

COMPOSITIONS AND METHODS USEFUL FOR OIL EXTRACTION**CROSS-REFERENCE TO RELATED APPLICATIONS**

[001] This application claims the benefit of U.S. Provisional Patent Application No. 61/545,817, filed on October 11, 2011, which is incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

[002] The present invention relates to compositions comprising plant material, and methods for using the same to extract a hydrocarbon-containing substance such as oil, coal tar, creosote, sludge, bitumen or refined products thereof from a substrate or to remediate a substrate such as sand, soil, rock, sediment, metal, glass, porcelain, concrete or water.

BACKGROUND

[003] World petroleum supplies are finite. Thus, as world petroleum demand has increased (84,337 M bpd worldwide in 2009; US Energy Information Administration), easily accessible reserves have been depleted. Furthermore, much of the world's proven conventional petroleum reserves are located in regions which are politically unstable. Accordingly, supplies of petroleum from such regions might be uncertain since production of petroleum or the transportation of petroleum products from such regions might be interrupted.

[004] Bituminous sands, colloquially known as oil sands or tar sands, are a type of unconventional petroleum deposit. The sands typically comprise naturally occurring mixtures of sand, clay, water, and a dense and viscous form of petroleum known as bitumen. 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 oil sands to be profitably extracted and refined. Thus, oil sands are now a viable alternative to conventional crude oil. Oil sands might represent as much as two-thirds of the world's total "liquid" hydrocarbon resources, with at least 1.7 trillion recoverable BOE (barrel of oil equivalent) in the Canadian Athabasca oil sands alone.

[005] Extra-heavy oil and bitumen flow very slowly, if at all, toward oil-producing wells under normal reservoir conditions. Accordingly, in certain oil recovery operations from oil

sands, the oil is made to flow into wells by using *in situ* techniques that reduce its viscosity by injecting steam, solvents, or hot air into the sands. These processes typically use large amounts of water and require large amounts of energy relative to conventional oil extraction. Further, typical extraction processes applied to oil sands generate significantly higher amounts of greenhouse gases per barrel relative to the production of conventional oils due to the increased energy requirements for recovery of oil from oil sands.

[006] In other oil sand mining operations, where oil sands are relatively close to the earth's surface, surface mining has been used to extract the oil contained therein. After removing the overburden (the soil covering the oil sands), the sands are mechanically excavated and transported to a refining facility.

[007] In one surface-mining method, after excavation, hot water and caustic soda (NaOH) are added to the sand. The resultant slurry is piped to the extraction plant where it is agitated and oil is skimmed off the mixture. The combination of hot water, sodium hydroxide, a flocculant and agitation generally releases bitumen from the oil sand, and the oil floats to the top of separation vessels where it is separated. Then, the separated oil is further treated to remove residual water and fine solids before subsequent processing to convert the heavy oil to usable products.

[008] Such conventional processes to extract oil from oil sands also employ mixing the oil sand with high pH water, and then aerating the resultant mixture with air to produce froth (see, e.g., Masliyah, J.; Zhou, Z. J.; Xu, Z.; Czarnecki, J.; Hamza, H.: "Understanding water-based bitumen extraction from Athabasca oil sands." *The Canadian Journal of Chemical Engineering* **2004**, 82, (4), 628-654). A slurry of high pH water and oil sand is placed in a primary separation cell (PSC). Agitation and introduction of air assists in separating oil from the oil sand, and creates a froth in which the oil is entrained. The froth is removed, deaerated, and sent to feed tanks for further treatment. The remaining sand, comprising residual oil not removed in the PSC, is treated as "middlings" or as bottoms using the same process for extracting oil from oil sands in the PSC (i.e., high pH water and aeration). The froth from these subsequent processes is recycled to the PSC. The overall enhancement of oil from the oil in the froth is approximately 60% by mass over the iterative removal steps.

[0009] About two tons of oil sands are required to produce one barrel (roughly 1/8 of a ton) of oil. After oil extraction, the spent sand and other materials are typically transported back to the mine for disposal. However, even with improved extraction processes, up to 10% of the oil in the oil sands can be left in the resultant tailings. Thus, the process is inefficient. The tailings can contain significant amounts of oil and other pollutants which must be disposed of in an environmentally sound manner. In conventional oil sand mining operations, this has resulted in large lagoons containing high levels of oil and other pollutants. Accordingly, there is a need for improved compositions and methods for extraction of oil from oil sands that are more efficient (e.g., can remove higher amounts of oil), use less energy, and produce tailings that are environmentally benign.

[0010] In addition, in conventional oil production processes, methods of enhancing oil recovery are known. These include, but are not limited to hydraulic fracturing of rock formations containing hydrocarbon deposits. In hydraulic fracturing operations, a fluid (e.g., water) which can comprise various additives (e.g., acids, rheology modifiers, detergents, gels, gas, proppant, etc.) is introduced into a rock formation under high pressure to fracture the rock formation. Such fracturing of a hydrocarbon-bearing rock formation effectively increases the surface area of rock exposed to a wellbore (i.e., along the fracture faces), and accordingly, allows more hydrocarbon to flow into the well bore. However, the viscosity of the oils contained in the formation can limit the utility of hydraulically fracturing rock formations which contain heavy oils. That is, if the viscosity of the oil is too high, increasing the surface area of the formation exposed to the well bore along the fracture might not significantly increase production rates. Accordingly, there is a need for hydraulic fracturing fluids which can enhance total oil recovery or increase oil production rates.

[0011] In addition, remediation of environmentally compromised sites (e.g., hazardous waste sites) is an ongoing challenge. For example, there are many sites where hydrocarbons (e.g., crude oil, coal tar, creosote, refined oil products) have been spilled or discharged into the environment. Such discharges can result in contamination of soil or water, and can contaminate groundwater supplies. Accordingly, such contaminated sites or waters (e.g., rivers, streams, ponds and harbors) require remediation to extract contaminants.

[0012] There are several known remediation technologies. One method comprises excavation of contaminated soil. However, remediation by excavation has traditionally been a “dig and haul” process, wherein contaminated soils are excavated and disposed of in landfills or destroyed by thermal treatments such as incineration. In the case of landfill disposal of contaminated soil, the problem of soil contamination is not resolved as the soil is relocated and moved to another location. In the case of thermal desorption, the hydrocarbon or other pollutants can be destroyed, but typically produces a large carbon footprint, which, in and of itself, is not an environmentally friendly process, since energy is required and greenhouse gases are produced.

[0013] Chemical treatment (e.g., oxidation) has also been utilized in the remediation of contaminated soil. This process comprises excavation of the contaminated soil, followed by chemical treatment to chemically modify or degrade the pollutants to potentially less toxic or hazardous forms. However, such methods can require large quantities of specialized chemicals to oxidize the contaminants, and can be ineffective at oxidizing certain pollutants.

[0014] Another remediation method comprises injection of a material into the soil to sequester contaminants, with a goal of immobilizing them and preventing them from migrating. For example, stabilization/solidification (S/S) is a remediation or treatment technology that relies on the reaction between a binder and soil to stop, prevent or reduce the mobility of contaminants. Stabilization comprises the addition of liquid or solid materials to contaminated soil to produce more chemically stable constituents. Solidification comprises the addition of liquid or solid reagents to a contaminated material to impart physical, for example, dimensional stability, so that they are constrained in a solid product and to reduce mobility of the contaminants. However, such methods might not be desirable since over time, the solids can break down or degrade, releasing the hydrocarbons or other pollutants back into the environment.

[0015] Accordingly, there is a need for cost-effective methods for extracting contaminants (e.g., hydrocarbons) from soils and other substrates at environmentally compromised or contaminated sites and for sequestering contaminants *in situ* in a cost effective manner.

SUMMARY OF THE INVENTION

[0016] The present invention provides aqueous compositions comprising about 1 wt% to about 50 wt% of plant material, 0 to about 20 wt% of a polysaccharide, 0% to about 10 wt% of an alcohol, 0% to about 15 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and about 10 wt% to about 95 wt% of water, wherein the aqueous composition has a pH of from about 9 to about 13.

[0017] The present invention further provides extractants comprising about 0.1 wt% to about 2 wt% of plant material, 0 to about 2 wt% of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 10 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and about 90 wt% to about 99.9 wt% water. The aqueous compositions and extractants are useful for extracting a hydrocarbon-containing substance from a substrate or for remediating a substrate.

[0018] The present invention further provides substantially anhydrous compositions comprising about 20 wt% to about 99.9 wt% of plant material, 0 to about 20 wt%, of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 50 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and 0% to about 10 wt% water. The aqueous compositions and extractants can be dried to form substantially anhydrous compositions, which are useful for convenient handling or storage.

[0019] The present invention also provides methods for extracting a hydrocarbon-containing substance from a substrate, comprising contacting the substrate with an aqueous composition or extractant of the invention under conditions effective for extracting at least some of the hydrocarbon-containing substance from the substrate.

[0020] The present invention further provides methods for remediating a substrate, comprising contacting the substrate with an aqueous composition or extractant of the invention under conditions effective for remediating the substrate.

[0021] The present invention further provides hydraulic fracturing fluids comprising an aqueous composition or extractant of the invention.

[0022] The present invention also provides methods for extracting a hydrocarbon-containing substance from a substrate, comprising hydraulically fracturing the substrate with a hydraulic fracturing fluid of the invention.

[0023] The present invention also provides methods for making a substantially anhydrous compositions comprising about 20 wt% to about 99.9 wt% of plant material, 0 to about 20 wt%, of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 50 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and 0% to about 10 wt% water, comprising removing water from an aqueous composition of the invention.

[0024] The present invention also provides methods for making substantially anhydrous compositions comprising about 20 wt% to about 99.9 wt% of plant material, 0 to about 20 wt%, of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 50 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and 0% to about 10 wt% water, comprising removing water from an extractant of the invention.

[0025] The present invention also provides methods for preparing extractants comprising about 0.1 wt% to about 2 wt% of plant material, 0 to about 2 wt% of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 10 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and about 90 wt% to about 99.9 wt% water, comprising adding water to an aqueous composition of the invention.

[0026] The present invention also provides methods for preparing extractants comprising about 0.1 wt% to about 2 wt% of plant material, 0 to about 2 wt% of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 10 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and about 90 wt% to about 99.9 wt% water, comprising adding water to a substantially anhydrous composition of the invention.

[0027] The present invention also provides methods for preparing aqueous compositions of the invention comprising admixing with water a substantially anhydrous composition of the invention.

[0028] The present invention further provides laundry detergents comprising the aqueous composition of the invention, an extractant of the invention, or a substantially anhydrous composition of the invention.

[0029] The present invention further provides methods for removing a hydrocarbon-containing substance from fabric comprising contacting the fabric with a laundry detergent of the invention.

[0030] The present invention also provides methods for precipitating fines contained in a vessel further containing a hydrocarbon-containing material and an aqueous composition of the invention or an extractant of the invention, the methods comprising acidifying the contents of said vessel to a pH of about 4.6 or less.

[0031] The present aqueous compositions, extractants, substantially anhydrous compositions (each being a “Composition of the Invention”) and methods, and advantages thereof, are further illustrated by the following non-limiting detailed description and Examples.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] **FIGS. 1A-B** are photographs showing a side view of the vessel containing the mixture of Example 3 after 60 min of stirring, then briefly allowing the mixture to settle (**FIG. 1A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 1B**), also after 60 min of stirring.

[0033] **FIGS. 2A-B** are photographs showing a side view of the vessel containing the mixture of Example 4 after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 2A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 2B**), also after 60 min of stirring.

[0034] **FIGS. 3A-B** are photographs showing a side view of the vessel containing the mixture of Example 5 after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 3A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 3B**), also after 60 min of stirring.

[0035] **FIGS. 4A-B** are photographs showing a side view of the vessel containing the mixture of Example 6 after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 4A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 4B**), also after 60 min of stirring.

[0036] **FIGS. 5A-B** are photographs showing a side view of the vessel containing the mixture of Example 7 after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 5A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 5B**), also after 60 min of stirring.

[0037] **FIGS. 6A-B** are photographs showing a side view of the vessel containing the mixture of Example 8 after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 6A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 6B**), also after 60 min of stirring.

[0038] **FIGS. 7A-B** are photographs showing a side view of the vessel containing the mixture of Example 9 after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 7A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 7B**), also after 60 min of stirring.

[0039] **FIGS. 8A-B** are photographs showing a side view of the vessel containing the mixture of Example 10 after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 8A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 8B**), also after 60 min of stirring.

[0040] **FIGS. 9 and 10** are photographs showing a top-down (**FIG. 9**) and side (**FIG. 10**) view of the contents in the beaker in Example 13 before stirring.

[0041] **FIG. 11** is a photograph showing the contents of the beaker in Example 13 after stirring for 4 min, then allowing most of the solids to settle. **FIG. 11** shows stringers of oil separating from the oil sand.

[0042] **FIG. 12** is a photograph showing the contents of the beaker in Example 13 after stirring for 10 minutes. **FIG. 12** shows stringers of oil separating from the oil sand.

[0043] **FIG. 13** is a photograph showing the contents of the beaker in Example 13, showing that sand free of oil that had settled to the bottom of the beaker a few minutes after stirring was stopped.

[0044] **FIG. 14** is a photograph showing the contents of the beaker in Example 13, showing that agglomerating oil deposits sat on top of the sand after decanting the solution into another beaker.

[0045] **FIGS. 15-16** are photographs showing the contents of the beaker of Example 13 after stirring 30 min, then decanting the solution into another beaker. **FIG. 15** is a photograph of “free” oil sticking to the glass of the beaker in which the oil sand and extractant were stirred, after decanting the extractant liquid comprising some extracted oil into a second beaker. **FIG. 16** is a photograph showing the remaining sand and oil in the beaker in which the oil sand and extractant were stirred after decanting the extractant liquid comprising some extracted oil into the second beaker.

[0046] **FIG. 17** is a photograph showing the sand, oil and magnetic stir bar remaining in the beaker of Example 13 after stirring for 1 hour and decanting the resultant supernatant.

[0047] **FIG. 18** is a photograph showing the oil remaining on the glass of the first beaker of Example 13 after transferring the sand, oil and extractant to a second beaker.

[0048] **FIG. 19** is a chart showing the size distribution of the solids in the Athabasca oil sands of Example 14.

[0049] **FIG. 20** depicts a series of photographs showing the contents of the beakers in Example 17, illustrating the effects of adding a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight to light tar oil in a glass beaker with subsequent stirring, and the effect of adding water to light tar oil in a glass beaker with subsequent stirring.

[0050] **FIG. 21** depicts a series of photographs showing the contents of the beakers in Example 18, illustrating the effects of adding a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight to coal tar in a glass beaker with subsequent stirring, and the effect of adding water to coal tar in a glass beaker with subsequent stirring.

[0051] **FIG. 22** depicts series of photographs showing the contents of the beakers in Example 19, illustrating showing the effects of adding a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight to oil-contaminated sludge in a glass beaker with subsequent stirring, and the effect of adding water to oil-contaminated sludge in a glass beaker with subsequent stirring.

[0052] **FIG. 23** is a process flow diagram illustrating the process described in Example 21 for frothing and extracting oil from Athabasca oils sand and quantifying recovery of oil therefrom, to quantitatively asses the foaming properties of Compositions of the Invention.

[0053] **FIG. 24** depicts three photographs illustrating aeration experiments performed as described in Example 21, but without recovery and quantification of oil, to qualitatively asses the foaming properties of illustrative Compositions of the Invention.

[0054] **FIG. 25** depicts two photographs illustrating the results of when coal tar coated sand is stirred with a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight for two hours, then aerated as described in Example 21.

[0055] **FIG. 26** depicts a series of photographs showing the effect of reducing the pH of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight on suspended fines after extraction and removal of extracted oil from a 5 g sample of Athabasca oil sand in the experiment described in Example 23.

DETAILED DESCRIPTION

[0056] The word ‘about’ when immediately preceding a numerical value means a range of plus or minus 10% of that value, e.g., “about 50” means 45 to 55, “about 25,000” means 22,500 to 27,500, etc. Furthermore, the phrases “less than about” a value or “greater than about” a value should be understood in view of the definition of the term “about” provided herein.

Compositions of the Invention

Aqueous Compositions

[0057] In a first aspect, the present invention aqueous compositions comprising about 1 wt% to about 50 wt% of plant material, 0 to about 20 wt% of a polysaccharide, 0% to about 10 wt% of an alcohol, 0% to about 15 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and about 10 wt% to about 95 wt% of water. In some embodiments, the plant material comprises a plant protein.

[0058] In other embodiments, the aqueous compositions comprise from about 1 to about 30 wt% of plant material and 0 to about 10 wt% of a polysaccharide. In certain embodiments, the aqueous compositions comprise from about 1 to about 10 wt% of plant material and 0 to about 5 wt% of a polysaccharide. In still other embodiments, the aqueous compositions comprise from about 1 to about 5 wt% of plant material and 0 to about 1 wt% of a polysaccharide. In some embodiments, the aqueous compositions do not comprise a polysaccharide other than that present in or derived from the plant material. In other embodiments, the aqueous compositions do not comprise a polysaccharide.

[0059] Polysaccharides which are useful in the present aqueous composition are typically water-soluble, e.g., soluble in water or water-alcohol solutions. In general, the polysaccharides are plant-derived polysaccharides, including related materials such as pectins. Examples of polysaccharides that are useful for the present aqueous compositions include, but are not limited to, water-soluble cellulose derivatives, seaweed polysaccharides such as alginate and carrageenan, seed mucilaginous polysaccharides, complex plant exudate polysaccharides such as gum arabic, tragacanth, guar gum, pectin, ghatti gum and the like, and microbially synthesized polysaccharides such as xanthan gum, or mixtures of such polysaccharides. In certain embodiments, the polysaccharide is guar gum, pectin, gum arabic and mixtures thereof. In some embodiments, the polysaccharide is a synthetic polysaccharide such as synthetic guar. In one embodiment, the polysaccharide is guar gum. In some embodiments, the present aqueous compositions do not comprise one or more of the aforementioned polysaccharides other than that present in or derived from the plant material. In other embodiments, the present aqueous compositions do not comprise one or more of the aforementioned polysaccharides.

[0060] The polysaccharide can be present in the aqueous compositions in an amount ranging from 0 to about 20 wt% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, about 10 wt% to about 11 wt%, about 11 wt% to about 12 wt%, about 12 wt% to about 13 wt%, about 13 wt% to about 14 wt%, about 14 wt% to about 15 wt%, about 15 wt% to about 16 wt%, about 16 wt% about 17 wt%, about 17 wt% to about 18 wt%, about 18 wt% to about 19 wt%, about 19 wt% to about 20 wt%, or any other value or range of values therein). In some embodiments, the polysaccharide is present in an amount of from about 0.1 wt% to about 5 wt%. In other embodiments, the present aqueous compositions do not comprise a polysaccharide (i.e., 0 wt%).

[0061] Similarly, plant material useful in the present aqueous compositions can be those from any plant. The plant material can include any part of the plant, *e.g.*, trunk, stems, seeds, roots, leaves, branches, bark, flowers, nuts, sprouts, or any other part of a plant. In some embodiments, the plant material comprises plant protein. In some embodiments, the plant proteins are prolamines. In certain embodiments, the plant is a cereal plant. Suitable cereal plants include, but are not limited to, corn, rice, wheat, barley, sorghum, millet, rye, triticale, fonio, buckwheat, spelt, quinoa, flax, or mixtures thereof. In other embodiments, the plant material is lentils (e.g., green, yellow, black), soy beans, hemp seed, chia, grass, wheat grass and barley (e.g., pearl, groat). In some embodiments, the plant is cotton, and the plant material is cotton seeds. In some embodiments, the plant is flax, and the plant material is flax seeds. In some embodiments, the plant is wheat, and the plant material is wheat germ. In some embodiments, the plant material is corn gluten meal. In still other embodiments, the corn gluten meal comprises a protein, and the protein is gluten. In other embodiments, the gluten is corn gluten.

[0062] In some embodiments, the plant material has a protein content of from about 5 wt% to about 100 wt% (e.g., 5 to about 10 wt%, about 10 wt% to about 15 wt%, about 15 wt% to about 20 wt%, about 20 wt% to about 25 wt%, about 25 wt% to about 30 wt%, about 30 wt% to about 35 wt%, about 35 wt% to about 40 wt%, about 40 wt% to about 45 wt%, about 45 wt% to about 50 wt%, about 50 wt% to about 55 wt%, about 55 wt% to about 60 wt%, about 60 wt% to

about 65 wt%, about 65 wt% to about 70 wt%, about 70 wt% to about 75 wt%, about 75 wt% to about 80 wt%, about 80 wt% to about 85 wt%, about 85 wt% to about 90 wt%, about 90 wt% to about 95 wt%, about 95 wt% to about 100 wt%, or any other value or range of values therein) of the plant material.

[0063] In some embodiments, the present aqueous compositions comprise a plant protein as measured by Biuret assay (as described hereinbelow), in an amount ranging from about 0.1 ppt (part per thousand) to about 100 ppt (e.g., from about 0.1 ppt to about 0.2 ppt, from about 0.2 ppt to about 0.3 ppt, from about 0.3 ppt to about 0.4 ppt, from about 0.4 ppt to about 0.5 ppt, from about 0.5 ppt to about 0.6 ppt, from about 0.6 ppt to about 0.7 ppt, from about 0.7 ppt to about 0.8 ppt, from about 0.8 ppt to about 0.9 ppt, from about 0.9 ppt to about 1.0 ppt, from about 1 ppt to about 5 ppt, from about 5 ppt to about 10 ppt, from about 10 ppt to about 15 ppt, from about 15 ppt to about 20 ppt, from about 20 ppt to about 25 ppt, from about 25 ppt to about 30 ppt, from about 30 ppt to about 35 ppt, from about 35 ppt to about 40 ppt, from about 40 ppt to about 45 ppt, from about 45 ppt to about 50 ppt, from about 50 ppt to about 55 ppt, from about 55 ppt to about 60 ppt, from about 60 ppt to about 65 ppt, from about 65 ppt to about 70 ppt, from about 70 ppt to about 75 ppt, from about 75 ppt to about 80 ppt, from about 80 ppt to about 85 ppt, from about 85 ppt to about 90 ppt, from about 90 ppt to about 95 ppt, from about 95 ppt to about 100 ppt, or any other value or range of values therein) of the aqueous composition.

