AB) of a following processing stage (AB/VC) via a heat exchanger plate (20),

wherein condensation of the water vapor at step (d) occurs along a surface of the heat exchanger plate (20),

and wherein latent heat resulting from condensation of the water vapor along the surface of the heat exchanger plate (20) on the vapor chamber (VC) side is transferred to the adsorbent bed (AB) of the following processing stage (AB/VC).

27. The atmospheric water generation method according to claim 26, wherein step (c) includes heating the adsorbent bed (AB) of a first one of the processing stages (AB/VC) to supply thermal energy to the adsorbent material contained therein,

and wherein step (d) includes cooling the vapor chamber (VC) of a last one of the processing stages (AB/VC) to cause condensation of the water vapor contained therein.

28. The atmospheric water generation method according to claim 26, wherein the heat exchanger plate (20) is provided with a plurality of protruding heat transfer elements (200a, 200b) extending from the heat exchanger plate (20) into the vapor chamber (VC) of the preceding processing stage (AB/VC) and/or into the adsorbent bed (AB) of the following processing stage (AB/VC).

29. The atmospheric water generation method according to claim 25, wherein step (a) includes providing one or more heat transfer tubes (25) extending through at least one of the adsorbent beds (AB),

and wherein step (c) includes supplying thermal energy to the adsorbent bed (AB) via the one or more heat transfer tubes (25).

30. The atmospheric water generation method according to claim 29, wherein step (c) includes feeding water vapor coming from a preceding stage (AB/VC; HM, M1-M3) of the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) to the one or more heat transfer tubes (25),

and wherein latent heat resulting from condensation of the water vapor along inner walls of each heat transfer tube (25) is transferred to the surrounding adsorbent bed (AB).

31. The atmospheric water generation method according to claim 25, wherein step (a) includes providing a plurality of processing modules (M1-M4) distributed one after the other in sequence, each processing module (M1-M4) including a plurality of the adsorbent beds (AB) interposed between a plurality of the adjacent vapor chambers (VC),

wherein step (a) further includes providing one or more heat transfer tubes (25) extending through each of the adsorbent beds (AB) of each processing module (M1-M4),

wherein step (c) includes supplying thermal energy to the adsorbent beds (AB) of each processing module (M1-M4) by feeding water vapor coming from a preceding module (HM, M1-M3) of the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) to the heat transfer tubes (25),

wherein latent heat resulting from condensation of the water vapor along inner walls of each heat transfer tube (25) is transferred to the surrounding adsorbent bed (AB),

and wherein step (c) further includes feeding water vapor coming from the vapor chambers (VC) of each processing module (M1-M4) to a following module (M2-M4, CM) of the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$).

32. The atmospheric water generation method according to claim 31, wherein step (a) includes further providing a heating module (HM) located immediately before the plurality of processing modules (M1-M4) and a condenser module (CM) located immediately after the plurality of processing modules (M1-M4),

wherein the heating module (HM) includes a plurality of the adsorbent beds (AB) interposed between a plurality of the adjacent vapor chambers (VC),

wherein step (c) includes feeding the heat transfer tubes (25) of a first one (M1) of the plurality of processing modules (M1-M4) with water vapor coming from the vapor chambers (VC) of the heating module (HM),

wherein the condenser module (CM) includes a plurality of condensation chambers (CC),

and wherein step (d) includes feeding the condensation chambers (CC) of the condenser module (CM) with water vapor coming from the vapor chambers (VC) of a last one (M4) of the plurality of processing modules (M1-M4).

33. The atmospheric water generation method according to claim 29, wherein step (d) includes draining the condensate condensing in each heat transfer tube (25) via a drainage port.

34. The atmospheric water generation method according to claim 23, wherein the adsorbent structure includes a coated adsorbent layer (CA) provided on a side of a heat transfer structure (30, 300a, 300b; 40) in the adjacent vapor chamber (VC).

35. The atmospheric water generation method according to claim 34, wherein the processing stages (CA/VC) are distributed one after the other in sequence,

wherein the vapor chamber (VC) of a preceding processing stage (CA/VC) is coupled to the coated adsorbent layer (CA) of a following processing stage (CA/VC) via the heat transfer structure (30, 300a, 300b; 40),

wherein condensation of the water vapor at step (d) occurs along a surface of the heat transfer structure (30, 300a, 300b; 40),

and wherein latent heat resulting from condensation of the water vapor along the surface of the heat transfer structure (30, 300a, 300b; 40) on the vapor chamber (VC) side is transferred to the coated adsorbent layer (CA) of the following processing stage (CA/VC).

36. The atmospheric water generation method according to claim 35, wherein step (c) includes heating the coated adsorbent layer (CA) of a first one of the processing stages (CA/VC) to supply thermal energy to the adsorbent material,

and wherein step (d) includes cooling the vapor chamber (VC) of a last one of the processing stages (CA/VC) to cause condensation of the water vapor contained therein.

37. The atmospheric water generation method according to claim 35, wherein the heat transfer structure (30, 300a, 300b) includes a heat exchanger plate (30) provided with a plurality of protruding heat transfer elements (300a, 300b) extending from the heat exchanger plate (30) into the vapor chamber (VC) of the preceding processing stage (CA/VC) and/or into the vapor chamber (VC) of the following processing stage (CA/VC) where the coated adsorbent layer (CA) is provided.

38. The atmospheric water generation method according to claim 23, wherein step (d) includes draining the condensate condensing in part or all of the vapor chambers (VC).

39. The atmospheric water generation method according to claim 23, including operating first and second atmospheric water generation units ($AWGU_1$, $AWGU_2$) side by side,

wherein the first atmospheric water generation unit ($AWGU_1$) is operated during a first cycle to cause desorption of water vapor at step (c), while the second atmospheric water generation unit ($AWGU_2$) is operated to cause adsorption of water at step (b),

and wherein operation of the first atmospheric water generation unit ($AWGU_1$) is switched during a second cycle to cause adsorption of water at step (b), while operation of the second atmospheric water generation unit ($AWGU_2$) is switched to cause desorption of water vapor at step (c).

40. The atmospheric water generation method according to claim 23, including coupling of the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) to a thermal storage device (TS).

41. The atmospheric water generation method according to claim 23, including coupling of the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) to a thermal energy source (TES) originating from solar energy or industrial waste heat processes.

42. The atmospheric water generation method according to claim 41, including using heat generated by a solar energy harvesting system.

43. The atmospheric water generation method according to claim 42, wherein the solar energy harvesting system is a photovoltaic (PV) system.

44. The atmospheric water generation method according to claim 43, wherein the photovoltaic (PV) system is a concentrated photovoltaic (CPV) system.

45. The atmospheric water generation method according to claim 23, further comprising the step of maintaining the at least one atmospheric water generation unit ($AWGU_1$, $AWGU_2$) in a partial vacuum condition during desorption.

46. The atmospheric water generation method according to claim 45, wherein the partial vacuum condition is maintained by reducing overall system pressure in the adsorbent structures (AB: CA) and vapor chambers (VC) using a vacuum pump connected to one or more collection tanks collecting the condensate.