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(54) **Titre : PROCÉDE DE DESHYDRATATION DE RESIDUS MINÉRAUX PAR TRAITEMENT DE CES RESIDUS AVEC AU MOINS UN TENSIOACTIF ET AU MOINS UN POLYMERÉ**
(54) **Title: PROCESS FOR DEWATERING MINERAL TAILINGS BY THE TREATMENT OF THESE TAILINGS WITH AT LEAST ONE SURFACTANT AND AT LEAST ONE POLYMER**

(57) **Abrégé/Abstract:**

Disclosed is a process of dewatering a suspension comprising particulate solids dispersed in an aqueous liquid, the particulate solids comprises clay and mineral particles of size below 50µm, which process comprises the steps of (a) subjecting the suspension to a kinetic energy stage to produce a modified suspension; (b) addition of at least one surfactant and at least one polymer to the suspension during and/or after step (a); (c) dewatering the treated suspension obtained after having conducted steps (a) and (b).



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- (54) Title: PROCESS FOR DEWATERING MINERAL TAILINGS BY THE TREATMENT OF THESE TAILINGS WITH AT LEAST ONE SURFACTANT AND AT LEAST ONE POLYMER
- (57) Abstract: Disclosed is a process of dewatering a suspension comprising particulate solids dispersed in an aqueous liquid, the particulate solids comprises clay and mineral particles of size below 50µm, which process comprises the steps of (a) subjecting the suspension to a kinetic energy stage to produce a modified suspension; (b) addition of at least one surfactant and at least one polymer to the suspension during and/or after step (a); (c) dewatering the treated suspension obtained after having conducted steps (a) and (b).

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Process for dewatering Mineral Tailings by the treatment of these tailings with at least one surfactant and at least one polymer

5 Description

The present invention relates to the treatment of mineral material, especially waste mineral slurries. The invention is particularly suitable for the disposal of tailings and other waste material resulting from mining and mineral processing operations. The invention is particularly suitable
10 for the treatment of oil sand tailings and especially mature fine tailings (MFT) derived from oil sand tailings.

Processes of treating mineral ores or oil sands in order to extract mineral values or in the case of oil sands to extract hydrocarbons will normally result in waste material. Often the waste material consists of an aqueous slurry or sludge comprising particulate mineral material, for instance
15 clay, shale, sand, grit, oil sand tailings, metal oxides etc. admixed with water.

In some cases the waste material such as mine tailings can be conveniently disposed of in an underground mine, to form backfill. Generally backfill waste comprises a high proportion of
20 coarse large sized particles together with other smaller sized particles and is pumped into the mine as slurry where it is allowed to dewater leaving the sedimented solids in place. It is common practice to use flocculants to assist this process by flocculating the fine material to increase the rate of sedimentation. However, in this instance, the coarse material will normally sediment at a faster rate than the flocculated fines, resulting in a heterogeneous deposit of coarse and
25 fine solids.

For other applications it may not be possible to dispose of the waste in a mine. In these instances, it is common practice to dispose of this material by pumping the aqueous slurry to lagoons, heaps or stacks and allowing it to dewater gradually through the actions of sedimentation, drainage and evaporation.
30

For example in oil sands processing, the ore is processed to recover the hydrocarbon fraction, and the remainder, including both process material and the gangue, constitutes the tailings that are to be disposed of. In oil sands processing, the main process material is water, and the
35 gangue is mostly sand with some silt and clay. Physically, the tailings consist of a solid part (sand tailings) and a more or less fluid part (sludge). The most satisfactory place to dispose of these tailings is, of course, in the existing excavated hole in the ground. It turns out, however, that the sand tailings alone from the one cubic foot of ore occupy just about one cubic foot. The amount of sludge is variable, depending on ore quality and process conditions, but average
40 about 8.5 L (0.3 cubic feet). The tailings simply will not fit back into the hole in the ground.

There is a great deal of environmental pressure to minimise the allocation of new land for disposal purposes and to more effectively use the existing waste areas. One method is to load

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multiple layers of waste onto an area to thus form higher stacks of waste. However, this presents a difficulty of ensuring that the waste material can only flow over the surface of previously rigidified waste within acceptable boundaries, is allowed to rigidify to form a stack, and that the waste is sufficiently consolidated to support multiple layers of rigidified material, without the risk of collapse or slip. Thus the requirements for providing a waste material with the right sort of characteristics for stacking is altogether different from those required for other forms of disposal, such as back-filling within a relatively enclosed area.

In a typical mineral or oil sands processing operation, waste solids are separated from solids that contain mineral values in an aqueous process. The aqueous suspension of waste solids often contains clays and other minerals, and is usually referred to as tailings. These solids are often concentrated by a flocculation process in a thickener to give a higher density underflow and to recover some of the process water. It is usual to pump the underflow to a surface holding area, often referred to as a tailings pit or dam or more usually a tailings pond in the case of oil sands. Once deposited at this surface holding area, water will continue to be released from the aqueous suspension resulting in further concentration of the solids over a period of time. Once a sufficient volume of water has been collected this is usually pumped back to the mineral or oil sands processing plant.

The tailings pond or dam is often of limited size in order to minimise the impact on the environment. In addition, providing larger tailings ponds can be expensive due to the high costs of earth moving and the building of containment walls. These ponds tend to have a gently sloping bottom which allows any water released from the solids to collect in one area and which can then be pumped back to the plant. A problem that frequently occurs is when fine particles of solids are carried away with the run-off water, thus contaminating the water and having a detrimental impact on subsequent uses of the water.

In many mineral and oil sands processing operations, for instance a mineral sands beneficiation process, it is also common to produce a second waste stream comprising of mainly coarse (> 0.1 mm) mineral particles. It is particularly desirable to dispose of the coarse and fine waste particles as a homogeneous mixture as this improves both the mechanical properties of the dewatered solids, greatly reducing the time and the cost eventually required to rehabilitate the land. However, this is not usually possible because even if the coarse waste material is thoroughly mixed into the aqueous suspension of fine waste material prior to deposition in the disposal area, the coarse material will settle much faster than the fine material resulting in banding within the dewatered solids. Furthermore, when the quantity of coarse material to fine material is relatively high, the rapid sedimentation of the coarse material may produce excessive beach angles which promote the run off of aqueous waste containing high proportions of fine particles, further contaminating the recovered water. As a result, it is often necessary to treat the coarse and fine waste streams separately, and recombine these materials by mechanically re-working, once the dewatering process is complete.

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Generally oil sands tailings ponds are located within close proximity of the oil sands mining and extraction operations in order to facilitate pipeline transportation, discharging and management of the tailings. A tailings pond may be contained within a retaining structure which may be referred to as a dyke structure. A suitable dyke structure may generally be constructed by placing the sand fraction of the tailings within cells or on beaches. Tailings streams initially discharged into the ponds may have relatively low densities and solids contents, for instance around 0.5 to 10% by weight.

In an oil sands tailings pond, the process water, unrecovered hydrocarbons and minerals settle naturally to form different strata. The upper stratum can be predominantly water that maybe recycled as process water to the extraction process. The lower stratum can contain settled residual hydrocarbon and minerals which are predominantly fines. It is usual to refer to this lower stratum as "mature fine tailings" (MFT). It is known that mature fine tailings consolidate extremely slowly and may take many hundreds of years to settle into a consolidated solid mass. Consequently mature fine tailings and the ponds containing them are a major challenge to tailings management and the mining industry.

The composition of mature fine tailings tends to be highly variable. The upper part of the stratum may have a mineral content of about 10% by weight but at the bottom of the stratum the mineral content may be as high as 50% by weight. The variation in the solids content is believed to be as a result of the slow settling of the solids and consolidation occurring over time. The average mineral content of the MFT tends to be of about 30% by weight.

The MFT generally comprises a mixture of sand, fines and clay. Generally the sand may be referred to siliceous particles of a size greater than 44 μm and may be present in the MFT in an amount of up to 15% by weight. The remainder of the mineral content of the MFT tends to be made up of a mixture of clay and fines. Generally the fines refer to mineral particles no greater than 44 μm . The clay may be any material traditionally referred to as clays by virtue of its mineralogy and will generally have a particle size of below 2 μm . Typically, the clays tend to be water swelling clays, such as montmorillonites. The clay content may be up to 75% by weight of the solids.

