A method, an apparatus, and a computer program product for treating fracking fluids are provided in which a dispersion system receives a portion of a body of fracking fluid collected in a well. The dispersion system may comprise a hydrodynamic mixing chamber and a nozzle. An additive comprising one or more of ozone and oxygen may be mixed with a portion of collected fluid passing through the mixing chamber. The nozzle may disperse a mixture of the collected fluid and additive received from the mixing chamber. The system may comprise a controller having at least one processor configured to monitor the level of the additive or a contaminant in the well. The processor may be configured to cause a portion of the fluid to be pumped from the well through an outflow main when the level of fluid in the well exceeds a threshold level.
Figure 6
**Figure 9**

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**System Operating Requirements**

- **Flow gallons per minute at 24 psi, 28 psi, 51 psi**: 16 gpm, 9 gpm, 5 gpm
- **Flow gallons per minute at 24 psi, 28 psi, 51 psi**: 16 gpm, 9 gpm, 5 gpm
- **Rotational Speed Range**: 1800 to 2500 rpm
- **Pump Horsepower**: 1.5 hp
- **Pump Horsepower**: 1.5 hp
- **Discharge Main Diameter**: 2.4 inches
- **Discharge Main Diameter**: 2.4 inches
- **Optimum Minimum Diameter Required**: 1 inch
- **Optimum Minimum Diameter Required**: 1 inch
- **Wet Well Minimum Diameter Required**: 24 feet
- **Wet Well Minimum Diameter Required**: 24 feet

**Specifications**

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**Figure 9**
Figure 11
Treatment

Inflow of fluid (130)

Treat fluid in well (130)

Level?

Pump fluid from well (130)

Treat fluid in mains (130)

Figure 13
COAL SEAM GAS FRACKING SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATION(S)

Pursuant to 35 U.S.C. §119(e), this application claims the benefit of U.S. Provisional Application Ser. No. 61/525,679 filed on Aug. 19, 2011, and U.S. Provisional Application Ser. No. 61/613,382 filed on Mar. 20, 2012, the contents of which are hereby incorporated by reference herein in their entirety.

BACKGROUND

1. Field

The present invention relates generally to systems and methods for treating fluids in used fracturing subterranean seams carrying hydrocarbons or coal.

2. Background

Fracking is a method of hydraulically fracturing subterranean coal seams to improve the rate and total recovery of gas therefrom. A coal seam is fractured with acid and a proppant-laden fracturing fluid ("fracking fluid") in alternating injection stages. The initial injection stage of the fracturing fluid generally contains from about 0 to about 4 pounds of a spherical proppant having a particle size distribution substantially between 60 and 140 mesh. The subsequent fracturing fluid injection stages are alternated with injection stages of a smaller volume of acid. The proppant loading in the fracking fluid is increased with each injection stage until the loading is from about 8 to about 12 pounds of proppant per gallon of fluid.

SUMMARY

In an aspect of the disclosure, a fracking fluid treatment system comprises a dispersion system that receives a portion of fracking fluid collected in a well. The dispersion system may comprise a dynamic mixing chamber and a nozzle. An additive comprising one or more of ozone and oxygen may be mixed with a portion of collected fluid passing through the mixing chamber. The nozzle may disperse a mixture of the collected fluid and additive received from the mixing chamber.

In some embodiments, the system comprises a controller having at least one processor. The processor may be configured to monitor the level of the additive in the well. The processor may be configured to control a fraction of the fluid to be pumped from the well through an outflow main when the level of fluid in the well exceeds a threshold level. The processor may be configured to control a rate of flow of the additive to the mixing chamber. In some embodiments, the dispersion system comprises a manifold that communicates the portion of fluid and the additive to the mixing chamber.

In some embodiments, the additive comprises liquid ozone. The controller may control the rate of flow of the liquid ozone based on measurements provided by sensors deployed in the well. The measurements may include a measurement of residual ozone level in the fluid collected in the well. The measurements may include a measurement of sulfide in the fluid collected in the well. The measurements may include a measurement of hydrogen sulfide in the well.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevation depicting an example of the presently claimed apparatus deployed within a well.

FIG. 2 shows a cross-sectional view of a mixer according to certain aspects of the invention.

FIG. 3 shows variously angled views of a deflector vane according to certain aspects of the invention.

FIG. 4 is a detailed view of a mixer.

FIG. 5 is a detailed view of a mixer.

FIG. 6 shows a spray assembly according to certain aspects of the invention.

FIG. 7 shows a well having deployed therein, a spray assembly according to certain aspects of the invention.

FIG. 8 depicts mounting brackets used for mounting a spray assembly according to certain aspects of the invention.

FIG. 9 is a table of specifications associated with certain embodiments of the invention.

FIG. 10 shows a spray head according to certain aspects of the invention.

FIG. 11 shows a simplified example of a computing system employed in certain embodiments of the invention.

FIG. 12 shows a simplified processing system.

FIG. 13 is a flow chart illustrating a simplified process according to certain aspects of the invention.

FIG. 14 is a block diagram illustrating an example of an infuser used in fluid treatment system

FIG. 15 is a schematic illustrating an example of an infuser used in fluid treatment system

DETAILED DESCRIPTION

The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

Several aspects of water treatment systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawing by various blocks, modules, components, circuits, steps, processes, algorithms, etc. (collectively referred to as “elements”). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

By way of example, an element, or any portion of an element, or any combination of elements may be implemented with a “processing system” that includes one or more processors. Examples of processors include microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardw are circuits, and other suitable hardware configured to perform the various functionality described throughout this d-
closure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. The software may reside on a computer-readable medium. A computer-readable medium may include, by way of example, a magnetic storage device (e.g., hard disk, floppy disk, magnetic strip), an optical disk (e.g., compact disk (CD), digital versatile disk (DVD)), a smart card, a flash memory device (e.g., card, stick, key drive), random access memory (RAM), read only memory (ROM), programmable ROM (PRW), erasable PROM (EPROM), electrically erasable PROM (EEPROM), a register, a removable disk, a carrier wave, a transmission line, and any other suitable medium for storing or transmitting software. The computer-readable medium may be resident in the processing system, external to the processing system, or distributed across multiple entities including the processing system. Computer-readable medium may be included in a computer-program product. By way of example, a computer-program product may include a computer-readable medium in packaging materials. Those skilled in the art will recognize how best to implement the described functionality presented throughout this disclosure depending on the particular application and the overall design constraints imposed on the overall system.

[0027] Embodiments of the present invention will now be described in detail with reference to the drawings, which are provided as illustrative examples so as to enable those skilled in the art to practice the invention. Notably, the figures and examples below are not meant to limit the scope of the present invention to a single embodiment, but other embodiments are possible by way of interchange of some or all of the described or illustrated elements. Wherever convenient, the same reference numbers will be used throughout the drawings to refer to same or like parts. Where certain elements of these embodiments can be partially or fully implemented using known components, only those portions of such known components that are necessary for an understanding of the present invention will be described, and detailed descriptions of other portions of such known components will be omitted so as not to obscure the invention. In the present specification, an embodiment showing a singular component should not be considered limiting, rather, the invention is intended to encompass other embodiments including a plurality of the same component, and vice-versa, unless explicitly stated otherwise herein. Moreover, applicants do not intend for any term in the specification or claims to be ascribed an uncommon or special meaning unless explicitly set forth as such. Further, the present invention encompasses present and future known equivalents to the components referred to herein by way of illustration.

[0028] Certain embodiments of the invention provide systems and methods for treating fluids introduced into wells and/or extracted from wells. In some embodiments, the fluid to be treated is encountered or used for fracturing subterranean seams (“fracking”), and may comprise water, proppants, chemicals and other substances, which may be additives and/or contaminants. In some embodiments, treatment includes introducing pressurized oxygen and/or ozone into the fluid to be treated.

[0029] In one example, a pressurized stream of ozone and/or oxygen may be introduced into fracking fluid, which is injected into subterranean coal seams. The fracking fluid may comprise a saturated stream of fluid, such as pressurized water and/or steam. The fracking fluid is typically laden with one or more proppants. The fracking fluid may be used to create hydraulic fractures or to expand natural fractures in the seam. A proppant is typically introduced to maintain the fracture opening. Examples of proppants include grains of sand, ceramics, and other particulate materials.

[0030] The quantity and point of introduction of ozone may be selected to accomplish one or more purpose, including those illustrated in Table 1, below. Ozone may be introduced as a biocide and for well maintenance and stabilization. Ozone may be introduced to facilitate flow and entry of proppant, and/or to improve hydraulic performance within the well.

