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(54) **PHOTOINHIBITION OF MICROBIAL NITRIFICATION IN POTABLE WATER**

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(57) **ABSTRACT**

A system for the photo-inhibition of microbial nitrification of potable water may include overhead, floating or submerged lamps (fluorescent, incandescent, LED, etc. . . .) with spectral emission between 315-430 nm, headspace and submerged light meters for measuring the intensity above and below the water surface, a water mixing device to manage full water column dose, and a controller for operating associated lamp and mixer operations. The applied irradiance may typically be equal to or exceed 0.01 W/m^2.

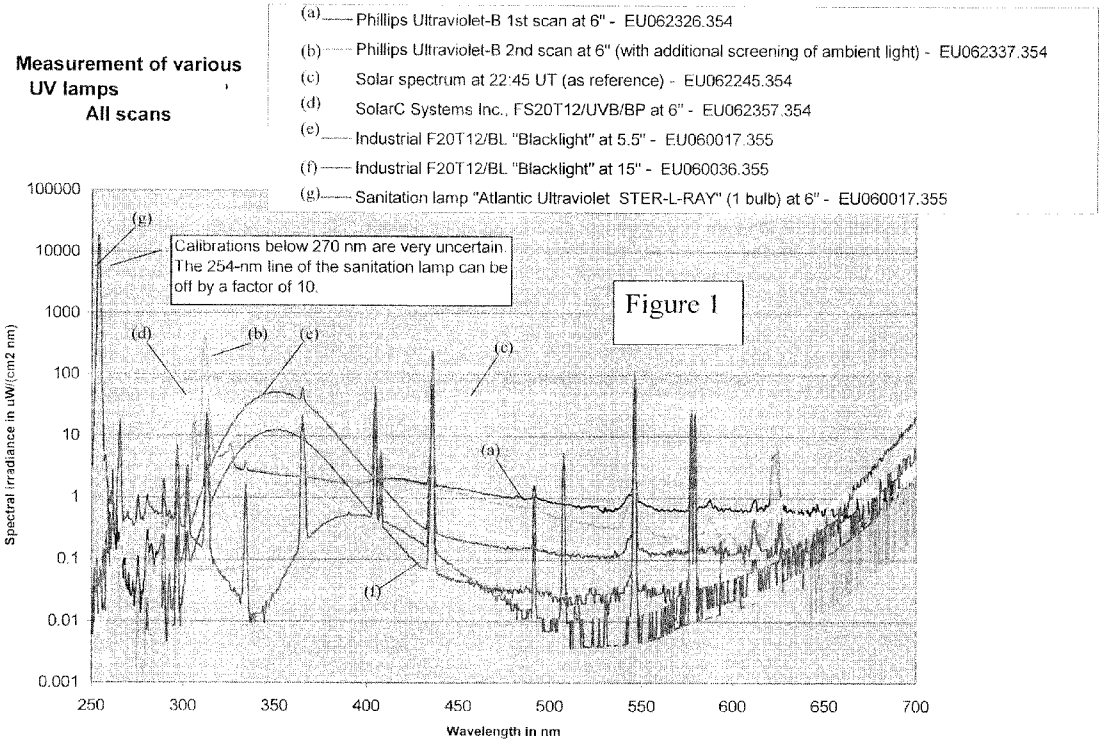

Measurement of various UV lamps
All scans
(a) Phillips Ultraviolet-B 1st scan at 6" - EU062326.354
(b) Phillips Ultraviolet-B 2nd scan at 6" (with additional screening of ambient light) - EU062337.354
(c) Solar spectrum at 22:45 UT (as reference) - EU062245.354
(d) SolarC Systems Inc., FS20T12/UVB/BP at 6" - EU062357.354
(e) Industrial F20T12/BL "Blacklight" at 5.5" - EU060017.355
(f) Industrial F20T12/BL "Blacklight" at 15" - EU060036.355
(g) Sanitation lamp "Atlantic Ultraviolet STER-L-RAY" (1 bulb) at 6" - EU060017.355
Calibrations below 270 nm are very uncertain. The 254-nm line of the sanitation lamp can be off by a factor of 10.
Spectral irradiance in uW/(cm2 nm)
100000
10000
1000
100
10
1
0.1
0.01
0.001
250
300
350
400
450
500
550
600
650
700
Wavelength in nm

