8-1-2011

Bring Your Own Water Treatment System: United States patent

Evan A. Thomas
Portland State University

Maximilian Gold

Citation Details
Gold, M., Thomas, E., Bring Your Own Water Treatment SystemUnited States Patent US 8,002,993 B2, issued August 23, 2011

US008002993B2

(12) **United States Patent**
Gold et al.

(10) **Patent No.: US 8,002,993 B2**
(45) **Date of Patent: Aug. 23, 2011**

(54) **BRING YOUR OWN WATER TREATMENT SYSTEM**

(76) Inventors: **Maximilian Gold**, Boulder, CO (US); **Evan A. Thomas**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/129,026**

(22) Filed: **May 29, 2008**

(65) **Prior Publication Data**

US 2008/0296227 A1 Dec. 4, 2008

Related U.S. Application Data

(60) Provisional application No. 60/932,221, filed on May 30, 2007.

(51) **Int. Cl.**
B01D 37/00 (2006.01)

(52) **U.S. Cl.** **210/748.11**; 210/792; 210/804; 210/807; 210/138; 210/265; 210/275

(58) **Field of Classification Search** .... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,677,405	A *	7/1972	Keith, Jr.	210/774
3,965,004	A *	6/1976	Garber	210/691
4,021,347	A *	5/1977	Teller et al.	210/195.1
4,145,279	A *	3/1979	Selby, III	210/614
4,849,100	A	7/1989	Papandrea	
5,258,121	A *	11/1993	Jordan et al.	210/605
5,462,674	A *	10/1995	Butters et al.	210/748.11
5,466,367	A *	11/1995	Coate et al.	210/96.1
5,593,574	A *	1/1997	VanToever	210/150
5,597,479	A *	1/1997	Johnson	210/192
5,679,257	A *	10/1997	Coate et al.	210/695
5,792,369	A *	8/1998	Johnson	210/748.12
5,843,304	A *	12/1998	Marchesseault et al.	210/143
5,868,927	A *	2/1999	Smith et al.	210/202
5,993,659	A *	11/1999	Schenk et al.	210/618
6,077,431	A *	6/2000	Kawanishi et al.	210/609
6,436,283	B1	8/2002	Duke	
6,802,981	B2 *	10/2004	Ryazanova et al.	210/726
6,916,427	B2 *	7/2005	Roth	210/709
6,926,878	B2	8/2005	Santina	
7,153,060	B1	12/2006	Bennion	
2003/0205535	A1 *	11/2003	Roth	210/748
2008/0296227	A1 *	12/2008	Gold et al.	210/663
2009/0176300	A1 *	7/2009	Gallagher et al.	435/290.1

OTHER PUBLICATIONS

Installation, Operation and Maintenance Owner's Manual, "Sterilight silver uv disinfection," Oct. 2006, pp. 1-18, Ontario, Canada.
Triangular Wave Technologies, Inc. Fluid Management Solutions in brochure "Triangular Wave Technologies Patent Ultra-Violet Disinfection System," New Jersey, USA.
Zarges "Packaging, transportation, storage," pp. 1-99, Weilheim, Germany.

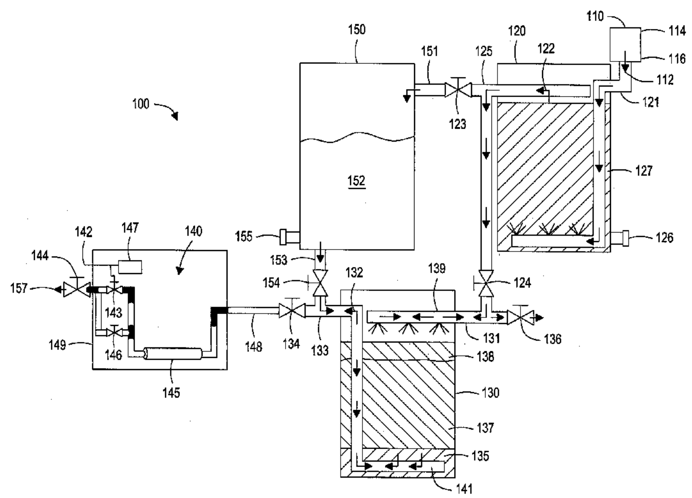
* cited by examiner

Primary Examiner — Robert James Popovics
(74) *Attorney, Agent, or Firm* — Edmonds & Nolte, P.C.

(57) **ABSTRACT**

A method and apparatus for filtering a fluid is presented. In one embodiment, the apparatus converts contaminated water into water having a lower turbidity and bacterial contamination level than the contaminated water. The apparatus includes a settling unit for at least partially settling a portion of the water; a filter unit having a filtration media; wherein the filtration media comprises sand, anthracite coal, burnt rice husks, diatomaceous earth, gravel, pumice gravel, or combinations thereof; a sanitation unit; wherein the sanitation unit is an ultraviolet disinfection unit; a backwash unit; wherein the settling unit is in fluid communications with the filter unit and the backwash unit, the backwash unit is in fluid communications with the filter unit, and the filter unit is in fluid communications with the sanitation unit; and wherein at least a portion of the settling unit is elevated above the filter unit.

5 Claims, 5 Drawing Sheets



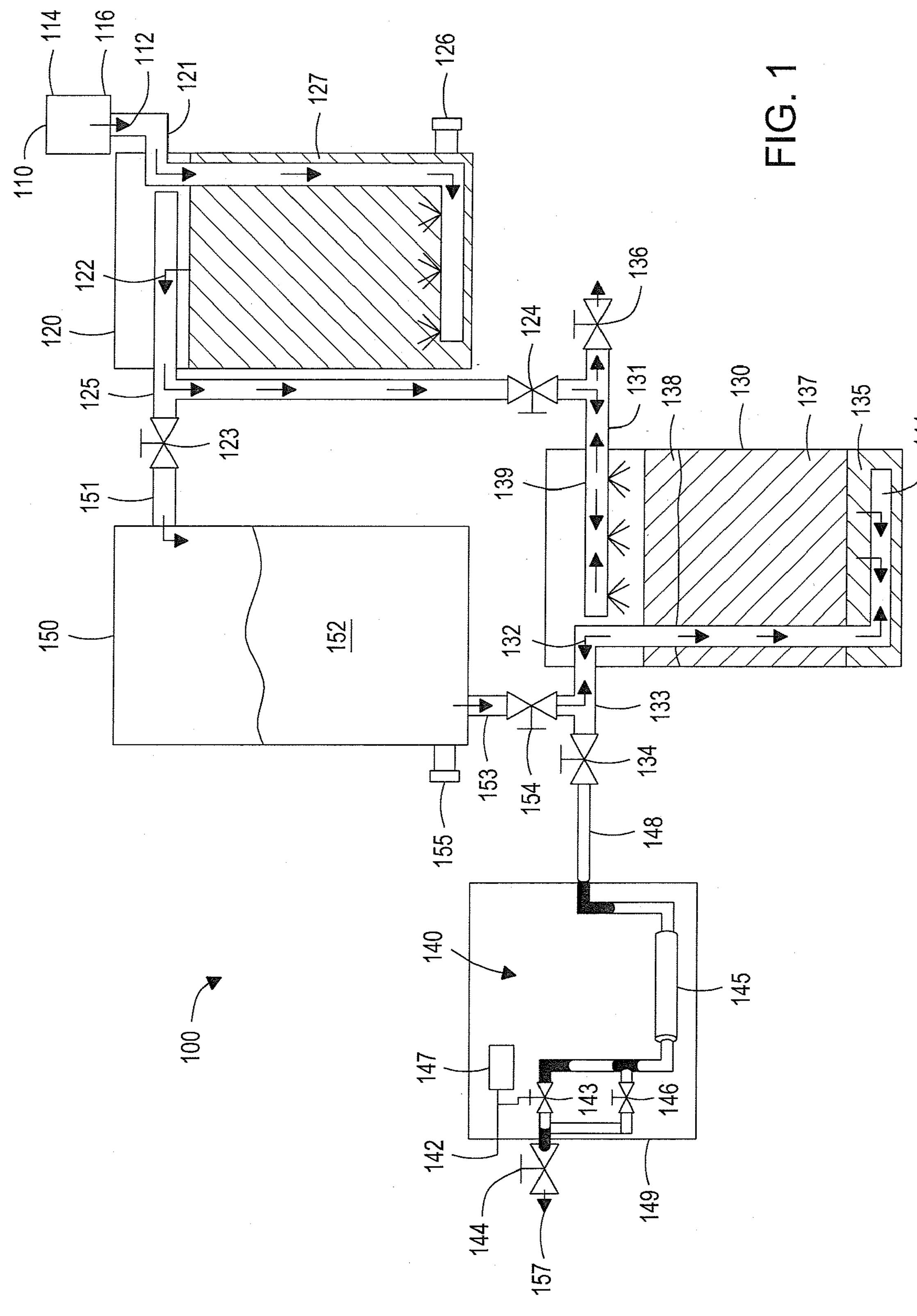

114
116
112
110
121
127
126
120
122
125
123
151
124
136
131
138
130
137
135
141
139
150
152
132
133
153
154
134
155
148
140
145
147
143
146
142
149
144
157
100

