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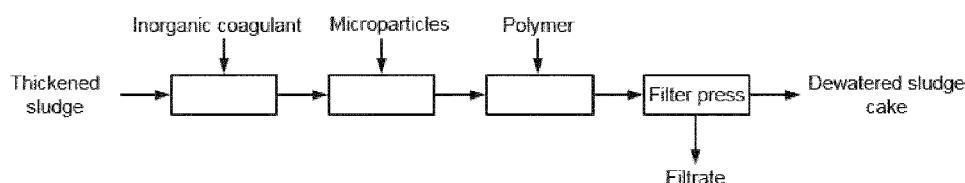
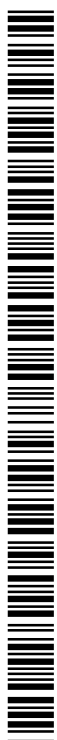


Fig.2

(57) Abstract: The present invention relates to a process for treatment of undigested or anaerobically digested sludge comprising the steps of providing an inorganic coagulant; adding said inorganic coagulant to the sludge to provide a chemically treated sludge; providing a polymer; providing microparticles; adding the polymer and microparticles to the chemically treated to provide a chemically conditioned sludge; and dewatering the chemically conditioned sludge using a mechanical equipment to obtain a dewatered sludge cake.



PROCESS FOR IMPROVED SLUDGE DEWATERING

Technical field

The present invention relates to dewatering of sludge using different additives to provide a sufficient amount of water removal.

5 Background

A lot of waste waters are produced worldwide today. With increasing industrialisation and enlarging municipal areas, the valuable water resources becomes even more valuable. As more wastewater is produced, more sludge for disposal is obtained. In order to be careful with the condition of the Earth
10 providing efficient and environmentally friendly ways of using the Earth's resources is of utmost importance for the future.

When wastewaters are treated different types of sludges are obtained as byproducts depending on which type of process is used for a specific wastewater treatment plant (WWTP). The sludge obtained during a
15 wastewater purification process may be considered a refuse or a product to be used in further processes. Independently of the classification of the sludge obtained it is often desirable to make sure that the sludge volume is decreased as much as possible to e.g. concentrate the product obtained, lower transportation costs and/or lower waste handling costs.

20 Municipal wastewater or sewage treatment generally involves three stages, called primary, secondary and tertiary treatment.

Municipal wastewater contains a lot of different substances which are not desirable in water. Influent of a municipal wastewater treatment may be black and gray waters.

25 A pre-treatment removes all materials that can be easily collected from the raw sewage or wastewater before they damage or clog any pumps and sewage lines of primary treatment apparatuses

The primary treatment is designed to remove coarse, suspended and floating solids from raw sewage. It includes screening to trap solid objects and
30 sedimentation by gravity to remove suspended solids. This level is sometimes

referred to as “mechanical treatment”, although chemicals are often used to accelerate the sedimentation process. The primary sludge may be composted, put on landfill, dewatered or dried to reduce the water content, and/or digested for methane production.

- 5 After the primary treatment, the wastewater is directed to a secondary treatment, which includes a biological treatment and removes the dissolved organic matter, phosphorus and nitrogen that escapes the primary treatment. This is achieved by microbes consuming the organic matter, and converting it to carbon dioxide, water, and energy for their own growth and reproduction.
- 10 The secondary sludge may be composted, put on landfill, dewatered, dried and/or digested for methane production.

Tertiary treatment is sometimes defined as anything more than primary and secondary treatment in order to further purify the waters.

- The sludge obtained in the different steps may be further decomposed,
- 15 e.g. to provide biogas, and the digestate obtained may be dewatered to minimize the water content of the final solids cake obtained. For sludge downstream processing such as transport, composting, incineration, and disposal as high dry solids content as possible is desirable.

- Sludge is often divided into three categories depending on which
- 20 treatment process have been used.

- Undigested sludge is the sludge obtained from a wastewater treatment of a WWTP. The composition of the undigested sludge depends on the sludge genesis inside the WWTP. Often it is a mix between primary and secondary sludge, and sometimes tertiary sludge, strongly depending on the
- 25 locally installed methods of the WWTP. Due to a difference in feed sludge and/or treatment conditions of the WWTP the sludge may contain different proportions of sludge from each treatment step of the WWTP, which may be varying over days and weeks. An example of this could be that more secondary sludge is obtained during the winter and more primary sludge may
- 30 be obtained during the summer. These variations may cause problems in the dewatering of the sludge. A known option to handle such undesirable variations is to provide an anaerobic digestion of the sludge, typically of about

25 days, to form a buffer for seasonal variations in sludge quality, and to deliver more stable conditions for dewatering.