Figure 1

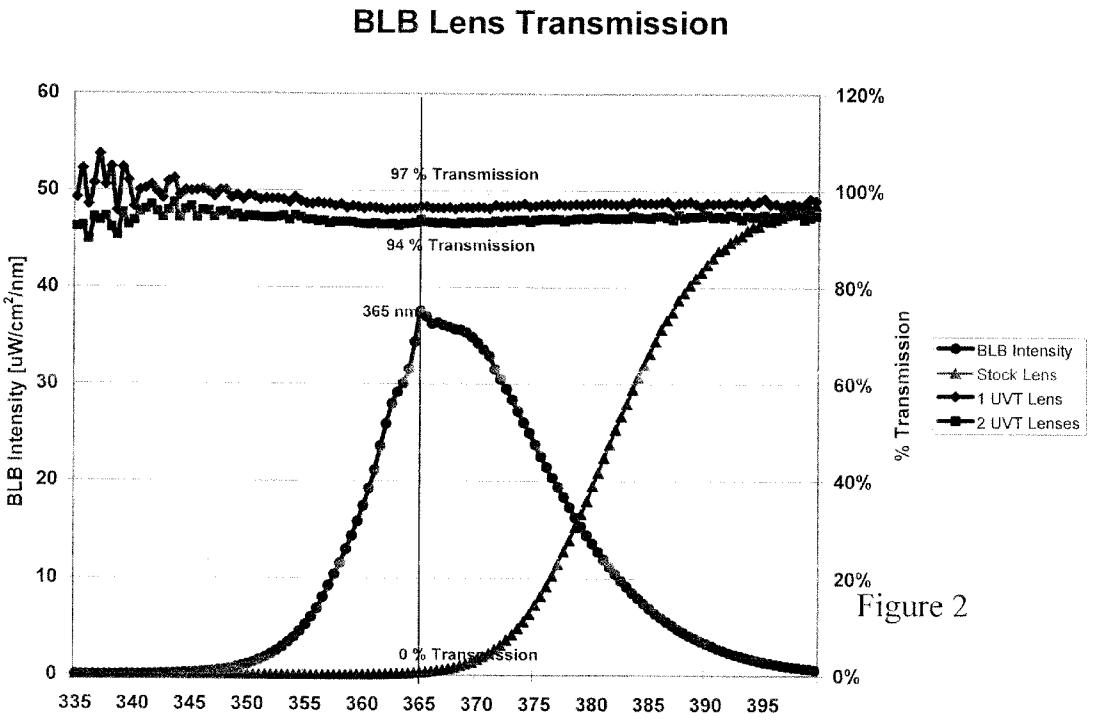

BLB Lens Transmission
BLB Intensity [uW/cm²/nm]
% Transmission
97 % Transmission
94 % Transmission
365 nm
0 % Transmission
BLB Intensity
Stock Lens
1 UVT Lens
2 UVT Lenses
60
50
40
30
20
10
0
120%
100%
80%
60%
40%
20%
0%
335 340 345 350 355 360 365 370 375 380 385 390 395