[0064] Prolamine is a cereal-derived protein that is typically soluble in dilute aqueous alcohol solutions. Examples of suitable prolamines that are useful in the present aqueous compositions include, but are not limited to, corn-derived prolamine (also referred to as zein), barley-derived prolamine or hordein, wheat-derived prolamine or gliadin, or corn gluten. Zein is extractable from corn or maize.

[0065] Zein can be extracted from corn gluten by physical separation means or chemical separation means. In one embodiment, the zein has a molecular weight of about 20,000 to about 35,000 Da. In another embodiment, the zein has a molecular weight of from about 19,000 Da to about 22,000 Da.

[0066] In certain embodiments, the plant protein is separated from plant material. For example, the plant material can be combined with a solvent or solvent blend to extract plant

protein from the plant material. In certain embodiments, the plant material can be combined with a solvent or solvent blend to separate the plant protein from the plant material. Suitable solvents can include water, or an organic solvent, in the absence or presence of water. Suitable organic solvents include, but are not limited to, C₁ to C₃ alcohols such as methanol, ethanol, *n*-propanol and *i*-propanol; glycols such as ethylene glycol, propylene glycol, polyethylene glycol; glycol ethers; amine solvents such as butylamine; aminoalcohols such as ethanolamine, diethanolamine, diisopropanolamine; ketone-containing solvents such as acetone, acetic acid and acetamide; aromatic alcohols such as benzyl alcohol; and mixtures thereof.

[0067] In other embodiments, the plant material can be combined with a solvent or solvent blend and then can be treated with acid or base to separate plant protein from the plant material. Suitable acids and bases for separation of plant protein from plant material are those as described herein which are useful in a preparing a Composition of the Invention. In some embodiments, the pH of the mixture of the plant material and solvent may be adjusted to from about 2 to about 14 (e.g., from about 2 to about 3, from about 3 to about 4, from about 4 to about 5, from about 5 to about 6, from about 6 to about 7, from about 7 to about 8, from about 8 to about 9, from about 9 to about 10, from about 10 to about 11, from about 11 to about 12, from about 12 to about 13, from about 13 to about 14, or any other value or range of values therein). The mixture of the plant material and solvent, which can further comprise an acid or base, may be agitated (e.g., stirring, mixing).

[0068] In some embodiments, the plant material or plant protein may reduced in size prior to use in the present aqueous compositions. For example, the plant material or plant protein may be ground, chopped, pulverized, milled or macerated to reduce the size of the plant material, to enable the dissolution, suspension or admixture of the plant material or protein in the present aqueous compositions. For example, the plant material or plant protein may be ground, chopped or macerated to provide particulate sizes (e.g., length, width or average diameter) ranging from about 0.1 mm to about 1 cm (e.g., from about 0.1 mm to about 0.2 mm, from about 0.2 mm to about 0.3 mm, from about 0.3 mm to about 0.4 mm, from about 0.4 mm to about 0.5 mm, from about 0.5 mm to about 0.6mm, from about 0.6 mm to about 0.7 mm, from about 0.7 mm to about 0.8 mm, from about 0.8 mm to about 0.9 mm, from about 0.9 mm to about 1 mm, from about 1 mm to about 2 mm, from about 2 mm to about 3 mm, from about 3 mm to about 4 mm, from

about 4 mm to about 5 mm, from about 5 mm to about 6 mm, from about 6 mm to about 7 mm, from about 7 mm to about 8 mm, from about 8 mm to about 9 mm, from about 9 mm to about 1 cm, or any other value or range of values therein).

[0069] The mixture comprising the plant material can be admixed, optionally with agitation, for a period of about 10 minutes, about 20 minutes, about 30 minutes, about 40 minutes, about 50 minutes, about 1 hour, about 2 hours, about 3 hours, about 4 hours, or any other value or range of values therein or thereabove) and at a temperature of from about 5 °C to about 100 °C (e.g., about 5 °C to about 10 °C, about 10 °C to about 15 °C, about 15 °C to about 20 °C, about 20 °C to about 25 °C, about 25 °C to about 30 °C, about 30 °C to about 35 °C, about 35 °C to about 40 °C, about 40 °C to about 45 °C, about 45 °C to about 50 °C, about 50 °C to about 55 °C, about 55 °C to about 60 °C, about 60 °C to about 65 °C, about 65 °C to about 70 °C, about 70 °C to about 75 °C, about 75 °C to about 80 °C, about 80 °C to about 85 °C, about 85 °C to about 90 °C, about 90 °C to about 95 °C, about 95 °C to about 100 °C, or any other value or range of values therein). The solvent and pH can be selected to suspend or solubilize protein present in the plant material. The remaining components (e.g., cellulosic material) from the plant material can precipitate out of solution, and the plant protein can then be separated by decanting the supernatant or by filtration.

[0070] In other embodiments, the plant protein may be obtained as a pre-separated material. For example, zein extracted from corn may be obtained commercially from, e.g., Chemieliva Pharmaceutical Co., Ltd., HBC Chem. Inc., Matrix Marketing GMBH, and Spectrum Chemical Mfg. Corp.

[0071] In some embodiments, the plant material is present in the aqueous compositions in an amount ranging from about 1 to 50 wt% (e.g., about 1 to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, about 10 wt% to about 11 wt%, about 11 wt% to about 12 wt%, about 12 wt% to about 13 wt%, about 13 wt% to about 14 wt%, about 14 wt% to about 15 wt%, about 15 wt% to about 20 wt%, about 20 wt% to about 25 wt%, about 25 wt% to about 30 wt%, about 30 wt% to about 35 wt%, about 35 wt% to about 40 wt%, about 40 wt% to about 45 wt%,

about 45 wt% to about 50 wt%, or any other value or range of values therein) of the aqueous composition. In some embodiments, the plant material is present in an amount of from about 1 wt% to about 30 wt%. In certain embodiments, the plant material is present in an amount of from about 1 wt% to about 10 wt%. In other embodiments, the plant material is present in an amount of from about 1 wt% to about 5 wt%.

[0072] The present aqueous compositions can further comprise an acid or a base. The acid or base is useful for adjusting the pH of the aqueous compositions. For example, the acid or base is useful for adjusting the pH of the present aqueous compositions to a pH of about 1 to about 14 (e.g., from about 1 to about 2, from about 2 to about 2, from about 3 to about 4, from about 4 to about 5, from about 5 to about 6, from about 6 to about 7, from about 7 to about 8, from about 8 to about 9, from about 9 to about 10, from about 10 to about 11, from about 11 to about 12, from about 12 to about 13, from about 13 to about 14, or any other value or range of values therein). In certain embodiments, the pH of the present aqueous composition ranges from about 3.5 to about 13; in other embodiments, from about 6.5 to about 8.5. In some embodiments, the pH is about 13; in other embodiments, the pH is about 7.5 to about 8.4. In certain embodiments, the pH of the present aqueous composition ranges from about 5 to about 13; from about 6 to about 13; from about 7 to about 13; from about 8 to about 13; from about 9 to about 13; from about 10 to about 13; from about 11 to about 13; from about 12 to about 13.

[0073] Such pH adjustment can improve the dispersibility of the protein or polysaccharide, if present, of the present aqueous compositions. Acids useful in the present aqueous compositions include inorganic acids such as carbonic acid, sulfuric acid, or hydrochloric acid. Organic acids can alternatively be employed. Suitable organic acids include C₁ to C₂₀ organic acids such as formic acid, citric acid, malic acid, adipic acid, tannic acid, lactic acid, ascorbic acid, acetic acid, fumaric acid, and mixtures thereof. In one embodiment, the acid is citric acid.

[0074] The acid can be present in the aqueous compositions in an amount from 0 wt% to about 10 wt% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8

wt% to about 9 wt%, about 9 wt% to about 10 wt%, or any other value or range of values therein) of the aqueous composition. In some embodiments, the acid is present from about 0.01 wt% to about 2 wt% of the aqueous compositions. In one embodiment, the acid is present in about 0.03 wt%. In some embodiments, the aqueous compositions do not comprise an acid.

[0075] The present aqueous composition can comprise a base. Bases useful in the present aqueous compositions are organic or inorganic bases. Suitable inorganic bases include alkali metal or alkaline earth metal compounds such as sodium hydroxide, lithium hydroxide, potassium hydroxide, sodium carbonate, potassium carbonate, sodium bicarbonate, potassium bicarbonate, magnesium carbonate and calcium carbonate. Other suitable bases include ammonium hydroxide, substituted amine bases and ammonia.

[0076] The base can present in the aqueous compositions in an amount from 0 wt% to about 15 wt% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, about 10 wt% to about 11 wt%, about 11 wt% to about 12 wt%, about 12 wt% to about 13 wt%, about 13 wt% to about 14 wt%, about 14 wt% to about 15 wt%, or any other value or range of values therein). In some embodiments, the base is present from about 1 wt% to about 15 wt% of the aqueous compositions. In one embodiment, the base is present in about 7 wt%. In some embodiments, the aqueous compositions do not comprise a base.

[0077] The present aqueous compositions can also comprise a salt. Salts useful in the present aqueous compositions include organic or inorganic salts. Suitable salts include alkali or alkaline earth metal salts such as sodium chloride, potassium chloride, calcium chloride, magnesium chloride, ammonium chloride, sodium bromide, potassium bromide, calcium bromide, magnesium bromide, ammonium bromide, sodium iodide, potassium iodide, calcium iodide, magnesium iodide, ammonium iodide, sodium sulfate, potassium sulfate, calcium sulfate, magnesium sulfate, ammonium sulfate.

[0078] The salt can present in the aqueous compositions in an amount from 0 wt% to about 10 wt% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2

wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, or any other value or range of values therein) of the aqueous composition. In some embodiments, the salt is present from about 0.01 wt% to about 0.05 wt% of the aqueous compositions. In some embodiments, the aqueous compositions do not comprise a salt.

[0079] The present aqueous compositions comprise water. The amount of water in the present aqueous compositions can range from about 10 to about 90 wt% (e.g., about 10 wt% to about 15 wt%, about 15 wt% to about 20 wt%, about 20 wt% to about 25 wt%, about 25 wt% to about 30 wt%, about 30 wt% to about 35 wt%, about 35 wt% to about 40 wt%, about 40 wt% to about 45 wt%, about 45 wt% to about 50 wt%, about 50 wt% to about 55 wt%, about 55 wt% to about 60 wt%, about 60 wt% to about 65 wt%, about 65 wt% to about 70 wt%, about 70 wt% to about 75 wt%, about 75 wt% to about 80 wt%, about 80 wt% to about 85 wt%, about 85 wt% to about 90 wt%, or any other value or range of values therein). In certain embodiments, the aqueous compositions comprise from about 80 wt% to about 90 wt% water. In one embodiment, the aqueous compositions comprise about 69 wt% water.

[0080] The present aqueous compositions can further comprise an organic solvent, in the absence or presence of water. Suitable organic solvents include, but are not limited to, C₁ to C₃ alcohols such as methanol, ethanol, *n*-propanol and *i*-propanol. Alternatively glycols such as ethylene glycol, propylene glycol and polyethylene glycol, and ketone-containing solvents such as acetone can be employed. In certain embodiments, the aqueous organic solvent is ethanol or *i*-propanol. In one embodiment, the aqueous compositions comprise water and an alcohol; in another embodiment, water and ethanol or *i*-propanol.

[0081] The amount of organic solvent, if present, can be selected based on factors such as its miscibility in water, if present, and the amount of protein. The organic solvent can be present in the aqueous compositions in an amount ranging from 0 wt% to about 10 wt% (e.g., 0 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, or any

other value or range of values therein) of the aqueous composition. In certain embodiments, the organic solvent is present in an amount of about 2.5 wt%. In some embodiments, the aqueous compositions do not comprise an organic solvent.

[0082] The present aqueous compositions can also comprise one or more other additives. Suitable additives include, but are not limited to, detergents, as surface tension modifiers, flocculants, dispersants, rheology modifiers and emulsifiers. Illustrative additives are polysorbates, oils (e.g., canola oil, vegetable oils, etc.) In some embodiments, the present aqueous compositions comprise lime (e.g., quick lime, slaked lime, Ca(OH)_2 , Type-S hydrated lime). In certain embodiments, the lime is Type-S hydrated lime. The additive(s) can be present in the aqueous compositions in amounts ranging from 0 to about 10% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, or any other value or range of values therein) of the aqueous composition. In certain embodiments, the additive is Type-S hydrated lime and is present in an amount of about 0.5 wt%. In some embodiments, the aqueous compositions do not comprise an additive. In some embodiments, the aqueous compositions do not comprise lime. In some embodiments, the aqueous compositions do not comprise S type hydrated lime.

[0083] In particular embodiments of the present invention, the aqueous compositions comprise a polysaccharide that is guar gum and plant material that is corn gluten meal. In other embodiments, the aqueous compositions further comprise one or more of water, isopropanol, citric acid, Type S hydrated lime, sodium hydroxide, and sodium chloride. In other embodiments of the present invention, the aqueous compositions comprise plant material that is corn gluten meal, and do not contain a polysaccharide other than that present in or derived from the corn gluten meal. In other embodiments, the aqueous compositions further comprise one or more of water, isopropanol, citric acid, Type S hydrated lime, sodium hydroxide, and sodium chloride.

[0084] Thus, in one embodiment, the present invention provides an aqueous composition comprising about 1 wt% to about 50 wt% of plant material, 0 to about 20 wt% of a

polysaccharide, 0% to about 10 wt% of an alcohol, 0% to about 15 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and about 10 wt% to about 95 wt% of water, wherein the aqueous composition has a pH of from about 9 to about 13.

[0085] In one embodiment, the aqueous composition comprises from about 1 wt% to about 30 wt% of the plant material and 0 to about 10 wt% of the polysaccharide. In certain embodiments, the aqueous composition comprises from about 1 wt% to about 10 wt% of the plant material and 0 to about 5 wt% of the polysaccharide. In other embodiments, the aqueous composition comprises from about 1 wt% to about 5 wt% of the plant material and 0 to about 1 wt% of the polysaccharide. In some embodiments, the plant a cereal. In some embodiments, the cereal is corn, rice, wheat, barley, sorghum, millet, rye, triticale, fonio, flax, buckwheat, spelt or quinoa. In one embodiment, the cereal is corn. In other embodiments, the plant material is lentils (e.g., green, yellow, black), soy beans, hemp seed, chia, grass, wheat grass and barley (e.g., pearl, groat). In some embodiments, the plant material comprises a plant protein. In some embodiments, the plant protein is from corn gluten meal. In other embodiments, the plant is cotton. In certain embodiments, the plant protein is prolamine, zein, hordein, or gliadin. In some embodiments, the polysaccharide of the present aqueous composition is alginate, carrageenan, gum Arabic, tragacanth gum, guar gum, pectin, ghatti gum, xanthan gum, or mixtures thereof. In some embodiments, the polysaccharide is about 0.5 wt% to about 2 wt% of the aqueous composition. In some embodiments, the aqueous compositions do not comprise any of the aforementioned polysaccharides other than those present in or derived from the plant material. In other embodiments, the aqueous compositions do not comprise any of the aforementioned polysaccharides. In other embodiments, the aqueous compositions do not comprise polysaccharide.

[0086] In some embodiments, the aqueous composition further comprises an alcohol. In certain embodiments, the alcohol is ethanol, methanol, or isopropanol. In one embodiment, the alcohol is isopropanol. In some embodiments, the alcohol is about 0 wt% to about 10 wt% of the aqueous composition. In some embodiments, the aqueous composition does not comprise an alcohol. In some embodiments, the aqueous composition further comprises a base. In certain embodiments, the base is an inorganic base or an inorganic base. In other embodiments, the

inorganic base is an alkali metal or alkaline earth metal base. In some embodiments, the inorganic base is sodium hydroxide, lithium hydroxide, potassium hydroxide, sodium carbonate, potassium carbonate, sodium bicarbonate, potassium bicarbonate, magnesium carbonate or calcium carbonate. In certain embodiments, the base is about 0 wt% to about 10 wt% of the aqueous composition. In some embodiments, the aqueous composition does not comprise a base.

[0087] In some embodiments, the aqueous composition further comprises a salt. In certain embodiments, the salt is sodium chloride, potassium chloride, calcium chloride, magnesium chloride, ammonium chloride, sodium bromide, potassium bromide, calcium bromide, magnesium bromide, ammonium bromide, sodium iodide, potassium iodide, calcium iodide, magnesium iodide, ammonium iodide, sodium sulfate, potassium sulfate, calcium sulfate, magnesium sulfate, ammonium sulfate, sodium nitrate, potassium nitrate, magnesium nitrate, calcium nitrate, ammonium nitrate or mixtures thereof. In certain embodiments, the salt is about 0 wt% to about 10 wt% of the aqueous composition. In some embodiments, the aqueous composition does not comprise a salt.

[0088] In some embodiments, the aqueous composition further comprises an acid. In certain embodiments, the acid is an organic acid. In other embodiments, the acids include inorganic acids. In certain embodiments, the inorganic acids include carbonic acid, sulfuric acid, or hydrochloric acid. In some embodiments, the acid is a C1-C20 organic acid. In certain embodiments, the acid is citric acid, formic acid, ascorbic acid, acetic acid, malic acid, adipic acid, tannic acid, lactic acid, fumaric acid, or mixtures thereof. In one embodiment, the acid is citric acid. In certain embodiments, the acid is about 0 wt% to about 10 wt% of the aqueous composition. In some embodiments, the aqueous composition does not comprise an acid.

[0089] In some embodiments, the aqueous composition of further comprises an additive. In certain embodiments, the additive is lime. In one embodiment, the lime is Type S Hydrated certain embodiments, the additive is lime. In certain embodiments, the lime is Type S Hydrated Lime. In certain embodiments, the Type S Hydrated Lime is about 0 wt% to about 10 wt% of the aqueous composition. In some embodiments, the aqueous composition does not comprise an additive. In some embodiments, the aqueous composition does not comprise lime.

[0090] In some embodiments, the aqueous composition comprises about 10 wt% to about 90 wt% water. In certain embodiments, the aqueous composition comprises about 80 wt% to about 90 wt% water. In certain embodiments, the aqueous composition comprises a polysaccharide and the polysaccharide and plant protein are in the form of a complex. In certain embodiments, the pH of the aqueous composition is from about 6 to about 8. In certain embodiments, the aqueous composition does not comprise a polysaccharide other than that derived from the plant material, wherein the plant material is corn gluten meal, and wherein the aqueous composition optionally further comprises one or more of isopropanol, citric acid, Type S hydrated lime, sodium hydroxide, and sodium chloride. In one embodiment, the aqueous compositions further comprise a substrate.

Preparation of the Aqueous Compositions

[0091] The present aqueous compositions can be prepared by admixing the aqueous compositions' components, optionally in the presence of water or an organic solvent. For example, the aqueous compositions can be prepared by admixing the plant material component, in an amount as described hereinabove, with one or both of water and an organic solvent to form a plant material mixture. The plant material mixture can be a suspension or solution and can further comprise an acid or base. The plant material can be added to the water, the organic solvent or both, or *vice versa*. The plant material mixture can be stirred or agitated until the plant material is suspended or substantially dissolved (e.g., about 10 minutes, about 20 minutes, about 30 minutes, about 40 minutes, about 50 minutes, about 1 hour, about 2 hours, about 3 hours, about 4 hours, or any other value or range of values therein or thereabove). The plant material mixture can be heated at a temperature of from about 5 °C to about 100 °C (e.g., about 5 °C to about 10 °C, about 10 °C to about 15 °C, about 15 °C to about 20 °C, about 20 °C to about 25 °C, about 25 °C to about 30 °C, about 30 °C to about 35 °C, about 35 °C to about 40 °C, about 40 °C to about 45 °C, about 45 °C to about 50 °C, about 50 °C to about 55 °C, about 55 °C to about 60 °C, about 60 °C to about 65 °C, about 65 °C to about 70 °C, about 70 °C to about 75 °C, about 75 °C to about 80 °C, about 80 °C to about 85 °C, about 85 °C to about 90 °C, about 90 °C to about 95 °C, about 95 °C to about 100 °C, or any other value or range of values

therein), optionally with mixing. In certain embodiments, the plant material mixture is prepared at ambient temperature (e.g., about 23 °C).

[0092] In some embodiments, the plant material is wetted with water (e.g., contacted or admixed with water, soaked in water, saturated with water) prior to admixing with other ingredients to form the present aqueous compositions. For example, the plant material may wetted with water for a time period ranging from about 5 minutes to about 168 hours (e.g., from about 5 minutes to about 10 minutes, from about 10 minutes to about 20 minutes, from about 20 minutes to about 30 minutes, from about 30 minutes to about 40 minutes, from about 40 minutes to about 50 minutes, from about 50 minutes to about 1 hour, from about 1 hour to about 2 hours, from about 2 hours to about 3 hours, from about 3 hours to about 4 hours, from about 4 hours to about 5 hours, from about 5 hours to about 6 hours, from about 6 hours to about 7 hours, from about 7 hours to about 8 hours, from about 8 hours to about 9 hours, from about 9 hours to about 10 hours, from about 10 hours to about 11 hours, from about 11 hours to about 12 hours, from about 12 hours to about 14 hours, from about 14 hours to about 16 hours, from about 16 hours to about 18 hours, from about 18 hours to about 20 hours, from about 20 hours to about 22 hours, from about 22 hours to about 24 hours, from about 24 hours to about 28 hours, from about 28 hours to about 32 hours, from about 32 hours to about 36 hours, from about 36 hours to about 40 hours, from about 40 hours to about 44 hours, from about 44 hours to about 48 hours, from about 48 hours to about 72 hours, from about 72 hours to about 96 hours, from about 96 hours to about 120 hours, from about 120 hours to about 144 hours, from about 144 hours to about 168 hours, or any other value or range of values therein). In some embodiments, the wetted plant material may be admixed with the water employed for wetting. In some embodiments, the plant material is wetted in a sterile environment. In other embodiments, the plant material which has been wetted with water may be separated from the wetting water (e.g., when the plant material has been immersed in water to effect said wetting) by, e.g., decantation or filtration, prior to admixing the protein with additional components of the present aqueous compositions. In some embodiments, the plant material is not wetted.

