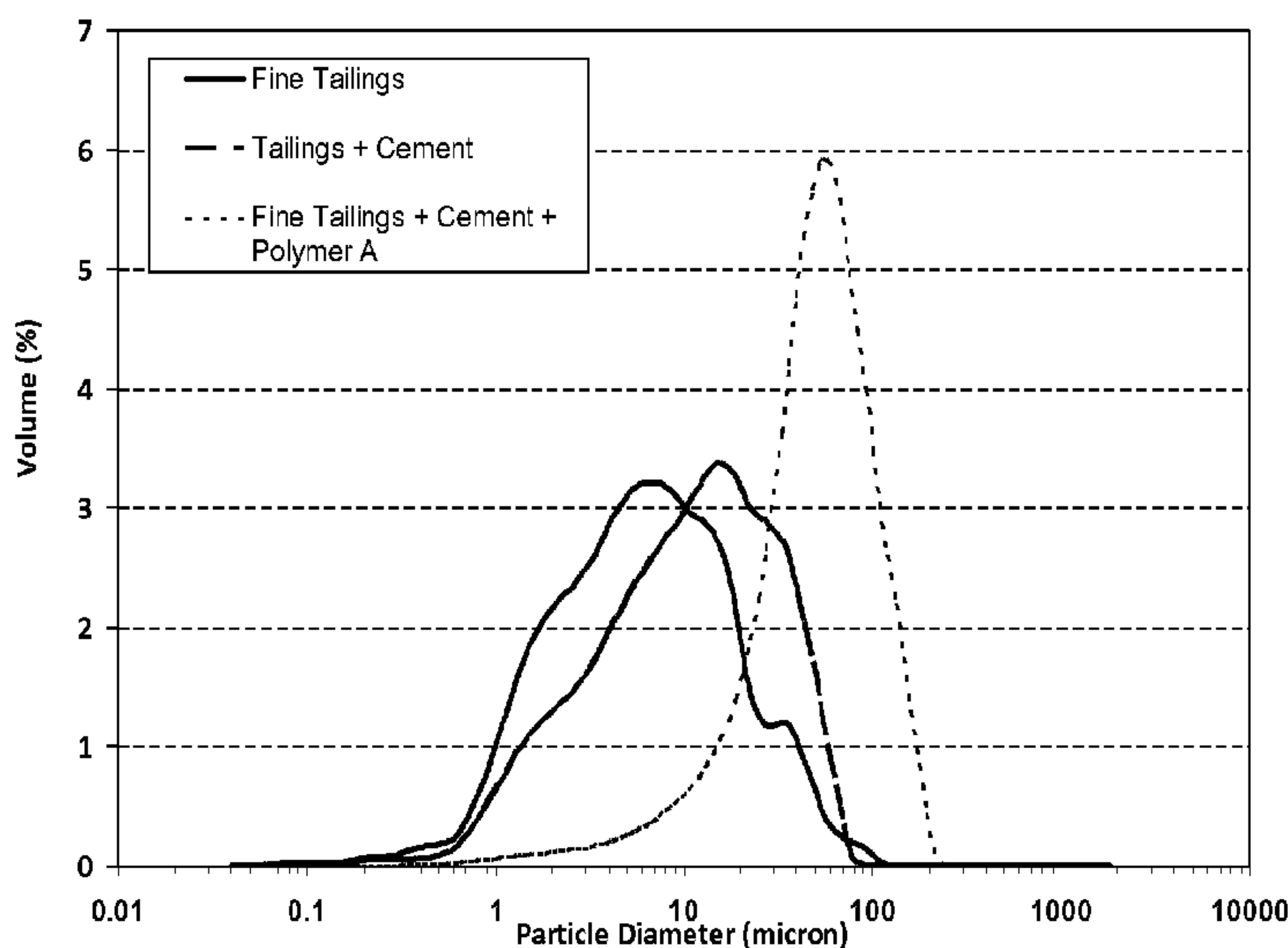




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(57) **Abrégé/Abstract:**

A process for treating a tailings stream which comprises water and solids such as sand and clay, the process comprising the steps of: (i) adding a cement to the tailings stream; and (ii) separating at least a portion of the cement and solids from the tailings stream. The process may also comprise the addition of one or more coagulants or flocculants to the tailings stream.

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(54) **Title:** PROCESSES FOR TREATING A TAILINGS STREAM

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## PROCESSES FOR TREATING A TAILINGS STREAM

### FIELD OF THE ART

[0001] The present disclosure relates generally to processes for treatment of a tailings stream.

### BACKGROUND

[0002] Bituminous sands, or oil sands, are a type of petroleum deposit. The sands contain naturally occurring mixtures of sand, clay, water, and a dense and extremely viscous form of petroleum technically referred to as bitumen (or colloquially "tar" due to its similar appearance, odor, and color). Oil sands are found in large amounts in many countries throughout the world, and most abundantly in Canada and Venezuela. Oil sand deposits in northern Alberta in Canada (Athabasca oil sands) contain approximately 1.6 trillion barrels of bitumen, and production from oil sands mining operations is presently approximately one million barrels of bitumen per day.

[0003] Oil sands reserves have only recently been considered to be part of the world's oil reserves, as higher oil prices and new technology enable them to be profitably extracted and upgraded to usable products. They are often referred to as unconventional oil or crude bitumen, in order to distinguish the bitumen extracted from oil sands from the free-flowing hydrocarbon mixtures known as crude oil traditionally produced from oil wells.