Anaerobic treatment of sludge provides a degradation of the organic mass by the anaerobic bacterial consortium. The sludge volumes decrease considerably. The organic matter of the sludge is transformed to mainly methane for energy production. The organic content of anaerobically digested sludge (anaerobic sludge) may be below 50%. In EU and US, more than 90% of all WWTP sludges are anaerobically treated to produce energy. The anaerobic treatment is also a way to effectively reduce disposal costs.

10 Aerobic treatment of sludge provides cell mass build-up to eliminate specific compounds. The sludge volume usually increases. Examples of materials eliminated by the aerobic treatment are pathogens for improved hygienization. Aerobic sludges are voluminous and difficult to dewater. They contain high amounts of organics, sometimes as much as 80%. In common
15 practice, aerobic sludges do not appear in Europe and US due to regulations relating to that the raw sludge has to go for an anaerobic digestion before it goes to the dewatering step in all WWTPs.

As can be understood aerobic sludges contain a high organic content, anaerobic sludges contain a decreased organic content and undigested
20 sludges contain an undefined mix of sludges depending on applied processes.

There are known processes that add chemicals to the sludge in order to obtain a moderate dewatering. In order to improve the dewatering of such sludges sometimes compounds are added which are less desirable to use
25 from an environmental perspective. Lime is an example of such an undesirable compound to use from an environmental view, and it additionally results in an increased amount of solid waste caused by high dosage of lime to meet the treatment requirements. Also, lime highly influences the amount of final residue left after a dewatering step, as the lime absorbs water. Lime
30 reacts with water and carbon dioxide. Lime also changes pH levels of the treated sludge. Thus, if e.g. about 1 kg of lime is used in a treatment process, it results in about 2 kg of sludge residue to be disposed of due to water absorption. Thus, also the increased sludge amount is an undesirable effect

of lime treatment. Even though lime provides good dewatering properties, it is undesirable in view of the aspects that it swells and increases in volume.

Sludge generated by wastewater treatment processes is preferably treated to remove as much of the organic part of the sludge as possible. It is also preferable that as little total solids as possible are remaining after a dewatering step (the finally obtained sludge cake) as the subsequent handling costs of the residue sludge cake highly influences the overall costs of the process. For known processes these two desirable properties have been difficult to combine.

As there is a desire to minimize the water content of the sludge obtained in a WWTP, ways to improve the solids content of a final solids cake are desirable. Several positive effects of increased solids content of the sludge are lowered costs connected to transport, composting, incineration, and/or disposal, and thus as high dry solids content as possible is desirable.

There is a demand to provide novel methods, which are more environmentally friendly compared to conventional methods. The novel processes should use more environmentally friendly components. It is also desirable to provide treatment methods which do not increase the amount of final sludge residues, which needs to be disposed of. In addition, there is still a demand for new improved procedures that efficiently treat the sludge to provide a sufficient and/or enhanced dewatering of the sludge.

Summary of the invention

The present invention provides a process for dewatering sludges. Also, lowered dosage of some added chemicals may be obtained, or the total overall chemical compound dosage may be lowered. The addition of inorganic coagulants and polymers to the sludge enables improved dewatering compared to no addition of chemicals. However, with the process according to the invention which also includes addition of a microparticle compound the subsequent dewatering is improved even further. The combination of polymer, inorganic coagulant and microparticles provide a structure within the sludge. The microparticles act as skeleton builders, to

provide a more open structure with spaces and pathways for any water contained in the sludge to use for draining.

Sludge which is chemically treated, e.g. before a dewatering step, forms aggregated sludge particles so called sludge flocs. Sludge flocs include
5 water connected to the matter in different ways. A large amount (about 70%) of the water of a sludge floc is characterised as free water. Free water is relating to large gatherings of water, which are relatively easy to reduce in a sludge dewatering process. Apart from free water also an amount of about 20% is characterised as capillary water. Capillary water is more tightly
10 bonded to the sludge flocs and is not really affected by known dewatering techniques. The sludge flocs also include internal water and adsorption and adhesion water. These water types are found in an amount of about 10% of a sludge floc. Internal water (can also be called cellular water) is found within the sludge cells which have been aggregated into flocs. Adsorption and
15 adhesion water is water tightly bound to the sludge cells' surfaces. In order to remove the internal water the cells would need to be ruptured or destroyed. A drawing in Figure 1 is provided to illustrate the composition of a sludge floc.

With the present combination of polymer, inorganic coagulant and microparticles the sludge does not swell by absorption of water, as is the case
20 for conventional lime addition. In addition, the present combination and process is able to remove more water from the sludge flocs, not only removing free water contained therein but also capillary water is at least partially removed from the flocs. Thus, the present solution to improve sludge treatment is solving several problematic issues raised for conventional
25 treatments.

The draining of water from the sludge may be facilitated by mechanical separation processes. The compounds added to the sludge give support by providing a structured sludge which helps to lower compressibility. Thus, mechanical dewatering further improves the decrease in water content of the
30 treated sludge residues.