<table>
<thead>
<tr>
<th>Classes of Additives</th>
<th>Purpose</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Biocides</td>
<td>Kill bacteria and reduce risk of fouling</td>
<td>Oxone instead of glutaraldehyde, 2,2 dibromo-3-nitropropionamide</td>
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<tr>
<td>Breaker</td>
<td>Facilitate proppant entry</td>
<td>Oxone instead of peroxodinitrates</td>
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<td>Clay stabilizer</td>
<td>Clay stabilization</td>
<td>Oxone instead of salts, i.e. strontium ammonium chloride</td>
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<td>Corrosion inhibitor</td>
<td>Well maintenance</td>
<td>Oxone instead of methanol</td>
</tr>
<tr>
<td>Crosslinker</td>
<td>Facilitate proppant entry</td>
<td>Oxone instead of potassium hydroxide</td>
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<tr>
<td>Friction reducer</td>
<td>Improve surface premixure</td>
<td>Oxone instead of sodium acrylate, polyacrylamide</td>
</tr>
<tr>
<td>Iron control</td>
<td>Well maintenance</td>
<td>Oxone instead of citric acid, thiglycolic acid</td>
</tr>
<tr>
<td>Scale inhibitor</td>
<td>Prevention of precipitation</td>
<td>Oxone instead of ammonium chloride, ethylene glycol, polyacrylate</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Reduction in fluid tension</td>
<td>Oxone instead of methanol, iso-propanol</td>
</tr>
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</table>

[0031] As shown in Table 1, oxygen and/or ozone serves as a replacement for various conventional classes of additives used for purposes, and can reduce the level of contaminants associated with treatment of the fracking fluid in conventional systems. For example, ozone may replace chemical additives used in conventional systems to tailor the injected material to the specific geological situation, protect the well, and improve its operation. A typical injected fracking fluid comprises approximately 99 percent water and 1 percent proppant, although these proportions may vary based on the type of well. The composition of injected fluid and additives may be changed during the operation of a well, and different additives and/or proportions of additives may be introduced at different times. For example, acid may be used initially to increase permeability, before proppants are introduced. As time progresses, the size of proppant particulates may be gradually increased, and finally, the well may be flushed with pressurized water.

[0032] Typically, at least a portion of the injected fluid is recovered and stored in tanks, pits and/or containers. The recovered fluid can be toxic due to the presence of chemical additives used in current or prior processes, and materials and
chemicals washed out from the subterranean seam and the ground between the surface and the seam. Recovered fracking fluid may be processed to enable reuse in further fracking operations. In some embodiments, the fracking fluid can be treated. Using systems and methods described herein, to the extent that portions of the recovered fracking fluids may be released into the environment after treatment. In some embodiments, at least a residual portion of the treated fluids may be placed in long-term or permanent deep-well storage.

[0033] The use of ozone and oxygen in place of conventionally used chemicals can reduce the quantity of toxins, known carcinogens and heavy metals which may otherwise pollute ground water near well sites. In the United States, Congress exempted fracturing fluid from regulations of the Safe Drinking Water Act in 2005. A number of chemicals, specifically biocides and certain petroleum products that are present in fracturing fluid are hazardous chemicals that may cause health risks that range from rashes to cancer. Some chemicals are identified as carcinogens. Some chemicals found injected into the earth identify as endocrine disruptors, which interrupt hormones and glands in the body that control development, growth, reproduction and behavior in animals and humans. At least some of the chemicals in Table 1 can be replaced or eliminated if pressurized oxygen or ozone is used according to certain aspects of the invention.

[0034] Certain embodiments comprise systems and apparatus that resolve environmental problems associated with fracking and other extraction and drilling applications. Ozone and/or oxygen may be effective in removing H₂S & Volatile organic compounds ("VOC") odor, iron bacteria, fat, oil and grease ("FOG") accumulation, and so on. For example, certain embodiments can be used to oxidize undesirable chemicals such as sulfides, ammonia and organic solvents, and can kill biofilm growth. Certain embodiments of the invention provide methods for controlling the operation of fracturing apparatus. In particular, computing systems may be deployed to monitor the environment within wells, forced mains, tanks, pits and other infrastructure used in fracturing systems. The fluids may include solid matter and/or particulates. There follows a description of certain fracturing fluid treatment systems that serve as an example of systems in which the presently disclosed control system can be deployed.

[0035] Certain embodiments of the present invention can be deployed to control fracturing apparatus in order to improve the efficiency and effectiveness of such equipment. Certain embodiments of the present invention can be retrofitted to conventional fracturing apparatus and it will be appreciated that certain components of fracturing equipment may be redesigned, adapted and/or reconfigured to maximize the advantages accruing from the present invention.

[0036] Various aspects of this disclosure apply to the preparation and treatment of fluids used for fracking and effluent or other fluids extracted from a subterranean seam during or after fracking. Thus, a fluid to be pressurized and introduced into the seam may be stored in a well or container, where it may be pretreated using an additive. Pretreatment may include removal of contaminants before introduction to the seam. Fluid to be introduced to the seam may be pressurized and may be treated by addition of an additive in an outflow conduit such as a pipe or pressure main using, for example, the infuser described in relation to FIG. 14. Fluid extracted from the seam may be treated in an inflow conduit such as a pipe or pressure main using, for example, the infuser described in relation to FIG. 14. The fluid extracted from the seam may be collected in a one or more of a series of wells or other containers and may be treated while in the well. Accordingly, aspects of the present invention may be used for fluid preparation and fluid cleanup or restoration.

[0037] As depicted in FIG. 1, a fracking apparatus according to certain aspects of the invention may include a well or storage tank 10. Ozone and/or oxygen may be introduced into well 10 using a spray mechanism 15, which can be mounted on, or suspended from a frame or bracket 11 such that it extends into and is configurable to clean interior of well 10 and to treat a body of liquid 100 contained within well 10. The well-cleaning apparatus may be attached to fasteners 12 at the top of a well 10. It is contemplated that certain embodiments may provide a well-cleaning apparatus within a tank, a drum, a vault or other vessel, conduit or container. For the purpose of description, the terms well, tank, drum, vault, sump or other container will be used henceforth interchangeably as “well 10.” In the example of FIG. 1, a fluid is transmitted through pipe or hose 17 to a conduit 14 and, from there, to spray assembly 15 which directs jets of fluid using deflectors 16 of spray assembly 15. In certain embodiments, spray assembly 15 is rotatably mounted to conduit 14 such that spray assembly 15 may rotate around axis of rotation 13 in order to obtain rotating water jets. Rotation is typically driven by force of water pressure. In operation, jets may provide a spray to the walls of the well, the surface of liquids 100 in the well 10 or tank and other equipment located within the well 10. The hose or pipe 17 is typically coupled to the conduit at coupling 18 and the fluid provided for cleaning can be obtained from an external source of water or derived from an effluent or residual fracturing fluid extracted from a seam and pumped from the well by a submersible or other pump 19. It will be appreciated that, in conventional systems, pump 19, conduit 14, coupling 18 and jets may be subject to clogging, even where the system and its components are designed to pass anticipated solids such as, for example, particulates and solids up to 50 mm in diameter and 90 mm long.

[0038] Certain embodiments of the present invention provide a spray assembly 15 for use in an automatic well washer that can reduce and/or eliminate the occurrence of blockage from accumulation of solid matter in a fluid stream used to wash the well, vault or tank. Referring to FIGS. 2 and 3, a spray assembly according to certain aspects of the invention typically comprises a mixer 20 and one or more deflectors 30 that cooperate to direct a flow of fluid to spray to the walls of the well 10, the surface of liquid 19 in the well 10 and other equipment located within the well 10. Mixer 20 is configured to optimize, control and generate flows and currents that prevent buildup of solid materials in an interior chamber 22 of a mixer 20 and on the deflectors 30. Deflectors 30 are typically used to direct the flow of fluid to a target area for cleaning and may be angled or tilted in a manner that causes the spray head to rotate. The deflectors may have preset tension mechanisms fitted that allow the deflectors to automatically maintain the required revolutions per minute ("RPM") at any given pressure and/or flow, from the mixing chamber outlets, needed for the successful rotation speed of the hydrodynamic mixing chamber so it does not interfere with any fitted level sensors that are existing within the wet well area. These sensors could include ultra sonic, electric float, pressure switch type mechanisms.

[0039] In conventional systems, eddy currents may create areas of low pressure within a spray head and variations in pressure may be observed during a pumping cycle, or when a
flow fluid or liquid through the system and/or when a pump ceases operation. In response to such variations, conventional equipment may become progressively clogged as solids settle at junctions or distributors (e.g. in a tee piece), in small diameter pipe lines, fittings, bends, elbows, valves and areas of low pressure. Clogging can lead to partial or complete obstruction of the system. However, a mixing chamber constructed according to certain aspects of the invention avoids the potential for obstruction.

[0040] Certain embodiments provide a spray assembly 15 that includes mixer 20 having specifically engineered curves calculated to provide clog free operation of washer head using un-filtered stream of fracking fluid and effluent. The example of FIG. 2 shows one embodiment where dimensions are typical for use in many described applications. Radii of curvature, cross-sectional diameters and other dimensions are selected based on parameters attributable to the application, including range of viscosity of the fluid, maximum and minimum size of solids, pressure developed by pump 19 and operating temperatures. Fluid flowing into chamber 22 from inlet 24 is directed to outlets 26 and 28. An impact surface 220 defined generally opposite the inlet is constructed to minimize undesired reflections and resultant waves, eddies and vortices in the fluid. Thus, the fluid flows through chamber 22 relatively smoothly. In some embodiments, the fluid can be caused to swirl, rotate or be otherwise agitated as desired.