FIG. 1

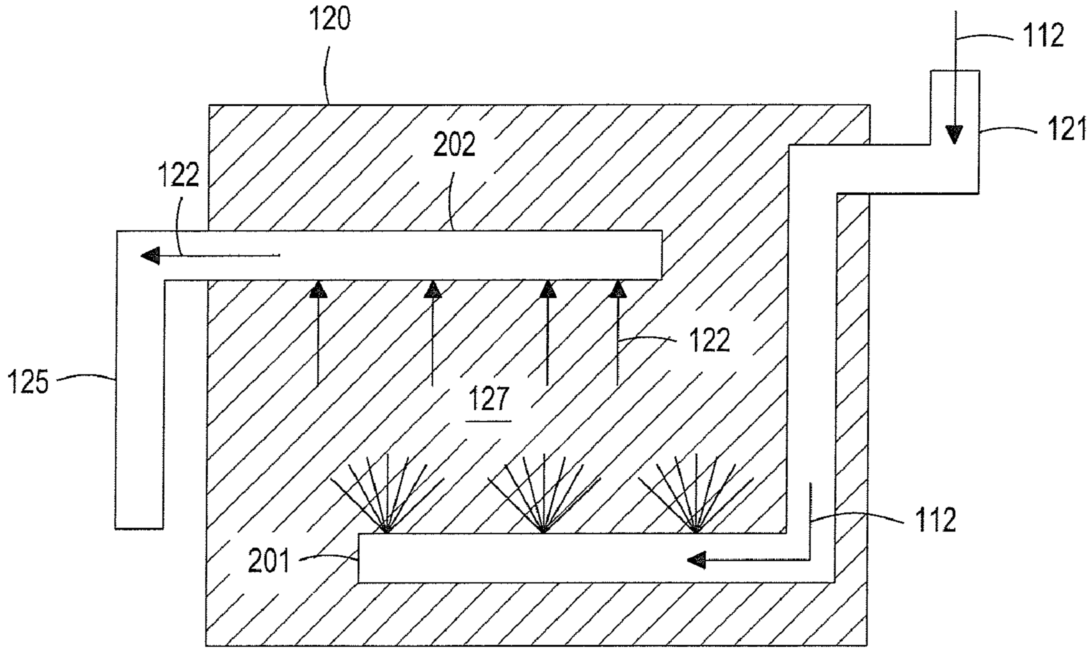

120
112
121
202
122
122
125
127
112
201

FIG. 2

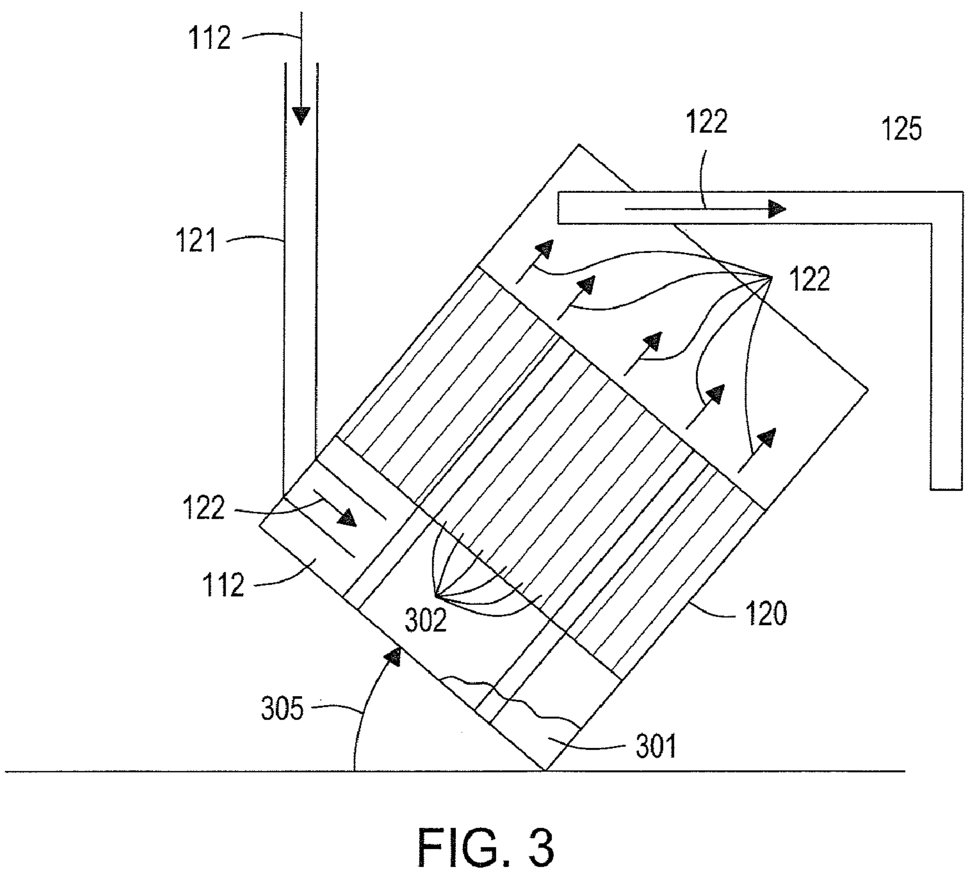
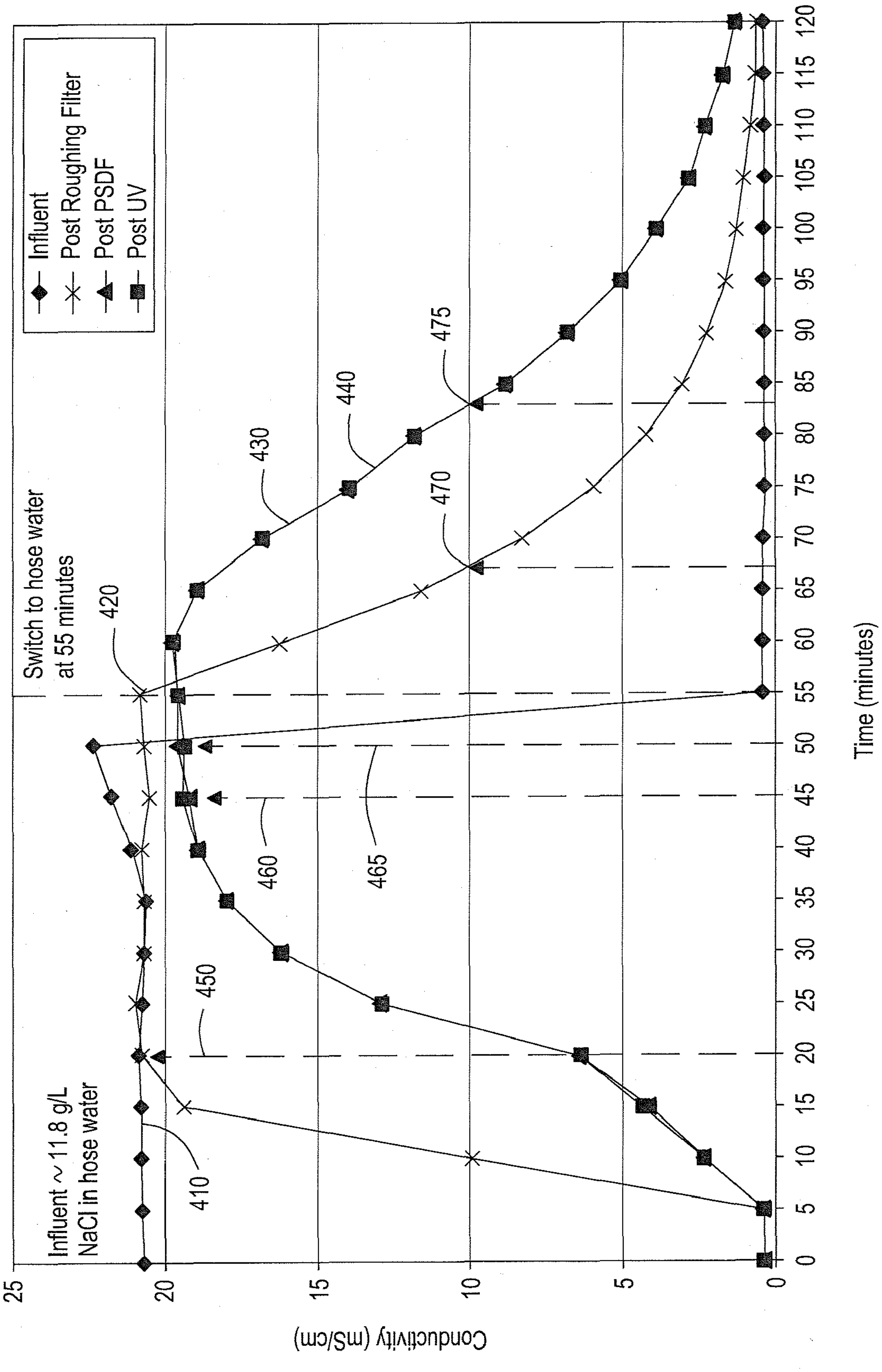