One aspect of the present invention relates to a process for treatment of undigested or anaerobically digested sludge comprising the steps of:

- providing an inorganic coagulant;

- adding said inorganic coagulant to the sludge to provide a chemically treated sludge;

- providing a polymer;

- providing microparticles;

5 - adding the polymer and microparticles to the chemically treated to provide a chemically conditioned sludge; and

- dewatering the chemically conditioned sludge using a mechanical equipment to obtain a dewatered sludge cake.

According to one embodiment the inorganic coagulant is selected from
10 salts of aluminum, iron, magnesium, calcium, zirconium and zinc, or any combination thereof; preferably selected from the group chlorides, and sulphates, and any combination thereof; and preferably calcium chloride, calcium sulphate, zinc chlorides, iron chlorides, iron sulphates, aluminium chlorides, and aluminium sulphates, and any combination thereof.

15 According to one embodiment the inorganic coagulant is selected from the group ferrous chloride, ferric chloride, ferrous sulphate, ferric sulphate, ferrous chlorosulphate, ferric chlorosulphate, polyferrous sulphate, polyferric sulphate, polyferrous chloride, polyferric chloride, polyaluminium sulphate, polyaluminium chloride, polyferrous aluminium chloride, polyferric aluminium
20 chloride, polyferrous aluminium sulphate, and polyferric aluminium sulphate, and any combination thereof.

According to one embodiment the polymer is a cationic, nonionic and anionic polymer; and preferably cationic polymer.

According to one embodiment the polymer is selected from the group
25 polyacrylamide, polyamine, polydiallyldimethylammonium chloride (polyDADMAC), melamine formaldehydes, natural polymers, natural polysaccharides, and cationic or anionic derivatives thereof, and any combination thereof; preferably the polymer is selected from polyacrylamide, polyamine and polyDADMAC, and any combination thereof; and preferably
30 the polymer is selected from polyacrylamides, and any combination thereof.

According to one embodiment the microparticles are selected from the group titanium dioxide, zirconium oxide, zinc oxide, aluminium oxide, clays and colloidal silica, and any combination thereof; and preferably titanium

dioxide zirconium oxide, zinc oxide, aluminium oxide, betonites, hectorites, smectites, and silica sols, and any combination thereof.

According to one embodiment the polymer and microparticles are added to the sludge in any order or simultaneously.

- 5 According to one embodiment the process further comprises a mixing step wherein the inorganic coagulant is mixed in the sludge to provide the chemically treated sludge.

- According to one embodiment the process further comprises a mixing step wherein the polymer and/or microparticles are mixed in the chemically
10 treated sludge to provide the chemically conditioned sludge.

- According to one embodiment the process further comprises a thickening step before the dewatering step. The coagulant may be added before, during and/or after such a thickening step, preferably during and/or after. The polymer and/or microparticles may be added during and/or after
15 such a thickening step.

 According to one embodiment the mechanical equipment used for the dewatering employs screwing, centrifugation and/or filtration; preferably is selected from belt press, centrifuge, filter press (disk filter press), and screw press; and preferably is a belt press.

- 20 According to one embodiment the dewatered sludge cake has a dry content of at least 20 wt%; preferably at least 25 wt%; preferably at least 30 wt%; preferably at least 35 wt%; and preferably at least 40 wt%.

- According to one embodiment the inorganic coagulant is provided in an amount of 0.5-100 kg/ton dry solids of sludge, preferably 5-70 kg/ton dry
25 solids of sludge, preferably 5-50 kg/ton dry solids of sludge, and preferably 10-50 kg/ton dry solids of sludge.

- According to one embodiment the polymer is provided in an amount of 0.4-10 kg/ton dry solids of sludge, preferably 0.8-6 kg/ton dry solids of sludge, preferably 1.2-5 kg/ton dry solids of sludge, and preferably 1.6-4 kg/ton dry
30 solids of sludge.

 According to one embodiment the microparticles are provided in an amount of 0.075-100 kg/ton dry solids of sludge, preferably 0.15-40 kg/ton dry solids of sludge.

Short description of the drawings

Figure 1 shows a schematic drawing of a sludge floc, including different water types connected to it.

Figure 2 shows a schematic drawing of an embodiment of the present
5 process.

Figure 3 shows a schematic drawing of another embodiment of the present process.

10 Detailed description

The present invention provides a method for dewatering sludges, preferably sludges from WWTPs.

The sludge that may be treated according to the present invention may be an undigested sludge or an anaerobic sludge. Specifically undigested
15 sludges are of interest.

Undigested sludges are unpredictable to handle in the dewatering process. Also, they may contain organic matter which is hazardous for the health of humans and/or animals. Thus, these sludges are often treated with excessive amounts of chemicals. The chemicals used are often undesirable
20 from an environmental perspective as they need to be aggressive enough to treat the sludge so that the sludge becomes easier and better to handle, and using such in excessive amounts of such chemicals only makes the situation worse for WWTP workers and the environment. In many cases, aggressive, corrosive, and dangerous chemicals are not accepted by the operators of the
25 WWTPs for sludge treatment.

