

(19) 日本国特許庁(JP)

(12) 公表特許公報(A)

(11) 特許出願公表番号

特表2004-530530

(P2004-530530A)

(43) 公表日 平成16年10月7日(2004.10.7)

(51) Int.Cl.⁷

C02F 3/34

F I

C02F 3/34

1 O 1 A

C02F 3/34

Z A B

テーマコード (参考)

4 D O 4 O

審査請求 未請求 予備審査請求 有 (全 313 頁)

(21) 出願番号 特願2002-532170 (P2002-532170)
 (86) (22) 出願日 平成13年10月5日 (2001.10.5)
 (85) 翻訳文提出日 平成15年4月4日 (2003.4.4)
 (86) 国際出願番号 PCT/US2001/031411
 (87) 国際公開番号 W02002/028780
 (87) 国際公開日 平成14年4月11日 (2002.4.11)
 (31) 優先権主張番号 60/238,878
 (32) 優先日 平成12年10月6日 (2000.10.6)
 (33) 優先権主張国 米国 (US)

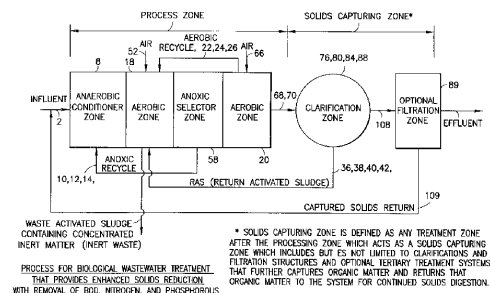
(71) 出願人 503128375
 プレミア ウェイストウォーター インタ
 ナショナル, リミテッド ライアビリテ
 ィ カンパニー
 アメリカ合衆国, ネバダ 89118, ラ
 スベガス, エス. プロキオン 5340
 (74) 代理人 100071272
 弁理士 後藤 洋介
 (74) 代理人 100077838
 弁理士 池田 憲保
 (72) 発明者 ガルシア, ポール ジー.
 アメリカ合衆国, ネバダ 89109, ラ
 スベガス, ユニット イー-3078, 1
 500 スターダスト O-163

最終頁に続く

(54) 【発明の名称】 促進された固形物の減量 (E S R) での廃水処理装置および方法

(57) 【要約】

生化学的酸素要求量を減少させ、かつ、生物学的栄養塩の減少を利用して、内生呼吸による蒸発残留物の減量率を改善できる廃水処理方法。この廃水処理方法では、効率のよい曝気供給系を用いて有機物の酸化に必要な時間を劇的に減少させ、有機物および微生物を再循環、細断、均質化し、従来の系よりもかなり多くの回数にわたって塊 (mass) 全体を酸素処理することで、生物学的な固形物消化率を高める。



【特許請求の範囲】

【請求項 1】

含水蒸発残留物を再循環させ、混合し、懸濁液状態に保つ場である嫌気性コンディショナー領域に、流入廃水の流れを送る段階と、
 無酸素性セクター領域から前記嫌気性コンディショナー領域に低酸素濃度の混合液懸濁物質を送り、前記嫌気性コンディショナー領域内を溶存酸素濃度の低い状態に維持する段階と、
 前記嫌気性コンディショナー領域からの流出物を第 1 の好気性反応槽領域に送り、前記嫌気性コンディショナー領域の流出物を前記第 1 の好気性反応槽領域で浄化領域からの戻り汚泥と混合することで、前記第 1 の好気性反応槽領域の中身を再循環させて曝気し、かつ
 10 前記第 1 の好気性反応槽領域の中身に含まれる沈殿性固形物を分別し、これによって固形物や他の有機物を分解及び酸化させ、挿入固形物 (insert solid) を蓄積する段階と、
 蓄積された不活性固形物を前記第 1 の好気性反応槽領域から排出する段階と、
 前記無酸素性セクター領域の水溶液を再循環させて混合する前記無酸素性セクター領域に前記第 1 の好気性反応槽領域から水溶液の流出物を送る段階と、
 前記無酸素性セクター領域の水溶液のうち低酸素濃度／混合液懸濁物質に相当する第 1 の部分を前記嫌気性コンディショナー領域に移送し、前記無酸素性セクター領域の水溶液の第 2 の部分を第 2 の好気性反応槽領域に移送する段階と、
 前記第 2 の好気性反応槽領域に含まれる水溶液を再循環させて曝気することで沈殿性固形物
 20 を分別し、これによって懸濁物質や他の有機物を分解及び酸化させる段階と、
 前記第 2 の好気性反応槽領域の水溶液の第 1 の部分を前記第 1 の好気性反応槽領域に送る段階と、
 前記第 2 の好気性反応槽領域の水溶液の第 2 の部分を前記浄化領域に送り、該浄化領域内の水溶液から固形物を沈殿または分離させる段階と、
 前記浄化領域から沈殿または分離させた、戻り汚泥に相当する固形物を、前記第 1 の好気性反応槽領域に送る段階と、
 前記浄化領域の水溶液を濾過領域に送り、該濾過領域に送られる水溶液から固形物を沈殿
 30 または分離させる段階と、
 前記濾過領域の流出物のうち液体分を排出液タンクに移送し、前記濾過領域の流出物の沈殿または分離させた固形分を再プロセッシング用に前記流入廃水の流れに移送する段階と、
 を含むことを特徴とする廃棄物を含有する水溶液を処理するための方法。

【請求項 2】

含水蒸発残留物を再循環させ、混合し、懸濁状態に保つ場である嫌気性コンディショナー領域に、微生物を含む流入廃水の流れを送り、無酸素性セクター領域から前記嫌気性コンディショナー領域への低酸素濃度の混合液懸濁物質のフローを調節して前記嫌気性コンディショナー領域内を溶存酸素濃度の低い状態に維持する、ぜいたくなリン摂取 (luxury phosphorous uptake) の第 1 段階を達成する段階と、
 前記嫌気性コンディショナー領域からの流出物を第 1 の好気性反応槽領域に送り、前記嫌気性コンディショナー領域の流出物を前記第 1 の好気性反応槽領域で浄化領域から供給さ
 40 れる戻り汚泥と混合することで、前記第 1 の好気性反応槽領域の中身を再循環させて曝気し、かつ、硝化が発生し、前記第 1 の好気性反応槽領域の中身に含まれる沈殿性固形物を分別し、これによってぜいたくなリン摂取の第 2 段階を促進しつつ懸濁物質や他の有機物を分解及び酸化させ、挿入固形物を蓄積する段階と、
 蓄積された不活性固形物を前記第 1 の好気性反応槽領域から排出する段階と、
 前記無酸素性セクター領域の水溶液を再循環させて混合する前記無酸素性セクター領域に前記第 1 の好気性反応槽領域から水溶液の流出物を送り、かつ、水溶液中に含まれる有機物の消費と同時に生物学的リンの脱硝化ならびに放出が起こるように前記無酸素性セクター領域内に低酸素環境を存在させる段階と、
 無酸素性セクター領域の水溶液のうち低酸素濃度／混合液懸濁物質に相当する第 1 の部
 50

分を前記嫌気性コンディショナー領域に移送し、前記無酸素性セクター領域の水溶液のうち少なくとも第2の部分には微生物ならびに栄養塩が豊富に含まれる、前記無酸素性セクター領域の水溶液の第2部分を第2の好気性槽領域に移送する段階と、
前記第2の好気性反応槽領域に含まれる水溶液を再循環させて曝気することで硝化を発生させ、沈殿性固形物を分別し、これによって懸濁物質や他の有機物を分解及び酸化させると共に、微生物による大量のリン消費につながる前記ゼイタクナリン摂取の第2段階をさらに促進する段階と、
前記第2の好気性反応槽領域の水溶液の第1部分を前記第1の好気性反応槽領域に送る段階と、
前記第2の好気性反応槽領域の水溶液の第2部分を前記浄化領域に送り、該浄化領域に送られる水溶液から固形物を沈殿または分離させる段階と、
前記浄化領域から沈殿または分離させた固形物を戻り汚泥として前記第1の好気性反応槽領域に送る段階と、
前記浄化領域の水溶液を濾過領域に送り、該濾過領域に送られる水溶液から固形物を沈殿または分離させる段階と、
前記濾過領域の流出物のうち液体分を排出液タンクに移送し、前記濾過領域の流出物の沈殿または分離させた固形分を再プロセッシング用に前記流入廃水の流れに移送する段階と、を含むことを特徴とする廃棄物を含む水溶液を生物処理して有機物質、窒素およびリンを減少させるための方法。