[0004] Conventional crude oil is normally extracted from the ground by drilling oil wells into a petroleum reservoir, and allowing oil to flow into them under natural reservoir pressures. Although artificial lift and techniques such as water flooding and gas injection are usually required to maintain production as reservoir pressure drops towards the end of a field's life. Because extra-heavy oil and bitumen flow very slowly, if at all, towards producing wells under normal reservoir conditions, the sands may be extracted by strip mining or the oil made to flow into wells by in situ techniques which reduce the viscosity, such as by injecting steam, solvents, and/or hot air into the sands. These processes can use more water and require larger amounts of energy than conventional oil extraction, although many conventional oil fields also require large amounts of water and energy to achieve good rates of production.

[0005] Water-based oil sand extraction processes include ore preparation, extraction and tailings treatment stages wherein a large volume of solids-laden aqueous tailings is produced. One such extraction process is called the hot water process. In the hot water process the displacement of bitumen from the sands is achieved by wetting the surface of the sand grains with an aqueous solution containing a caustic wetting agent, such as

sodium hydroxide, sodium carbonate or sodium silicate. The resulting strong surface hydration forces operative at the surface of the sand particles give rise to the displacement of the bitumen by the aqueous phase. The name of the process comes from the fact that the system is operated at temperatures near the boiling point of water. Once the bitumen has been displaced and the sand grains are free, the phases can be separated by froth flotation based on the natural hydrophobicity exhibited by the free bituminous droplets at moderate pH values (Hot water extraction of bitumen from Utah tar sands, Sepulveda *et al.* S. B. Radding, ed., Symposium on Oil Shale, Tar Sand, and Related Material - Production and Utilization of Synfuels: Preprints of Papers Presented at San Francisco, California, August 29 – September 3, 1976; vol. 21, no. 6, pp. 110–122 (1976)).

**[0006]** The recovered bitumen froth generally consists of 60% bitumen, 30% water and 10% solids by weight. The recovered bitumen froth needs to be cleaned to reject the contained solids and water to meet the requirement of downstream upgrading processes. Depending on the bitumen content in the ore, between 90 and 100% of the bitumen can be recovered using modern hot water extraction techniques.

**[0007]** Hydrophilic and biwetted ultrafine solids, mainly clays and other charged silicates and metal oxides, tend to form stable colloids in water and exhibit a very slow settling and dewatering behavior, resulting in tailing ponds that can take several years to manage. The slow settling of fine (<44  $\mu\text{m}$ ) and ultrafine clays (<1  $\mu\text{m}$ ) and the large demand of water during oil sand extraction process have promoted research and development of new technologies during the last 20 years to modify the water release and to improve settling characteristics of tailings streams. These include process additives such as variations in pH, salinity and addition of chemical substances. Currently, two technologies commonly used in the oil sands industry are the consolidated tailings (CT) process and the paste technology. Gypsum is used in the CT technology as a coagulant while polyelectrolytes, generally polyacrylamides of high density, are used as flocculants in the paste technology. Flocculants, or flocculating agents, are chemicals that promote flocculation by causing colloids and other suspended particles in liquids to aggregate, forming a floc. Flocculants are used in water treatment processes to improve the sedimentation or filterability of small particles.

**[0008]** Various inorganic and/or organic flocculants are currently in use in tailings treatments. The adequate dosage of gypsum and/or flocculants during the tailings disposition improves the oil sands process efficiency because these substances act as modifiers of the interaction forces responsible for holding particles together. Consequently, the addition of these chemicals can enhance the settling rate of tailings for consolidation and land reclamation and promote the recovery of water and its recirculation in the oil sands process. Recently some silicates and silica microgel have been proposed for treating tailings and separation of ultrafine solids. Silica could cause some problems, however, because it could be

precipitated by the presence of excess calcium and magnesium. The resulting silicate scale could foul pipe surfaces and other surfaces.

[0009] When tailings are treated with gypsum (calcium sulfate) to flocculate the particles there is a problem that excess calcium can be present in the water recycled from the tailings, and this calcium can make it very hard to extract bitumen from oil sands.

[0010] US Patent No. 5,804,077 discloses a method for treating whole aqueous tailings produced by a water-based extraction process to recover bitumen from oil sand, said tailing containing suspended coarse sand and clay fines, comprising desanding the whole tailings by settling out substantially all of the sand to yield desanded tailings; adding about 100 to 200 ppm of calcium sulfate to the desanded tailings; settling the mixture to produce clarified water and sludge; and recycling the clarified water to the plant as process water.

[0011] The Canadian government has recently required all companies exploiting the Canadian Oil Sands to have plans to treat their aqueous dispersions of tailings so that the tailings will be trafficable within ten years.

#### **BRIEF SUMMARY**

[0012] A process is provided for treating a tailings stream which comprises water and solids such as sand and clay the process comprising the steps of: (i) adding a cement to the tailings stream; and (ii) separating at least a portion of the cement and solids from the tailings stream.

[0012a] In another aspect it is provided a process for treating a tailings stream which comprises water and solids, the process comprising the steps of:

(i) adding a cement to the tailings stream; and

(ii) separating at least a portion of the cement and the solids from the tailings stream; wherein the cement comprises one or more hydraulic cements.

#### **BRIEF DESCRIPTION OF THE FIGURES**

[0013] Figure 1 shows a particle size distribution as a function of time for tailings streams that were untreated, treated with cement, and treated with cement and a polymer flocculant, in accordance with one or more of the examples.

[0014] Figure 2 shows particle size distribution as a function of time for tailings streams that were untreated, treated with cement, and treated with cement and a polymer flocculant, in accordance with one or more of the examples.