112
122
125
121
122
122
112
302
120
305
301

FIG. 3



Influent
Post Roughing Filter
Post PSDF
Post UV
Switch to hose water at 55 minutes
Influent ~11.8 g/L NaCl in hose water
410
420
430
440
450
460
465
470
475
Conductivity (mS/cm)
Time (minutes)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120

FIG. 4

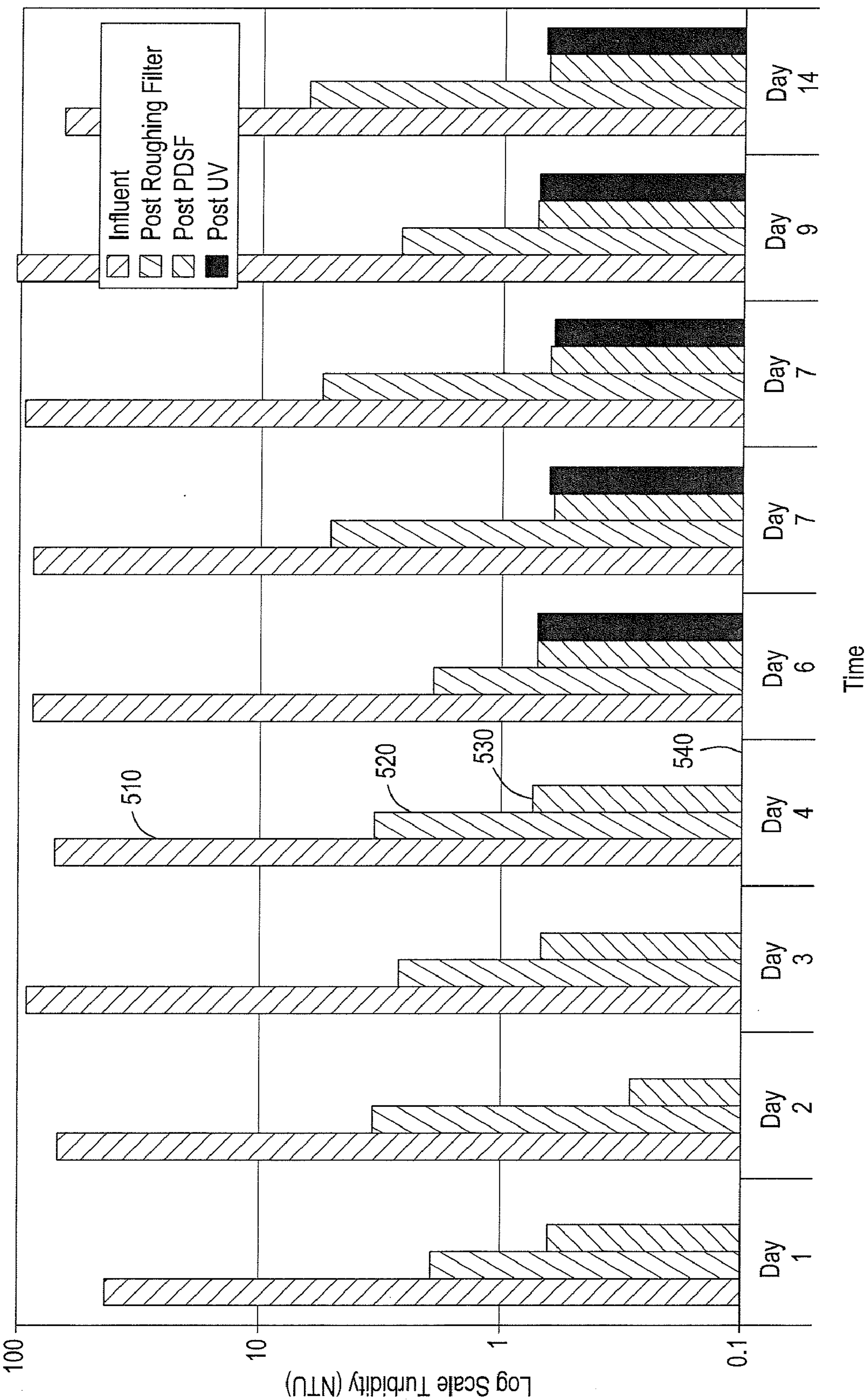

Influent
Post Roughing Filter
Post PDSF
Post UV
Log Scale Turbidity (NTU)
100
10
1
0.1
510
520
530
540
Day 1
Day 2
Day 3
Day 4
Day 6
Day 7
Day 7
Day 9
Day 14
Time

FIG. 5

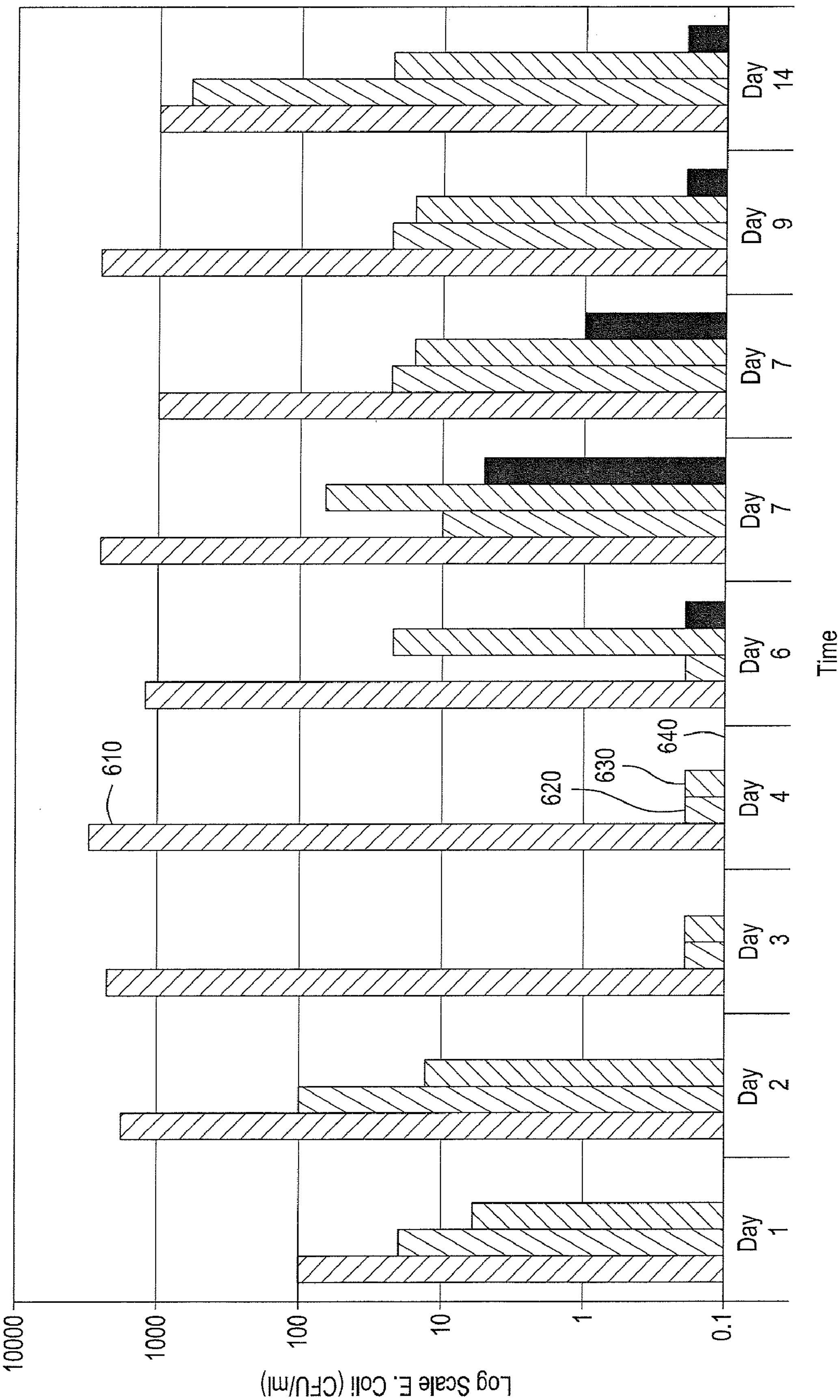

Log Scale E. Coli (CFU/ml)
10000
1000
100
10
1
0.1
Day 1
Day 2
Day 3
Day 4
Day 6
Day 7
Day 7
Day 9
Day 14
Time
610
620
630
640

FIG. 6

BRING YOUR OWN WATER TREATMENT SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application having Ser. No. 60/932,221, filed on May 30, 2007, which is incorporated by reference herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Embodiments of the present invention generally relate to methods and processes for water purification. More particularly, embodiments of the present invention relate to methods and processes for purifying water in remote and/or economically disadvantaged communities.

