



(51) International Patent Classification:

C02F 1/36 (2006.01)

C02F 11/15 (2019.01)

C02F 11/12 (2019.01)

(21) International Application Number:

PCT/AU2021/050246

(22) International Filing Date:

18 March 2021 (18.03.2021)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2020900843

19 March 2020 (19.03.2020)

AU

(71) Applicant: THE UNIVERSITY OF QUEENSLAND

[AU/AU]; St Lucia, Queensland 4072 (AU).

(72) Inventors: ZARE, Firuz; 27 Sprenger Street, Fig Tree

Pocket, Queensland 4069 (AU). GHASEMI, Negareh;

65 Saturn Crescent, Bridgeman Downs, Queensland 4035 (AU).

(74) Agent: SPRUSON & FERGUSON; GPO Box 3898, Sydney, New South Wales 2001 (AU).

(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, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, 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, GH, GM, KE, LR, LS, MW, MZ, NA, RW, 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, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: DEWATERING PROCESS

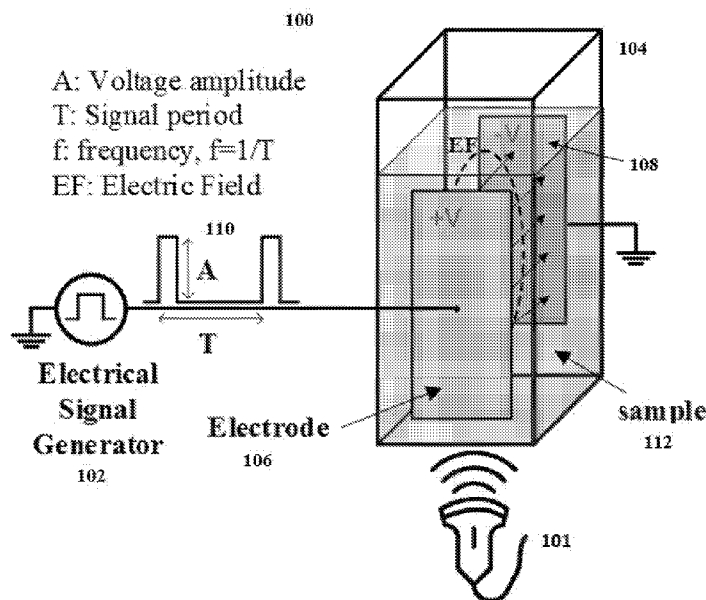


Figure 1

(57) **Abstract:** Disclosed herein is a method of dewatering organic sludges comprising subjecting a portion of the organic sludge to ultrasound to release water bound within, or to the organic sludge; and subjecting the portion of the organic sludge to a pulsed electric field with an electrical frequency of from about 10 kHz up to about 1 MHz and a peak electric field strength of from about 5 V/cm up to about 500 V/cm to separate the released water from the organic sludge.



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))*

DEWATERING PROCESS

Field

[0001] The invention relates to methods and/or systems for dewatering organic sludges, for example those associated with wastewater treatment processes.

Background

[0002] There is need to develop better and/or alternative methods for dewatering of organic sludges to reduce the volume of the sludge and/or recover water.

[0003] Reducing sludge volume helps mitigate the cost of further sludge treatment processes and disposal e.g. particularly the costs associated with the transportation of sludge to a disposal site. Furthermore, there is a need for in-situ recovery of water from sludges in water stressed areas.

[0004] It is an object of the invention to address at least one of the aforementioned problems of the prior art.

Summary of Invention

[0005] In a first aspect of the invention, there is provided a method of dewatering organic sludges comprising:

subjecting a portion of the organic sludge to ultrasound to release water bound within, or to the organic sludge; and

subjecting the portion of the organic sludge to a pulsed electric field with an electrical frequency of from about 10 kHz up to about 1 MHz and a peak electric field strength of from about 5 V/cm up to about 500 V/cm to separate the released water from the organic sludge.

[0006] By “bound” it is meant that water is attracted to or is interacting with and/or adsorbed to surfaces of the organic sludge, by way of example, the water may be physisorbed to surfaces of particulate matter within the organic sludge and/or be electrostatically attracted or bound to charged moieties within the organic sludge, and/or be chemically or physically bound to or held within other components of the sludge (e.g. within cellular or other biological materials). That

is, “bound water” is not “free water”, wherein “free water” refers to water molecules that do not interact with the components of the organic sludge and, for example, substantially interact with only other water molecules (for example via hydrogen bonding) and/or with charged ions in solution.

[0007] In one or more forms of the invention, the step of subjecting the portion of the organic sludge to ultrasound and the step of subjecting the portion of the organic sludge are cyclic treatment steps that are carried out simultaneously. However, in alternative forms of the invention, the step of subjecting the portion of the organic sludge to ultrasound and the step of subjecting the portion of the organic sludge are cyclic treatment steps carried out in series.

[0008] In an embodiment, the ultrasound is of sufficient power and ultrasonic frequency to induce cavitation in the portion of the organic sludge.

[0009] In an embodiment, the ultrasound is of sufficient power and ultrasonic frequency to induce sonoporation within a biological component of the portion of the organic sludge.