[0041] In particular, the structure, location and dimensions of certain curved sections are calculated to enable free flow of un-filtered liquids. Fluid entering a first orifice 24, which serves as an inlet, passes to interior chamber 22 where the flow splits and exits the interior chamber 22 through other orifices 26 and 28 that serve as outlets to vent the liquid. The shape and dimensions of interior chamber 22 are selected to cause deposits of particulates, solids and bio-solids to be rolled and circulated into the liquid passing through the interior chamber 22. Particulates, solids and bio-solids are then pushed by the liquid flow liquid out of outlets 26 and 28.

[0042] In certain embodiments, mixer 20 can cause liquid to flow around solids and otherwise apply pressure to solids which have previously settled within interior chamber 22, including settlements occurring due to end of a pump cycle or during periods of low fluid flow. The structure of interior chamber 22 can create an agitation that causes accumulated particulates, solids and bio-solids to be lifted and circulated and eventually carried through outlets 26 and 28.

[0043] FIG. 3 depicts various views of a deflector 30 that can be used in conjunction with spray assembly 15. One or more deflectors 30 can be attached to mixer 20. In certain embodiments, deflector 30 is designed to respond to hydrodynamic forces created by the liquid as it is expelled through outlets 46 and 48. As the fluid passes over surfaces of the deflector 30, it may exert direct pressure on the surfaces of deflector 30 and/or generate aerodynamic or hydrodynamic pressure differences that cause the desired rotation. Thus, the volume and pressure of the liquid forced out of the mixer 20 can be used to cause and control rotation of the spray assembly. Rotation typically occurs when deflector 30 is suitably angled with respect to the onflow from outlets 26 and 28 and with respect to an axis of rotation 13 of the spray assembly. Thus, deflector 30 may have a "park" angle at which deflector 30 causes no rotational motion.

[0044] In certain embodiments, speed of rotation can be controlled by configuration and position of deflectors 30. A desired speed of rotation can be selected in this manner. Typically the angle of deflector 30 relative to an axis of rotation 13 of the spray assembly is selected to control speed of rotation. Speed of rotation may be automatically controlled to limit rotation to the desired speed of rotation by varying the angle and position of deflectors 30 based on current speed of rotation. In particular, angle and/or position of deflectors 30 may be automatically adjusted in response to changes in pressure and volume of liquid passing through the outlets 26 and 28 of mixer 20. Consequently, the disclosed system may accommodate a broad range of pumps 19 and modes of operation of those pumps 19. For example, the system may accommodate a pump 19 driven at different rates selected to obtain different throughputs.

[0045] In certain embodiments, a pre-tensioned spring system can be used to control angle and or position of deflectors 30 based on actual speed of rotation. Such control can reduce liquid dispersal to a "ribbon action" and can prevent aerosol action and/or misting that can cause release of undesired gas components. In some embodiments, speed of rotation may be automatically controlled using aerodynamic or hydrodynamic elements attached to the deflector and/or mixer 20, whereby the additional elements generate a force resistant to rotation proportional to the speed of rotation of spray assembly 15.

[0046] In certain embodiments, spray assembly 15 may be free to translate along the axis of rotation under the force of the outflow from outlets 26 and 28. Additional mechanisms may adjust the angle and direction of the deflector 30 after translation a predetermined distance, causing a reversal in direction and resulting in an oscillation of the spray assembly 15 that increases the area treated by the system. In certain embodiments the form, size and angle of the deflectors 30 can be used to control surface area of spray coverage.

[0047] The spray assembly 15 may be operated in applications where full-size solids are required to pass through freely without obstruction and clogging at various volumes and pressures. Full-size solids include solids that can pass through an inlet orifice having a predetermined diameter.

[0048] In certain embodiments, liquids containing particulates, solids and bio-solids passing through mixer 20 are typically agitated, oxygenated and homogenized. Moreover, a surface of a liquid contained by the well may be agitated, oxygenated and homogenized by the action of spray assembly 15. In addition to agitation, oxygenation and homogenization substances such as fat, oil, grease and bio-film present on the surface of the liquid in the well may be solubilized. In certain embodiments, mixer 20 can be sized to accommodate other outflows without fixing a new mixing chamber by simply attaching flow reducers to outlet orifices. FIGS. 4 and 5 are engineering drawings showing detailed design information associated with one example of a spray assembly 15 according to certain aspects of the invention.

[0049] FIG. 7 shows an example of a pumping station 70 that may supply a fracking fluid for introduction into a fracking system. A spray assembly 73 used to pretreat the fluid is fitted using bracket 74. Bracket 74 is used in this example to mount the spray head assembly to a pipe. FIG. 8 shows two examples of brackets that can be used: bracket 80 is typically used to mount spray assembly to a wall and bracket 82 has loop fasteners 83 and 84 for attachment to a pipe, as shown in FIG. 7. Spray head 73 can deliver a spray, typically a ribbon spray, which breaks up and prevents build-up of organic and bio-organic material that can include fat, oil, grease and biofilm on surface of well fluid 72. Fluid is pumped from the well
using pumps 71 and 72 and a portion of the pumped fluid is typically extracted from a tap in a pipe 76 or 77 pressurized by the pump; this portion is directed to the spray head assembly 73 for mixing and spraying. As described above, spray head assembly 73 typically includes a hydrodynamic mass transfer mixing chamber that oxygenates fluids, thereby increasing oxygen levels in the well. In one example, fluid mixed in spray assembly 73 has increased dissolved oxygen content that has been measured at 800% or more of the dissolved oxygen observed in conventional systems. Because a portion of the fluid in the well is recycled, particulates and other solids can be homogenized by agitation through the nozzle and by spraying.

[0050] In certain embodiments, the use of the described spray assembly 73 (and see FIG. 6) automates cleaning of the pumping station and reduces maintenance overhead by reducing or eliminating fat, oil, grease and biofilm accumulation, in addition to pretreating the fracking fluid. The spray head 73 may be rotated under the force of fracking fluid flowing or may remain static. Accordingly, the cleaning mechanism can be powered by the pump already available within the pumping station.

[0051] In certain embodiments, the rotary head assembly 73 may be selected from a plurality of different assembly types. The number of nozzles used on the head assembly 73 may vary. In some embodiments, the number of nozzles may be selected to provide maximum coverage when a spray head assembly is fixed and does not rotate, but produces a fixed spray pattern (see FIG. 10). For example, a stationary spray head assembly may be deployed in small diameter wells. However, some variants of the spray head assembly 73 may be differentiaated by a diameter of the intake pipe which may be selected based on the intended application. In one example, a large diameter head assembly may be selected to handle wastewater having relatively large particulates. Larger diameter head assemblies may be used to handle larger fluid flows. Smaller diameter head assemblies may be used where solid content in fluids provided to the head assembly is minimized in size using, for example, a grinding pump. An example of operational characteristics and specifications for various head assemblies provided according to certain aspects of the invention is shown in FIG. 9.

[0052] Certain embodiments of the invention may be used in a variety of water applications, in effluent cleaning stations, and/or fracking fluid supply tanks. The rotary head assembly can be fitted with inserts that modify the flow rate. For example, a ¼" or ⅛" insert can lower flow requirements while providing superior oxygenation, surface agitation, and wash down action. Spray assembly may be mounted on the side of a well or hung from a top edge of the well and can be fed using piping or hoses from a pipe that is driven by the pump. In certain embodiments, the spray assembly can be mounted to one or more pipes including, for example, a pipe that carries fluid driven by a pump, from which pipe the spray assembly 62 (FIG. 6) is fed. It will be appreciated that the pump typically operates when accumulation of waste or other well content increases above a “high-water” threshold and ceases operation when the content falls below a “low-water” threshold. Accordingly, the system can operate intermittently or continuously according to the rate of flow into the well.

[0053] An alternative nozzle can be used in a spray assembly that is configured to handle smaller particulates. A nozzle, such as hydro spear nozzle shown in FIG. 10, can comprise a mixing chamber and delivery system that delivers a ribboned stream of recycled wastewater. Mixing chamber may comprise a reduced size chamber that can promote agitation in order to oxygenate recycled wastewater and to introduce additional turbulence that mitigates obstruction. The resultant spray agitates the surface of the well wastewater, thereby breaking up accumulated fat, oil, grease and biofilm. Increased oxygenation and further homogenization are promoted that breaks down solids further and mixes homogenized matter with air, bacteria, and creates an even dispersal of the matter.

[0054] The spray nozzle assembly 73 in a smaller well may be mounted on the side of a well or hung from a lid or top edge of the well but is typically mounted on a discharge pipe used to feed the spray assembly. The spray assembly is typically fed by tap on a pipe 76 and 77 that communicates fluids driven by a grinder pump (e.g. pump 71 or 72). The spray assembly 73 can operate automatically to clean the well based on the cyclic activity of the grinder pump 71 or 72. The pump typically turns on when accumulation of waste or other well content increases above a “high-water” threshold and turns off when the content falls below a “low-water” threshold. Accordingly, the system can operate intermittently or continuously according to the rate of flow into the well.