Additional variations in the composition of MFT maybe as a result of the residual hydrocarbon which may be dispersed in the mineral or may segregate into mat layers of hydrocarbon. The MFT in a pond not only has a wide variation of compositions distributed from top to bottom of the pond but there may also be pockets of different compositions at random locations throughout the pond.

In addition, aqueous suspensions waste solids from mining and mineral processing operations including mining tailings, such as MFT, held in ponds of holding areas may also contain coarse debris. The type and composition of this coarse debris depends on the origin of the suspension. In the case of MFT the coarse debris tends to be of different sizes, shapes and chemical com-

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positions. For instance, MFT may include coarse debris such as biomass, such as wood or other plant material; petrified matter; solids having a density low enough to float at or near the surface of the pond; glass; plastic; metal; bitumen globules; or mats. The coarse debris found other mining tailings may include similar debris as in the case of MFT, with the exception of bitumen materials and may also include other debris materials such as lumps of ore or other masses depending on the geology of the ore mine, the ore extraction processing technique, or the location of the tailings pond.

It is known that aqueous suspensions and mining tailings, such as MFT, may be dewatered and solidified through the action chemical treatments. A typical chemical treatment employs the addition of chemical flocculating agents to bring about flocculation and be so formed flocculated suspensions can be subjected to dewatering.

It is well known to concentrate these oil sand tailings in a thickener to give a higher density underflow and to recover some of the process water as mentioned above.

For example, Xu.Y et al, *Mining Engineering*, November 2003, pages 33 to 39 describe the addition of anionic flocculants to the oil sand tailings in the thickener before disposal.

The underflow can be disposed of and/or subjected to further drying for subsequent disposal in an oil sand tailings stacking area.

In the Bayer process for recovery of alumina from bauxite, the bauxite is digested in an aqueous alkaline liquor to form sodium aluminate which is separated from the insoluble residue. This residue consists of both sand, and fine particles of mainly ferric oxide. The aqueous suspension of the latter is known as red mud.

After the primary separation of the sodium aluminate solution from the insoluble residue, the sand (coarse waste) is separated from the red mud. The supernatant liquor is further processed to recover aluminate. The red mud is then washed in a plurality of sequential washing stages, in which the red mud is contacted by wash liquor and is then flocculated by addition of a flocculating agent. After the final wash stage the red mud slurry is thickened as much as possible and then disposed of. Thickening in the context of this specification means that the solids content of the red mud is increased. The final thickening stage may comprise settlement of flocculated slurry only, or sometimes, includes a filtration step. Alternatively or additionally, the mud may be subjected to prolonged settlement in a lagoon. In any case, this final thickening stage is limited by the requirement to pump the thickened aqueous suspension to the disposal area.

The mud can be disposed of and/or subjected to further drying for subsequent disposal on a mud stacking area. To be suitable for mud stacking the mud should have a high solids content and, when stacked, should not flow but should be relatively rigid in order that the stacking angle should be as high as possible so that the stack takes up as little area as possible for a given

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volume. The requirement for high solids content conflicts with the requirement for the material to remain pumpable as a fluid, so that even though it may be possible to produce a mud having the desired high solids content for stacking, this may render the mud unpumpable.

- 5 The sand fraction removed from the residue is also washed and transferred to the disposal area for separate dewatering and disposal.

EP-A-388108 describes adding a water-absorbent, water-insoluble polymer to a material comprising an aqueous liquid with dispersed particulate solids, such as red mud, prior to pumping
10 and then pumping the material, allowing the material to stand and then allowing it to rigidify and become a stackable solid. The polymer absorbs the aqueous liquid of the slurry which aids the binding of the particulate solids and thus solidification of the material. However this process has the disadvantage that it requires high doses of absorbent polymer in order to achieve adequate solidification. In order to achieve a sufficiently rigidified material it is often necessary to use doses
15 as high as 10 to 20 kilograms per tonne of mud. Although the use of water swellable absorbent polymer to rigidify the material may appear to give an apparent increase in solids, the aqueous liquid is in fact held within the absorbent polymer. This presents the disadvantage that as the aqueous liquid has not actually been removed from the rigidified material and under certain conditions the aqueous liquid could be desorbed subsequently and this could risk re-
20 fluidisation of the waste material, with the inevitable risk of destabilising the stack.

WO-A-96/05146 describes a process of stacking aqueous slurry of particulate solids, which comprises admixing an emulsion of a water-soluble polymer dispersed in a continuous oil phase with the slurry. Preference is given to diluting the emulsion polymer with a diluent, and which is
25 preferably in a hydrocarbon liquid or gas and which will not invert the emulsion. Therefore it is a requirement of the process that the polymer is not added in to the slurry as an aqueous solution.

WO-A-0192167 describes a process where a material comprising a suspension of particulate solids is pumped as a fluid and then allowed to stand and rigidify. The rigidification is achieved
30 by introducing into the suspension particles of a water soluble polymer which has an intrinsic viscosity of at least 3 dl/g. This treatment enables the material to retain its fluidity as being pumped, but upon standing causes the material to rigidify. This process has the benefit that the concentrated solids can be easily stacked, which minimises the area of land required for disposal. The process also has the advantage over the use of cross linked water absorbent polymers in that water from the suspension is released rather than being absorbed and retained by
35 the polymer. The importance of using particles of water soluble polymer is emphasised and it is stated that the use of aqueous solutions of the dissolved polymer would be ineffective. Very efficient release of water and convenient storage of the waste solids is achieved by this process, especially when applied to a red mud underflow from the Bayer alumina process.

40 WO2004/060819 describes a process in which material comprising an aqueous liquid with dispersed particulate solids is transferred as a fluid to a deposition area, then allowed to stand and

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rigidify, and in which rigidification is improved whilst retaining the fluidity of the material during transfer, by combining with the material an effective rigidifying amount of an aqueous solution of a water-soluble polymer. Also described is a process in which dewatering of the particulate solids is achieved.

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Canadian patent application 2512324 describes a process for the rigidification of a suspension which is or comprises oil sand tailings. The process involves transferring the suspension as a fluid to a deposition area in which an effective rigidifying amount of an aqueous solution of a water-soluble polymer is combined with the suspension during transfer and then allowing the so treated suspension to stand and rigidify. The rigidification is improved whilst retaining the fluidity of the material during transfer. The process was particularly suited to the treatment of tailings as they are produced from the oil sands processing operation.

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WO 01/05712 A1 discloses a process for treating an aqueous suspension of suspended solids by adding a concentrated polymer solution and a dilute polymer solution. This process is conducted to treat mineral tailings in general, tailings comprising very small particles like oil sand tailings, especially MFT, are not mentioned.

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US 6,039,189 discloses a process in which suspended solids in a mineral suspension, usually an aqueous mineral suspension, are separated by sedimentation. Sedimentation is conducted by the addition of a polymeric material and a surfactant to prevent a layer of solids such as a thick crust forming on the upper surface of the suspension, and the apparatus containing it, during the sedimentation process.

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However, suspensions which contain a very high proportion of fine solids and clays, such as MFT, are particularly difficult to dewater and generally require very high doses of chemical treatment aids.

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Therefore it is an objective of the present invention to achieve a more efficient process for dewatering a suspension containing high levels of fine solids and clays, especially MFT derived from oil sand tailings. In particular it would be desirable if such a process required reduced levels of chemical treatment aids. Moreover, it would be desirable for the process of removing water or dewatering process is a rigidification process. A further object is to reduce the viscosity of the mineral slurry before a polymer is added. In addition the water release of the slurry shall be improved.

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The present invention therefore relates to a process of dewatering a suspension comprising particulate solids dispersed in an aqueous liquid, said particulate solids comprises clay and mineral particles of size below 50 μm , which process comprises the steps of,

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(a) Subjecting the suspension to a kinetic energy stage to produce a modified suspension;

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(b) Addition of at least one surfactant and at least one polymer to the suspension during and/or after step (a);

(c) Dewatering the treated suspension obtained after having conducted steps (a) and (b)

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in which the kinetic energy stage is a shearing stage and/or application of ultrasonic energy to the suspension.