Even if anaerobically treated sludge has undergone a strong transformation and degradation of its organic part, the organic fraction is often still more than 50% of the whole sludge structure, depending of the efficiency of the anaerobic digestion. The organic part still contains large amounts of
30 hazardous compounds and pathogens. Despite the transformation of the organic matter in anaerobically treated sludge, it is still classified as hazardous matter. In addition, the organic part contains the major part of the bound water, which is a major obstacle for dewatering. A reduction of the

sludge volume is therefore a matter of high priority for every WWTP. Any improvement of the dewatering properties of the sludge by novel and advanced chemical and physical methods, featuring reduced chemical consumption, will therefore lead to a minimization of the whole sludge volume for disposal, including the hazardous compounds that are bound the organic part of the sludge.

The present sludge treatment solution involves a chemical conditioning of the sludge and also a mechanical treatment.

Inorganic coagulants are preferably metal salts may be selected from the group salts of aluminum, iron, magnesium and zinc, or any combination thereof. Examples of suitable inorganic coagulant are selected from ferrous, ferric and aluminium containing salts. The inorganic coagulants may include metal salts including chlorides and sulphates thereof. In one embodiment, the inorganic coagulants are selected from the group zinc chlorides, iron chloride, iron sulphate, aluminium chloride, and aluminium sulphates, and any combination thereof. More specifically, the inorganic coagulants that may be used may be selected from the group ferrous chloride, ferric chloride, ferrous sulphate, ferric sulphate, ferrous chlorosulphate, ferric chlorosulphate, polyferrous sulphate, polyferric sulphate, polyferrous chloride, polyferric chloride, polyaluminium sulphate, polyaluminium chloride, polyferrous aluminium chloride, polyferric aluminium chloride, polyferrous aluminium sulphate, and polyferric aluminium sulphate, and any combination thereof. The inorganic coagulants are preferably added before the polymer. The inorganic coagulants are preferably added before the microparticles.

The inorganic coagulants may be provided in an amount of 0.5-100 kg/ton dry solids (DS) of sludge, such as 5-70 kg/ton DS of sludge, 5-50 kg/ton DS of sludge, or 10-50 kg/ton DS of sludge.

The present polymer may be selected from linear or structured polymers. Structured polymers may be e.g. branched and/or crosslinked. Branched polymers can be divided in three different groups, where the type of branching is described. Branched polymers may be e.g. short-chain branched, long-chain branched or hyperbranched.

The present polymer may be selected from cationic, nonionic and anionic polymers. In a preferred embodiment the polymer is a cationic polymer.

The present polymer may be selected from the group polyacrylamide, polyamine, polydiallyldimethylammonium chloride (polyDADMAC), melamine formaldehydes, natural polymers, such as tannins and lignin, natural polysaccharides, such as starch, cellulose, hemicellulose alginate, guar gum, pectin, chitin and chitosan, and cationic or anionic derivatives thereof, and any combination thereof. For example, the compounds may be selected from polyacrylamide, polyamine and polyDADMAC, and any combination thereof. A preferred polymer is cationic polyDADMAC, cationic polyacrylamide or a cationic polyamine, or any combination thereof.

The polymers used may have different molecular weights. The molecular weights are preferably within the range 10 000 – 8 000 000 Daltons (Da). In one embodiment the polyamines may have a molecular weight of about 10 000 to about 250 000 Da. In one embodiment the polyDADMACs may have a molecular weight of about 100 000 to about 300 000 Da. In one embodiment the polyacrylamides may have a molecular weight of about 1 000 000 to about 4 000 000 Da. In one embodiment the polyacrylamides of high molecular weight (HMW) quality may have a molecular weight of about 4 000 000 to about 8 000 000 Da.

The polymers may be provided in an amount of 0.4-10 kg/ton dry solids (DS) of sludge, such as 0.8-6 kg/ton DS of sludge, 1.2-5 kg/ton DS of sludge, or 1.6-4 kg/ton DS of sludge.

The present microparticles increase in the amount of free drainage achievable with the present invention. Many different materials may be used for these microparticles. The microparticles may be selected from inorganic materials, such as metal oxides, e.g. titanium dioxide (TiO_2), zirconium oxide (ZrO_2), zinc oxide (ZnO), and aluminium oxide (Al_2O_3), which may have a particle size between 10-150 nm; or different types of clays, e.g. bentonites, hectorites, smectites; or colloidal silica, more specifically silica sols; or any combination thereof. Magnetite (Fe_3O_4) is not a preferred metal oxide according to the present invention due to the magnetic properties thereof. The

materials are considered environmentally friendly. Silica sols have been found to in a good way replace undesirable compounds like lime. The needed addition amounts of clays or silica sols are considerably lower compared to lime, especially for silica sols.

