



(22) **Date de dépôt/Filing Date:** 2013/08/09

(41) **Mise à la disp. pub./Open to Public Insp.:** 2015/02/09

(45) **Date de délivrance/Issue Date:** 2015/06/23

(51) **Cl.Int./Int.Cl.** **C10G 1/00** (2006.01),
C10C 3/08 (2006.01), **C10G 1/04** (2006.01)

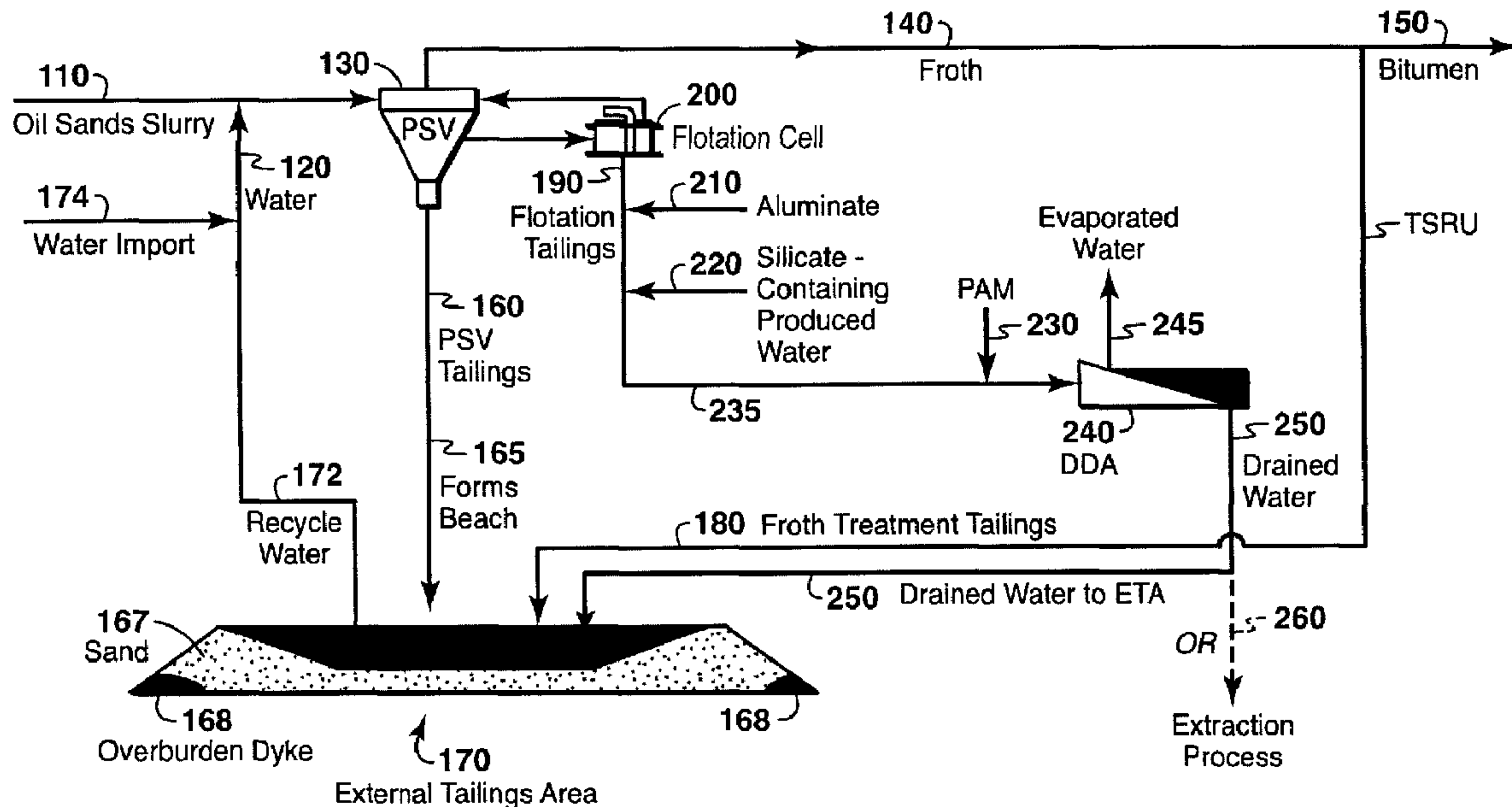
(72) **Inventeurs/Inventors:**
LIN, CHRISTOPHER, CA;
SPEIRS, BRIAN C., CA;
SARKAR, AMITAVA, CA;
ZHU, REN, CA;
LUNN, STUART R.D., CA

(73) **Propriétaire/Owner:**
IMPERIAL OIL RESOURCES LIMITED, CA

(74) **Agent:** BORDEN LADNER GERVAIS LLP

(54) **Titre : PROCÉDE D'UTILISATION D'UN FLUX CONTENANT DU SILICATE PROVENANT D'UNE OPERATION SUR LES HYDROCARBURES OU D'UNE SOURCE GEOTHERMIQUE POUR TRAITER DES RESIDUS FLUIDIQUES PAR LE BIAIS D'UNE MICRO-AGGLOMERATION CHIMIQUEMENT INDUITE**

(54) **Title: METHOD OF USING A SILICATE-CONTAINING STREAM FROM A HYDROCARBON OPERATION OR FROM A GEOTHERMAL SOURCE TO TREAT FLUID TAILINGS BY CHEMICALLY-INDUCED MICRO-AGGLOMERATION**



(57) **Abrégé/Abstract:**

Disclosed is a method for treating oil sands tailings. The tailings are conditioned with an aluminate and treated with a silicate-containing stream from a hydrocarbon operation or from a geothermal source to produce chemically-induced micro-agglomerates (CIMA) and water.



ABSTRACT

Disclosed is a method for treating oil sands tailings. The tailings are conditioned with an aluminate and treated with a silicate-containing stream from a hydrocarbon operation or from a geothermal source to produce chemically-induced micro-agglomerates (CIMA) and water.

METHOD OF USING A SILICATE-CONTAINING STREAM FROM A HYDROCARBON OPERATION OR FROM A GEOTHERMAL SOURCE TO TREAT FLUID TAILINGS BY CHEMICALLY-INDUCED MICRO-AGGLOMERATION

FIELD

[0001] The present disclosure relates generally to the field of processing of mined oil sands. More particularly, the present disclosure relates to the treatment of tailings from an oil sands bitumen extraction process that generates tailings comprising fine particles such as clays.