Figure 2

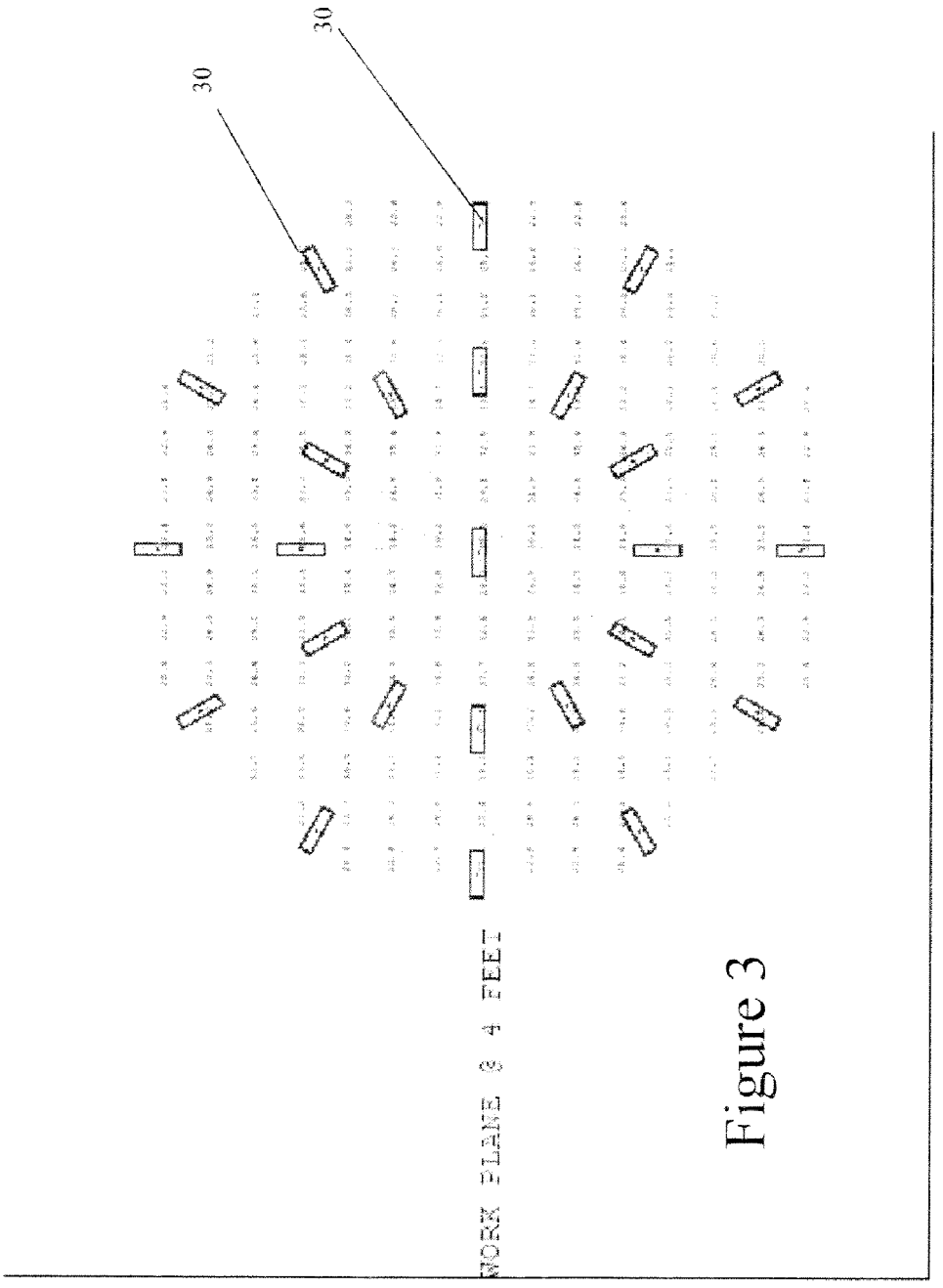


Figure 3

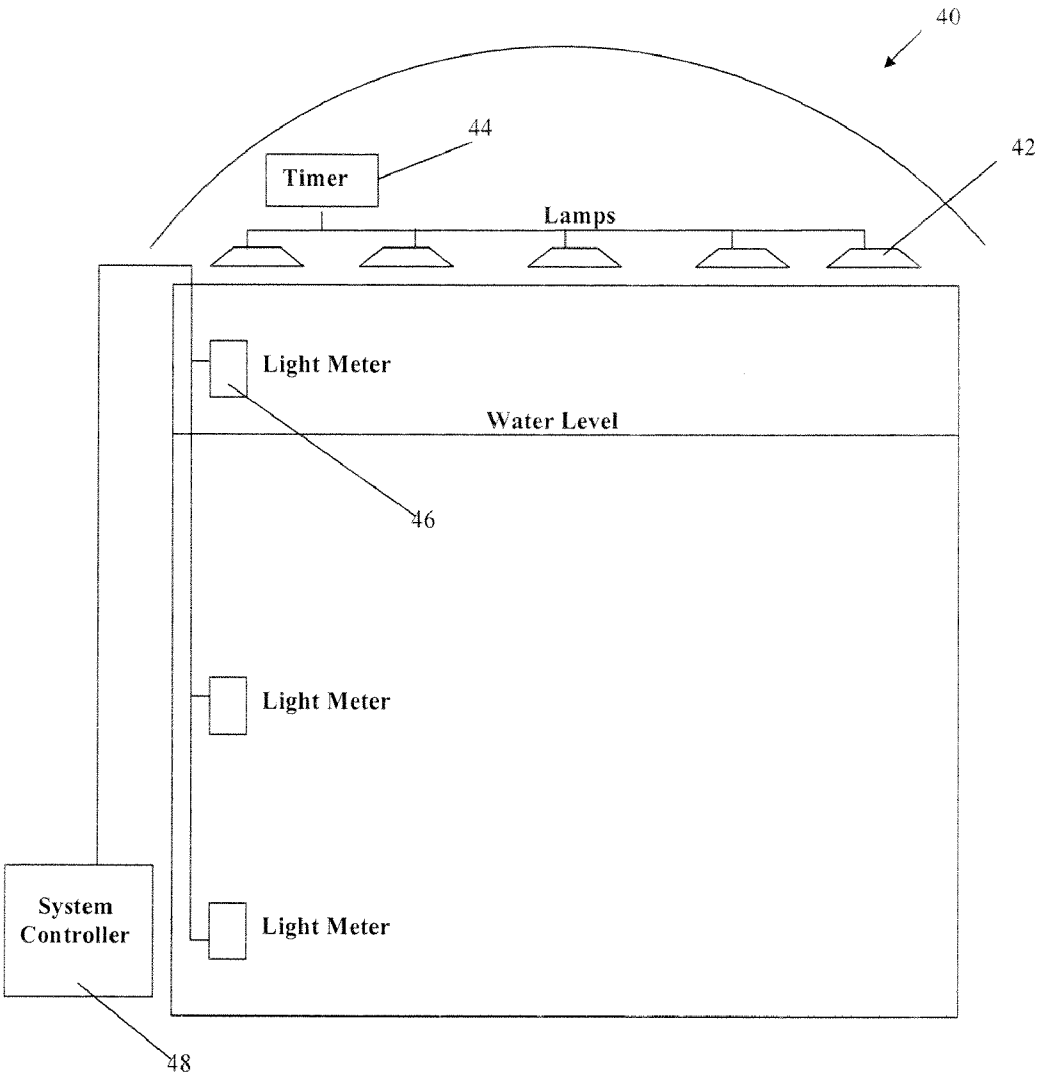

40
44
Timer
42
Lamps
Light Meter
Water Level
46
Light Meter
Light Meter
System Controller
48