[0010] In an embodiment, the ultrasonic frequency is from about 1 kHz to about 5 MHz range. In one form of this embodiment, the ultrasonic frequency is from about 3 kHz. Preferably, the ultrasonic frequency is from about 5 kHz. More preferably, the ultrasonic frequency is from about 7 kHz. Most preferably, the ultrasonic frequency is from about 10 kHz. Additionally, or alternatively, the ultrasonic frequency is up to about 1 MHz. Preferably, the ultrasonic frequency is up to about 500 kHz. More preferably, the ultrasonic frequency is up to about 100 kHz. Most preferably, the ultrasonic frequency is up to about 50 MHz. The power level is determined by the size, type and volume of the object and flow rate.

[0011] In an embodiment, the electrical frequency is from about 2.5 kHz. Preferably, the electrical frequency is from about 5 kHz. More preferably, the electrical frequency is from about 7.5 kHz. Most preferably, the electrical frequency is from about 10 kHz. Additionally, or alternatively, in an embodiment, the electrical frequency is up to about 750 kHz. Preferably, the electrical frequency is up to about 500 kHz. More preferably, the electrical frequency is up to about 250 kHz. Most preferably, the electrical frequency is up to about 100 kHz.

[0012] In an embodiment, the peak electric field strength is from about 6 V/cm. Preferably, the peak electric field strength is from about 7 V/cm. More preferably, the peak electric field

strength is from about 8 V/cm. Most preferably, the peak electric field strength is from about 10 V/cm. Additionally, or alternatively, in an embodiment, the peak electric field strength is up to about 300 V/cm. Preferably, the peak electric field strength is up to about 200 V/cm. More preferably, the peak electric field strength is up to about 100 V/cm. Most preferably, the peak electric field strength is up to about 50 V/cm.

[0013] In an embodiment, the pulsed electric field has a duty cycle of from about 5% to about 90%. Preferably, the duty cycle is from about 10%. More preferably, the duty cycle is from about 15%. Most preferably, the duty cycle is from about 20%. Additionally, or alternatively, it is preferred that the duty cycle is up to about 80%. More preferably, the duty cycle is up to about 70%. Most preferably, the duty cycle is up to about 60%.

[0014] In an embodiment, the pulsed electric field is generated using a unipolar voltage signal.

[0015] In an embodiment, the pulsed electric field is a continuous pulsed electric field.

[0016] In an embodiment, prior to the step of subjecting the portion of the organic sludge to ultrasound, the method comprises locating at least the portion of the organic sludge between two electrodes (e.g. which are preferably in the form of two electrode plates); and

wherein the step of subjecting the portion of the organic sludge to ultrasound is carried out while the portion of the organic sludge is located between the two electrodes.

[0017] In an embodiment, the step of subjecting at least the portion of the organic sludge to the pulsed electric field further comprises passing an electric current through at least the portion of the organic sludge. The electric voltage waveform and amplitude depend on the conductivity of the organic sludge, the dimension of the chamber and size of the electrodes. This causes the freed water to migrate away from the organic sludge in the direction of the electric field.

[0018] In forms of the above embodiment in which the method comprises locating at least the portion of the organic sludge between two electrodes (such as between two electrode plates), the step of passing the electric current through at least the portion of the organic sludge further comprises passing the electric current between the two electrodes.

[0019] In an embodiment, the method of dewatering organic sludges is carried out after anaerobic digestion of the organic sludge.

[0020] In an embodiment, the organic sludge is an activated sludge.

[0021] In an embodiment, the organic sludge has a volatile solids content of at least about 15 g/L, and/or a total chemical oxygen demand of at least about 20 g/L up to about 80 g/L, and/or a total Kjeldahl nitrogen content of at least about 1 g N/L up to about 3 g N/L, and/or an ammonium nitrogen content of from about 40 mg/L up to about 1500 mg/L.

[0022] In an embodiment, the organic sludge has an apparent viscosity of from about 50 cP to about 1000 cP when measured at a shear rate of 100 s^{-1} and at 25°C .

[0023] In an embodiment, the organic sludge comprises particles with a D10 in the range of from about $10 \mu\text{m}$ up to $120 \mu\text{m}$, and/or a D50 in the range of from about $50 \mu\text{m}$ up to $400 \mu\text{m}$, and/or a D90 in the range of from about $130 \mu\text{m}$ up to $500 \mu\text{m}$.

[0024] In an embodiment, the organic sludge has a zeta potential in the range of from about -10 mV to about -30 mV.

[0025] In a second aspect of the invention, there is provided an apparatus for dewatering an organic sludge with water bound within or thereto, the system comprising:

an ultrasonic transducer configured to apply ultrasound to the organic sludge;

two spaced apart electrodes configured to apply a pulsed electric field to organic sludge located therebetween; and

an electric signal generator configured to generate the pulsed electric field at an electrical frequency of from about 1 kHz up to about 1 MHz and at sufficient voltage to provide the pulsed electric field with a peak electric field strength of from about 5 V/cm up to about 500 V/cm.