BACKGROUND

[0002] Fluid tailings streams are typically by-products of mining operations that are composed of water and solid particles. In order to recover the water and consolidate the solids, solid/liquid separation techniques must be applied. In oil sands processing, there are different fluid tailings streams with different compositions. For example, a typical fresh tailings stream comprises water, sand, silt, clay, and residual bitumen. However, if the tailings stream is derived from a froth treatment process, it will also comprise residual solvents and other hydrocarbonaceous materials (e.g. asphaltenes).

[0003] Oil sands tailings typically comprise a substantial amount of fine particles (defined as solids that are less than 44 microns) and clays. The bitumen extraction process uses hot water and chemical additives such as sodium hydroxide or sodium citrate to remove the bitumen from the solid particles. The side effect of these chemical additives is that they change the inherent water chemistry and thus the solids in the aqueous phase acquire a negative charge. Due to strong electrostatic repulsion, the fine particles form a stabilized suspension that does not settle by gravity, even after a considerable amount of time. In fact, if the suspension is left alone for 3-5 years, a gel-like layer known as mature fine tailings (MFT) will be formed and this type of tailings is very difficult to consolidate even with current technologies.

[0004] In oil sands tailings treatment, various types of polyacrylamides (PAM) have been tested for the flocculation of tailings solids. While polyacrylamides are generally useful for fast consolidation of tailings solids, they are not selective towards fine particles and clays. As a result, the water recovered from a PAM consolidation process is rarely good enough for recycling because of high fines content in the water. Therefore, this water needs to be placed in a tailings pond where the fine particles eventually turn into MFT. Additionally, tailings treated with PAM are shear sensitive so transportation of

thickened tailings to a dedicated disposal area (DDA) and general materials handling can become a challenge.

[0005] US Patent Application Publication No. 2010-0187181 (Sortwell) describes the use of zeolite to assist in the dispersion of components in aqueous mineral slurries to release and separate individual components of the slurry. Upon dispersion, Sortwell describes a process to consolidate residual mineral solids using multivalent cations and PAM.

[0006] US Patent Application Publication No. 2010-0126910 (Moffett et al.) describes the treatment of a tailings stream by contacting it with a polysilicate microgel, a polyacrylamide, a multivalent metal compound and/or a low molecular weight cationic organic polymer.

[0007] The synthesis of polysilicate microgel was described in a series of patents, including for example, US Patent Nos. 4,927,498 (Rushmere), 4,954,220 (Rushmere), 6,060,523 (Moffett et al.) and 6,274,112 (Moffett et al.).

[0008] Canadian Patent No. 2 515 581 and US Patent Application Publication No. 2006-0207946 (Scammell et al.) describe 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 rigidify, in which rigidification is improved with an effective rigidifying amount of aqueous solution of a water-soluble polymer.

SUMMARY

[0009] It is an object of the present disclosure to obviate or mitigate at least one disadvantage of previous systems or methods.

[0010] Disclosed is a method for treating oil sands tailings. The tailings are conditioned with an aluminate and treated with a silicate-containing stream from a hydrocarbon operation or from a geothermal source to produce chemically-induced micro-agglomerates (CIMA) and water.

[0011] The foregoing has broadly outlined the features of the present disclosure so that the detailed description that follows may be better understood. Additional features will also be described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] These and other features, aspects and advantages of the disclosure will become apparent from the following description, appending claims and the accompanying drawings, which are briefly described below.

[0013] Fig. 1 is a simplified flow diagram illustrating an overview of a method of forming CIMAs; and

[0014] Fig. 2 is a simplified flow diagram illustrating an overview of in-line flocculation of flotation tailings using the disclosed CIMAs process.

[0015] It should be noted that the figures are merely examples and no limitations on the scope of the present disclosure are intended thereby. Further, the figures are generally not drawn to scale, but are drafted for purposes of convenience and clarity in illustrating various aspects of the disclosure.

DETAILED DESCRIPTION

[0016] Generally, the present disclosure provides a method for treating oil sands tailings. The tailings are conditioned with an aluminate and treated with a silicate-containing stream from a hydrocarbon operation or from a geothermal source to produce CIMAs and water.

[0017] The present disclosure provides a process in which CIMAs of fine particles are formed in the fluid tailings stream. Micro-agglomerates are predominately much less than 1 mm in diameter, with the majority between 2 and 100 microns, and they principally comprise fine particles of the oil sands. The CIMAs, when combined with a typical PAM, can enhance tailings flocculation and dewatering, and lead to an increase in the strength of the tailings deposit. Simply put, the tailings deposit following the CIMA process generally has a greater strength than PAM treated tailings. The disclosed process allows water recycling (for example to an extraction process) to be an option and may reduce the size of the tailings pond significantly by increasing the dewatering of the tailings.

[0018] The present disclosure may provide a method for treating a tailings stream from an oil sands bitumen extraction process, the tailings stream comprising fine particles and clays, the method including conditioning the tailings stream with an aluminate to produce a conditioned tailings stream, and treating the conditioned tailings stream with a silicate-containing stream from a hydrocarbon operation or from a geothermal source to produce a treated tailings stream comprising CIMAs and water.

[0019] The aluminate may comprise sodium aluminate. The aluminate may be selected from the group consisting of potassium aluminate, aluminum sulfate, aluminum oxide, aluminum chloride, polyaluminum chloride, polyaluminum sulfate, and mixtures thereof. The aluminate may include an aluminate complex.

[0020] The silicate-containing stream from a hydrocarbon operation may be one of the following four streams: a thermal in-situ waste stream, a thermal in-situ non-waste stream, a hydrocarbon mining stream and a stream from a geothermal source.

[0021] A "thermal in-situ waste stream" is a stream that is considered a waste stream from a hydrocarbon production operation where heat is used to assist or enable hydrocarbon production. Such streams would generally be of low value, and would commonly be disposed of, and optionally treated, prior to disposal. Examples include boiler blowdown water, evaporator blowdown water, boiler in series blowdown water, waste streams such as a sludge or lagoon supernatant, and water for evaporators or crystallizers. Such streams generally have high silica and TDS (total dissolved solids) contents and are commonly turned into cakes or disposed of in a well. Using a waste stream may be particularly attractive because of its low value.