#### **DETAILED DESCRIPTION**

[0015] Processes for treating tailings streams are provided, wherein the tailings are treated with cement to produce coagulated solids. After the treatment the coagulated solids are usually left for gravity settling or are mechanically separated.

[0016] It has been surprisingly discovered that tailings streams, in particular oil sands tailings streams, can be treated with cement to remove fine or ultrafine solids from

tailings streams. In an exemplary embodiment, the process can be used for consolidation and dewatering and consolidation of tailings streams.

**[0017] Tailings**

**[0018]** The expressions “tailings”, “tailings stream”, “process oil sand tailings”, or “in-process tailings” as used herein refer to tailings that are directly generated as bitumen is extracted from oil sands. Process tailings contain coarse and fine particles. The solid particles contain a majority of coarse particles. The coarse particles are essentially comprised of silicates (e.g. sand) and clays. Fine tailings are generated after the process tailings are sent to a settling pond. Eventually, the coarse tailings settle fast to the bottom of the pond, leaving a weak gel of fine tailings (average diameter <44  $\mu\text{m}$ ) suspended in the water. Fine tailings tend to be almost entirely composed of clays. While fine tailings primarily consist of particles that are smaller than 44  $\mu\text{m}$  in diameter, the majority of the solids in the process tailings have diameters between 44 and 1000  $\mu\text{m}$  and above. Ultrafine solids (<1  $\mu\text{m}$ ) may also be present in the tailings stream. The tailings can be one or more of any of the tailings streams produced in a process to extract bitumen from an oil sands ore. The tailings are one or more of the coarse tailings, fine tailings, and froth treatment tailings. In exemplary embodiments, the tailings may comprise paraffinic or naphthenic tailings, for example paraffinic froth tailings. The tailings may be combined into a single tailings stream for dewatering or each tailings stream may be dewatered individually. Depending on the composition of the tailings stream, the additives may change, concentrations of additives may change, and the sequence of adding the additives may change. Such changes may be determined from experience with different tailings streams compositions.

**[0019]** In one embodiment, the tailings stream is produced from an oil sands ore and comprises water and solids, for example sand and fines. In one embodiment, the tailings stream comprises at least one of the coarse tailings, fine tailings, ultrafine tailings or froth treatment tailings.

**[0020] Cement**

**[0021]** In exemplary embodiments, the cement process aid may be any of a variety of cements and pozzalanic materials. In one embodiment, the cement contains one or more hydraulic cements. Exemplary hydraulic cements include Portland cement, Portland-based cement, pozzolana cement, gypsum cement, high alumina cement, slag cement, silica cement, kiln dust or mixtures thereof. Exemplary Portland cements may be those classified as class A, C, H and G cements according to American Petroleum Institute (API) specification for materials and testing for well cements. They can also be classified by ASTM C150 or EN 197 in classes of I, II, III, IV and V. In one embodiment, the cement is a hydraulic cement that comprises calcium, aluminum, silicon, oxygen and/or sulfur which may set and harden by reaction with water. In one embodiment, the cement is an alkaline cement. In a particular embodiment, the cement comprises a mixture of two or more hydraulic cements..

**[0022]** In one embodiment, the cement comprises one or more types of Portland cement. Portland cement is the most common type of cementitious material used around the world. It consists mainly of calcium silicates and aluminates and some iron-containing phases. When mixed with water, Portland cement undergoes various hydration reactions resulting in raised pH as well as generation of new species including calcium silicate hydrates (CSHs). CSH may bind strongly to other mineral grains, resulting in aggregation and a settling process.

**[0023]** Portland cement (also referred to as Ordinary Portland Cement or OPC) is a basic ingredient of concrete, mortar, stucco and most non-specialty grout. Portland cement is a mixture that results from the calcination of natural materials such as limestone, clay, sand and/or shale. In particular, Portland cement comprises a mixture of calcium silicates, including  $\text{Ca}_3\text{SiO}_5$  and  $\text{Ca}_2\text{SiO}_4$ , which result from the calcination of limestone ( $\text{CaCO}_3$ ) and silica ( $\text{SiO}_2$ ). This mixture is known as cement clinker. In order to achieve the desired setting qualities in the finished product, calcium sulfate (about 2-8%, most typically about 5%), usually in the form of gypsum or anhydrite, is added to the clinker and the mixture is finely ground to form the finished cement powder. For example, a typical bulk chemical composition of Portland cement is about 61 to about 67 wt% calcium oxide ( $\text{CaO}$ ), about 12 to about 23 wt% silicon oxide ( $\text{SiO}_2$ ), about 2.5 to about 6 wt% aluminum oxide ( $\text{Al}_2\text{O}_3$ ), about 0 about 6 wt% ferric oxide ( $\text{Fe}_2\text{O}_3$ ) and about 1.5 about 4.5 wt% sulfate. The properties of Portland Cement can be characterized by the mineralogical composition of the clinker. Major clinker phases present in Portland cements include: Alite ( $3\text{CaO}\cdot\text{SiO}_2$ ), Belite ( $2\text{CaO}\cdot\text{SiO}_2$ ), Aluminate ( $3\text{CaO}\cdot\text{Al}_2\text{O}_3$ ) and Ferrite ( $4\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot\text{Fe}_2\text{O}_3$ ).

**[0024]** In an exemplary embodiment, the cement is a fine powder mixture which contains more than 90% Portland cement clinker, calcium sulfate and up to 5% minor constituents (see European Standard EN197.1).