10

20

【請求項3】

流入口と流体的に連結された嫌気性コンディショナー領域であって、前記流入口を介して流入廃水の流れを受入れ、含水蒸発残留物が懸濁液状態に保たれるような方法で前記嫌気性コンディショナー領域内の廃水を再循環させ、かつ、前記嫌気性コンディショナー領域内を溶存酸素濃度の低い状態に維持するために無酸素性セクター領域から低酸素濃度の混合液懸濁物質の流れを受入れる、前記嫌気性コンディショナー領域と、
前記嫌気性コンディショナー領域と流体的に連結された第1の好気性反応槽領域であって、浄化領域から供給される戻り汚泥と混合される前記嫌気性コンディショナー領域の流出物を受入れることで、前記第1の好気性反応槽領域の中身を再循環させて曝気し、かつ、沈殿性固形物を分別し、これによって懸濁物質や他の有機物を分解及び酸化させ、不活性固形物を蓄積し、蓄積された不活性固形物が前記第1の好気性反応槽領域から排出される、前記第1の好気性反応槽領域と、
前記嫌気性コンディショナー領域および前記第1の好気性反応槽領域と流体的に連結された無酸素性セクター領域であって、前記第1の好気性反応槽領域からの水溶液の流出物を受入れ、前記無酸素性セクター領域内の水溶液を再循環および混合し、前記無酸素性セクター領域の水溶液のうち低酸素濃度／混合液懸濁物質に相当する第1部分を前記嫌気性コンディショナー領域に送る、前記無酸素性セクター領域と、
前記無酸素性セクター領域および前記第1の好気性反応槽領域と流体的に連結された第2の好気性反応槽領域であって、前記無酸素性セクター領域の水溶液の第2部分を受入れ、前記第2の好気性領域内の水溶液を再循環させて曝気することで、沈殿性固形物を分別し、前記第2の好気性反応槽領域の水溶液の第1部分を前記第1の好気性反応槽領域に送る、前記第2の好気性反応槽領域と、
前記第2の好気性領域および前記第1の好気性領域と流体的に連結された浄化領域であって、前記第2の好気性反応槽領域の水溶液の第2部分を受入れることで、沈殿または分離させ、かつ、前記水溶液から固形物を捕捉し、戻り汚泥に相当する沈殿固形物を前記第1の好気性反応槽領域に送る、前記浄化領域と、
前記浄化領域、前記流入口および流出口と流体的に連結された濾過領域であって、前記浄化領域からの流出物を受入れ、前記浄化領域の中身の液体分から固形物を分離し、排水に相当する前記濾過領域の中身の第1部分を前記流出口に送り、分離された固形物に相当する前記濾過領域の中身の第2部分を前記流入口に送って再プロセッシング用に前記流入廃水の流れと混合する、前記濾過領域と、を含むことを特徴とする廃棄物を含む水溶

30

40

50

液を処理するための装置。

【発明の詳細な説明】

【0001】

関連出願へのクロスリファレンス

本願は米国特許法 35 U S C 第 1 1 9 (e) (3 5 U S C § 1 1 9 (e)) の定めにより、米国仮特許出願第 6 0 / 2 3 8 , 8 7 8 号の優先権の利益を主張するものであり、その開示内容全体を本願明細書に援用する。

【0002】

発明の背景

技術分野

本発明は、廃液に対する処理性を改善できる廃液処理方法および装置に関し、特に、改善された機能性、操作性、曝気手法を利用して、廃液に対する処理性を改善する方法および装置に関する。

【0003】

背景情報

現在、廃水処理プラントでは、広大な敷地でエネルギーと資材、労力を比較的高い率で費やす従来の方法に基づくプロセスを利用している。こうした従来の廃水処理方法に伴って発生するコストが高くなるのは、ポンプ、送風機、エアコンプレッサ、スクレーパ、フィルタなどの装置、化学薬品、熱、プレス、凝固剤、凝集剤、沈殿剤および脱水などを用いて廃水フローのすべての要素を処理し、取り扱い、監視しているためである。従来の廃水処理システムではエネルギー消費量の大きい方法で廃水を処理している。これらの方法としては、好気性消化（又は有気性分解）、嫌気性消化（又は無気性分解）、汚泥濃縮および固形分の脱水処理法があげられるが、これに限定されるものではない。こうした処理に伴って発生するコストはプラントの稼動エネルギー予算の約 8 5 % に達する。

【0004】

廃水処理の対象となる典型的な流入廃水の流れの場合、全廃水の流れの 9 9 . 9 % が水であり、約 0 . 1 % が有機固形物や無機固形物、溶存物質である。また、一般的な流入廃水の流れには、さまざまな濃度で栄養塩も含まれている。廃水の流れに含まれる除去すべき栄養塩には、これを分解するのに必要な酸素要求量がある。この酸素要求量を業界では生化学的酸素要求量（B O D）と呼んでいる。約 0 . 1 % の固形物のうち、約 1 0 % から 2 0 % が B O D の約 3 5 % を含む沈殿性固形物である。B O D の残りの 6 5 % は廃棄物の溶存有機物分の中に含まれている。図 1 3 を参照のこと。

【0005】

従来の廃水処理システムの固形物（汚泥）処理系では、減少させるべき有機物の体積が約 5 0 % に減るレベルまでプロセッシングエネルギーが分解によって費やされ、有機物の体積で残りの 5 0 % については、埋立処分、焼却および土地応用を含むがこれに限定されるものではない、さまざまな手段によって廃棄される。これによってさらにエネルギーが消費され、固形物を処理するための費用もかかる。有機物を廃棄する必要性をほとんど皆無にできるシステムおよび方法が得られると有益であろうと思われる。

【0006】

発明の目的および概要

本発明の一目的は、有機物および化学薬品を含有する廃液を処理するための装置および方法を提供することにある。

【0007】

本発明の別の目的は、活性汚泥の処理と処理領域の再循環とを併用し、かつ、曝気装置の有効性を高めて、有機物の分解に必要な時間およびエネルギーを抑えることにある。

【0008】

本発明のさらに他の目的は、システムからの有機沈殿固形物の意図的な除去である廃棄活性汚泥（W A S）の形で有機物の消費量を実質的に減少させ、よって固形物処理施設での作業量およびコストを低減することにある。

10

20

30

40

50

【0009】

本発明の別の目的は、産業型の栄養塩を高濃度で含有する水性廃水（aqueous wastewater）を処理するための装置および方法を提供することにある。

【0010】

本発明のさらに他の目的は、化学的酸素要求量（COD）、BOD、アンモニアおよびリンを一般的な濃度で含む都市廃棄物を処理することにある。

【0011】

本発明のさらに他の目的は、動物型の廃棄物に典型的に見られるCOD、BOD、アンモニアおよびリンの濃度レベルが高い主力産業廃棄物を処理することにある。

【0012】

本発明のさらに別の目的は、工業製品のメーカーや家畜排泄物処理施設から発生し得るもののなどの現場設備からの廃水を前処理するための装置および方法を提供することにある。

【0013】

本発明の他の目的は、従来の曝気システムよりも優れ、かつコスト的に手ごろであり、曝気、混合、均質化、細断を組み合わせることができる、効率的な再循環曝気システム（RCAS）を利用することにある。

【0014】

本発明のさらに他の目的は、従来の処理システムよりも、設計、操作、構築、初期化、管理、拡張および保守が容易な装置および方法を提供することにある。

【0015】

本発明のさらに他の目的は、従来の処理システムよりも、プロセッシング条件やフロー条件の変更に適応しやすく、自動化、監視、制御が容易な装置および方法を提供することにある。

【0016】

本発明のさらに別の目的は、同様の廃水処理要件と比較すると、従来の廃水処理プラントでの場合よりも全体の土地専有面積（敷地面積）が小さい装置および方法を提供することにある。

【0017】

本発明のさらに別の目的は、従来の廃水処理システムよりも動作させる上で経済的な装置および方法を提供することにある。

【0018】

本発明のさらに他の目的は、従来の廃水処理システムよりも建築および稼働費用が小さい装置および方法を提供することにある。

【0019】

本発明のさらに他の目的は、強烈な曝気を供給する機能に関して、散気装置を設置するタンク床面積が制限されないようにすることで、処理タンクの曝気槽で一層多量の廃水を処理する機能を高める装置および方法を提供することにある。

【0020】

本発明のさらに他の目的は、減衰係数（ k_d ）を非常に大きくできる装置および方法を提供することにある。

【0021】

本発明のさらに別の目的は、従来の処理システムよりも平均細胞滞留時間（MCRT）を長くすることで、揮発性固形分の破壊量を増やし、これに続く固形物の処理作業を抑えることのできる装置および方法を提供することにある。

【0022】

本発明のさらに別の目的は、従来の処理システムの柔軟性の高い食物対微生物（F/M）比の範囲の前後で極めて柔軟性の高い食物対微生物（F/M）比の範囲を得られる装置および方法を提供することにある。

【0023】

本発明のさらに他の目的は、混合液懸濁物質（MLSS）濃度の一層短時間での上昇、運

10

20

30

40

50

転開始時の電力コスト低減および種汚泥運搬コストの低減を含むがこれに限定されるものではない、始動コストを抑えることで、効率を高めつつ設計フローの対応範囲を拡げる装置および方法を提供することにある。