10 The process brings about significant improvements in removing water from the suspension using lower levels of treatment chemicals than previously possible.

By mineral particles of particle size below 50 μm , we mean solid mineral particles that are not water swelling clays that may generally be referred to as fines. Often these mineral particles may be referred to as silt. Usually these mineral particles have a size of no greater than 44 μm .

15 Typically they will have a size between 2 μm and 44 μm , although their size may be smaller. The mineral origin of the particles often will be silica and/or quartz and/or feldspar.

The mineral particles may typically be present in the suspension in an amount of at least 10% by weight of the mineral content. Often the particles may be present in amount of at least 15%
20 by weight, preferably of at least 20% by weight, of the solids content. In some cases the solids content of the suspension may be made up to 50 or 60% by weight.

The clay may be any material traditionally referred to as clays by virtue of its mineralogy and will tend to have a particle size of below 2 μm . Generally the clays may tend to be a mixture of
25 clays. Typically the clay component may comprise kaolinite; illite; chlorite; montmorillonites; kaolinite-smectite mixtures; illite-smectite mixtures. The clay content of the suspension would usually be at least 20% by weight of the solids and may be as much as 75% by weight of the solids.

Without being limited by theory the inventors believe that suspensions which contain a high
30 proportion of very small sized mineral particles and clay particles, especially where they have been held in tailings ponds over a considerable time, even many years, such as oil sands derived MFT, exhibit three-dimensional particle network structure based on the clays. These network structures are believed to include clay-clay intra-particle networks and clay-inter-particle network structures which incorporate the fine mineral particles. The inventors believe that these
35 network structures comprise clay particles linked to each other and network structures where clay particles and the fine particles are linked together by clay particles. Further, it is believed that this network structure is responsible for retaining more water than in suspensions of equivalent solids. Furthermore, it is considered that the electrostatic forces within the clay inter-particle structure may be responsible for the difficulty in achieving adequate water release with conventional doses of chemical treatment aids.
40

Unexpectedly, the inventors discovered that applying kinetic energy to the suspension provides a modified suspension which is significantly more conducive to releasing water by chemical treatment by the addition of at least one surfactant and at least one polymer. The inventors believe that the action of the kinetic energy on the suspension directly interacts with the clay-clay
5 intra-particle network structures and the clay inter-particle network structures. In fact, it is believed that the kinetic energy will at least partially breakdown these network structures.

Preferably, the suspension comprises mature fine tailings derived from oil sands tailings.

10 By kinetic energy we mean that suspension is subjected some energy which is or induces motion within the suspension. In one form the kinetic energy may be ultrasonic energy. Generally it is expected that the application of ultrasonic energy will induce vibrations which will at least partially break down the network structures. Other forms of kinetic energy may be alternative means for inducing vibrations.

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One particularly suitable form of kinetic energy is shearing.

According to a preferred embodiment of the present invention the shearing stage comprises subjecting the suspension to shearing employing a shearing device and in which the shearing
20 device is selected from the group consisting of:

a shearing device comprising moving elements which rotate, preferably impellers, kneading components, or moving plates;

a milling device comprising moving elements;

a static mixer,

25 preferably in which the operation of the moving elements is at least 5 cycles per second.

The present invention therefore preferably relates to the process according to the present invention, wherein the shearing stage comprises subjecting the suspension to shearing employing a shearing device and in which the shearing device is selected from the group consisting of:

30 a shearing device comprising moving elements which rotate, preferably impellers, kneading components, or moving plates;

a milling device comprising moving elements;

a static mixer,

35 preferably in which the operation of the moving elements is at least 5 cycles per second.

The application of kinetic energy, in particular shearing, according to step (a) may be carried out in a shearing vessel before being transferred to the next step of the process. Alternatively, the shearing may be carried out in line as the suspension is being transferred.

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Any conventional shearing device may be employed as such devices are very well known in the industry and also described in the literature. Industrial scale shear devices, for instance shear

mixing devices or shear pumps are available from a variety of manufacturers, for instance IKA which manufactures Ultra Turrax high shear devices, for instance the devices in the Ultra Turrax UTL 2000 range; Fluko-high shear mixers; Silverson high shear mixers, for instance Ultramix mixers or In-line mixers; Euromixers; Greaves; Admix Inc which manufactures Rotosolver high shear devices; Charles Ross and Son Company which manufactures Ross high shear mixers; Robbins Myers which manufactures Greerco high shear mixers; Powershear Mixers.

Suitable shearing devices generally have moving elements, such as rotating components, for instance impellers; kneeding components; or moving plates. The mixing pumps may also contain static elements such as baffles or plates, for instance containing orifices. The moving elements will tend to move quite rapidly in order to generate shear. In general this will depend upon the mode of action within the shearing chamber and the size of the volume that is being sheared. This may be for instance at least 5 cycles per second (5 s^{-1}), preferably at least 6 cycles per second (6 s^{-1}), more preferably at least 7 cycles per second (7 s^{-1}), most preferably at least 8 cycles per second (8 s^{-1}), even more preferably 9 cycles per second (9 s^{-1}), and usually at least 10 cycles per second (10 s^{-1}), suitably at least 20 cycles per second (20 s^{-1}). Typically this may be up to 170 s^{-1} , up to 200 s^{-1} or up to 300 s^{-1} or more.

When the suspension, for instance oil sands derived MFT, is subjected to shearing, the period of shearing may be referred to as the residence time. The residence time in the shearing device may be, for instance at least 1 second. Often it will be at least 5 seconds and sometimes at least 10 seconds. It may be up to 30 seconds or more or it may be up to 15 seconds or up to 20 seconds. In some situations it may be at least 20 seconds, for instance at least 1 min and often may be several hours, for instance up to 10 hours or more. Suitably the residence time may be at least 5 min, suitably at least 10 min and often at least 30 min. In many cases it may be at least one hour. In some cases the residence time may be up to 8 hours but desirably less than this.

The shearing device may even be a milling device. Milling devices include colloid mills, cone mills and rotor mills etc. In general milling devices tend to have moving elements, for instance cones, screens or plates containing gaps, grooves, slots or orifices which move against other static elements. The moving elements may move instance by rotation. These devices tend to generate a high level of shear stress on liquids and other materials passing through them. The moving elements tend to combine high-speed with a very small shear gap which produces intense friction on the material being processed. The friction and shear that result is commonly referred to as wet milling. In one form the milling device may contain a rotor and a stator, which are both cone-shaped and may have one or more stages of fine grooves, gaps, slots or orifices. This stator can be adjusted to obtain the desired gap setting between the rotor and stator. The grooves, gaps, slots or orifices may change direction in each stage to increased turbulence. The moving elements will tend to move quite rapidly in order to generate sufficient shear. This may be for instance at least 5 cycles per second (5 s^{-1}), preferably at least 6 cycles per second (6 s^{-1}), more preferably at least 7 cycles per second (7 s^{-1}), most preferably at least 8 cycles per second (8 s^{-1}), even more preferably 9 cycles per second (9 s^{-1}), and usually at least 10 cycles

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per second (10 s^{-1}), suitably at least 20 cycles per second (20 s^{-1}). Typically this may be up to 170 s^{-1} , up to 200 s^{-1} or up to 300 s^{-1} or more.

Alternatively the suspension may be passed through a static mixer or other static elements
5 which bring about a shearing action, for instance baffles in a pipeline or alternatively a constriction in a pipeline.

The inventors have noted that during the application of kinetic energy, for instance by shearing of the suspension, in particular the oil sands derived MFT, a notable reduction in viscosity of the
10 suspension can occur. The inventors considered that this may be as a result of the clay-clay intra-particle network structures and clay inter-particle network structures being broken down and releasing water previously entrained within these networks. It is thought that this availability of the water may bring about a reduction in viscosity. Typically viscosity may be measured by an instrument called a controlled stress rheometer, such as Brookfield RS. Viscosity may be
15 measured at 25°C .