[0022] A "thermal in-situ non-waste stream" is a stream that is not considered a waste stream from a hydrocarbon production operation where heat is used to assist or enable hydrocarbon production. Examples include raw produced water, de-oiled or partially de-oiled produced water, and softened or partially softened produced water. Produced water is generally not considered a waste stream because it is commonly purified and recycled into an in-situ process as steam. One type of thermal in-situ hydrocarbon production is a thermal in-situ oil sands operation, which is discussed in more detail below. By way of example only, one well-known commercial in-situ oil sands operation is SAGD (solvent-assisted gravity drainage). In a SAGD process, steam is injected into the ground to reduce the viscosity of the in-situ bitumen to permit bitumen production. Water is also produced and is separated from the bitumen to form "produced water". Produced water comprises silicates, which are generally considered undesirable. However, as disclosed herein, produced water may be used as a silicate source for the CIMA process. An alternative would be to use commercial grade colloidal silica, which could be expensive given the high volume involved. Experiments detailed below showed that such silicate-containing produced water was effective for treating tailings.

[0023] A "hydrocarbon mining stream" is a stream that stems from a hydrocarbon mining extraction operation. Examples include kettle boiler streams, and drum boiler blowdown water from an oil sands mining operation.

[0024] The fourth stream is a stream from a "geothermal source". It is known that thermal energy has the ability to "leach" silicate compounds from natural minerals and geological formations. Therefore, streams with a high enough silicate content from geothermal sources could be a potential silicate source for CIMA.

[0025] Suitable silicate-containing streams will have a high enough silicate content to achieve the desired treatment to form suitable agglomerates (for instance, greater than 50 wppm Si). Suitable silicate-containing streams will also have low enough TDS so as not to hinder the CIMA process to an unacceptable extent (for instance, less than 2000 wppm).

[0026] Treating the conditioned tailings stream may comprise mixing to enhance agglomerate formation. Mixing may be provided by transportation through a pipeline.

[0027] The method may include adding an organic agglomerating polymer after the formation of the CIMA to produce a flocculated tailings stream. The organic agglomerating polymer may include a flocculating polymer. The flocculating polymer may comprise a PAM. The organic agglomerating polymer may be selected from the group consisting of: a cationic, anionic, nonionic or amphoteric polyacrylamide, a copolymer of acrylamide and diallyl dimethyl ammonium chloride, a copolymer of acrylamide and diallylaminoalkyl (meth)acrylates, a copolymer of acrylamide and dialkyldiaminoalkyl (meth)acrylamide, and mixtures thereof.

[0028] The method may include discharging the flocculated tailings stream to a DDA. Water may be collected from the DDA for recycling.

[0029] The tailings stream may be alkaline. The tailings stream may include coarse sand tailings or fine tailings, or a combination of coarse sand tailings and fine tailings.

[0030] The tailings stream may comprise flotation or middling tailings. The tailings stream may comprise froth treatment tailings. The tailings stream may comprise MFT. The tailings stream may comprise Thickened Tailings (TT). The tailings stream may comprise Primary Separation Vessel (PSV) or Coarse Tailings.

[0031] The tailings stream may be treated with 10 to 2000 ppmw sodium aluminate (SA), 10-2000 ppmw silicate (S), and 50-1000 ppmw polyacrylamide PAM. The tailings stream may be treated with 200-1000 ppmw SA, 20-100 ppmw S, and 100-1000 ppmw PAM. The tailings stream may be treated at a temperature in a range of 10°C to 40°C.

[0032] The tailings stream may be treated with 10-1000 ppmw SA, 10-1000 ppmw S, and 25-500 ppmw PAM. The tailings stream may be treated with 10 ppmw SA, 10 ppmw S, and 50-100 ppmw PAM. The tailings stream may be treated at a temperature in a range of 60°C to 95°C.

[0033] The tailings stream may be treated with 10-4000 ppmw SA, 10-4000 ppmw S, and 100-2000 ppmw PAM. The tailings stream may be treated with 1000-2000 ppmw SA,

100-2000 ppmw S, and 500-2000 ppmw PAM. The tailings stream may be treated at a temperature in a range of 5°C to 30°C. The tailings stream may be treated at a temperature in a range of 5°C to 20°C.

[0034] The method may include diluting the MFT with water prior to treating the tailings stream.

[0035] The tailings stream may be treated with 10-2000 ppmw SA, 10-2000 ppmw S, and 50-1000 ppmw PAM. The tailings stream may be treated with 200-1000 ppmw SA, 20-100 ppmw S, and 100-1000 ppmw PAM. The tailings stream may be treated at a temperature in a range of 10°C to 40°C.

[0036] The tailings stream may be treated with 10-1000 ppmw SA, 10-1000 ppmw S, and 10-500 ppmw PAM. The tailings stream may be treated with 10 ppmw SA, 10 ppmw S, and 10-200 ppmw PAM. The tailings stream may be treated at a temperature in a range of 20°C to 40°C.

[0037] The method may include increasing the alkalinity of the tailings stream prior to conditioning the tailings stream.

[0038] The method may include conditioning or treating or both conditioning and treating the tailings stream with a tailings treating technology. The tailings treating technology may be selected from the group of thickening, centrifugation, and in-line flocculation. The method may include following the tailings treating technology with thin or thick lift drying.

[0039] CIMAs of fine particles may be produced in a fluid tailings stream. Such agglomerates may be used to enhance overall tailings flocculation and dewatering. The CIMAs may be formed by an in-situ chemical reaction that binds the fine particles together (including clays). The CIMA process enhances the quality of the discharged water and creates chemically-bonded microstructures of fine particles that are stronger and more shear resistant than traditional flocs formed by physical consolidation.

[0040] The process of generating CIMAs of fine tailings involves forming a chemical bond between the fine particles and clays.

[0041] Referring to Fig. 1, in a conditioning stage 5, a tailings stream 10 from an oil sands bitumen extraction process may be conditioned with an aluminate 20, for instance sodium aluminate (or similar aluminum species, including but not limited to, potassium aluminate, aluminum sulfate, aluminum oxide, aluminum chloride, polyaluminum chloride, or polyaluminum sulfate) to produce a conditioned tailings stream 30. In alkaline environments (e.g. oil sands tailings), fine particles and clays 40 carry a negative charge characterized by a negative zeta potential. Aluminate complexes can

neutralize the negative charge and form a layer of coating 50 around the fine particles and clays 40. When this occurs, natural coagulation begins due to van der Waals interactions.