【0024】

本発明のさらに別の目的は、プラントの運転開始時の始動状態の間、一種の連続回分式反応システムに円錐底形のタンクを用いる装置および方法を提供することにある。

【0025】

本発明のさらに他の目的は、損なわれた状態から回復する微生物をすみやかに成長させるために、プロセスを完全に損なった状態の後でマイクロコロニーを短時間で成長させることのできる一種の連続回分式反応に円錐底形のタンクを用いる装置および方法を提供することにある。 10

【0026】

本発明のさらに他の目的は、従来の廃水処理システムよりも所望の排水品質まで廃水进行处理するための装置数およびプロセス数を減らした処理プラントを提供することにある。

【0027】

本発明のさらに別の目的は、掻き取り、かき集め、ブラシなどによる清掃装置を清澄装置内に必要とせず浄化によって液体から固形物を分離する装置を提供することにある。

【0028】

本発明のさらに他の目的は、清澄装置と、濾過構造と、有機物をさらに捕捉して、この有機物を固形物の連続消化用に好気性領域に戻す任意の三次処理システムとを含むがこれに限定されるものではない、固形物捕捉領域として作用する装置を提供することにある。 20

【0029】

本発明のさらに他の目的は、有機窒素を酸化して一層安定した硝酸塩化合物にし、これを廃棄物の流れにおいて脱硝化工程で還元することによって廃棄物の流れに含まれる総窒素量を減少させる装置を提供することにある。

【0030】

本発明のさらに別の目的は、微生物での分解（消化）によって廃棄物の流れに含まれるリンを減少させ、新たな細胞の成長を有機物の分解に利用する装置を提供することにある。

【0031】

本発明のさらに他の目的は、領域に特有であるがタンクに特有のものではない処理工程を提供することにある。 30

【0032】

本発明のさらに別の目的は、特定のフローならびに特定の処理工程に適応できるシステム設計を提供することにある。

【0033】

本発明のさらに他の目的は、R C A Sシステムのトロイダル渦作用を廃水中の病原体数の低減に利用することにある。

【0034】

本発明のさらに別の目的は、水溶液の化学的酸化を可能にする装置および方法を提供することにある。 40

【0035】

本発明のさらに別の目的は、微生物コロニーならびにコロニーの栄養源となる基質を均質化するための方法を提供することにある。

【0036】

本発明のさらに他の目的は、大きな微生物フロックを小さな微生物フロックに分配することにある。

【0037】

本発明のさらに他の目的は、中心を含む微生物フロック全体を好気性に維持させることにある。

【0038】

本発明のさらに別の目的は、好気性プロセスで高濃度の溶存酸素を提供することにある。

【0039】

本発明のさらに別の目的は、コストと廃水貯水池の必要性に対する他の選択肢を提供することにある。

【0040】

本発明のさらに他の目的は、周知の廃水処理システムおよび方法における欠点を解消することにある。

【0041】

本発明に対する用途ならびに本発明の機能を示すにあたり、都市廃水の未処理の原水を処理対象の廃液の一例としてとりあげる。しかしながら、本発明による装置および方法の実施例は他のさまざまな廃棄物の処理に利用できるものである。 10

【0042】

本発明において用いる曝気という用語は、二次流体フロー（液体または気体）を一次流体フロー（液体または気体）に加えることを意味する。

【0043】

本発明によれば、微生物の酸素摂取率を増す酸素移動効率を高めるRCA S（再循環曝気システム）によって強烈な曝気を提供し、有機物を機能化、細断および均質化し、有機物を実質的に100%消化して、廃水の有機物を処理することができる。これは、分散曝気などの従来の曝気を利用している従来の処理方法に比してプロセッシングエネルギーをかなり有効に活用するものである。また、本発明によれば、一次浄化設備、嫌気性消化（無気分解）設備、好気性消化（有気分解）設備、一次処理貯水池、焼却炉および関連の設備、汚泥濃縮設備およびスラッジ運搬設備などの従来の多くのエネルギー消費装置が削減または排除される。 20

【0044】

本発明によれば、廃水中の有機物を一層効率的かつ完全に消化することができる。廃水の全BODの有機物分を第1の好気性反応槽領域および第2の好気性反応槽領域で曝気を利用して処理し、嫌気性コンディショナー領域および無酸素性セクター領域では、水中環境に微生物が容易に呼吸できるだけの十分な分子状酸素が溶存しない条件（貧酸素条件とも呼ばれる）に廃水を維持する。この貧酸素条件は一般に、硝酸塩などの化学的に結合した酸素が存在する環境であると言われる。嫌気性コンディショナーの領域、第1の好気性反応槽領域、無酸素性セクターおよび第2の好気性反応槽領域では、有機物を積極的に消化する。 30

【0045】

本発明の一形態によれば、廃棄物を含有する水溶液を処理するための方法が、含水蒸発残留物を再循環させ、混合し、懸濁液状態に保つ場である嫌気性コンディショナー領域に、流入廃水の流れを送る段階と、無酸素性セクター領域から前記嫌気性コンディショナー領域に低酸素濃度の混合液懸濁物質を送り、前記嫌気性コンディショナー領域内を溶存酸素濃度の低い状態に維持する段階と、 40

前記嫌気性コンディショナー領域からの流出物を第1の好気性反応槽領域に送り、前記嫌気性コンディショナー領域の流出物を前記第1の好気性反応槽領域で浄化領域からの戻り汚泥と混合することで、前記第1の好気性反応槽領域の中身を再循環させて曝気し、かつ、前記第1の好気性反応槽領域の中身に含まれる沈殿性固形物を分別し、これによって固形物や他の有機物を分解及び酸化させ、挿入固形物を蓄積する段階と、蓄積された不活性固形物を前記第1の好気性反応槽領域から排出する段階と、前記無酸素性セクター領域の水溶液を再循環させて混合する前記無酸素性セクター領域に前記第1の好気性反応槽領域から水溶液の流出物を送る段階と、前記無酸素性セクター領域の水溶液のうち低酸素濃度／混合液懸濁物質に相当する第1の部分の前記嫌気性コンディショナー領域に移送し、前記無酸素性セクター領域の水溶液の第2部分を第2の好気性反応槽領域に移送する段階と、 50

前記第2の好気性反応槽領域に含まれる水溶液を再循環させて曝気することで沈殿性固形物を分別し、これによって懸濁物質や他の有機物を分解及び酸化させる段階と、
前記第2の好気性反応槽領域の水溶液の第1の部分を前記第1の好気性反応槽領域に送る段階と、

前記第2の好気性反応槽領域の水溶液の第2の部分を前記浄化領域に送り、該浄化領域内の水溶液から固形物を沈殿または分離させる段階と、

前記浄化領域から沈殿または分離させた、戻り汚泥に相当する固形物を、前記第1の好気性反応槽領域に送る段階と、

前記浄化領域の水溶液を濾過領域に送り、該濾過領域に送られる水溶液から固形物を沈殿または分離させる段階と、

前記濾過領域の流出物のうち液体分を排出液タンクに移送し、前記濾過領域の流出物の沈殿または分離させた固形分を再プロセッシング用に前記流入廃水の流れに移送する段階と、を含む。

【0046】

本発明の別の形態によれば、廃棄物を含有する水溶液を生物処理して有機物質、窒素およびリンを減少させるための方法が、

含水蒸発残留物を再循環させ、混合し、懸濁状態に保つ場である嫌気性コンディショナー領域に、微生物を含む流入廃水の流れを送り、無酸素性セクター領域から前記嫌気性コンディショナー領域への低酸素濃度の混合液懸濁物質のフローを調節して前記嫌気性コンディショナー領域内を溶存酸素濃度の低い状態に維持する、ぜいたくなリン摂取の第1段階を達成する段階と、

前記嫌気性コンディショナー領域からの流出物を第1の好気性反応槽領域に送り、前記嫌気性コンディショナー領域の流出物を前記第1の好気性反応槽領域で浄化領域から供給される戻り汚泥と混合することで、前記第1の好気性反応槽領域の中身を再循環させて曝気し、かつ、硝化が発生し、前記第1の好気性反応槽領域の中身に含まれる沈殿性固形物を分別し、これによってぜいたくなリン摂取の第2段階を促進しつつ懸濁物質や他の有機物を分解及び酸化させ、挿入固形物を蓄積する段階と、

蓄積された不活性固形物を前記第1の好気性反応槽領域から排出する段階と、

前記無酸素性セクター領域の水溶液を再循環させて混合する前記無酸素性セクター領域に前記第1の好気性反応槽領域から水溶液の流出物を送り、かつ、水溶液中に含まれる有機物の消費と同時に生物学的リンの脱硝化ならびに放出が起こるように前記無酸素性セクター領域内に低酸素環境を存在させる段階と、

無酸素性セクター領域の水溶液のうち低酸素濃度／混合液懸濁物質に相当する第1の部分を前記嫌気性コンディショナー領域に移送し、前記無酸素性セクター領域の水溶液のうち少なくとも第2の部分には微生物ならびに栄養塩が豊富に含まれる、前記無酸素性セクター領域の水溶液の第2の部分を第2の好気性槽領域に移送する段階と、