Generally the viscosity of the modified (for instance sheared) suspension would often be below 90% of the viscosity of the suspension prior to the application of kinetic energy, such as the shearing stage. Preferably the viscosity of the modified suspension, for instance sheared sus-
20 pension, is no more than 80% of the viscosity of the suspension before the application of kinetic energy, such as shearing and more preferably no more than 70%. More preferably still the modified suspension, for instance sheared suspension, viscosity will be up to 60% and in particular less than 50% of the suspension before the application of kinetic energy, for instance un-sheared suspension. In some cases the viscosity of the modified suspension, for instance
25 sheared suspension, may be as little as 0.001% of the suspension before the application of kinetic energy, for instance shearing, or even below. Often the modified suspension, for instance sheared suspension, will be at least 0.05% or 0.1% of the suspension before the application of kinetic energy, for instance un-sheared suspension. In many cases the modified suspension, for instance sheared suspension will be at least 1%, at least 5% or at least 10% of the suspension
30 before the application of kinetic energy, for instance un-sheared suspension.

Generally the change in viscosity from the suspension before the application of kinetic energy to the modified suspension tends to increase as the clay content of the suspension increases.

35 The process of the present invention involves addition of at least one surfactant and at least one polymer to the suspension during and/or after step (a), according to step (b). According to a preferred embodiment of the present invention, step (b) is conducted after step (a). According to another preferred embodiment of the present invention, step (b) is conducted during step (a), i.e. the at least one polymer and the at least one surfactant are added while the suspension is
40 treated in a kinetic energy stage, wherein the kinetic energy stage is a shearing stage and/or application of ultrasonic energy to the suspension.

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According to a further embodiment of the present invention, the addition according to step (b) can be conducted partly during step (a) and/or partly after step (a), wherein the complete amount of at least one polymer and at least one surfactant is added during and/or after step (a), i.e. before step (c).

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Particularly preferably, step (b) is conducted after step (a), i.e. the suspension is first subjected to a kinetic energy stage, wherein the kinetic energy stage is a shearing stage and/or application of ultrasonic energy to the suspension to produce a modified suspension, and at least one polymer and at least one surfactant are then added to this modified suspension.

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The addition of at least one surfactant and at least one polymer facilitates the removal of water in the dewatering step. It is believed that the dewatering is facilitated because the surface tension of water is lowered by the addition of a surfactant. In addition the viscosity is lowered after the addition of at least one surfactant and the at least one polymer can contact the mineral particles in a more easy way. Further, the inventors believe that the availability of water released from the clay-clay intra-particle network structures and clay inter-particle network structures facilitates the integration of the polymers throughout the solids of the suspension.

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The dewatering of the treated suspension according to step (c) may employ any known dewatering method. For instance the dewatering step may involve sedimentation of the treated suspension to produce settled sediment. Such a process may be carried out in a vessel for example a gravimetric thickener or in a settlement pond. Alternatively the dewatering process may involve pressure dewatering, for example using a filter press, a belt press or a centrifuge.

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According to a first preferred embodiment of the present invention, dewatering in step (c) of the process according to the present invention is conducted by sedimentation.

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Preferably the dewatering process is a process of rigidification of the solids in the suspension and the dewatering step is part of the rigidification process. Thus in a preferred form of the invention the modified, preferably sheared, suspension is transferred as a fluid to a deposition area, then allowed to stand and rigidifying, in which the at least one surfactant and at least one polymer are added to the modified, preferably sheared, suspension during the transfer of the suspension.

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According to a second preferred embodiment of the present invention, dewatering in step (c) of the process according to the present invention is conducted by rigidification.

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Rigidification is a term that refers to a networked structure of particulate solids. Compared with settling or sedimentation, rigidification is faster, produces more recovered water and results in a chemically bonded tailings that occupy a smaller surface area, which is more quickly rehabilitated. Rigidified tailings are also less likely to spread laterally after deposition enabling

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more efficient land use; and would more rapidly form a solid structure in the form of a beach or stack; and have a greater yield stress when deposited, with increased uniformity or homogeneity of coarse and fine particles. Further by reason of its heaped geometry as a beach or stack such rigidified material would result in downward compression forces, driving water out of the stack and more rapid release of water, with better clarity.

Therefore, dewatering in step (c) of the process according to the present invention is preferably conducted by sedimentation and/or rigidification.

Desirably the at least one surfactant and/or at least polymer may be added to the modified suspension in the form of solutions, preferably aqueous solutions.

According to a preferred embodiment of the process according to the present invention, the at least one surfactant and the at least one polymer are added simultaneously or separately, more preferably separately, i.e. sequentially, wherein both sequences like surfactant first, polymer second or polymer first and surfactant second, are possible.

Therefore, the present invention preferably relates to the process according to the present invention, wherein the at least one surfactant and the at least one polymer are added simultaneously or separately, preferably separately.

Further, the at least one surfactant and/or at least polymer may be added to the modified suspension in the form of solutions, preferably aqueous solutions, either simultaneously or separately.

According to a preferred embodiment of the process according to the present invention the at least one surfactant is added first, and the at least one polymer is added afterwards.

Therefore, the present invention preferably relates to the process according to the present invention, wherein the at least one surfactant is added first and the at least one polymer is added afterwards.

The addition of at least one surfactant and at least one polymer, preferably as aqueous solution(s), allows the modified suspension to retain sufficient fluidity during transfer and then once the material is allowed to stand it will form a solid mass strong enough to support subsequent layers of rigidified material. We have unexpectedly found that the addition of the at least one surfactant and at least one polymer, preferably as aqueous solutions, to the modified suspension does not cause instant rigidification or substantially any settling of the solids prior to standing.

The at least one surfactant and the at least one polymer may be metered directly into the suspension as separate, preferably aqueous, solutions. By substantially simultaneously the two

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solutions should be added at approximately the same dosing point. Where the at least one surfactant and the at least one polymer are added to the suspension separately, they may be added in either order. For instance if the at least one surfactant is added first, the at least one polymer, preferably in solution, may be added after mixing is completed but should be added before the dewatering stage. Alternatively, it may be desirable to add the at least one surfactant, preferably as aqueous solution, after the addition of the at least one polymer, preferably as aqueous solution. When the at least one surfactant and the at least one polymer are added separately it may be appropriate to allow or apply some degree mixing between the dosing stages in order to allow the at least one surfactant to become distributed throughout the suspension solids. This mixing may for instance include allowing the treated suspension to pass some distance along a flow line which optionally contains bends, baffles, constrictions or other features which induce gentle mixing.

Preferably the at least one surfactant and the at least one polymer, preferably as aqueous solutions, are introduced separately.

According to a further embodiment, the at least one surfactant and the at least one polymer are introduced into the suspension as one aqueous composition comprising both.

An aqueous composition comprising both, the at least one surfactant and the at least one polymer, comprises the at least one surfactant preferably in an amount of from 10 to 99% by weight, based on whole composition, and the at least one polymer preferably in an amount of from 0.05 to 1.0 % by weight, more preferably 0.2 to 0.75% by weight, particularly preferably 0.25 to 0.5% by weight, based on whole composition.

The preferably used aqueous solution of at least one surfactant preferably has a concentration of surfactant of 0.01 to 99 % by weight, more preferably 10 to 99 % by weight, most preferably 50 to 99% by weight, in each case based on the aqueous solution. According to a further preferred embodiment the surfactant is not added in solution but without any solvent.

Within the limits as outlined above, the amount of surfactant that is added in step (b) of the process according to the present invention is further preferably adjusted to an amount that reduce the surface tension of the suspension to less than 40 dynes/cm.

The preferably used aqueous solution of at least one polymer preferably has a concentration of polymer of 0.05 to 1.0% by weight, more preferably 0.2 to 0.75% by weight, most preferably 0.25 to 0.5% by weight. According to a further preferred embodiment the polymer is not added in solution but without any solvent.

According to the invention the at least one polymer may be either anionic, cationic, non-ionic, amphoteric or zwitterionic, preferably anionic or non-ionic.