Figure 4

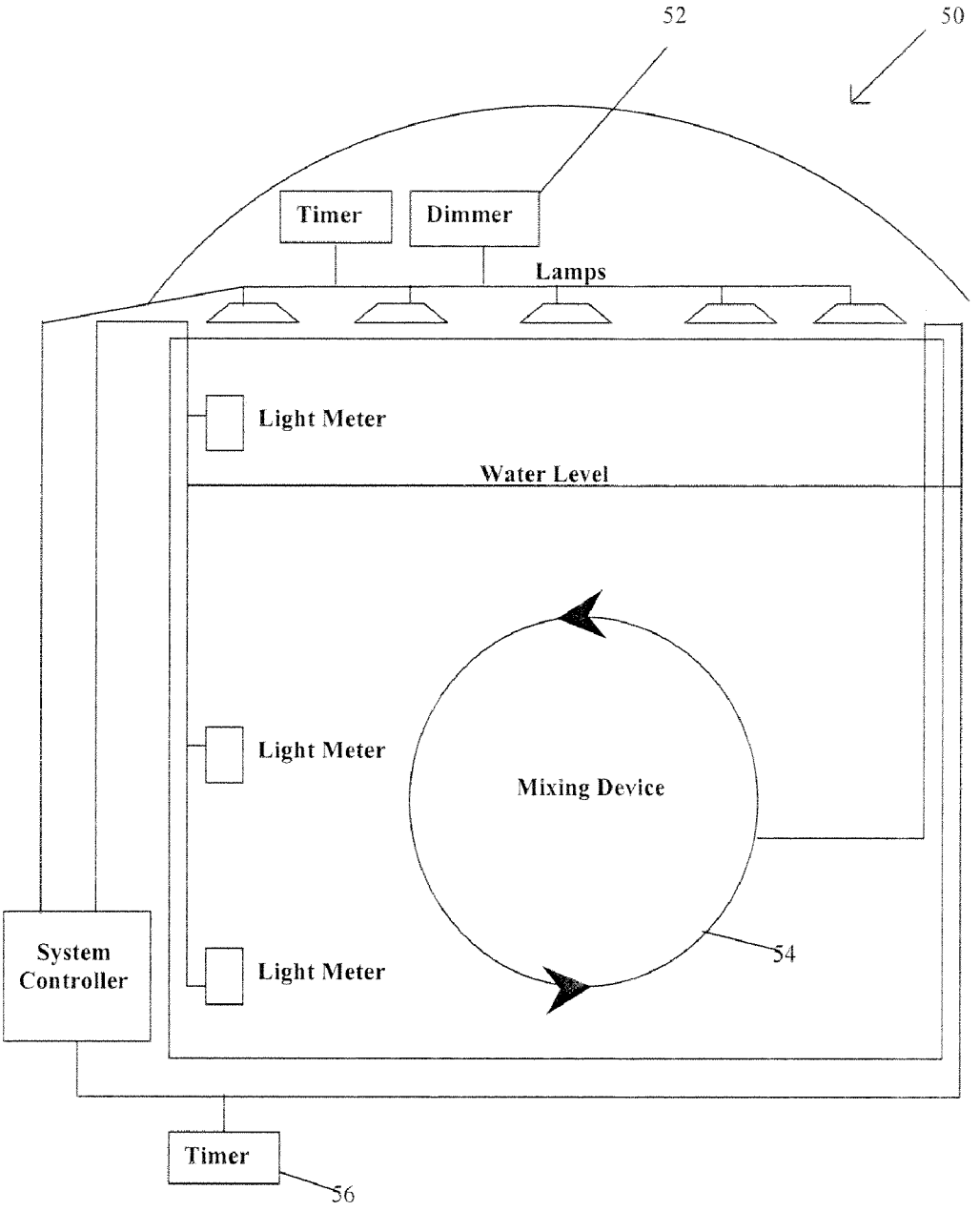

52
50
Timer
Dimmer
Lamps
Light Meter
Water Level
Light Meter
Mixing Device
Light Meter
54
System Controller
Timer
56

Figure 5

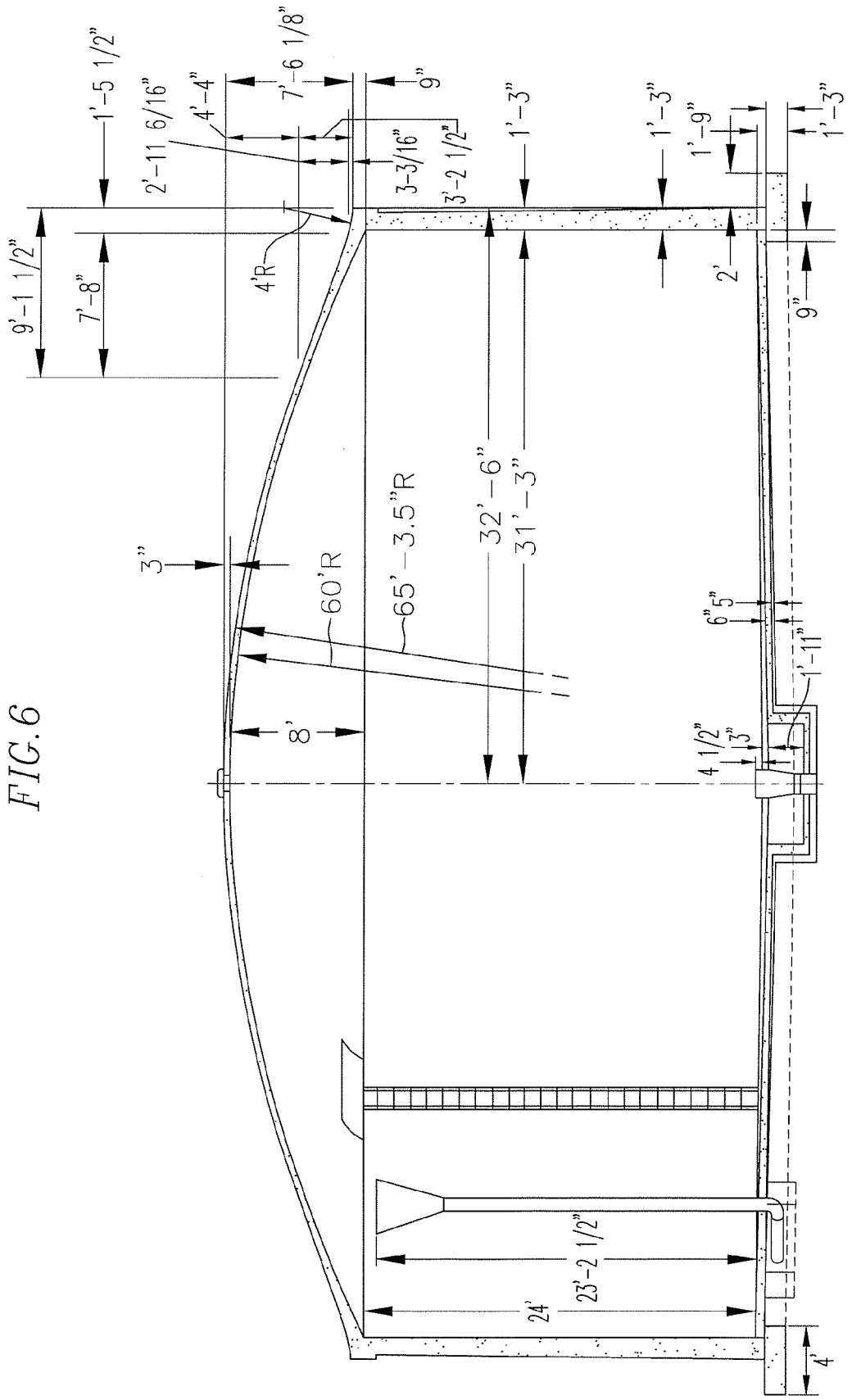

1'-5 1/2"
2'-11 6/16"
4'-4"
7'-6 1/8"
9"
3-3/16"
3'-2 1/2"
1'-3"
1'-3"
1'-9"
1'-3"
9'-1 1/2"
7'-8"
4'R
2'
9"
3"
60'R
65'-3.5"R
32'-6"
31'-3"
6"5"
1'-11"
8'
4 1/2"
3"
23'-2 1/2"
24'
4'