前記第2の好気性反応槽領域に含まれる水溶液を再循環させて曝気することで硝化を発生させ、沈殿性固形物を分別および細断し、これによって懸濁物質や他の有機物を分解及び酸化させると共に、微生物による大量のリン消費につながる前記ぜいたくなリン摂取の第2段階をさらに促進する段階と、

前記第2の好気性反応槽領域の水溶液の第1の部分を前記第1の好気性反応槽領域に送る段階と、

前記第2の好気性反応槽領域の水溶液の第2の部分を前記浄化領域に送り、該浄化領域に送られる水溶液から固形物を沈殿または分離させる段階と、

前記浄化領域から沈殿または分離させた固形物を戻り汚泥として前記第1の好気性反応槽領域に送る段階と、

前記浄化領域の水溶液を濾過領域に送り、該濾過領域に送られる水溶液から固形物を沈殿または分離させる段階と、

前記濾過領域の流出物のうち液体分を排出液タンクに移送し、前記濾過領域の流出物の沈殿または分離させた固形分を再プロセッシング用に前記流入廃水の流れに移送する段階と、

10

20

30

40

50

を含む。

【0047】

本発明の別の形態によれば、廃棄物を含有する水溶液を処理するための装置が、
流入口と流体的に連結された嫌気性コンディショナー領域であって、前記流入口を介して
流入廃水の流れを受入れ、含水蒸発残留物が懸濁液状態に保たれるような方法で前記嫌気
性コンディショナー領域内の廃水を再循環させ、かつ、前記嫌気性コンディショナー領域
内を溶存酸素濃度の低い状態に維持するために無酸素性セクター領域から低酸素濃度の
混合液懸濁物質の流れを受入れる、前記嫌気性コンディショナー領域と、
前記嫌気性コンディショナー領域と流体的に連結された第1の好気性反応槽領域であって
、浄化領域から供給される戻り汚泥と混合される前記嫌気性コンディショナー領域の流出
物を受入れることで、前記第1の好気性反応槽領域の中身を再循環させて曝気し、かつ、
沈殿性固形物を分別し、これによって懸濁物質や他の有機物を分解及び酸化させ、不活性
固形物を蓄積し、蓄積された不活性固形物が前記第1の好気性反応槽領域から排出される
、前記第1の好気性反応槽領域と、
前記嫌気性コンディショナー領域および前記第1の好気性反応槽領域と流体的に連結され
た無酸素性セクター領域であって、前記第1の好気性反応槽領域からの水溶液の流出物
を受入れ、前記無酸素性セクター領域内の水溶液を再循環および混合し、前記無酸素性
セクター領域の水溶液のうち低酸素濃度／混合液懸濁物質に相当する第1の部分を前記
嫌気性コンディショナー領域に送る、前記無酸素性セクター領域と、
前記無酸素性セクター領域および前記第1の好気性反応槽領域と流体的に連結された第
2の好気性反応槽領域であって、前記無酸素性セクター領域の水溶液の第2の部分を受
入れ、前記第2の好気性領域内の水溶液を再循環させて曝気することで、沈殿性固形物を
分別し、前記第2の好気性反応槽領域の水溶液の第1の部分を前記第1の好気性反応槽領
域に送る、前記第2の好気性反応槽領域と、
前記第2の好気性領域および前記第1の好気性領域と流体的に連結された浄化領域であ
って、前記第2の好気性反応槽領域の水溶液の第2の部分を受入れることで、沈殿または分
離させ、かつ、前記水溶液から固形物を捕捉し、戻り汚泥に相当する沈殿固形物を前記第
1の好気性反応槽領域に送る、前記浄化領域と、
前記浄化領域、前記流入口および流出口と流体的に連結された濾過領域であって、前記浄
化領域からの流出物を受入れ、前記浄化領域の中身の液体分から固形物を分離し、排水に
相当する前記濾過領域の中身の第1の部分を前記流出口に送り、分離された固形物に相当
する前記濾過領域の中身の第2の部分を前記流入口に送って再プロセッシング用に前記流入
廃水の流れと混合する、前記濾過領域と、を含む。

【0048】

本発明の上記の目的および他の目的、特徴および利点については、添付の図面を参照して
以下に述べる実施例の詳細な説明から明らかになる。

【0049】

実施例の詳細な説明

本発明の方法および装置を実施および利用して、化学的廃液および生物学的廃液を処理す
ることができる。本発明は、固形物の好気性生物学的分解、生物学的酸化、化学的酸化お
よび物理的分離などのさまざまな厳密に好気性の処理方法ならびにこれらの処理方法の併
用によって、水溶液中の廃液を清浄化するものである。本発明は、栄養塩を除去する目的
の化学薬品に対する依存度が小さくなることから好気性の処理方法を用いる点で効率的で
ある。これらの方法は、上記処理工程の枠内でのさまざまな安定化段階にみられる。

【0050】

本発明による処理工程の枠内でのおよその性能レベル（原水 v s . 排水）は以下のとお
りである。

【0051】

酸化とこれに続く重力沈殿によって原水の全BOD（生化学的酸素要求量）濃度を90%
から99.5%減少させる。

【0052】

有機窒素を酸化によって第1のアンモニアと第2の亜硝酸塩と第3の硝酸塩とに還元する。

【0053】

原水のアンモニア窒素濃度を硝化によって95%から99.5%減少させる。

【0054】

上記の硝化プロセスで生じた亜硝酸塩および硝酸塩の窒素濃度を脱硝化によって50%から99.5%減少させる。

【0055】

ぜいたくなP摂取によって原水の全リン濃度を90%から99.5%減少させる。

10

【0056】

強烈な酸化によって全有機懸濁物質濃度の最大99.5%を破壊する。

【0057】

以下の説明では、処理のために水溶液がプロセス領域間を進む際に上記の性能レベルを達成する本発明の方法について述べる。本発明の設計では、プロセッシング領域内での栄養塩の酸化に必要な全水理学的滞留時間が約4から8時間であると好ましい。

【0058】

プロセスの性能

廃液として発生する有機物および化学薬品の処理を、酸化または生物学的な手段のいずれかによって安定化させる。この安定化は、実際には一連のプロセスである。たとえば、都市廃水を処理する場合、アンモニアを窒素ガスに変換する際の安定化を数段階にわたって行うプロセスである。アンモニア(NH_3)を生物学的に酸化して亜硝酸塩(NO_2)にし、続いてこれを有機的に安定化させて硝酸塩(NO_3)とする。次の段階ならびに最終段階は脱硝化として知られている。この段階が終わると、酸素量が極めて低いレベルまで減少し、窒素ガスすなわち N_2 を大気中に放出しつつ NO_3 の形での元素結合(elemental bound)酸素が呼吸に利用される。

20

【0059】

もうひとつの処理形態として、曝気による化合物の酸化があげられる。酸化で生じる反応によって、化学元素または化合物が電子を失う。このようにして電子を失うことで、元素または化合物が一層安定する。

30

【0060】

生物処理は都市廃水の処理時において最も重要な段階のひとつであるため、本発明ならびにその装置および方法を理解しやすくするために、この処理について簡単に説明する。生物処理時、微生物は廃水中の栄養塩(BOD)を食べ、変換し、または消費する。これらの栄養塩は本質的に生物分解性の有機物または化学薬品である。従来のシステムでは未処理の廃水を沈降によって物理的に処理しているが、廃棄物に含まれる沈殿できない物質や溶存物質に含まれるBODが高い割合(BODの約65%)であるため、浪費によって除去できるのはBODのわずか約35%である。本発明では、浮遊増殖処理方法によって好気性消化処理を利用し、水溶液中の全BODを95%除去以上のレベルまで処理する。

【0061】

液体廃棄物中には、1)有機物、2)無機物という2つのタイプの固形物が含まれている。無機固形物については生物処理で分解除去することができない。このため、無機固形物または不活性固形物がプロセッシングシステム中に蓄積されはじめたら、不活性固形物を除去または浪費しなければならない。この浪費は、有機固形物に対する不活性固形物の濃度比が予め定められた値になると促進される。ほとんどの都市型廃水中の無機固形物または不活性固形物の含有割合はシステムに送られてくる全固形物含有量に比して小さいため、不活性浪費には実質的に90日間から360日間の範囲以上の時間がかかる場合がある。一般的な都市廃棄物の流れにおける有機固形物の含量は廃水中の固形物の約70%から85%を占める。これらの固形物のうちおよそ80%から85%は一般に溶存物質であり、沈殿しないものであるが、これらの固形物のうち15%から20%は沈殿性である。しか

40

50

しながら、本発明では好気性プロセッシング領域それぞれの再循環プロセスで上記の沈殿性固形物を細断することで、微生物による消費を一層容易にすることができる。

【0062】

この細断によって、微生物コロニーおよび沈殿性固形物を均質化することができ、本発明の好気性消化処理工程が促進される。このように沈殿性固形物が均質であることで、すべての食物基質がほとんど溶存物質になり、微生物コロニーが容易に消費できるようになる。