[0026] In an embodiment, the ultrasound is of sufficient power and ultrasonic frequency to induce cavitation in the portion of the organic sludge.

[0027] In an embodiment, the ultrasound is of sufficient power and ultrasonic frequency to induce sonoporation within a biological component of the portion of the organic sludge.

[0028] In an embodiment, the ultrasonic frequency is from about 10 Hz to about 50 Hz.

[0029] In an embodiment, the electrical frequency is from about 2.5 kHz. Preferably, the electrical frequency is from about 5 kHz. More preferably, the electrical frequency is from about 7.5 kHz. Most preferably, the electrical frequency is from about 10 kHz. Additionally, or alternatively, in an embodiment, the electrical frequency is up to about 750 kHz. Preferably, the electrical frequency is up to about 500 kHz. More preferably, the electrical frequency is up to about 250 kHz. Most preferably, the electrical frequency is up to about 100 kHz.

[0030] In an embodiment, the peak electric field strength is from about 6 V/cm. Preferably, the peak electric field strength is from about 7 V/cm. More preferably, the peak electric field strength is from about 8 V/cm. Most preferably, the peak electric field strength is from about 10 V/cm. Additionally, or alternatively, in an embodiment, the peak electric field strength is up to about 300 V/cm. Preferably, the peak electric field strength is up to about 200 V/cm. More preferably, the peak electric field strength is up to about 100 V/cm. Most preferably, the peak electric field strength is up to about 50 V/cm.

[0031] In an embodiment, the pulsed electric field has a duty cycle of from about 5% to about 90%. Preferably, the duty cycle is from about 10%. More preferably, the duty cycle is from about 15%. Most preferably, the duty cycle is from about 20%. Additionally, or alternatively, it is preferred that the duty cycle is up to about 80%. More preferably, the duty cycle is up to about 70%. Most preferably, the duty cycle is up to about 60%.

[0032] In an embodiment, the pulsed electric field is generated using a unipolar voltage signal.

[0033] In an embodiment, the pulsed electric field is a continuous pulsed electric field.

[0034] In an embodiment, the electric signal generator is configured to pass an electric current between the two spaced apart electrodes.

[0035] In a third aspect of the invention, there is provided the use of an apparatus according to the second aspect and/or embodiments thereof to dewater organic sludges.

[0036] In forms of the first, second, or third aspects (and/or embodiments thereof), the organic sludge is in the form of an activated sludge, such as from a wastewater treatment process.

[0037] In forms of the first, second, or third aspects (and/or embodiments thereof), the organic sludge comprises organic sludge solids, and the organic sludge solids have a specific gravity of at least 2. Generally, higher specific gravities are advantageous as these result in more effective dewatering treatment processes.

Brief Description of Drawings

[0038] **Figure 1** is a schematic illustration of a static organic sludge dewatering system according to one embodiment of the invention.

[0039] **Figure 2** is a schematic illustration of a dynamic organic sludge dewatering system according to another embodiment of the invention.

[0040] **Figure 3** is a circuit diagram of a high frequency converter with a design based on an AC-DC diode rectifier with an adjustable auto-transformer to control DC voltage.

[0041] **Figure 4** is a circuit diagram of an AN 34092B gate drive.

Description of Embodiments

[0042] The present invention relates to a method and apparatus for dewatering organic sludge, such as activated sludge, that comprises the application of ultrasound to the organic sludge to release water bound within the organic sludge as free water which free water can be readily separated from the organic sludge via the application of a pulsed electric field.

[0043] Without wishing to be bound by theory, the inventors are of the view that propagating ultrasonic waves throughout a liquid or semi-liquid organic sludge generates a mechanical force within the sludge via compression and rarefaction cycles associated with the ultrasonic waves. That is, the average distance between molecules in the sludge medium is changed (e.g. decreased and increased with the compression and rarefaction components of the ultrasonic wave) which causes cavitation and/or sonoporation when the average distance between molecules exceeds a critical distance. During sonoporation, microbubbles are generated which then burst with continuous exposure to ultrasound.

[0044] When the bubbles are burst, the release of this high pressure causes a variety of different effects within the sludge medium, such as ionization and generation of free radicals. These effects can result in chemical and mechanical changes within the sludge medium. An advantageous chemical change is the breaking the chemical bonds within the sludge medium that bind water within or to the sludge so that this bound water is released in the form of free water. An advantageous mechanical effect is that the ultrasound excitation can change viscosity of a liquid or semi-liquid sludge which may promote the separation of the freed water from the sludge as discussed below.

[0045] The inventors have also found a pulsed electric field can be used to separate the free water from the sludge by moving that free water away from the sludge in the direction of field excitation. The freed water can be forced to move and directed with a pulsed electric field which creates a dewatering stream channel for removal of the freed water. The inventors have found that a pulsed electric field with a frequency of from about 1 kHz up to about 1 MHz and a peak electric field strength of from about 1 V/cm up to about 500 V/cm is particularly useful for the removal of the freed water.