FIG. 6

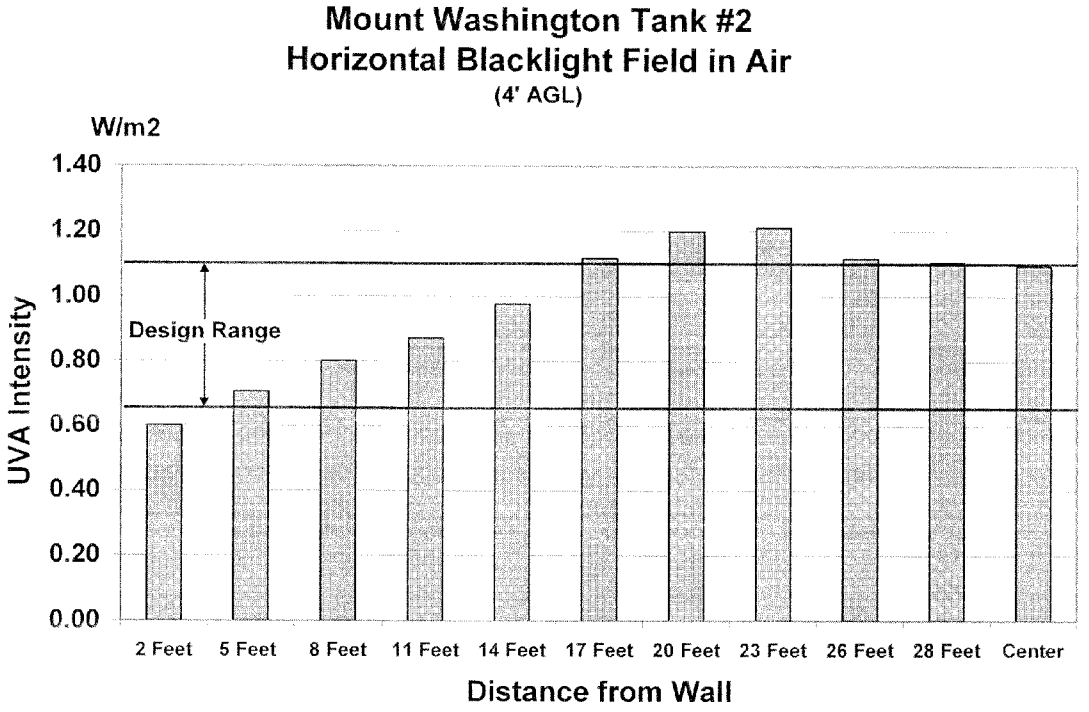

Mount Washington Tank #2
Horizontal Blacklight Field in Air
(4' AGL)
W/m2
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
UVA Intensity
Design Range
2 Feet
5 Feet
8 Feet
11 Feet
14 Feet
17 Feet
20 Feet
23 Feet
26 Feet
28 Feet
Center
Distance from Wall

Figure 7

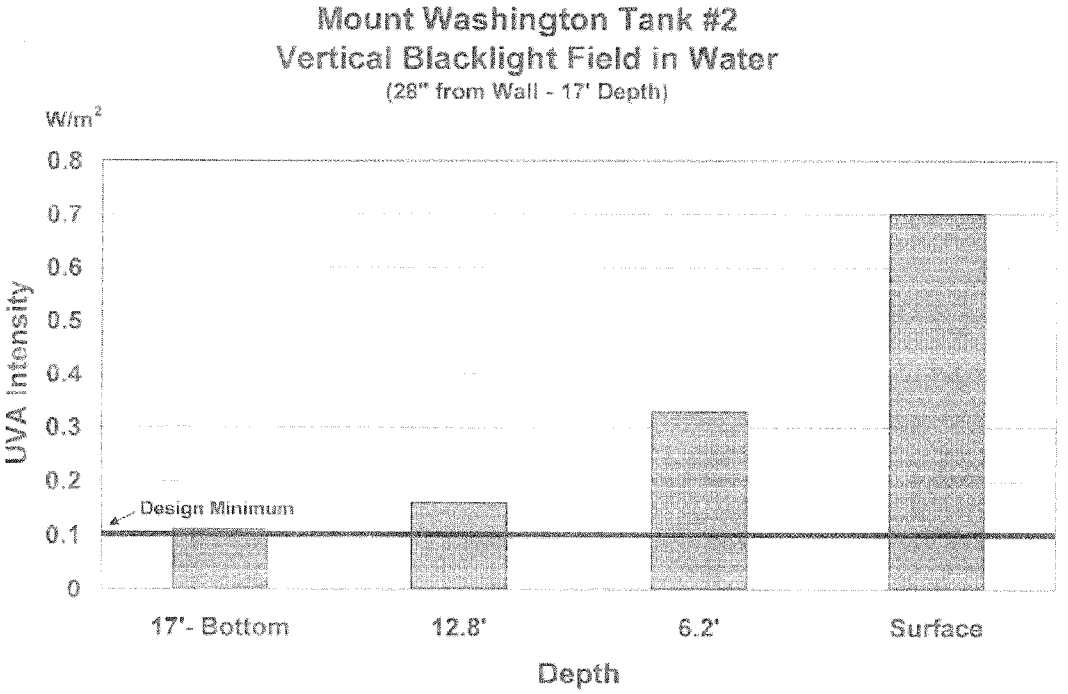

Mount Washington Tank #2
Vertical Blacklight Field in Water
(28" from Wall - 17' Depth)
W/m²
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
UVA Intensity
Design Minimum
17'- Bottom
12.8'
6.2'
Surface
Depth