[0055] In certain embodiments, a spray assembly may be configured or adapted to deliver chemicals and other additives to the interior of the well, including, for example, one or more of a detergent, an oxidizer (such as O₃ or O₂), bleach, calcium nitrate, ferric chloride, magnesium hydroxide, peroxide, milk of magnesia and/or other chemical selected to target and breakdown a material or group of materials. These additives may be introduced to the well to oxidize compounds that can cause odor and corrosion within fracking fluid treatment systems. It will be appreciated that hydrogen sulfide may react with lime in concrete walls of wells and such reaction can cause structural damage. Hydrogen sulfide may also produce sulfuric acid that can attack and corrode metal and other infrastructure of a well. The oxidation process enabled according to certain aspects of the invention can oxidize sulfides in a wet well, including as it enters a force main, thereby eliminating conditions favorable for anaerobic bacteria to produce H₂S. The oxidation process enabled according to certain aspects of the invention can provide an oxygen/ozone mix that is a powerful oxidant that inhibits incoming anaerobic bacteria present in the wet well/force main by reducing sulfide levels while increasing dissolved oxygen (“DO”). Introduction of ozone and oxygen into the force main can augment these effects.

[0056] With reference also to FIG. 6, certain embodiments of the invention provide one or more input ports for feeding one or more chemicals 610, 611 into the mixing chamber of head assemblies. Input ports may direct one or more chemical feeds 610 and 611 to manifold 66 that, in the example of FIG. 6, mixes the one or more chemicals 610 and 611 with the fluid 61 (from well 70 or pump 71, 72) at, or close to, the point of entry to spray head 60. Input ports can be provided at tap points of pipe 76 or 77 and/or as part of manifold 66 that receives flow 61 from a pump 71 or 72. Spray head assemblies 73 that are used in the described examples of treatment systems typically comprise a hydrodynamic mass transfer mixing chamber that receives fluid 61 from the pump and that mixes the fluid 61 with additives such as chemical feeds 610 and 611 from manifold 66. In the absence of chemical feeds 610 and 611, the mixing chamber improves oxygenation of the fluid 61 by achieving mass transfer as it passes through the
The chemical feeds 610 and 611 may include a feed that improves and/or augments oxygenation. In one example, the one or more chemical feeds may include generated oxygen and or ozone by a higher pressure feed.

Spray head assembly 73 may be mounted to enable rotation of at least a portion of assembly 73, such that nozzles are continuously or continually repositioned in a plane or within a generally cylindrical volume. Rotation is typically powered by the force of pressure of fluid 61, by a pressurized feed 610 or 611 and/or by impact of fluids or solids on vanes provided in the interior of, or on the exterior of the head assembly 73. The mixing chamber is typically constructed to generate turbulence in the fluid, cause mixing and aeration of fluid 61 that is to be applied to the surface of water in a well and/or to the walls of the well.

In certain embodiments, a selection of materials 610, 611 can be added to and mixed with fracking fluid 61 through an input port or a plurality of input ports. The additives can be released intermittently according to a fixed schedule, by manual intervention of maintenance staff and/or in response to a control system configured to measure chemical and biomaterial content and/or build up. In one example, a flow of ozone can be provided to fluid 61 received from a pump 71, 72 at a rate that is determined by one or more factors, including, rate of flow of the fluid 61, quantity of fluid 71 in well 70, measurements of odoriferous, or other undesirable compounds (e.g., hydrogen sulfide) in the well 70. For example, hydrogen sulfide, whether in a gaseous or an aqueous state, is an example of undesirable compounds commonly associated with waste water. A variety of chemicals, organic compounds and/or other products may be mixed with the wastewater and the combination, quantity and/or timing of introduction of such compounds may be controlled based on well conditions and a treatment plan. Treatment plans, schedules and rules may be provided to avoid undesired interactions of the additives. Additives such as oxygen and ozone may be used to enhance breakdown of fat, oil, grease and biofilm. Additives may comprise a detergent, an oxidizer or other chemical selected to target and breakdown a material or group of materials. Additives may also comprise an organism added to effect biological breakdown of materials. As will be appreciated, certain additives may react with or interfere with other additives, or with different additives may be added at different times, typically to achieve different purposes.

In one example, certain embodiments of the invention pretreat contaminated water that contains various levels of sulfide (H₂S) in aqueous and gaseous state, sulfite, sulfates and carbonaceous biochemical oxygen demand (CBOD). Elemental sulfur may be produced and is typically, flushed from the system. Sulfite and sulfate contaminants are typically oxidized to effect change of the aqueous sulfide ion and subsequent sulfur forms. Certain embodiments of the invention enable improved mixing and mass transfer of additives with contaminated water and the increased contact, including time of contact, can improve oxidation of sulfides and sulfates in contaminated water to produce insoluble free sulfur, thereby eliminating or significantly reducing odors.

In one example, hydrogen sulfide and aqueous sulfide is easily oxidized by ozone to form sulfite. Initial oxidation is to form elemental sulfur. Further oxidation dissolves the elemental sulfur to sulfite and continued ozone oxidation ultimately forms sulfate. More ozone is required to produce sulfate from hydrogen sulfide than is required for sulfur. To achieve this, certain embodiments of the invention employ a process of direct injection of concentrated ozone and/or oxygen gas into a flowing stream of contaminated water through a mixing and dispersion system maintained in a well, container, pump station and/or tank, etc., used for treating a body of contaminated water. The mixing and dispersion systems described above can direct a flow of oxidant onto the surface of the body of contaminated water through the delivery system in order to complete the oxidation of aqueous sulfur and to accomplish marginal ancillary disinfection as the introduction of ozone and oxygen as per this method will typically increase the pH within the liquid flow, achieving a pH range of between 6 and 9. The mixing head and nozzle can be provided in a compact form (see FIG. 10) that can be introduced into small or large wells, lift stations, pumping stations and grinder stations.
other undesired gas components that can cause further release of $\text{H}_2\text{SO}_3$ or $\text{H}_2\text{SO}_4$. Systems and methods according to certain aspects of the invention can deliver chemicals such as oxidants, an organism and/or bioactive materials, alone or in proportions that can be adjusted to safely clean, decontaminate and purify wastewater. Chemical additives may be delivered to the interior of the well, including, for example, one or more of a detergent, an oxidizer (such as $\text{O}_2$ or $\text{O}_3$), bleach, calcium nitrate, ferric chloride, magnesium hydroxide, peroxide, milk of magnesia and/or other chemical selected to target and breakdown a material or group of materials. In certain embodiments, an ozone generator 119 may be operated and controlled together with a well monitoring system 116c-116d such that the addition of ozone may be optimized according to application needs and capabilities of the ozone generator 119. A computer-based controller 110 can monitor output of ozone generator 119 and can increase or decrease rate of generation of ozone as necessitated by the consumption of ozone in treating wells 111 and forced or gravity mains 113 and 115. In certain embodiments, the controller 110 may control the flow of wastewater through mains 113 and 115 based on the conditions of available ozone needed to treat the flow of contaminated water. For the purposes of this discussion, mains 113 and 115 can include any combination of force mains or gravity mains. In certain embodiments, water flows through main 115 may originate at an upstream pumping station (not shown) and, for ease of description, it will be assumed that operation of main 115 may be similar to the operation of main 113.

In one example, the levels of fluid in upstream wells can be allowed to increase as needed to allow downstream wells to accumulate sufficient ozone and/or to increase ozone generation to meet increases in demand. Furthermore, the controller may provide ozone to in-line treatment systems 112, 114 for forced mains and gravity mains 113 and 115, based on calculated rates of flow and pumping cycles. For example, when flow of contaminated fluids are increased, a pumping station 111 may not have sufficient time to remove contaminants from the contaminated water and controller 110 may cause increased quantities of ozone or other additives to be introduced to a downstream forced main treatment point 112 in order to effect oxidation of the sulfides in the main 113. Controller 110 typically calculates the rate of introduction of ozone based on measured ozone and contaminants in the main, in addition to measured contaminated water flow rates using the programmed algorithms. Similarly, in response to increases in contaminants associated with inflows from main 115, controller 110 may cause treatment station 114 to increase rate of injection of ozone or other additives to main 115.

A single ozone generator 119 may supply oxygen and ozone to a well 111 and to one or more main 113 that feed or conduct fluid to and/or away from the well 111. The controller 110 may control plural ozone generators 119. For example, if a forced main treatment point 112 or 114 is located at a sufficiently great distance upstream or downstream of a well 111 supplied by the ozone generator 119, it may impractical to feed the remote treatment point from primary generator 119 and a secondary generator (not shown) maybe deployed close to the remote treatment point 12 or 114. Control over the remote generator may be effected using wired or wireless communication network of commands from the controller 110, which may receive remote measurements using the same communication network.