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The at least one surfactant is preferably either co-ionic with the at least one polymer or non-ionic. In another preferred form the at least one surfactant is non-ionic and the at least one polymer is cationic, anionic or non-ionic.

- 5 Suitable doses of polymer range from 10 grams to 10,000 grams per tonne of material solids. Generally the appropriate dose can vary according to the particular material and material solids content. Preferred doses are in the range 30 to 3,000 grams per tonne, while more preferred doses are in the range of from 60 to 200 or 400 grams per tonne, in each case in respect of the sum of all polymers.

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In some instances better results may be obtained when the suspension, particular the oil sands derived MFT, is relatively concentrated and homogenous. It may also be desirable to combine the addition of at least one surfactant and of at least one polymer with other additives. For instance the flow properties of the material through a conduit may be facilitated by including a
15 dispersant. Typically where a dispersant is included it would be included in conventional amounts. However, we have found that surprisingly the presence of dispersants or other additives does not impair the rigidification of the material on standing. It may also be desirable to pre-treat the material with either an inorganic or organic coagulant to pre-coagulate the fine material to aid its retention in the rigidified solids.

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Thus in the present invention the at least one surfactant and the at least one polymer, preferably as aqueous solutions, are preferably added directly to the aforementioned modified suspension. The at least one polymer, preferably its aqueous solution, may consist wholly or partially of water-soluble polymers. Thus the at least one polymer may comprise a blend of cross-linked
25 polymer and water soluble polymer, provided sufficient of the polymer is in solution or behaves as though it is in solution to bring about rigidification on standing.

According to the present invention at least one polymer may be used, for example one, two, three, four etc. Particularly preferably one polymer is used.

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According to a further preferred embodiment there may be a physical blend of swellable polymer and soluble polymer or alternatively a lightly cross-linked polymer for instance as described in EP202780. Although the polymer may comprise some cross-linked polymer it is preferred to the present invention that a significant amount of water soluble polymer is present. When the
35 polymer comprise some swellable polymer it is desirable that at least 80% of the polymer is water-soluble.

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Preferably the at least one polymer is used which is wholly or at least substantially water soluble. The water soluble polymer may be branched by the presence of branching agent, for instance as described in WO-A-9829604, for instance in claim 12, or alternatively the water soluble polymer is substantially linear.

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Preferably the at least one polymer is of moderate to high molecular weight. It will have an intrinsic viscosity of at least 3 dl/g and generally at least 5 or 6 dl/g, although the at least one polymer may be of significantly high molecular weight and exhibit an intrinsic viscosity of 25 dl/g or 30 dl/g or even higher. Preferably the at least one polymer will have an intrinsic viscosity in the
5 range of 6 dl/g to 30 dl/g, more preferably 11 dl/g or 12 dl/g to 18 dl/g or 25 dl/g. In case that more than one polymer is used according to the present invention, it is possible that the polymers have the same or different molecular weights.

Intrinsic viscosity of polymers may be determined by preparing an aqueous solution of the polymer (0.5 to 1% w/w) based on the active content of the polymer. 2 g of this 0.5 to 1% w/w polymer solution is diluted to 100 ml in a volumetric flask with 50 ml of 2M sodium chloride solution that is buffered to pH 7.0 (using 1.56 g sodium dihydrogen phosphate and 32.26 g disodium hydrogen phosphate per litre of deionised water) and the whole is diluted to the 100 ml mark with deionised water. The intrinsic viscosity of the polymers is measured using a Number 1 suspended level viscometer at 25 °C in 1M buffered salt solution.
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The at least one polymer may be a natural polymer, for instance polysaccharides such as starch, guar gum or dextran, or a semi-natural polymer such as carboxymethyl cellulose or hydroxyethyl cellulose. Preferably the at least one polymer is synthetic and preferably it is formed from an ethylenically unsaturated water-soluble monomer or blend of monomers.
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The present invention preferably relates to the process according to the present invention in which the at least one polymer is formed from ethylenically unsaturated water-soluble monomer or blend of monomers.
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The at least one polymer may be cationic, non-ionic, amphoteric or anionic.

The at least one polymer may be formed from any suitable water-soluble monomers. Typically the water soluble monomers have solubility in water of at least 5g/100 ml at 25 °C.
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The present invention preferably relates to the process according to the present invention in which the at least one polymer is anionic.

Particularly preferred anionic polymers are formed from monomers selected from ethylenically unsaturated carboxylic acid and sulphonic acid monomers, preferably selected from (meth) acrylic acid, allyl sulphonic acid and 2-acrylamido-2-methyl propane sulphonic acid (AMPS), and their salts, optionally in combination with non-ionic co-monomers, preferably selected from (meth) acrylamide, hydroxy alkyl esters of (meth) acrylic acid and N-vinyl pyrrolidone.
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The present invention preferably relates to the process according to the present invention in which the at least one polymer is non-ionic.
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Preferred non-ionic polymers are formed from ethylenically unsaturated monomers selected from (meth) acrylamide, hydroxy alkyl esters of (meth) acrylic acid and N-vinyl pyrrolidone.

5 The present invention preferably relates to the process according to the present invention in which the at least one polymer is cationic.

Preferred cationic polymers are formed from ethylenically unsaturated monomers selected from dimethyl amino ethyl (meth) acrylate - methyl chloride, (DMAEA.MeCl) quat, diallyl dimethyl ammonium chloride (DADMAC), trimethyl amino propyl (meth) acrylamide chloride (ATPAC)
10 optionally in combination with non-ionic co-monomers, preferably selected from (meth) acrylamide, hydroxy alkyl esters of (meth) acrylic acid and N-vinyl pyrrolidone.

In some instances, it has been found advantageous to separately add combinations of polymer types. Thus an aqueous solution of an anionic, cationic or non-ionic polymer may be added to
15 the above mentioned material first, followed by a second dose of either a similar or different water soluble polymer of any type.

In the invention, the at least one polymer may be formed by any suitable polymerisation process. The at least one polymer may be prepared for instance as gel polymers by solution
20 polymerisation, water-in-oil suspension polymerisation or by water-in-oil emulsion polymerisation. When preparing gel polymers by solution polymerisation the initiators are generally introduced into the monomer solution.

Optionally a thermal initiator system may be included. Typically a thermal initiator would include
25 any suitable initiator compound that releases radicals at an elevated temperature, for instance azo compounds, such as azo-bis-isobutyronitrile. The temperature during polymerisation should rise to at least 70 °C but preferably below 95 °C. Alternatively polymerisation may be effected by irradiation (ultra violet light, microwave energy, heat etc.) optionally also using suitable radiation initiators. Once the polymerisation is complete and the polymer gel has been allowed to
30 cool sufficiently the gel can be processed in a standard way by first commuting the gel into smaller pieces, drying to the substantially dehydrated polymer followed by grinding to a powder. Alternatively polymer may be supplied in the form of polymer gels, for instance as neutron type gel polymer logs.

35 Such polymer gels may be prepared by suitable polymerisation techniques as described above, for instance by irradiation. The gels may be chopped to an appropriate size as required and then on application mixed with the material as partially hydrated water soluble polymer particles.

The polymers may be produced as beads by suspension polymerisation or as a water-in-oil
40 emulsion or dispersion by water-in-oil emulsion polymerisation, for example according to a process defined by EP-A-150933, EP-A-102760 or EP-A126528.

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Alternatively the at least one polymer may be provided as a dispersion in an aqueous medium. This may for instance be a dispersion of polymer particles of at least 20 microns in an aqueous medium containing an equilibrating agent as given in EP-A-170394. This may for example also include aqueous dispersions of polymer particles prepared by the polymerisation of aqueous monomers in the presence of an aqueous medium containing dissolved low IV polymers such as poly diallyl dimethyl ammonium chloride and optionally other dissolved materials for instance electrolyte and/or multi-hydroxy compounds e. g. polyalkylene glycols, as given in WO-A-9831749 or WO-A-9831748.