[0042] After the conditioning stage 5, the conditioned tailings stream 30 may be treated, in a treating stage 25, with a silicate 60 to produce treated tailings 70. In the treating stage 25, a series of polycondensation reactions begin to occur as soluble silicates react instantaneously or quickly with aluminate complexes to form a stable, chemical bond. The net effect of this in-situ bonding is the rearrangement of the fine particles and clays 40 into a CIMA 80.

[0043] After the formation of the CIMA 80, a flocculent, such as a PAM 90 may be added to the treated tailings 70, in a flocculating stage 85, to increase the settling rate and allow dense, "macro-agglomerates" 95 of particles to form through polymeric flocculation to produce a flocculated tailings stream 100.

[0044] The aluminate may be added before, or concurrently with silicate-containing produced water. The silicate-containing produced water may be added before, or concurrently with the aluminate.

[0045] The flocculent may be any suitable organic agglomerating polymer, including but not limited to, any cationic, anionic, nonionic or amphoteric polyacrylamides, a copolymer of acrylamide and diallyl dimethyl ammonium chloride, a copolymer of acrylamide and diallylaminoalkyl (meth)acrylates, and a copolymer of acrylamide and dialkyldiaminoalkyl (meth)acrylamide.

[0046] As used herein, the flocculated "macro-agglomerates" are generally greater than 500 microns, up to millimeters in size. These "macro-agglomerates" comprise both the fine particles (less than 44 microns) and sand grains of the oil sands. The addition of the PAM 90 increases the overall dewatering rate due to enhanced settling rate.

[0047] The method described herein provided enhanced quality of water discharged from the flocculated tailings stream 100 and the chemically-bonded microstructures of fine particles are stronger and more shear resistant than flocs formed by a typical PAM without conditioning and treating to form the CIMA 80.

[0048] The method described herein for tailings flocculation and dewatering may be used in relation to various tailings treating technologies including thickening, centrifugation, and in-line flocculation followed by thin or thick lift drying. Due to the robustness of the method described herein, the method may be applied to various oil sands tailings streams including flotation/middling tailings, froth treatment tailings

(including paraffinic froth treatment (PFT) or naphthenic froth treatment (NFT)), mature fine tailings (MFT), primary separation vessel (PSV)/coarse tailings, and thickened tailings (TT).

[0049] In-line flocculation of flotation tailings using the method described herein is illustrated in Fig. 2, in context with a known process for extracting bitumen from oil sands.

[0050] Referring to Fig. 2, an oil sands slurry 110, with water 120 may be conveyed to a Primary Separation Vessel (PSV) 130 where, through known processes, froth 140 carries bitumen 150 for recovery. PSV tailings 160, which are relatively coarse sand tailings, are collected in an external tailings area (ETA) 170, tending to form what is referred to as a beach 165 comprising sand 167. An overburden dyke 168 holds the sand 167 in place. Recycle water 172 may be recovered from the ETA 170 and be recycled as a source of water 120. Import water 174 may also provide a source of water 120.

[0051] Froth treatment tailings 180 from a Tailings Solvent Recovery Unit (TSRU) may be also collected in the external tailings area 170. Flotation tailings 190 from flotation cell 200 may be treated using the method disclosed herein.

[0052] Aluminate 210, silicate-containing produced water 220 and PAM 230 may be added in sequence, for example by pumping, injection, or otherwise, into a pipeline 235 extending between the flotation cell 200 and a dedicated disposal area (DDA) 240 where the flocculated tailings are discharged. Between 100 ppmw and 1000 ppmw of sodium aluminate, which represents 100 and 1000 g/T of dry tailings, silicate of between 10 and 1000 ppmw with respect to dry tails (introduced via silicate-containing produced water), and PAM of between 50 and 500 ppmw with respect to dry tails may be added.

[0053] The aluminate 210 and PAM 230 may also be added as aqueous solutions. The concentration of sodium aluminate (the source of aluminate) may be about 1 wt%. This means 1g of sodium aluminate solid in 99g of distilled water. The mixture may be well mixed and added to the tailings. PAM 230 generally comes as solids and is mixed with water. PAM 230 solution, having a concentration of between about 0.1 wt% and about 0.5 wt% solution, may be used.

[0054] Flotation and middling tailings, froth treatment tailings, mature fine tailings, thickened tailings, PSV/coarse tailings, or combinations thereof, may be treated according to the following formulations, which are examples only.

[0055] PSV/Coarse tailings may be treated at a temperature between about 20°C and about 40°C.

[0056] The high shear within the pipeline 235 provides mixing to enhance agglomerate formation. A portion of water from the DDA 240 may evaporate as

evaporated water 245. Drained water 250 may be drained or otherwise captured from the DDA 240 and may be used for an extraction process 260 or other re-use or heat recovery, or a combination thereof, or sent to the ETA 170 for storage.

[0057] While the method described herein has been described in detail with respect to flotation tailings 190, it may similarly also be applied to PSV tailings 160 or froth treatment tailings 180, or other oil sands tailings, or combinations thereof.

[0058] Utilizing the method described herein, in-line flocculation directly treats fresh tailings and can reduce or potentially eliminate the formation of MFT.

Silicate-containing Stream

[0059] By way of background, "silicates" are a class of compounds of which silica is a member. "Silica" is also known as silicon dioxide.

[0060] The amount of silicate used may be selected depending on the type of tailings been treated, and may be, for instance, 10-4000 ppmw based on the weight of dry tails. Additionally, the process can accommodate a wide range of silicate concentrations in the produced water since the process can accommodate more or less produced water. If less water is desired, the produced water could be diluted with another aqueous source, for instance another produced water stream with a lower silicate concentration.

[0061] For this process, silicate concentrations in the produced water could be, for instance, 10-10,000 ppmw, or may be 50-1,000 ppmw, but may also be outside of these ranges.

[0062] Ideally, the silicate-containing stream will not introduce an amount of total dissolved solids (TDS), for instance sodium compounds that will unduly interfere with the tailings treatment or subsequent extraction using recycled water.

[0063] The produced water used may be raw produced water or may be processed prior to its introduction into the CIMA process. For instance, the produced water may de-oiled or partially de-oiled produced water, or softened or partially softened water.