During the preparation of the cement, a grinding process may be controlled to obtain a powder with a broad particle size range, in which typically 15% by mass consists of particles below 5  $\mu\text{m}$  diameter, and 5% of particles above 45  $\mu\text{m}$ . The measure of particle fineness usually used is the "specific surface area", which is the total particle surface area of a unit mass of cement. The rate of initial reaction (up to 24 hours) of the cement on addition of water is directly proportional to the specific surface area. Typical values are 320–380  $\text{m}^2\cdot\text{kg}^{-1}$  for general purpose cements, and 450–650  $\text{m}^2\cdot\text{kg}^{-1}$  for "rapid hardening" cements.

**[0025]** In an exemplary embodiment, supplementary cementitious materials, such as fly ash, silica fume or natural pozzolans may be used together with the cement. As used herein, a pozzolan is a material which, when combined with calcium hydroxide, exhibits cementitious properties.

**[0026] Tailing Treatment Process**

**[0027]** It is an objective of the exemplary processes described herein to separate the solids, while enabling recovery of as much of the water as possible. Surprisingly, by using the exemplary processes, a faster settling rate and a more complete separation of the solids from the water has been achieved, improving process efficiency relative to conventional processes for treating tailings streams.

**[0028]** In an exemplary embodiment, a process for treating a tailings stream which comprises sand, clay fines and water may comprise the steps of: (i) adding a cement to the tailings stream; and (ii) separating the solids from the flocculated stream. In an exemplary embodiment, the process may further comprise adding a flocculant, for example a polymer flocculant. In exemplary embodiments, the flocculant may be added before, concurrently with, or after the cement is added to the tailings stream.

**[0029]** According to the embodiments, the separation step may be accomplished by any means known to those skilled in the art, including but not limited to centrifuges, hydrocyclones, decantation, filtration, thickeners or another mechanical separation method.

**[0030]** The addition step of the embodiments results in the production of coagulated solids. In one embodiment, the process provides efficient dewatering of the tailings and no other chemicals are necessary as cement alone is a sufficiently potent coagulant. In other embodiments, the process may further comprise adding a coagulant or a flocculant, or a combination thereof, for example a polymer flocculant. The step of adding a cement to the tailings stream may be simultaneous or sequential with the step of adding one or more polymer flocculants to the tailings stream. In certain embodiments, the process comprises adding sequentially the cement, then adding the one or more polymer flocculants to the tailings stream. In other embodiments, the process comprises adding simultaneously the cement and the one or more polymer flocculants to the tailings stream.

**[0031]** In exemplary embodiments, the tailings stream or solids comprises sand.

**[0032]** In exemplary embodiments, the process comprises a desanding step. In an exemplary embodiment, the cement, and optionally the flocculant, may be added to the tailings stream before desanding or after desanding. Desanding is a process wherein the tailings are settled for a period of time to form desanded tailings as the supernatant. Desanding may also be done for example by hydrocyclone.

**[0033]** In exemplary embodiments, one or more polymer flocculants having a molecular weight of greater than about 100,000 Daltons or greater than about 1,000,000 Daltons may be added to the tailing stream during or after the cement is added to the tailings stream. In exemplary embodiments, the one or more polymer flocculants is a high molecular weight non-ionic polyacrylamide flocculant or a medium molecular weight high charged polyacrylate flocculant.

**[0034]** In certain embodiments, the clays in the supernatant, which may be present as a very dilute suspension, can be removed if desired or necessary by any means known in the art, or by the addition of more of the cement.

**[0035]** In certain embodiments, the process may optionally comprise adding one or more cationic coagulants or cationic flocculants to the tailings stream. The one or more cationic coagulants or flocculants may be added to the tailings stream before or at the same time as the cement, or added to the flocculated stream after the separation step. In an exemplary embodiment, a cationic coagulant or flocculant may be added to the supernatant. In exemplary embodiments, the cationic flocculant or coagulant is a poly(diallyl dimethyl ammonium chloride) compound; an epi-polyamine compound; a polymer that contains one or more quaternized ammonium groups, such as acryloyloxyethyltrimethylammonium chloride, methacryloyloxyethyltrimethylammonium chloride, methacrylamidopropyltrimethylammonium chloride, acrylamidopropyltrimethylammonium chloride; or a mixture thereof. In exemplary embodiments, one or more inorganic coagulants may be added to the tailings stream. An inorganic coagulant may, for example, reduce, neutralize or invert electrical repulsions between particles. Exemplary inorganic coagulants include inorganic salts such as aluminum sulfate, ferric chloride, lime, calcium chloride, magnesium chloride, or various commercially available iron or aluminum salts coagulants.

**[0036]** In the exemplary embodiments, the process may provide enhanced flocculation of the solid materials in the tailings, better separation of the solids from water, an increased rate of separation of the solids from the water, and/or may expand the range of operating conditions which can be tolerated while still achieving the desired level of separation of solids from water within a desired period of time.

**[0037]** The exemplary processes described herein may provide flocculant bed with higher densities, leading to settled beds that can dewater faster and build yield strength faster than comparable treatments without cement. In a particular embodiment, the exemplary processes accelerate dewatering of the tailings.

**[0038]** In exemplary embodiments, the processes may be used to dewater the tailings so as to provide trafficable solids, or solids which possess a yield stress of greater than about 5000 Pa after one year, or a yield stress of greater than about 10000 Pa within five years. In certain embodiments, the cement is added to the tailings stream to accelerate dewatering or to produce tailings that achieve 2500 Pa yield stress after centrifugation.