[0093] In other embodiments, an acid or a base is added to water, organic solvent or both, and the resultant solution is added to the plant material mixture, or *vice versa*. The acid or base can be undiluted or present as a mixture with water or an organic solvent. After addition of the

acid or base, in certain embodiments the plant material mixture is allowed to stand for a period of time prior to addition of other components. For example, the plant material mixture can be allowed to stand for a period of about 10 minutes, about 20 minutes, about 30 minutes, about 40 minutes, about 50 minutes, about 1 hour, about 2 hours, about 3 hours, about 4 hours, about 8 hours, or any other value or range of values therein or thereabove). The plant material mixture can be allowed to stand at a temperature of from about 5 °C to about 100 °C (e.g., about 5 °C to about 10 °C, about 10 °C to about 15 °C, about 15 °C to about 20 °C, about 20 °C to about 25 °C, about 25 °C to about 30 °C, about 30 °C to about 35 °C, about 35 °C to about 40 °C, about 40 °C to about 45 °C, about 45 °C to about 50 °C, about 50 °C to about 55 °C, about 55 °C to about 60 °C, about 60 °C to about 65 °C, about 65 °C to about 70 °C, about 70 °C to about 75 °C, about 75 °C to about 80 °C, about 80 °C to about 85 °C, about 85 °C to about 90 °C, about 90 °C to about 95 °C, about 95 °C to about 100 °C, or any other value or range of values therein). In certain embodiments, after addition of the acid or base, the plant material mixture is allowed to stand at ambient temperature (e.g., about 23 °C).

[0094] Where the aqueous compositions comprise a polysaccharide other than that which is present or derived from the plant material, the polysaccharide is added to the plant material mixture, or *vice versa*. In some embodiments, protein from the plant material and polysaccharide form a protein-polysaccharide complex in solution. Typically the plant material and polysaccharide are admixed with agitation (e.g., stirring, mixing). The mixture comprising the plant material and polysaccharide can be admixed with agitation for a period of about 10 minutes, about 20 minutes, about 30 minutes, about 40 minutes, about 50 minutes, about 1 hour, about 2 hours, about 3 hours, about 4 hours, or any other value or range of values therein or thereabove) and at a temperature of from about 5 °C to about 100 °C (e.g., about 5 °C to about 10 °C, about 10 °C to about 15 °C, about 15 °C to about 20 °C, about 20 °C to about 25 °C, about 25 °C to about 30 °C, about 30 °C to about 35 °C, about 35 °C to about 40 °C, about 40 °C to about 45 °C, about 45 °C to about 50 °C, about 50 °C to about 55 °C, about 55 °C to about 60 °C, about 60 °C to about 65 °C, about 65 °C to about 70 °C, about 70 °C to about 75 °C, about 75 °C to about 80 °C, about 80 °C to about 85 °C, about 85 °C to about 90 °C, about 90 °C to about 95 °C, about 95 °C to about 100 °C, or any other value or range of values therein). In certain embodiments, the mixture comprising the plant material and polysaccharide is agitated at ambient temperature (e.g., about 23 °C).

[0095] In some embodiments, a salt is added to the plant material mixture, or *vice versa*, typically with agitation (e.g., stirring, mixing). The plant material mixture can be agitated for a period of about 10 minutes, about 20 minutes, about 30 minutes, about 40 minutes, about 50 minutes, about 1 hour, about 2 hours, about 3 hours, about 4 hours, or any other value or range of values therein or thereabove) and at a temperature of from about 5 °C to about 100 °C (e.g., about 5 °C to about 10 °C, about 10 °C to about 15 °C, about 15 °C to about 20 °C, about 20 °C to about 25 °C, about 25 °C to about 30 °C, about 30 °C to about 35 °C, about 35 °C to about 40 °C, about 40 °C to about 45 °C, about 45 °C to about 50 °C, about 50 °C to about 55 °C, about 55 °C to about 60 °C, about 60 °C to about 65 °C, about 65 °C to about 70 °C, about 70 °C to about 75 °C, about 75 °C to about 80 °C, about 80 °C to about 85 °C, about 85 °C to about 90 °C, about 90 °C to about 95 °C, about 95 °C to about 100 °C, or any other value or range of values therein). In certain embodiments, the plant material mixture is agitated at ambient temperature (e.g., about 23 °C).

[0096] The plant material mixture can then be admixed with one or more additives described above. The plant material mixture can be added to the one or more additives, or *vice versa*. Typically the plant material mixture and one or more additives are admixed with agitation (e.g., stirring, mixing). The resultant mixture can be agitated for a period of time until it becomes uniform, e.g., a solution or a uniform suspension. For example, the resultant mixture can be agitated for a period of about 10 minutes, about 20 minutes, about 30 minutes, about 40 minutes, about 50 minutes, about 1 hour, about 2 hours, about 3 hours, about 4 hours, or any other value or range of values therein or thereabove) and at a temperature of from about 5 °C to about 100 °C (e.g., about 5 °C to about 10 °C, about 10 °C to about 15 °C, about 15 °C to about 20 °C, about 20 °C to about 25 °C, about 25 °C to about 30 °C, about 30 °C to about 35 °C, about 35 °C to about 40 °C, about 40 °C to about 45 °C, about 45 °C to about 50 °C, about 50 °C to about 55 °C, about 55 °C to about 60 °C, about 60 °C to about 65 °C, about 65 °C to about 70 °C, about 70 °C to about 75 °C, about 75 °C to about 80 °C, about 80 °C to about 85 °C, about 85 °C to about 90 °C, about 90 °C to about 95 °C, about 95 °C to about 100 °C, or any other value or range of values therein). In certain embodiments, the resultant mixture is agitated at ambient temperature (e.g., about 23 °C).

[0097] The resultant mixture is then allowed to stand without agitation to allow any undissolved or unsuspended solids to precipitate. The resultant mixture can be allowed to stand at a temperature of from about 5 °C to about 100 °C (e.g., about 5 °C to about 10 °C, about 10 °C to about 15 °C, about 15 °C to about 20 °C, about 20 °C to about 25 °C, about 25 °C to about 30 °C, about 30 °C to about 35 °C, about 35 °C to about 40 °C, about 40 °C to about 45 °C, about 45 °C to about 50 °C, about 50 °C to about 55 °C, about 55 °C to about 60 °C, about 60 °C to about 65 °C, about 65 °C to about 70 °C, about 70 °C to about 75 °C, about 75 °C to about 80 °C, about 80 °C to about 85 °C, about 85 °C to about 90 °C, about 90 °C to about 95 °C, about 95 °C to about 100 °C, or any other value or range of values therein) for a period of about 10 minutes, about 20 minutes, about 30 minutes, about 40 minutes, about 50 minutes, about 1 hour, about 2 hours, about 3 hours, about 4 hours, about 8 hours, or any other value or range of values therein or thereabove). In certain embodiments, after admixture with an additive, the resultant mixture is allowed to stand at ambient temperature (e.g., about 23 °C), until any undissolved or unsuspended solids present have precipitated. The resultant mixture can then be decanted or filtered to remove the solids therefrom, and the solids are discarded, to provide the present aqueous composition in the form of a solvent mixture. The solvent mixture generally has a final pH ranging from about 5 to about 14 (e.g., from about 5 to about 6, from about 6 to about 7, from about 7 to about 8, from about 8 to about 9, from about 9 to about 10, from about 10 to about 11, from about 11 to about 12, from about 12 to about 13, from about 13 to about 14, or any other value or range of values therein). In certain embodiments, the pH ranges from about 6 to about 8. In other embodiments, the pH is about 13. In certain embodiments, the pH of the solvent mixture ranges from about 5 to about 13; from about 6 to about 13; from about 7 to about 13; from about 8 to about 13; from about 9 to about 13; from about 10 to about 13; from about 11 to about 13; from about 12 to about 13.

[0098] In certain embodiments, the resultant mixture can be further purified via the application of gravity or another force that can effect separation of one or more unwanted by-products (e.g., solids, gels, suspensions and the like) from the present aqueous compositions. For example, in some embodiments, the resultant mixture is subject to centrifugal force effected by a centrifuge to remove one or more unwanted by-products. The centrifugal force applied can be expressed in terms of relative centrifugal force (RCF), as a number (n) times the force of gravity (g), and has units of g, wherein 1 g is the force of gravity at sea level. RCF can be a convenient

value to use when describing the centrifugal force acting on a given material because it is a constant that is independent of the apparatus used. Thus, in some embodiments, the RCF applied to the resultant mixture is from about 100 g to about 20,000 g (e.g., from about 10 g to about 1,000 g, from about 1,000 g to about 2,000 g, from about 2,000 g to about 3,000 g, from about 3,000 g to about 4,000 g, from about 4,000 g to about 5,000 g, from about 5,000 g to about 6,000 g, from about 6,000 g to about 7,000 g, from about 7,000 g to about 8,000 g, from about 8,000 g to about 9,000 g, from about 9,000 g to about 10,000 g, from about 10,000 g to about 11,000 g, from about 11,000 g to about 12,000 g, from about 12,000 g to about 13,000 g, from about 13,000 g to about 14,000 g, from about 14,000 g to about 15,000 g, from about 15,000 g to about 16,000 g, from about 16,000 g to about 17,000 g, from about 17,000 g to about 18,000 g, from about 18,000 g to about 19,000 g, from about 19,000 g to about 20,000 g, or any other value or range of values therein). In some embodiments, the RCF ranges from about 12,000 g to about 18,000 g. In other embodiments, the RCF ranges from about 15,000 g to about 18,000 g. After such centrifugation, the supernatant may be removed by, e.g., suction, decantation, filtration and the like, to afford the present aqueous compositions.

Extractants

[0099] The present compositions can be combined with water to form an extractant useful in the methods described herein. Thus, in another embodiment, the present invention relates to extractants comprising about 0.1 wt% to about 2 wt% of plant material, 0 to about 2 wt% of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 10 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and about 90 wt% to about 99.9 wt% water. In some embodiments, the extractant comprises about 0.1 wt% to about 1 wt% of plant material and 0 to about 1 wt% of a polysaccharide. In certain embodiments, the extractant comprises about 0.1 wt% to about 0.5 wt% of plant material and 0 to about 1 wt% of a polysaccharide. In some embodiments, the extractant does not comprise a polysaccharide other than that present in or derived from the plant material. In other embodiments, the aqueous compositions do not comprise a polysaccharide.

[00100] The polysaccharide can be present in the extractants in an amount ranging from about 0 to about 2 wt% (e.g., about 0.01 wt% to about 0.05 wt%, about 0.05 wt% to about 0.1

wt%, about 0.1 wt% to about 0.2 wt%, about 0.2 wt% to about 0.3 wt%, about 0.3 wt% to about 0.4 wt%, about 0.4 wt% to about 0.5 wt%, about 0.5 wt% to about 1.0 wt%, about 1.0 wt% to about 1.5 wt%, about 1.5 wt% to about 2.0 wt%, or any other value or range of values therein). In some embodiments, the polysaccharide is present in an amount of from 0 wt% to about 1 wt%. In other embodiments, the present extractants do not comprise a polysaccharide other than that present in or derived from the plant material. When present, polysaccharides which are useful in the present extractants include those as described herein which can be employed in the present aqueous compositions.

[00101] In some embodiments, the plant material is present in the extractants in an amount ranging from about 0.1 to about 2 wt% (e.g., about 0.01 wt% to about 0.05 wt%, about 0.05 wt% to about 0.1 wt%, about 0.1 wt% to about 0.2 wt%, about 0.2 wt% to about 0.3 wt%, about 0.3 wt% to about 0.4 wt%, about 0.4 wt% to about 0.5 wt%, about 0.5 wt% to about 0.6 wt%, about 0.6 wt% to about 0.7 wt%, about 0.7 wt% to about 0.8 wt%, about 0.8 wt% to about 0.9 wt%, about 0.9 wt% to about 1.0 wt%, about 1.0 wt% to about 1.5 wt%, about 1.5 wt% to about 2.0 wt%, or any other value or range of values therein). Plant materials which are useful in the present extractant include those as described herein which can be employed in the present aqueous compositions. In some embodiments, the plant material is present in an amount of from about 0.1 wt% to about 1 wt%. In certain embodiments, the plant material is present in an amount of from about 0.1 wt% to about 0.5 wt%.

[00102] The present extractants can further comprise an acid or a base. Acids and bases useful in the present extractants are those as described hereinabove which are useful in the present aqueous compositions. The acid can be present in the extractants in an amount from 0 wt% to about 1 wt% (e.g., about 0 to about 0.01 wt% , about 0.01 wt% to about 0.05 wt%, about 0.05 wt% to about 0.1 wt%, about 0.1 wt% to about 0.2 wt%, about 0.2 wt% to about 0.3 wt%, about 0.3 wt% to about 0.4 wt%, about 0.4 wt% to about 0.5 wt%, about 0.5 wt% to about 0.6 wt%, about 0.6 wt% to about 0.7 wt%, about 0.7 wt% to about 0.8 wt%, about 0.8 wt% to about 0.9 wt%, about 0.9 wt% to about 1 wt%, or any other value or range of values therein). In some embodiments, the acid is present from about 0.01 wt% to about 1 wt% of the extractant. In some embodiments, the extractant does not comprise an acid.

[00103] The base can be present in the extractants in an amount from 0 wt% to about 1 wt% (e.g., about 0 to about 0.01 wt% , about 0.01 wt% to about 0.05 wt%, about 0.05 wt% to about 0.1 wt%, about 0.1 wt% to about 0.2 wt%, about 0.2 wt% to about 0.3 wt%, about 0.3 wt% to about 0.4 wt%, about 0.4 wt% to about 0.5 wt%, about 0.5 wt% to about 0.6 wt%, about 0.6 wt% to about 0.7 wt%, about 0.7 wt% to about 0.8 wt%, about 0.8 wt% to about 0.9 wt%, about 0.9 wt% to about 1 wt%, or any other value or range of values therein). In some embodiments, the base is present from about 0.01 wt% to about 1 wt% of the extractants. In some embodiments, the extractant does not comprise a base.

[00104] The present extractants can also comprise a salt. Salts useful in the present extractants are those as described hereinabove which are useful in the present aqueous compositions. The salt can be present in the extractants in an amount from 0 wt% to about 1 wt% (e.g., about 0 to about 0.01 wt% , about 0.01 wt% to about 0.05 wt%, about 0.05 wt% to about 0.1 wt%, about 0.1 wt% to about 0.2 wt%, about 0.2 wt% to about 0.3 wt%, about 0.3 wt% to about 0.4 wt%, about 0.4 wt% to about 0.5 wt%, about 0.5 wt% to about 0.6 wt%, about 0.6 wt% to about 0.7 wt%, about 0.7 wt% to about 0.8 wt%, about 0.8 wt% to about 0.9 wt%, about 0.9 wt% to about 1 wt%, or any other value or range of values therein). In some embodiments, the salt is present from about 0.01 wt% to about 1 wt% of the extractant. In some embodiments, the extractant does not comprise a salt.

[00105] The present extractants can further comprise an organic solvent. Organic solvents which can be present in the extractants include those describe above which can be present in the aqueous compositions of the invention. The amount of organic solvent, if present, can be in an amount of 0 wt% to about 1 wt% (e.g., about 0 to about 0.01 wt% , about 0.01 wt% to about 0.05 wt%, about 0.05 wt% to about 0.1 wt%, about 0.1 wt% to about 0.2 wt%, about 0.2 wt% to about 0.3 wt%, about 0.3 wt% to about 0.4 wt%, about 0.4 wt% to about 0.5 wt%, about 0.5 wt% to about 0.6 wt%, about 0.6 wt% to about 0.7 wt%, about 0.7 wt% to about 0.8 wt%, about 0.8 wt% to about 0.9 wt%, about 0.9 wt% to about 1 wt%, or any other value or range of values therein). In some embodiments, the extractant dos not comprise an organic solvent. In some embodiments, the extractant dos not comprise an alcohol.

[00106] The present extractants can also comprise one or more other additives. Additives that can be present in the extractants include those describe above which can be present in the aqueous compositions of the invention. The additive(s) can be present in the extractants in amounts ranging from 0 to about 1 wt% (e.g., about 0 to about 0.01 wt% , about 0.01 wt% to about 0.05 wt%, about 0.05 wt% to about 0.1 wt%, about 0.1 wt% to about 0.2 wt%, about 0.2 wt% to about 0.3 wt%, about 0.3 wt% to about 0.4 wt%, about 0.4 wt% to about 0.5 wt%, about 0.5 wt% to about 0.6 wt%, about 0.6 wt% to about 0.7 wt%, about 0.7 wt% to about 0.8 wt%, about 0.8 wt% to about 0.9 wt%, about 0.9 wt% to about 1 wt%, or any other value or range of values therein). In certain embodiments, the additive is Type-S hydrated lime. In some embodiments, the extractant dos not comprise an additive. In some embodiments, the extractant does not comprise lime. In some embodiments, the extractant does not comprise Type-S hydrated lime.

[00107] The amount of water in the present extractants can range from about 90 to about 99.9 wt% (e.g., about 90 wt% to about 91 wt%, about 91 wt% to about 92 wt%, about 92 wt% to about 93 wt%, about 93 wt% to about 94 wt%, about 94 wt% to about 95 wt%, about 95 wt% to about 96 wt%, about 96 wt% to about 97 wt%, about 97 wt% to about 98 wt%, about 98 wt% to about 99 wt%, about 99 wt% to about 99.5 wt%, about 99.5 wt% to about 99.9 wt%, or any other value or range of values therein). In certain embodiments, the extractant comprises from about 95 wt% to about 99.9% wt% water.

[00108] In particular embodiments of the present invention, the extractants comprise a polysaccharide that is guar gum and plant material that is corn gluten meal. In other embodiments of the present invention, the extractants comprise plant material that is corn gluten meal and does not contain a polysaccharide other than that present in the corn gluten meal. In other embodiments, the extractants optionally further comprise one or more of water, isopropanol, citric acid, Type S hydrated lime, sodium hydroxide, and sodium chloride.

[00109] Thus, in some embodiments, the present invention extractants comprising about 0.1 wt% to about 2 wt% of plant material, 0 to about 2 wt% of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 10 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and about 90 wt% to about 99.9 wt% water.

In certain embodiments, the extractant comprises from about 0.1 wt% to about 1 wt% of the plant material and 0 to about 1 wt% of the polysaccharide. In certain embodiments, the extractant comprises about 0.1 wt% to about 0.5 wt% of the plant material and 0 to about 0.1 wt% of the polysaccharide. In some embodiments, the plant material comprises plant protein. In some embodiments, the plant proteins are prolamines. In some embodiments, the plant of the extractant is a cereal. In certain embodiments, the cereal is corn, rice, wheat, barley, sorghum, millet, rye, triticale, fonio, buckwheat, wheat grass, wheat, spelt or quinoa. In certain embodiments, the cereal is corn. In other embodiments, the plant material is lentils (e.g., green, yellow, black), hemp seed, chia, grass, wheat grass and barley (e.g., pearl, groat). In some embodiments, the polysaccharide of the extractant is alginate, carrageenan, gum Arabic, tragacanth gum, guar gum, pectin, ghatti gum, xanthan gum, or mixtures thereof. In certain embodiments, the extractant does not comprise polysaccharide other than that present in or derived from the plant material. In certain embodiments, the extractant does not comprise any of the aforementioned polysaccharides other than that present in or derived from the plant material. In certain embodiments, the polysaccharide is about 0.05 wt% to about 0.2 wt% of the extractant. In some embodiments, the extractant does not comprise polysaccharide.

[00110] In some embodiments, the extractant further comprises an alcohol. In certain embodiments, the alcohol is ethanol, methanol, or isopropanol. In one embodiment, the alcohol is isopropanol. In some embodiments, the alcohol is about 0 wt% to about 1 wt% of the extractant. In some embodiments, the extractant does not comprise an alcohol.

[00111] In certain embodiments, the extractant further comprises a base. In other embodiments, the base is an inorganic base or an inorganic base. In some embodiments, the inorganic base is an alkali metal or alkaline earth metal base. In certain embodiments, the inorganic base is sodium hydroxide, lithium hydroxide, potassium hydroxide, sodium carbonate, potassium carbonate, sodium bicarbonate, potassium bicarbonate, magnesium carbonate or calcium carbonate. In one embodiment, the base is 0 wt% to about 1 wt% of the extractant. In some embodiments, the extractant does not comprise a base.

[00112] In certain embodiments, the extractant further comprises a salt. In some embodiments, the salt is sodium chloride, potassium chloride, calcium chloride, magnesium chloride, ammonium chloride, sodium bromide, potassium bromide, calcium bromide, magnesium bromide, ammonium bromide, sodium iodide, potassium iodide, calcium iodide, magnesium iodide, ammonium iodide, sodium sulfate, potassium sulfate, calcium sulfate, magnesium sulfate, ammonium sulfate, sodium nitrate, potassium nitrate, magnesium nitrate, calcium nitrate, ammonium nitrate or mixtures thereof. In certain embodiments, the salt is 0 wt% to about 1 wt% of the extractant. In some embodiments, the extractant does not comprise a salt.

[00113] In certain embodiments, the extractant further comprises an acid. In other embodiments, the acids include inorganic acids. In certain embodiments, the inorganic acids include carbonic acid, sulfuric acid, or hydrochloric acid. In some embodiments, the acid is an organic acid. In certain embodiments, the acid is a C1-C20 organic acid. In other embodiments, the acid is citric acid, formic acid, ascorbic acid, acetic acid, malic acid, adipic acid, tannic acid, lactic acid, fumaric acid, or mixtures thereof. In one embodiment, the acid is citric acid. In certain embodiments, the acid is 0 wt% to about 1 wt% of the extractant. In some embodiments, the extractant does not comprise an acid.

[00114] In some embodiments, the extractant further comprises an additive. In certain embodiments, the additive is lime. In one embodiment, the lime is Type S Hydrated Lime. In some embodiments, the extractant does not comprise an additive. In certain embodiments, the Type S Hydrated Lime is 0 wt% to about 1 wt% of the extractant. In some embodiments, the extractant does not comprise lime. In some embodiments, the extractant does not comprise S type hydrated lime. In certain embodiments, the extractant comprises about 95 wt% to about 99 wt% water. In some embodiments, the pH of the extractant is from about 5 to about 14. In certain embodiments, the pH of the extractant is from about 6 to about 8. In certain embodiments, the pH of the extractant ranges from about 5 to about 13; from about 6 to about 13; from about 7 to about 13; from about 8 to about 13; from about 9 to about 13; from about 10 to about 13; from about 11 to about 13; from about 12 to about 13. In certain embodiments, the extractant does not comprise a polysaccharide other than that present in or derived from the plant

material. In one embodiment, the extractant does not comprise a polysaccharide other than that derived from the plant material, the plant material is corn gluten meal, and the aqueous composition further comprises isopropanol, citric acid, Type S hydrated lime, sodium hydroxide, and sodium chloride. In certain embodiments, the extractant further comprises a substrate.