【0063】

微生物コロニーのフロックが本発明のR C A Sシステムを通過する際、大きなフロック部分が小さなフロック粒子に分配される。フロックサイズを小さくすることで、フロックの表面積が増し、必要な食物や酸素と一層密に接触するようになるため、微生物コロニーが基質を消費しやすくなる。 10

【0064】

中身全体にわたって微生物コロニーを好気性に保つと、基質および微生物コロニーの消化速度が増す。R C A Sシステムは、フロック粒子の中心で好気性の条件を維持することができるように微生物コロニーを分配後の小さなフロック粒子に保って基質の消化を高める。フロック粒子が小さくなったため、好気性領域中の溶存酸素濃度をフロック粒子の中心で容易に達成できる。また、これによって好気性領域を溶存酸素濃度の高い状態に維持することができる。

【0065】

本発明のプロセッシング・好気性消化処理（有気分解）システムは、生物学的混合培養を利用して有機廃棄物を細分化する生物系によって得られる。本発明の好気性消化処理システムは、懸濁液中で非光合成微生物すなわちバイオマスを高い密度で増殖および維持し、このバイオマスが有機廃棄物を消費する。好気性消化条件下では、減少した有機化合物が酸化されて最終生成物である二酸化炭素および水になる。 20

【0066】

非光合成微生物が増殖して生存できるか否かは、これらの微生物が有機物を代謝してエネルギーを得る能力に左右される。従来の好気性処理工程では、有機物の完全代謝と合成が起こって生物学的な増殖物が大量に生じるが、プロセスが生物学的に過負荷になって排水の品質が危うくならないようにするためには、これをシステムから除去しなければならない。本発明では、バイオマスの完全に好気性の消化処理（有気性分解処理）を活用し、F/M（食物対微生物）比を（0.05から0.80の範囲）に制御してバランスさせ、さらに酸素の供給を制御およびバランスさせて、微生物環境を図2の「内生呼吸期」の一番右に維持する。このようにすることで、有機物が完全代謝および合成されるだけでなく、プロセスの終了時に生物学的固形物が大幅に減少する。 30

【0067】

本発明のもうひとつの特徴として、多量の有機窒素をアンモニアに変換し、アンモニアを亜硝酸塩に変換し、亜硝酸塩を硝酸塩に変換する硝化サイクルを利用することがあげられる。続いて、窒素を大気に放出して硝酸塩を脱硝すると、廃棄物の流れに含まれる全窒素が減少する。 40

【0068】

本発明のさらに他の特徴として、好気性反応槽領域で起こるものなどの高酸素濃度時の間に細胞壁の発達ならびに新たな細胞増殖用の食物ソースとして、システムに入るリンを微生物によって消費することがあげられる。

【0069】

以下、図1を参照すると、微生物の特徴的な増殖パターンが示されている。同図において、相対バイオマス濃度（垂直軸）を時間（水平軸）の関数として図表化してある。新たな環境に適応するための短い時間の経過後、微生物は有機物を消費し、培地中の生存細胞数ならびにバイオマス数を指数関数的に増やししながら二分裂で複製する。これは図1の図表の一番左の部分に示した「対数増殖期」である。「対数増殖期」では、微生物が有機物を 50

処理する能力と微生物が呼吸に利用できる溶存酸素の量の両方によって代謝率が制限される。

【0070】

図1に示す「減衰増殖期」は、微生物の増殖に必要な有機物が不足した状態が長くなることで発生する。「減衰増殖期」では、微生物の複製率が低下する。「減衰増殖期」における微生物の増殖は、微生物濃度と増殖制限有機物濃度の両方の関数である。

【0071】

「減衰増殖期」の次は「静止期」である。「静止期」では、バイオマス濃度が最大値に達し、低濃度の残りの有機物によってバイオマスの増殖率が実質的に制限され、比較的一定の状態になる。

10

【0072】

「静止期」には「内生呼吸期」が続く。「内生呼吸期」では生存可能な微生物が処理中の廃水中にまだ残っている少量の有機物を取り合う。最終的には、死滅率が複製率を上回るような形で微生物の飢餓が起こる。このため、「内生呼吸期」には水溶液中のバイオマスの濃度が減少する。本発明では、プロセッシング基準に対して一定の濃度に維持した混合液体懸濁物質（MLSS）濃度で確認した場合の微生物の死滅率が微生物の増殖率と等しくなるように内生呼吸（ER）を制御する。

【0073】

以下、本発明による廃水処理について詳細に説明する。本発明では、廃水処理プロセッシングを、

20

（1）全有機窒素および全リンの低減を含むがこれに限定されるものではない、有機廃棄物を消費するための質量生物学的（mass biological）好気性消化（または有気性分解）

（2）固形物捕捉領域の浄化／沈降

（3）固形物を好気性反応槽プロセスに戻して固形物捕捉領域の沈殿固形物を再処理という三段階で行う。

【0074】

本発明のプロセッシング方法では、長い平均細胞滞留時間（MCRT）、中程度の食物対微生物（F/M）比、強烈な曝気からなる環境を維持することで、有機廃棄物を消費し、内生呼吸期において微生物を強制的に生存させる。

30

【0075】

このプロセスの浄化／沈降段階を利用して、重力沈殿によって固形物を上清（残りの液体）から分離する。詳細については後述するが、懸濁物質を含む水溶液が好気性反応槽領域No. 2（図4のタンク20）から浄化領域（図4の清澄装置No. 1、2、3および4に対応する浄化領域（タンク76、80、84および88）に流入したら、上清の速度を落として固形物を重力で沈殿させることができるようにする。浄化タンクの底に沈殿固形物がわずかに集まりはじめたら、これを頻繁かつすみやかに除去してタンクの好気性反応槽No. 1の領域（タンク18）に戻し、さらに処理する。上清（清澄度が高めの水溶液）をプロセスに送り続け、ここで三次浄化または濾過などの任意の三次処理によってさらに処理し、排出前に生物学的物質および不活性物質をほぼ完全に除去するようにしてもよい。受水域の流れ、蒸発池、造園水利、農業水利または他のタイプの処理所が、このような廃水の受入先になることもある。

40

【0076】

本発明のものなどの好気性消化処理システムでは、有機廃棄物を消費するために懸濁液中で微生物の個体群を増殖および維持しなければならない。図1に示されるように、個々の微生物は短時間で増殖するが、運転開始時すなわち大きな負荷変動が発生しているときには、最初の低濃度の微生物が有機廃棄物をすみやかに分解できるだけの十分に高いレベルまで増えるには時間がかかる。したがって、MLSSの濃度を迅速に高める方法を用いることが重要になる。従来のシステムに関しては、MLSS濃度を許容できる動作レベルに到達させるまでのプラントの始動時間は30から45日間もの範囲におよぶ。本発明を用

50

いると、本発明でプラントの始動時間を14日間以下に短縮することが可能である。微生物に対する毒性ショック負荷が原因のプラントの再稼働に必要な時間も従来のプラントの時間の要件より短縮される。これらの方法については後述する。

【0077】

好気性消化システムに共通の設計コンセプトのひとつに、平均細胞滞留時間（MCRT）がある。これは、微生物がシステム内に滞在する平均時間である。従来の処理システムのMCRTは、排水中に含まれる固形物の量とプロセッシングサイクルから引き抜いた廃棄物スラッジ中の余剰固形物とに対する、活性汚泥プロセスの微生物固形物量と関係がある。本発明では、排水中の固形物の量のみに対する、MCRTは好気性処理工程における微生物固形物の量と関係がある。廃棄活性汚泥として引き抜かれる揮発性固形物は実質的に皆無であるため、これは故意でない浪費である。従来のシステムでの一般的なMCRT値は15から30日間である。しかしながら、本発明でのMCRT値は30日目で始まり、150から250日以上の数値に達する（図3参照）。従来の好気性処理システムでのMCRT値が30日よりも長くなると動作上の問題が発生することがある。懸濁物質の濃度が高く濁った状態が続くなどにより排水品質が悪くなる一般的な原因のひとつに、固形物の浪費不足によるシステム内での固形物の過剰堆積がある。排水品質が悪くなる他の諸々の理由としては、極端に古く速度の遅い沈殿固形物、固形物の酸化しすぎ、固形物の脱凝集があげられる。結果として、従来の好気性処理システムでは、折に触れて余剰固形物を意図的に廃棄し、図3に示す範囲内のMCRTを保つようにすると望ましい。本発明などの場合、すべての有機固形物をほぼ完全に消化することができるため、余剰固形物の除去は 10 20

【0078】

固形物の量は、従来のシステムでの値を図3に示すMLSS（混合液体懸濁物質）の濃度で表される。従来のシステムでの一般的なMLSS値は、接触安定化システムの場合で値域の最低値1,000mg/L、完全混合および長時間曝気システムの場合で6,000mg/Lの範囲である。本発明の嫌気性コンディショナー領域、無酸素性セクター領域および好気性反応槽領域での微生物固形物の量（MLSS）（たとえば、詳細については後述する図4を参照のこと）は、2,000～8,000mg/L以上の範囲である。本発明の装置および方法では、本発明で使用するものなどの効率的な曝気供給系装置（再循環曝気システムまたは「RCAS」）を用いることで、一般的な都市型廃棄物の有機物をほぼ完全に消化する場合は図3に示すMLSS濃度を維持し、非一般的な産業型廃棄物の有機物をほぼ完全に消化する場合は図3に示す高いMLSS濃度を維持することができる。本発明において使用する曝気装置は、米国特許第5,893,641（Garcia）に記載されているものであり、その開示内容全体を本願明細書に援用する。 30