[0046] The present invention finds use for in-situ dewatering processes or dewatering at various treatment stages in a dewatering process and may be used in place of an existing dewatering process or as an additional unit process prior to, during, or after an existing dewatering process. In one example, the method and apparatus of the invention is used instead of a traditional gravity separator, thus reducing capital expense. In another example, the method and apparatus of the invention is used as an additional dewatering step after gravity separation to further thicken the underflow from a gravity thickener prior to storage. In still a further example, the method and apparatus of the invention is integrated into an existing unit process, and may for example, be integrated into a gravity thickener to treat the thickened organic sludge prior to discharge as underflow from the gravity thickener. Furthermore, this additional treatment step may be useful in place of, or prior to, other existing thickening unit process such as vacuum filtration, pressure filtration, or gravity belt thickening.

[0047] **Figure 1** is an illustrative embodiment of a static organic sludge dewatering system 100 according to one embodiment of the invention. The system 100 comprises an ultrasonic transducer 101, an electric signal generator 102, and chamber 104 arranged between electrodes 106 and 108. Ultrasonic transducer 101 is configured to apply ultrasound to sample 112 of

sufficient power and frequency to induce sonoporation and/or cavitation in the organic sludge and release bound water from the organic sludge, e.g. frequency of from about 5 kHz to few MHz. Electric signal generator 102 is configured to generate an electric signal 110 at a frequency of from about 10 kHz up to about 1000 kHz such that a pulsed electric field with an electric field strength of from about 10 V/cm up to about 50 V/cm is generated across chamber 104 and current flows between electrodes 106 and 108 when chamber 104 contains organic sludge sample 112, such as in the form of an activated sludge.

[0048] The electric voltage waveform and amplitude depend on the conductivity of the organic sludge, the dimension of the chamber and size of the plates. As generally discussed above, the inventors are of the view that the pulsed electric field causes high frequency resonance within the organic sludge which moves the released water away from the organic sludge in the direction of the applied current. The released water can then be readily removed from the system 100 by means known to those skilled in the art, e.g. decanted or otherwise pumped from an outlet of the system 100. The remaining organic sludge is at higher solids content and thus are more easily and cost effectively stored or disposed of.

[0049] A typical treatment time for an in-situ dewatering process is from about 5 minutes up to about 1 hour, subject to the nature of the organic sludge being dewatered and the dewatering parameters being used.

[0050] The static system 100 may be adapted for batch or semi batch operation. The static system 100 may include a chamber 104 for receiving the and retaining the organic sludge for treatment. Alternatively, the chamber 104 may instead be a space defined by the separation of the two electrodes 106 and 108. In this case, the electrodes may be lowered or submerged into the organic sludge for localised treatment of the organic sludge.

[0051] **Figure 2** is an illustrative embodiment of a dynamic organic sludge dewatering system according to another embodiment of the invention for a plug flow type dewatering processes. The system 200 comprises: an ultrasonic transducer 201, an electric signal generator 202, and flow chamber 204 with electrodes 206 and 208 arranged in opposite walls of flow chamber 204. Flow chamber 204 includes: an inlet 210 through which organic sludges are pumped via pump 212, a free water outlet 214, and a dewatered organic sludge outlet 216. Ultrasonic transducer 201 is configured to apply ultrasound to an organic sludge sample flowing between electrodes

206 and 208 of sufficient power and frequency to induce sonoporation and/or cavitation in the organic sludge sample and release bound water from the organic sludge, e.g. frequency of from about 5 kHz to about few MHz. Electric signal generator 202 is configured to generate an electric signal 218 at a frequency of from about 10 kHz up to about 1000 kHz such that a pulsed electric field with an electric field strength of from about 10 V/cm up to about 50 V/cm is generated across flow chamber 204 and current flows between electrodes 206 and 208 as organic sludge is pumped therethrough. As above, the application of the pulsed electric field separates the bound water from the organic sludge. Freed water is discharged through free water outlet 214 and dewatered organic sludge is discharged through outlet 216.

Examples

[0052] The following example describes an experimental setup for dewatering an organic sludge according to one embodiment of the invention.

[0053] **Figure 1** illustrates a reaction vessel for the application of ultrasound and high voltage pulsed power signals to the organic sludge via plate electrodes. Characteristics of an exemplary activated sludges are provided in **Table 1** below:

Table 1: Exemplary activated sludges

Parameter	Sample 1	Sample 2
Total Solids (TS) (g/L)	33.2 ± 0.3	40.1 ± 2.8
Volatile Solids (VS) (g/L)	21.9 ± 0.4	33.2 ± 2.6
Total Chemical Oxygen Demand (TCOD) (g/L)	30.0 ± 0.9	54.4 ± 5.9
Total Kjeldahl Nitrogen (TKN) (g N/L)	1.6 ± 0.2	2.0 ± 0.1
Ammonium Nitrogen ($\text{NH}_4^+\text{-N}$) (mg/L)	1243 ± 12	65.9 ± 20.1

[0054] The high voltage pulsed power signals can be applied with an electric signal generator. The electric signal generator is a high frequency converter with a design based on an AC-DC diode rectifier with an adjustable auto-transformer to control DC voltage. The DC voltage is supplied to a single phase inverter based on GaN semiconductor technology with an ultra-fast switching frequency and transient. A complete Half bridge power circuit with High Efficiency 600V 70m Ω X-GaN transistor is utilised for DC-AC inverter topology. A circuit diagram of an electric signal generator is shown in **Figure 3**.