**[0039]** In the exemplary embodiments, the dewatered solids may be handled or processed in any manner as necessary or desired. In one embodiment, the dewatered solids should be handled in compliance with governmental regulations. In some embodiments, the resultant solids may be disposed of, sent to a tailings pond for additional settling, or when solids are a concentrated source of minerals, the solids may be used as raw materials or feed to produce compounds for commercial products. In the exemplary embodiments, the separated

water may be handled or processed in any manner as necessary or desired. In one embodiment, the separated water may be recycled to the process (“recycled water”). For example, the recycled water may be added to the crushed oil sands ore for bitumen extraction. Recycled water may also be added to the process at any point where water is added.

**[0040]** In the exemplary embodiments, the processes may be carried out at broad pH conditions, such as a pH of about 6 to about 12, or about 8.5 to about 10.5. In certain embodiments of the process, it is not necessary to adjust the pH.

**[0041]** In the exemplary embodiments, the processes may be carried out at temperature of about 0°C to about 100°C, or about ambient temperature to about 90°C, or about 20°C to about 90°C.

**[0042]** In one embodiment, the processes produce at least about 20 %, at least about 25 %, at least about 30 %, at least about 35 %, at least about 40 %, at least about 45 %, or at least about 50 %, by weight, of bed solids.

**[0043]** In one embodiment, the processes produce less than about 2 wt%, less than about 1.5 wt%, less than about 1 wt%, less than about 0.5 wt%, or less than about 0.3 wt% solids in the supernatant.

**[0044]** In the exemplary embodiments, the dosage of the cement can be any dosage that will achieve a necessary or desired result. In one embodiment, the dosage of cement added to the tailings stream is in the range of about 10 to about 10000 grams cement per ton of suspended dry solids (g/t), about 100 to about 5000 g/t, about 100 to about 2000 g/t, about 50 to about 1700 g/t, about 100 to about 1600 g/t, about 500 to about 1150 g/t, or about 500 to about 1000 g/t. In one embodiment, the dosage of cement is about 300 g/t, about 350 g/t, about 400 g/t, about 450 g/t, about 500 g/t, about 550 g/t, about 600 g/t, about 650 g/t, about 700 g/t, about 750 g/t, about 800 g/t, about 850 g/t, about 900 g/t, about 950 g/t, about 1000 g/t, about 1050 g/t, about 1100 g/t, about 1150 g/t, about 1200 g/t, about 1250 g/t, about 1300 g/t, about 1350 g/t, about 1400 g/t, about 1450 g/t, about 1500 g/t, about 1550 g/t, or about 1600 g/t. In a particular embodiment, the dosage of cement is the dosage effective to coagulate fine tailings.

**[0045]** In one embodiment, the dosage of the cement added to the tailings stream is in the range of about 100 ppm to about 2000 ppm, about 200 ppm to about 2000 ppm, about 300 ppm to about 2000 ppm, about 400 ppm to about 1500 ppm, or about 400 ppm to about 1000 ppm.

**[0046]** As used herein, the terms “polymer,” “polymers,” “polymeric,” and similar terms are used in their ordinary sense as understood by one skilled in the art, and thus may be used herein to refer to or describe a large molecule (or group of such molecules) that contains recurring units. Polymers may be formed in various ways, including by polymerizing monomers and/or by chemically modifying one or more recurring units of a precursor

polymer. A polymer may be a “homopolymer” comprising substantially identical recurring units formed by, e.g., polymerizing a particular monomer. A polymer may also be a “copolymer” comprising two or more different recurring units formed by, e.g., copolymerizing two or more different monomers, and/or by chemically modifying one or more recurring units of a precursor polymer. The term “terpolymer” may be used herein to refer to polymers containing three or more different recurring units.

[0047] In exemplary embodiments, the polymer flocculants may be anionic or nonionic. Any anionic or nonionic polymer flocculants having a molecular weight of greater than about 100,000 Daltons, that are known in the art may be used in the processes described herein. Nonlimiting examples of exemplary polymer flocculants include, for example, flocculant-grade homopolymers, copolymers, and terpolymers prepared from monomers such as (meth)acrylic acid, (meth)acrylamide, 2-acrylamido-2-methylpropane sulfonic acid, and ethylene oxide. In one embodiment, the polymer flocculant is an anionic polymers. In one embodiment, the polymer flocculant is a nonionic polymers. In one embodiment, the polymer flocculant is a mixture of anionic polymers and nonionic polymers.

[0048] In the exemplary embodiments, the dosage of the one or more polymer flocculant can be any dosage that will achieve a necessary or desired result. In one embodiment, the dosage of the one or more polymer flocculant is about 25 g/dry T to about 1000 g/dry T, about 50 g/dry T to about 500 g/dry T, about 50 g/dry T to about 400 g/dry T, about 50 g/dry T to about 300 g/dry T, about 50 g/dry T to about 100 g/dry T, or about 50 g/dry T to about 200 g/dry T. In one embodiment, the dosage of the one or more polymer flocculant is less than about 500 g/dry T, less than about 400 g/dry T, less than about 300 g/dry T, less than about 200 g/dry T, or less than about 100 g/dry T.

[0049] In one embodiment, the dosage of the one or more polymer flocculant added to the tailings stream is in the range of about 100 ppm to about 2000 ppm, about 200 ppm to about 2000 ppm, about 300 ppm to about 2000 ppm, about 400 ppm to about 1500 ppm, or about 400 ppm to about 1000 ppm.

## EXAMPLES

[0050] Example 1.

