US005861095A

# United States Patent [19]

Vogel et al.

[11] **Patent Number: 5,861,095**

[45] **Date of Patent: Jan. 19, 1999**

[54] **METHOD AND DEVICE FOR TREATING WASTEWATER**

[75] Inventors: **Steven M. Vogel**, Minnetonka; **Surya R. Pidaparti**, Eagan, both of Minn.

[73] Assignee: **Lemna Corporation**, Saint Paul, Minn.

[21] Appl. No.: **833,603**

[22] Filed: **Apr. 9, 1997**

[51] **Int. Cl.**[6] ........ **C02F 3/30**

[52] **U.S. Cl.** ........ **210/605**; 210/615; 210/621; 210/630; 210/150; 210/195.1; 210/903

[58] **Field of Search** ........ 210/605, 615, 210/616, 620, 621, 622, 629, 630, 150, 151, 195.1, 202, 219, 220, 259, 903

[56] **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,234,123 | 2/1966 | Hinde | 210/605 |
| 3,701,727 | 10/1972 | Kormanik | 210/605 |
| 4,479,876 | 10/1984 | Fuchs | 210/630 |
| 4,867,883 | 9/1989 | Daigger et al | 210/630 |
| 4,917,805 | 4/1990 | Reid | 210/630 |
| 5,096,577 | 3/1992 | Ngo et al. | 210/151 |
| 5,196,111 | 3/1993 | Nicol et al. | 210/605 |
| 5,256,281 | 10/1993 | Ngo et al. | 210/151 |
| 5,338,452 | 8/1994 | Pidaparti | 210/603 |
| 5,342,522 | 8/1994 | Marsman et al. | 210/605 |
| 5,400,549 | 3/1995 | Morgan | 52/23 |
| 5,421,999 | 6/1995 | Poole et al. | 210/150 |
| 5,534,141 | 7/1996 | McAnaney et al. | 210/110 |

OTHER PUBLICATIONS

Lemna Corporation, "Floating Modular Cover Systems", published prior to Apr. 9, 1997.

"If you think natural treatment systems are limited in scope . . . It's time to look at a Lemna® System," 1992.

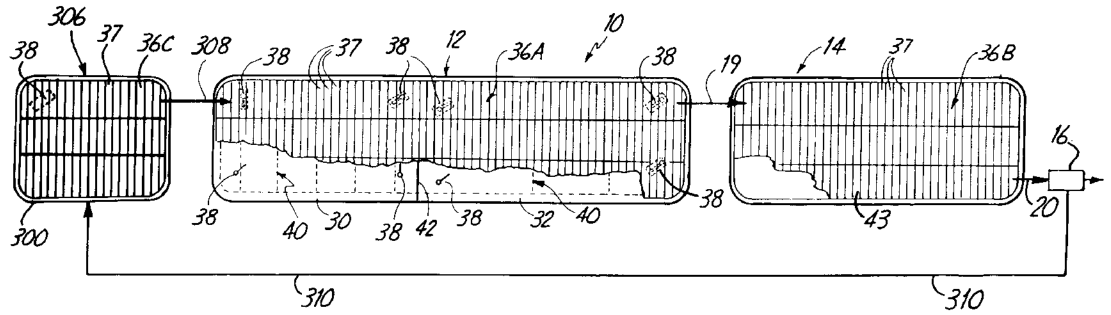
*Primary Examiner*—Christopher Upton

*Attorney, Agent, or Firm*—Kinney & Lange, P.A.

[57] **ABSTRACT**

A wastewater treatment system substantially reduces wastewater treatment time and increases treatment capacity. The system includes at least one completely covered aerobic reactor cell and a completely covered quiescent anaerobic reactor cell. The system can also include a polishing reactor for further treating wastewater after treatment by the anaerobic reactor cell. The covered aerobic reactor cell preferably includes a pair of subcells in which a first cell includes continuous mixing and aeration of the wastewater and the second cell includes only intermittent mixing and aeration of the treated wastewater. The sytem optionally includes a completely covered anoxic reactor cell for treating wastewater prior to treatment by the completely covered aerobic reactor cell. The anoxic reactor cell receives partially treated wastewater recirculated from the polishing reactor.