5 The microparticles may have a particle size of about 0.01-100 μm .

The clays, such as betonites, hectorites, smectites, may have a particle size between 1-100 μm , e.g. 1-60 μm . These are microparticles.

The metal oxides, such as titanium oxide, zirconium oxide, zinc oxide, and aluminium oxide, which may have a particle size between 10-150 nm.

10 The colloidal silica or silica sols are characterized below and are also very small microparticles. This means that the metal oxides and silicas all are very small microparticles, i.e. nanosized microparticles, and these may also be referred to as nanoparticles herein.

 Silica sol that could be used may be linear or more branched in
15 structure. The SiO_2 particles of the mentioned silicas tend to aggregate together. High aggregation is important to get good interaction with the polymer to form dense flocs which aids in the mechanical dewatering stage, e.g. using pressing.

 The colloidal silica or silica sols may be surface modified. Examples of
20 modifications may be aluminium surface modified materials.

The silica sols may have a specific surface area of e.g. 700 to 1100 m^2/g . The s-values of the silica sols may vary e.g. between 14 and 34. Total solids of silica sol may vary e.g. between 8 and 16 wt%.

 Silica sols may be divided into 3 types based on structure. Low
25 structure means that most SiO_2 particles are separate particles, medium structure means that SiO_2 particles are formed into chain-like aggregates, and high structure means that the SiO_2 aggregates are branch-like.

 Titanium dioxide, zirconium oxide, zinc oxide, and aluminium oxide are preferably nano-sized particles, and they also show enhanced the dewatering
30 performance.

The microparticles may be provided in an amount of 0.075-100 kg/ton dry solids (DS) of sludge, such as 0.15-40 kg/ton DS of sludge.

For example, when clays, e.g. betonites, hectorites, smectites, are used the amount provided may be about 5-50 kg/ton dry solids (DS) of sludge, such as 10-40 kg/ton DS of sludge.

For example, when nanosized microparticles, such as metal oxides
5 (e.g. titanium dioxide, zirconium oxide, zinc oxide, and aluminium oxide), are used the amount provided may be about 0.5-5 kg/ton dry solids (DS) of sludge, such as 1-4 kg/ton DS of sludge.

For example, when nanosized microparticles, such as colloidal silica, e.g. silica sols, are used the amount provided may be about 0.075-0.75 kg/ton
10 dry solids (DS) of sludge, such as 0.15-0.6 kg/ton DS of sludge.

The combination of compounds is easy to handle and use. Silica sols are often provided as a stable liquid. Clays, like bentonite, may be provided as a powder. If powders are used the process may include an extra mixing step to provide a good distribution of the microparticles and a more
15 homogenous effect during the subsequent liquid separation step.

The use of microparticles in the process influences the dewatering so that the amount of inorganic coagulant needed may be decreased. Microparticles containing silica sols are nanosized structured silicon dioxide particles having a large surface area and good flocculating capability. Thus,
20 reductions in inorganic coagulant dosage may be done.

In the present the inorganic coagulant is first added to the sludge. After this first addition polymer and microparticles are added, which may be performed in either order or simultaneously, to the sludge. The treated sludge is thereafter dewatered using a mechanical equipment to obtain a dewatered
25 sludge cake. It is to be noted that in one embodiment the microparticles are added before the polymer.

The sludge to be dewatered may be subjected to a thickening step as a pretreatment step before and/or during any polymer and/or microparticles are added. This is done in order facilitate the overall processing of the sludge
30 and lower the amount of chemicals needed to be added in the subsequential step. Some dewatering equipment requires a minimum solids content to function in an optimal manner. Sludge thickening is preferably performed to obtain a solids content of about 2-5 wt%. A thickening step may be performed

using a step selected from sedimentation, flotation, centrifugation and rotating drum separation, and any combination thereof. Devices that can be used include e.g. sedimentation thickeners, air floatation thickeners, centrifuges and gravity belt thickeners.

- 5 Polymers need to be added before the sludge can be dewatered (in the mechanical dewatering step), but may be added during and/or after the thickening step, depending on the process used. However, it is to be noted that the inorganic coagulant is always to be added before the polymer. In the case of a thickening step, the inorganic coagulant may need to be added
10 before, during and/or after such a step, depending on if polymer is added during and/or after the thickening step.

- The chemically treated sludge (including the inorganic coagulants, polymers and microparticle compound) may be separated into liquid and solids using a mechanical dewatering step. The dewatering of the sludge may
15 be done by a separation selected from pressing, centrifugation and filtration, and any combination thereof. The separation methods may be performed using any one of a decanter centrifuge, screw press, disk filter press, filter press and belt filter press, and any combination thereof. Dewatering using a device that uses gravity alone may be used according to the present invention
20 but it is preferred that the sludge is dewatered by firmly pressing or squeezing the sludge.