[0055] GaN switching devices require special PCB boards with very low loop inductances and gate drives. Given this, a AN 34092B gate drive (see **Figure 4**) can be used which (i) supports high switching frequency ($\sim 4\text{MHz}$), (ii) achieves safe operation by negative voltage source and active miller clamp, and (iii) facilitates gate drive design with high precision gate current source. High / Low side Isolated DC-DC modules are used to provide the necessary bias of the gate drivers for high and low side semiconductor switches. The isolation of these modules is greater than 3000V.

[0056] Control signaling can be generated by an advanced micro-controller TMS320F28379D, connected to a PC with Matlab/Simulink software to program Pulse Width Modulation strategy, generating unipolar signal with adjustable frequency and duty cycle.

[0057] Several electrical pulses with different amplitudes and duty cycles can be used to stimulate the organic sludge samples inside the reaction vessel.

[0058] The reaction vessel may be oriented horizontally to allow the separated water (freed water) to run out of the reaction vessel.

CLAIMS

1. A method of dewatering organic sludges comprising:
subjecting a portion of the organic sludge to ultrasound to release water bound within, or to the organic sludge; and
subjecting the portion of the organic sludge to a pulsed electric field with an electrical frequency of from about 10 kHz up to about 1 MHz and a peak electric field strength of from about 5 V/cm up to about 500 V/cm to separate the released water from the organic sludge.
2. The method of claim 1, wherein the ultrasound is of sufficient power and ultrasonic frequency to induce cavitation in the portion of the organic sludge.
3. The method of claim 1, wherein the ultrasound is of sufficient power and ultrasonic frequency to induce sonoporation within a biological component of the portion of the organic sludge.
4. The method of claim 2 or 3, wherein the ultrasonic frequency is from about 10 kHz to about 50 kHz.
5. The method of any one of the preceding claims, wherein the pulsed electric field is generated using a unipolar voltage signal.
6. The method of any one of the preceding claims, wherein the pulsed electric field is a continuous pulsed electric field.
7. The method of any one of the preceding claims, wherein the step of subjecting at least the portion of the organic sludge to the pulsed electric field further comprises passing an electric current through at least the portion of the organic sludge.
8. The method of claim 7, wherein the released water migrates away from the organic sludge in the direction of the electric field.
9. The method of any one of the preceding claims, wherein prior to the step of subjecting the portion of the organic sludge to ultrasound, the method comprises locating at least the portion of the organic sludge between two electrodes; and

wherein the step of subjecting the portion of the organic sludge to ultrasound is carried out while the portion of the organic sludge is located between the two electrodes.

10. The method of any one of the preceding claims, wherein the method of dewatering organic sludges is carried out after anaerobic digestion of the organic sludge.

11. The method of any one of the preceding claims, wherein the organic sludge is an activated sludge.

12. The method of any one of the preceding claims, wherein the organic sludge has a total solids content of at least about 20 g/L.

13. The method of any one of the preceding claims, wherein the organic sludge has a volatile solids content of at least about 15 g/L, and/or a total chemical oxygen demand of at least about 20 g/L up to about 80 g/L, and/or a total Kjeldahl nitrogen content of at least about 1 g N/L up to about 3 g N/L, and/or an ammonium nitrogen content of from about 40 mg/L up to about 1500 mg/L.

14. The method of any one of the preceding claims, wherein the organic sludge has an apparent viscosity of from about 50 cP to about 1000 cP when measured at a shear rate of 100 s^{-1} and at 25 °C.

15. The method of any one of the preceding claims, wherein the organic sludge comprises particles with a D10 in the range of from about 10 μm up to 120 μm , and/or a D50 in the range of from about 50 μm up to 400 μm , and/or a D90 in the range of from about 130 μm up to 500 μm .

16. The method of any one of any one of the preceding claims, wherein the organic sludge has a zeta potential in the range of from about -10 mV to about -30 mV.

17. An apparatus for dewatering an organic sludge with water bound within or thereto, the system comprising:

an ultrasonic transducer configured to apply ultrasound to the organic sludge;

two spaced apart electrodes configured to apply a pulsed electric field to organic sludge located therebetween; and

an electric signal generator configured to generate the pulsed electric field at an electrical frequency of from about 1 kHz up to about 1 MHz and at sufficient voltage to provide the pulsed electric field with a peak electric field strength of from about 5 V/cm up to about 500 V/cm.

18. The apparatus of claim 17, wherein the ultrasound is of sufficient power and ultrasonic frequency to induce cavitation in the portion of the organic sludge.

19. The apparatus of claim 17, wherein the ultrasound is of sufficient power and ultrasonic frequency to induce sonoporation within a biological component of the portion of the organic sludge.