**9 Claims, 4 Drawing Sheets**



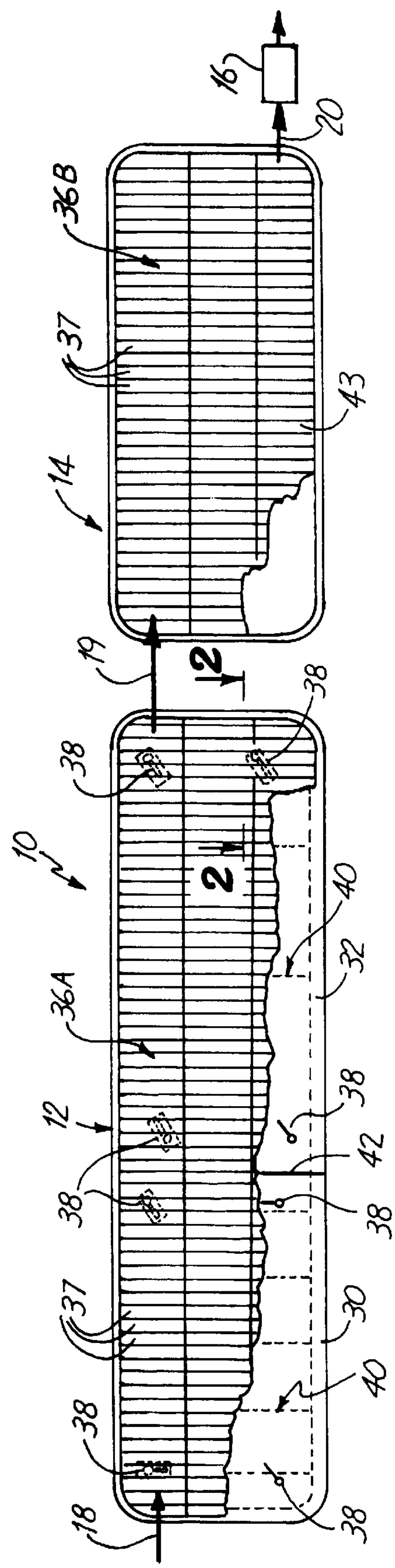



Fig. 1

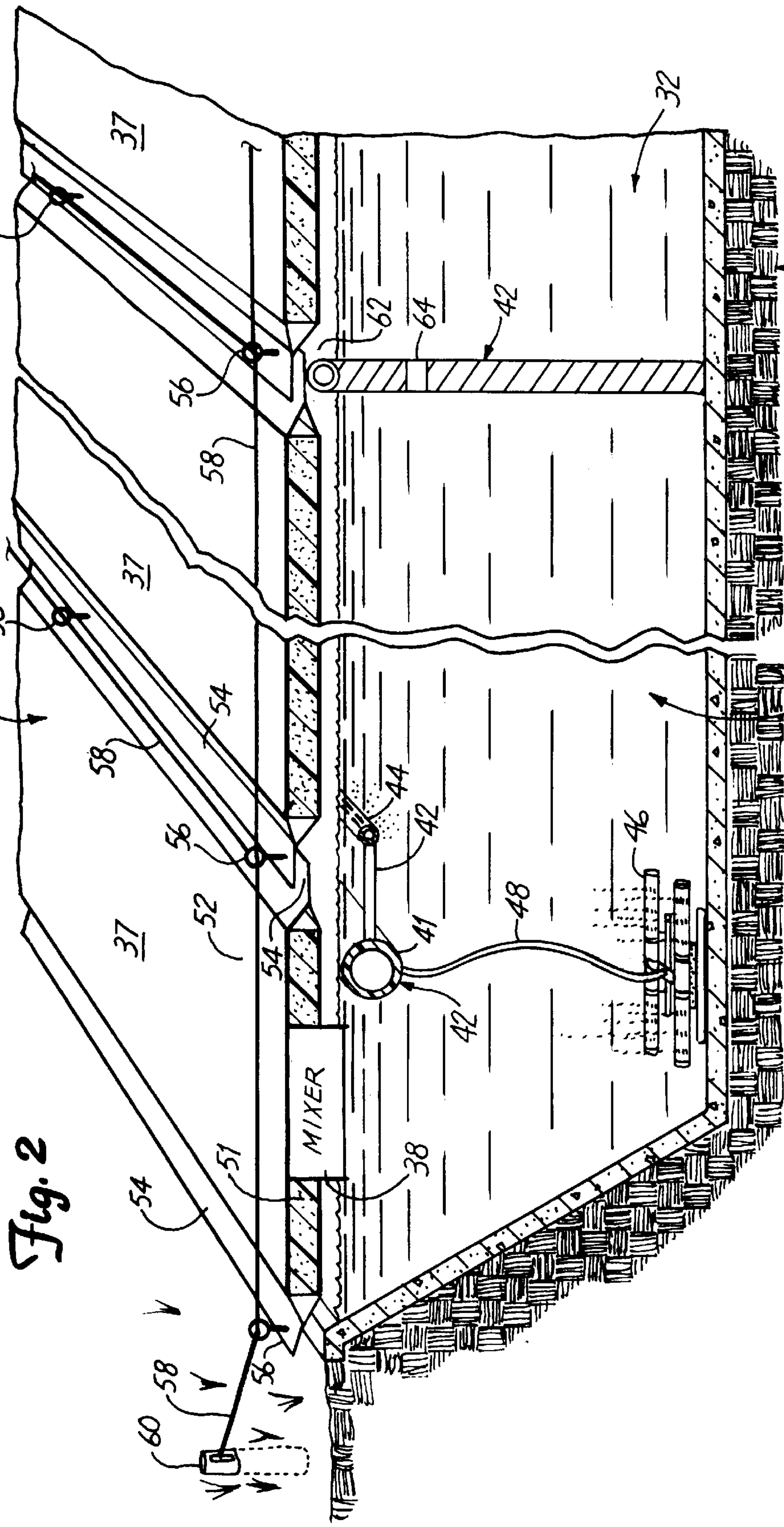

32
12
37
56
62
64
42
58
37
56
36A
54
58
30
44
42
46
56
48
52
54
41
37
42
MIXER
38
51
54
58
56
60

Fig. 2

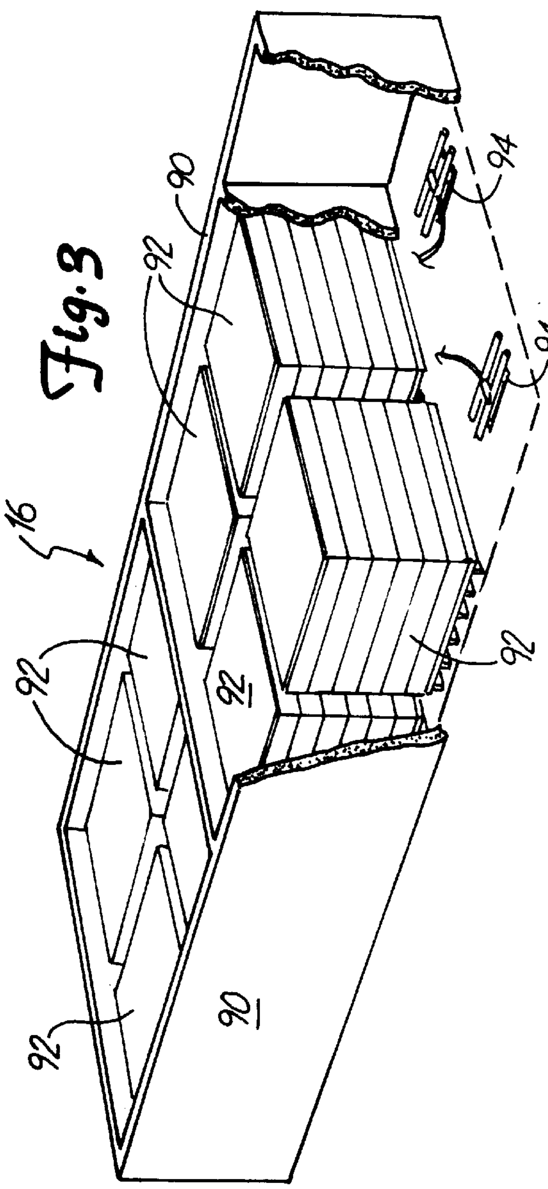

16
90
92
92
92
92
92
92
90
94
94

Fig. 3

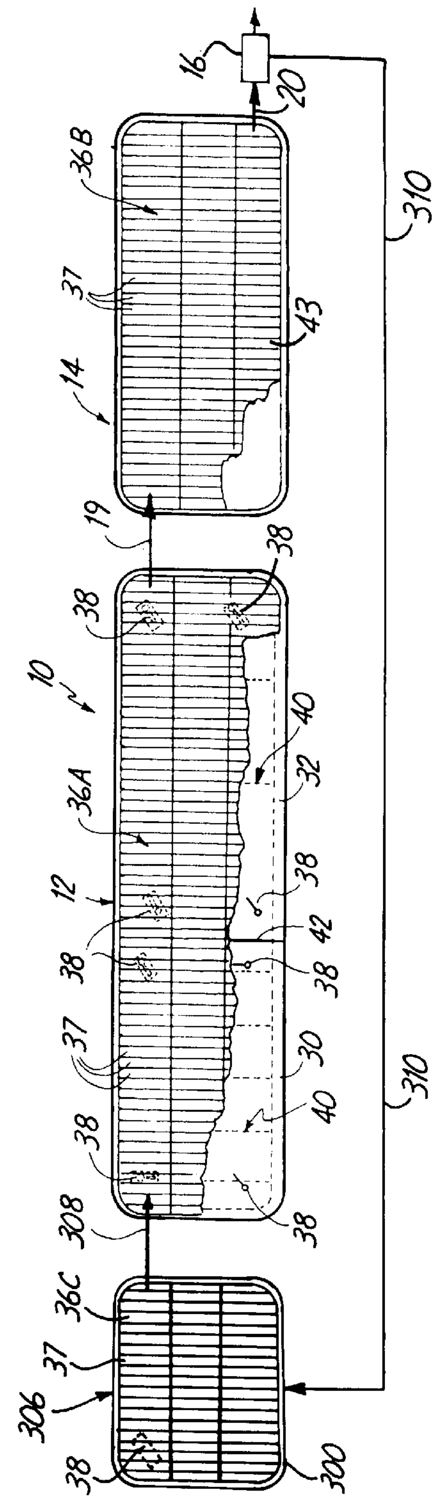

16
20
36B
37
43
14
310
19
38
38
10
40
32
36A
12
38
42
38
38
37
30
40
38
38
308
36C
37
306
38
300
310

Fig. 5

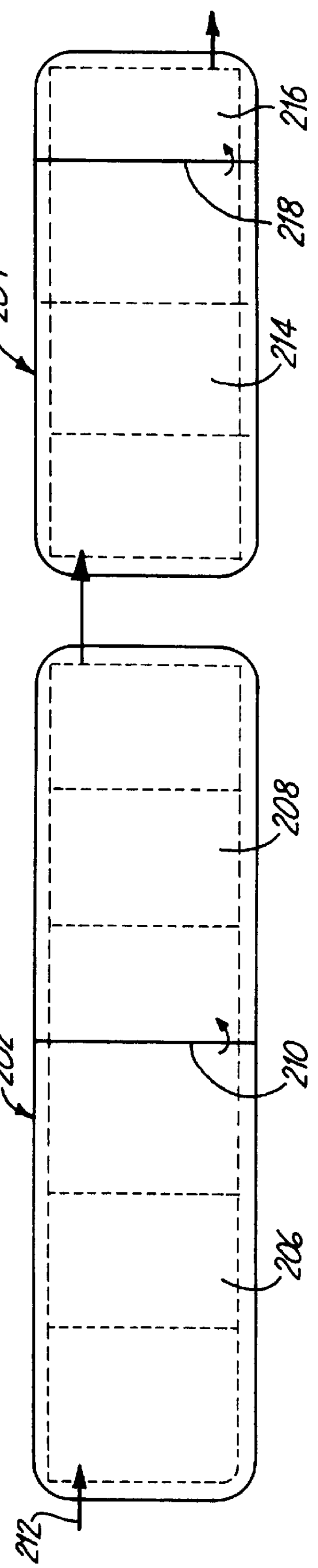



Fig. 4
PRIOR ART

# METHOD AND DEVICE FOR TREATING WASTEWATER

## BACKGROUND OF THE INVENTION

The present invention relates to wastewater treatment systems and in particular to a covered lagoon based wastewater treatment system. A lagoon is any earthen basin for containing a body of water.

Conventional lagoon based wastewater treatment systems rely on open air lagoons to permit aerobic and anaerobic treatment of wastewater. A lagoon is any earthen basin for containing a body of water, such as a treatment reactor cell. Lagoon based systems require a large amount of space, on the order of several acres. Once the treatment capacity for a lagoon based system is reached, additional capacity can only be accomplished by building additional lagoons, which requires a significant capital expenditure and the use of more land. In addition, traditional lagoon based systems cannot achieve more stringent effluent limits required by recent environmental regulation changes without further increasing the treatment time or without adding costly mechanical adaptations. Neither of these options are desirable.

Traditional lagoon based systems have several shortcomings. Open air ponds produce odors and permit algae growth which inhibits wastewater treatment. In addition, open air ponds expose the treatment pond to ambient air conditions. In cold climates, this exposure significantly slows treatment and reduces the effectiveness of the treatment since biological activity of the bacteria are decreased. In particular, bacteria which remove ammonia nitrogen are significantly inhibited.