Examples

- Tests were performed to see the improvement in dewatering and
25 impact on addition amounts of the compounds. Undigested sludge was treated with FeCl_3 as inorganic coagulant, a cationic polyacrylamide as polymer, and bentonite or silica sols as microparticles. The polymer used had a molecular weight of about 6 000 000 – 6 500 000 Da. The polymer was added as a polymer product having a solids content of about 44 wt%. The
30 dosages mentioned in the examples relates to the dosages of the polymer product. The bentonite used had a surface area of about 400 m^2/g , and a monomorillonite content of about 70%. The bentonite material had a particle size specification as follows: particles $>53 \mu\text{m}$, max 0.1%. The silica sol used

had a specific surface area (SSA) of 750 m²/g, and a S value (defined as the percentage of silica in the dispersed phase) of 34. The structure of the silica sol was of medium structure and it had no surface modifications. The silica sol was added as a silica sol product having a solids content of about 15 wt%.

- 5 The dosages mentioned in the examples relates to the dosages of the silica sol product. Additions are presented herein as kg per ton dry solids [kg/t DS] of sludge.

To evaluate the tests measurements were made on cake dryness and Capillary Suction Time (CST).

- 10 For the tests, 200 g of sludge was transferred to a 250 mL beaker. Coagulant was first added and rapidly mixed with the sludge. Afterwards, polymer or microparticle was added and the sludge was again mixed until flocs began to form. For the cake dryness tests, the sludge was then poured into an aluminium cup and then a device called Minipress was used to press
- 15 the chemically-conditioned sludge under pressure. This simulates filter press dewatering. Cake dryness measures the solids content of the dewatered sludge (for the tests herein: after pressing at 0.8 mPa for 15 minutes, followed by heating overnight). The solids content of the resulting dewatered sludge “cake” (cake dryness) was measured after drying the cake in an oven at
- 20 105°C overnight.

- CST has been used since the 1970s as a quick and reliable method of characterising sludge filterability and conditionability. The capillary suction pressure generated by standard filter paper is used to ‘suck’ water from the sludge. The rate at which water permeates through the filter paper varies
- 25 depending on the condition of the sludge and the filterability of the cake formed on the filter paper. CST is obtained from two electrodes placed at a standard interval from the funnel. The time taken for the water front to pass between these two electrodes constitutes the CST. A low CST value indicates good dewatering.

- 30 As reference a sample using only inorganic coagulant and polymer was tested. Also the result for untreated sludge is provided.

Table 1. A comparison of sludge dewatering effects using different additives and amounts, and calculations of wet sludge tonnage for disposal.

	FeCl ₃ (kg/tDS)	Polymer (kg/tDS)	Lime (kg/t DS)	Bentonite (kg/tDS)	Silica sol (kg/tDS)	CST (s)	Cake dryness (%)	Inorganic solids increase from the addition of chemicals
Untreated						235.6		
Ref 1 Lime	70	0	200	0	0	14.6	47	27.0%
Ref 1	50	6	0	0	0	8.5	38	5.0%
1	40	6	0	0	1	6.4	40	4.1%
2	30	6	0	0	2	10.0	42	3.2%
3	20	6	0	0	3	13.1	42	2.3%
4	10	6	0	0	4	39.0	41	1.4%
5	30	4	0	0	2	20.9	41	3.2%
6	40	6	0	10	0	5.3	37	5.0%
7	30	6	0	20	0	6.5	36	5.1%
8	20	6	0	30	0	9.0	33	5.0%
9	10	6	0	40	0	19.5	31	5.1%
10	10	8	0	40	0	6.1	32	5.1%

Table 2. A comparison of sludge dewatering effects using different additives and amounts. Different types of microparticles are compared.

	FeCl ₃ (kg/tDS)	Polymer (kg/tDS)	Lime (kg/t DS)	Al ₂ O ₃ , 10nm (kg/tDS)	Al ₂ O ₃ , 150 nm (kg/tDS)	ZrO ₂ , 20-40 nm	Silica sol	ZnO, 20~30 nm	ZnO 150 nm	CST (s)	Cake dryness (%)	Inorganic solids increase from the addition of chemicals
Untreated										266.6		
Ref 2 Lime	50	0	200	0	0	0	0	0	0	13.8	47.6	25%
Ref 2	50	6	0	0	0	0	0	0	0	8.6	39.0	5.0%
11	30	6	0	2	0	0	0	0	0	15.5	42.6	3.5%
12	30	6	0	0	2	0	0	0	0	14.9	43.4	3.3%
13	30	6	0	0	0	2	0	0	0	15.1	41.8	3.5%
14	30	6	0	0	0	0	2	0	0	13.3	42.0	3.5%
15	30	6	0	0	0	0	0	2	0	13.9	42.7	3.3%
16	30	6	0	0	0	0	0	0	2	14.8	42.8	3.3%

As can be seen from the tests, the amount of coagulant used may be decreased considerably and still obtain a low CST value when being replaced at least partially by a microparticle. Addition of microparticles helped to enhance the sludge dewatering performance as indicated by the higher cake dryness and low dosage of microparticles could avoid increasing the amount of inorganic solids in the dewatered sludge. Upon review of the last column in tables 1 and 2 the difference in solids residue of the sludge cake between lime treated sludge and sludge treated according to the present invention is distinct.