[0067] Forced main treatment site 112, 114 may comprise an injection system that directly injects ozone, oxygen and/or other additives into the main 113, 115. In one example, forced main treatment point 112 or 114 comprises a mixing chamber that receives a portion of the contaminated fluid and adds and/or mixes a treatment chemical or additive before reintroducing the mixed fluid and additive/chemical to the main 113. Controller 110 may directly control operation of treatment station 112, 114 and/or may cooperate with a local controller collocated with, or embodied in treatment station 112, 114, typically control mixing of chemicals/additives based on measured content of contaminant and/or additive or other chemical in the main 113, 115. For example, the rate of addition of ozone may be increased when levels of residual ozone in the main 113 or 115 drop. In some embodiments, rate of addition of chemicals and additives may be controlled based on the rate of flow of fluid through main 113 or 115, the pressure measured in the main 113, 115 and/or the state of operation of a pump 118 in the pumping station 111. For example, downstream station 112 may be operated in a first mode when a pump 118 is actively pumping waste water into force main 113 and may operate in a second mode when the pump 118 is inactive. The modes may be distinguished by the rate of introduction of additive such as ozone, an interval in time between sequential injections of the additive, weighting of measurements from sensors 116a-116b used in a control algorithm, and so on. Activity of the pump may be determined using one or more signals, where the signal may include a signals provided by a sub-component of the controller 110, a pump 118, a valve controlling access to the main 113, a sensor 116b which can be a pressure detector, a flow detector, etc. Force and gravity mains may use different means for determining pump activity: for example, pressure changes may not sufficiently identify pump activity feeding gravity mains.

[0068] In certain embodiments, fluids are treated using a spray assembly placed within a well. The fluids may include treatment of water, including waste water, well water, sewage, storm water, contaminated water, grey water, oil well brines, and so on. The fluid may include solid matter. The spray assembly may be fixed to a well wall, a cover of the well, a top edge of the well, the floor of the well of the well or mounted on one or more pipes or other fixtures located within the well.

[0069] A process for treating the fluid comprises providing a portion of the fluid to the spray assembly. Typically, the portion of the fluid is provided using a pump used to evacuate fluid when the fluid content of the well exceeds a threshold level. The portion of fluid may be diverted through a tap on a pipe pressurized by the pump. The pump may be a grinding pump used to grind the solid matter, thereby reducing the size of solids in the fluid. The process also includes a step of introducing the fluid to a mixing chamber that introduces turbulence to the fluid. The turbulence typically aerates and/or oxygenates the fluid. Materials can be added to the fluid prior to its entry into the mixing chamber. The materials are added through one or more input ports.

[0070] In certain embodiments, the mixing chamber has a curved inner surface which receives the forces of the fluids entering the mixing chamber. The form of the curved surface is selected to minimize clogging and/or adherence of solid matter. Solid matter striking the curved surface is subjected to a force that tends to break apart the solids. The mixing chamber typically provides an output of homogenized, oxygenated fluid to one or more nozzle.
In certain embodiments, the process includes driving the homogenized, oxygenated fluid through the one or more nozzles to obtain a spray. The spray may be a ribbon spray. The process may also include selectively directing the spray to the surface of fluid remaining in the well. The process may also include selectively directing the spray to a wall of the well. The process may also include selectively directing the spray to fittings within the well, where the fittings can include piping, pumps, ladders, and so on. The spray may deliver one or more of the added materials to the fluid in the well, the wall of the well and to other elements of the well.

In some embodiments, the added materials can be released according to a fixed schedule. In some embodiments, the added materials can be released by manual intervention of a person. In some embodiments, the added materials can be released in response to a control system configured to measure chemical and biomaterial content and/or buildup. The added materials may comprise one or more of a chemical, an organic compound and bio-augmentation products. The added materials enhance breakdown of one or more materials that can include fat, oil, grease and bio-film. The added materials may comprise a detergent, an oxidizer or other chemical selected to target and breakdown a material or group of materials and may further comprise an organism added to effect biological breakdown of materials.

In certain embodiments, the process includes causing the spray to cyclically treat portions of the well. In some embodiments, cyclically treating includes causing a portion of the spray assembly to rotate. Causing a portion of the spray assembly to rotate may include providing a portion of the spray to one or more vanes that, through hydrodynamic action cause a portion of the spray assembly to rotate around a rotatable joint. In some embodiments, cyclically treating includes cycling the pump such that washing occurs at intervals of time. The intervals of time may coincide with cycles of pumping fluids from the well through a force main. The intervals may be calculated by a control system.

In certain embodiments, a computer-based control system 110 is employed to control treatment operations. As depicted in FIG. 11, a computer system 110 receives inputs from a variety of sensors 116 to 116/ located inside and around the well as well as in association with mains 113 upstream and downstream of the well. An example of a computer system is described in more detail below. Sensors 116 to 116/ may be used to monitor a plurality of operating parameters and may, for example, be used to detect pressures in forced mains, fluid levels in wells, presence of certain chemicals in the well, in feed pipes and in forced mains. Sensors 116 to 116/ may additionally be provided in components of the system, including in one or more pumps 118, within a body of fluid in well 111 or mains 113, in main treatment stations 112, in oxygen generator 119 and/or ozone storage tanks (not shown, but typically a component of generators 119) and/or external to the system (see sensor 116/ / ) and deployed to obtain measurements of environmental conditions and contamination. The computing system 110 may provide control signals to pumps 118, valves, oxygen generators associated with the well. For example, one of pumps 118 may be operated to evacuate a portion of a body of waste water contained in a well, while another of pumps 118 may be used to drive a portion of the waste water to a fracking system that comprises a nozzle and mixing chamber. It is contemplated that the fracking system may operate using a pump 118 that evacuates a portion of the well to an outflow main and that cleaning and evacuation may be concurrent and/or may be asynchronously provided using a system of valves controlled by the controller 110. The computer system may also be used to directly control, interact with, and/or monitor systems deployed to directly control the operation of other treatment systems, including, for example, forced main treatment systems.

In one example, a forced main treatment system may receive ozone from an ozone generator and may pump the ozone into the forced main to control odors. Accordingly, sensors may be deployed to detect the presence of compounds and ions that include sulfur, hydrogen sulfide, ammonia and other gases or compounds that may give rise to odors or harmful chemical effects. As appropriate, the computing system may initiate ozone pumping in a forced main or other pipe to control the level of gas and odor. Sensors and ozone pumping devices typically form a closed loop control system that is configured to control the rate of release of ozone and total volume of release to counteract the level of sulfide or hydrogen sulfide detected. These sensors may also detect oxygen deficiency and or concentrations that infringe upon recognized lower explosive limit (LEL), upper explosive limit (UEL) and/or OSHA permissible exposure limits (PEL's) required for safety regulation. Other chemicals and organic materials may be monitored to identify direct cause of undesirable effects and to help identify causal agents such as bacteria and/or other organic materials that can be treated by release of chemicals, organic compounds and/or bio-augmentation products may be mixed with the wastewater. Additives may be used to enhance breakdown of fat, oil, grease and bio-film. Additives may comprise a detergent, an oxidizer (such as O₂ or O₃), bleach, calcium nitrate, ferric chloride, magnesium hydroxide, peroxide, milk of magnesia and/or other chemical selected to target and breakdown a material or group of materials.

The computing system may monitor flow of fluids in the fracking system and in forced mains to determine the rate of introduction of additives. The rate may be capped to prevent an excess of additive that would be wasted if released into the system. Typically, the system can control the rate of pumping of waste fluids and can calculate the amount of additive to be introduced into the well and/or forced main and therefore can accurately calculate the rate of release of materials for a known time during which pumping occurs. Typically, release of additives is suppressed when well pumps are inactive; however, it is possible to pump ozone and other additives to address buildup of undesirable chemicals and organic products. In a forced main, a portion of the fluid in the main can be diverted for mixing with the additive and pumped back into the main. In a well, the well pump or an auxiliary pump may be used to provide a carrier fluid for introducing the additive.

The computing system may communicate with sensors, pumps, additive dispensers, ozone generators/pumps using wired or wireless communication methods, such communication methods being well known to those in the data communication and computing arts. In the example of forced main treatment systems, considerable distance may exist between well and forced main treatment system and communication may often include a wireless network. In the latter example, benefit can be accrued by controlling both systems using a common controller. In one example, the forced main treatment system may have limited capacity and, the controller may selectively increase levels of additive in the well such
that when the fluid is pumped into the forced main, residual levels of the additive continue to neutralize undesirable agents, chemicals and organic matter. In another example, a single ozone generator may provide ozone to both the well systems and the forced main system and a degree of balancing may be required where the ozone generator has limited capability.

[0078] Turning now to FIG. 12, certain embodiments of the invention employ a processing system that includes at least one computing system 1200 deployed to perform certain of the steps described above. Computing systems may be a commercially available system that executes commercially available operating systems such as Microsoft Windows®, UNIX or a variant thereof, Linux, or a real time operating system and/or a proprietary operating system. The architecture of the computing system may be adapted, configured and/or designed for integration in the processing system, for embedding in one or more of an image capture system, a manufacturing/machining system, and/or a graphics processing workstation. In one example, computing system 1200 comprises a bus 1202 and/or other mechanisms for communicating between processors, whether those processors are integral to the computing system 120 (e.g. 1204, 1205) or located in different, perhaps physically separated computing systems 1200. Device drivers 1203 may provide output signals used to control internal and external components.