[0051] In this example, consolidation of oil sands tailings by using Portland cements is examined by mixing tailings containing 22.17% solids with Portland cements. A 40 ml sample of tailings was centrifuged at G-force 670 for 10 min. Residual fine solids in supernatant were measured gravimetrically. As given in Table 1, it has been found that centrifuging the tailings resulted in 1.36% solids in supernatant and 69.62% solids in settled bed. Centrifugation of tailings treated with 500 ppm of cements resulted in 0.36% or 0.23% residual fine solids in supernatant and 57.53% or 53.36% solids in settled beds, providing

evidence of a reduction in suspended fine solids in supernatant. More significant reduction of suspended fine solids can be obtained using cement treatments at dosage of 1000 ppm or higher. Some of the variation in solid content of settled beds when tailings are treated with cement can be attributed to differences in solids packing from dense close packing to more open network and immobilization of fine particles which in turn can result in faster dewatering.

[0052] Table 1. Consolidation of oil sands tailings by addition of Portland Cements.

Experiment Number	Cem A Dosage (ppm)	Cem W Dosage (ppm)	Solids in Supernatant (wt%)	Solids in Settled Bed (wt%)
1	None	None	1.36	69.62
2	500	None	0.36	57.53
3	1000	None	0.09	47.98
4	2000	None	0.00	46.79
5	4000	None	0.00	51.35
6	None	500	0.23	53.36
7	None	1000	0.07	48.70
8	None	2000	0.00	50.10
9	None	4000	0.00	47.54

Cem A: Grey Portland cement Type I/II (Lehigh Cement, Alberta, Canada)

Cem W: White Portland cement Type I (Federal White Cement, Ontario, Canada)

[0053] Example 2. Effect of Cement and Polyacrylamide Flocculant Treatment on Aggregation of Fine Tailings.

[0054] In this example, aggregation of fine tailings was investigated using an inline particle size measurement by dynamic light scattering. Particle size distributions (PSD) were determined with a Beckman Coulter LS230, which measures the angular dependence of scattered light (mainly in the forward direction). A fine fraction of oil sand tailing solids was initially separated from coarser fraction by gravitation over a period of 4 hours. Subsequently, a 1.0 mL sample was dispersed in the impeller driven flow loop of the analyzer containing tap water (approximately 700 mL) without additional chemical dispersants. Particle size distributions were computed as equivalent-sphere size distributions based on

Mic scattering and Fraunhofer diffraction formalisms applied to the scattering data. Measurements were taken during each test at 30, 60 and 120 seconds after addition of the solids to the diluent under continuous agitation at a single impeller speed. This procedure was used to assess whether a steady-state size distribution had been achieved. In most cases, particle size distributions reached steady state after 60 sec of mixing and were used for comparisons. Then 0.1 g of Portland cement was added to the suspended fines slurry and PSD was monitored over the time intervals of 5 minutes. Then 0.5 mL of polymer flocculant solution (0.4% in water of Superfloc® N-300 or Superfloc® A-190K, both available from Kemira Oyj) was added to the above diluted slurry. Results are presented in Figures 1 and 2. These figures show the particle size distribution as a function of time upon addition of cement and a high molecular weight non-ionic polyacrylamide flocculant (Figure 1) or a medium molecular weight high charged polyacrylate flocculant (Figure 2) to a sample of fine tailings.

[0055] As represented in PSD graphs, fine solids agglomerate upon addition of cement and larger aggregates are formed. In this regard, cement material show similar behavior as inorganic coagulants for agglomeration of fine solid particles. In order to further enhance agglomeration of fine solids, a flocculant may be added. As shown in Figures 1 and 2, addition of a polymer flocculant to the fine tailings treated by cement, resulted in complete elimination of ultrafine solids (less than 1 micron) and formation of larger aggregates as large as 200 – 600 microns within 60 seconds.

[0056] Example 3. Rheological Investigations.

[0057] Some insight on the microstructure of networks of flocculated particles may be acquired from their rheological behavior. Rheological investigations were conducted at 22 °C on an Anton-Paar MCR 300 rheometer equipped with a six-bladed Anton Paar ST 22-6V-16/106 spindle. Measurements are accomplished by inserting the spindle into a flocculated sample until the tips of the vanes were covered, and then logarithmically increasing the shear stress from 0.1 Pa until the sample began to flow. The yield stress value can be determined by calculating the point at which a log-log plot of shear stress versus viscosity deviated from linearity. Samples of oil sand tailings (22.17% solids in process water) were treated with cement and a high molecular weight non-ionic polyacrylamide flocculant (Superfloc® N-300, available from Kemira Oyj). The fluids were centrifuged at G-force 670 for 5 min. The supernatant is decanted and settled beds were used for rheological measurement. Residual fine solids in supernatant were measured gravimetrically. Rheological measurement on settled beds showed an increase in shear stress for cement treated tailings compared to other treatments as given in Table 3 and suspended fine solids in supernatant are significantly reduced and eliminated.

[0058] Table 3. Analytical data for settled beds from treated tailings.

Experiment Number	Cement Dosage (ppm)	Flocculant Dosage (ppm)	Yield Stress (Pa)	Solids in Supernatant (wt %)
1	None	None	217	1.82
2	None	500	1299	0.74
3	500	500	1609	Less than 0.01
4	1000	500	2573	Less than 0.01

[0059] Example 4. Capillary Suction Time Tests.