Preparation of the Extractants

[00115] The present extractants can be made by adding water to the aqueous compositions of the invention as described herein. A desired water percentage of the present extractants can be selected in view of a particular application, such as oil sand extraction, coal tar extraction, hydraulic fracturing, soil remediation, or spill cleanup as described hereinbelow.

[00116] Thus, in one embodiment, the present invention provides method for making an extractant comprising about 0.1 wt% to about 2 wt% of plant material, 0 to about 2 wt% of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 10 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and about 90 wt% to about 99.9 wt% water, comprising adding water to an aqueous composition of the present invention in an amount of from about 90 wt% to about 99.9 wt%. In certain embodiments, the method comprises preparing an extractant comprising about 0.1 wt% to about 2 wt% of plant material, 0 to about 2 wt% of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 10 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and about 90 wt% to about 99.9 wt% water, comprising adding water to a substantially anhydrous composition as described herein in an amount of from about 90 wt% to about 99.9 wt%.

Substantially Anhydrous Compositions

[00117] The present aqueous compositions or extractants can be dried to form a substantially anhydrous composition. "Substantially anhydrous" means that the compositions comprise no more than about 10% water; in another embodiment, no more than about 5% water; in another embodiment, no more than about 2% water; in another embodiment, no more than about 1% water by weight of the composition; in another embodiment, no more than about 0.5%

water by weight of the composition; and in another embodiment, no more than about 0.1% by weight of the composition.

[00118] Thus, in another aspect, the present invention relates to substantially anhydrous compositions comprising about 20 wt% to about 99.9 wt% of plant material, 0 to about 20 wt%, of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 50 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and 0% to about 10 wt% water. The plant material and, if present, the polysaccharide of the present substantially anhydrous compositions can be present in relative amounts such that they form a complex. Polysaccharides which are useful in the present substantially anhydrous compositions include those as described herein. In some embodiments, the present substantially anhydrous compositions do not comprise polysaccharide other than that derived from the plant material. In other embodiments, the present substantially anhydrous compositions do not comprise polysaccharide.

[00119] The polysaccharide can be present in the substantially anhydrous compositions in an amount ranging from about 0 to about 20 wt% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, about 10 wt% to about 11 wt%, about 11 wt% to about 12 wt%, about 12 wt% to about 13 wt%, about 13 wt% to about 14 wt%, about 14 wt% to about 15 wt%, about 15 wt% to about 16 wt%, about 16 wt% about 17 wt%, about 17 wt% to about 18 wt%, about 18 wt% to about 19 wt%, about 19 wt% to about 20 wt%, or any other value or range of values therein). In some embodiments, the polysaccharide is present in an amount of from 0 wt% to about 10 wt%. In other embodiments, the present substantially anhydrous compositions do not comprise a polysaccharide other than that present in or derived from the plant material. When present, polysaccharides that are useful in the present substantially anhydrous compositions include those as described herein.

[00120] In some embodiments, the plant material is present in the substantially anhydrous compositions in an amount ranging from about 20 wt% to about 99.9 wt% (e.g., about 20 wt% to about 25 wt%, about 25 wt% to about 30 wt%, about 30 wt% to about 35 wt%, about 35 wt% to

about 40 wt%, about 40 wt% to about 45 wt%, about 45 wt% to about 50 wt%, about 50 wt% to about 55 wt%, about 55 wt% to about 60 wt%, about 60 wt% to about 65 wt%, about 65 wt% to about 70 wt%, about 70 wt% to about 75 wt%, about 75 wt% to about 80 wt%, about 80 wt% to about 85 wt%, about 85 wt% to about 90 wt%, about 90 wt% to about 91 wt%, about 91 wt% to about 92 wt%, about 92 wt% to about 93 wt%, about 93 wt% to about 94 wt%, about 94 wt% to about 95 wt%, about 95 wt% to about 96 wt%, about 96 wt% to about 97 wt%, about 97 wt% to about 98 wt%, about 98 wt% to about 99 wt%, about 99 wt% to about 99.5 wt%, about 99.5 wt% to about 99.9 wt%, or any other value or range of values therein). Plant materials which are in the present substantially anhydrous compositions include those as described herein. In some embodiments, the plant material is present in an amount of from about 85 wt% to about 99.9 wt%. In certain embodiments, the plant material is present in an amount of from about 95 wt% to about 99.9 wt%. In some embodiments, the plant material comprises a plant protein.

[00121] The present substantially anhydrous compositions can further comprise an acid or a base. Acids and bases useful in the present substantially anhydrous compositions are those as described hereinabove. The acid can be present in the substantially anhydrous compositions in an amount from 0 wt% to about 10 wt% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, or any other value or range of values therein). In some embodiments, the acid is present from about 0.01 wt% to about 2 wt% of the substantially anhydrous compositions. In some embodiments, the substantially anhydrous compositions do not comprise an acid.

[00122] The base can present in the substantially anhydrous compositions in an amount from 0 wt% to about 50 wt% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, about 10 wt% to about 15 wt%, about 15 wt% to about 20 wt%, about 20 wt% to about 25 wt%, about 25 wt% to about 30 wt%, about 30 wt% to about 35 wt%, about 35 wt% to about 40 wt%, about 40 wt% to about 45 wt%, about 45 wt% to about 50 wt%, or any other value or range of values therein). In some

embodiments, the base is present from about 0.01 wt% to about 5 wt% of the substantially anhydrous compositions.

[00123] The substantially anhydrous compositions can also comprise a salt. Salts useful in the substantially anhydrous compositions are those as described hereinabove. The salt can be present in the substantially anhydrous compositions in an amount from 0 wt% to about 10 wt% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, or any other value or range of values therein). In some embodiments, the salt is present from about 0.01 wt% to about 1 wt% of the substantially anhydrous compositions. In some embodiments, the substantially anhydrous compositions do not comprise a salt.

[00124] As stated above, the substantially anhydrous compositions can comprise water. The amount of water in the substantially anhydrous compositions can range from 0 to about 10 wt% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, or any other value or range of values therein). In certain embodiments, the substantially anhydrous compositions comprise less than about 5 wt % water (e.g., less than about 4 wt %, less than about 3 wt %, less than about 2 wt %, less than about 1 wt % less than about 0.9 wt %, less than about 0.8 wt %, less than about 0.7 wt %, less than about 0.6 wt %, less than about 0.5 wt %, less than about 0.4 wt %, less than about 0.3 wt %, less than about 0.2 wt %, less than about 0.1 wt %, or any other value or range of values therein or therebelow).

[00125] The substantially anhydrous compositions can further comprise an organic solvent. Organic solvents which can be present in the substantially anhydrous compositions include those described above. The amount of organic solvent, if present, can be in an amount of 0 wt% to about 1 wt% (e.g., 0 to about 0.05 wt%, about 0.05 wt% to about 0.1 wt%, about 0.1 wt% to about 0.2 wt%, about 0.2 wt% to about 0.3 wt%, about 0.3 wt% to about 0.4 wt%, about

0.4 wt% to about 0.5 wt%, about 0.5 wt% to about 0.6 wt%, about 0.6 wt% to about 0.7 wt%, about 0.7 wt% to about 0.8 wt%, about 0.8 wt% to about 0.9 wt%, about 0.9 wt% to about 1.0 wt%, or any other value or range of values therein). In certain embodiments, the substantially anhydrous compositions do not comprise organic solvent.

[00126] The substantially anhydrous compositions can also comprise one or more other additives. Additives that which can be present in the substantially anhydrous compositions include those described above. The additive(s) can be present in the substantially anhydrous compositions in amounts ranging from 0 to about 10% (e.g., 0 to about 0.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 3 wt% to about 4 wt%, about 4 wt% to about 5 wt%, about 5 wt% to about 6 wt%, about 6 wt% to about 7 wt%, about 7 wt% to about 8 wt%, about 8 wt% to about 9 wt%, about 9 wt% to about 10 wt%, or any other value or range of values therein). In certain embodiments, the additive is Type-S hydrated lime. In some embodiments, the substantially anhydrous compositions do not comprise an additive. In some embodiments, the substantially anhydrous compositions do not comprise lime.

[00127] In particular embodiments of the present invention, the substantially anhydrous compositions comprise a polysaccharide that is guar gum and plant material that is corn gluten meal. In other embodiments of the present invention, the substantially anhydrous compositions comprise plant material that is corn gluten meal and do not comprise a polysaccharide other than that present in or derived from the corn gluten meal. In other embodiments, the substantially anhydrous compositions comprise one or more of water, isopropanol, citric acid, Type S hydrated lime, sodium hydroxide, and sodium chloride.

[00128] Thus, in certain embodiments the present invention provides substantially anhydrous compositions comprising about 20 wt% to about 99.9 wt% of plant material, 0 to about 20 wt%, of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 50 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and 0% to about 10 wt% water. In certain embodiments, the substantially anhydrous composition comprises about 85 wt% to about 99.9 wt% of the plant material and 0 to about 10 wt% of the polysaccharide. In other embodiments, the substantially anhydrous composition of comprises about 95 wt% to about 99.9 wt% of the plant material and 0 to about 5 wt% of the

polysaccharide. In certain embodiments, plant is a cereal. In other embodiments, the cereal is corn, rice, wheat, barley, sorghum, millet, rye, triticale, fonio, buckwheat, spelt or quinoa. In certain embodiments, the cereal is corn. In some embodiments, the plant material is corn gluten meal. In certain embodiments, the plant is cotton. In some embodiments the plant material comprises a plant protein. In other embodiments, the plant protein is prolamine, zein, hordein, or gliadin.

[00129] In some embodiments, the substantially anhydrous composition comprises a polysaccharide which is alginate, carrageenan, gum Arabic, tragacanth gum, guar gum, pectin, ghatti gum, xanthan gum, or mixtures thereof. In other embodiments, the substantially anhydrous composition does not comprise one or more of the aforementioned polysaccharides. In certain embodiments, the polysaccharide is 0 wt% to about 20 wt% of the substantially anhydrous composition. In other embodiments, the substantially anhydrous composition does not comprise polysaccharide other than that present in or derived from the plant material. In some embodiments, the substantially anhydrous composition further comprises an alcohol. In one embodiment, the alcohol is ethanol, methanol, or isopropanol. In other embodiments, the alcohol is isopropanol. In certain embodiments, the alcohol is about 0 wt% to about 1 wt% of the substantially anhydrous composition. In some embodiments, substantially anhydrous composition does not comprise an alcohol.

[00130] In certain embodiments, the substantially anhydrous composition further comprises a base. In some embodiments, the base is an inorganic base or an inorganic base. In certain embodiments, inorganic base is an alkali metal or alkaline earth metal base. In certain embodiments, the inorganic base is sodium hydroxide, lithium hydroxide, or potassium hydroxide. In certain embodiments, the base is 0 wt% to about 10 wt% of the substantially anhydrous composition. In some embodiments, substantially anhydrous composition does not comprise a base.

[00131] In certain embodiments, the substantially anhydrous composition further comprises a salt. In some embodiments, the salt is sodium chloride, potassium chloride, calcium chloride, magnesium chloride, ammonium chloride, sodium bromide, potassium bromide,

calcium bromide, magnesium bromide, ammonium bromide, sodium iodide, potassium iodide, calcium iodide, magnesium iodide, ammonium iodide, sodium sulfate, potassium sulfate, calcium sulfate, magnesium sulfate, ammonium sulfate, potassium nitrate, calcium nitrate, magnesium nitrate, ammonium nitrate, or mixtures thereof. In certain embodiments, the salt is 0 wt% to about 10 wt% of the substantially anhydrous composition. In some embodiments, substantially anhydrous composition does not comprise a salt.

[00132] In some embodiments, the substantially anhydrous composition further comprises an acid. In other embodiments, the acids include inorganic acids. In certain embodiments, the inorganic acids include carbonic acid, sulfuric acid, or hydrochloric acid. In some embodiments, the acid is an organic acid. In certain embodiments, the acid is a C1-C20 organic acid. In certain embodiments, the acid is citric acid, formic acid, ascorbic acid, acetic acid, malic acid, adipic acid, tannic acid, lactic acid, fumaric acid, or mixtures thereof. In other embodiments, the acid is citric acid. In some embodiments, the acid is 0 wt% to about 10 wt% of the substantially anhydrous composition. In some embodiments, substantially anhydrous composition does not comprise an acid.

[00133] In certain embodiments, the substantially anhydrous composition further comprises an additive. In some embodiments, the additive is lime. In certain embodiments, the lime is Type S Hydrated Lime. In certain embodiments, the Type S Hydrated Lime is 0 wt% to about 10 wt% of the substantially anhydrous composition. In some embodiments, substantially anhydrous composition does not comprise an additive. In some embodiments, substantially anhydrous composition does not comprise lime.

[00134] In some embodiments, the substantially anhydrous composition comprises 0 wt% to about 10 wt% water. In other embodiments, the substantially anhydrous composition comprises 0 wt% to about 1 wt% water. In some embodiments, the substantially anhydrous composition does not comprise a polysaccharide other than the present in or derived from the plant material.

Preparation of the Substantially Anhydrous Compositions

[00135] The aqueous compositions or extractants described herein can be dehydrated to form the present substantially anhydrous compositions. The substantially anhydrous compositions can later be reconstituted with a suitable solvent as described herein to provide the aqueous compositions or extractants. This allows for preparation of substantially anhydrous compositions, which can be easier and or less costly to handle, maintain or store. For example, once the present aqueous compositions or extractants as described herein have been prepared, their solvent can be removed to yield a substantially anhydrous composition. In preparing the present substantially anhydrous compositions, an acid or base as described herein can be added to adjust the pH prior to solvent removal. For example, the pH can be adjusted to from about 5 to about 14 (e.g., from about 5 to about 6, from about 6 to about 7, from about 7 to about 8, from about 8 to about 9, from about 9 to about 10, from about 10 to about 11, from about 11 to about 12, from about 12 to about 13, from about 13 to about 14, or any other value or range of values therein).

[00136] Any number of solvent removal techniques useful for obtaining a substantially anhydrous composition, e.g., from an aqueous composition or extractant can be used to prepare the substantially anhydrous compositions, including, but not limited to, vacuum drying, centrifugation, evaporation, freeze drying, air drying, lyophilization, convection oven drying or a combination thereof. One method for removing the solvent is vacuum drying, which safely removes and recovers the solvent while drying the product to provide the present substantially anhydrous compositions. The substantially anhydrous compositions can be further processed by grinding or milling to a desired mesh particle size. The substantially anhydrous compositions can also be subjected to particle-size reduction to form, for example, powders. The substantially anhydrous compositions can be subsequently admixed with water or organic solvent to provide a reconstituted aqueous composition or extractant for immediate or later use.

[00137] Thus, in certain embodiments, the present invention provides a method of making a substantially anhydrous composition comprising about 20 wt% to about 99.9 wt% of plant material, 0 to about 20 wt%, of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 50 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and 0% to about 10 wt% water, comprising removing water from an aqueous composition of the present invention. In certain embodiments, removing water comprises

drying. In certain embodiments, drying comprises heating the aqueous composition or subjecting the aqueous composition to reduced pressure. In some embodiments, the invention provides a method of making a substantially anhydrous composition comprising about 20 wt% to about 99.9 wt% of plant material, 0 to about 20 wt%, of a polysaccharide, 0% to about 1 wt% of an alcohol, 0% to about 50 wt% of a base, 0% to about 10 wt% of a salt, 0% to about 10 wt% of an acid, 0% to about 10 wt% of an additive, and 0% to about 10 wt% water, comprising removing water from an extractant of the present invention. In some embodiments, removing water from the extractant comprises drying the extractant. In some embodiments, drying comprises heating the extractant or subjecting the extractant to reduced pressure.

Methods

[00138] In one aspect the present invention provides methods for extracting a hydrocarbon-containing substance from a substrate, comprising contacting the substrate with an aqueous composition or extractant under conditions effective for extracting at least some of the hydrocarbon-containing substance from the substrate. In one embodiment, “extracting” as used herein includes removing a hydrocarbon-containing substance from the surface of a substrate. In another embodiment, “extracting” as used herein includes extracting the hydrocarbon-containing substance from pores, fractures, cracks, fissures, crevices or interstitial spaces of a substrate.

[00139] In some embodiments, the hydrocarbon-containing substance is grease or oil, including heavy oil, crude oil, refined oil, shale oil, bitumen, coal tar, synthetic oil, and fractions or products thereof; automotive oil; oil from oil sand, for example, from Athabasca, Venezuela or Utah oil sand; oil obtained from hydraulic fracturing; and oil from the skin of an animal. In other embodiments, the hydrocarbon-containing substance comprises natural gas liquids.

[00140] In certain embodiments, the substrate is soil, sand, beach sand, oil sand, heavy-oil sand, rock, wood, paper, skin, water, gravel, mud, clay, plant, hair, fabric, glass, porcelain, concrete or metal. The substrate can be a solid or a liquid. Where the substrate is a solid, it can be a solid comprising a pore, fracture, crack, fissure or crevice; a smooth, non-porous solid; or a particulate material such as a powder, sand, gravel, silt or sediment.

[00141] In certain embodiments, the substrate is water. In one embodiment, the substrate is a waterbody. A waterbody can include ponds, lakes, streams, rivers, oceans, seawater, fresh water, salt water, brackish water, groundwater, wastewater, and the like. Accordingly, in one embodiment, the substrate is a waterbody. In this regard, a hydrocarbon-containing substance can be extracted from a waterbody by treating it with a present aqueous composition or extractant. In certain embodiments, the substrate is soil. In other embodiments, the substrate is sediment. In other embodiments, the substrate is metal. In one embodiment, the substrate is a metal storage tank. In another embodiment, the substrate is a metal pipe. In another embodiment, the substrate is glass. In another embodiment, the substrate is porcelain. In another embodiment, the substrate is a concrete.

[00142] In one embodiment, the substrate is fabric. Fabric can include any woven material or fibers, including natural fibers such as cotton, wool, linen, silk, hemp, jute, etc., and synthetic fibers including rayon, polyester, nylon, etc. Thus, in certain embodiments, the present methods may be employed to extract a hydrocarbon-containing substance from fabric or woven materials. In some embodiments, the present invention provides a laundry detergent comprising a Composition of the Invention. In certain embodiments, the present invention provides a method for extracting a hydrocarbon-containing substance from fabric comprising contacting the fabric with a laundry detergent comprising a Composition of the Invention.

[00143] Accordingly, in another aspect, the present invention provides laundry detergents comprising an aqueous composition of the present invention. In some embodiments, the laundry detergent comprises an extractant of the present invention. In other embodiments, the laundry detergent comprises a substantially anhydrous composition of the present invention. In some embodiments, the invention further provides a method for removing a hydrocarbon-containing substance from fabric comprising contacting the fabric with the laundry detergent comprising a Composition of the Invention

[00144] The present methods can be performed at less-than elevated temperature (e.g., at about 23 °C). However, in certain embodiments, it can be advantageous to heat a mixture of an aqueous composition or extractant and a substrate to improve or accelerate extraction or remediation. Thus, the present methods can be performed at a temperature of from about 5 °C to

about 100 °C (e.g., about 5 °C to about 10 °C, about 10 °C to about 15 °C, about 15 °C to about 20 °C, about 20 °C to about 25 °C, about 25 °C to about 30 °C, about 30 °C to about 35 °C, about 35 °C to about 40 °C, about 40 °C to about 45 °C, about 45 °C to about 50 °C, about 50 °C to about 55 °C, about 55 °C to about 60 °C, about 60 °C to about 65 °C, about 65 °C to about 70 °C, about 70 °C to about 75 °C, about 75 °C to about 80 °C, about 80 °C to about 85 °C, about 85 °C to about 90 °C, about 90 °C to about 95 °C, about 95 °C to about 100 °C, or any other value or range of values therein).

[00145] The present methods are also useful for extracting hydrocarbon-containing substance (e.g., crude oil) from the skin of an animal, such as a fish, bird or mammal, for example, after an oil spill. Thus, in certain embodiments, the animal is a living animal. In other embodiments, the animal is a dead animal, which might be cleaned or decontaminated.

[00146] According to the present invention, extracting a hydrocarbon-containing substance comprises contacting the substrate with an aqueous composition or extractant under conditions that are effective for extracting at least some of the hydrocarbon-containing substance from the substrate. A hydrocarbon-containing substance comprises one or more hydrocarbons. In some embodiments, the hydrocarbon is aromatic, such as benzene, toluene, naphthalene, xylene and a polycyclic aromatic hydrocarbon (PAH). Illustrative PAHs include naphthalene, fluorene, phenanthrene, pyrene, chrysene, and C₁-C₁₀ homologs thereof. A C₁ homolog of a PAH is a PAH having a methyl group. A C₂ homolog of a PAH is a PAH having, for example, an ethyl group or two methyl groups. A C₃ homolog of a PAH is a PAH having, for example, a methyl and an ethyl group, three methyl groups, an n-propyl group or an i-propyl group. A C₄ homolog of a PAH is a PAH having, for example, two ethyl groups, four methyl groups, an ethyl group and two methyl groups, a methyl group and an n-propyl group, a methyl group and an i-propyl group, an n-butyl group, a sec-butyl group, and i-butyl group or a t-butyl group. In other embodiments, the hydrocarbon comprises one or more heteroatoms such as oxygen, nitrogen and sulfur. In some embodiment, the hydrocarbon is a heteroaromatic compound such as pyridine, pyrazine, quinoline, furan, or thiophene, or a polycyclic aromatic compound optionally comprising one or more heteroatoms such as N, O or S.

[00147] In other embodiments, the hydrocarbon is nonaromatic, such as a cycloalkane, cycloalkene, and straight- branched-chain alkane, alkene and alkyne. In some embodiments, the non-aromatic hydrocarbon is a linear, branched or cyclic pentane, hexane, heptane, octane, nonane, or C₁₀ – C₂₀ alkane. In other embodiments, the hydrocarbon is a heteroatom-containing partially or fully saturated linear, branched, cyclic or caged compound. In some embodiments, the hydrocarbon comprises an ester, an amide, an amine, an imine, a carboxylic acid, a sulfide, a sulfoxide, a sulfone, a nitroxide or a nitron moiety. In other embodiments, the hydrocarbon comprises a halogen. In some embodiments, the hydrocarbon-containing substance is an oil. Such oils include light oils having an API (American Petroleum Institute) gravity higher than 31.1 °API (i.e., a density of less than 870 kg/m³), medium oils having an API gravity between 22.3 °API and 31.1 °API (i.e., a density of from 870 kg/m³ to 920 kg/m³), heavy oils having an API gravity below 22.3 °API to 10.0 °API (i.e., a density of from 920 kg/m³ to 1000 kg/m³), or extra heavy oil having an API gravity below 10.0 °API (i.e., a density of greater than 1000 kg/m³). Thus, light, medium and heavy oils are less dense than water, whereas extra heavy oil is more dense than water. In some embodiments, the oil is a light tar oil. A light tar oil is an oil having an API gravity of 22.3 °API to 10.0 °API.