- 10 The, preferably aqueous, solution of at least one polymer is typically obtained by dissolving the polymer in preferably water or by diluting a more concentrated solution of the polymer. Generally solid particulate polymer, for instance in the form of powder or beads, is dispersed in preferably water and allowed to dissolve with agitation. This may be achieved using conventional make up equipment. Desirably, the polymer solution can be prepared using the Auto Jet Wet (trade-mark) supplied by BASF SE. Alternatively; the polymer may be supplied in the form of a reverse phase emulsion or dispersion which can then be inverted into preferably water.

According to the present invention the at least one surfactant is selected from surfactants generally known to the skilled artisan. For example, the at least one surfactant may be anionic, non-ionic, amphoteric or zwitterionic.

The present invention therefore preferably relates to the process according to the present invention in which the at least one surfactant is cationic, anionic, non-ionic, amphoteric or zwitterionic.

- 25 Examples of anionic surfactants that are used according to the present invention are:

Sulphonate type, such as alk(en)yl sulphonates, alkoxylated alk(en)yl sulphates, ester sulphonates and/or soaps. Suitable surfactants of the sulphonate type are advantageously C9-C13 alkylbenzene sulphonates, olefin sulphonates, i.e. mixtures of alkene- and hydroxyalkane sulphonates, and disulphonates, as are obtained, for example, by the sulphonation with gaseous sulphur trioxide of C12-C18 monoolefins having a terminal or internal double bond and subsequent alkaline or acidic hydrolysis of the sulphonation products.

Alk(en)yl sulphates, such as alk(en)yl sulphates like the alkali and especially the sodium salts of the sulphuric acid half-esters of the C12-C18 fatty alcohols, for example, from coconut butter alcohol, tallow alcohol, lauryl, myristyl, cetyl or stearyl alcohol or from C8-C20 oxo alcohols and those half-esters of secondary alcohols of these chain lengths. Alk(en)yl sulphates of the cited chain lengths that comprise a synthetic straight chain alkyl group manufactured petrochemically are also preferred. The C12-C16 alkyl sulphates and C12-C15 alkyl sulphates as well as C14-C15 alkyl sulphates and C14-C16 alkyl sulphates are particularly preferred on the grounds of laundry performance. The 2,3-alkyl sulphates, which can be obtained from Shell Oil Company under the trade name DANTM, are also suitable anionic surfactants.

Alk(en)yl ether sulphates, such as sulphuric acid mono-esters derived from straight-chained or branched C7-C21 alcohols ethoxylated with 1 to 6 moles ethylene oxide are also suitable, such as 2-methyl-branched C9-C11 alcohols with an average of 3.5 mol ethylene oxide (EO) or C12-
 5 C18 fatty alcohols with 1 to 4 EO.

Ester sulphonates, such as the esters of alpha-sulpho fatty acids (ester sulphonates), e.g., the alpha-sulphonated methyl esters of hydrogenated coco-, palm nut- or tallow acids are likewise suitable.

10 Ether carboxylic acids, such as the ether carboxylic acids, obtainable by treating fatty alcohol ethoxylates with sodium chloroacetate in the presence of basic catalysts. They have the general formula: $RO(CH_2CH_2O)_pCH_2COOH$ with $R = C1-C18$ and $p = 0.1$ to 20. Ether carboxylic acids are insensitive to water hardness and possess excellent surfactant properties.

15 Soaps, in particular, can be considered as further anionic surfactants. Saturated fatty acid soaps are particularly suitable, such as the salts of lauric acid, myristic acid, palmitic acid, stearic acid, hydrogenated erucic acid and behenic acid, and especially soap mixtures derived from natural fatty acids such as coconut oil fatty acid, palm kernel oil fatty acid or tallow fatty acid.
 20 Those soap mixtures are particularly preferred that are composed of 50 to 100 wt. % of saturated C12-C24 fatty acid soaps and 0 to 50 wt. % of oleic acid soap.

Examples of non-ionic surfactants that are used according to the present invention are:

25 Alcohol alkoxyates, preferably alkoxyated and/or propoxyated, particularly primary alcohols having preferably 8 to 18 carbon atoms and an average of 1 to 12 mol ethylene oxide (EO) and/or 1 to 10 mol propylene oxide (PO) per mol alcohol. C8-C16-Alcohol alkoxyates, advantageously ethoxylated and/or propoxyated C10-C15-alcohol alkoxyates, particularly C12-C14 alcohol alkoxyates, with an ethoxylation degree between 2 and 10, preferably between 3 and 8,
 30 and/or a propoxylation degree between 1 and 6, preferably between 1.5 and 5, are particularly preferred. The cited degrees of ethoxylation and propoxylation constitute statistical average values that can be a whole or a fractional number for a specific product. Preferred alcohol ethoxylates and propoxyates have a narrowed homolog distribution (narrow range ethoxylates/propoxyates, NRE/NRP). In addition to these non-ionic surfactants, fatty alcohols with
 35 more than 12 EO can also be used. Examples of these are (tallow) fatty alcohols with 14 EO, 16 EO, 20 EO, 25 EO, 30 EO or 40 EO.

Fatty acid ester alkoxyates. Another class of preferred non-ionic surfactants, which are used either as the sole non-ionic surfactant or in combination with other non-ionic surfactants, in particular, together with alkoxyated fatty alcohols and/or alkyl glycosides, are alkoxyated, preferably ethoxylated or ethoxylated and propoxyated fatty acid alkyl esters preferably containing 1 to
 40 4 carbon atoms in the alkyl chain, more particularly the fatty acid methyl esters which are de-

scribed, for example, in Japanese Patent Application JP-A-58/217598 or which are preferably produced by the process described in International Patent Application WO-A-90/13533. Methyl esters of C12-C18 fatty acids containing an average of 3 to 15 EO, particularly containing an average of 5 to 12 EO, are particularly preferred.

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Alkyl oligoglucosides. Of course, the derivatives as mentioned above can also be combined with the alkyl oligoglucosides representing the starting molecules. Suitable types are discussed above.

10 Amine oxides, for example, N-coco alkyl-N,N-dimethylamine oxide and N-tallow alkyl-N,N-dihydroxyethylamine oxide, and the fatty acid alkanolamides may also be suitable. The quantity in which these non-ionic surfactants are used is preferably no more than the quantity in which the ethoxylated fatty alcohols are used and, particularly no more than half that quantity.

15 Gemini surfactants; the so-called gemini surfactants can be considered as further surfactants. Generally speaking, such compounds are understood to mean compounds that have two hydrophilic groups and two hydrophobic groups per molecule. As a rule, these groups are separated from one another by a "spacer". The spacer is usually a hydrocarbon chain that is intended to be long enough such that the hydrophilic groups are a sufficient distance apart to be able
20 to act independently of one another. These types of surfactants are generally characterized by an unusually low critical micelle concentration and the ability to strongly reduce the surface tension of water. In exceptional cases, however, not only dimeric but also trimeric surfactants are meant by the term gemini surfactants.

25 Examples of amphoteric or zwitterionic surfactants that are used according to the present invention are:

Betaines. Amphoteric or ampholytic surfactants possess a plurality of functional groups that can ionize in aqueous solution and thereby - depending on the conditions of the medium - exhibit
30 anionic or cationic character to the compounds (see DIN 53900, July 1972). Close to the isoelectric point (around pH 4), the amphoteric surfactants form inner salts, thus becoming poorly soluble or insoluble in water. Amphoteric surfactants are subdivided into ampholytes and betaines, the latter existing as zwitterions in solution. Ampholytes are amphoteric electrolytes, i.e. compounds that possess both acidic as well as basic hydrophilic groups and therefore behave
35 as acids or as bases depending on the conditions. Especially betaines are known surfactants which are mainly produced by carboxyalkylation, preferably carboxymethylation, of amine compounds. The starting materials are preferably condensed with halocarboxylic acids or salts thereof, more particularly sodium chloroacetate, one mole of salt being formed per mole of betaine. The addition of unsaturated carboxylic acids, such as acrylic acid for example, is also possible.
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Examples of suitable betaines are the carboxyalkylation products of secondary and, in particular, tertiary amines which correspond to formula $R^1R^2R^3N-(CH_2)_qCOOX$ where R^1 is an alkyl radical having 6 to 22 carbon atoms, R^2 is hydrogen or an alkyl group containing 1 to 4 carbon atoms, R^3 is an alkyl group containing 1 to 4 carbon atoms, q is a number of 1 to 6 and X is an alkali and/or alkaline earth metal or ammonium. Typical examples are the carboxymethylation products of hexylmethanamine, hexyldimethanamine, octyldimethanamine, decyldimethanamine, C12/14-cocoalkyldimethanamine, myristyldimethanamine, cetyldimethanamine, stearyldimethanamine, stearylethylmethanamine, oleyldimethanamine, C16/18-tallowalkyldimethanamine and their technical mixtures, and particularly dodecyl methanamine, dodecyl dimethanamine, dodecyl ethylmethanamine and technical mixtures thereof. The commercially available products include Dehyton® AB (Cognis GmbH)