[0064] While the produced water could be treated to remove contaminants, so long as the contaminants do not unduly interfere with the tailings treatment, for economic reasons and all else being equal, it would generally be wise to use produced water that has not been unnecessarily cleaned, for instance water that would otherwise be suitable for steam generation in an SAGD operation.

[0065] Produced water from thermal in-situ oil sands processes (e.g. SAGD and CSS) commonly has a silicate content that approaches 300 ppmw. Produced water

treatment from in-situ operations to prepare boiler-feed-water (BFW) for steam generation in once through steam generators (OTSG) typically involves the use of a skim tank, induced gas flotation (IGF), hot/warm lime softening (HLS/WLS), and weak acid cation exchange (WACS) softening.

[0066] Due to the robustness of the CIMA process, various produced water streams with a high enough silicate content from all thermal in-situ operations and geothermal sources can be a potential silicate source for CIMA.

[0067] It is known that thermal energy has the ability to “leach” silicate compounds from natural minerals and geological formations. Therefore, any water streams with a high enough silicate content from thermal in-situ operations and/or geothermal sources could be a potential silicate source for CIMA.

[0068] For example, the OTSG blowdown from SAGD operations (typically a waste stream with residual heat content) may be a good stream for integration with CIMA because using this stream may reduce wastewater management requirements in a SAGD operation. Other suitable streams may include HLS feed and outlet streams where silicate contents are typically in the range of 250 to 300 ppmw and 30 to 150 ppmw, respectively.

[0069] As shown in the Examples section below, the silicate-containing produced water from an in-situ oil sands process was found to be effective in the CIMA process. This integrative process may be an attractive option to reduce CIMA operating expenses and/or to improve wastewater management in in-situ operations.

[0070] Water treatment technologies using IGF, HLS, and WACS are well documented. The primary chemical reactions associated with HLS are: lime softening, caustic softening, soda ash softening, and alkalinity reduction. Most of these reactions result in precipitation of calcium carbonate and magnesium hydroxide that leads to a reduction in water hardness. Silica enters the HLS as very small particulates that cannot be effectively filtered from the water in the sludge bed or in the WACS afterfilters. Silica is reduced in the HLS through the physical process of adsorption. Silica, present in the HLS as negatively-charged colloids, is adsorbed on the positively-charged magnesium hydroxide present in the system. The outlet stream from the HLS typically contains greater than 30 ppmw of silica which becomes a component of the BFW.

Examples

[0071] Lab-scale proof of concept studies confirmed that the silica present in the in-situ process water can be used in the CIMA process. In Experiment 1, CIMA was formulated with commercial colloidal silica and was used to treat fluid tailings. In Experiment 2, CIMA was formulated with treated produced water from a CSS operation in the Cold Lake area of Alberta and used to treat the same tailings. In both CIMA experiments, the chemical dosages were the same and the performance data were comparable. A comparative example using only a single flocculant was conducted and it is clear that the performance of a single flocculant was not as desirable as CIMA using commercial colloidal silica or silicate-containing produced water.

Lab Data:

[0072] As a proof-of-concept, treated produced water from Cold Lake with a silica content of 24 ppm and a TDS of 47 ppm was used in Experiment 2. The chemical dosage for each experiment is outlined below:

	Flotation Tailings (g)	Sodium Aluminate (g/T tailings)	Silica (g/T tailings)	PAM (g/T tailings)
Experiment 1	150	800	100	250
Experiment 2	150	800	100	250
Comparative	150	N/A	N/A	250

	Experiment 1: CIMA (using commercial colloidal silica)	Experiment 2: CIMA (using produced water from an in-situ process)	Comparative Experiment: Single Flocculant
Supernatant turbidity (NTU)	60.5	69.8	282
Initial yield stress of tailings deposit (Pa)	357	334	120

In-situ Oil Sands Operations

[0073] In order to provide further context to the produced water used herein as a silicate source, a brief description of in-situ oil sands processes will now be provided.

[0074] Where deposits lie well below the surface, bitumen may be extracted using in-situ ("in place") techniques. One example of an in-situ technique is the steam-assisted gravity drainage method (SAGD). In SAGD, directional drilling is employed to place two horizontal wells in the oil sands, a lower well and an upper well positioned above it. Steam is injected into the upper well to heat the bitumen and lower its viscosity. The bitumen and condensed steam will then drain downward through the reservoir under the action of gravity and flow into the lower production well, whereby these liquids can be pumped to the surface. At the surface of the well, the condensed steam and bitumen are separated, and the bitumen is diluted with appropriate light hydrocarbons for transport to a refinery or an upgrader. An example of SAGD is described in U.S. Patent No. 4,344,485 (Butler).

[0075] In other processes, such as in Cyclic Steam Stimulation (CSS), the same well is used both for injecting a fluid and for producing oil. In CSS, cycles of steam injection, soak, and oil production are employed. Once the production rate falls to a given level, the well is put through another cycle of injection, soak, and production. An example of CSS is described in U.S. Patent No. 4,280,559 (Best).

[0076] Steam flood (SF) involves injecting steam into the formation through an injection well. Steam moves through the formation, mobilizing oil as it flows toward the production well. Mobilized oil is swept to the production well by the steam drive. An example of steam flooding is described in U.S. Patent No. 3,705,625 (Whitten).

[0077] Other thermal processes include Solvent-Assisted Steam Assisted Gravity Drainage (SA-SAGD), an example of which described in Canadian Patent No. 1,246,993 (Vogel); Vapour Extraction (VAPEX), an example of which is described in U.S. Patent No. 5,899,274 (Frauenfeld); Liquid Addition to Steam for Enhanced Recovery (LASER), an example of which is described in U.S. Patent No. 6,708,759 (Leaute et al.); and Combined Steam and Vapour Extraction Process (SAVEX), an example of which is described in U.S. Patent No. 6,662,872 (Gutek), and derivatives thereof.

Flotation and Middling Tailings

[0078] Flotation/middling tailings may be treated according to the recipe: 10 to 2000 ppmw SA; 10-2000 ppmw S; and 50-1000 ppmw PAM. Flotation/middling tailings may be treated according to the recipe: 200-1000 ppmw SA; 20-100 ppmw S; and 100-1000 ppmw PAM.

[0079] Flotation/middling tailings may be treated at a temperature between about 10°C and about 40°C.