2. Description of the Related Art

Over a billion people in the world lack access to safe drinking water. Water-borne disease is a leading cause of illness in the developing world, contributing to the death of 15 million children every year, on average. Two primary measures of water cleanliness include turbidity levels and bacterial counts. While numerous technological, medical, and educational solutions have been implemented to provide better water quality for developing communities, no single solution has been able to provide water having reasonably acceptable turbidity and bacterial contamination levels for a majority of the communities where there are little or no available treatment infrastructures or surplus energy resources. There is a need therefore for a water treatment method and apparatus that directly addresses the specific constraints and requirements of poor, rural, mountainous, and/or densely populated communities. There is also a need for a water treatment method and apparatus that directly addresses the United Nations Millennium Development Goals (MDG), including reducing child mortality, improving maternal health, combating disease, ensuring environmental sustainability, and developing a global partnership for development.

SUMMARY

The following presents a general summary of several aspects of the disclosure in order to provide a basic understanding of at least some aspects of the disclosure. This summary is not an extensive overview of the disclosure. It is not intended to identify key or critical elements of the disclosure or to delineate the scope of the claims. The following summary merely presents some concepts of the disclosure in a general form as a prelude to the more detailed description that follows.

An exemplary method for converting contaminated water into water having a lower turbidity and bacterial contamination level than the contaminated water includes supplying the contaminated water to a water treatment system comprising a settling unit for at least partially settling a portion of the water, a filter unit having a filtration media, a sanitation unit, and a backwash unit, wherein the settling unit is in fluid communications with the filter unit and the backwash unit, the backwash unit is in fluid communications with the filter unit, and the filter unit is in fluid communications with the sanitation unit; and wherein at least a portion of the settling unit is elevated above the filter unit.

Disclosed is an apparatus for converting contaminated water into water having a lower turbidity and bacterial contamination level than the contaminated water including a

settling unit for at least partially settling a portion of the water; a filter unit having a filtration media; wherein the filtration media includes sand, anthracite coal, burnt rice husks, diatomaceous earth, gravel, pumice gravel, or combinations thereof; a sanitation unit; wherein the sanitation unit is an ultraviolet disinfection unit; a backwash unit; wherein the settling unit is in fluid communications with the filter unit and the backwash unit, the backwash unit is in fluid communications with the filter unit, and the filter unit is in fluid communications with the sanitation unit; and wherein at least a portion of the settling unit is elevated above the filter unit.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

FIG. **1** depicts a schematic of an illustrative water treatment system according to one or more embodiments described.

FIG. **2** depicts a schematic cross-section view of an illustrative up-flow settling unit according to one or more embodiments.

FIG. **3** depicts a schematic cross-section view of an illustrative settling unit having one or more settling tubes disposed therein according to one or more embodiments.

FIG. **4** depicts a graph of the results of the salt-water tracer study performed on at least one embodiment of the present invention.

FIG. **5** depicts a graph of the turbidity reduction performance of at least one embodiment of the present invention.

FIG. **6** depicts a graph of the bacteria reduction performance of at least one embodiment of the present invention.

DETAILED DESCRIPTION

A detailed description will now be provided. Each of the appended claims defines a separate invention, which for infringement purposes is recognized as including equivalents to the various elements or limitations specified in the claims. Depending on the context, all references below to the "invention" may in some cases refer to certain specific embodiments only. In other cases it will be recognized that references to the "invention" will refer to subject matter recited in one or more, but not necessarily all, of the claims. Each of the inventions will now be described in greater detail below, including specific embodiments, versions and examples, but the inventions are not limited to these embodiments, versions or examples, which are included to enable a person having ordinary skill in the art to make and use the inventions, when the information in this patent is combined with available information and technology.

FIG. **1** depicts a schematic of an illustrative water treatment system according to one or more embodiments described. In one or more embodiments, an illustrative water treatment system **100** can include a fluid inlet **110**, a roughing separator or "settling" unit **120**, a filter unit **130**, a sanitation unit **140**, and a backwash unit **150**. The fluid inlet **110**, the settling unit **120**, the filter unit **130**, the sanitation unit **140**, and the backwash unit **150** can be in fluid communications with each other. The sanitation unit **140** can have a power source **142** and a sanitation chamber **145**.

The fluid inlet **110** can be any opening, container, or vessel capable of receiving and/or communicating an input fluid **112**, for example water. The fluid inlet **110** can be one or more pre-existing fluid pipelines, one or more inlets, one or more buckets, one or more funnels, one or more barrels, one or more drums, and/or one or more other containers capable of receiving and directing the input fluid **112**. In one or more embodiments, the fluid inlet **110** can have an inlet end **114** and an outlet end **116**.

In one or more embodiments, the settling unit **120** can be any container or vessel capable of retaining a fluid. The settling unit **120** can be one or more buckets, one or more open barrels, one or more sealed barrels, one or more open drums, one or more sealed drums, one or more plastic fifty-five gallon drums, and/or one or more other containers capable of retaining the fluid. The settling unit **120** can include a settling inlet **121** and a settling outlet **125**. The settling inlet **121** can be in fluid communications with the inside and the outside of the settling unit **120**. The settling inlet **121** can be in fluid communications with the outlet end **116** of the fluid inlet **110**. The settling outlet **125** can be in fluid communications with the inside and the outside of the settling unit **120**. The settling outlet **125** can be in fluid communications with the filter unit **130**. A valve **124** can be disposed between the settling unit **120** and the filter unit **130**. The settling outlet **125** can be in fluid communications with the backwash unit **150**. A fluid control valve **123** can be disposed between the settling unit **120** and the backwash unit **150**.

FIG. **2** depicts a schematic cross-section view of an illustrative up-flow settling unit according to one or more embodiments. In one or more embodiments, the settling unit **120** can be an up-flow settling unit known in the art and can include a settling distribution arm **201**, an over-drain **202**, and a gravel bed **127** disposed inside the settling unit **120**. In one or more embodiments, the settling unit **120** can have the settling inlet **121** and the settling outlet **125**.

FIG. **3** depicts a schematic cross-section view of an illustrative settling unit having one or more settling tubes disposed therein according to one or more embodiments. In one or more embodiments, the settling unit **120** can have the settling inlet **121** and the settling outlet **125** and can include one or more settling tubes **302** disposed therein. In one or more embodiments, the settling tubes **302** can be arranged in a circular pattern or any pattern within the settling unit **120** such that a fluid can flow from the settling inlet **121** to the settling outlet **125** or vice versa.

In one or more embodiments, the settling unit **120** can be inclined at an angle **305** to accelerate the rate of settling. In one or more embodiments, the settling tubes **302** can be inclined inside the settling unit **120** at an appropriate angle to the vertical or horizontal to accelerate the rate of settling. In one or more embodiments, the settling unit **120** can be inclined at an angle **305** of about 20 degrees to about 80 degrees to the horizontal. In one or more embodiments, the settling unit **120** can be inclined at an angle **305** of about 40 degrees to about 80 degrees to the horizontal. In one or more embodiments, the settling unit **120** can be inclined at an angle **305** of about 50 degrees to about 70 degrees to the horizontal. In one or more embodiments, the settling unit **120** can be inclined at an angle **305** of about 50 degrees to about 60 degrees to the horizontal.

Referring again to FIG. **1**, in one or more embodiments, the filter unit **130** can be any container or vessel capable of retaining the fluid. The filter unit **130** can be one or more buckets, one or more open barrels, one or more sealed barrels, one or more open drums, one or more sealed drums, one or more plastic fifty-five gallon drums, and/or one or more other containers capable of retaining the fluid. The filter unit **130** can include a filter inlet **131** and a filter outlet **133**. The filter inlet **131** can be in fluid communications with the inside and the outside of the filter unit **130**. The filter inlet **131** can be in fluid communications with the settling outlet **125** of the settling unit **120**. The filter outlet **133** can be in fluid communications with a drain **141** and the inside and the outside of the filter unit **130**. The filter outlet **133** can be in fluid communications with the sanitation unit **140**.