Alkylamido betaines. Other suitable betaines are the carboxyalkylation products of amidoamines corresponding to formula $R^1CO-NH-(CH_2)_p-N(R^3)(R^4)-(CH_2)_qCOOX$ in which R^1CO is an aliphatic acyl radical having 6 to 22 carbon atoms and 0 or 1 to 3 double bonds, R^2 is hydrogen or an alkyl radical having 1 to 4 carbon atoms, R^3 is an alkyl radical having 1 to 4 carbon atoms, p is a number from 1 to 6, q is a number from 1 to 3 and X is an alkali and/or alkaline earth metal or ammonium. Typical examples are reaction products of fatty acids having 6 to 22 carbon atoms, like for example caproic acid, caprylic acid, caprinic acid, lauric acid, myristic acid, palmitic acid, palmoleic acid, stearic acid, isostearic acid, oleic acid, elaidic acid, petroselinic acid, linolic acid linoleic acid, elaeostearic acid, arachidonic acid, gadoleic acid, behenic acid, erucic acid and their technical mixtures with N,N-dimethylaminoethylamine, N,N-dimethylaminopropylamine, N,N-diethylaminoethylamine und N,N-diethylaminopropylamine, which are condensed with sodium chloroacetate. The commercially available products include Dehyton® K and Dehyton® PK (Cognis GmbH) as well as Tego®Betaine (Goldschmidt).

Imidazolines. Other suitable starting materials for the betaines to be used for the purposes of the invention are imidazolines. These substances are also known and may be obtained, for example, by cyclizing condensation of 1 or 2 moles of C6-C22 fatty acids with polyfunctional amines, such as for example aminoethyl ethanolamine (AEEA) or diethylenetriamine. The corresponding carboxyalkylation products are mixtures of different open-chain betaines. Typical examples are condensation products of the above- mentioned fatty acids with AEEA, preferably imidazolines based on lauric acid, which are subsequently betainised with sodium chloroacetate. The commercially available products include Dehyton® G (Cognis GmbH).

A suitable and effective rigidifying amount of the at least one surfactant and the at least one polymer, preferably as aqueous solutions, can be mixed with the modified, preferably sheared, suspension prior to a pumping stage. In this way the at least one surfactant and the at least one polymer, preferably as aqueous solutions, can be distributed throughout the modified, preferably sheared, suspension. Alternatively, the solutions can be introduced and mixed with the modified, preferably sheared, suspension during a pumping stage or subsequently. The most effective point of addition will depend upon the substrate and the distance from the kinetic energy

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stage to the deposition area. If the conduit is relatively short it may be advantageous to dose the solutions close to where the modified, preferably sheared, suspension flows from the kinetic energy device. On the other hand, where the deposition area is significantly remote from the kinetic energy device it may be desirable to introduce the solutions closer to the outlet. In some instances it may be convenient to introduce the solutions into the modified, preferably sheared, suspension as it exits the outlet.

Preferably the treated suspension will be pumped as a fluid to an outlet at the deposition area and the so treated suspension allowed to flow over the surface of rigidified material. The suspension is allowed to stand and rigidify and therefore forming a stack of rigidified material. This process may be repeated several times to form a stack that comprises several layers of rigidified solids of the suspension. The formation of stacks of rigidified material has the advantage that less area is required for disposal.

The rheological characteristics of the treated suspension as it flows through the conduit to the deposition area is important, since any significant reduction in flow characteristics could seriously impair the efficiency of the process. It is important that there is no significant settling of the solids as this could result in a blockage, which may mean that the plant has to be closed to allow the blockage to be cleared. In addition it is important that there is no significant reduction in flow characteristics, since this could drastically impair the pumpability on the suspension. Such a deleterious effect could result in significantly increased energy costs as pumping becomes harder and the likelihood of increased wear on the pumping equipment.

The rheological characteristics of the suspension as it rigidifies is important, since once the treated suspension is allowed to stand it is important that flow is minimised and that solidification of the treated suspension proceeds rapidly. If the treated suspension is too fluid then it will not form an effective stack and there is also a risk that it will contaminate water released from the suspension. It is also necessary that the rigidified material is sufficiently strong to remain intact, but must be compressable, and withstand the weight of subsequent layers of rigidified suspension being applied to it.

Preferably the process of the invention will achieve heaped disposal geometry and will co-immobilise the fine and any coarse fractions of the solids in the suspension and also allowing any released water to have a higher driving force to separate it from the suspension by virtue of hydraulic gravity drainage. The heaped geometry appears to give a higher downward compaction pressure on underlying solids which seems to be responsible for enhancing the rate of dewatering. We find that this geometry results in a higher volume of waste per surface area, which is both environmentally and economically beneficial.

A preferred feature of the present invention is the release of aqueous liquor that often occurs during the rigidification step. Thus in a preferred form of the invention the suspension is dewatered during rigidification to release liquor containing significantly less solids. The liquor can

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then be returned to the process thus reducing the volume of imported water required and therefore it is important that the liquor is clear and substantially free of contaminants, especially migrating particulate fines. Suitably the liquor may for instance be recycled to the mining operation, for instance oil sands operation, from which the suspension originates. Alternatively, the
 5 liquor can be recycled to the spirals or other processes within the same plant.

The present invention also includes a test method for evaluating suspensions which contain fine mineral particles and clay, especially mature fine tailings derived from oil sands tailings.

10 A further aspect of the invention defines a method of testing a suspension which comprises particulate solids dispersed in an aqueous liquid, said particulate solids comprises clay and mineral particles of size below 50 μm , which method comprises the steps of,

- 15 (a) Subjecting the suspension to a kinetic energy stage to produce a modified suspension;
 - (b) Addition of at least one surfactant and at least one polymer to the modified suspension before, during and/or after step (a);
 - 20 (c) Transferring the polymer treated suspension obtained after having conducted steps (a) and (b) onto a mesh; and
 - (d) Measuring the water drained through the mesh and measuring the angle formed between the base of the solids retained on the mesh and a line drawn between the perimeter of the solids at the highest point in the centre of the solids
 25
- in which the kinetic energy stage is a shearing stage and/or application of ultrasonic energy to the suspension.

30 The method according to the present invention can be conducted in principle in any sequence as outlined above. According to a first embodiment, step (b) is conducted before step (a), i.e. the sequence is (b), (a), (c) and (d). According to a second embodiment, step (b) is conducted during step (a), i.e. the sequence is (b) and (a) at one time, (c) and (d). According to a third embodiment, which is most preferred, step (b) is conducted after step (a), i.e. the sequence is (a), (b), (c) and (d).

35 The present invention therefore preferably relates to the method according to the present invention, wherein step (b) is conducted after step (a).

40 According to a further embodiment of the present invention, the addition according to step (b) can be conducted partly before step (b), partly during step (a) and/or partly after step (a), wherein the complete amount of at least one polymer and at least one surfactant is added before, during and/or after step (a), i.e. before step (c).

The suspension may be in accordance with the suspension already defined herein. Preferably the suspension comprises mature fine tailings (MFT) that have been derived from oil sands tailings.

5

By kinetic energy we mean that suspension is subjected some energy which is or induces motion within the suspension. In one form the kinetic energy may be ultrasonic energy. Generally it is expected that the application of ultrasonic energy will induce vibrations which will at least partially break down the network structures. Other forms of kinetic energy may be alternative means for inducing vibrations.