Finally, traditional lagoon based systems produce sludge that settles in all the basins requiring periodic shutdown of the treatment ponds to remove the sludge.

## SUMMARY OF THE INVENTION

A wastewater treatment system of the present invention substantially reduces wastewater treatment time and increases treatment capacity. The system includes at least one completely covered aerobic reactor cell and a completely covered quiescent anaerobic reactor cell. The system can also include a polishing reactor for further treating wastewater after treatment by the anaerobic reactor cell. The covered aerobic reactor cell preferably includes a pair of subcells in which a first cell includes complete mix treatment including aeration (and optional mixing) of the wastewater and the second cell includes partial mix treatment including aeration and intermittent mixing of the partially treated wastewater.

This system dramatically reduces wastewater treatment times and increases system capacity through several effects. First, the cover eliminates algae production by blocking sunlight and reduces odor migration from the ponds. Second, the cover provides insulation from ambient air conditions (e.g. freezing temperatures) to permit the reactor cells to operate at higher temperatures year round. Higher water temperatures are conducive to heightened biological activity of the aerobic and anaerobic treatment bacteria. Third, the system permits increased treatment capacity (e.g. doubled capacity) without increasing the number or size of the treatment ponds. This latter feature is significant since an additional treatment pond need not be built to increase treatment capacity. Alternatively, if a new system is being constructed, a high capacity treatment system can be built on a smaller footprint than a conventional system. In other words, the system greatly reduces the pond footprint required to treat a given volume of wastewater. Fourth, by covering the process, the polishing reactor will reduce ammonia regardless of the ambient air temperature. Fifth, the combination of the covered aerobic mixing cells and covered anaerobic settling zone prevents solids build up in the aerobic cells through treatment and mixing, which keeps the remaining solids suspended, and more nearly balances a rate of growth and decay in the anaerobic zone thereby limiting sludge removal to a periodic operation in the anaerobic settling zone only. Finally, the polishing reactor insures reduction of biochemical oxygen demand (BOD), total suspended solids (TSS) and ammonia-nitrogen ($NH_3$—N) to meet the most stringent effluent limits.



## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of a system of the present invention.

FIG. **2** is a sectional view of the system of FIG. **1** as taken along lines **2**—**2**.

FIG. **3** is an enlarged perspective view of FIG. **1** with portions broken away.

FIG. **4** is a plan view of a prior art conventional system prior to conversion to a system of the present invention.

FIG. **5** is a plan view of an alternate embodiment of the system of the present invention including an anoxic cell and recirculation loop.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

### Overview of Treatment System

FIG. **1** shows a top plan view of a wastewater treatment system **10** of the present invention. System **10** includes first pond **12**, second pond **14**, polishing reactor **16**, influent **18**, intermediate effluent **19**, and effluent **20**. First pond **12** includes complete mix aerobic cell **30**, partial mix aerobic cell **32**, cover system **36**A, mixers **38**, air diffusion system **40**, and hydraulic baffle **42**. Second pond **14** defines quiescent anaerobic cell **43** and includes cover system **36**B. Second pond **14** lacks mixers and lacks an air diffusion system. Sewage flows into the system **10** as influent **18**, through first pond **12**, second pond **14**, and polishing reactor **16** and exits system **10** as effluent **20**.

First pond **12** and second pond **14** include conventional inlet and out let regulators for controlling the flow rate of influent **18** and effluent **20** and intermediate effluent **19** between first pond **12** and second pond **14**.

First pond **12** defines a reactor that aerobically treats wastewater received through influent **18**. The wastewater to be treated generally contains carbonaceous COD and BOD, phosphorous, nitrogen and adsorbable pollutants. Bacteria within first pond **12** converts the dissolved organic waste material, phosphorous and nitrogen into stable by-products including carbon dioxide, nitrates, nitrites, water and biological solids (sludge) through processes of biological activity of the bacteria including biodegradation and nitrification.

Accordingly, both complete mix aerobic cell **30** and partial mix aerobic cell **32** includes mixers **38** and air diffusion system **40** (although cell **30** can operate without mixers **38**). Mixers **38** comprise floating mechanical surface aerators to provided both mixing and aeration. Mixers **38** are secured in place by tether lines secured to a wall of first pond **12** and second pond **14**, respectively. Mixers **38** are placed about complete mix aerobic cell **30** and partial mix aerobic cell **32** to permit a predetermined amount of mixing. The mixing equipment in partial mix aerobic cell **32** is operated intermittently to resuspend settled solids and assure their transport out of this cell.

Complete mix cell **30** and partial mix **32** are operated in the manner (i.e. speed of wastewater flow and/or amount of mixing) in which those skilled in the art use the terms complete mix and partial mix for lagoon based systems and as referenced by the EPA for such systems.

Air diffusion system **40** provides a grid of fine bubble diffused air aerators positioned primarily at the floor of first pond **12**. Air diffusion system **40** provides compressed air to wastewater within first pond **12** to mix the wastewater and biological solids to maximize contact between the bacteria and the dissolved organics within the wastewater and aerates the wastewater to further maximize the reaction between the bacteria and organics.

Cover system **36**A, **36**B essentially includes a removable modular pond cover system as disclosed in Morgan U.S. Pat. No. 5,400,549, titled INSULATED REMOVABLE POND COVER, which is hereby incorporated by reference. Cover system **36**A, **36**B includes a plurality of modules **37** arranged together to completely cover first pond **12** and second pond **16**. Cover system **36**A, **36**B is capable of letting gases generated by first pond **12** and second treatment pond **14** escape to the atmosphere and is capable of permitting precipitation (e.g. rain) to pass through the cover system **36**A, **36**B so that water does not build up on top of cover system **36**A,**36**B. Each module **37** includes a floating insulating component so that cover system **36**A, **36**B floats on top of the wastewater in ponds **12** and **14** while also insulating the water from atmospheric conditions such as cold air temperatures. This insulation facilitates aerobic and anaerobic treatment of wastewater since the biologic activity in the water is heightened at higher temperatures. The increased operating temperatures created by cover system **36**A, **36**B also permits year round nitrification regardless of ambient air temperatures. Cover system **36**A, **36**B also blocks exposure of the wastewater from the sun to prevent algae growth in pond **12** and pond **14**. A more detailed illustration of modules **37** of system **36** is provided in FIG. **2**.