In one or more embodiments, a granular based filter media can be disposed in the filter unit **130**. For example, the granular based filter media can include sand, anthracite coal, burnt rice husks, diatomaceous earth, gravel, pumice gravel, and/or any other granular media available in remote areas using locally available materials. For example, the granular based filter media can be the type of filter media found in a rapid sand filter. Rapid sand filters are known in the art and typically use relatively coarse sand and other granular media to remove particles and impurities that are trapped in a fluid. In one or more embodiments, the filter unit **130** can include a layer of sand **137**. In one or more embodiments, the filter unit **130** can include a layer of gravel **135** disposed below the layer of sand **137**. The filter unit **130** can include a layer of pumice gravel and/or anthracite coal **138** disposed on top of the layer of sand **137** and the layer of gravel **135**. In one or more embodiments, the layer of sand **137** can be prevented from entering the drain **141** by the layer of gravel **135**.

In one particular example of a filter unit **130** having a granular media, the filter unit **130** can be a fifty-five gallon drum having a filter media disposed therein. The filter media can include a layer of gravel **135** that is about six inches deep and disposed below a layer of sand **137** that is about twenty-two inches deep. The layer of sand **137** can include sand with an effective size of about 0.6 mm. In one or more embodiments, the layer of sand **137** can include sand with an effective size from about 0.3 mm to about 0.9 mm. The layer of sand **137** can include sand with an effective size from about 0.4 mm to about 1.3 mm. A layer of pumice gravel **138** that is about six inches deep can be disposed above the layer of sand **137**. The ratio of the depth of the layer of gravel **135** to the depth of the layer of sand **137** to the depth of the layer of pumice gravel **138** can be from about 1-to-2-to-1 to about 1-to-10-to-1. Using a granular based filter media can allow the filter unit **130** to be serviced in remote areas using locally available materials rather than using commercially produced filter media.

In one or more embodiments, the sanitation unit **140** can include an enclosure **149**, an inlet valve **134**, the sanitation inlet **148**, a disinfection unit **145**, a first flow control valve **143**, a second flow control valve **146**, a flow switch **142**, a power source **147**, and a sanitized fluid outlet valve **144**. In one or more embodiments, the disinfection unit **145**, the first flow control valve **143**, and the second flow control valve **146** can be disposed inside the sanitation unit **140**. In one or more embodiments, the sanitation inlet **148** and the sanitized fluid outlet valve **144** can be in fluid communications with the inside and the outside of the sanitation unit **140**. The inlet valve **134**, the sanitation inlet **148**, the disinfection unit **145**, the first flow control valve **143**, and the sanitized fluid outlet valve **144** can be in fluid communications with each other. In one or more embodiments, the second flow control valve **146** can be in fluid communications with the inlet valve **134**, the sanitation inlet **148**, the disinfection unit **145**, the first flow control valve **143**, and the sanitized fluid outlet **144**. In one or more embodiments, the flow switch **142** can be configured to operate one or more first flow control valves **143** and one or more disinfection units **145**. The second flow control valve

146 can be a standard hand valve. In one or more embodiments, if the first flow control valve **143** fails, the first flow control valve **143** can be bypassed via the second flow control valve **146**. In one or more embodiments, the flow switch **142** can be a push button switch. The power source **147** can be configured as a power supply controlled by the switch **142** to supply power to the one or more disinfection units **145** and the one or more first control valves **143**.

In one or more embodiments, the enclosure **149** can be any container or vessel. In one or more embodiments, the enclosure **149** can be a metal box. For example, the enclosure **149** can be a water-proof aluminum box sold under the trademark name ZARGES LOGISTIK. In one or more embodiments, the enclosure **149** can be selected from the line of boxes sold under the Zarges K 475 line of moisture, vapor proof protective cases.

In one or more embodiments, the disinfection unit **145** can be an ultraviolet disinfection unit. For example, the disinfection unit **145** can be an ultraviolet disinfection unit available from R-Can Environmental Incorporated sold under the trademark name STERILIGHT ULTRAVIOLET DISINFECTION SYSTEM. The disinfection unit **145** can be an ultraviolet disinfection unit available from Triangular Wave Technologies, Inc. sold under the trademark name TRIANGULAR WAVE TECHNOLOGIES UV-4 (TWT-UV-4) ULTRAVIOLET DISINFECTION SYSTEM or any know ultraviolet disinfection unit.

In one or more embodiments, the ultraviolet disinfection unit can be configured to operate using a battery power source. For example, the STERILIGHT and TWT-UV-4 ultraviolet disinfection systems can be configured to operate using a 12V DC power source. In one or more embodiments, the ultraviolet disinfection unit can be configured to operate using one or more solar cells. Electrical energy from the one or more solar cells can be stored in one or more batteries. For example, storage can be provided by one or more 200 amp-hour 12-volt truck battery. The ultraviolet disinfection unit can be configured to operate using alternating current (AC) power. For example, the electrical energy from the one or more solar cells or from the one or more batteries can be converted to AC power through the use of an inverter, not shown. Other power generating sources can include wind turbines, paddle wheels, pedal generators, or other known power generating sources.

In one or more embodiments, the ultraviolet disinfection unit can include a ballast to stabilize the current flow through the ultraviolet disinfection unit. The ultraviolet lamp of the disinfection unit **145** can be enclosed in a protective quartz sleeve that is transparent to UV radiation while protecting the lamp from the fluid that can be present in the disinfection unit **145**.

In one or more embodiments, the backwash unit **150** can be any container or vessel capable of retaining the fluid. The backwash unit **150** can be one or more buckets, one or more open barrels, one or more sealed barrels, one or more open drums, one or more sealed drums, one or more plastic fifty-five gallon drums, and/or one or more other containers capable of retaining the fluid. The backwash unit **150** can include the fluid control valve **123**, a backwash inlet **151**, a backwash outlet **153**, a backwash control valve **154**, and a backwash drain **155**. In one or more embodiments, the backwash inlet **151**, the backwash outlet **153**, and the backwash drain **155** can be in fluid communications with the inside and the outside of the backwash unit **150**. In one or more embodiments, the fluid control valve **123** can be in fluid communication with the backwash inlet **151**. The backwash control valve **154** can be in fluid communication with the backwash outlet **153**.

It should be understood that the words "retain", "retaining", or "retention" do not imply any limitations as to the retention capability of any given container or vessel in the one or more embodiments herein. For example, the fluid inlet **110**, the settling unit **120**, and/or the filter unit **130** are not required to perfectly retain a given fluid and can leak at least some fluid outside the water treatment system **100**.

Referring again to FIG. **1**, in one or more embodiments during operation, the input fluid **112** can be directed through the system **100** to produce the improved water supply **157**. For example, the input fluid **112** can be water. The water can flow through at least the settling unit **120**, the filter unit **130**, and the sanitation unit **140** to produce an improved water supply **157** having at least lower turbidity and reduced bacteria levels than the water introduced into the system **100**. In one or more embodiments, the bacteria can be reduced by orders of magnitudes over the bacteria levels of the water introduced into the system **100**.

The input fluid **112** can be turbid water, bacteria-contaminated water, a rain-water, surface water and/or combinations thereof. The input fluid **112** can originate from one or more sources including but not limited to lakes, streams, collected rain-water, pooled rain water, wells, and/or municipal taps. The input fluid **112** can be introduced into the fluid inlet **110** and directed to the settling unit **120**. The fluid inlet **110** can include a screen, not shown, for filtering large contaminants from the input fluid **112**. In one or more embodiments, the input fluid **112** can be rough filtered before introduction to the fluid inlet **110**.

The input fluid **112** can be input in a continuous stream or in batches. In one or more embodiments, a batch can include an amount of fluid contained in any size bucket or any size container. For example, water can be introduced into the fluid inlet **110** by a user who has carried about one gallon of water in a bucket from a ground water source to the fluid inlet **110**. The user can introduce about five gallons of water to the fluid inlet **110** by carrying the water in a container from a water source to the fluid inlet **110**.

The input fluid **112** can be introduced into the fluid inlet **110** at any rate and can be at any temperature. The input fluid **112** can be introduced at a rate of about 1 gallon per minute to about 5 gallons per minute. The maximum flow rate through the system **100** can be based on the head loss through the clean media disposed in the filter unit **130** and the height of the input over the output, for example, the height of the elevation difference between the settling unit **120** and the filter unit **130**. The flow rate can be sized to match the maximum rated flowrate of the sanitation unit **150**. The input fluid **112** can be introduced into the inlet **110** while the input fluid **112** has an average temperature of about 10 degrees Celsius to about 40 degrees Celsius.

After introduction to the fluid inlet **110**, the input fluid **112** can enter the bottom of the settling unit **120** through the settling inlet **121**. As the input fluid **112** travels up through the settling unit **120**, the settling unit **120** can separate or settle entrained sediment from the input fluid **112** and produce a settled fluid **122**. Settling is defined herein as the process by which particulates in a fluid settle to the bottom of a volume in which the fluid resides. Settleable solids are defined herein as the particulates that settle out of a given fluid.