10

One particularly suitable form of kinetic energy is shearing. General and preferred embodiments of shearing are outlined above.

15 The present invention preferably relates to the method according to the present invention in which the kinetic energy is shearing and the modified suspension is a sheared suspension.

The shearing may be carried out by any suitable shearing devices that may be employed in a laboratory. Typically such shearing devices may be domestic or laboratory shearing devices, such as those manufactured by Silverson or Moulinex. One particularly suitable shearing device comprises a flat paddle impeller.

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Suitably a sample of the suspension, desirably MFT, may be placed into a beaker or other convenient receptacle, suitably having a circular cross-section. The shearing member of the shearing device should then be inserted into the suspension. When the shearing device comprises a flat paddle impeller it is preferred that the length of the paddle fits substantially across the diameter of the beaker or receptacle. By this we mean that there may be up to 1, 2, or 3 mm clearance between the wall of the beaker or receptacle and the ends of the flat paddle.

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Desirably the sample should be sheared by operating the shearing device at a rate of at least 200 rpm, preferably at least 300 rpm and more preferably at least 400 rpm, especially at the 450 rpm. There is no upper limit to the rate of shearing but generally this would tend to depend on the type of shearing device and this would tend not to be greater 10,000 rpm or 20,000 rpm. In the case of the shearing device with the flat paddle impeller the upper rate of shearing may be no more than 1000 rpm and usually less than this. A desirable rate of shearing when using the flat paddle impeller may be in the range of between 200 and 800 rpm, preferably between 300 and 700 rpm, more preferably between 400 and 600 rpm, especially between 450 and 550 rpm.

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The duration of the shearing will tend to be at least 1 or 2 seconds and usually at least 5 seconds and in some cases at least 30 seconds or at least 1 min. The period of shearing may be longer than this, for instance up to 30 min or more. Generally the period of shearing would be up to 20 min.

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Typically the at least one surfactant and the at least one polymer will normally be used in amounts, and in case of solutions, in concentrations, as mentioned above. Following the addition of the surfactant and polymer solutions to the modified, preferably sheared, suspension, it may be desirable to assist the surfactant to be integrated throughout the solids of the suspension. This may be achieved by stirring. Alternatively the surfactant treated suspension may be transferred to a sealed container and inverted several times, for instance between 2 and 10 inversions, suitably between 3 and 5 inversions.

- 10 The mesh onto which the treated suspension is applied maybe any suitable mesh which allows water to drain through it and retain the solids on top of it. The mesh may be part of a sieve. The mesh may be made from metal or other material such as plastic.

- 15 The test method is useful for determining which surfactant and/or polymer products are likely to be most effective for the treatment of the suspension. The method should also be useful in determining the optimal doses of surfactant and/or polymer solutions.

- 20 The present invention further relates to the use of a combination of at least one surfactant, at least one polymer and the application of kinetic energy for dewatering a suspension comprising particulate solids dispersed in an aqueous liquid, said particulate solids comprises clay and mineral particles of size below 50 μm .

- 25 In respect of the at least one surfactant, at least one polymer, the application of kinetic energy and the suspension to be dewatered, the above mentioned definitions and preferred embodiments apply.

Claims

1. A process of dewatering a suspension comprising particulate solids dispersed in an aqueous liquid, said particulate solids comprises clay and mineral particles of size below 50 μm , which process comprises the steps of,
 - (a) subjecting the suspension to a kinetic energy stage to produce a modified suspension;
 - (b) addition of at least one surfactant and at least one polymer to the suspension during and/or after step (a);
 - (c) Dewatering the treated suspension obtained after having conducted steps (a) and (b)
 in which the kinetic energy stage is a shearing stage and/or application of ultrasonic energy to the suspension.
2. Process according to claim 1, wherein the shearing stage comprises subjecting the suspension to shearing employing a shearing device and in which the shearing device is selected from the group consisting of:
 - a shearing device comprising moving elements which rotate, preferably impellers, kneading components, or moving plates;
 - a milling device comprising moving elements;
 - a static mixer,
 preferably in which the operation of the moving elements is at least 5 cycles per second.
3. A process according to claim 1 or 2 in which the suspension comprises mature fine tailings derived from oil sands tailings.
4. A process according to any of claims 1 to 3 in which the modified suspension has a viscosity which is less than 90% of the viscosity of the suspension prior to the kinetic energy stage.
5. A process according to any preceding claim in which the modified suspension is transferred as a fluid to a deposition area, then allowed to stand and rigidify, in which the at least one surfactant and at least one polymer are added to the modified suspension in step (b) during transfer of the modified suspension.
6. A process according to any preceding claims in which the kinetic energy is shearing and the modified suspension is a sheared suspension.

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7. A process according to any preceding claim in which the at least one polymer is formed from ethylenically unsaturated water-soluble monomer or blend of monomers.
- 5 8. A process according to any of the preceding claims in which the at least one surfactant and the at least one polymer are added simultaneously or separately, preferably separately.
9. A process according to any of the preceding claims in which the at least one surfactant is added first and the at least one polymer is added afterwards.
- 10 10. A process according to any of the preceding claims in which the at least one polymer is added in solution, preferably in aqueous solution.
- 15 11. A process according to any of the preceding claims in which the at least one surfactant is anionic, cationic, non-ionic, amphoteric or zwitterionic.
12. A process according to any of the preceding claims in which the at least one polymer is anionic.
- 20 13. A process according to claim 12 in which the at least one polymer is formed from monomer(s) selected from the group consisting of (meth)acrylic acid, allyl sulphonic acid and 2-acrylamido-2-methyl propane sulphonic acid as the free acids or salts thereof, optionally in combination with non-ionic co-monomers, selected from the group consisting of (meth)acrylamide, hydroxy alkyl esters of (meth)acrylic acid and N-vinyl pyrrolidone.
- 25 14. A process according to any preceding claim in which the at least one polymer is non-ionic.
15. A process according to claim 14 in which the at least one polymer is formed from monomer(s) selected from the group consisting of (meth) acrylamide, hydroxy alkyl esters of (meth) acrylic acid and N-vinyl pyrrolidone.
- 30 16. A process according to any preceding claim in which the at least one polymer is cationic.
17. A process according to claim 16 in which the at least one polymer is formed from monomer(s) selected from the group consisting of dimethyl amino ethyl (meth)acrylate - methyl chloride, (DMAEA.MeCl) quat, diallyl dimethyl ammonium chloride (DADMAC), trimethyl amino propyl (meth)acrylamide chloride (ATPAC) optionally in combination with non-ionic co-monomers, selected from the group consisting of (meth) acrylamide, hydroxy alkyl esters of (meth)acrylic acid and N-vinyl pyrrolidone.
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18. A method of testing a suspension which comprises particulate solids dispersed in an aqueous liquid, said particulate solids comprises clay and mineral particles of size below 50 μm , which method comprises the steps of,

- 5 (a) Subjecting the suspension to a kinetic energy stage to produce a modified suspension;
- (b) Addition of at least one surfactant and at least one polymer to the modified suspension before, during and/or after step (a);
- 10 (c) Transferring the polymer treated suspension obtained after having conducted steps (a) and (b) onto a mesh; and
- (d) Measuring the water drained through the mesh and measuring the angle formed between the base of the solids retained on the mesh and a line drawn between the perimeter of the solids at the highest point in the centre of the solids.
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in which the kinetic energy stage is a shearing stage and/or application of ultrasonic energy to the suspension.

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19. The method according to claim 18, wherein step (b) is conducted after step (a).

20. A method according to claim 18 or 19 in which the suspension comprises mature fine tailings derived from oil sands tailings.

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21. A method according to any of claims 18 to 20 in which the kinetic energy is shearing and the modified suspension is a sheared suspension.

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22. The use of a combination of at least one surfactant, at least one polymer and the application of kinetic energy for dewatering a suspension comprising particulate solids dispersed in an aqueous liquid, said particulate solids comprises clay and mineral particles of size below 50 μm .