CLAIMS

1. A process for treatment of undigested or anaerobically digested sludge comprising the steps of:
- 5 - providing an inorganic coagulant;
 - adding said inorganic coagulant to the sludge to provide a chemically treated sludge;
 - providing a polymer;
 - providing microparticles;
- 10 - adding the polymer and microparticles to the chemically treated to provide a chemically conditioned sludge; and
 - dewatering the chemically conditioned sludge using a mechanical equipment to obtain a dewatered sludge cake.
- 15 2. The process according to claim 1, wherein the inorganic coagulant is selected from salts of aluminum, iron, magnesium, calcium, zirconium and zinc, or any combination thereof; preferably selected from the group chlorides, and sulphates, and any combination thereof; and preferably calcium chloride, calcium sulphate, zinc chlorides, iron chlorides, iron
- 20 sulphates, aluminium chlorides, and aluminium sulphates, and any combination thereof.
3. The process according to claim 1 or 2, wherein the inorganic coagulant is selected from the group ferrous chloride, ferric chloride, ferrous sulphate,
- 25 ferric sulphate, ferrous chlorosulphate, ferric chlorosulphate, polyferrous sulphate, polyferric sulphate, polyferrous chloride, polyferric chloride, polyaluminium sulphate, polyaluminium chloride, polyferrous aluminium chloride, polyferric aluminium chloride, polyferrous aluminium sulphate, and polyferric aluminium sulphate, and any combination thereof.
- 30 4. The process according to anyone of claims 1-3, wherein the polymer is a cationic, nonionic and anionic polymer; and preferably cationic polymer.

5. The process according to anyone of claims 1-4, wherein the polymer is selected from the group polyacrylamide, polyamine, polydiallyldimethylammonium chloride (polyDADMAC), melamine formaldehydes, natural polymers, natural polysaccharides, and cationic or anionic derivatives thereof, and any combination thereof; preferably the polymer is selected from polyacrylamide, polyamine and polyDADMAC, and any combination thereof; and preferably the polymer is selected from polyacrylamides, and any combination thereof.
6. The process according to anyone of claims 1-5, wherein the microparticles are selected from the group titanium dioxide, zirconium oxide, zinc oxide, aluminium oxide, clays and colloidal silica, and any combination thereof, and preferably titanium dioxide, zirconium oxide, zinc oxide, aluminium oxide, bentonites, hectorites, smectites, and silica sols, and any combination thereof.
7. The process according to anyone of claims 1-6, wherein the polymer and microparticles are added to the sludge in any order or simultaneously.
8. The process according to anyone of claims 1-7, further comprising a mixing step wherein the inorganic coagulant are mixed in the sludge to provide the chemically treated sludge.
9. The process according to anyone of claims 1-8, further comprising a mixing step wherein the polymer and/or microparticles are mixed in the chemically treated sludge to provide the chemically conditioned sludge.
10. The process according to anyone of claims 1-9, wherein the mechanical equipment used for the dewatering employs screwing, centrifugation and/or filtration; preferably is selected from belt press, centrifuge, filter press (disk filter press), and screw press; and preferably is a belt press.
11. The process according to anyone of claims 1-10, wherein the dewatered sludge cake has a dry content of at least 20 wt%; preferably at least 25 wt%;

preferably at least 30 wt%; preferably at least 35 wt%; and preferably at least 40 wt%.

12. The process according to anyone of claims 1-11, wherein the inorganic
5 coagulant is provided in an amount of 0.5-100 kg/ton dry solids of sludge,
preferably 5-70 kg/ton dry solids of sludge, preferably 5-50 kg/ton dry solids of
sludge, and preferably 10-50 kg/ton dry solids of sludge.

13. The process according to anyone of claims 1-12, wherein the polymer is
10 provided in an amount of 0.4-10 kg/ton dry solids of sludge, preferably 0.8-6
kg/ton dry solids of sludge, preferably 1.2-5 kg/ton dry solids of sludge, and
preferably 1.6-4 kg/ton dry solids of sludge.

14. The process according to anyone of claims 1-13, wherein the
15 microparticles are provided in an amount of 0.075-100 kg/ton dry solids of
sludge, preferably 0.15-40 kg/ton dry solids of sludge.