20. The apparatus of any one of claim 18 or 19, wherein the ultrasonic frequency is from about 10 Hz to about 50 Hz.

21. The apparatus of any one of claims 17 to 20, wherein the electric signal generator is configured to generate the pulsed electric field using a unipolar voltage signal.

22. The apparatus of any one of claims 17 to 21, wherein electric signal generator is configured to generate a continuous pulsed electric field.

23. The apparatus of any one of claims 17 to 22, wherein the electric signal generator is configured to pass an electric current between the two spaced apart electrodes.

24. The apparatus of any one of claims 17 to 23, wherein the electrical frequency is from about 10 kHz up to about 500 kHz, and/or the field strength is from about 10 V/cm up to about 50 V/cm, and/or the pulsed electric field has a duty cycle of from about 5% to about 90%.

25. Use of an apparatus according to any one of claims 17 to 24 to dewater organic sludge.

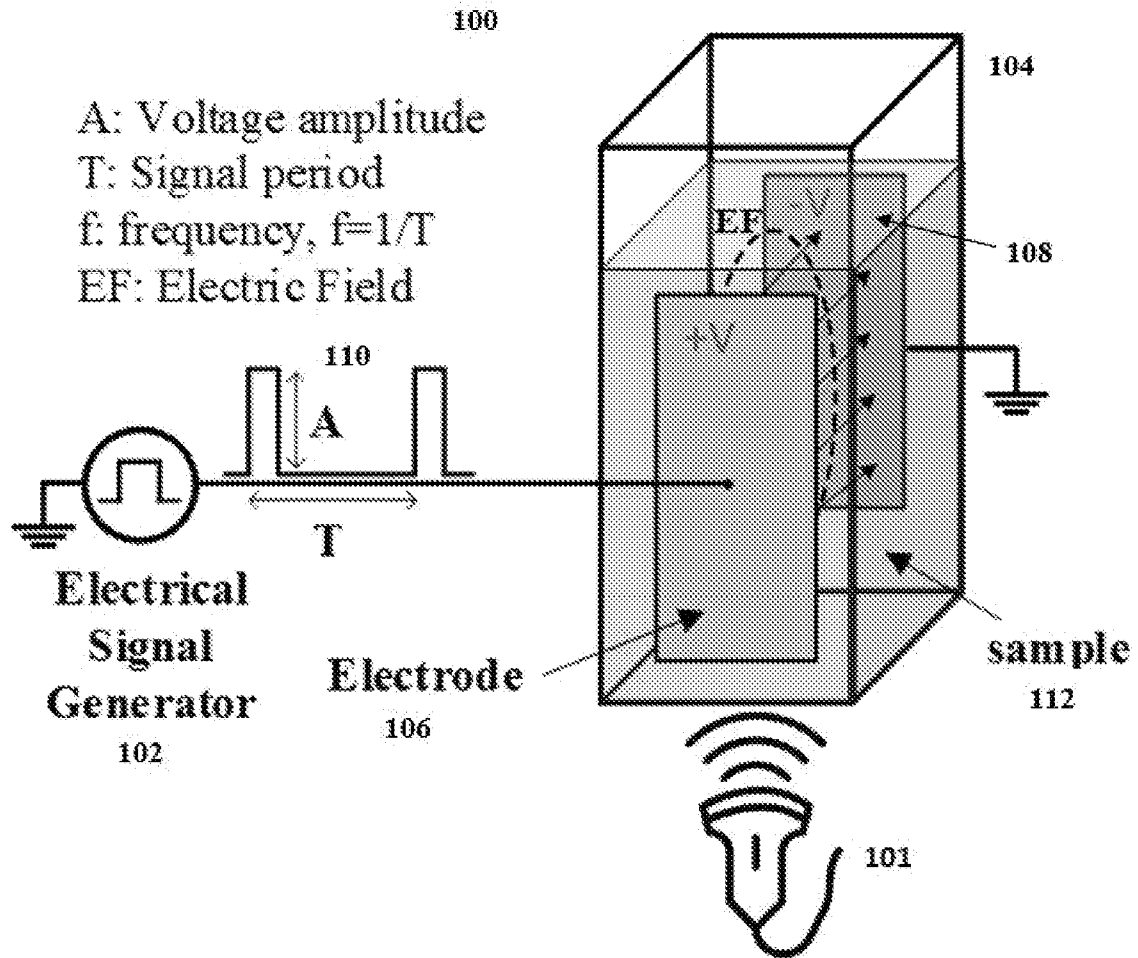


Figure 1

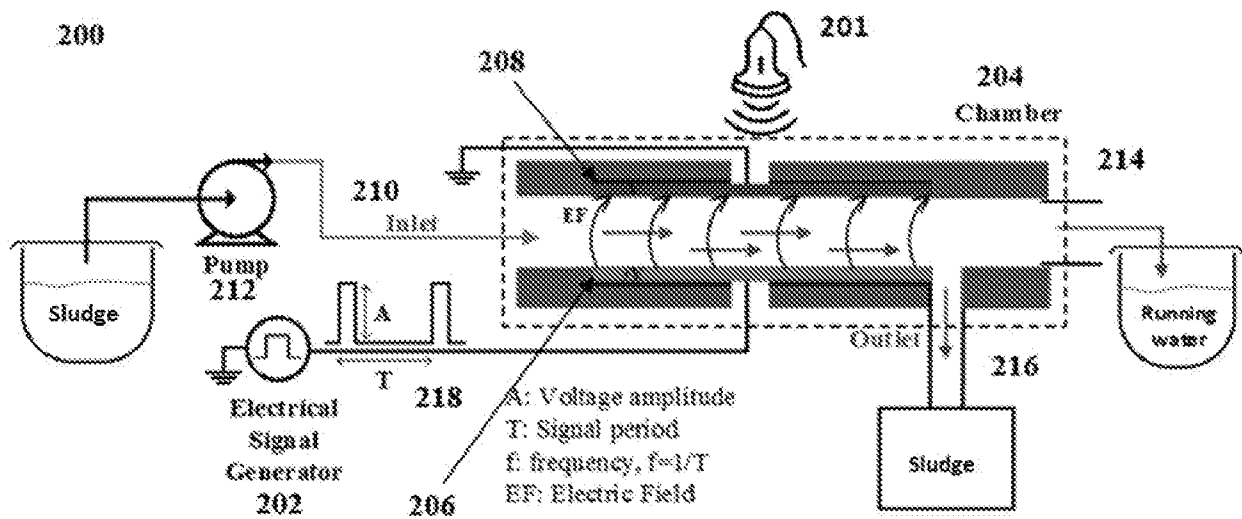


Figure 2

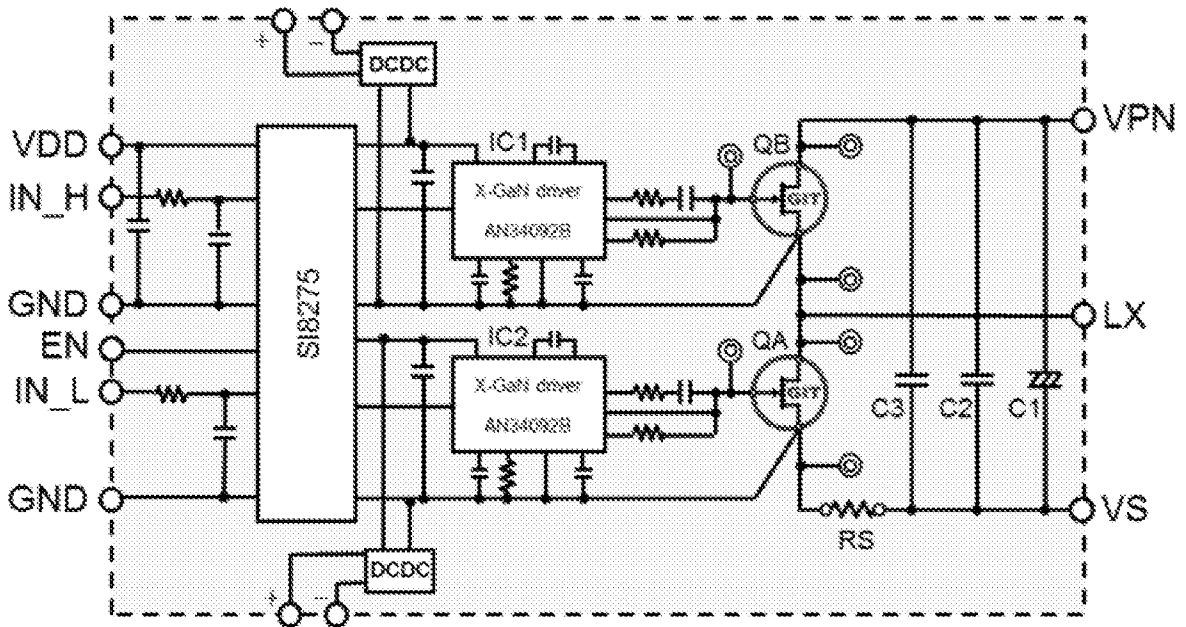


Figure 3

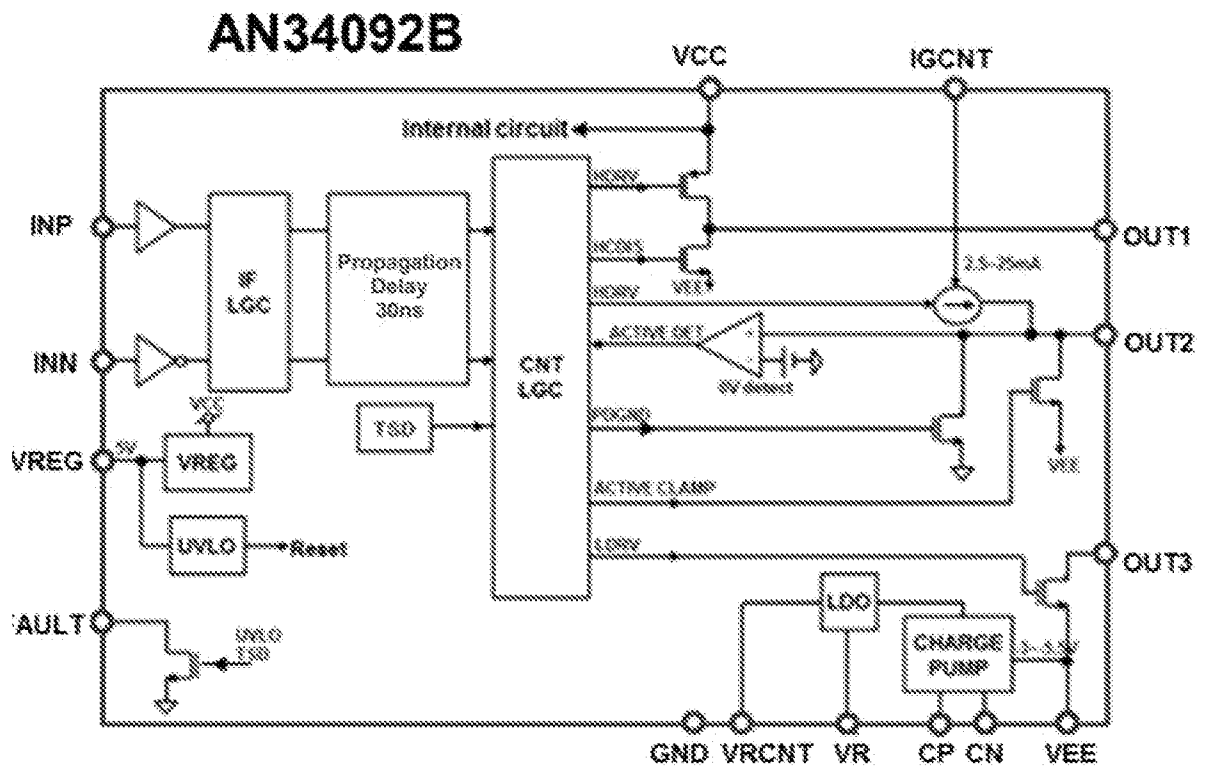


Figure 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2021/050246

A. CLASSIFICATION OF SUBJECT MATTER

C02F 1/36 (2006.01) C02F 11/12 (2019.01) C02F 11/15 (2019.01)

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)