[00148] In other embodiments, the hydrocarbon-containing substance is coal tar. “Coal tar” as used herein refers to a dense non-aqueous phase liquid (DNAPL) which comprises mixture of highly aromatic hydrocarbons, where the mixture optionally comprises aliphatic hydrocarbons. Coal tar is typically a brown or black liquid having a very high viscosity, and is generally not pourable from a vessel at ambient temperatures. Coal tar is one by-product of the manufacture of coke from coal, or from gasification of coal. Coal tar can be complex or variable mixtures and can comprise one or more phenols, polycyclic aromatic hydrocarbons (PAHs), and heterocyclic compounds. “Coal tar sand” as used herein is a mixture of sand and coal tar, e.g., sand coated with coal tar, or coal tar with sand mixed or embedded therein.

[00149] In other embodiments, the hydrocarbon-containing substance is sludge, e.g., from a storage tank employed for storing industrial sewage or other waste materials. Such sludge can comprise any hydrocarbon-containing substance as described herein, including light oils, medium oils, heavy oils, extra-heavy oils, bitumen, or coal tar as described herein, in addition to

sediment such as sand, silt or clay, metals or waxes. An oil-contaminated sludge is a sludge as which comprises an oil.

[00150] In certain embodiments, the oil is crude oil. In some embodiments, the crude oil is a sweet crude oil (oil having relatively low sulfur content, e.g., less than about 0.42% sulfur). In other embodiments, the crude oil is a sour crude oil (oil having relatively high sulfur content e.g., about 0.42% or more sulfur). In some embodiments, the hydrocarbon-containing substance is bitumen. Bitumen, also referred to as asphalt, typically comprises polycyclic aromatic hydrocarbons. In some embodiments, the hydrocarbon-containing substance comprises one or more petroleum distillates. In other embodiments, the hydrocarbon-containing substance is diesel fuel. In other embodiments, the hydrocarbon-containing substance is heating oil. In other embodiments, the hydrocarbon-containing substance is jet fuel. In other embodiments, the hydrocarbon-containing substance is aviation gasoline. In other embodiments, the hydrocarbon-containing substance is kerosene.

[00151] In some embodiments, the methods for extracting a hydrocarbon-containing substance from a substrate further comprise recovering the hydrocarbon-containing substance and optionally purifying it. For example, where the hydrocarbon-containing substance is crude oil, the extracted crude oil can be recovered and optionally refined to provide one or more conventional oil-derived products.

[00152] In some embodiments, the hydrocarbon-containing substance is removed from the substrate's surface. In other embodiments, hydrocarbon-containing substance is extracted from the substrate. In some embodiments the present methods for extracting the hydrocarbon-containing substance result in the formation of a biphasic or multiphasic mixture in which one of the phases is agglomerated hydrocarbon-containing substance (e.g., in the form of an "oil ball"), which can be easily removed from the aqueous composition or extractant by, for example, skimming, decantation, centrifugation or filtration. In certain embodiments, the hydrocarbon-containing substance extracted or removed from the substrate forms one or more agglomerations that can be spherical or spheroid in shape. In some embodiments, the agglomerations of hydrocarbon-containing material may range in diameter from about 0.1 mm to about 1 cm. The size of the present agglomerations can depend on the amount of hydrocarbon-containing

substance present. Thus, where a large amount of hydrocarbon-containing substance is present, the agglomerations may be relatively larger in diameter, ranging from about 1 mm to about 10 cm or larger. In other embodiments, the hydrocarbon-containing substance does not agglomerate, but forms a layer on the top of the present aqueous compositions or extractants.

[00153] In still other embodiments, the hydrocarbon-containing substance can form “stringers,” e.g., thread-like or filamentous masses of the hydrocarbon substance that can be extracted or removed from a substrate. For example, such stringers can have a width or diameter of from about 0.1 mm to about 1 cm or larger. The size of the present stringers can depend on the amount of hydrocarbon-containing substance present. Thus, where a large amount of hydrocarbon-containing substance is present, the stringers may be relatively larger in width or diameter, ranging from about 1 mm to about 10 cm or larger. Similarly, the stringers may have a length ranging from, e.g., about 5 mm to about 5 cm when employed in bench-scale experiments. As described with respect to width or diameter of the present stringers, that the length of the present stringers can depend on the amount of hydrocarbon-containing substance present.

[00154] In certain embodiments, the present methods further comprise subjecting the aqueous composition, extractant or substrate to agitation. Thus, a substrate can be contacted with the aqueous composition or extractant, and subjected to mixing, stirring, fluid circulation, or any technique known in the art for agitating a mixture.

[00155] In some embodiments, the present methods can further comprise aerating the present aqueous compositions or extractants when admixed or combined with a substrate comprising a hydrocarbon-containing material. Aeration can be effected by introducing a gas into a mixture comprising the present aqueous compositions or extractants and a substrate containing a hydrocarbon-containing substance. In some embodiments the gas is air. In other embodiments, the gas is an inert gas such as carbon dioxide, nitrogen or argon. Aeration can be conducted before stirring or agitation of the mixture, concurrent with stirring or agitation, after stirring or agitation, or any combination of before, during and after stirring or agitation. Such aeration of the present aqueous compositions or extractants can be effected by employing a suitable device for introducing a gas into a fluid, e.g., a fritted glass bubble, a gas manifold, solid or pliable tubes, etc. Gas may be introduced into the mixture at a rate ranging from 0.01 L/min

to about 10 L/min per liter of aqueous composition or extractant (e.g., from about 0.01 L/min to about 0.1 L/min, from about 0.1 L/min to about 0.2 L/min, from about 0.2 L/min to about 0.3 L/min, from about 0.3 L/min to about 0.4 L/min, from about 0.4 L/min to about 0.5 L/min, from about 0.5 L/min to about 0.6 L/min, from about 0.6 L/min to about 0.7 L/min, from about 0.7 L/min to about 0.8 L/min, from about 0.8 L/min to about 0.9 L/min, from about 0.9 L/min to about 1 L/min, from about 1 L/min to about 2 L/min, from about 2 L/min to about 3 L/min, from about 3 L/min to about 4 L/min, from about 4 L/min to about 5 L/min, from about 5 L/min to about 6 L/min, from about 6 L/min to about 7 L/min, from about 7 L/min to about 8 L/min, from about 8 L/min to about 9 L/min, from about 9 L/min to about 10 L/min, or any other value or range of values therein). The amount of gas introduced per liter of aqueous composition or extractant can depend on the total amount of solution present and the size of the container in which the aqueous composition or extractant is combined with the substrate containing the hydrocarbon-containing substance to be extracted. Extracted hydrocarbon-containing material in the produced froth may be separated from the froth by skimming or centrifugation. In such processes, hydrocarbon-containing material may be recovered from an extractant or aqueous composition after an extraction and frothing process, and then the extractant or aqueous composition can be recycled for reuse in an extraction process.

[00156] Aeration of the present aqueous compositions or extractants can create foam from the aqueous compositions or extractants. Such foams can have sufficient mechanical strength and/or stability to entrain or carry hydrocarbon-containing material which has been removed or extracted from a substrate. Thus, aeration may provide a foam which entrains and transports an extracted hydrocarbon-containing substance out of the vessel in which such a substrate was combined with the present aqueous compositions or extractants.

[00157] In some embodiments, the present methods for extracting a hydrocarbon-containing substance from a substrate comprise hydraulically fracturing the substrate with a fracturing fluid that comprises a present aqueous composition or extractant. The method can comprise injecting a fracturing fluid comprising a present composition or extractant into a substrate (e.g., a rock formation) at a pressure effective to fracture the substrate. Surface pumping pressures can range from about 500 psi (pounds-per-square-inch, lb/in²) to about 15,000 psi (e.g., about 500 psi, about 1,000 psi, about 1,500 psi, about 2,000 psi, about 2,500 psi,

about 3,000 psi, about 3,500 psi, about 4,000 psi, about 4,500 psi, about 5,000 psi, about 5,500 psi, about 6,000 psi, about 6,500 psi, about 7,000 psi, about 7,500 psi, about 8,000 psi, about 8,500 psi, about 9,000 psi, about 9,500 psi, about 10,000 psi, about 10,500 psi, about 11,000 psi, about 11,500 psi, about 12,000 psi, about 12,500 psi, about 13,000 psi, about 13,500 psi, about 14,000 psi, about 14,500 psi, about 15,000 psi). The surface pumping pressure can vary depending on fluid injection rates, well depth and orientation (e.g., vertical, horizontal, inclined, etc.), formation type (e.g., sandstone, limestone, etc.), perforation size and number of perforations in the production casing across the production zone being fractured, etc. Furthermore, fluid pumping pressures typically vary over the course of the fracturing operation, and can increase, decrease, or both during the course of a fracturing operation.

[00158] The fracturing fluid can further comprise one or more additives such as a proppant, viscosity modifier, radioactive tracer, gel, alcohol, detergent, acid, fluid-loss additive, gas (e.g., nitrogen or carbon dioxide) dispersant or flocculant. The fracturing fluid can then be recovered or produced from the substrate (e.g., via a wellbore), extracting the hydrocarbon-containing substance from the substrate as the fracturing fluid is recovered or produced. The resultant mixture of the fracturing fluid and extracted hydrocarbon-containing substance can be further processed to separate the hydrocarbon-containing substance from the fracturing fluid.

[00159] Accordingly, in certain embodiments, the present invention provides a hydraulic fracturing fluid comprising an aqueous composition of the present invention. In certain embodiments, the hydraulic fracturing fluid further comprises an additive. In some embodiments, the additive is one or more of a proppant, a viscosity modifier, a radioactive tracer, a gel, an alcohol, a detergent, an acid, a fluid loss additive, a gas, a dispersant or a flocculant. In other embodiments, the present invention provides a hydraulic fracturing fluid comprising an extractant of the present invention. In certain embodiments, the hydraulic fracturing fluid further comprises an additive. In certain embodiments, the additive is one or more of a proppant, a viscosity modifier, a radioactive tracer, a gel, an alcohol, a detergent, an acid, a fluid loss additive, a gas, a dispersant or a flocculant. In certain embodiments, the invention further provides a method for extracting a hydrocarbon-containing substance from a substrate, comprising hydraulically fracturing the substrate with a hydraulic fracturing fluid comprising an aqueous composition of the present invention. In other embodiments, the present

invention provides a method for extracting a hydrocarbon-containing substance from a substrate, comprising hydraulically fracturing the substrate with a hydraulic fracturing fluid comprising an extractant of the present invention.

[00160] The extraction efficiency, i.e., amount of hydrocarbon-containing substance that can be extracted from a substrate, ranges from about 5 wt% of the substrate's hydrocarbon-containing substance to 100 wt% of the substrate's hydrocarbon-containing substance; in one embodiment from about 10 wt% of the substrate's hydrocarbon-containing substance to about 90 wt% of the substrate's hydrocarbon-containing substance; in other embodiments, at least about 5 wt%, at least about 10 wt%, at least about 15 wt%, at least about 20 wt%, at least about 25 wt%, at least about 30 wt%, at least about 35 wt%, at least about 40 wt%, at least about 45 wt%, at least about 50 wt%, at least about 55 wt%, at least about 60 wt%, at least about 65 wt%, at least about 70 wt%, at least about 75 wt%, at least about 80 wt%, at least about 85 wt%, at least about 90 wt%, at least about 95 wt%, at least about 96 wt%, at least about 97 wt%, at least about 98 wt%, at least about 99 wt%, about 99.5 wt%, or greater than about 99.5 wt%, (or any other value or range of values therein or thereabove) of the total amount of hydrocarbon-containing substance present in or on the substrate.

[00161] In some embodiments, the present methods may be performed at ambient pressure. In other embodiments, the present methods may be conducted at a reduced pressure from about 100 mm Hg to about 760 mm Hg (e.g., from about 100 mm Hg to about 200 mm Hg, from about 200 mm Hg to about 300 mm Hg, from about 300 mm Hg to about 400 mm Hg, from about 400 mm Hg to about 500 mm Hg, from about 500 mm Hg to about 600 mm Hg, from about 600 mm Hg to about 700 mm Hg, from about 700 mm Hg to about 760 mm Hg, or any other value or range of values therein). In other embodiments, the present methods may be performed at an elevated pressure from about 760 mm Hg to about 7600 mm Hg (e.g., from about 760 mm Hg to about 1520 mm Hg, from about 1520 mm Hg to about 2280 mm Hg, from about 2280 mm Hg to about 3040 mm Hg, from about 3040 mm Hg to about 3800 mm Hg, from about 3800 mm Hg to about 4560 mm Hg, from about 4560 mm Hg to about 5320 mm Hg, from about 5320 mm Hg to about 6080 mm Hg, from about 6080 mm Hg to about 6840 mm Hg, from about 6840 mm Hg to about 7600 mm Hg, or any other value or range of values therein).

[00162] The present invention further provides methods for remediating a substrate, comprising contacting the substrate with an aqueous composition or extractant of the invention under conditions effective for remediating the substrate. As used herein, the term “remediating” includes extracting at least some hydrocarbon-containing substance from a substrate. Such hydrocarbon-containing substances and substrates are those described above. Remediating can include purifying water such that it becomes potable, suitable for swimming or non-toxic to aquatic species; converting contaminated soil to that which is useful as farmland or for real estate; converting oil sand to sand that is suitable for commercial or recreational use, etc. Thus, remediating a substrate can substantially improve the quality of a substrate, for example, rendering it non-toxic. In some embodiments, remediating the substrate includes removing a hydrocarbon-containing substance from the surface of a substrate, or extracting the hydrocarbon-containing substance from pores, fractures, cracks, fissures or crevices in a substrate. The present methods are useful for remediating environmentally contaminated sites, soils or animals.

[00163] Accordingly, in certain embodiments, the present invention provides methods for remediating a substrate, comprising contacting the substrate with an aqueous composition of the present invention under conditions effective for remediating the substrate. In some embodiments, the substrate is soil, sand, wood, paper, skin, a waterbody, gravel, mud, clay, plant, hair, fabric, glass, porcelain, concrete, metal or an animal. In certain embodiments, the substrate is a waterbody. In other embodiments, the substrate is soil. In some embodiments, the substrate is an animal. In some embodiments, the animal is a living animal. In other embodiments, the animal is a dead animal. In certain embodiments, remediating comprises extracting a hydrocarbon-containing substance from the substrate. In other embodiments, the contacting occurs at an aqueous composition or a substrate temperature of about 5°C to about 90°C (e.g., about 5 °C, about 10 °C, about 15 °C, about 20 °C, about 25 °C, about 30 °C, about 35 °C, about 40 °C, about 45 °C, about 50 °C, about 55 °C, about 60 °C, about 65 °C, about 70 °C, about 75 °C, about 80 °C, about 85 °C, about 90 °C, or any other value or range of values therein). In one embodiment, the contacting occurs at an aqueous composition or a substrate temperature of about 4°C to about 38°C. In some embodiments, the method further comprises subjecting the aqueous composition or substrate to agitation. In some embodiments, the agitation is mixing. In some embodiments, the hydrocarbon-containing substance is grease, oil, coal tar,

bitumen, coal tar sand, sludge, oil-contaminated sludge, light tar oil or creosote. In certain embodiments, the oil is automotive oil. In other embodiments, the automotive oil is synthetic automotive oil. In some embodiments, the oil is crude oil. In some embodiments, the hydrocarbon-containing substance comprises one or more petroleum distillates. In other embodiments, the hydrocarbon-containing substance is diesel fuel. In other embodiments, the hydrocarbon-containing substance is heating oil. In other embodiments, the hydrocarbon-containing substance is jet fuel. In other embodiments, the hydrocarbon-containing substance is aviation gasoline. In other embodiments, the hydrocarbon-containing substance is kerosene.

[00164] In another aspect, the present invention provides a method for remediating a substrate, comprising contacting the substrate with an extractant of the present invention under conditions effective for remediating the substrate. In certain embodiments, the substrate is soil, sand, wood, paper, skin, a waterbody, gravel, mud, clay, plant, hair, fabric, metal or an animal. In other embodiments, the substrate is a waterbody. In some embodiments, the substrate is soil. In other embodiments, the substrate is an animal. In some embodiments, the animal is a living animal. In other embodiments, the animal is a dead animal. In some embodiments, remediating comprises extracting a hydrocarbon-containing substance from the substrate. In certain embodiments, contacting occurs at an extractant or substrate temperature of about 5° to about 90°C (e.g., about 5 °C, about 10 °C, about 15 °C, about 20 °C, about 25 °C, about 30 °C, about 35 °C, about 40 °C, about 45 °C, about 50 °C, about 55 °C, about 60 °C, about 65 °C, about 70 °C, about 75 °C, about 80 °C, about 85 °C, about 90 °C, or any other value or range of values therein). In one embodiment, the contacting occurs at an aqueous composition or a substrate temperature of about 4°C to about 38°C. In other embodiments, the method further comprises subjecting the extractant or substrate to agitation. In some embodiments, the agitation is mixing. In certain embodiments, agitation comprises sonication. In other embodiments, agitation is effected by microwave. In other embodiments, the hydrocarbon-containing substance is grease, oil, coal tar, bitumen, coal tar sand, sludge, oil-contaminated sludge, light tar oil or creosote. In some embodiments, the oil is automotive oil. In other embodiments, the automotive oil is synthetic automotive oil. In certain embodiments, the oil is crude oil. In some embodiments, the hydrocarbon-containing substance comprises one or more petroleum distillates. In other embodiments, the hydrocarbon-containing substance is diesel fuel. In other embodiments, the

hydrocarbon-containing substance is heating oil. In other embodiments, the hydrocarbon-containing substance is jet fuel. In other embodiments, the hydrocarbon-containing substance is aviation gasoline. In other embodiments, the hydrocarbon-containing substance is kerosene.

[00165] In another aspect, the present methods result in the sequestration of hydrocarbon-containing substance present in or on the substrate. Such methods can comprise introducing a present aqueous composition or extractant into the soil, e.g., the soil's subsurface, via, e.g., groundwater monitoring or one or more remediation wells. Without being bound by any particular theory of the mechanism of such sequestration, introducing a present aqueous composition or extractant into the soil can effectively encapsulate or agglomerate hydrocarbon-containing substance therein, rendering it relatively immobile. Accordingly, such methods can also render the hydrocarbon-containing substance effectively inert via sequestration.

[00166] The present methods can be performed by allowing the substrates and present aqueous compositions or extractants to contact within a container, such as a tank, vessel, pool or pit. The contacting can be performed at atmospheric pressure or above in a batch, semi-batch or continuous mode, for example, where hydrocarbon-containing substance is continuously removed from the substrate. In some embodiments, the present aqueous compositions or extractants are reused after removing hydrocarbon-containing substance from a substrate or after remediating a substrate. In other embodiments, "fresh," previously unused aqueous composition or extractant is continuously contacted with the substrate.

[00167] Contacting is conducted under conditions that are effective for extracting at least some hydrocarbon-containing substance from the substrate or for remediating the substrate. Thus, in certain embodiments, the contacting time is about 10 minutes, about 20 minutes, about 30 minutes, about 40 minutes, about 50 minutes, about 60 minutes, about 2 hours, about 3 hours, about 4 hours, about 5 hours, about 6 hours, about 12 hours, about 18 hours, about 24 hours, about two or three days, about a week, about a month or about several months (or any other value or range of values therein or thereabove). In addition, contacting can be conducted at a temperature of from about 5 °C to about 90 °C (e.g., about 5 °C, about 10 °C, about 15 °C, about 20 °C, about 25 °C, about 30 °C, about 35 °C, about 40 °C, about 45 °C, about 50 °C, about 55 °C, about 60 °C, about 65 °C, about 70 °C, about 75 °C, about 80 °C, about 85 °C, about 90 °C,

or any other value or range of values therein). In one embodiment, the contacting occurs at an aqueous composition or a substrate temperature of about 4°C to about 38°C. In one embodiment, the contacting is conducted at a temperature of from about 5 °C to about 50 °C; in other embodiments from about 20 °C to about 30 °C. In other embodiments the contacting occurs at about 20 °C, at about 30 °C, at about 40 °C, at about 50 °C, at about 60 °C, at about 70 °C, at about 80 °C, at about 90 °C, or any other value or range of values therein or thereabove).

[00168] In certain embodiments, it can be advantageous to adjust the pH of the substrate or the aqueous compositions or extractants, for example, to effect a desired separation or to promote formation of aggregates of hydrocarbon-containing substance. Thus, in certain embodiments, the pH of the substrate or the present aqueous compositions or extractants can be adjusted to about 13, about 12, about 11, about 10, about 9, about 8, about 7, about 6, about 5, about 4, about 3 (or any other value or range of values therein or therebelow). Such pH adjustment can be performed by adding an acid or base as previously described herein. The acid or base can be added continuously, or in aliquots. The acid or base can be added undiluted or as a mixture in water or organic solvent.

[00169] Industrial extraction of oil from the Athabasca oil sands produces wastewater comprising fines, or small particulates, in the oil extraction process. These fines can remain suspended in waste water and prevent recycling of water in an extraction process, or alternatively, prevent discharge of fines-laden wastewater into the environment. Accordingly, a method to promote rapid settling of fines, thereby allowing discharge of the wastewater from an extraction process, is desirable. Thus, in one embodiment, the present invention provides a method for precipitating fines contained in a vessel further containing a hydrocarbon-containing material and a aqueous composition or an extractant as described herein, comprising acidifying the contents of said vessel to a pH of about 4.6 or less.

[00170] Any Composition of the Invention as described herein may be employed in an extraction process which produces fines-laden water. The resultant fines-laden water, which can further comprise hydrocarbon-containing material, can then be acidified to reduce the pH of the fines-laden water to less than about 4.6, and precipitate the fines suspended therein. Acids which may be suitable for reducing the pH of the fines-laden water may include organic or inorganic

acids. For example, the inorganic acids may include hydrofluoric acid, hydrochloric acid, hydrobromic acid, hydroiodic acid, sulfurous acid, sulfuric acid, phosphoric acid, nitric acid and carbonic acid. Organic acids can alternatively be employed. Suitable organic acids include C₁ to C₂₀ organic acids such as formic acid, citric acid, malic acid, adipic acid, tannic acid, lactic acid, ascorbic acid, acetic acid, fumaric acid, and mixtures thereof.