In one or more embodiments, the settling unit **120** can at least partially settle the input fluid **112** prior to the fluid exiting through the settling outlet **125** as the settled fluid **122**. For example, the settling unit **120** can include a gravel settling filter or an inclined tube settler, as described above with reference to FIG. **2** and FIG. **3** respectively. As the fluid travels through the settling unit **120**, inherent forces, for example gravity, centripetal force, and momentum, can cause entrained sediment to sink downward and the resultant settled fluid **122** can have a lower turbidity than the input fluid **112**.

In gravel settling filters, such as those described above with reference to FIG. **2**, as the fluid snakes it's way through the gravel matrix, the sharp turns can cause particles to get stuck to the gravel on the outside of the individual gravel pieces, filtering some of the sediment from the water. Flocculation can also occur. For example, as the particles get stuck to the individual gravel pieces, other particles begin to flock together with those that are stuck to the gravel. As the flocks get larger, they can begin to break off the gravel and fall to the bottom of the settling unit **120**, resulting in even more particles being removed from the input fluid **112** prior to exiting the settling unit **120**.

In one or more embodiments, the input distribution arm **201** can be disposed inside the settling unit **120** such that some space is left between the input distribution arm **201** and the bottom of the settling unit **120**. Any sinking sediment can sink below the input distribution arm **201**, thereby minimizing re-entrainment. In one or more embodiments, a drain, not shown, can be disposed in the bottom of the settling unit **120**. The drain can allow any accumulated sediment to be drained from the bottom of the settling unit **120**.

In one or more embodiments, the sediment settled out of the input fluid **112** can collect in the sediment collection reservoir **301**. The sediment in the sediment collection reservoir **301** can be removed from the settling unit **120** via an access port, not shown, disposed in the bottom or side of the settling unit **120**.

Referring again to FIG. **1**, the settling outlet **125** can be in fluid communications with the filter unit **130** for directing the settled fluid **122** to the filter unit **130**. In one or more embodiments, the settling outlet **125** can be in fluid communications with the backwash unit **150**. At least a portion of the settled fluid **122** can be selectively directed, via the fluid control valve **123**, to the backwash unit **150** as a stored backwashing fluid **152**. The majority of the settled fluid **122** can be directed to the filter unit **130** to remove additional contaminants and produce a filtered fluid **132**.

The valve **124** can control fluid flow between the settling unit **120** and the filter unit **130**. A siphon break, not shown, can be disposed between the settling unit **120** and the filter unit **130** to prevent air bubbles from impeding flow through the settling outlet **125**. The siphon break can also serve to prevent water from being siphoned out of the settling unit **120** and/or the filter unit **130**. In one or more embodiments, the siphon break can be an air release valve in series with a vacuum relief valve, a vertical pipe that extends above the maximum hydraulic gradient line of the settling unit **120**, or any device with similar operational capabilities.

In one or more embodiments, the settled fluid **122** can be directed to the filter unit **130** via one or more conduits, illustratively shown between the settling unit **120** and the filter unit **130**. The one or more conduits can be relatively small in diameter. The one or more conduits can have a diameter of about ½" or more; about ¾" or more; about 1" or more; or larger depending on the overall design parameters of the system **100**. The size and number of the conduits can be selected to maximize the feed pressure to the filter unit **130**. The relatively small diameter hose or piping can increase the average pressure at which the filter unit **130** can operate and/or can throttle the settled fluid **122** volume so as to increase the time the settling unit **120** can be exposed to a higher pressure so that a greater volume of the input fluid **112** can be exposed to the higher pressure. By exposing the input fluid **112** to the higher pressure, the speed of settling and filtration can be increased. This can result in a larger fraction of an individual amount of water that can be treated under the maximal head. For example, to maximize the fraction of an individual amount of water treated under the maximal head in the system **100** having a settling unit **120** with a 55 gallon capacity, elevated about 10 feet above a filter unit **130**, the relatively small diameter treatment conduit can be a ½-inch vinyl hose or ½-inch plastic pipe.

In one or more embodiments, the filter unit **130** can include a plastic, water-tight fifty-five gallon drum with a removable lid (not shown). The filter media can be disposed in a central portion of the filter unit **130**, between a distributor **139** and a drain **141**. The distributor **139** can be in fluid communications with the filter inlet **131**. The distributor **139** can be configured for removal without the use of tools to facilitate maintenance access to the filter media disposed in the filter unit **130**.

In one or more embodiments, where pumice gravel and sand are used as a filter media, the layer of pumice gravel **138** can pre-filter the settled fluid **122** so as to lighten the filtration load on the layer of sand **137**. The layer of pumice gravel **138** can have a larger size and lower density than the sand **137** and can float on top of the sand. By pre-filtering the settled fluid **122**, the layer of pumice gravel **138** can lengthen the interval between backwashes, explained below, of the filter unit **130**.

The drain **141** can be in fluid communications with the filter outlet **133**. The filter outlet **133** can be in fluid communications with a sanitation inlet **148** of the sanitation unit **140**. The distributor **139** can distribute the settled fluid **122** about the inside of the filter unit **130**. The distributor **139** can be cross-shaped, not shown, to support an even distribution of the settled fluid **122** about the inside of the filter unit **130**. Holes, not shown, can be disposed along the length of the distributor **139** to distribute the settled fluid **122** about the inside of the filter unit **130**. The holes can be sized such that the size of any given hole can be proportional to the square of the distance of the given hole from the inlet of the distributor **139**. The drain **141** can direct a filtered fluid **132** to the sanitation unit **140**.

The filter unit **130** can be configured to significantly reduce operational maintenance. The filter unit **130** can be oversized relative to the anticipated loading rate of the system **100**. For example, the anticipated loading rate of the system can be from about 100 liters per day to about 10,000 liters per day and the filter unit **130** can be oversized by a factor of from about 2 to about 50. This deviation from the traditional set of parameters for filters, for example rapid sand filters, reduces the maintenance interval of the filter unit **130** by more than an order of magnitude. This reduction in maintenance requirements allows the filter unit **130** to be maintained by a single person who can attend to the filter from about once every few weeks to about once every few months depending on usage, input fluid **112** quality, and other known factors.

In one particular example where the filter unit **130** is a rapid sand filter, a typical rapid sand filter has turbidity reduction characteristics of between 0.3 log to 0.5 log, and 0.3 log to 1 log reduction of *E. Coli*. Based on a range of inputted turbidity and E. Coli counts, the resultant anticipated performance can be calculated. These results indicate that for turbidity, the filter unit **130** anticipated performance can be a reduction of about 50% to about 70%, and for *E. Coli* between 50% and 90%.

Referring again to FIG. **1**, the sanitation unit **140** can deactivate living pathogens from the filtered fluid **132** to produce an improved water supply **157**. The sanitation unit **140** effectiveness is impacted primarily by the quantity and nature of particulates in the filtered water **132**. The anticipated average sanitation unit **140** performance may be greater than about a 70% reduction in bacteria counts, regardless of input turbidity, and about 100% bacteria reduction at less than 50 Nephelometric Turbidity Units (NTU) input turbidity at ~4 liters per minute (lpm), and about 95% reduction at less than 30 NTU and ~30 lpm.

In one or more embodiments, the flow switch **142** can activate a ballast for proving power to the disinfection unit **145** for a timed interval, while also actuating an electrical solenoid valve, the first flow control valve **143**, to allow the water flow through the system **100**. In one or more embodiments, the first flow control valve **143** can be on a delay timer to allow for an ultraviolet lamp in the disinfection unit **145** to warm-up.

In one or more embodiments, the disinfection unit **145** can require a warm up period prior to disinfecting the filtered water **132**. In one or more embodiments, a built-in warm up timer safeguard circuit, not shown, can be disposed in the sanitation unit **140** to prevent water flow through the disinfection unit **145** while the unit **145** is warming up. For example, the flow switch **142** can be a push button switch that, when depressed, can activate the built-in warm up timer safeguard circuit to turn on the UV light to allow for warm up, prior to allowing fluid flow through the system **100**. The circuit can also automatically stop the fluid flow by closing one or more of the control valves **143** or **146** and turning off the UV light. It is possible then, using one or more embodiments, to have hands free operation of the system **100** to produce an improved water supply **157**, having lower turbidity and bacterial counts, after the switch **142** is activated. It is also possible to have assurance that the UV light is warmed up prior to fluid flow and assurance that the system **100** can be shut off automatically.

In one or more embodiments, the disinfection unit **145** can disinfect about twelve liters of water per minute. In one or more embodiments, the disinfection unit **145** can disinfect about twenty liters of water per minute. The ultraviolet lamp can be designed to operate for 365 days of continuous use. In one or more embodiments, the ultraviolet lamp can be used for about one hour to about five hours per day. Temporary failure of the ultraviolet lamp should not completely disable use of the system **100**, as users can still receive filtered water having a quality better than the average water quality found in remote areas where the present invention can be used.