Hydraulic baffle **42** extends transversely across first pond **12** to separate first pond **12** into complete mix aerobic cell **30** and partial mix aerobic **32**. Baffle **42** is positioned to divide first pond **12** into two parts. Baffle **42** preferably comprises a non-porous fabric sheet connected to the sides of pond **12** and defines a flow passage substantially smaller than the transverse cross sectional area of first pond **12**. Baffle **42** essentially permits gradual controlled flow of partially treated wastewater from cell **30** into cell **32**.

Second treatment pond **14** defines a basin containing intermediate effluent **19** from first treatment pond **12** and defines quiescent anaerobic cell **43**. Second pond **14** lacks mixers **38**, air diffusion system **40**, and baffle **42**. however, second pond **14** does include cover system **36**B which completely covers second pond **14**, and which has a structure identical to cover system **36**A that covers first treatment pond **12**.

Anaerobic cell **43** of second treatment pond **14** defines a reactor which allows deposition of suspended solids and removal of dissolved organic matter when bacteria within cell **43** convert the dissolved organic waste material into carbon dioxide, methane, biological solids (sludge) in the absence of oxygen, nitrate or sulfates. This settling step permits a large amount of suspended solids to settle or precipitate out of the wastewater after the aerated treatment in first pond **12**.

Polishing reactor **16** is disclosed in Poole et. al. U.S. Pat. No. 5,421,999, titled FLOATING NITRIFICATION REACTOR IN A TREATMENT POND, which is hereby incorporated by reference. The reactor consists of aerated submerged attached-growth media modules, which maintain an adequate population of bacteria for this treatment step. The reactor removes residual BOD from the preceding treatment step and provides nitrification.

FIG. **2** is an enlarged cross sectional view of a portion of first pond **12** which further illustrates its previously described components including complete mix aerobic cell **30** and partial mix aerobic cell **32** shown on opposite sides of baffle **42**. As seen in FIG. **2**, cover system **36**A includes cover modules **37**, with each module **37** having floating insulation member **51**, durable geomembrane casing **52** and edges **54**. Cover system **36** further includes pins **56**, cable **58** and anchor **60**. Baffle **42** includes float **62** and port **64** for permitting a small continuous flow of partially treated wastewater from complete mix aerobic cell **30** to partial mix aerobic cell **32**.

In addition, FIG. **2** shows previously discussed air diffusion system **40**, which includes main air conduit **41**, lateral air conduit **42**, upper air diffuser unit **44** and lower air diffuser units **46**, and air lines **48**. For illustrative purposes, FIG. **2** only shows a single air conduit **41**, single lateral air conduit **42**, single upper air diffuser unit **44**, and single lower air diffuser unit **46**. However, first pond **12** includes an entire network or grid of upper and lower diffuser units **44** and **46** (fed by multiple main air conduits **41** and lateral conduits **42**) arranged in both cells **30** and **32** of first pond **12** to provide fine bubble air diffusion throughout first pond **12**. As shown in FIG. **1**, a denser network of main air conduits **41** (and consequently, more air bubble diffusers) is provided in complete mix aerobic cell **30** than in partial mix aerobic cell **32** since partial mix aerobic cell **32** requires less aeration and mixing than cell **30**.

As shown in FIG. **2**, previously described cover module **37** of cover system **36**A, **36**B is defined by closed cell insulation member **51** sealed within a sheet casing **52** of durable geomembrane. Gases emitted by biological treatment activity escapes treatment pond **12** upward between edges **54** of adjacent modules **37**, while rain/precipitation is permitted to pass downward through edges **54** between adjacent modules **37** into first pond **12**. Cover system **36**A and **36**B permits odor containment since modules **37** completely cover pond. Insulation member **51** of modules **37** provide heat insulation since member **51** has insulation factor from R-8 up to R-25. Individual modules **37** also preferably include openings formed in select modules **37** to house floating mechanical equipment such as floating mixers **38** or other stationary mechanical equipment. Modules **37** can also includes hatches for access to submerged equipment or for sampling the wastewater. The buoyancy of the rigid cover system **36**A, **36**B is sufficient to support the weight of several crew members who may be walking or working on cover system **36**A, **36**B.

## Polishing Reactor

FIG. **3** is an enlarged perspective view of previously described polishing reactor **16** with portions broken away for illustration. As shown in FIG. **3**, polishing reactor **16** further includes housing **90**, modules **92** and preaeration diffusers **94**. Pre-aeration diffusers **94** consist of rack mounted coarse bubble diffusers located under the modules **92** which evenly distribute the air and shear coarse bubbles into very fine bubbles. This process raises the dissolved oxygen level in polishing reactor **16** to bring food and oxygen to the nitrifiers to allow a biomass attached to modules **92** to nitrify the ammonia. The polishing reactor **16** enhances the growth of nitrification bacteria to facilitate conversion of ammonia to nitrates and nitrites in an aerobic environment.

Each module **92** is comprised of plastic cross-flow media contained in a stainless steel support structure. One or more of the first modules **92** are intended for final BOD removal/polishing and are made from less dense trickling filter media and can absorb any concentration excursions without fouling. The remaining modules **92** in the polishing reactor **16** are made of a high density media and are intended for nitrification (i.e. ammonia-nitrogen ($NH_3$—N) polishing). The large surface area of the media allows for growth of a thin bacterial film capable of nitrification and BOD reduction.

Modules **92** and aeration diffusers **94** can be supported in the water column either by floats or leg supports. Individual modules **92** are isolated within separate cells within reactor **16** to provide efficiency and highest possible biological reaction rates. This individual module cell structure of two or more modules **92** increases effectiveness of the system by preventing dilution into the total volume of the reactor **16**, thereby maintaining the highest food concentration possible.