[00171] The acid can be added in concentrated form, or as an aqueous solution. The acid is generally added to the solution in which the fines are present, and can be added with concomitant agitation. Alternatively, the solution may be agitated after addition of the acid. Such agitation may include mechanical agitation, or hydraulic mixing provided by pumping and circulation of the fines-laden fluid in the vessel in which it is contained.

[00172] The vessel may be a metal or polymer tank, or may be an earthen pit or excavated reservoir, which may be lined to prevent fluid communication of the wastewater with groundwater and/or subterranean water-nearing formations. After addition of the acid, and mixing to disperse the acid in solution, the solution is typically allowed to stand for a period of time to allow the fines to settle, and for any hydrocarbon-containing material released from the fines or present in the solution to float to the surface. Settling times may range from about 1 minute to about 1 week (e.g., from about 1 minute to about 2 minutes, from about 2 minutes to about 5 minutes, from about 5 minutes to about 10 minutes, from about 10 minutes to about 20 minutes, from about 20 minutes to about 30 minutes, from about 30 minutes to about 40 minutes, from about 40 minutes to about 50 minutes, from about 50 minutes to about 1 hour, from about 1 hour to about 2 hours, from about 2 hours to about 3 hours, from about 3 hours to about 4 hours, from about 4 hours to about 5 hours, from about 5 hours to about 6 hours, from about 6 hours to about 7 hours, from about 7 hours to about 8 hours, from about 8 hours to about 9 hours, from about 9 hours to about 10 hours, from about 10 hours to about 11 hours, from about 12 hours to about 12 hours, from about 12 hours to about 1 day, from about 1 day to about 2 days, from about 2 days to about 3 days, from about 3 days to about 4 days, from about 4 days to about 5 days, from about 5 days to about 6 days, from about 6 days to about 1 week, or any other value or range of values therein). Residual hydrocarbon-containing material released during or after acidification and/or settling can be recovered by, e.g., skimming. In other embodiments, remaining hydrocarbon-containing material may be separated by centrifugation. In such

processes, hydrocarbon-containing material may be recovered from an extractant or aqueous composition after an extraction process; fines can be removed by lowering the pH; and then remaining hydrocarbon-containing material can be removed by centrifugation. The remaining extractant or aqueous composition can then be recycled for reuse in an extraction process.

[00173] In other embodiments, the aqueous compositions or extractants further comprise a substrate, which can be present in the aqueous composition or extractant in a weight ratio of substrate:aqueous composition or extractant from about 0.01:1 to about 1:1, in one embodiment, from about 0.1:1 to about 1:1. However, the substrate:aqueous composition or extractant ratio is not limited, and can be selected according to a particular application and to minimize the amount of the aqueous composition or extractant employed.

[00174] Thus, in certain embodiments, the present invention provides a method for extracting a hydrocarbon-containing substance from a substrate, comprising contacting the substrate with an aqueous composition of the present invention under conditions effective for extracting at least some of the hydrocarbon-containing substance from the substrate. In other embodiments, the substrate is soil, sand, wood, rock, paper, skin, a waterbody, gravel, mud, clay, plant, hair, fabric, metal, glass, porcelain, concrete or an animal. In some embodiments, the substrate is a waterbody. In other embodiments, the substrate is soil. In other embodiments, the substrate is an animal. In some embodiments, the animal is a living animal. In one embodiment, the animal is a dead animal. In other embodiments, the extracting comprises removing the hydrocarbon-containing substance from the surface of the substrate. In some embodiments, the contacting occurs at an aqueous composition or a substrate temperature of about 5° to about 50°C. In other embodiments, the method further comprises subjecting the aqueous composition or the substrate to agitation. In one embodiment, the agitation is mixing. In certain embodiments, agitation comprises sonication. In other embodiments, agitation is effected by microwave. In some embodiments, the hydrocarbon-containing substance is grease, oil, coal tar, bitumen, coal tar sand, sludge, oil-contaminated sludge, light tar oil or creosote. In other embodiments, the oil is automotive oil. In other embodiments, automotive oil is synthetic automotive oil. In certain embodiments, the oil is crude oil. In some embodiments, the hydrocarbon-containing substance comprises one or more petroleum distillates. In other embodiments, the hydrocarbon-containing substance is diesel fuel. In other embodiments, the

hydrocarbon-containing substance is heating oil. In other embodiments, the hydrocarbon-containing substance is jet fuel. In other embodiments, the hydrocarbon-containing substance is aviation gasoline. In other embodiments, the hydrocarbon-containing substance is kerosene.

[00175] In another aspect, the present invention provides a method for extracting a hydrocarbon-containing substance from a substrate, comprising contacting the substrate with an extractant of the present invention under conditions effective for extracting at least some of the hydrocarbon-containing substance from the substrate. In certain embodiments, the substrate is soil, sand, wood, rock, paper, skin, a waterbody, gravel, mud, clay, plant, hair, fabric, metal or an animal. In other embodiments, the substrate is a waterbody. In some embodiments, the substrate is soil. In other embodiments, the substrate is an animal. In some embodiments, the animal is a living animal. In one embodiment, the animal is a dead animal. In certain embodiments, extracting comprises removing the hydrocarbon-containing substance from the surface of the substrate. In some embodiments, contacting occurs at an extractant or a substrate temperature of about 5° to about 90°C. In some embodiments, the method further comprises subjecting the extractant or the substrate to agitation. In certain embodiments, the agitation is mixing. In some embodiments, the hydrocarbon-containing substance is grease, oil, coal tar, bitumen, coal tar sand, sludge, oil-contaminated sludge, light tar oil or creosote. In other embodiments, the oil is automotive oil. In some embodiments, the automotive oil is synthetic automotive oil. In some embodiments, the oil is crude oil.

[00176] In another aspect the present invention provides a method for extracting a hydrocarbon-containing substance from a substrate, comprising contacting the substrate with an aqueous composition of the present invention under conditions effective for extracting at least some of the hydrocarbon-containing substance from the substrate. In some embodiments, extracting comprises removing a hydrocarbon-containing substance from the surface of the substrate. In other embodiments, the present methods for extracting hydrocarbon-containing substance from a substrate, comprising contacting the substrate with an extractant of the present invention under conditions effective for extracting at least some of the hydrocarbon-containing substance from the substrate. In certain embodiments, extracting comprises removing a

hydrocarbon-containing substance from the surface of the substrate. In another embodiment, the present methods for remediating a substrate comprise contacting a substrate with an aqueous composition of the present invention under conditions effective for remediating the substrate. In some embodiments, remediating the substrate comprises sequestering one or more contaminants in the substrate. In other embodiments, the present methods for remediating a substrate comprise contacting the substrate with an extractant of the present invention under conditions effective for remediating the substrate. In some embodiments, remediating the substrate comprises sequestering one or more contaminants in the substrate.

[00177] The following non-limiting examples illustrate various aspects of the present invention.

EXAMPLES

Example 1

[00178] An illustrative aqueous composition of the invention comprising plant material, but not comprising polysaccharide other than that present in or derived from the plant material, was prepared as follows. Citric acid (4.91 grams) was dissolved in 0.714 kg of 70% isopropanol at about 23 °C. Corn gluten meal (2.28 kg) was added, and the resultant mixture was allowed to stir for 2 hours. 2.844 kg of a 50% aqueous sodium hydroxide solution was added to 13.6 kg of water, the resultant diluted sodium hydroxide solution was added to the isopropanol/corn gluten meal mixture, and the resultant mixture was allowed to stand for 6 hours. Sodium chloride (9.1 g) was then added, also with stirring. The resultant mixture was then allowed to stand an additional 2 hours. S-type hydrated lime (90.8 g) was then added with stirring, and the resultant mixture was stirred until uniform. The solids were allowed to settle, and the supernatant was decanted to provide the illustrative aqueous composition as the decanted supernatant.

Example 2

[00179] An illustrative aqueous composition of the invention comprising plant material and polysaccharide was prepared as follows. Citric acid (4.91 grams) was dissolved in 0.714 kg of 70% isopropanol at about 23 °C. Corn gluten meal (2.28 kg) was added, and the resultant

mixture was allowed to stir for 2 hours. 2.844 kg of a 50% aqueous sodium hydroxide solution was added to 13.6 kg of water, the resultant diluted sodium hydroxide solution was added to the isopropanol/corn gluten meal mixture, and the resultant mixture was allowed to stand for 6 hours. Guar gum (113.5 g) wetted with 70% isopropanol was then added to the isopropanol/corn gluten meal mixture with stirring. Sodium chloride (9.1 g) was then added, also with stirring. The resultant mixture was then allowed to stand an additional 2 hours. S-type hydrated lime (90.8 g) was then added with stirring, and the resultant mixture was stirred until uniform. The solids were allowed to settle, and the supernatant was decanted to provide the illustrative aqueous composition as the decanted supernatant.

Example 3

[00180] In a glass vessel, the aqueous composition of Example 1 (2.5 g) was combined with water (47.5 g) to provide an extractant. To the extractant was added 5 g of Athabasca oil sand. The pH of the resultant mixture was 13.2. The mixture was then stirred using a magnetic stir bar for 135 minutes at about 23 °C. After 15 minutes of stirring, some extraction of oil from the oil sand was observed. Complete extraction of the oil, as determined by the observation of clean sand in the bottom of the vessel after a brief settling period, was not observed. **FIGS. 1A-B** are photographs showing a side view of the mixture in the vessel after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 1A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 1B**), also after 60 min of stirring. This example demonstrates that an illustrative Composition of the Invention is useful for extracting at least some hydrocarbon-containing oil from a substrate.

Example 4

[00181] In a glass vessel, the aqueous composition of Example 1 (2.5 g) was combined with water (47.5 g) to provide an extractant. To the extractant was added 5 g of Athabasca oil sand. The pH of the mixture was then adjusted to about 11.1 with 1M citric acid. The mixture was then stirred using a magnetic stir bar for 135 minutes at about 23 °C. After 15 minutes of stirring, some extraction of oil from the oil sand was observed. Complete extraction of the oil, as determined by the observation of clean sand in the bottom of the vessel after a brief settling period, was observed after 60 min of stirring. **FIGS. 2A-B** are photographs showing a side view

of the mixture in the vessel after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 2A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 2B**), also after 60 min of stirring. This example demonstrates that an illustrative Composition of the Invention is useful for extracting hydrocarbon-containing oil from a substrate.

Example 5

[00182] In a glass vessel, the aqueous composition of Example 1 (2.5 g) was combined with water (47.5 g) to provide an extractant. To the extractant was added 5 g of Athabasca oil sand. The pH of the mixture was then adjusted to about 9.1 with 1M citric acid. The mixture was then stirred using a magnetic stir bar for 135 minutes at about 23 °C. After 15 minutes of stirring, some extraction of oil from the oil sand was observed. Complete extraction of the oil, as determined by the observation of clean sand in the bottom of the vessel after a brief settling period, was observed after 60 min of stirring. **FIGS. 3A-B** are photographs showing a side view of the mixture in the vessel after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 3A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 3B**), also after 60 min of stirring. This example demonstrates that an illustrative Composition of the Invention is useful for extracting hydrocarbon-containing oil from a substrate.

Example 6

[00183] In a glass vessel, the aqueous composition of Example 1 (2.5 g) was combined with water (47.5 g) to provide an extractant. To the extractant was added 5 g of Athabasca oil sand. The pH of the mixture was then adjusted to about 6.9 with 1M citric acid. The mixture was then stirred using a magnetic stir bar for 135 minutes at about 23 °C. After 15 minutes of stirring, some extraction of oil from the oil sand was observed. Complete extraction of the oil, as determined by the observation of clean sand in the bottom of the vessel after a brief settling period, was observed after 60 min of stirring. **FIGS. 4A-B** are photographs showing a side view of the mixture in the vessel after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 4A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 4B**), also after 60 min of stirring. This example demonstrates that an illustrative Composition of the Invention is useful for extracting hydrocarbon-containing oil from a substrate.

Example 7

[00184] In a glass vessel, the aqueous composition of Example 2 (2.5 g) was combined with water (47.5 g) to provide an extractant. To the extractant was added 5 g of Athabasca oil sand. The pH of the resultant mixture was 13.2. The mixture was then stirred using a magnetic stir bar for 135 minutes at about 23 °C. After 15 minutes of stirring, some extraction of oil from the oil sand was observed. Complete extraction of the oil, as determined by the observation of clean sand in the bottom of the vessel after a brief settling period, was not observed. **FIGS. 5A-B** are photographs showing a side view of the mixture in the vessel after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 5A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 5B**), also after 60 min of stirring. This example demonstrates that an illustrative Composition of the Invention is useful for extracting at least some hydrocarbon-containing oil from a substrate.

Example 8

[00185] In a glass vessel, the aqueous composition of Example 2 (2.5 g) was combined with water (47.5 g) to provide an extractant. To the extractant was added 5 g of Athabasca oil sand. The pH of the mixture was then adjusted to about 11.1 with 1M citric acid. The mixture was then stirred using a magnetic stir bar for 135 minutes at about 23 °C. After 15 minutes of stirring, some extraction of oil from the oil sand was observed. Complete extraction of the oil, as determined by the observation of clean sand in the bottom of the vessel after a brief settling period, was observed after 60 min of stirring. **FIGS. 6A-B** are photographs showing a side view of the mixture in the vessel after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 6A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 6B**), also after 60 min of stirring. This example demonstrates that an illustrative Composition of the Invention is useful for extracting hydrocarbon-containing oil from a substrate.

Example 9

[00186] In a glass vessel, the aqueous composition of Example 2 (2.5 g) was combined with water (47.5 g) to provide an extractant. To the extractant was added 5 g of Athabasca oil sand. The pH of the mixture was then adjusted to about 9.1 with 1M citric acid. The mixture

was then stirred using a magnetic stir bar for 135 minutes at about 23 °C. After 15 minutes of stirring, some extraction of oil from the oil sand was observed. Complete extraction of the oil, as determined by the observation of clean sand in the bottom of the vessel after a brief settling period, was observed after 60 min of stirring. **FIGS. 7A-B** are photographs showing a side view of the mixture in the vessel after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 7A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 7B**), also after 60 min of stirring. This example demonstrates that an illustrative Composition of the Invention is useful for extracting hydrocarbon-containing oil from a substrate.

Example 10

[00187] In a glass vessel, the aqueous composition of Example 2 (2.5 g) was combined with water (47.5 g) to provide an extractant. To the extractant was added 5 g of Athabasca oil sand. The pH of the mixture was then adjusted to about 7 with 1M citric acid. The mixture was then stirred using a magnetic stir bar for 135 minutes at about 23 °C. After 15 minutes of stirring, some extraction of oil from the oil sand was observed. Complete extraction of the oil, as determined by the observation of clean sand in the bottom of the vessel after a brief settling period, was observed after 60 min of stirring. **FIGS. 8A-B** are photographs showing a side view of the mixture in the vessel after 60 min of stirring then briefly allowing the mixture to settle (**FIG. 8A**), and a top view of the inside of the vessel after decanting the supernatant (**FIG. 8B**), also after 60 min of stirring. This example demonstrates that an illustrative Composition of the Invention is useful for extracting hydrocarbon-containing oil from a substrate.

[00188] Polycyclic aromatic hydrocarbons (PAHs) and their alkylated analogs are ubiquitous environmental pollutants. They are in fossil fuels, and their by-products can enter the environment from natural seeps or runoff from asphalt. Incomplete combustion of organic materials can result in transporting these compounds over long distances as gaseous molecules or organically-bound particulate matter. In addition, there are tens of thousands of coal-tar contaminated gas plants worldwide that are and will continue to contribute to PAH pollution.

[00189] Some PAHs are toxic, mutagenic, and carcinogenic, and therefore pose risk to human health and the environment. Alkylated PAHs have been shown to contribute substantially to the toxicity of PAH mixtures, in some cases accounting for 80% of the toxic burden. Similarly, PASH bioaccumulates and can be toxic, mutagenic, and carcinogenic.

[00190] The US EPA provides guidelines for estimating the hazards posed by contaminated soils and sediments based on the concentration of 18 parent PAH and 16 C1 to C4 alkylated homologs. Thus, the removal and/or recovery of PAH is of importance in the remediation of environmentally compromised sites and/or in the extraction of oil. The following Examples 11 and 12 demonstrate that illustrative Compositions of the Invention are effective for removing or extracting PAH from coal tar or from Athabasca oil sand.

Example 11

[00191] In a glass vessel, the aqueous composition of Example 1 (2.5 g) was combined with water (47.5 g) to provide an extractant. Athabasca oil sand (5g) was added to the vessel. The resultant mixture was stirred using a magnetic stir bar for 4 hr at about 23 °C, and an oil ball was formed. The PAH content of the oil sand was measured by GC-MS before and after extraction, to determine the extractant's extraction efficiency. PAHs whose concentration was detected include naphthalene, fluorene, phenanthrene, pyrene, chrysene, and C₁-C₄ homologs thereof. A C₁ homolog of a PAH is a PAH having a methyl group. A C₂ homolog of a PAH is a PAH having, for example, an ethyl group or two methyl groups. A C₃ homolog of a PAH is a PAH having, for example, a methyl and an ethyl group, three methyl groups, an n-propyl group or an i-propyl group. A C₄ homolog of a PAH is a PAH having, for example, two ethyl groups, four methyl groups, an ethyl group and two methyl groups, a methyl group and an n-propyl group, a methyl group and an i-propyl group, an n-butyl group, a sec-butyl group, and i-butyl group or a t-butyl group. The results of these analyses are shown in Table 1 below:

Table 1 - PAH Concentrations in Oil Sand Before and After Extraction (µg PAH/g Sand)

PAH	Before Extraction (µg/g)	After Extraction (µg/g)
Naphthalene	not detected	not detected
C ₁ homolog	not detected	not detected
C ₂ homolog	not detected	not detected
C ₃ homolog	not detected	not detected
C ₄ homolog	not detected	not detected
Fluorene	not detected	not detected
C ₁ homolog	3.3	not detected
C ₂ homolog	not detected	not detected
C ₃ homolog	not detected	not detected
C ₄ homolog	not detected	not detected
Phenanthrene	3.6	not detected
C ₁ homolog	24.1	0.4
C ₂ homolog	38.9	0.6
C ₃ homolog	47.2	0.7
C ₄ homolog	7.7	not detected
Pyrene	5.6	not detected
C ₁ homolog	2.1	not detected
C ₂ homolog	not detected	not detected

C ₃ homolog	not detected	not detected
C ₄ homolog	not detected	not detected
Chrysene	2.7	not detected
C ₁ homolog	9.0	not detected
C ₂ homolog	9.2	not detected
C ₃ homolog	not detected	not detected
C ₄ homolog	not detected	not detected

[00192] This example demonstrates that an illustrative Composition of the Invention is useful for extracting PAH-containing oil from a substrate.

[00193] Based on the low PAH content of the Athabasca oil sand, as shown in Example 11 above, relative to coal tar, as shown in Example 12, below, it was important to confirm for a larger group of PAH if the percent reduction in PAH content is characteristic of the present extraction methods employing Compositins of the Invention. Thus, a coal tar sand was extracted as described in Example 12, below.

Example 12

[00194] In a glass vessel, the aqueous composition of Example 1 (2.5 g) was combined with water (47.5 g) to provide an extractant. Coal tar sand from a North Carolina gasification plant site (5g, 15 wt% coal tar) was added to the extractant. The resultant mixture was stirred using a magnetic stir bar for 90 minutes at about 23 °C. Extraction of the coal tar from the sand was observed after 10 minutes, and a ball of coal tar was observed at 90 minutes. The polycyclic aromatic hydrocarbon (PAH) content of the coal tar sand was measured by GC-MS before and after above-described extraction to determine the extractant's extraction efficiency. The results of these analyses are shown in Table 2 below:

Table 2 - PAH Concentrations in Coal Tar Sand Before and After Extraction (mg PAH/kg Sand)

PAH	Before Extraction	After Extraction	% Extraction
Acenaphthene	1.3	0.0	100

Acenaphthylene	392.4	7.4	98.1
Anthracene	418.8	8.5	98.0
benz[a]anthracene	299.9	6.7	97.8
benzo[a]pyrene	216.1	4.8	97.8
Benzo[b]fluoranthene	103.9	2.6	97.5
benzo[ghi]perylene	77.1	1.7	97.9
benzo[k]fluoranthene	126.6	2.6	98.0
Chrysene	299.3	6.8	97.7
dibenz[ah]anthracene	23.2	0.4	98.1
Fluoranthene	712.5	11.7	98.4
Fluorene	419.5	8.3	98.0
Indeno[1,2,3-cd]pyrene	79.9	1.5	98.1
Naphthalene	502.5	8.1	98.4
Phenanthrene	1444.5	31.4	97.8
Pyrene	853.2	15.1	98.2

[00195] This example demonstrates that an illustrative Composition of the Invention is useful for extracting PAH-containing coal tar from a substrate.

[00196] The percent decrease in PAH content in the tar sand as shown in Example 12, above, was consistent from homolog to homolog. Since the concentration of the various PAHs measured decreases in similar amounts, these data indicate that the extractant removes PAH from the coal tar sand without selectivity.

Example 13

[00197] Athabasca oil sand (5g) was added to a 100 ml glass beaker. An extractant of a mixture of the aqueous composition of Example 1 (2.5 g) in water (47.5 g) was added to the Athabasca oil sand (5g) at about 23 °C. **FIGS. 9** and **10** are photographs showing a top-down (**FIG. 9**) and side (**FIG. 10**) view of the contents in the beaker before stirring (see also white magnetic stir bar in photograph). Evident in **FIGS. 9** and **10** is the lumpiness of the oil sands, and that the sand is completely surrounded by oil. Also shown are air bubbles, produced upon addition of the extractant to the oil sands. In contrast, no bubbles appeared when pouring merely water over the oil sands or when pouring the extractant into an empty beaker. The extractant was yellow in color.

[00198] The mixture of extractant and oil sand was then stirred. **FIG. 11** is a photograph showing the contents of the beaker after stirring for 4 min, then allowing most of the solids to settle. **FIG. 11** shows stringers of oil separating from sand. This result is consistent with conventional, elevated temperature, water-based oil sand extraction processes. **FIG. 11** shows separation occurring at room temperature within the same 5 minute timeframe as in current conventional, elevated temperature, water-based oil sand extraction processes. Evident is the change in color of the solution and the appearance of loosely scattered “free” oil and sand particles from the lumpy oil sands. As particles settle, oil-containing sands sit on top of “cleaner” sand as it is beginning to separate from the lumpier oil sands.