Figure 8

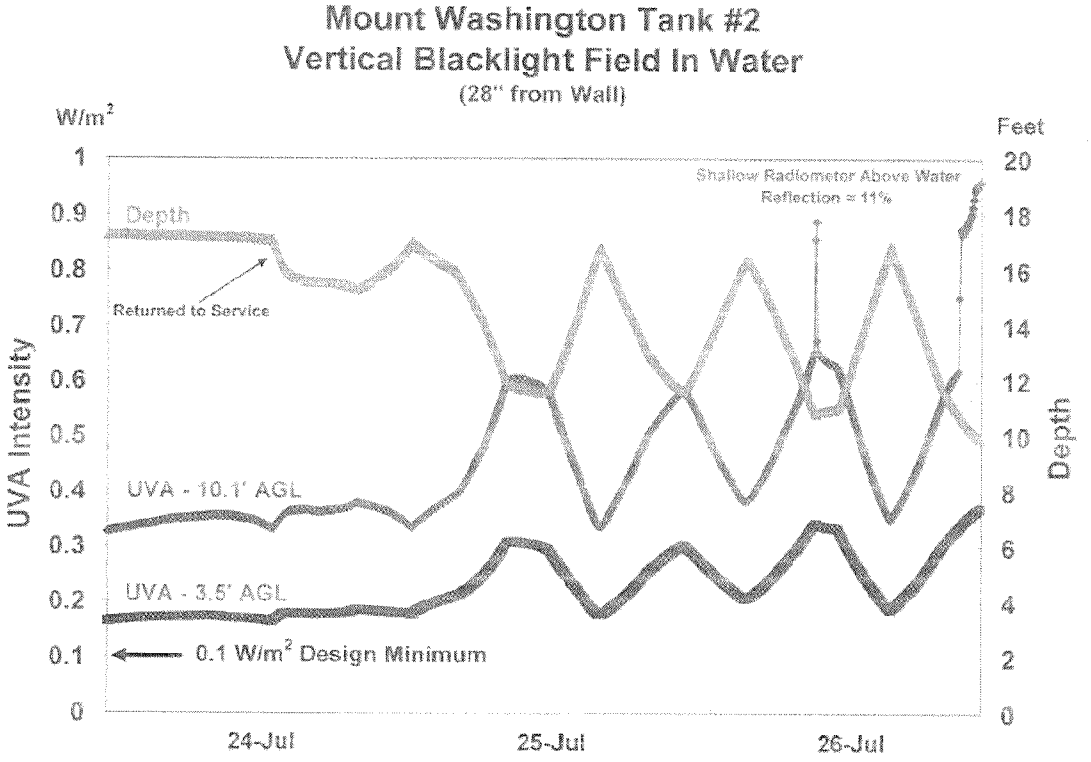

Mount Washington Tank #2
Vertical Blacklight Field In Water
(28" from Wall)
W/m²
Feet
UVA Intensity
Depth
Shallow Radiometer Above Water
Reflection ≈ 11%
Depth
Returned to Service
UVA - 10.1' AGL
UVA - 3.5' AGL
0.1 W/m² Design Minimum
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
18
16
14
12
10
8
6
4
2
0
24-Jul
25-Jul
26-Jul

Figure 9

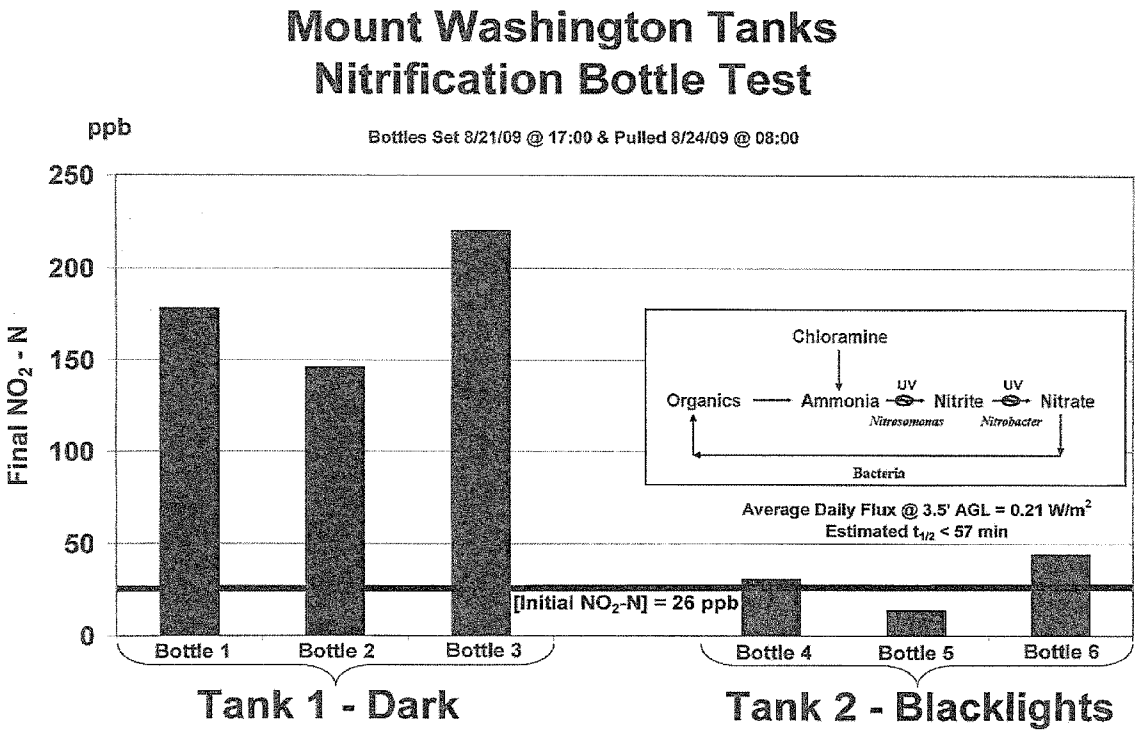

Mount Washington Tanks
Nitrification Bottle Test
ppb
Bottles Set 8/21/09 @ 17:00 & Pulled 8/24/09 @ 08:00
Final NO2 - N
250
200
150
100
50
0
Chloramine
Organics
Ammonia
UV
Nitrite
UV
Nitrate
Nitrosomonas
Nitrobacter
Bacteria
Average Daily Flux @ 3.5' AGL = 0.21 W/m2
Estimated t1/2 < 57 min
[Initial NO2-N] = 26 ppb
Bottle 1
Bottle 2
Bottle 3
Bottle 4
Bottle 5
Bottle 6
Tank 1 - Dark
Tank 2 - Blacklights