[0060] The Capillary Suction Time (CST) test has been used since the 1970's as a practical, yet empirical method for characterizing dewatering and the state of colloidal materials in wastewater treatment facilities. The main use for the CST is to determine filterability of the flocculated solids after the addition of coagulant and/or flocculant aids. The dewatering properties of materials excised from settled beds of treated tailings were measured using a capillary suction time method as described in Standard Method APHA 2710 G (APHA 1999). CST measurements were carried out using a CST instrument from Venture Innovations Inc. (California, USA). The CST is the time interval it takes an aqueous solution to traverse between two radial positions in a filter paper (Whatman No. 40, 9 cm) under the influence of capillary suction. A low CST value implies good sludge dewatering; i.e. the water from the paste releases quickly with little impediment. Each measurement was conducted at least in triplicate and the average presented here. The time for distilled water blanks ( $10.8 \pm 0.7$  sec) was subtracted from sample times to improve comparisons and to account for variation in characteristics of the filter paper used. Data given in Table 4, indicates that cement and polymer flocculant treatments resulted in generally more expanded beds with better dewatering rates (lower CST values) than did untreated or treatment with polymer flocculants only.

[0061] Table 4. Dewatering characteristics of tailings with chemical treatments.

Experiment Number	Cement Dosage (ppm)	Flocculant Dosage (ppm)	CST (sec)
1	None	None	218.4
2	None	500*	114.0
3	1000	500*	60.6
4	None	500**	84.0
5	1000	500**	24.1

\*High molecular weight non-ionic polyacrylamide flocculant (Superfloc® N-300, Kemira)

\*\* Medium molecular weight high charged polyacrylate flocculant (Supercloc®A-190K, Kemira)

[0062] In the preceding specification, various exemplary embodiments have been described. It will, however, be evident that various modifications and changes may be made thereto, and additional embodiments may be implemented, without departing from the broader scope of the exemplary embodiments as set forth in the claims that follow. The specification and drawings are accordingly to be regarded in an illustrative rather than restrictive sense.

## CLAIMS

We claim:

1. A process for treating a tailings stream which comprises water and solids, the process comprising the steps of:
  - (i) adding a cement to the tailings stream; and
  - (ii) separating at least a portion of the cement and the solids from the tailings stream;wherein the cement comprises one or more hydraulic cements.
2. The process of claim 1, wherein the one or more hydraulic cements comprises one or more alkaline cements.
3. The process of claim 1, wherein the one or more hydraulic cements is selected from the group consisting of: Portland cements, pozzalana cements, gypsum cements, high alumina cements, slag cements, kiln dust and mixtures thereof.
4. The process of claim 1, wherein the one or more hydraulic cements comprises one or more types of Portland cement.
5. The process of claim 1, wherein the separation of the solids from the tailings stream is by centrifuge, hydrocyclone, decantation, filtration, thickening or another mechanical separation method.
6. The process of claim 1, wherein the process further comprises adding one or more coagulants or flocculants, or a combination thereof.
7. The process of claim 6, wherein the process comprises adding a polymeric flocculant.
8. The process of claim 1, wherein the process further comprises a desanding step.
9. The process of claim 8, wherein the cement is added to the tailings stream before desanding.
10. The process of claim 8, wherein the cement is added to the tailings stream after desanding.

11. The process of claim 1, wherein the one or more hydraulic cements are selected from Portland cements classified as class A, C, H or G by the American Petroleum Institute, Portland cements classified in classes I, II, III, IV or V by ASTM C150 or EN 197, and mixtures thereof.

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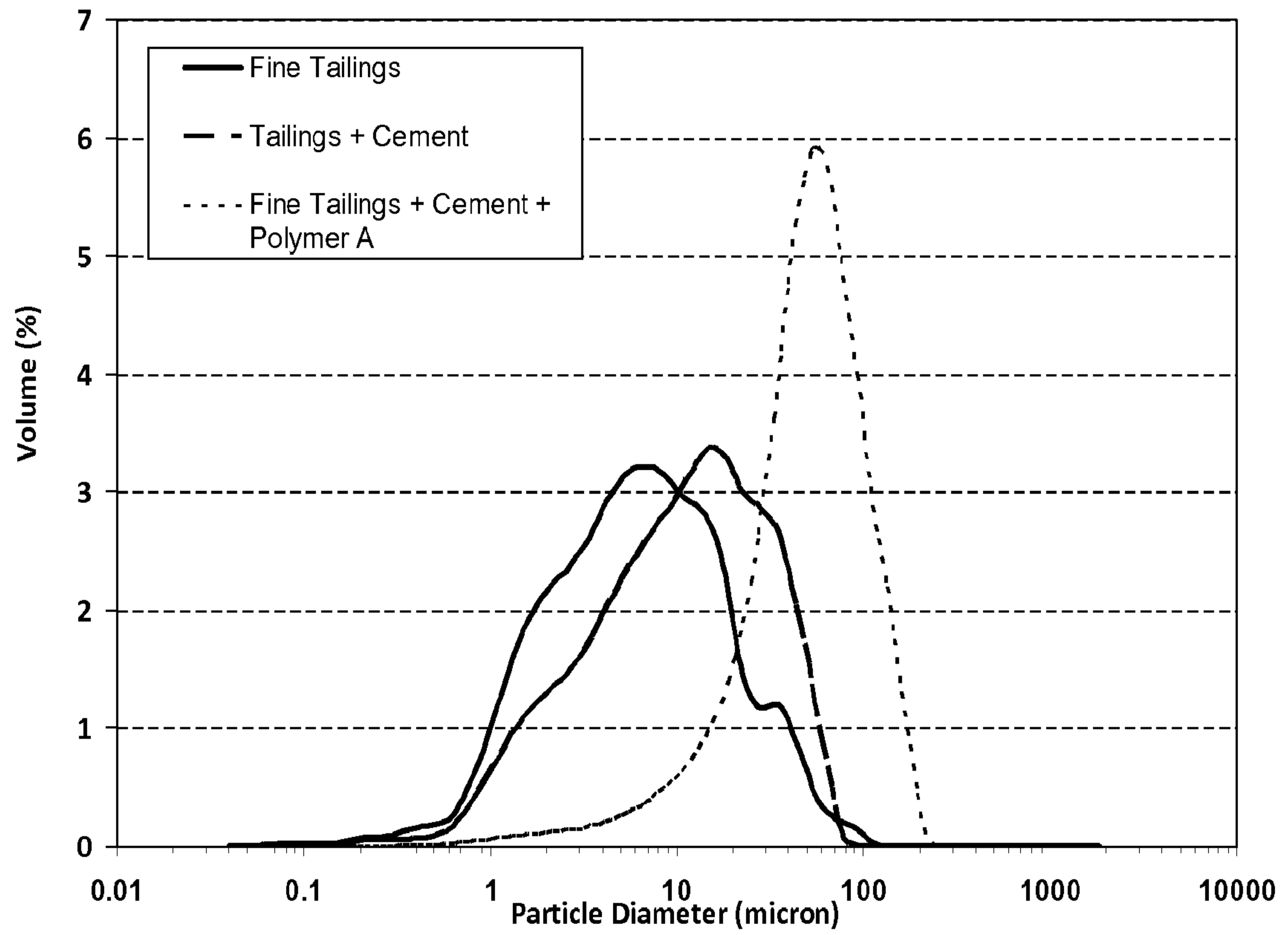