[0079] Computing system 1200 also typically comprises memory 1206 that may include one or more of random access memory (“RAM”), static memory, cache, flash memory and any other suitable type of storage device that can be coupled to bus 1202. Memory 1206 can be used for storing instructions and data that can cause one or more of processors 1204 and 1205 to perform a desired process. Main memory 1206 may be used for storing transient and/or temporary data such as variables and intermediate information generated and/or used during execution of the instructions by processor 1204 or 1205. Computing system 1200 also typically comprises non-volatile storage such as read only memory (“ROM”) 1208, flash memory, memory cards or the like; non-volatile storage may be connected to the bus 1202, but may equally be connected using a high-speed universal serial bus (USB), Firewire or other such bus that is coupled to bus 1202. Non-volatile storage can be used for storing configuration, and other information, including instructions executed by processors 1204 and/or 1205. Non-volatile storage may also include mass storage device 1210, such as a magnetic disk, optical disk, flash disk that may be directly or indirectly coupled to bus 1202 and used for storing instructions to be executed by processors 1204 and/or 1205, as well as other information.

[0080] Computing system 1200 may provide an output for a display system 1212, such as an LCD flat panel display, including touch panel displays, electroluminescent display, plasma display, cathode ray tube or other display device that can be configured and adapted to receive and display information to a user of computing system 1200. Typically, device drivers 1203 can include a display driver, graphics adapter and/or other modules that maintain a digital representation of a display and convert the digital representation to a signal for driving a display system 1212. Display system 1212 may also include logic and software to generate a display from a signal provided by system 1200. In that regard, display 1212 may be provided as a remote terminal or in a session on a different computing system 1200. An input device 1214 is generally provided locally or through a remote system and typically provides for alphanumeric input as well as cursor control 1216 input, such as a mouse, a trackball, etc. It will be appreciated that input and output can be provided to a wireless device such as a PDA, a tablet computer or other system suitable equipped to display the images and provide user input.

[0081] Processor 1204 executes one or more sequences of instructions. For example, such instructions may be stored in main memory 1206, having been received from a computer-readable medium such as storage device 1210. Execution of the sequences of instructions contained in memory 1206 causes processor 1204 to perform process steps according to certain aspects of the invention. In certain embodiments, functionality may be provided by embedded computing systems that perform specific functions wherein the embedded systems employ a customized combination of hardware and software to perform a set of predefined tasks. Thus, embodiments of the invention are not limited to any specific combination of hardware circuitry and software.

[0082] The term “computer-readable medium” is used to define any medium that can store and provide instructions and other data to processor 1204 and/or 1205, particularly where the instructions are to be executed by processor 1204 and/or 1205 and/or other peripheral of the processing system. Such medium can include non-volatile storage, volatile storage and transmission media. Non-volatile storage may be embodied on media such as optical or magnetic disks, including DVD, CD-ROM and BluRay. Storage may be provided locally and in physical proximity to processors 1204 and 1205 or remotely, typically by use of network connection. Non-volatile storage may be removable from computing system 1204, as in the example of BluRay, DVD or CD storage or memory cards or sticks that can be easily connected or disconnected from a computer using a standard interface, including USB, etc. Thus, computer-readable media can include floppy disks, flexible disks, hard disks, magnetic tape, any other magnetic medium, CD-ROMs, DVDs, BluRay, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, RAM, PROM, EPROM, FLASH/EEPROM, any other memory chip or cartridge, or any other medium from which a computer can read.

[0083] Transmission media can be used to connect elements of the processing system and/or components of computing system 1200. Such media can include twisted pair wiring, coaxial cables, copper wire and fiber optics. Transmission media can also include wireless media such as radio, acoustic and light waves. In particular radio frequency (RF), fiber optic and infrared (IR) data communications may be used.

[0084] Various forms of computer readable media may provide instructions and data for execution by processor 1204 and/or 1205. For example, the instructions may initially be retrieved from a magnetic disk of a remote computer and transmitted over a network or modem to computing system 1200. The instructions may optionally be stored in a different storage or a different part of storage prior to or during execution.

[0085] Computing system 1200 may include a communication interface 1218 that provides two-way data communication over a network 1220 that can include a local network 1222, a wide area network or some combination of the two. For example, an integrated services digital network (ISDN) may be used in combination with a local area network (LAN). In another example, a LAN may include a wireless link. Net-
work link 1220 typically provides data communication through one or more networks to other data devices. For example, network link 1220 may provide a connection through local network 1222 to a host computer 1224 or to a wide area network such as the Internet 1228. Local network 1222 and Internet 1228 may both use electrical, electromagnetic or optical signals that carry digital data streams.

[0086] Computing system 1200 can use one or more networks to send messages and data, including program code and other information. In the Internet example, a server 1230 might transmit a requested code for an application program through Internet 1228 and may receive in response a downloaded application that provides for the anatomical delineation described in the examples above. The received code may be executed by processor 1204 and/or 1205.

[0087] FIG. 13 is a flow chart illustrating a process for controlling operation of the simplified example shown in FIG. 11. At step 130, an inflow of contaminated fracking fluid to pump station 111 is detected. Sensors in station 111 are monitored to determine levels of contaminants and levels of fluid in the station 111. As necessary, the body of fluid may be treated at step 132 with a flow of fluid obtained from the station 111 that has been mixed with additives that comprise ozone received from ozone generator 119. If the level of fluid in the station 111 is detected at step 134 to exceed a threshold level, then a portion of the fluid may be pumped through forced main 113 at step 136. It is contemplated that, in some embodiments, the portion of fluid may be provided to a gravity fed main. At step 138, ozone may be selectively provided to main 113 based on measurements of conditions in the main 113. Ozone is typically added to main 113 using treatment station 112.

[0088] In certain embodiments, computing system 110 can monitor upstream, downstream and in-station conditions and can adjust flow of additives according to detected conditions. Additives may include ozone from ozone generator 119 and/or oxygen and other chemicals. The computing system 110 may comprise an industrial controller collocated with the station 111, a forced main treatment location 112 and/or an ozone generator 119. The computing system 110 may be at least partially embodied in a remote device such as a network server. In operation, computing system monitors the presence of one or more contaminants and may control one or more of the quantity and the rate of introduction of oxidant or additive accordingly. For example, the interval between treatments may be increased or decreased based on rate of inflow and/or rate of increase of contaminants measured in the station 111. The quantity of oxidant may be increased or decreased according to conditions in the well. For example, a sudden inflow of waste water may result in a step increase of contaminants that may be best treated with short-term increase in the amount of additive provided to the station 111.

[0089] In certain embodiments, computing system 110 may pre-treat inflows by causing a treatment station (not shown) on an inflow force main 115 to inject oxidants into the force main 115. Pre-treatment may be performed periodically and/or in response to changes in measured contaminant levels measured in the inflow force main 115 or in inflows received at a pumping station 111. In certain embodiments, computing system 110 may cause a treatment station 112 on an outflow force main 113 to inject oxidants into the force main 113. Treatment at the outflow main 113 may be performed according to a schedule and/or may be performed based on measured levels of contaminants and/or additives in the force main 113. Treatment of force main 113 may also be initiated by computing system 110 based on contaminant levels measured in the pumping station 111 as the waste water is pumped into force main 113. Computing system 110 can typically be configured to adjust treatment plans, schedules and levels based on whether an inflow or outflow main is a force main or gravity main and/or based on whether a main treatment system 112 is available on the inflow or outflow main.

[0090] In certain embodiments, a control algorithm is executed by the computing system 110 to control treatment of the waste water system. Control algorithm is typically configured to manage a closed-loop system that includes additive injection elements and instruments that measure controlled chemicals and/or additives in the system. The wastewater treatment system may comprise multiple pump and/or grinder stations 111 interconnected by force and/or gravity mains, whereby the outflow main of one station serves as the inflow main of another station. Control algorithm can typically be configured to model force and gravity mains in the system and may model throughputs, lengths of mains. Control algorithm may be adaptive such that variations from expected performance or capacity of an element can be incorporated into a model of the element. Certain embodiments automatically adjust to environmental conditions, including ambient temperature and humidity, and these systems may adjust treatment schedules and schemes based on prior histories of measurements under similar conditions.

[0091] Certain embodiments comprise systems and methods for gas infusion to an unfiltered liquid particle saturation device. A gas infusion device may be operated pneumatically or by force of vacuum. In certain embodiments, the device operates as an alternating multistage side stream gas infusion device. A closed loop system may infuse gas into a liquid in multiple stages. The gas, gasses, and/or other fluids may be infused into a side stream of liquid diverted or extracted from a greater body of liquid flow, where the side stream may comprise a relatively small fraction of the total volume of liquid to be treated. The side stream may be drawn from a main, feed pipe, pressure vessel, etc. in alternating succession over a timed cycle so to achieve regular constant saturation of gas into the side stream liquid. The side stream liquid may then be reintroduced into a greater body of liquid flow, and the treated side stream may be pressurized to a greater pressure than the pressure of the main body of liquid. Accordingly, the returned side stream fluid may be mixed with the main body fluid and extends treatment to the main body.