The water column is insulated throughout first and second ponds **12** and **14**, thereby permitting a higher temperature be maintained for allowing nitrification year round. Housing **90** is located near system effluent **20** and is a portion of second pond **14** that is isolated by a baffle (e.g. nonporous fabric baffle similar to baffle **42**) from cell **43** or alternatively, is in a separate concrete, metal or plastic structure.

When used after wastewater treatment with appropriate detention times in complete mix aerobic cell **30**, partial mix aerobic cell **32**, and anaerobic cell **43** as described above, polishing reactor **16** is capable of achieving biochemical oxygen demand (BOD) less than 10 mg/l, total suspended solids (TSS) less than 10 mg/l, ammonia-nitrogen ($NH_3$—N) as low as 1 mg/l and dissolved oxygen (D.O.) more than 6 mg/l.

## Operation of System

As seen in FIG. **1**, in operation, influent **18** enters covered complete mix aerobic cell **30** of first pond **12** and is subject to aerobic biodegradation and nitrification with aerobic bacteria. Aggressive and continuous mixing and aeration of wastewater in aerobic cell **30** is accomplished through mixers **38** and air diffusion system **40**, which provide dissolved oxygen and mixing action to heighten biological activity in the wastewater. Wastewater is typically detained in complete mix aerobic cell **30** for about 3 days resulting in a reduction of biochemical oxygen demand (BOD) from 250 mg/L to 40 mg/L.

Accordingly after treatment in aerobic cell **30**, partially treated wastewater migrates through baffle **42** (via port **64**) from complete mix aerobic cell **30** to partial mix aerobic cell **32**. The partially treated wastewater is subject to further diffused air injections and some mixing. In addition, wastewater in cell **32** is aggressively mixed on an intermittent basis (e.g. 10% of total detention time in cell **32**) to re-suspend solids that have settled in cell **32**. Since it is not desirable that solids accumulate in partial mix aerobic cell **32**, this intermittent aggressive mixing ensures that the majority of solids will be transported to anaerobic treatment cell **43** in second pond **14**. Wastewater is typically detained in partial mix aerobic cell **32** for about **4** days resulting in a reduction of biochemical oxygen demand (BOD) from 40 mg/L to 25 mg/L.

After treatment in partial mix aerobic cell **32**, partially treated wastewater flows as intermediate effluent **19** into anaerobic cell **43** in second pond **14**. Anaerobic cell **43** is a quiescent settling zone free of mixing, aeration, and agitation to permit solids to settle out of the wastewater. After aerobic treatment in aerobic cells **30** and **32**, and after detention in anaerobic cell **43** for about 4 days, the total suspended solids (TSS) are reduced from 250 mg/L to about 15 mg/L. In addition, after detention for 4 days in anaerobic cell **43**, BOD is reduced from 25 mg/L to about 20 mg/L.

Finally, partially treated wastewater from anaerobic cell **43** in second pond **14** flows into polishing reactor **16**. Polishing reactor is an aerobic environment first configured to remove residual BOD from the prior treatment steps. As an example, polishing reactor **16** reduces BOD from 20 mg/L to about 15 mg/L. In addition, polishing reactor **16** includes modules **92** adapted to ensure nitrification of wastewater down to 1 mg/L $NH_3$—N.

This treatment level, particulary the nitrification of ammonia, can be accomplished regardless of ambient air temperatures, which would otherwise preclude treatments to these low effluent levels. Moreover, with this system, sludge production is reduced by 85% to 94% when compared to extended air activated sludge facilities. Accordingly, sludge need only be removed from anaerobic cell **43** on a periodic basis once every seven to eleven years.

## Example 1—Retrofit of Conventional Pond System

An existing lagoon treatment facility has an aerating pond system as shown in FIG. **5**. Conventional system **200** includes first pond **202** and second pond **204**. First pond **202** is a conventional aerobic treatment cell including a first cell **206** and second cell **208**. First pond **202** covers 1.1 acres, is 8 feet deep and is designed to permit a total 14 day detention time of wastewater within pond **202**. Hydraulic baffle **210** splits pond **202** so that the wastewater is detained in cell **206** for 7 days and detained in cell **208** for 7 days. The incoming influent has 250 mg/L BOD and 250 mg/L TSS.

Second pond **204** is 0.66 acres, 8 feet deep and constructed/regulated to cause a total 8 day detention of wastewater. Second pond **204** includes main cell **214** and polishing/rock filter **216** and baffle **218** for separating main cell **214** and filter **216**. The wastewater is detained in main cell **214** for 7 days and then detained in filter **216** for 1 day.

At 150,000 gallons of effluent flow per day with effluent limits of 30 mg/L BOD AND 30 MG/L tss, this system is already hydraulically overloaded. It is desired to double the capacity of the system to 300,000 gallon per day. In addition, more stringent effluent limits of 10 mg/L BOD, 15 mg/L TSS and 2 mg/L $NH_3$—N must be achieved.

With conventional technology, increasing this treatment facility's capacity would require building an additional pond or new system. However, with the system of the present invention, the new desired capacity of 300,000 gallon per day and more stringent effluent limits are met without building an additional pond system. Specifically, the conventional system **200** is converted into system **10** with the following steps. When the conversion is finished, the system will have the features and attributes shown in FIGS. **1–3**. First, conventional hydraulic baffle is removed from first pond **202** and is replaced with a hydraulic baffle like baffle **42** (see FIGS. **1** and **2**). As shown in FIG. **1** the new baffle **42** is placed to divided the first pond so that the first cell **30** is slightly smaller than second cell **32**. Second, an air diffusion system **40** and mixers **38** are installed in cells **30** and **32** of first pond **12** and cover system **36** is added to completely cover first pond **12**. Mixers **38** preferably have a capacity of 3 HP in first cell **30** and a capacity of 5 HP in second cell **32** to permit more aggressive intermittent mixing in second cell **32**. In addition, any diffusion or mixing system in conventional second pond **204** is removed to convert that pond into a quiescent settling cell **43**. Cover system **36**B is added to completely cover second pond **204**. In addition, rock/polishing filter **216** is removed or isolated so that it is inactive and not part of the wastewater treatment system. Finally, polishing reactor **16** is added as a new structure or formed as an isolated portion of second pond **204** by using a baffle to separate the polishing reactor from the anaerobic reactor cell in the second pond **204** (e.g., polishing reactor **16** is substituted for rock/polishing filter **216**).