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)

Database: PATENW, Google patents, Google scholar; IPC/CPC Marks - C02F11/15, C02F11/12, C02F11/21, Y02W10/20, C02F1/36, C02F1/469, C02F2201/002, C02F2201/48; Key words: ULTRA_SONIC+, ULTRA_SOUND+, PULS+, PEAK, SIGNAL+, ELECTR+, GENERAT+, FIELD?, SLUDG+, WAST+, ENVIRONMENT+, SONOPORAT+, SONOCHEM+, ACOUST+, CAVIT+, RELEAS+, REMOV+, REDUC+, SEPARAT+, WATER, LIQUID?; Also searched in Google Patents and Google scholar with key words like DEWATERING, SLUDGE, ELECTRICAL, ULTRASOUND and similar key words; Applicant and inventors' name searched in IP Australia internal database and in Espacenet;

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

☒ 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	"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
"D" document cited by the applicant in the international application	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search
21 May 2021

Date of mailing of the international search report
21 May 2021

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
Email address: pct@ipaustalia.gov.au

Authorised officer

Praveen Jain
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No. +61262223653

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2021/050246
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2019/175229 A1 (NATURAL SYNERGIES LTD) 19 September 2019 Abstract, Claims, page 5 line 26 - 30, page 6 line 4 - 6, page 19 line 10	1 - 25