[00199] **FIG. 12** is a photograph showing the contents of the beaker after stirring for 10 minutes. Evident are longer stringers of “free” oil separated from the sands. Conversely, **FIG. 13** is a photograph showing sand “free” of oil that has settled to the bottom of the beaker a few minutes after stirring was stopped. **FIG 14** is a photograph showing the agglomerating oil deposits sitting on top of the sand after decanting the solution into another beaker.

[00200] **FIGS. 15-16** are photographs showing the contents of the beaker after stirring 30 minutes and then decanting the solution into a second beaker. **FIG. 15** is a photograph of “free” oil sticking to the glass of the beaker in which the oil sand and extractant were stirred, after decanting the extractant liquid comprising some extracted oil into a second beaker. **FIG. 16** is a photograph showing the remaining sand and oil in the beaker in which the oil sand and extractant were stirred after decanting the extractant liquid comprising some extracted oil into the second beaker. As shown in **FIG. 16**, the remaining oil in the bottom of the beaker begins to pool as a dense, non-aqueous phase liquid (DNAPL), which, for the most part, has separated from the sand.

[00201] **FIG. 17** is a photograph showing the sand, oil and magnetic stir bar remaining in the beaker after stirring for 1 hour and decanting the resultant supernatant. **FIG. 18** is a photograph showing the oil remaining on the glass of the first beaker after transferring the sand, oil and extractant to a second beaker.

[00202] This example demonstrates that an illustrative Composition of the Invention is useful for extracting oil from Athabasca oil sands.

Example 14

[00203] Athabasca oil sand (5 g comprising 15 ± 6 wt% oil and 83 ± 6 % sand) was combined with 50 mL of toluene and stirred at about 23 °C. This toluene extraction was repeated seven times for each 5 g sample of Athabasca oil sand. The extractions were performed in triplicate (i.e., three different samples). A total of 2% of the mass of the oil sand was lost during separation of “free” oil from sand. As reported below, mass of oil (wt%) or mass of sand (wt%) are reported as the mass percent of each versus the total sample weight (i.e., mass of oil = oil extracted from Athabasca oil sand (g)/ total mass of original Athabasca oil sand sample (g) x 100; mass of sand = mass of sand remaining after extraction (g)/mass of original Athabasca oil sand sample (g) x 100). Variation among the three extractions is reported as RSD (relative standard deviation). A summary of these analyses is shown below in Table 3:

Table 3 - Mass Percent Oil and Sand in Athabasca Oil Sand by Solvent Extraction

	Extraction 1	Extraction 2	Extraction 3
Mass of Oil (wt%)	16%	16%	14%
Mass of Sand (wt%)	84%	82%	84%
Average Mass of Oil (wt%)	15%	Average Mass of Sand (wt%)	
			83%
RSD	6%	RSD	1%

[00204] The Athabasca oil sand was also analyzed by Alberta Innovates – Technology Futures of Canada to determine its total oil, water and solids content, as shown below in Table 4:

Table 4 - Mass Percent Oil, Water and Solids and Sand in Athabasca Oil Sand by Solvent Extraction

Total Athabasca Oil Sand (grams)	Total Mass Recovered (grams)	Oil (grams)	Water (grams)	Solids (grams)	Oil (wt %)	Water (wt %)	Solids (wt %)	Total Recovery (%)
87.03	86.18	10.68	1.00	74.50	12.27	1.15	85.6	99.02

[00205] In a glass vessel, the aqueous composition of Example 1 (2.5 g) was combined with water (47.5 g) to provide an extractant. Athabasca oil sand (5g) was added to the extractant. The mixture of oil sand and extractant was stirred using a magnetic stir bar for 4 hr at about 23 °C. Oil recovery extraction efficiency after 4 hr stirring, based on total oil present in the Athabasca oil sand, was 84 ± 10 wt% based on the oil sand composition as shown in Table 3, above. However, if the oil sand composition data from the analyses performed by Alberta Innovates – Technology Futures of Canada in Table 4 above are used as the baseline for oil content in the oil sands, the extraction efficiency of an illustrative Composition of the Invention approaches 100%. These findings are impressive when contrasted with commercial recoveries of 80-95 wt% of oil from oil sands given that the present illustrative Composition of the Invention was employed at room temperature, whereas commercial extractions processes operate between 35 °C and 80 °C and need surfactants, steam, and air.

[00206] The particle-size distribution of the solids in the Athabasca oil sands was also determined (FIG. 19). The values from the particle size distribution analysis FIG. 19 were as follows:

Volume Statistics (Arithmetic)					
Calculations from 0.375 µm to 2000 µm					
Volume:	100%				
Mean:	121.8 µm	S.D.:	59.13 µm		
Median:	127.9 µm	Variance:	3496 µm ²		
Mean/Median ratio:	0.953	C.V.:	48.5%		
Mode:	153.8 µm	Skewness:	-0.385 Left skewed		
		Kurtosis:	-0.462 Platykurtic		
d ₁₀ :	24.59 µm	d ₅₀ :	127.9 µm	d ₉₀ :	194.4 µm
<10%	<25%	<50%	<75%	<90%	
24.59 µm	87.78 µm	127.9 µm	164.1 µm	194.4 µm	

[00207] In summary, these findings show that an illustrative Composition of the Invention can provide at least as efficient extraction of oil from Athabasca oil sand relative to conventional, elevated temperature, water-based oil sand extraction processes.

Example 15

[00208] Athabasca oil sand (5 g) was combined with water (50 g) and stirred 4 hr at room temperature. The resultant mixture did not comprise a Composition of the Invention.

[00209] No extraction of oil from the oil sand was observed.

Example 16

[00210] To quantify the amount of protein present in illustrative aqueous compositions of the invention, a Biuret assay was employed. Each aqueous composition described in Table 5, below, was assayed to determine total protein concentration in parts per thousand (ppt). In each experiment, a first solution was prepared by dissolving 3.46 g of cupric sulfate in 20 mL of 50 °C water. A second solution was prepared by dissolving 34.6 g of sodium citrate and 20.0 g of sodium carbonate in 80mL of 50 °C water. After allowing the first and second solutions to cool to 23 °C, the first and second solutions were combined and mixed, yielding the Biuret assay reagent. Commercially sourced zein was dissolved in 70% isopropanol, and a calibration curve using various concentrations of zein was constructed. To measure the concentration of protein in the various aqueous compositions listed in Table 5, comprising as defined in Example 24 below, one mL of the aqueous composition was admixed with 1 ml of a 6 parts:100 (weight/weight) sodium hydroxide solution. To this mixture was added 0.4 mL of the Biuret assay reagent; providing a total volume was 2.4 mL. The test mixture's absorbance was measured at 545 nm in a 1 cm polystyrene cuvette after approximately 90 minutes. The absorbance was correlated to the calibration curve to provide protein concentration in the test mixture in parts per thousand. The results of the Biuret assay experiments are shown below:

Table 5. Protein concentration of Illustrative Aqueous Compositions as Determined via Biuret Assay.

Aqueous Composition	Protein Source	Mass of NaOH (g)	Mass of Protein Source (g)	Protein Concentration (ppt)
4.1	Corn Gluten Meal	15.9	39.8	53.4
10.2.1	Corn	15.9	19.9	41.3

	Gluten Meal			
12.2.6	Wheat Germ	45.0	19.9	35.4
12.2.2	Wheat Germ	30.0	19.9	30.0
12.1.6	Wheat Germ	45.0	19.9	32.5
13.2.4	Flax Seed Meal	15.9	19.9	21.1
2.1.7	Corn Gluten Meal	15.9	19.9	23.0
13.2.3	Flax Seed Meal	45.0	19.9	15.5

Example 17

[00211] Approximately 5 ml of light tar oil obtained from an industrial oil storage tank in New Jersey (light tar oil is an oil having a viscosity similar to room-temperature honey or syrup, which is less dense than water, and is pourable) was introduced into each of two glass beakers. The light tar oil, while less dense than water, adhered to the bottom of the glass beaker. To the first beaker was added approximately 50 ml of water (labeled “water”). To the second beaker was added approximately 50 ml of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight (labeled “Example 1”).

[00212] **FIG. 20** is a series of photographs showing the effects of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight versus water on light tar oil. The first photograph, on the far left, shows the light tar oil in the bottom of a glass beaker before the addition of either water or a Composition of the Invention. The top row of photographs is a time-lapse set of images showing the effects of adding water to light tar oil as described. Although the mechanical effect of pouring water spreads the light tar oil apart, it does not disperse the light tar oil in solution. As shown in **FIG. 20**, stirring with a glass pipette does not disperse the light tar oil; instead the light tar oil sticks to the beaker and the pipette. After

vigorous stirring with the pipette, only small balls of light tar oil are formed, which eventually float to the surface.

[00213] In contrast, the bottom row of photographs in **FIG. 20** illustrates the effect of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight on the light tar oil. Immediately upon addition, “stringers” of light tar oil begin to form from the tar oil and are released from the mass of tar oil adhering to the bottom of the beaker. Stirring the mixture with a glass pipette, as shown, releases more stringers, and the mixture becomes dark with the amount of released light tar oil. After allowing the mixture to stand for approximately 20 seconds, the light tar oil begins to float to the top of the mixture. This experiment illustrates the ability of a Composition of the Invention to remove light tar oil from a substrate.

Example 18

[00214] Approximately 5 ml of coal tar obtained from a utility plant in North Carolina was introduced into each of two glass beakers. The coal tar adhered to the bottom of the glass beaker. To the first beaker was added approximately 50 ml of water (labeled “water”). To the second beaker was added approximately 50 ml of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight (labeled “Ex. 1”).

[00215] **FIG. 21** is a series of photographs showing the effects of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight versus water on coal tar. The first photograph, on the far left, shows the coal tar in the bottom of a glass beaker before the addition of either water or a Composition of the Invention. The top row of photographs is a time-lapse set of images showing the effects of adding water to coal tar as described. The mechanical effect of pouring water on coal tar does not disperse any of the coal tar in solution. As shown, stirring with a glass pipette also does not disperse the coal tar; instead the coal tar sticks to the beaker and the pipette. After vigorous stirring with the pipette, no coal tar is released from the mass adhered to the bottom of the beaker.

[00216] In contrast, the bottom row of photographs in **FIG. 21** illustrates the effect of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight on the coal tar. Upon stirring, the coal tar forms stringers in solution. The solution darkens with increased stirring, as more coal tar is liberated from the mass of coal tar adhered to the bottom of the beaker. Upon standing, the coal tar forms balls, which sink to the bottom of the beaker. This experiment illustrates the ability of a Composition of the Invention to remove coal tar from a substrate.

Example 19

[00217] Approximately 10 ml of oil-contaminated sludge, comprising sediment and oil, was introduced into each of two glass beakers. To the first beaker was added approximately 50 ml of water (labeled “water”). To the second beaker was added approximately 50 ml of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight (labeled “Ex. 1”).

[00218] **FIG. 22** is a series of photographs showing the effects of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight versus water on oil-contaminated sludge. The first photograph, on the far left, shows the oil-contaminated sludge in the bottom of a glass beaker before the addition of either water or a Composition of the Invention. The top row of photographs is a time-lapse set of images showing the effects of adding water to oil-contaminated sludge as described. The mechanical effect of pouring water on the oil-contaminated sludge breaks up the sludge slightly, but even with subsequent stirring, the majority of the oil-contaminated sludge remains adhered to the bottom of the beaker and the oil from the oil-contaminated sludge does not disperse in the solution. As shown, stirring with a glass pipette does not disperse the oil in the oil-contaminated sludge.

[00219] In contrast, the bottom row of photographs in **FIG. 22** illustrates the effect of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight on the oil-contaminated sludge. Upon stirring, the solution darkens, and oil is liberated from the oil-contaminated sludge. This experiment illustrates the ability of a Composition of the Invention to remove oil from oil-contaminated sludge.

Example 20

[00220] Athabasca oil sand (5g) was added to a 100 ml glass beaker. 50 ml of an extractant made by admixing the aqueous composition of Example 1 (2.5 g) and water (47.5 g) was added to the Athabasca oil sand at about 23 °C. The resultant mixture was stirred for 2 hrs. After stirring and allowing the solids to settle, the mixture was decanted and the extracted oil and sand were separated, then dried and weighed to determine recovery of oil. The supernatant recovered after stirring was reserved. A second sample of Athabasca oil sand and clean stir bar was added to a clean beaker, the reserved supernatant was added to the beaker, and the resultant mixture was stirred at 1000 rpm for 2 hours with a magnetic stir bar. This extraction, recovery, and re-use of the reserved supernatant was repeated for a total of 6 extraction iterations. Table 6, below, reports the percent of oil recovered, where the reserved supernatant is re-used for multiple sequential extractions of separate samples of Athabasca oil sands.

Table 6. Recovery of oil when extractant is used iteratively.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
wt% of oil recovered	90%	89%	86%	99%	93%	106%
Average	94%					
RSD	8%					

[00221] As can be seen from the results presented in Table 6 above, the total recovery of oil from each 5 g sample of Athabasca oil sand does not change within error over successive extractions with the same extractant. This experiment illustrates the ability of a Composition of the Invention to be reused to remove oil from Athabasca oil sands.

Example 21

[00222] Approximately 5 g of Athabasca oil sand (containing 15 wt % oil), 50 ml of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight, and a stir bar were added to a small glass beaker and stirred for 10 minutes. The small beaker was placed inside a larger beaker, and the mixture in the small beaker was aerated by introducing air into the mixture via a fritted glass bubbler at 0.15L/min for 10 min. The aeration formed an oil-

entrained froth which spilled over the sides of the small beaker into the larger beaker. The froth and oil in the larger beaker, and the sand and oil remaining in the small beaker, were each separately collected, dried, and then extracted with a 50/50 (v/v) mixture of toluene and dichloromethane. After removal of the toluene/dichloromethane solvent mixture under vacuum, the percent mass of oil recovered from each of the small and larger beakers was calculated to determine the amount of oil carried from the small beaker to the larger beaker by the froth generated during aeration. **FIG. 23** is a process flow diagram illustrating the process employed for frothing and extracting oil from Athabasca oils sands. Forty-three wt% of the oil present in the 5 g of Athabasca oil sand was found to have been transported from the small beaker to the larger beaker by the froth generated during aeration. This amount is significant. Unlike the industrial process described hereinabove, wherein oil sands are treated (e.g., stirred with high pH water and aerated) multiple times to remove oil therefrom, the present 43 wt% recovery was effected in a single aeration step. This example illustrates the ability of a Composition of the Invention to remove oil from Athabasca oil sand using aeration.

[00223] **FIG. 24** is a series of photographs from three aeration experiments performed as described above, but without recovery and quantification of oil in the small and larger beakers, to qualitatively assess the frothing properties of the present Compositions of the Invention when aerated. The experiments employed (i) a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight (labeled “Ex. 1”), (ii) a solution comprising 5 parts of composition 2.2.8 (as described in Example 24 below) and 95 parts water by weight (labeled “2.2.8”), and (iii) a solution comprising 5 parts of composition 8.1 (as described in Example 24 below) and 95 parts water by weight (labeled “8.1”). All three photographs in **FIG. 25** show froth with entrained oil being carried out of the small beaker and into the larger beaker. This example illustrates the ability of Compositions of the Invention to remove oil from Athabasca oil sand with aeration.

Example 22

[00224] Approximately 5 g of coal tar sand was placed in a glass beaker. 50 ml of an extractant made by admixing the aqueous composition of Example 1 (2.5 g) and water (47.5 g) was added to the beaker at about 23 °C. The resultant mixture was stirred for 2 hours, then

aerated for 10 minutes as described in Example 21. **FIG. 25** is a series of two photographs illustrating the results. Coal tar from the coal tar sand is initially carried out with the froth, but its lower portion contains little or no coal tar (see photograph on the left in **FIG. 25**). After briefly agitating the sand and coal tar at the bottom of the beaker during aeration of the mixture, additional coal tar was carried out by the froth produced during aeration (see photograph on the right in **FIG. 25**). This example illustrates the ability of a Composition of the Invention to remove coal tar from coal tar sand with aeration.

Example 23

[00225] **FIG. 26** is a series of photographs showing the settling effect on suspended fines by reducing the pH of a solution comprising 5 parts of the composition of Example 1 and 95 parts water by weight, after extraction and removal of extracted oil from a 5 g sample of Athabasca oil sand. Athabasca oil sand (5g) was added to a 100 ml glass beaker. 50 ml of an extractant made by admixing the aqueous composition of Example 1 (2.5 g) and water (47.5 g) was added to the Athabasca oil sand at about 23 °C. The resultant mixture was stirred for 2 hrs. After stirring, the mixture was decanted, extracted oil and sand were removed from the decanted mixture, and the remaining mixture, comprising suspended fines, was placed in a 100 ml glass beaker, was then acidified from pH 13 to pH 4.7. The pH of the mixture was then adjusted to 4.6, and as shown in **FIG. 26**, the fines in the mixture were precipitated over a 160 second time period. In addition, residual oil in the mixture was observed to rise to the top of the mixture concurrent with the observed precipitation of fines. This example illustrates that acidification of a Composition of the Invention, after extraction and removal of oil from Athabasca oil sand, can effect precipitation of fines.

Example 24

[00226] A series of Experiments was performed to evaluate illustrative compositions of the invention prepared using various plant sources, and to assess the effect of various components in Compositions of the Invention. Each composition was prepared by the method described in Experiment 1, then 5 parts by weight of it were admixed with 95 parts by weight of water to provide a solution of the composition to be tested. The contents of each composition are

described in Tables 7-18, below. All experiments employed the method for extracting light tar oil as described in Example 17, using the light tar oil described therein.

EXPERIMENT SERIES 1

[00227] Experiment series 1 was performed as shown in Table 7, employing corn gluten meal as the plant source.

Table 7 – Results of Experiment Series 1

Expt. #	Plant Source (g)	50% NaOH (g)	H ₂ O (mL)	NaCl (g)	S-type hydrated lime (g)
1.2	39.8	15.89	237.8	0.159	0
1.3	39.8	15.89	237.8	0	1.58
1.4	39.8	15.89	237.8	0.159	1.58

[00228] The compositions of Table 7 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 2.1

[00229] Experiment series 2.1 was performed as shown in Table 8, employing corn gluten meal at the protein source at a reduced concentration relative to the composition of Example 1.

Table 8 – Results of Experiment Series 2.1

Expt. #	Plant Source (g)	Citric Acid (g)	70% isopropanol(mL)	50% NaOH (g)	H ₂ O (mL)	NaCl (g)	S-type hydrated lime (g)
2.1.1	19.9	0.086	15.89	15.89	237.8	0.159	1.58
2.1.3	19.9	0	0	15.89	237.8	0.159	0
2.1.4	19.9	0	0	15.89	237.8	0	1.58
2.1.5	19.9	0	0	15.89	237.8	0.159	1.58
2.1.6	19.9	0.086	15.89	15.89	237.8	0	0
2.1.7	19.9	0.086	15.89	15.89	237.8	0	1.58
2.1.8	19.9	0.086	15.89	15.89	237.8	0.159	0

[00230] The compositions of Table 8 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 2.2

[00231] Experiment series 2.2 was performed as shown in Table 9, employing corn gluten meal at the protein source at a reduced concentration relative to the composition of Example 1.

Table 9 – Results of Experiment Series 2.2

Expt. #	Plant Source (g)	Citric Acid (g)	70% isopropanol (mL)	50% NaOH (g)	H ₂ O (mL)	NaCl (g)	S-type hydrated lime (g)
2.2.1	9.95	0.086	15.89	15.89	237.8	0.159	1.58
2.2.3	9.95	0	0	15.89	237.8	0.159	0
2.2.4	9.95	0	0	15.89	237.8	0	1.58
2.2.5	9.95	0	0	15.89	237.8	0.159	1.58
2.2.6	9.95	0.086	15.89	15.89	237.8	0	0
2.2.7	9.95	0.086	15.89	15.89	237.8	0	1.58
2.2.8	9.95	0.086	15.89	15.89	237.8	0.159	0

[00232] The compositions of Table 9 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 2.3

[00233] Experiment series 2.3 was performed as shown in Table 10, employing corn gluten meal at the protein source at a reduced concentration relative to the composition of Example 1.

Table 10 – Results of Experiment Series 2.3

Expt. #	Plant Source (g)	Citric Acid (g)	70% isopropanol(mL)	50% NaOH (g)	H ₂ O (mL)	NaCl (g)	S-type hydrated lime (g)
2.3.3	4.98	0	0	15.89	237.8	0.159	0
2.3.4	4.98	0	0	15.89	237.8	0	1.58
2.3.8	4.98	0.086	15.89	15.89	237.8	0.159	0

[00234] The compositions of Table 10 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 4

[00235] Experiment series 4 was performed as shown in Table 11, employing corn gluten meal as the plant source with added polysaccharide.

Table 11 – Results of Experiment Series 4

Expt. #	Plant Source (g)	Citric Acid (g)	70% isopropanol(mL)	50% NaOH (g)	H ₂ O (mL)	Guar Gum (g)	NaCl (g)	S-type hydrated lime (g)
4.1	39.8	0.086	15.89	15.89	237.8	1.978	0.159	1.58
4.2	39.8	0	0	15.89	237.8	1.978	0	0
4.3	39.8	0	0	15.89	237.8	1.978	0.159	0
4.4	39.8	0	0	15.89	237.8	1.978	0	1.58
4.5	39.8	0	0	15.89	237.8	1.978	0.159	1.58
4.6	39.8	0.086	15.89	15.89	237.8	1.978	0	0
4.7	39.8	0.086	15.89	15.89	237.8	1.978	0	1.58
4.8	39.8	0.086	15.89	15.89	237.8	1.978	0.159	0

[00236] The compositions of Table 11 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 4b

[00237] Experiment series 4b was performed as shown in Table 12, employing cotton seed meal as the plant source with added polysaccharide.