Figure 1

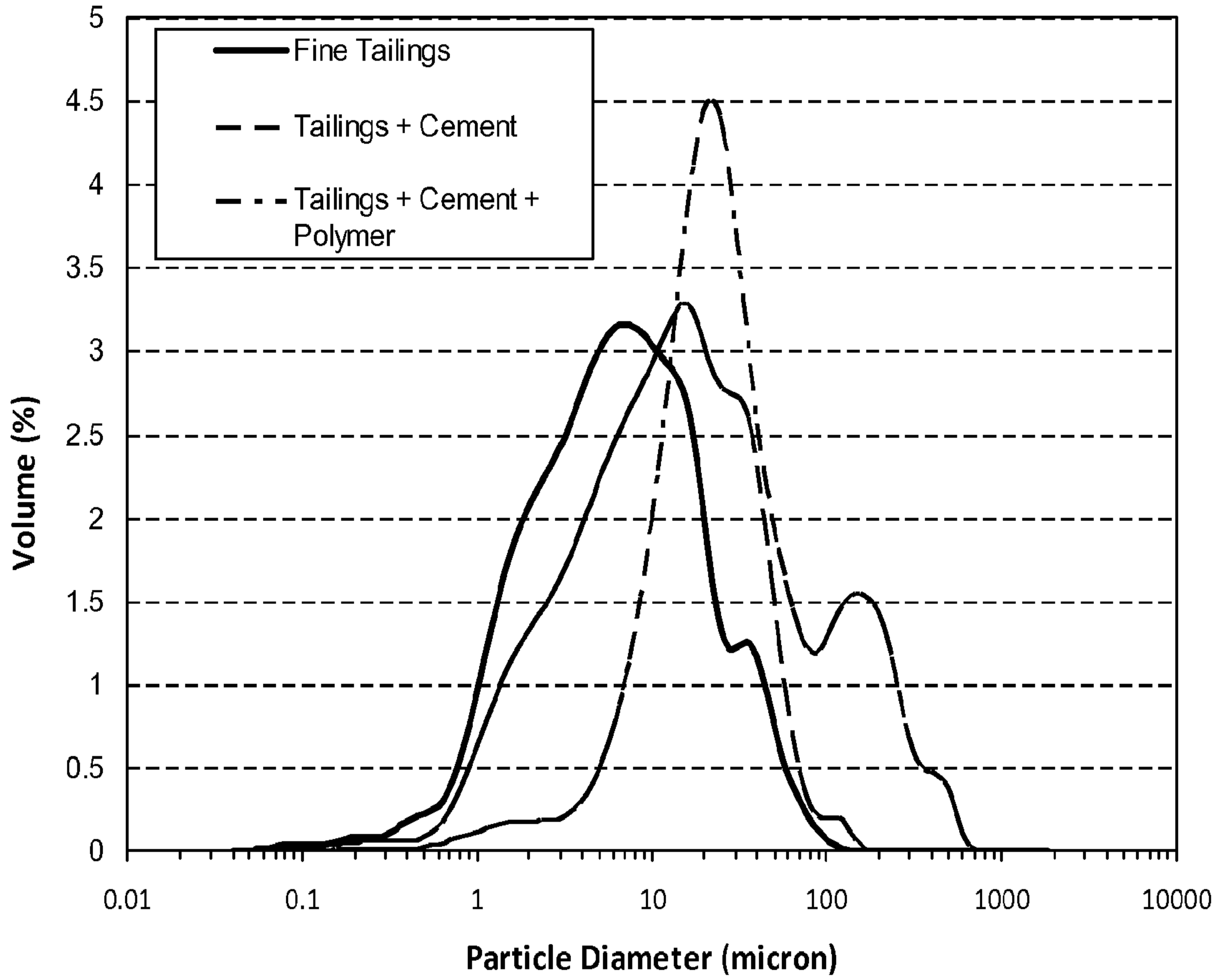


Figure 2