【0079】

本発明によって実現されるプロセスでは、上述した効率的な曝気供給系（RCAS）を用いて、酸素移動、循環、均質性および深層混合に必要な大気を供給することで、全有機固形物の消化（分解）という成果も得られる。上述したタイプの曝気システムを利用する、上記にて実現したプロセスのもうひとつの利点として、好気性反応槽領域内に滞留しているMLSSの混合および二次酸素化があげられる。この混合と二次酸素化は、好気性反応槽領域の最下端からMLSS中身を除去し、実質的にサイド（side）水深の表面下三分の二の高さで再酸素処理したMLSSを排出して各タンクに戻すことによって行われる。MLSSの二次酸素化は、RCASによって混入し、曝気されたMLSSと一緒に運搬された過剰なエントレインドエアが、導管を経由して好気性反応槽領域の中身の中まで流動できるようにして達成される。好気性反応槽領域のMLSSを一次酸素化および二次酸素化すると、溶存酸素（DO）濃度が実質的に3.0から5.0mg/Lの範囲のレベルになる。好気性反応槽領域の溶存酸素濃度を、従来の好気性消化システムの上限側の範囲を上回る動作レベルである2.0mg/Lに維持する。したがって、特に、本発明は、その効率的な酸素化処理工程によって有機固形物を高い度合いで消化（分解）するものである。 40 50

【0080】

本発明で達成される溶存酸素濃度は通常よりも高く、十分な混合も達成されるため、従来の曝気システムで達成されるよりも有機物の減衰係数 (k_d) の比率が高くなる。「減衰」という語は、 F/M をMCRTに関連付ける式で揮発性(有機)懸濁物質の破壊(消化)を表すのに用いられる用語である。従来の曝気システムの k_d 値は0.04から0.06であり、平均0.05であるのに対し、本発明では、 k_d が実質的に0.10または従来の曝気システムの二倍であるため、消化(分解)率を高くすることができる。減衰係数を求めるのに用いる式については図17を参照のこと。

【0081】

従来の酸素移動効率は、反応槽に供給した気体状酸素の印加質量に対する生物細胞に達する酸素質量の割合で表される。RCASによって得られた空気泡からの酸素移動の比率は、導管内での廃水の酸素移動係数およびタンク内での酸素移動係数、廃水の酸素飽和係数、水溶液中の現在の溶存酸素濃度および酸素飽和濃度を含むがこれに限定されるものではない、廃水特性に応じて変化するいくつかの因子の関数である。

10

【0082】

従来の好気性生物処理システムでは、廃水中の有機物の代謝によってシステム内の微生物の生物塊(増殖)が増大する。余剰微生物をシステムから除去または廃棄し、食物供給と酸素の供給先である曝気槽内に存在する微生物の塊との間の適切なバランスを維持する。このバランスを食物対微生物(F/M)比と呼ぶ。当業者であれば、従来の曝気槽で維持される0.05から0.20の F/M 比によって長時間曝気システムの動作が規定されることは周知であろう。 F/M 比を大きくすると代謝率にどのように影響するかを図2に示す。図2の「指数増殖期」は有機物の除去率を最大にする上では望ましいが、この期では微生物は分散増殖するため、重力によって溶液から沈殿させようとしてもうまくいかない。さらに、消費されていない余剰有機物が溶液中にあり、これを従来の曝気システムの分散増殖した微生物コロニーで除去することはできないため、余剰有機物が排水に混じってシステムの外に出てしまう。したがって、従来の曝気処理システムは高い F/M 比で稼働され、結果としてBOD除去が非効率的かつ不十分なものとなる。

20

【0083】

F/M 比が低いと、曝気槽内での全体としての代謝活性は内生的となる。この期では、有機物の代謝はほぼ完全であり、微生物は短時間で凝集して重力によって溶液から沈殿される。BOD除去効率が高い方が望ましいときは内生期で稼働するとよい。

30

【0084】

一般的な従来の曝気処理システムの F/M 比は、長時間曝気に必要な低率で0.05から0.2の範囲、従来の処理率で0.2から0.4、高率処理の場合での上限側の範囲で0.4から1.5である。しかしながら、本発明では、 F/M 比を0.05から0.8の範囲に維持し、低率全体、従来の比率全体および高率処理工程の一部を包含して、単一の処理プラント設計で十分な柔軟性が得られるようにしている。この柔軟性は、処理システムの流量を増やして有機物の濃度を一定に保つと単に曝気装置を調節して再循環用ポンプのスピードを高めるだけで再循環率を高めることができ、これによって曝気供給率が増す点から明らかである。したがって、本願明細書ならびに米国特許第5,893,641号に記載されているものなどの曝気供給系を利用して達成される十分な量の利用可能な酸素を用いて、上記にて列挙した本発明の F/M 比の範囲で微生物に有機物を完全に代謝させることができるだけでなく、強烈な曝気によって、微生物が食物源を消費するにつれて食物源が減少し、食物の取り合いが増える。内生呼吸処理工程の場合と同様に、 F/M 比を高めて0.8にしても微生物は生きるために共食いをする。内生呼吸の共食い状態が長期間にわたって続くと、本発明の好気性消化プロセスに伴って起こる固形物蓄積の質量を確実に減らすことができる。上述した曝気装置および供給系を用いて経済的に可能なように多量の溶存酸素を維持しつつ本発明などによって F/M 比を維持することで、有機物の酸化が短時間で終了する。

40

【0085】

50

図 2 および図 16 に示されるように、微生物の M C R T が長くなると、微生物のすみやかな沈殿がますます促進されて浄化プロセスに利益がもたらされる。

【0086】

本発明で用いる「浪費」という用語をよりよく理解するために、以下の説明を行う。不活性固形物の濃度を高くするときには、生物学的プロセッシング領域内に十分な量の生物学的微生物が滞留できるように上記固形物を除去または浪費しなければならない。したがって、図 4、図 5、図 6、図 7、図 8、図 9、図 10 および図 18 に示すように、無機固形物または不活性固形物を好気性反応槽 No. 1 から除去するようにしてきた。不活性濃度が除去レベルに達したら予め定められた量の固形物を除去する。この浪費前の不活性固形物の濃度は、原水流での極めて低濃度（図 13 に示すように沈殿性固形物の約 0.001 %）から生物学的プロセッシング領域内の蒸発残留物濃度の実質的に 50 % に達し得るレベルまで安定して上昇している。不活性固形物と混ざった有機固形物があるが、生物学的プロセッシング領域から廃棄された有機固形物の総重量は、生物学的プロセッシング領域に流入した有機固形物の総重量に比して実質的に 0.01 % から 0.5 % の間である。この不活性固形物および有機固形物の浪費については、生物学的プロセッシング領域内の不活性固形物の濃度が許容可能なプロセッシングレベルまで落ちるまで周期的に継続しなければならない。

【0087】

浄化は処理済みの水溶液からバイオマスを分離することであると定義できる。従来の好気性処理・固形物分離システムは、凝固および凝集によってシステム内に大量の微生物を保持しようとしているが、従来のプロセスおよび装置の性質上、動作エネルギーコスト面での制約に加えて浪費が起こる。このため、生物学的固形物が清澄装置の底に沈殿する。続いて、システムの所望の処理消化機能を超えた分の活性汚泥である生物学的固形物（活性汚泥）の一部を、意図的にシステムから浪費（除去）しつつ生物学的固形物の大部分を曝気槽に戻す。本発明では、生物学的固形物を浄化領域（図 4 の清澄装置 No. 1、2、3、4）内のすべての無機固形物と一緒に沈殿させ、これを好気性反応槽 No. 1 の領域（図 4 のタンク 18）に戻してさらにプロセッシングすることで、システム内に微生物を保持する。戻り汚泥（RAS）を吸い出して好気性反応槽 No. 1 の領域に戻す頻度とガロン数によってブランケットの深さ（清澄装置の底部に蓄積されたスラッジ）を最低値に調節できるように注意する。この RAS 吸い出し頻度であれば生物学的固形物が浄化領域に長時間とどまることはないが、そうでないと腐敗して気化し、浄化領域の表面に浮遊してくる。浄化領域内での流水速度が最小限になるように RAS 流の吸い出しを観察および調節する。流水速度が高くなると、浄化領域での沈殿が非効率的になり、排水中で生物学的固形物の持ち越しが発生する可能性がある。