Froth Treatment Tailings (PFT and NFT)

[0080] Froth treatment tailings may be treated according to the recipe: 10-1000 ppmw SA; 10-1000 ppmw S; and 25-500 ppmw PAM. Froth treatment tailings may be treated according to the recipe: 10 ppmw SA; 10 ppmw S; and 50-100 ppmw PAM.

[0081] Froth treatment tailings may be treated at a temperature between about 60°C and about 95°C.

Mature Fine Tailings (MFT)

[0082] MFT may be treated according to the recipe: 10-4000 ppmw SA; 10-4000 ppmw S; and 100-2000 ppmw PAM. MFT may be treated according to the recipe: 1000-2000 ppmw SA; 100-2000 ppmw S; and 500-2000 ppmw PAM.

[0083] MFT may be treated at a temperature between about 5°C and about 30°C. The temperature may be between about 5°C and about 20°C. Water may be used to dilute the MFT prior to treatment.

Thickened Tailings (TT)

[0084] TTs may be treated according to the recipe: 10-2000 ppmw SA; 10-2000 ppmw S; and 50-1000 ppmw PAM. TTs may be treated according to the recipe: 200-1000 ppmw SA; 20-100 ppmw S; and 100-1000 ppmw PAM.

[0085] TTs may be treated at a temperature between about 10°C and about 40°C.

PSV/Coarse Tailings

[0086] PSV/Coarse Tailings may be treated according to the recipe: 10-1000 ppmw SA; 10-1000 ppmw S; and 10-500 ppmw PAM. PSV/course tailings may be treated according to the recipe: 10 ppmw SA; 10 ppmw S; and 10-200 ppmw PAM.

[0087] As utilized herein, the terms “approximately,” “about,” “substantially,” and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numeral ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and are considered to be within the scope of the disclosure.

[0088] The scope of the claims should not be limited by particular embodiments set forth herein, but should be construed in a manner consistent with the specification as a whole.

[0089] The articles "the", "a" and "an" are not necessarily limited to mean only one, but rather are inclusive and open ended so as to include, optionally, multiple such elements.

CLAIMS:

1. A method for treating a tailings stream from an oil sands bitumen extraction process, the tailings stream comprising fine particles and clays, the method comprising:
conditioning the tailings stream with an aluminate to produce a conditioned tailings stream; and
treating the conditioned tailings stream with silicate-containing stream from a hydrocarbon operation or from a geothermal source, to produce a treated tailings stream comprising chemically-induced micro-agglomerates (CIMA) and water.
2. The method of claim 1, wherein the silicate-containing stream has a silicate concentration of 10-10,000 ppmw.
3. The method of claim 1, wherein the silicate-containing stream has a silicate concentration of 50-1,000 ppmw.
4. The method of any one of claims 1 to 3, wherein the silicate-containing stream is from a hydrocarbon operation.
5. The method of claim 4, wherein the silicate-containing stream from a hydrocarbon operation is a thermal in-situ waste stream.
6. The method of claim 5, wherein the thermal in-situ waste stream is boiler blowdown water.
7. The method of claim 5, wherein the thermal in-situ waste stream is evaporator blowdown water.
8. The method of claim 5, wherein the thermal in-situ waste stream is boiler in series blowdown water.
9. The method of claim 5, wherein the thermal in-situ waste stream is a sludge or lagoon supernatant.

10. The method of claim 5, wherein the thermal in-situ waste stream is water for evaporators or crystallizers.
11. The method of claim 4, wherein the silicate-containing stream from a hydrocarbon operation is a thermal in-situ non-waste stream.
12. The method of claim 11, wherein the thermal in-situ non-waste stream is raw produced water.
13. The method of claim 11, wherein the thermal in-situ non-waste stream is de-oiled or partially de-oiled produced water.
14. The method of claim 11, wherein the thermal in-situ non-waste stream is softened or partially softened produced water.
15. The method of any one of claims 1 to 14, wherein the silicate-containing stream is from one of the following in-situ oil sands operations: cyclic steam stimulation (CSS), steam-assisted gravity drainage (SAGD), solvent-assisted SAGD (SA-SAGD), combined steam and vapour extraction (SAVEX), liquid addition to steam for enhancing recovery (LASER), vapour extraction (VAPEX), steam flooding, or a derivative thereof.
16. The method of claim 15, wherein the in-situ oil sands operation is cyclic steam stimulation (CSS).
17. The method of claim 15, wherein the in-situ oil sands operation is steam-assisted gravity drainage (SAGD).
18. The method of claim 15, wherein the in situ oil sands operation is solvent assisted steam assisted gravity drainage (SA-SAGD).
19. The method of claim 15, wherein the in situ oil sands operation is liquid addition to steam for enhancing recovery (LASER).

20. The method of claim 15, wherein the in situ oil sands operation is vapor extraction (VAPEX).
21. The method of claim 15, wherein the in situ oil sands operation is steam flooding.
22. The method of claim 15, wherein the in situ oil sands operation is a thermal recovery process.
23. The method of claim 4, wherein the silicate-containing stream from a hydrocarbon operation is a stream that stems from a hydrocarbon mining extraction operation.
24. The method of claim 23, wherein the silicate-containing stream is a kettle boiler stream.
25. The method of claim 23, wherein the silicate-containing stream is a drum boiler blowdown stream.
26. The method of any one of claims 1 to 3, wherein the silicate-containing stream is from a geothermal source.
27. The method of any one of claims 1 to 26, wherein the aluminate comprises sodium aluminate.
28. The method of any one of claims 1 to 26, wherein the aluminate is selected from the group consisting of potassium aluminate, aluminum sulfate, aluminum oxide, aluminum chloride, polyaluminum chloride, polyaluminum sulfate, and mixtures thereof.
29. The method of any one of claims 1 to 28, wherein the treating the conditioned tailings stream comprises mixing to enhance agglomerate formation.