Some manufacturers of commercial ultraviolet units do not recommend intermittent use of their ultraviolet units because intermittent use can decrease lamp lifetime. But, because the system **100** can be used for much less than 24 hours per day, it is predicted that the trade-off in lamp life versus allowing intermittent use will be acceptable.

In one or more embodiments, for a disinfection unit **145** with an approximate 40 watts draw, a solar-panel and battery combination or photovoltaic power supply can be sized to provide power to the system **100** for about seven hours per day. For example, the disinfection unit **145** can be powered by a 50 or 102 watt solar-panel power supply. In one or more embodiment, the disinfection unit **145** can sanitize at least from about 5,000 liters per day to about 28,000 liters per day or more. The photovoltaic power supply system can be designed to account for losses from temperature, wiring, and battery, charge controller and inverter efficiencies. The losses due to temperature can be obtained by determining the average temperature and peak sun hours in the location where the system **100** can be deployed. The United States National Aeronautics and Space Administration (NASA) maintains a website, called the surface solar energy website, that contains average temperature and peak sun hours for locations throughout the world.

The filter unit **130** may require cleaning from time to time. In one or more embodiments, as water travels through the filter unit **130**, contaminants can accumulate in the voids between the media granules disposed in the filter unit **130** and eventually increase the pressure drop through the filter unit **130**, preventing it from passing fluid at an acceptable rate. At this point, the filter unit **130** can be backwashed to remove the accumulation of contaminants and allow the filter unit **130** to pass and filter fluid again. This backwashing action can be achieved by discharging an amount of water from the backwash unit **150** through the filter unit **130**, in the opposite direction of normal filtration flow. By passing a volume of water through the filtration media disposed in the filter unit **130** in the opposite direction of normal filtration flow, accumulated debris in the filter media layers can be washed away by fluidization. Fluidization is the process of flowing a fluid in the opposite direction of the normal flow to fluidize the filter media and place the contaminants in suspension to lift them off the media and force the contaminants out of the filter unit **130**. The media in the filter unit **130** is typically more dense than the contaminants and will tend to stay in the filter unit **130** while the contaminants are washed away by the turbulent flow process.

To achieve this effect without a pump, the system **100** can be installed with an elevation differential between the backwash unit **150** and the filter unit **130**. For example, the backwash unit **150** can be elevated from about 6 feet to about 18 feet above the filter unit **130**. The hydrostatic head generated by this elevation differential along with relatively large diameter conduits directing the flow between the backwash unit **150** and the filter unit **130** can be used to power the backwashing. For example, in a system **100** that includes a filter unit **130** having a volume of about 55 gallons, the elevation and conduit size for directing fluid from the backwash unit **150** to the filter unit **130** can be sized to create a flow rate of about 25 gallons per minute through the filter unit **130** during the backwash process.

In one or more embodiments, the fluid control valve **123** can be disposed between the settling outlet **125** and the backwash inlet **151** for directing at least a portion of the settled fluid **122** into the backwash unit **150**. The fluid control valve **123** can be any device capable of diverting at least a portion of the settled fluid **122** to the backwash unit **150**. For example, the fluid control valve **123** can be a valved branch in the plumbing between the settling unit **120** and the backwash unit **150**. The valved branch can act as a weir, shunting a fraction of each input slug of fluid coming from the settling unit **120** to the backwash unit **150**. The amount of water flowing into the backwash unit **150** can be controlled by the degree of aperture of the valve **123**.

In one or more embodiments, the settling outlet **125** and the backwash inlet **151** can be one or more tube segments that can direct the fluid between the settling unit **120** and the backwash unit **150**. The fluid control valve **123** can be disposed anywhere along the length of the one or more tube segments between the settling unit **120** and the backwash unit **150** and can constrict flow between the settling unit **120** and the backwash unit **150**.

In one or more embodiments, the fluid control valve **123** can be replaced by a circular plate disposed in the fluid flow path between the settling unit **120** and the backwash unit **150**. The circular plate can constrict flow between the settling unit **120** and the backwash unit **150**. The circular plate can have an aperture disposed therein. The aperture can be any shape and can act as a weir between the settling unit **120** and the backwash unit **150**. For example, the aperture can be shaped like an oval, a "v", a keyhole, a circle, a half-moon, or any shape.

In one or more embodiments, all of the flow through the system **100** can be induced using gravitational forces by elevating at least the fluid inlet **110** and the settling unit **120** above the filter unit **130**. For example, the fluid inlet **110**, the settling unit **120**, and the backwash unit **150** can be elevated from about 4 feet to about 18 feet above the filter unit **130** and the sanitation unit **140**. The fluid inlet **110**, the settling unit **120**, and the backwash unit **150** can be elevated from about 8 feet to about 18 feet above the filter unit **130**. In one or more embodiments, the fluid inlet **110**, the settling unit **120**, and the backwash unit **150** can be elevated from about 8 feet to about 12 feet above the filter unit **130**.

By elevating the fluid inlet **110** and the settling unit **120** above at least the filter unit **130**, the filter unit **130** can operate under hydrostatic pressure to maximize filtration speed. For example, the settling unit **120** and the filter unit **130** can be sized as two fifty-five gallon containers in fluid communications via a ½ inch diameter tube. When the elevation between the settling unit **120** and the filter unit **130** is from about 13 feet to about 16 feet, the filter unit **130** can operate at a maximum pressure of about 14 feet of water (6 psi, 41 kPa) to produce a speed of treatment through the system **100** of about 10 liters per minute to about 15 liters per minute. The system **100** can provide from about 5,000 liters to about 10,000 liters of treated water per. While typical filters have pretreatment processes or other types of influent control, in one or more embodiments the filter unit **130** influent can be quite variable with the only pretreatment process being the settling unit **120**.

Using gravitational forces can eliminate the need for motors or pumps, eliminating the need for energy sources such as fossil fuels or municipality provided electricity. Eliminating motors and pumps can be a significant advantage in remote locations where fossil fuels and other energy sources can be scarce. Eliminating motors and pumps can also reduce the carbon foot-print that would be associated with a water filtration system or apparatus that requires pumps and/or motors for inducing fluid flow.

In one or more embodiment, the system **100** can be initially charged by adding water to the inlet **110** until at least some water flows from the sanitized fluid outlet **144**. After initial charging of the system **100**, the system **100** can be used to filter a batch of water. For example, a batch of water can be introduced to the inlet **110**. The act of adding water can provide the hydraulic energy needed to drive the water through the system **100**. The flow switch **142** can be actuated to begin the flow of the fluid through the system **100**. Upon activation of the flow switch **142**, an amount of improved water supply **157**, roughly equivalent to the amount of water in the batch minus a small donation to the backwash unit **150**, can be received from the sanitation unit **140**. Because system **100** pressurization can be provided by each batch of water added, the amount of improved water supply **157** delivered to the user can be limited to no more than the amount introduced. This can prevent users from taking more water than they have provided to the system **100**. In one or more embodiments, it is not possible to take more water out of the system **100** than a user puts in. In one or more embodiments, water will only come out of the sanitized fluid outlet **144** if the system **100** is being driven by the addition of water from a user. Additionally, the treated water can be delivered within minutes, because the system **100** is already primed and pressurized with water added by previous users.

In one or more embodiments, the system **100** can serve as a water reservoir. For example, the system **100** can be primed and then an amount of water can be added to the fluid inlet **110**. The fluid inlet **110** can be sized to hold an amount of water sufficient to meet the needs of a community for a period of time, for example one day. When someone in the community wants water, the water can be filtered and withdrawn from the system **100** through out the day.

The system **100** can be designed to provide a high volume of water to residents currently drinking turbid and bacteria-contaminated water. The system **100** may not always bring water quality up to first world standards, but rather can quickly increase the quality of water for residents accustomed to drinking water of poor quality. The goal is to get from "bad" quality water (more than 1,000 fecal coliform per 100 milliliters) to "moderate" quality water (less than 10 fecal coliforms per 100 milliliters), not necessarily to meet the stringent quality standards of industrial countries. Additionally, the system **100** does not have to replace all sources of water for the residents in remote areas.

One of the innovative aspects of the system **100** is that the energy required to drive the system **100** both nominally and in backwash operation can be provided by gravity and the sun. In one specific example, the cumulative result can be a system **100** that can treat a five-gallon bucket (about 20 liters) of water in about two minutes using only solar power and gravity.