【0088】

本発明を用いると、曝気サイクル内での水理学的滞留時間は、完全混合およびプラグ流れプロセスの範囲であり、一部が高純度酸素プロセスの範囲になる一方で、長時間曝気プロセスの利点が引き出される。図 3 に示されるように（同図の一番右の列を参照のこと）、長時間曝気プロセスでは一般に 18 から 36 時間をかけて有機物をほぼ完全に酸化させる（処理する）。本発明では、有機物について実質的に 4 から 8 時間以内に同じ結果が得られる。効率的な曝気供給系を用いることで、本発明は有機物を酸化させるのに必要な時間を劇的に削減している。これは、それぞれの中身を 2 時間毎に容量で実質的に 100 % 再循環している、好気性反応槽領域（図 4 のタンク 18、20）、嫌気性コンディショナー領域（図 4 のタンク 8）、無酸素性セクター領域（図 4 のタンク 58）の各々に設けられた曝気供給系によって達成される。嫌気性コンディショナー領域と好気性反応槽領域および無酸素性セクター領域の両方の再循環率とを組み合わせると、24 時間の時間内に全プロセッシング再循環率が処理工程に入る原水流の 200 % 以上になる。この曝気システムは、有機物および微生物を再循環し、細断し、均質化し、塊全体を従来のシステムよりもずっと多い回数で酸素処理するため、従来のシステムよりも短時間で生物学的固形物の消化率が高くなる。従来の処理システムにおける一般的な再循環率は、完全混合システム

では原水流 1 日あたり 25 から 100 パーセント、プラグ流れシステムでは原水流 1 日あたり 25 から 50 パーセント、長時間曝気システムでは原水流 1 日あたり 75 から 150 パーセントの範囲である。再循環率は、従来の活性汚泥処理システムでの場合、原水流に対する戻り汚泥 (RAS) の再循環割合のみを示す。本発明はこれと同じタイプの RAS 再循環割合を用いてはいるが、本発明では上述したプロセッシング再循環割合も利用して、従来の活性汚泥処理システムで可能なよりも固形物消化率を高めている。

【0089】

以下、本発明による生物処理法について説明する。微生物細胞の組成物は、重量で 70 から 90 パーセントが水、10 から 30 パーセントが乾燥物質で構成される。この乾燥物質のうち、70 から 95 パーセントが有機物で 5 から 30 パーセントが無機物である。有機乾燥物質は、95 パーセントが炭素、酸素、窒素、水素およびリンで構成され、残りがそれぞれ微量物質で構成される。本発明では、極めて長い MCRT を維持することで、有機化合物の完全な酸化の目的のみならず、バイオマス (廃水中の廃棄物を食べる生きた生物と、死んだ生物とその他の残骸とで構成される有機物質の塊) の消費の目的でも微生物が利用できる有機物の大半を活用している。このバイオマスにも上記の要素が含まれる。活性汚泥プロセスでは、炭素、酸素、窒素および水素を細胞材料の主な構成要素として利用し、リンについては、核酸、リン脂質、ヌクレオチドの構成要素として利用する。微生物はそれぞれの環境から化合物を手に入れ、バイオジェネティックスによるエネルギー生成と生合成による新たな細胞物質の合成という 2 通りの基本的な一次代謝活動を行う。微生物は、光、有機化合物および無機化合物から独力でエネルギーを生成する。微生物がエネルギーとして利用する主な無機化合物としては、アンモニウム (NH_4)、亜硝酸塩 (NO_2)、溶存硫黄 (H_2S)、元素硫黄があげられる。これらの化合物が酸化され、放出されるエネルギーが細胞の維持や新たな細胞物質の合成に利用され、微生物が移動できるものであれば微生物の移動にも利用される。微生物には、生合成に無機炭素を利用する独立栄養性微生物と生合成に有機炭素を利用する従属栄養微生物の 2 つのタイプがある。

【0090】

炭素は微生物細胞の乾燥質量の約 50 パーセントを占める。つまり、生合成の際に使われる主な元素は炭素なのである。微生物は、新たな細胞を成長させるためのエネルギーのひとつとして、脂肪酸、アミノ酸、糖類、有機酸などの有機化合物か二酸化炭素 (CO_2) のいずれかを利用する。生物学的プロセスによって有機炭素が微生物の生合成物質と二酸化炭素などの気体とに変換され、これを大気中に放出することができる。本発明の RAS による好気性反応槽の中身を容量で 200% 再循環することで、従来のシステムよりも高い頻度で一層効率的に微生物をそれぞれの炭素源と接触させることができる。

【0091】

酸素および水素は細胞材料に用いられる主な気体元素である。微生物の気泡材料の酸素源は、分子状酸素、有機化合物に見られ、あるいは二酸化炭素にも見られることがある。本発明では好気性反応槽の曝気供給系 (RCAS) を用いて栄養塩と微生物の水溶液に直接酸素を供給する。このようにすることで、微生物はバイオジェネティックスおよび生合成に利用できる酸素源の大半を用いて最も簡単な方法で呼吸をする機会を得ることになる。微生物の細胞材料の水素源は、分子状水素および有機化合物状態に見られる。電子受容体としての酸素を微生物の分類に用いる。すなわち、酸素を利用する微生物を好気性菌と呼び、酸素を利用しない微生物を嫌気性菌と呼ぶ。本発明では、好気性反応槽での有機化合物の安定化と分解に好気性菌を利用する。

【0092】

窒素は微生物のタンパク質および核酸の主な源であり、14 パーセントの細胞材料を含む。微生物は、窒素ガス (N_2)、アンモニア-窒素 ($\text{NH}_3 + \text{NH}_4$)、亜硝酸塩 (NO_2)、硝酸塩 (NO_3) の形で無機窒素を利用することができる。土壌の窒素固定と同様に、利用される窒素ガスは最初にアンモニウム (NH_4) に変換され、続いて有機窒素に変換されなければならないが、アンモニア-窒素 (NH_3) を、100 パーセント用意が整って微生物が栄養補給の目的で利用できるものであるとみなすことができる。アンモニ

ア (NH_3) を亜硝酸塩 (NO_2) および硝酸塩 (NO_3) に変換することで、 NO_2 および NO_3 を唯一の窒素源として利用する微生物に門戸が開かれる。しかしながら、微生物がこの窒素を増殖源として利用できるようにするのに必要なエネルギー量は大きい。これらの微生物は、 NO_2 および NO_3 を窒素源として利用するためのエネルギーを得るのにさらに多くの量の有機化合物を酸化しなければならない。このため、 NH_3 を窒素源として用いる場合よりも微生物の増殖率が低くなる。本発明では、極めて長い M C R T および可変の F / M 比を維持して微生物が増殖する量を抑える際に、この低い増殖率を長所として利用する。相まって、微生物はさらに多くの量の有機化合物を消費しなければならない、短時間で複製することはできない。窒素を除去するのに用いられる生物学的除去プロセスには 3 通りある。すなわち、アンモニア化成とこれに続く硝化および脱硝化である。アンモニア化成および硝化は好気性反応槽で起こり、脱硝化は無酸素性セクターで起こる。アンモニア化成は、タンパク質およびペプチドの形で有機窒素を得てこれをアンモニアとアンモニウムとに分解する従属栄養微生物によって行われる。アンモニアを NO_2 に変換し、さらに NO_3 に変換する独立栄養性微生物は硝化を担う。このプロセスの第三段階は、別の群の従属栄養微生物が NO_3 を NO_2 に還元し、続いて NO に還元して最後は大気中に放出できる N_2 にする脱硝化である。

10

【0093】

微生物は、細胞合成、細胞維持の間とエネルギー伝達時とにリンを利用する。このため、原水のリンのうち約 10 から 30 パーセントが微生物によって消費され、その代謝プロセスに利用される。しかしながら、増殖に必要な量以上にリンを蓄積する能力のある微生物が 3 種類ある。これはぜいたくなリン摂取と呼ばれる。3 種類の微生物すなわち、アシネトバクター、シュドモナスおよびモラクセラは、リンをポリリン酸顆粒の形で蓄積する能力があることから、ポリ P バクテリアと総称される。ポリ P バクテリアは、ストレス条件下におかれたときにポリリン酸塩をエネルギー源として利用することができる。これらのバクテリアは好気性の条件下におかれたときのみ上記の余分な量のリンを蓄積できるため、本発明では溶存酸素を十分な量で維持して好気性反応槽領域内でぜいたくなリン摂取を保証している。本発明では、微生物用が必要なストレス条件に達して、これらのポリ P バクテリアがポリリン酸塩をエネルギーとして利用できるようにするためのエリアとして、嫌気性コンディショナー領域を利用し、これによって排水の流れに含まれるリンの量を減らす。

20

30

【0094】

要するに、炭素、窒素およびリンは微生物のバイオジェネティックスと生合成とによって減少する。これらの栄養塩の除去量は、栄養塩の濃度ならびにこれらの栄養塩が微生物に曝露される時間の長さとは直接関連している。栄養塩が均質性によって微生物および酸素と接触する時間数を長くすると、本発明の場合のように、有機消化プロセスを加速することができる。2 時間の水理的滞留時間を実質的に満たすように領域を設計し、好気性反応槽領域から流出する前にこの領域の全中身を 2 時間毎に容量で 100 % 再循環および再曝気することで、微生物が生物学的消化プロセスを加速する環境が得られる。固形物捕捉領域から除去され、プロセッシング領域に戻されたすべての生物学的固形物が、同様にこの加速された生物学的消化の対象となる。上記にて概説したように、本発明ではこの効果が得られるため、さらに大きな水理的滞留能を利用できるかのようにする一方で、従来の処理システムに比して小さなフットプリント設計を利用している。