Y	MAHMOUD A ET AL, "Electrical field: A historical review of its application and contributions in wastewater sludge dewatering", WATER RESEARCH, ELSEVIER, AMSTERDAM, NL, vol. 44, no. 8, ISSN 0043-1354, (20100401), pages 2381 - 2407, (20100206), XP026993902 Abstract, Page 2382, 2385 - 2400, Table - 3, Fig. 8	1 - 25
Y	CN 109095742 A (UNIV HOHAI) 28 December 2018 & English machine translation retrieved from Google Patents and English Abstract from EPODOC Abstract, Claims, Figures	1 - 25
Y	CN 209144004 U (UNIV HOHAI) 23 July 2019 & English machine translation retrieved from Google Patents and English Abstract from EPODOC Abstract, Claims, Figures	1 - 25
Y	CN 109824235 A (RAO BINQI) 31 May 2019 & English machine translation retrieved from Google Patents and English Abstract from EPODOC Abstract, Claims, Figures	1 - 25

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2021/050246	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
WO 2019/175229 A1	19 September 2019	WO 2019175229 A1	19 Sep 2019
		CN 111902372 A	06 Nov 2020
		EP 3765411 A1	20 Jan 2021
		US 2021039975 A1	11 Feb 2021
CN 109095742 A	28 December 2018	CN 109095742 A	28 Dec 2018
		CN 109095742 B	12 Jan 2021
CN 209144004 U	23 July 2019		
CN 109824235 A	31 May 2019	CN 109824235 A	31 May 2019
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2019)			