Example One

A field unit was produced and tested: The field unit included a fluid inlet **110**, a settling unit **120**, a filter unit **130**, a sanitation unit **140**, and a backwash unit **150**. The fluid inlet **110**, the settling unit **120** and the backwash unit **150** were elevated about 10 feet above the filter unit **130** and the sanitation unit **140**. During nominal operations, water treatment with the field unit began when a user poured water from a container into the inlet **110**. The user then carried the now-empty container down to the output side of the sanitation unit **140**. The user placed the container under the sanitized fluid outlet **144** and activated the flow switch **142**. Treatment took about two minutes for a typical 20-liter jerry can of water. Untreated water droplets remaining in the user's bucket were diluted with many liters of treated water.

Because treatment water was stored in the field unit, users did not receive the same water that they poured into the inlet **110**. Rather, the user's added water served to displace a nearly equal volume of water through the field unit. After proving that the field unit as described above would flow water successfully, additional testing was performed to show the effectiveness of at least one embodiment of the system **100**.

Example Two

First, a salt tracer study was conducted to characterize the residence time of the processed water in each of the treatment stages **120**, **130**, and **140**, with reference to Example One above. The tracer study involved inputting ~12 g NaCl/liter water solution into one embodiment of the present invention at 9 lpm for 55 minutes, then switching to clean water. The conductivity **410** of the influent, the conductivity **420** of the fluid post settling unit **120**, the conductivity **430** of the fluid post filter unit **130**, and the conductivity **440** of the fluid post sanitation unit **140** were taken every five minutes.

FIG. **4** depicts a graph of the results of the salt-water tracer study performed on at least one embodiment of the present invention. These results indicate that at a flow rate of 9 liter per minute, the settling unit **120** residence time **450** was approximately 20 minutes, while the filter unit **130** residence time **460** was approximately 25 minutes. The sanitation unit **140** residence time **465** was approximately five minutes. After the clean water was started at approximately fifty-five minutes, the time **470** to reduce the salt concentration in the settling unit **120** to about half what it was prior to adding clean water to the system was about twelve minutes. The time **475** to reduce the salt concentration in the filter unit **130** to about half what it was prior to adding clean water to the system was about twenty-six minutes. Estimates were made on the amount of time needed for each subsequent stage to reach a steady conductivity, indicative of salt concentration. These results were important to consider when designing the long-term test described below, with reference to FIGS. **5**-**6**, such that test points of effluent accurately reflect influent water treated.

The system under test was then challenged with activated sludge, a byproduct of wastewater treatment, as the primary contaminant in the influent water. Activated sludge was used because it is primarily bacteria flocs, and therefore the turbidity in the water tracks bacterial contamination well. This long-term test involved an automated batch dosing system that mixed activated sludge with clean water and then pumped the mixture into the system under test at a rate of approximately seven liters per minute. Each batch was approximately 100 liters, and around seven batches were run per day separated by two hour intervals. In total, about 8,800 liters of wastewater at around 75 NTU (measured with a Hach 2100P Turbidimeter) was pumped into the system **100** over ten days. The test was stopped when the effluent flowrate had reduced to about one-third of a liter per minute because of media fouling. Turbidity results for this test are presented in FIG. **5**. *E. Coli* colony forming unit (CFU/ml) results (collected with 3M Petrifilm plates) are presented in FIG. **6**.

FIG. **5** depicts a graph of the turbidity reduction performance of at least one embodiment of the present invention. The turbidity **510** for the influent was between about 50 and 100 NTU. The results show that the settling unit **120** can perform most of the filtration as indicated by the turbidity **520** of the water after the settling unit **120**. The filter unit **130** can successfully finish the filtration to bring the turbidity **530** down to less than one NTU. This can be explained by the batch nature of the process wherein particulates are introduced to the settling unit **120** and allowed to settle below the distributor **139** between batches.

FIG. **6** depicts a graph of the bacteria reduction performance of at least one embodiment of the present invention. The E-coli level **610** of the influent was measured as well as the *E-coli* levels **620**, **630**, and **640** which were taken post settling unit **120**, post filter unit **130**, and post sanitation unit **140** respectively. The UV light in the sanitation unit **140** is shown to successfully deactivate most of the remaining bacteria having a measured turbidity **540** of zero during the first four days of testing. The bacteria results show that the system **100** can consistently bring the concentration of bacteria down from several thousand colonies per milliliter of water **610** to two or less **640**.

A backwash of the system was then performed with water that had been diverted to the backwash unit **150** during a previous test from the settling unit **120**, as is nominal operation. The diverted water was left to sit in the backwash unit **150** for several weeks. The turbidity of the water in the backwash unit **150** was 2.24 NTU before backwashing. This water was then run through the filter unit **130**. The system was then switched back to nominal operation, and run at seven liters per minute. The effluent water from the filter unit was immediately 0.98 NTU, falling to 0.72 NTU after 1.5 minutes, 0.68 after 3 minutes, and 0.36 after 5 minutes. These results indicate that minimal flushing volume is needed to maintain filter unit **130** performance at less than 1 NTU after backwashing.

Example Three

Another field test was performed in a remote village in Africa to check the performance of a representative water filtration system under actual operational conditions. The field test was conducted in September and October of the year 2007 in the community of Mungonero. Referring to FIG. **1**, a field system was constructed having a fluid inlet **110**, a settling unit **120**, a filter unit **130**, a sanitation unit **140**, and a backwash unit **150**. The fluid inlet **110**, the settling unit **120** and the backwash unit **150** were elevated about 10 feet above the filter unit **130** and the sanitation unit **140**. The people of the community of Mungonero carried water, on a daily basis, to the inlet **110** of the representative water filtration system and received from the representative system an improved water supply **157** approximately equal in volume to the amount they added to the representative system. Several test samples were taken over the test period.

During the field test in Mungonero, the Turbidity of the rainwater was consistently improved to about 2 NTU by filtering the rainwater through the representative system. Over time, even though the coliforms and *E. Coli* colonies were present and/or increasing in the rainwater, the representative water filtration system eliminated all coliforms and *E. Coli* from the resultant improved water supply **157**. These results show that the representative water filtration system performed very well for improving both turbidity and bacterial contamination. By effectively improving the water quality measures of turbidity and bacterial contamination, the representative water filtration system shows that one or more of the embodiments of the system **100** described herein can effectively provide water having an improved quality.

One unexpected result from using the one or more embodiments described herein is that the turbidity of the water after filtration can be above 1 NTU and the filtered water can still be bacterial de-contaminated. Another unexpected result from using the one or more embodiments described herein is that the system **100** still provides acceptably drinkable water after backwash with water that has only been settled in the settling unit **120**. Conventional practice is to backwash filtration units similar to the filter unit **130** using very clean water. Another unexpected result from using the one or more embodiments described herein is that the up-flow settling unit **120** depicted in FIG. **2** above can act as a floculator, a settling unit, and a filtration unit in one.

Certain embodiments and features have been described using a set of numerical upper limits and a set of numerical lower limits. It should be appreciated that ranges from any lower limit to any upper limit are contemplated unless otherwise indicated. Certain lower limits, upper limits and ranges can appear in one or more claims below. All numerical values are "about" or "approximately" the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

Various terms have been defined above. To the extent a term used in a claim is not defined above, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Furthermore, all patents, test procedures, and other documents cited in this application are fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A method for converting contaminated water into water having a lower turbidity and bacterial contamination level than the contaminated water comprising the steps of:

supplying the contaminated water to a water treatment system comprising:

an upflow settling unit for at least partially settling a portion of the contaminated water;

a filter unit having a granular filtration media selected from the group consisting of sand, anthracite coal, burnt rice husks, diatomaceous earth, gravel pumice gravel and combinations thereof;

a sanitation unit comprising an ultraviolet disinfection unit; and

a backwash unit, wherein at least a portion of the settling unit is elevated above an inlet to the filter unit and is in fluid communication with the filter unit and the backwash unit, at least a portion of the backwash unit is elevated above the filter unit and is in fluid communication with the filter unit, and the filter unit is in fluid communication with the sanitation unit;

settling the contaminated water through the upflow settling unit and filtering the resulting settled water through the filter unit at a flow rate of about 3.5 liters per minute to about 15 liters per minute;

selectively directing at least a portion of water exiting the settling unit to the backwash unit after settling;

sanitizing water exiting the filter unit in the sanitation unit at a flow rate of about 3.5 liters per minute to about 15 liters per minute;

recovering a water having a lower turbidity and lower bacterial contamination than the contaminated water, wherein the contaminated water is passed through the settling unit, the filter unit, and the sanitation unit using gravitational forces; and

backwashing the filter unit using the water selectively directed to the backwash unit.

2. The method of claim **1**, wherein the contaminated water is supplied to the water treatment system one batch at a time.

3. The method of claim **1**, wherein the ultraviolet disinfection unit is powered using a solar power energy source.

4. The method of claim **1**, wherein the upflow settling unit and the backwash unit are elevated above the filter unit.

5. The method of claim **1**, further comprising an electronic timer circuit having the capability to control the ultraviolet disinfection unit and the flow of water through the water treatment system.

* * * * *