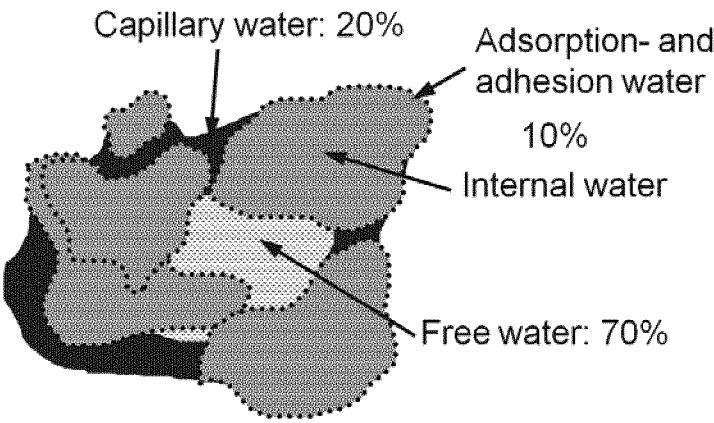


Fig. 1

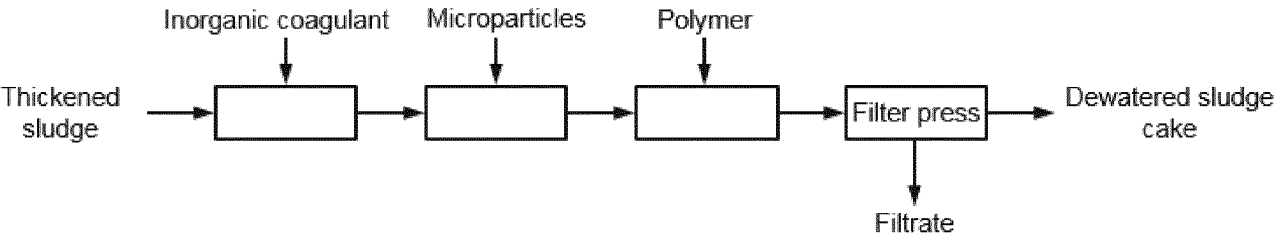


Fig.2

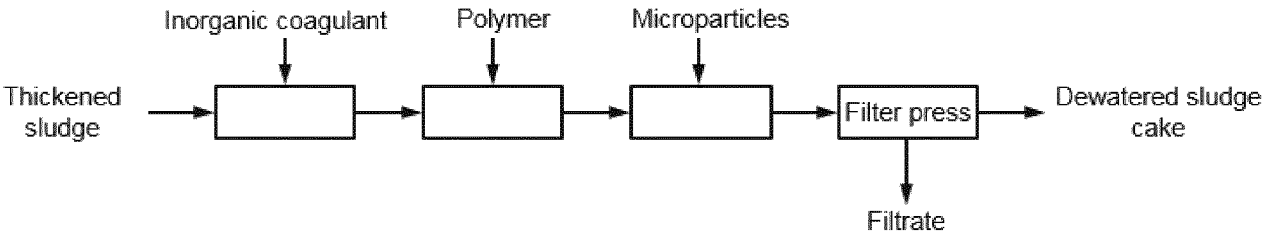


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/072613

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01D21/01 C02F1/52 C02F1/56 C02F11/14
ADD. C02F11/12

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)
B01D C02F

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	EP 1 115 663 A1 (NALCO CHEMICAL CO [US]) 18 July 2001 (2001-07-18) paragraph [0001] paragraph [0011] - paragraph [0026] claims 1-7; examples 1-2 -----	1-14
A	US 5 906 750 A (HAASE RICHARD ALAN [US]) 25 May 1999 (1999-05-25) the whole document -----	1-14
A	EP 2 039 658 A1 (KUBINGER ULRICH [AT]) 25 March 2009 (2009-03-25) the whole document -----	1-14
A	US 7 291 275 B1 (DAVIS ROBERT A [US] ET AL) 6 November 2007 (2007-11-06) the whole document -----	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/072613

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1115663	A1	18-07-2001	AR 020473 A1 15-05-2002
			AT 340148 T 15-10-2006
			AU 4845799 A 10-04-2000
			CA 2341895 A1 30-03-2000
			DE 69933300 T2 04-01-2007
			DK 1115663 T3 29-01-2007
			EP 1115663 A1 18-07-2001
			ES 2273503 T3 01-05-2007
			JP 2002526253 A 20-08-2002
			NO 20011367 A 09-05-2001
			NZ 510317 A 19-12-2003
			PT 1115663 E 31-01-2007
			TW 509663 B 11-11-2002
			US 6083404 A 04-07-2000
			WO 0017112 A1 30-03-2000
US 5906750	A	25-05-1999	AU 3219599 A 25-10-1999
			US 5906750 A 25-05-1999
			WO 9951533 A1 14-10-1999
EP 2039658	A1	25-03-2009	AT 504788 A4 15-08-2008
			EP 2039658 A1 25-03-2009
US 7291275	B1	06-11-2007	NONE