The completed conversion of the conventional system **200** is shown in FIG. **1**. With the system **10** of the present invention in place, wastewater is detained for 7 days in first pond **12** including 3 days in first cell and for 4 days in second cell. The wastewater is then detained for 4 days in second pond **14**. This converted system now handles 300,000 gallons per day without increasing the footprint of the system and achieves more stringent effluent limits of 10 mg/L BOD, 15 mg/L TSS, and 2 mg/L $NH_3$—N after exiting polishing reactor **16**.

In some instances of retrofitting a conventional lagoon system, the original ponds are larger than necessary for use as a treatment pond in the treatment system of the present invention. In these instances, a first step of the retrofit conversion includes isolating one or more of the original lagoon ponds so that only a portion (e.g., one-half) of their original size is used as treatment ponds in the system of the present invention. The remainder of the original lagoon ponds remain idle (i.e., are not part of the system) and are reserved for use as an additional covered pond to meet future increased capacity.

### Examples 2 and 3—New Treatment System Construction

In another example, system **10** can be built as a new system as shown to treat 750,000 gallons per day and meet stringent effluent limits of 10 mg/L BOD, 15 mg/L TSS and 2 mg/L $NH_3$—N. In this instance, as seen in FIG. **1**, first pond **12** covers 1.73 acres and is 12 feet deep, and second pond **14** covers 1.26 acres and is 12 feet deep. Mixers **38** have a capacity of 7.5 HP. With this system, wastewater is detained in complete mix aerobic cell **30** for 3 days and detained in partial mix aerobic cell **32** for 3 days and finally detained in quiescent anaerobic cell **43** for 3 days. This process converts influent at 250 mg/L BOD, 250 mg/L TSS, and 30 $NH_3$—N to a clarified effluent at 10 mg/L BOD, 15 mg/L TSS, and 2 $NH_3$—N.

In another example, system **10** can be built as a new system as shown in FIG. **1** to treat 2 million gallons per day and meet stringent effluent limits of 10 mg/L BOD, 15 mg/L TSS and 2 mg/L $NH_3$—N. In this instance, the first pond **12** covers 4.12 acres and is 12 feet deep, and the second pond **14** covers 2.4 acres and is 12 feet deep. Complete mix cell **30** is 2.06 acres while partial mix cell is 2.06 acres. While cells **30**, **32**, and **43** can have many shapes, a square shape is preferred. With this system, wastewater is detained in complete mix aerobic cell **30** for 3 days and detained in partial mix aerobic cell **32** for 3 days and finally detained in quiescent anaerobic cell **43** for 4 days. This process converts influent at 250 mg/L BOD, 250 mg/L TSS, and 30 $NH_3$ to clarified effluent at 10 mg/L BOD, 15 mg/L TSS, and 2 mg/L $NH_3$—N.

In an alternative embodiment, the system of the present invention further includes the addition of a completely covered anoxic reactor cell **300** as shown in FIG. **5** The anoxic reactor cell is constructed similar to aerobic cells **30** and **32** in general appearance as part of a lagoon and includes at least one mixer **302**, does not include any aeration devices, and includes a cover system **36**C (like cover system **36**A) for covering the anoxic reactor cell. The anoxic reactor cell is operated as a complete mix cell in a manner known to those skilled in the art. The anoxic cell **300** is located prior to the complete mix aerobic cell **30** in the system **10** so that the influent intake port **308** of the complete mix aerobic reactor cell **30** acts as a discharge port of the anoxic reactor cell **300** for discharging partially treated wastewater from the anoxic cell **300** into the complete mix aerobic reactor cell **30**. In other words, untreated influent **306** first flows into and is treated by the anoxic cell **300** and then the anoxic cell **300** discharges the partially treated wastewater into the complete mix aerobic reactor cell **30** as influent **308**.

The anoxic reactor cell **300** is preferably used to attain near total nitrogen removal from the wastewater. This process is accomplished by directing a portion of the effluent exiting the polishing reactor **16**, which is high in nitrites, through recirculation loop **310** into the anoxic reactor cell **300** for mixing with the untreated wastewater. Since the anoxic reactor cell **300** lacks any molecular oxygen (as would be available with aeration, which is not present), the untreated wastewater seeks the oxygen in the nitrites, which thereby reduces biochemical oxygen demand and releasing the freed nitrogen into the atmosphere. According, this step both reduces BOD in the anoxic cell **300** and reduces the nitrogen in the cell. This latter step that occurs in the anoxic reactor cell **300** is called denitrification, which occurs at the higher water temperature.

In addition, the system of the present invention optionally includes additional components to heighten biologic activity of the treatement. For example, submerged attached growth media (which are known to those skilled in the art) can be added into the complete mix aerobic cell **30** to enhance biological treatment activity. Moreover, either or both of the complete mix anoxic cell **300** and the complete mix aerobic cell can include submerged attached growth media to enhance biological treatment activity.