Figure 10

Mount Washington Tank # 2
UVA Intensity & $t_{1/2}$
Depth Profiles

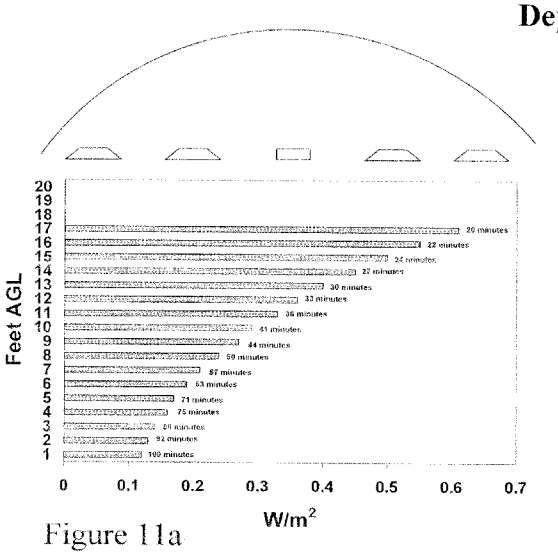


Figure 11a

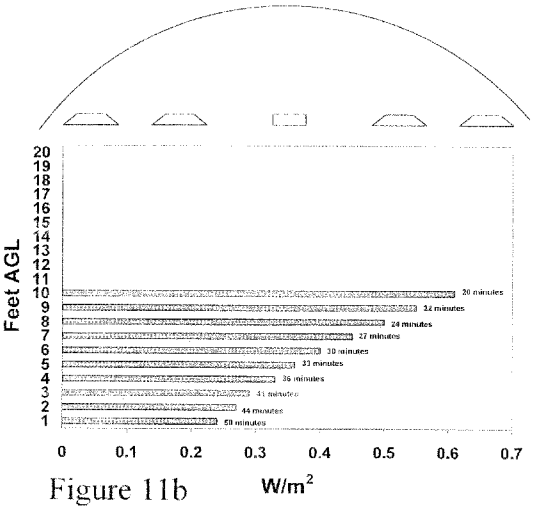


Figure 11b

PHOTOINHIBITION OF MICROBIAL NITRIFICATION IN POTABLE WATER

BACKGROUND OF THE INVENTION

[0001] The present invention generally relates to apparatus and methods for controlling microbial nitrification and more specifically, to apparatus and methods for providing a dose of ultraviolet-A (UVA)/Visible light in covered drinking water storage facilities to control nitrification.

[0002] It is well established in the scientific literature that the enzymes used by nitrifying microbes to first oxidize ammonia to nitrite and then nitrite to nitrate are inhibited by UVA and visible light. Potable water is often stored in large water storage tanks. Nitrifying microbes may produce nitrites and nitrates through the oxidation of ammonia produced by the degradation of chloramine disinfectant.

[0003] In covered drinking water storage, nitrification contributes to the loss of disinfectant residual, stimulates the growth of other nuisance microbes and produces nitrite and nitrate, both of which are regulated drinking water contaminants. Nitrate is the cause of methemoglobinemia (blue-baby syndrome) in infants.

SUMMARY OF THE INVENTION

[0004] In one aspect of the present invention, a system for the photo-inhibition of microbial nitrification of potable water comprises a tank for holding water; and at least one lamp irradiating light into the water.

[0005] These and other features, aspects and advantages of the present invention will become better understood with reference to the following drawings, description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** is a graph of incident irradiance over a spectrum between 250 and 700 nm for a variety of lamps;

[0007] FIG. **2** a graph showing the incident irradiance of an exemplary blue-blocking blacklight lamp (BLB) through various lenses;

[0008] FIG. **3** shows a lighting design according to an embodiment of the present invention;

[0009] FIG. **4** is a schematic drawing of a water storage tank having a microbial nitrification photo-inhibition system according to an exemplary embodiment of the present invention;

[0010] FIG. **5** is a schematic drawing of a water storage tank having a microbial nitrification photo-inhibition system according to an alternate exemplary embodiment of the present invention;

[0011] FIG. **6** is an engineering drawing of an exemplary storage tank used in the various studies described below;

[0012] FIG. **7** is a bar graph showing UVA intensity at various points, horizontally, at 4 feet above ground level (AGL) in air in the storage tank of FIG. **6**;

[0013] FIG. **8** is a bar graph showing UVA intensity at various points, vertically, at 28" from the wall of the storage tank of FIG. **6**.

[0014] FIG. **9** is a bar graph showing UVA intensity at various points, vertically, at 28" from the wall of the storage tank of FIG. **6**, over a three day period;

[0015] FIG. **10** is a graph describing results of a bottle test with and without the microbial nitrification photo-inhibition system of the present invention;

[0016] FIG. **11***a* is a chart describing the distribution of UVA intensity with depth at high water, including estimates of the time to half-inhibition for each flux; and

[0017] FIG. **11***b* is a chart describing the distribution of UVA intensity with depth at low water, including estimates of the time to half-inhibition for each flux.

DETAILED DESCRIPTION OF THE INVENTION

[0018] The following detailed description is of the best currently contemplated modes of carrying out exemplary embodiments of the invention. The description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating the general principles of the invention, since the scope of the invention is best defined by the appended claims.

[0019] Various inventive features are described below that can each be used independently of one another or in combination with other features.