[0092] As depicted in the example of FIGS. 14 and 15, an infusion device 1404 may be mounted in proximity to a pipe 1402 carrying a fluid to be treated. In one example, pipe 1402 may be a force main carrying wastewater. The infusion device 1404 may be coupled to the pipe by one or more mechanically taps 1406, 1408. The taps 1406, 1408 may be sized as appropriate for the application. The infusion device 1404 can be fitted back to back in modular way so to increase the infusion treatment process within a shorter time period.

[0093] The diffusion device 1404 is depicted in block schematic form generally at 1404. In certain embodiments, a first stage comprises a chamber A 1424, which is closed to atmosphere by an actuated valve B 1420 and actuated valve C 1430. Chamber A 1424 is filled with a gas mixture at a desired pressure. After chamber A 1424 is filled, Valve B 1420 is
opened to allow the flow of liquid 1410 from a fluid filled pipe 1402 to pass through the mechanically tapped point inlet port 1406 into hydrodynamic mixing chamber E 1422. The flow of liquid may be derived from a pressurized system and may therefore have a pressure that is greater than atmospheric pressure. The flow of liquid may then be introduced into chamber A 1424, where it is mixed with the gas mixture present in chamber A 1424. When pressure equalization occurs, such that chamber A 1424 is filled to the point where the influent cannot overcome the pressure of the fluid in chamber A 1424, Valve B 1420 is closed to seal chamber A 1424.

[0094] Next, compressed gas F 1428 may be provided, where Gas F 1428 may comprise oxygen and/or air, for example. Gas F 1428 is forced into Chamber A 1424 at a greater pressure than the influent pressure (i.e. the pressure achieved when valve B 1420 was closed). The introduction of compressed gas F 1428 increases pressure in Chamber A 1424 until a predefined pressure is achieved, or pressure equalization occurs. Flow of compressed gas F 1428 may be stopped, by flow control apparatus or through pressure equalization, and valve C 1430 is opened to enable evacuation of the treated fluid from Chamber A 1424, which may comprise a saturated liquid. The saturated liquid may be forced into hydrodynamic mixing chamber G 1432, and from there through shearing nozzle H 1434, through non return valve I 1436 and through mechanically tapped outlet port 1408 into the fluid filled pipe 1402.

[0095] In certain embodiments, a second stage includes closing valve C 1430 when chamber A 1424 is evacuated, thereby creating a sealed chamber and vacuum pump J 1440 may then be activated to evacuate excess residual pressurized atmosphere into chamber A 1442. Treatment gas 1428 may be simultaneously fed into a venturi of vacuum pump J 1440, creating a draw of gas by vacuum along with excess pressurized atmosphere of chamber A 1424 into chamber A 1442 until a specified volume of treatment gas and/or specified volume and pressure of compressed gas has been delivered into chamber A 1442. When treatment gas volume and pressure reach a predefined threshold, then vacuum pump J 1440 may be closed.

[0096] In certain embodiments, a third stage includes actuating Valve Bb in order to close chamber Aa to atmosphere while valve Cc is closed. Chamber Aa may then be filled with a treatment gas mixture at a desired pressure. When chamber Aa is filled and/or pressurized, valve Bb 1444 may be opened to allow a flow of liquid from fluid filled pipe 1402, which is typically pressurized to an operating pressure, to pass through the mechanically tapped point inlet port 1406 of the device into a hydrodynamic mixing chamber 1446. From chamber 1446, the flow may be provided into chamber Aa 1442, where it is mixed with the gas present in chamber Aa 1442. When chamber Aa 1442 is filled, such that pressure equalization occurs with regard to the operating pressure of the fluid flow, valve Bb 1444 may be closed to seal chamber Aa 1442. When valve Bb 1444 is closed, compressed gas 1428 flow, comprising oxygen and/or air, for example, may be forced into chamber Aa 1442 at a greater pressure than the equalized pressure in chamber Aa 1442 until a desired higher pressure is achieved. When the desired higher pressure is achieved, typically using a compressed gas 1428 flow, compressed gas 1428 flow stops actuated valve 1448 is opened. Chamber Aa 1442 is evacuated and purged of saturated liquid. Said saturated liquid under pressure is forced into hydrodynamic mixing chamber G 1432 then through shearing nozzle 1434, through non return valve I 1436 and then through mechanically tapped outlet port 1408 into the fluid filled pipe 1402.

[0097] In certain embodiments a fourth stage comprises closing a valve Cc 1448 when chamber Aa 1442 is evacuated, thereby creating a sealed chamber. A vacuum pump K (not shown) may be activated to evacuate excess residual pressurized atmosphere into chamber A 1424 during which time treatment gas is fed under low pressure into vacuum pump K venture, thereby creating a draw of gas by means of the vacuum along with excess pressurized atmosphere of chamber Aa 1442 into chamber A 1424, until a desired or predetermined volume of treatment gas and/or a desired or predetermined volume and pressure of compressed gas have been delivered into chamber A 1424. When treatment gas volume and pressure have achieved appropriate levels, then vacuum pump K is closed.

[0098] This four stage cycle may be repeated for the full duration of treatment process over prescribed time frame. In some embodiments, valves, vacuum pumps and other pneumatic components may be controlled using a processor, programmable logic controller (PLC), or the like. In certain embodiments, the treatment process may be affected with the addition of a dedicated liquid pump. The system may be employed with wastewater, grey water and other fluids containing particles that have a size of up to at least 50 mm.

[0099] Certain embodiments provide systems and methods for treating water in a force main. Some embodiments comprise conducting a portion of untreated fluid from a main into a first chamber. Some embodiments comprise sealing the first chamber. Some embodiments comprise infusing a treatment gas into the fluid in the first chamber under force of pressure of the treatment gas. Some embodiments comprise returning the fluid from the first chamber to the main.

[0100] In some embodiments, returning the fluid includes pressurizing the fluid in the first chamber. In some embodiments, the fluid is pressurized using compressed nitrogen. In some embodiments, the fluid is pressurized using compressed air. Some embodiments comprise mixing the fluid with the treatment gas in a second chamber. In some embodiments, the second chamber comprises a hydrodynamic mixing chamber. In some embodiments, the treatment gas comprises oxygen. In some embodiments, the treatment gas comprises ozone. In some embodiments, the treatment gas comprises air.

Additional Descriptions of Certain Aspects of the Invention

[0101] The foregoing descriptions of the invention are intended to be illustrative and not limiting. For example, those skilled in the art will appreciate that the invention can be practiced with various combinations of the functionalities and capabilities described above, and can include fewer or additional components than described above. Certain additional aspects and features of the invention are further set forth below, and can be obtained using the functionalities and components described in more detail above, as will be appreciated by those skilled in the art after being taught by the present disclosure.

[0102] Certain embodiments of the invention provide fluid treatment systems and methods. In some embodiments, the system comprises a collection station having a well for collecting fluid extracted from a subterranean seam during a subterraneous operation.

[0103] In some embodiments, the system comprises a dispersion system that receives a portion of collected fluid from the well. The dispersion system may comprise a hydrody-
dynamic mixing chamber and a nozzle. An additive comprising one or more of ozone and oxygen may be mixed with a portion of collected fluid passing through the mixing chamber. The nozzle may disperse a mixture of the collected fluid and additive received from the mixing chamber.

In some embodiments, the system comprises a controller having at least one processor. The processor may be configured to monitor the level of the additive in the well. The processor may be configured to cause a portion of the fluid to be pumped from the well through an outflow main when the level of fluid in the well exceeds a threshold level, when the concentration of contaminant exceeds a threshold level and/or the concentration of additive reaches a desired level. The processor may be configured to control a rate of flow of the additive to the mixing chamber. In some embodiments, the dispersion system comprises a manifold that communicates the portion of fluid and the additive to the mixing chamber.

In some embodiments, the additive comprises liquid ozone. The controller may control rate of flow of the liquid ozone based on measurements provided by sensors deployed in the well. The measurements may include a measurement of residual ozone level in the fluid collected in the well. The measurements may include a measurement of sulfide in the fluid collected in the well. The measurements may include a measurement of hydrogen sulfide in the well.

In some embodiments, the controller is configured to control one or more of an inflow treatment system and an outflow treatment system. The outflow treatment system may mix ozone with fluid pumped from the well. The outflow treatment system may mix ozone with fluid in a pipe providing the fluid to be collected by the well. At least a portion of the fluid pumped from the well may be introduced or reintroduced to the subterranean seam. The additive may comprise a proppant.

In some embodiments, a method for treating a fluid extracted from a subterranean seam comprises collecting a fluid extracted from the subterranean seam, mixing an additive comprising one or more of oxygen and ozone with the fluid collected from the subterranean seam in a hydrodynamic mixing chamber of a dispersion system, and controlling the rate of flow of an additive to the mixing chamber based on a measured concentration of the additive or a contaminant in the fluid collected from the subterranean seam and a rate of flow of the fluid collected from the subterranean seam. The hydrodynamic mixing chamber may provide a mixture of the fluid through a nozzle of the dispersion system to the fluid collected from the subterranean seam. The additive may comprise liquid ozone.