Table 12 – Results of Experiment Series 4b

Expt. #	Plant Source (g)	Citric Acid (g)	70% isopropanol (mL)	50% NaOH (g)	H ₂ O (mL)	Guar Gum (g)	NaCl (g)	S-type hydrated lime (g)
4b.1	19.9	0.086	15.89	15.89	237.8	1.978	0.159	1.58
4b.2	19.9	0	0	15.89	237.8	1.978	0	0
4b.3	19.9	0	0	15.89	237.8	1.978	0.159	0
4b.4	19.9	0	0	15.89	237.8	1.978	0	1.58
4b.5	19.9	0	0	15.89	237.8	1.978	0.159	1.58
4b.6	19.9	0	0	15.89	237.8	1.978	0	0
4b.8	19.9	0	0	15.89	237.8	1.978	0.159	0

[00238] The compositions of Table 12 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 6

[00239] Experiment series 6 was performed as shown in Table 13, employing wheat germ as the plant source.

Table 13 – Results of Experiment Series 6

Expt. #	Plant Source (g)	Citric Acid (g)	70% isopropanol(mL)	50% NaOH (g)	H ₂ O (mL)	Guar Gum (g)	NaCl (g)	S-type hydrated lime (g)
6.1	39.8	0.086	15.89	15.89	237.8	1.978	0.159	1.58

[00240] The compositions of Table 13 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 7

[00241] Experiment series 7 was performed as shown in Table 14, employing flax seed as the plant source.

Table 14 – Results of Experiment Series 7

Expt. #	Plant Source (g)	Citric Acid (g)	70% isopropanol (mL)	50% NaOH (g)	H ₂ O (mL)	Guar Gum (g)	NaCl (g)	S-type hydrated lime (g)
7.1	19.9	0.086	15.89	15.89	237.8	1.978	0.159	1.58

[00242] The compositions of Table 14 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 8

[00243] Experiment series 8 was performed as shown in Table 15, employing cotton seed meal in varying amounts as the plant source.

Table 15 – Results of Experiment Series 8

Expt. #	Plant Source (g)	Citric Acid (g)	70% isopropanol (mL)	50% NaOH (g)	H ₂ O (mL)	NaCl (g)	S-type hydrated lime (g)
8.1	19.9	0.086	15.89	15.89	237.8	0.159	0
8.2	9.95	0.086	15.89	15.89	237.8	0.159	0
8.3	4.975	0.086	15.89	15.89	237.8	0.159	0
8.4	19.9	0.086	15.89	15.89	237.8	0.159	1.58
8.5	9.95	0.086	15.89	15.89	237.8	0.159	1.58
8.6	4.975	0.086	15.89	15.89	237.8	0.159	1.58

[00244] The compositions of Table 15 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 10.2

[00245] Experiment series 10.2 was performed as shown in Table 16, employing corn gluten meal as the plant source, various concentration of base (sodium hydroxide), and corn gluten meal is either soaked in water for 12 hours prior to use (Expts. 10.2.1-10.2.3) or the used dry (Expts. 10.2.4-10.2.6).

Table 16 – Results of Experiment Series 10.2

Expt. #	Plant Source (g)	50% NaOH (g)	H ₂ O (mL)	NaCl (g)
10.2.1	19.9	15.89	253.69	0.159
10.2.2	19.9	30	253.69	0.159
10.2.3	19.9	45	253.69	0.159
10.2.4	19.9	15.89	253.69	0.159
10.2.5	19.9	30	253.69	0.159
10.2.6	19.9	45	253.69	0.159

[00246] The compositions of Table 16 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 12.2

[00247] Experiment series 12.2 was performed as shown in Table 17, employing wheat germ as the plant source, various concentration of base (sodium hydroxide), and the wheat germ is either soaked in water for 12 hours prior to use (Expts. 12.2.1-12.2.3) or used dry (Expts. 12.2.4-12.2.6).

Table 17 – Results of Experiment Series 12.2

Expt. #	Plant Source (g)	50% NaOH (g)	H ₂ O (mL)	NaCl (g)
12.2.1	19.9	15.89	253.69	0.159
12.2.2	19.9	30	253.69	0.159
12.2.3	19.9	45	253.69	0.159
12.2.4	19.9	15.89	253.69	0.159
12.2.5	19.9	30	253.69	0.159
12.2.6	19.9	45	253.69	0.159

[00248] The compositions of Table 17 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

EXPERIMENT SERIES 13.2

[00249] Experiment series 13.2 was performed as shown in Table 18, employing flax seed meal as the plant source, various concentration of base (sodium hydroxide), and the flax seed is either soaked in water for 12 hours prior to use (Expts. 13.2.1-13.2.3) or used dry (Expts. 13.2.4-13.2.6).

Table 18 – Results of Experiment Series 13.2

Expt. #	Plant Source (g)	50% NaOH (g)	H ₂ O (mL)	NaCl (g)
13.2.1	19.9	15.89	253.69	0.159
13.2.2	19.9	30	253.69	0.159
13.2.3	19.9	45	253.69	0.159
13.2.4	19.9	15.89	253.69	0.159
13.2.5	19.9	30	253.69	0.159
13.2.6	19.9	45	253.69	0.159

[00250] The compositions of Table 18 successfully released light tar oil from the mass of tar oil adhering to the bottom of the beaker. These experiments illustrate that Compositions of the Invention are effective in removing oil from a substrate.

Example 25

[00251] Compositions 10.2.1 and 12.2.6 as described in Example 24, above, were lyophilized, either before centrifugation, or after centrifugation to remove solids and gel formed during preparation. In addition, the Composition of Example 2 was lyophilized after its preparation by the method below.

[00252] Lyophilization was performed by placing each composition in a 50 mL loosely covered plastic vial, immersing the vial in liquid nitrogen for 30 min, then placing the vial in a bench-top manifold freeze dryer and applying vacuum (approximately 10^{-2} torr) for 48 hours. The compositions were weighed before and after lyophilization. The amount of liquid removed was determined by the difference between the initial mass of the composition prior to lyophilization and its mass after lyophilization. The results are reported in Table 19, below.

Table 19 – Mass of Solids Recovered and Liquid Removed in Centrifugation of Exemplary Compositions of the Invention

Expt. #	Mass of Solids (g)	Mass of Liquid Removed (g)
10.2.1 - Centrifuged	2.704	20.921
10.2.1 - Non-centrifuged	2.723	21.307
12.2.6 - Centrifuged	2.723	11.395
12.2.6 - Non-centrifuged	5.497	21.647
Example 2 - Centrifuged	3.492	21.139

[00253] The recovered solids from each composition were reconstituted with water. Reconstitution was performed in each of two ways: 1) adding water to provide a solution having a concentration equal to 5 parts of the composition prior to lyophilization and 95 parts water; and 2) by reconstituting the solids to provide a mixture having the same mass as the composition prior to lyophilization, then admixing 5 parts of the reconstituted mixture and 95 parts water. No observable differences were observed in preparing the compositions using the two reconstitution methods.

[00254] The efficacy of the reconstituted materials for extraction of light tar oil, extraction of coal tar, and frothing and extraction of Athabasca sand was assessed using methods described

hereinabove. The compositions were observed to perform essentially the same as comparable, non-lyophilized, non-reconstituted counterparts in each experiment.

[00255] These experiments illustrate that lyophilized and reconstituted Compositions of the Invention are effective for removing oil from a substrate, for extracting coal tar from coal tar sands, and for removing oil from Athabasca oil sand using frothing.

Example 26

[00256] An illustrative aqueous composition of the invention comprising plant material, but not comprising polysaccharide other than that present in or derived from the plant material, was prepared as follows. Citric acid (0.086 grams) was dissolved in 15.89 ml of 70% isopropanol at about 23 °C. Zein (26.5 g) was added, and the resultant mixture was allowed to stir for 2 hours. 15.89 g of a 50% aqueous sodium hydroxide solution was added to 237.8 g of water, the resultant diluted sodium hydroxide solution was added to the isopropanol/zein mixture, and the resultant mixture was allowed to stand for 6 hours. Sodium chloride (0.159 g) was then added, also with stirring. The resultant mixture was then allowed to stand for an additional 2 hours. S-type hydrated lime (1.58 g) was then added with stirring, and the resultant mixture was stirred until uniform. The solids were allowed to settle, and the supernatant was decanted to provide the illustrative aqueous composition as the decanted supernatant.

[00257] In a glass vessel, (2.5 g) of the aqueous composition prepared as described in paragraph [0256] was combined with water (47.5 g) to provide an extractant. Coal tar sand (5g, 15 wt% coal tar) from a North Carolina gasification plant site was added to the extractant. The resultant mixture was stirred using a magnetic stir bar for 90 minutes at about 23 °C. Extraction of the coal tar from the coal tar sand was observed.

[00258] This example demonstrates that an illustrative Composition of the Invention is useful for extracting coal tar from coal tar sand.

Example 27

[00259] A comparative composition comprising a polysaccharide, but not comprising plant material, was prepared as follows. Guar gum (1.978 g), citric acid (0.086 g), 15.89 ml of

70% isopropanol, sodium chloride (0.159 g), S-type hydrated lime (1.58 g) and 15.89 g of a 50% aqueous sodium hydroxide solution were added to 237.8 g of water at about 23 °C. The resultant mixture was stirred until uniform.

[00260] In a glass vessel, (2.5 g) of the comparative composition prepared as described in paragraph [0259] was combined with water (47.5 g) to provide a test extractant. Coal tar sand (5g, 15 wt% coal tar) from a North Carolina gasification plant site was added to the test extractant. The resultant mixture was stirred using a magnetic stir bar for 90 minutes at about 23 °C. No extraction of the coal tar from the coal tar sand was observed.

[00261] The embodiments described herein and illustrated by the foregoing examples should be understood to be illustrative of the present invention, and should not be construed as limiting. On the contrary, the present disclosure embraces alternatives and equivalents thereof, as embodied by the appended claims. Each reference disclosed herein is incorporated by reference herein in its entirety.

What is claimed is:

1. An aqueous composition comprising:
 - a. about 1 wt% to about 50 wt% of plant material;
 - b. 0% to about 20 wt% of a polysaccharide;
 - c. 0% to about 10 wt% of an alcohol;
 - d. 0% to about 15 wt% of a base;
 - e. 0% to about 10 wt% of a salt;
 - f. 0% to about 10 wt% of an acid;
 - g. 0% to about 10 wt% of an additive; and
 - h. about 10 wt% to about 95 wt% of water;wherein the aqueous composition has a pH of from about 9 to about 13.
2. The aqueous composition of claim 1, wherein the plant material comprises plant protein.
3. The aqueous composition of claim 1, wherein the plant is corn, rice, wheat, barley, flax, sorghum, millet, rye, triticale, fonio, buckwheat, spelt, cotton or quinoa.
4. The aqueous composition of claim 2, wherein the plant material is corn gluten meal.
5. The aqueous composition of claim 1, wherein the alcohol is ethanol, methanol, or isopropanol.
6. The aqueous composition of claim 1, wherein the base is sodium hydroxide, lithium hydroxide, or potassium hydroxide.
7. The aqueous composition of claim 1, wherein the salt is sodium chloride, potassium chloride, calcium chloride, magnesium chloride, ammonium chloride, sodium bromide, potassium bromide, calcium bromide, magnesium bromide, ammonium bromide, sodium iodide, potassium iodide, calcium iodide, magnesium iodide, ammonium iodide, sodium sulfate, potassium sulfate, calcium sulfate, magnesium sulfate, ammonium sulfate or mixtures thereof.

8. The aqueous composition of claim 1, wherein the acid is citric acid, formic acid, ascorbic acid, acetic acid, malic acid, adipic acid, tannic acid, lactic acid, fumaric acid, or mixtures thereof.
9. The aqueous composition of claim 1, wherein the additive is Type S Hydrated Lime.
10. The aqueous composition of claim 1, wherein the composition does not comprise a polysaccharide other than that present in or derived from the plant material, wherein the plant material is corn gluten meal, and wherein the aqueous composition further comprises isopropanol, citric acid, Type S hydrated lime, sodium hydroxide, and sodium chloride.
11. An extractant comprising:
 - a. about 0.1 wt% to about 2 wt% of plant material;
 - b. 0% to about 2 wt% of a polysaccharide;
 - c. 0% to about 1 wt% of an alcohol;
 - d. 0% to about 10 wt% of a base;
 - e. 0% to about 10 wt% of a salt;
 - f. 0% to about 10 wt% of an acid;
 - g. 0% to about 10 wt% of an additive; and
 - h. about 90 wt% to about 99.9 wt% water.
12. The extractant of claim 11, wherein the plant material comprises protein.
13. The extractant of claim 11, wherein the plant is corn, rice, wheat, barley, flax, sorghum, millet, rye, triticale, fonio, buckwheat, spelt, cotton or quinoa.
14. The extractant of claim 12, wherein the plant material is corn gluten meal.
15. The extractant of claim 11, wherein the alcohol is ethanol, methanol, or isopropanol.

16. The extractant of claim 11, wherein the base is sodium hydroxide, lithium hydroxide, or potassium hydroxide.
17. The extractant of claim 11, wherein the salt is sodium chloride, potassium chloride, calcium chloride, magnesium chloride, ammonium chloride, sodium bromide, potassium bromide, calcium bromide, magnesium bromide, ammonium bromide, sodium iodide, potassium iodide, calcium iodide, magnesium iodide, ammonium iodide, sodium sulfate, potassium sulfate, calcium sulfate, magnesium sulfate, ammonium sulfate or mixtures thereof.
18. The extractant of claim 11, wherein the acid is citric acid, formic acid, ascorbic acid, acetic acid, malic acid, adipic acid, tannic acid, lactic acid, fumaric acid, or mixtures thereof.
19. The extractant of claim 11, wherein the additive is Type S Hydrated Lime.
20. The extractant of claim 11, wherein the pH of the extractant is from about 9 to about 13.
21. The extractant of claim 11, wherein the extractant does not comprise polysaccharide other than that present in or derived from the plant material, wherein the plant material is corn gluten meal, and wherein the aqueous composition further comprises isopropanol, citric acid, Type S hydrated lime, sodium hydroxide, and sodium chloride.
22. A substantially anhydrous composition comprising:
 - a. about 20 wt% to about 99.9 wt% of plant material;
 - b. 0 to about 20 wt% of a polysaccharide;
 - c. 0% to about 1 wt% of an alcohol;
 - d. 0% to about 15 wt% of a base;
 - e. 0% to about 10 wt% of a salt;
 - f. 0% to about 10 wt% of an acid;
 - g. 0% to about 10 wt% of an additive; and
 - h. 0% to about 10 wt% water.

23. The substantially anhydrous composition of claim 22, wherein the plant material comprises plant protein.
24. The substantially anhydrous composition of claim 22, wherein the plant is corn, rice, wheat, barley, flax, sorghum, millet, rye, triticale, fonio, buckwheat, spelt, cotton or quinoa.
25. The substantially anhydrous composition of claim 23, wherein the plant material is corn gluten meal.
26. The substantially anhydrous composition of claim 22, wherein the alcohol is ethanol, methanol, or isopropanol.
27. The substantially anhydrous composition of claim 22, wherein the base is sodium hydroxide, lithium hydroxide, or potassium hydroxide.
28. The substantially anhydrous composition of claim 22, wherein the salt is sodium chloride, potassium chloride, calcium chloride, magnesium chloride, ammonium chloride, sodium bromide, potassium bromide, calcium bromide, magnesium bromide, ammonium bromide, sodium iodide, potassium iodide, calcium iodide, magnesium iodide, ammonium iodide, sodium sulfate, potassium sulfate, calcium sulfate, magnesium sulfate, ammonium sulfate, or mixtures thereof.
29. The substantially anhydrous composition of claim 22, wherein the acid is citric acid, formic acid, ascorbic acid, acetic acid, malic acid, adipic acid, tannic acid, lactic acid, fumaric acid, or mixtures thereof.
30. The substantially anhydrous composition of claim 22, wherein the additive is Type S Hydrated Lime.
31. The substantially anhydrous composition of claim 22, wherein the composition does not comprise polysaccharide other than that present in or derived from the plant material,

wherein the plant material is corn gluten meal, and wherein the aqueous composition further comprises isopropanol, citric acid, Type S hydrated lime, sodium hydroxide, and sodium chloride.

32. A method for extracting a hydrocarbon-containing substance from a substrate, comprising contacting the substrate with the aqueous composition of any of claims 1-10, under conditions effective for extracting at least some of the hydrocarbon-containing substance from the substrate.

33. The method of claim 32, wherein the substrate is soil, sand, wood, rock, paper, skin, a waterbody, gravel, mud, clay, plant, hair, fabric, metal, glass, porcelain, concrete, a living animal or a dead animal.

34. The method of claim 32 wherein the extracting comprises removing the hydrocarbon-containing substance from the surface of the substrate.

35. The method of claim 32, wherein the contacting occurs at an aqueous composition or a substrate temperature of about 5° to about 50°C.

36. The method of claim 32, wherein the method further comprises subjecting the aqueous composition or the substrate to agitation.

37. The method of claim 32, wherein the hydrocarbon-containing substance is grease, crude oil, coal tar, sludge, bitumen, automotive oil, one or more petroleum distillates, diesel fuel, heating oil, jet fuel, aviation gasoline, kerosene, creosote, coal tar sand, tar sand, light tar oil, bitumen, sludge, oil-contaminated sludge or refined products thereof.

38. A method for extracting a hydrocarbon-containing substance from a substrate, comprising contacting the substrate with the extractant of any of claims 11-20, under conditions effective for extracting at least some of the hydrocarbon-containing substance from the substrate.

39. The method of claim 38, wherein the substrate is soil, sand, wood, rock, paper, skin, a waterbody, gravel, mud, clay, plant, hair, fabric, metal, glass, porcelain, concrete, a living animal or a dead animal.
40. The method of claim 38, wherein the extracting comprises removing the hydrocarbon-containing substance from the surface of the substrate.
41. The method of claim 38, wherein the contacting occurs at an extractant or a substrate temperature of about 5° to about 50°C.
42. The method of claim 38, wherein the method further comprises subjecting the extractant or the substrate to agitation.
43. The method of claim 38, wherein the hydrocarbon-containing substance is grease, crude oil, coal tar, sludge, bitumen, automotive oil, one or more petroleum distillates, diesel fuel, heating oil, jet fuel, aviation gasoline, kerosene, creosote, coal tar sand, tar sand, light tar oil, bitumen, sludge, oil-contaminated sludge or refined products thereof.
44. A method for remediating a substrate, comprising contacting the substrate with the aqueous composition of any of claims 1-10, under conditions effective for remediating the substrate.
45. The method of claim 44, wherein the substrate is soil, sand, wood, paper, skin, a waterbody, gravel, mud, clay, plant, hair, fabric, metal, glass, porcelain, ceramic, a living animal or a dead animal.
46. The method of claim 44, wherein remediating comprises extracting a hydrocarbon-containing substance from the substrate.
47. The method of claim 44, wherein the contacting occurs at an aqueous composition or a substrate temperature of about 5° to about 50°C.

48. The method of claim 44, wherein the method further comprises subjecting the aqueous composition or substrate to agitation.
49. The method of claim 44, wherein the hydrocarbon-containing substance grease, crude oil, coal tar, sludge, bitumen, automotive oil, one or more petroleum distillates, diesel fuel, heating oil, jet fuel, aviation gasoline, kerosene, creosote, coal tar sand, tar sand, light tar oil, bitumen, sludge, oil-contaminated sludge or refined products thereof.
50. The method of claim 44, wherein extracting comprises removing a hydrocarbon-containing substance from the surface of the substrate.
51. The method of claim 44, wherein remediating the substrate comprises sequestering one or more contaminants in the substrate.
52. A method for remediating a substrate, comprising contacting the substrate with the extractant of any of claims 11-20, under conditions effective for remediating the substrate.
53. The method of claim 52, wherein the substrate is soil, sand, wood, paper, skin, a waterbody, gravel, mud, clay, plant, hair, fabric, metal, glass, porcelain, ceramic, a living animal or a dead animal.
54. The method of claim 52, wherein remediating comprises extracting a hydrocarbon-containing substance from the substrate.
55. The method of claim 52, wherein the contacting occurs at an extractant or a substrate temperature of about 5° to about 50°C.
56. The method of claim 52, wherein the method further comprises subjecting the extractant or substrate to agitation.

57. The method of claim 52, wherein the hydrocarbon-containing substance grease, crude oil, coal tar, sludge, bitumen, automotive oil, one or more petroleum distillates, diesel fuel, heating oil, jet fuel, aviation gasoline, kerosene, creosote, coal tar sand, tar sand, light tar oil, bitumen, sludge, oil-contaminated sludge or refined products thereof.
58. The method of claim 52, wherein extracting comprises removing a hydrocarbon-containing substance from the surface of the substrate.
59. The method of claim 52, wherein remediating the substrate comprises sequestering one or more contaminants in the substrate.
60. A hydraulic fracturing fluid comprising the aqueous composition of claim 1.
61. The hydraulic fracturing fluid of claim 60, further comprising a proppant, a viscosity modifier, a radioactive tracer, a gel, an alcohol, a detergent, an acid, a fluid loss additive, a gas, a dispersant or a flocculant.
62. A method for extracting a hydrocarbon-containing substance from a substrate, comprising hydraulically fracturing the substrate with the hydraulic fracturing fluid of claim 60.
63. A hydraulic fracturing fluid comprising the extractant of claim 11.
64. The hydraulic fracturing fluid of claim 63, further comprising a proppant, a viscosity modifier, a radioactive tracer, a gel, an alcohol, a detergent, an acid, a fluid loss additive, a gas, a dispersant or a flocculant.
65. A method for extracting a hydrocarbon-containing substance from a substrate, comprising hydraulically fracturing the substrate with the hydraulic fracturing fluid of claim 63.

66. A method for precipitating fines contained in a vessel further containing a hydrocarbon-containing material and the aqueous composition of claim 1, comprising acidifying the contents of said vessel to a pH of about 4.6 or less.

67. A method for separating fines from a hydrocarbon-containing material, comprising acidifying to a pH of about 4.6 or less, a mixture comprising the hydrocarbon-containing material, the fines, and an aqueous composition of claim 1; and allowing the fines to precipitate.

68. The method of claim 67, further comprising separating at least some of the precipitated fines from the mixture.

69. The method of claim 68, wherein separating comprises filtering or centrifuging the mixture.

70. A method for separating fines from a hydrocarbon-containing material, comprising acidifying to a pH of about 4.6 or less, a mixture comprising the hydrocarbon-containing material, the fines, and an extractant of claim 11; and allowing the fines to precipitate.

71. The method of claim 70, further comprising separating at least some of the precipitated fines from the mixture.

72. The method of claim 71, wherein separating comprises filtering or centrifuging the mixture.