### Conclusion

The wastewater treatment system of the present invention has numerous advantages. This system dramatically reduces wastewater treatment times and increases system capacity through several effects. First, the cover eliminates algae production by blocking sunlight and reduces odor migration from the ponds. Second, the cover provides insulation from ambient air conditions (e.g., freezing temperatures) to permit the reactor cells to operate at higher temperatures year round. Higher water temperatures are conducive to nitrification and heightened biological activity of the aerobic and anaerobic treatment bacteria. Third, the system permits increased treatment capacity (e.g., doubled capacity) without increasing the number or size of the treatment ponds. This latter feature is significant since an additional treatment pond need not be built to increase treatment capacity. Alternatively, if a new system is being constructed, a high capacity treatment system can be built on the same footprint of a conventional system. In other words, the system greatly reduces the pond footprint required to treat a given volume of wastewater. Fourth, by covering the process including theacrobic and anaerobic treatment cells, the polishing reactor will reduce ammonia regardless of ambient air temperature. Fifth, the combination of the covered aerobic mixing cells and covered anaerobic settling zone prevents solids build up in the aerobic cells through treatment and mixing, which keeps the remaining solids suspended, and more nearly balances a rate of growth and decay in the anaerobic zone to reduce sludge build up and confine it to the anaerobic settling zone. Finally, the polishing reactor insures reduction of residual biochemical oxygen demand (BOD), total suspended solids (TSS) and nitrification of excess ammonia-nitrogen ($NH_3$—N) to meet the most stringent effluent limits.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention. For example, the benefits of a covered system as described herein can still be substantially achieved by substantially covering the aerobic and anaerobic treatment cells instead of completely covering those cells.

What is claimed is:

**1**. A lagoon based apparatus for treating wastewater comprising:

a first treatment lagoon defining:

at least one complete mix first aerobic reactor cell including at least one an aeration device, and an influent intake port;

a partial mix aerobic second reactor cell including at least one aeration device and at least one mixing system, the second reactor cell being in communication with the complete mix aerobic reactor cell to receive effluent from the first cell;

a second treatment lagoon defining a quiescent anaerobic reactor cell in communication with the partial mix aerobic reactor cell to receive effluent from the partial mix aerobic cell;

a first cover covering the complete mix reactor cell;

a second cover covering the partial mix reactor cell;

a third cover covering the anaerobic reactor cell; and

a polishing reactor in communication with the anaerobic reactor cell to receive effluent from the anaerobic reactor cell and including a final effluent discharge port.

**2**. The appartus of claim **1** wherein the complete mix reactor cell further comprises a mixing system including at least one mixer.

**3**. The apparatus of claim **1** wherein the mixing system of the partial mix aerobic reactor cell operates at a first rate of mixing and at least a portion of the mixing system of the partial mix aerobic reactor cell is capable of intermittent operation to intermittently mix the partial mix aerobic reactor cell at a second rate of mixing higher than the first rate of mixing.

**4**. The apparatus of claim **1** and further comprising a hydraulic baffle and a first pond wherein the first aerobic cell and the second aerobic cell are defined on opposite sides of the baffle within the first pond.

**5**. The apparatus of claim **1** and further comprising:

an anoxic reactor cell including at least one mixer and a second influent intake port;

a fourth cover covering the anoxic reactor cell;

wherein the influent intake port of the complete mix aerobic reactor cell communicates with a discharge port of the anoxic reactor cell for discharging partially treated wastewater from the anoxic cell into the complete mix aerobic reactor cell.



**6**. A method of treating wastewater in lagoons comprising:

receiving an influent of wastewater into a complete mix covered aerobic reactor cell;

detaining the wastewater in the complete mix covered aerobic reactor cell for a first predetermined amount of time while mixing and aerating the wastewater in an environment with sufficient mixing and aeration to achieve complete mix aerobic treatment, wherein the cover maintains the temperature of the wastewater in the complete mix reactor cell at substantially the same temperature of the influent wastewater, thereby maximizing the kinetics of the aerobic treatment process;

transferring the wastewater from the complete mix covered aerobic reactor cell to a partial mix covered aerobic reactor cell after the first predetermined amount of time;

detaining the wastewater in the partial mix covered aerobic reactor cell for a second predetermined amount of time while aerating the wastewater and while mixing the wastewater to maintain a treatment environment to achieve partial mix aerobic treatment, wherein the cover maintains the temperature of the wastewater in the partial mix reactor cell at substantially the same temperature of the wastewater in the complete mix reactor cell, thereby maximizing the kinetics of the aerobic treatment process, and wherein the wastewater is intermittently mixed at an intensity to achieve a temporary complete mix treatment environment and with sufficient frequency to resuspend settled solids in the wastewater for transferring the solids out of the partial mix aerobic reactor cell with the wastewater;

transferring the wastewater from the partial mix covered aerobic reactor cell to a covered anaerobic reactor cell after the second predetermined amount of time;

detaining the wastewater in the covered anaerobic reactor cell for a third predetermined amount of time without aerating and without mixing the wastewater and wherein the cover maintains a temperature of the wastewater in the covered anaerobic cell at substantially the same temperature as the temperature of the wastewater in the partial mix reactor cell, thereby maximizing the kinetics of the anaerobic treatment process;

transferring the wastewater from the covered anaerobic reactor cell to a polishing reactor after the third predetermined amount of time;

detaining the wastewater in the polishing reactor cell for a fourth predetermined amount of time, which is less than the first predetermined amount of time, and attaining attached growth biological kinetics at a reaction rate commensurate with the elevated water temperature maintained by the covered aerobic and anaerobic reactor cells and providing sufficient reaction surface in the polishing reactor to achieve nitrification at the elevated water temperature regardless of ambient air temperature; and

discharging an effluent of treated wastewater from the polishing reactor.

**7**. The method of claim **6** wherein the receiving step further comprises receiving the influent wastewater into a complete mix covered, anoxic cell prior to being received into the complete mix aerobic reactor cell;

detaining the wastewater in the complete mix covered anoxic reactor cell for a predetermined amount of time while mixing the wastewater;

accepting a fraction of the wastewater from the effluent discharge port of the polishing reactor into the complete mix covered anoxic cell;

attaining denitrification in the anoxic reactor cell at the higher water temperature.



**8**. The method of claim **7** wherein at least one of the complete mix anoxic cell and the complete mix aerobic cell further comprises submerged attached growth media to enhance biological activity.

**9**. The method of claim **6** wherein the complete mix aerobic cell further comprises submerged attached growth media to enchance biological activity.

* * * * *