In some embodiments, the fluid from the subterranean seam may be collected in a containment vessel. The method may comprise measuring a concentration of at least one contaminant in the containment vessel. The method may comprise measuring a concentration of at least one contaminant in the containment vessel when the concentration of the at least one contaminant in the well exceeds a threshold concentration.

In some embodiments, the fluid from the subterranean seam is collected in a containment vessel. The method may comprise measuring a concentration of at least one contaminant in the containment vessel, and increasing the rate of flow of the additive when the concentration of at least one contaminant measured in the containment vessel exceeds a first predetermined threshold concentration. The method may comprise causing an upstream treatment station to introduce the additive to an inflow of the containment vessel when the at least one contaminant measured in the containment vessel exceeds a second predetermined threshold concentration.

Certain embodiments comprise a computer program product, including a computer-readable medium comprising code for: collecting a fluid extracted from a subterranean seam, mixing an additive comprising one or more of oxygen and ozone with the fluid collected from the subterranean seam in a hydrodynamic mixing chamber of a dispersion system, controlling the rate of flow of an additive to the mixing chamber based on a measured concentration of the additive or a contaminant in the fluid collected from the subterranean seam and a rate of flow of the fluid collected from the subterranean seam. The hydrodynamic mixing chamber may provide a mixture of the fluid through a nozzle of the dispersion system to the fluid collected from the subterranean seam. The additive may comprise liquid ozone and the fluid from the subterranean seam may be collected in a containment vessel. The computer-readable medium may comprise code for measuring a concentration of at least one contaminant in one or more of the containment vessel, an inflow of the containment vessel, and an outflow from the containment vessel. The computer-readable medium may comprise code for directing at least one of an upstream treatment station and a downstream treatment station to introduce the additive in the inflow or the outflow when the measured concentration of the at least one contaminant exceeds a predetermined threshold concentration.

Certain embodiments provide an apparatus for treating fluid extracted from a subterranean seam. A processing system of the apparatus may be configured to collect a fluid extracted from the subterranean seam and mix an additive comprising one or more of oxygen and ozone with the fluid in a hydrodynamic mixing chamber of a dispersion system. The hydrodynamic mixing chamber may provide a mixture of the additive and fluid through a nozzle of the dispersion system to the fluid collected from the subterranean seam. The processing system of the apparatus may be configured to control the rate of flow of an additive to the mixing chamber based on a measured concentration of the additive or a contaminant in the fluid collected from the subterranean seam and a rate of flow of the fluid collected from the subterranean seam. The additive may comprise liquid ozone. The fluid from the subterranean seam may be collected in a containment vessel, and the processing system may be configured to measure a concentration of at least one contaminant in one or more of the containment vessel, an inflow of the containment vessel, and an outflow from the containment vessel. The processing system may be configured to direct at least one of an upstream treatment station and a downstream treatment station to intro-
duce the additive in the inflow or the outflow when the measured concentration of the at least one contaminant exceeds a predetermined threshold concentration.

The claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. §112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or, in the case of a method claim, the element is recited using the phrase "step for:"

1. A treatment system comprising:
   a collection station having a well for collecting fluid extracted from a subterranean seam during a steam fracturing ("fracking") operation;
   a dispersion system that receives a portion of collected fluid from the well, the dispersion system comprising a hydrodynamic mixing chamber and a nozzle, wherein an additive comprising one or more of ozone and oxygen is mixed with a portion of collected fluid passing through the mixing chamber, and wherein the nozzle disperses a mixture of the collected fluid and additive received from the mixing chamber; and
   a controller comprising one or more processors configured to:
   monitor the level of the additive in the well,
   cause a portion of the fluid to be pumped from the well through an outflow main when the level of fluid in the well exceeds a threshold level, and
   control a rate of flow of the additive to the mixing chamber.

2. The treatment system of claim 1, wherein the dispersion system comprises a manifold that communicates the portion of fluid and the additive to the mixing chamber.

3. The treatment system of claim 1, wherein the additive comprises liquid ozone.

4. The treatment system of claim 3, wherein the controller controls rate of flow of the liquid ozone based on measurements provided by sensors deployed in the well.

5. The treatment system of claim 4, wherein the measurements include a measurement of residual ozone level in the fluid collected in the well.

6. The treatment system of claim 4, wherein the measurements include a measurement of sulfide in the fluid collected in the well.

7. The treatment system of claim 4, wherein the measurements include a measurement of hydrogen sulfide in the well.

8. The treatment system of claim 1, wherein the controller is configured to control one or more of an inflow treatment system and an outflow treatment system, wherein the outflow treatment system mixes ozone with fluid pumped from the well, and wherein the outflow treatment system mixes ozone with fluid in a pipe providing the fluid to be collected by the well.

9. The treatment system of claim 8, wherein at least a portion of the fluid pumped from the well is introduced to the subterranean seam.

10. The treatment system of claim 9, wherein the additive comprises a proppant.

11. A method for treating a fluid extracted from a subterranean seam, comprising the steps of:
    collecting a fluid extracted from the subterranean seam;
    mixing an additive comprising one or more of oxygen and ozone with the fluid collected from the subterranean seam in a hydrodynamic mixing chamber of a dispersion system, wherein the hydrodynamic mixing chamber provides a mixture of the fluid through a nozzle of the dispersion system to the fluid collected from the subterranean seam;
    and controlling the rate of flow of an additive to the mixing chamber based on a measured concentration of the additive or a contaminant in the fluid collected from the subterranean seam and a rate of flow of the fluid collected from the subterranean seam.

12. The method of claim 11, wherein the additive comprises liquid ozone.

13. The method of claim 12, wherein the fluid from the subterranean seam is collected in a containment vessel, and further comprising the steps of:
    measuring a concentration of at least one contaminant in an outflow from the containment vessel;
    and causing a downstream treatment station to mix the additive with fluid in the outflow when the measured concentration of the at least one contaminant exceeds a predetermined threshold concentration.

14. The method of claim 13, wherein the outflow is conducted away from the containment vessel in a force main, and further comprising the steps of:
    detecting whether fluid is flowing in the force main;
    and causing a downstream treatment station to introduce ozone into the force main when fluid is flowing in the force main.

15. The method of claim 14, wherein the fluid from the subterranean seam is collected in a containment vessel, and further comprising the steps of:
    measuring a concentration of at least one contaminant in the containment vessel;
    and causing an upstream treatment station to pre-treat the fluid in an inflow to the containment vessel when the concentration of the at least one contaminant in the well exceeds a threshold concentration.

16. The method of claim 12, wherein the fluid from the subterranean seam is collected in a containment vessel, and further comprising the steps of:
    measuring a concentration of at least one contaminant in the containment vessel;
    increasing the rate of flow of the additive when the concentration of at least one contaminant measured in the containment vessel exceeds a first predetermined threshold concentration; and
    causing an upstream treatment station to introduce the additive to an inflow of the containment vessel when the at least one contaminant measured in the containment vessel exceeds a second predetermined threshold concentration.

17. A computer-readable medium comprising code for:
    collecting a fluid extracted from a subterranean seam;
mixing an additive comprising one or more of oxygen and ozone with the fluid collected from the subterranean seam in a hydrodynamic mixing chamber of a dispersion system, wherein the hydrodynamic mixing chamber provides a mixture of the fluid through a nozzle of the dispersion system to the fluid collected from the subterranean seam; and controlling the rate of flow of an additive to the mixing chamber based on a measured concentration of the additive or a contaminant in the fluid collected from the subterranean seam and a rate of flow of the fluid collected from the subterranean seam.

18. The computer program product of claim 17, wherein the additive comprises liquid ozone, wherein the fluid from the subterranean seam is collected in a containment vessel, and wherein the computer-readable medium comprises code for:

measuring a concentration of at least one contaminant in one or more of the containment vessel, an inflow of the containment vessel, and an outflow from the containment vessel; and directing at least one of an upstream treatment station and a downstream treatment station to introduce the additive in the inflow or the outflow when the measured concentration of the at least one contaminant exceeds a pre-determined threshold concentration.

19. An apparatus for treating fluid extracted from a subterranean seam, comprising:

- a processing system configured to:
  - collect a fluid extracted from the subterranean seam;
  - mix an additive comprising one or more of oxygen and ozone with the fluid in a hydrodynamic mixing chamber of a dispersion system, wherein the hydrodynamic mixing chamber provides a mixture of the additive and fluid through a nozzle of the dispersion system to the fluid collected from the subterranean seam; and
  - control the rate of flow of an additive to the mixing chamber based on a measured concentration of the additive or a contaminant in the fluid collected from the subterranean seam and a rate of flow of the fluid collected from the subterranean seam.

20. The apparatus of claim 19, wherein the additive comprises liquid ozone, wherein the fluid from the subterranean seam is collected in a containment vessel, and wherein the processing system is configured to:

- measure a concentration of at least one contaminant in one or more of the containment vessel, an inflow of the containment vessel, and an outflow from the containment vessel; and
- direct at least one of an upstream treatment station and a downstream treatment station to introduce the additive in the inflow or the outflow when the measured concentration of the at least one contaminant exceeds a pre-determined threshold concentration.