30. The method of claim 29, wherein the mixing is provided by transportation through a pipeline.
31. The method of any one of claims 1 to 30, further comprising adding an organic agglomerating polymer after the formation of the CIMA to produce a flocculated tailings stream.
32. The method of claim 31, wherein the agglomerating polymer comprises a flocculating polymer.
33. The method of claim 32, wherein the flocculating polymer comprises a polyacrylamide (PAM).
34. The method of claim 31, wherein the organic agglomerating polymer is selected from the group consisting of: a cationic, anionic, nonionic or amphoteric polyacrylamide, a copolymer of acrylamide and diallyl dimethyl ammonium chloride, a copolymer of acrylamide and diallylaminoalkyl (meth)acrylates, a copolymer of acrylamide and dialkyldiaminoalkyl (meth)acrylamide, and mixtures thereof.
35. The method of any one of claims 31 to 34, further comprising discharging the flocculated tailings stream to a dedicated disposal area (DDA).
36. The method of claim 35, further comprising collecting water from the DDA for recycling.
37. The method of any one of claims 1 to 36, wherein the aluminate comprises an aluminate complex.
38. The method of any one of claims 1 to 37, wherein the tailings stream is alkaline.
39. The method of any one of claims 1 to 38, wherein the tailings stream comprises coarse sand tailings.

40. The method of any one of claims 1 to 39, wherein the tailings stream comprises fine tailings.
41. The method of any one of claims 1 to 38, wherein the tailings stream comprises flotation or middling tailings.
42. The method of claim 41, wherein the tailings stream is treated with 10 to 2000 ppmw sodium aluminate, 10-2000 ppmw silicate, and 50-1000 ppmw PAM.
43. The method of claim 41 or 42, wherein the tailings stream is treated with 200-1000 ppmw sodium aluminate, 20-100 ppmw silicate, and 100-1000 ppmw PAM.
44. The method of any one of claims 41 to 43, wherein the tailings stream is treated at a temperature in a range of 10°C to 40°C.
45. The method of any one of claims 1 to 38, wherein the tailings stream comprises froth treatment tailings.
46. The method of claim 45, wherein the tailings stream is treated with 10-1000 ppmw sodium aluminate, 10-1000 ppmw silicate, and 25-500 ppmw PAM.
47. The method of claim 45 or 46, wherein the tailings stream is treated with 10 ppmw sodium aluminate, 10 ppmw silicate, and 50-100 ppmw PAM.
48. The method of any one of claims 45 to 47, wherein the tailings stream is treated at a temperature in a range of 60°C to 95°C.
49. The method of any one of claims 1 to 38, wherein the tailings stream comprises mature fine tailings (MFT).
50. The method of claim 49, wherein the tailings stream is treated with 10-4000 ppmw sodium aluminate, 10-4000 ppmw silicate, and 100-2000 ppmw PAM.

51. The method of claim 49 or 50, wherein the tailings stream is treated with 1000-2000 ppmw sodium aluminate, 100-2000 ppmw silicate, and 500-2000 ppmw PAM.
52. The method of any one of claims 49 to 51, wherein the tailings stream is treated at a temperature in a range of 5°C to 30°C.
53. The method of claim 52, wherein the range is 5°C to 20°C.
54. The method of any one of claims 49 to 53, further comprising diluting the MFT with water prior to treating the tailings stream.
55. The method of any one of claims 1 to 38, wherein the tailings stream comprises Thickened Tailings (TT).
56. The method of claim 55, wherein the tailings stream is treated with 10-2000 ppmw sodium aluminate, 10-2000 ppmw silicate, and 50-1000 ppmw PAM.
57. The method of claim 55 or 56, wherein the tailings stream is treated with 200-1000 ppmw sodium aluminate, 20-100 ppmw silicate, and 100-1000 ppmw PAM.
58. The method of any one of claims 55 to 57, wherein the tailings stream is treated at a temperature in a range of 10°C to 40°C.
59. The method of any one of claims 1 to 38, wherein the tailings stream comprises primary separation vessel tailings or coarse tailings.
60. The method of claim 59, wherein the tailings stream is treated with 10-1000 ppmw sodium aluminate, 10-1000 ppmw silicate, and 10-500 ppmw PAM.
61. The method of claim 59 or 60, wherein the tailings stream is treated with 10 ppmw sodium aluminate, 10 ppmw silicate, and 10-200 ppmw PAM.

62. The method of any one of claims 59 to 61, wherein the tailings stream is treated at a temperature in a range of 20°C to 40°C.

63. The method of any one of claims 1 to 62, further comprising increasing the alkalinity of the tailings stream prior to conditioning the tailings stream.

64. The method of any one of claims 1 to 63, further comprising conditioning or treating or both conditioning and treating the tailings stream with a tailings treating technology.

65. The method of claim 64, wherein the tailings treating technology is selected from the group consisting of thickening, centrifugation, and in-line flocculation.

66. The method of claim 65, further comprising following the tailings treating technology with thin or thick lift drying.

67. A use of silicate-containing produced water from an in situ oil sands operation, for treating a tailings stream from an oil sands bitumen extraction process, to produce a treated tailings stream comprising CIMAs and water, wherein the tailings stream comprises fine particles and clays.

68. The use of claim 67, wherein the tailings stream is a conditioned tailings stream, having been conditioned with an aluminate.