[0020] Broadly, embodiments of the present invention generally provide an inhibiting dose of UVA/Visible light in covered drinking water storage facilities to prevent nitrification. Embodiments of the current invention use UVA/Visible radiation to control bacterial nitrification in an industrial setting.

[0021] As used herein, an "inhibiting dose" of UVA/Visible light may be radiation at a suitable wavelength and intensity over a specific period of time, typically **24** hours or less, to inhibit enzymes used in nitrifying microbes. For example, an inhibiting dose may be radiation having a wavelength between 315 and 430 nanometers (nm) and an incident irradiance of at least 0.01 watts per square meter (W/m^2) over a period of 24 hours, typically at least 0.01 W/m^2.

[0022] As used herein, the term "photo-inhibition", with respect to microbial nitrification, refers to not only the prevention of microbial nitrification in water, but also to the treatment of microbial nitrification once such a process has started. Similarly, "reducing" microbial nitrification of water refers not only to lessening the rate and/or degree of microbial nitrification, but also to the elimination of microbial nitrification of water.

[0023] Referring to FIG. **1**, there is shown a graph of incident irradiance over a spectrum between 250 and 700 nm for a variety of lamps. After several tests and exploration of a variety of lamps, a blue-blocking blacklight lamp was chosen as the lamp to use in the below described experiments. While this specific lamp was chosen for further study, the invention should not be limited to any particular lamp, provided that the lamp may provide an adequate dose to achieve the desired result of inhibiting microbial nitrification. For example, fluorescent, incandescent or LED lamps may be useful in various embodiments of the present invention.

[0024] Referring to FIG. **2**, there is shown a graph of the irradiance of an exemplary blue-blocking blacklight lamp (BLB) through various lenses. In this graph, the emission spectrum of the BLB lamp is shown by the line with the circles. This line should be read against the Y-axis on the left. The other three lines show the percent transmission of the BLB emission spectrum through various lenses—a stock lens (triangle-marked line), a UVA transmitting lens (diamond-marked line), and two stacked UVA transmitting lenses (square-marked line). As can be seen, the UVA transmitting lenses provided a greater transmittance throughout the entire measured spectrum (335-400 nm).

[0025] Referring now to FIG. **3**, there is shown a lighting design useful in a water storage tank, according to an embodi-

ment of the present invention. The lighting design uses a number of light banks **30**, each containing at least one lamp, such as at least one F40T12BLB median bipin fluorescent lamp (not shown). The exemplary lighting design of FIG. **3** may be based on comparative scans of warm white lamps with suitable design software. The lighting design of FIG. **3** should be taken as an exemplary lighting design and should not be considered as limiting the choice of lighting design useful in the present invention.

[0026] Referring to FIG. **4**, there is shown a schematic drawing of a water storage tank **40** having a microbial nitrification photo-inhibition system according to the present invention. The system may include a plurality of lamps **42**, such as the BLB lamps as described above. The lamps may be controlled by a timer **44**. The output of the lamps **42** may be measured by at least one light meter **46**. Typically, a number of light meters **46** may be disposed at various locations above ground level (AGL). For example, as shown in FIG. **4**, three light meters **46** may be disposed along one side of the water storage tank **40**. While the lamps **42** are shown above the water level, the lamps **42** may be located at various locations inside the water tank **40**, such as above the water level, submerged in the water within the tank **40**, or floating on top of the water in the tank **40**.

[0027] In one exemplary embodiment of the present invention, as shown in FIG. **5**, a water storage tank **50** may be similar to the water storage **40** described above, with the addition of a dimmer **52** for controlling the intensity of the output of the lamps. The water storage tank **50** may also include a mixing device **54** for mixing water stored in the tank **50**. The mixing device **54** may be controlled by a timer **56**. Control of the various components, such as the lamps, timers, dimmers, mixing devices and the like may be performed on-site or remotely via any known control technique. For example, a Supervisory Control and Data Acquisition (SCADA) system may be used to remotely control the system of the present invention.

[0028] Referring to FIG. **6**, there is shown an engineering drawing of an exemplary storage tank used in the various studies described below. FIG. **7** shows the UVA intensity at various points horizontally at 4 feet above ground level (AGL) in air in the storage tank of FIG. **6**. FIG. **8** shows the UVA intensity at various points, vertically, at 28" from the wall of the storage tank of FIG. **6**. FIG. **9** shows showing UVA intensity at various points, vertically, at 28" from the wall of the storage tank of FIG. **6**, over a three day period.

[0029] Referring now to FIG. **10**, there is shown a graph describing results of a bottle test with and without the microbial nitrification photo-inhibition system of the present invention. In this study, three 5-liter pyrex bottles, containing 3 liters of water in each, were suspended from two water storage tanks (six 5-liter pyrex bottles in total). The bottles were placed 3.5 feet above ground level in each tank. Nitrification had begun in the water sample prior to filling the pyrex bottles. One tank was kept in the dark and one tank was provided with UVA/Visible light according to an embodiment of the present invention. As can be seen from the graph of FIG. **10**, after 3 days, the tanks in the dark were of considerably poorer quality compared to those under light.

[0030] Referring to FIG. **11***a*, there is shown a chart describing the distribution of UVA intensity with depth at high water, including estimates of the time to half-inhibition for each flux. FIG. **11***b* shows a chart describing the distribution of UVA intensity with depth at low water, including estimates of the time to half-inhibition for each flux.

[0031] It should be understood, of course, that the foregoing relates to exemplary embodiments of the invention and that modifications may be made without departing from the spirit and scope of the invention as set forth in the following claims.

What is claimed is:

1. A system for the photo-inhibition of microbial nitrification of potable water, the system comprising:

a tank for holding water; and

at least one lamp illuminating the water.

2. A method for reducing microbial nitrification of potable water, the method comprising:

contacting the water with radiation having a wavelength between 315 and 430 nm; and

providing a sufficient intensity to contact all of the water at an incident irradiance of at least 0.01 W/m^2.

* * * * *