69. The use of claim 67 or 68, wherein 10-4000 ppmw of silicate is used.

1/2

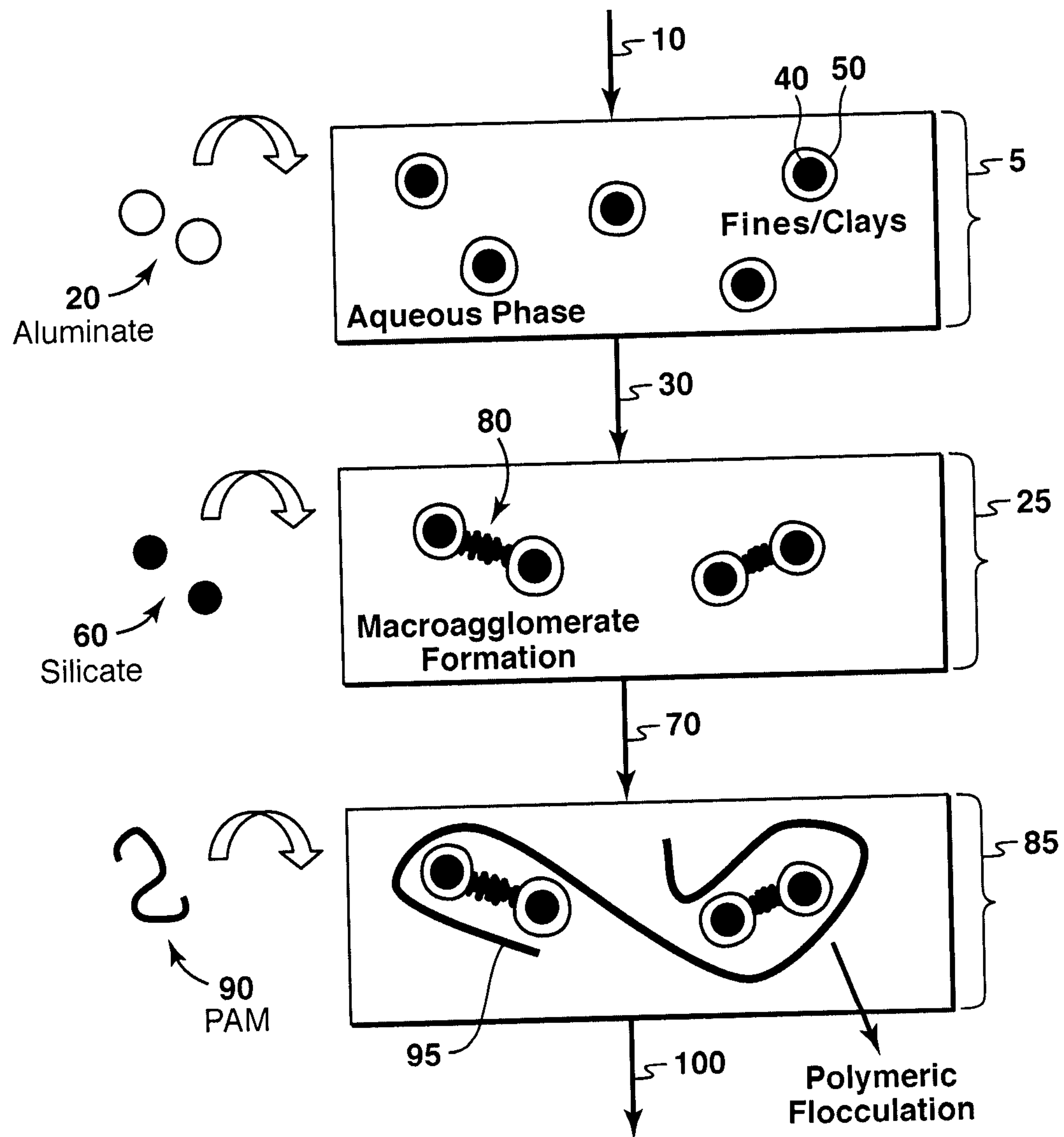


FIG. 1

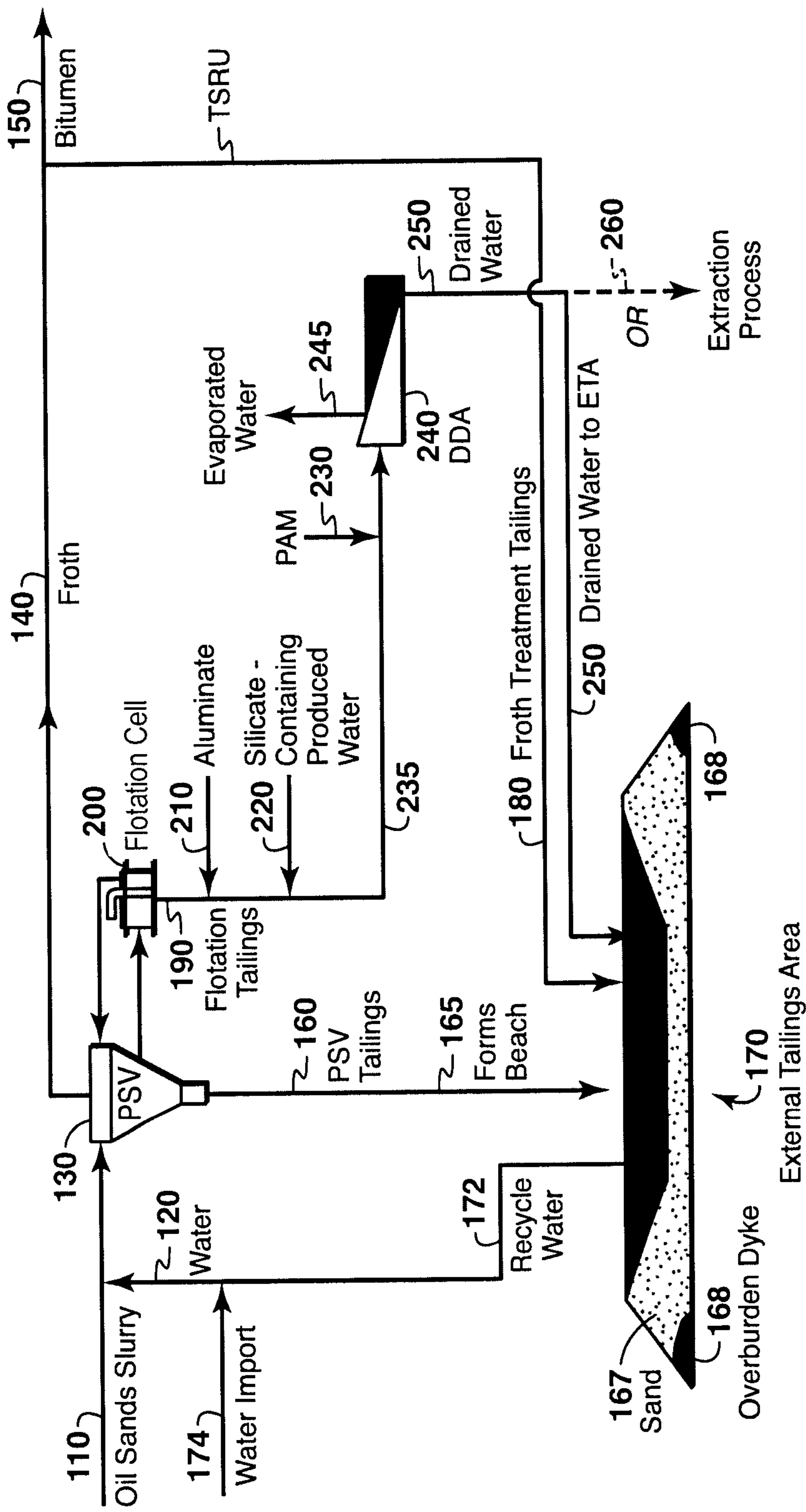


FIG. 2