40

【0095】

上述したように長い M C R T と柔軟な F / M 比とを使用し、再循環量を増やすことで、バイオマスの消費も起こり、消化によってプロセスでの有機固形物の減量が促進される。無機固形物が予め定められた濃度の達してはじめて、考え得る高いリン濃度で実質的にこれらの無機固形物の意図的な浪費が開始される。

【0096】

本発明の「enhanced solids reduction (促進された固形物の減量)」(ESR) 廃水処理システムのもうひとつの成分に、システム全体の一部としての

50

複数の領域（タンク）がある。各領域は、処理対象となる廃水の入ったタンク単体または複数のタンクのグループで構成されている。これらのタンクは、底部が円錐形の垂直円筒形からなる特定の形状のものであると好ましい。しかしながら、本発明を用いての前記廃水のプロセッシングは好ましいタンクに限定されるものではない。本発明のプロセスを用いての有効な処理は、底部が平坦または傾斜した正方形または長方形のタンクにも適用できる。各領域は、その領域に指定されたプロセス専用である。タンクの設計ならびにプロセス領域の構成はシステムのモジュール化を可能にする E S R 廃水処理システムの構成要素である。図 4 に示す領域、好ましい装置の実施例は、領域設計ごとに単一のタンクを含む形である。別の装置の実施例が、その領域に特有のプロセス機能を発揮する 1 つ以上のタンクのある領域に類するものであってもよい。あるいは、大容量の E S R 廃水処理システムの一例として、図 1 1 に示すタンクの数 1 領域として分類し、図 1 1 のタンクの数に似た別のモジュールを、体積の大きい処理プラントの設計基準を満たすときまでに必要な各追加の処理領域ごとに加えるようにしてもよい。別の設計に、本願明細書で説明するものと同じ処理プロセッシング手法を利用したさまざまなサイズのタンクを取り入れてもよい。

10

20

30

40

50

【0097】

処理の間に廃水の流れの所望の経路を促進する環境を作り出すために、底部がへこんだ形であるが好ましくは底部が円錐形（図 1 2 参照）である垂直円筒をタンクの設計に取り入れる。浄化領域内で固形物を沈殿させて濃縮するためには、円錐底タンクを用いることが必須であり、リンの含有量が高い無機固形物を周期的に除去すべく沈殿および濃縮する際にプロセス領域で有効に利用される。R C A S システムが好気性反応槽領域の底からポンプへのフローを受入れる際に、このシステムによって固形物を懸濁液中で維持する。次に、好気性反応槽領域の中身をポンプで送り、曝気して再循環させ、好気性反応槽に戻る R C A S 導管排出時の速度が好気性反応槽領域の中身を十分に混合できる速度になるようにする。

【0098】

所望の処理をしやすくするために、浄化時に円筒形を使用し、流入方向およびその位置決めされた基準点ならびに再循環排出方向およびその位置決めされた基準点を介してフローを駆り立てることで、沈殿固形物がタンクのさらに下の部分に到達して、蓄積、濃縮、処理できるよう特定の時間タンク内に滞留できるように、廃水を特定のスピードで特定の距離にわたって好ましくは回転方向である特定の方向に移動させる。移動している廃水の流量特性ならびに円錐底によって、円錐形の底（固形物濃縮機と呼ぶ）内の最も下の点における基準の中心点で沈殿固形物の蓄積が促進される。これで、蓄積された沈殿固形物を最も下の点にあるポートによって吸い出すことができる状態になる。

【0099】

図 4 の実施例を利用して、原水の B O D 含有量、T S S（全懸濁物質）含有量ならびに N H₃ 含有量が正常であり、通常硝化、脱硝化およびリンの低減が必要な場合の、都市廃水処理プラントの原水濃度で実証されているような好ましい流量特性を示す。図 4 では、懸濁物質と生物分解性有機物質とを含む、事前に篩を通した原水廃水を原水給水ラインに通し、これが各タンクへの取出し用給水器（take-off feeder）を含む原水スプリッタ（分流）ボックス（splitter box）に流入する。これによって、処理仕様を変えるために追求される可能な流量特性すべての代表として用いられる一般的な構成を図 4 で表すことができる。

【0100】

フローとプロセス

ここで図 4 を参照すると、プラグ流れタイプの流量特性（プロセスの実施例）を用いることに関して、硝化、脱硝化およびリンを低減するプロセッシング特性の完全な動作柔軟性が得られる本発明による促進された固形物の減量（E S R）廃水処理システムの実施例が示されている。本発明、特に R C A S システムの実施例の有効性がゆえに、従来の廃水処理工程よりも廃水のプロセッシングにおける経済性ならびに扱いやすさが改善される。実施例

は、4つの領域からなる生物学的プロセスならびに固形物捕捉処理領域に相当する。生物学的プロセッシング領域は、1)嫌気性領域と、2)好気性領域と、3)無酸素領域と、4)別の好気性領域とで構成されるが、これに限定されるものではない。固形物捕捉領域は、二次浄化、三次浄化、濾過および化学的付加で構成されるが、これに限定されるものではない。しかしながら、バルブを変えて流量特性を変えることで、他のどのようなプロセッシング実施例(後述)でも実現して利用することができる。本発明の好ましいプロセッシング実施例は、領域に特有であるがタンクに特有のものではないプロセッシングの方法である。

【0101】

好ましいプラグ流れ特性を得るために、この実施例では一般的な都市廃水であると見越した原水を、ライン2経由で、原水のフローを調節および/または処理タンクに分流する分流器ボックス4に送る。この実施例では、原水のフロー全体を、ライン6経由で、嫌気性コンディショナー領域として用いられるタンク8(V No. 1)に送り、これによってポンプ10と上述したRCASとを用いて2時間毎に実質的に1時間この領域の中身を容量単位で再循環させる。タンク8のサイズは処理対象となる原水の容量によって決まる。

【0102】

タンク8(嫌気性コンディショナー領域)は、生物学的リン(Bio-P)の放出である、ぜいたくなリン摂取の第1段階を開始する。このぜいたくなリン摂取の第1段階は、タンク内を酸素欠乏状態に維持することで達成される。嫌気性コンディショナー領域の溶存酸素濃度を0.10mg/L以下に維持し、Bio-Pの放出時に微生物が利用する揮発性脂肪酸(VFA)が形成されるようにする。Bio-Pを放出することで、一時的にリンが増加するが、同時に以後のプロセスでさらに多くの量のリンを微生物によって代謝できるようになる。ライン11からのタンク58(無酸素性セクター領域V No. 3)からポンプ12を用いてライン14経由でタンク8(嫌気性コンディショナー領域)に低酸素濃度の混合液体懸濁物質(MLSS)を制御下で導入することで、この領域の中身を低溶存酸素濃度で維持することができる。

【0103】

タンク8(V No. 1)からの含水蒸発残留物(TS)はライン16を通して動的好気性反応槽No. 1の領域であるタンク18(V No. 2)に流入する。また、タンク18は、別のフローであるMLSSリサイクル流も受入れる。このフローは動的好気性反応槽No. 2の領域であるタンク20(V No. 4)からのものである。タンク20からのフローはライン22からポンプ24を経由し、最後にライン26を経由して送られてくる。4つの清澄装置(タンク76、80、84、88)-(V No. 5、No. 6、No. 7およびNo. 8)各々からのもうひとつのフローが、戻り汚泥(RAS)の形でタンク18に入る。この戻り汚泥は、RASポンプ28、30、32、34を経由し、さらにライン36、38、40、42を経由して、最後にライン44、46、48、50をそれぞれ経由してタンク18に入る。ポンプ52から動力を得る、後述する再循環導管曝気システム(RCAS)を利用して、2時間毎に実質的に1時間、タンク18の中身を容量単位で再循環させる。再循環手順では、ポンプ52のRCASシステムを通る際に細断することによって、タンク18の中身すなわち沈殿性固形物を可溶化する。細断については、微生物の個体群によって一層容易に消費されるように、RCASシステムのトロイダル渦作用によってRCASシステムで水溶液内の固形物が処理される際に行う。また、再循環手順では、溶存酸素レベルが実質的に3.5mg/L以上の濃度で維持されるように、RCASシステムによって強烈な曝気も適用する。溶存酸素濃度をこれらのレベルに保つことで、微生物コロニーに住むバクテリアであるニトロソモナスおよびニトロバクターがアンモニア(NH₃)を酸化して亜硝酸塩(NO₂)に変え、最後に硝酸塩(NO₃)にすることになる。この領域の溶存酸素濃度を3.5mg/L以上に維持しておくこと、懸濁物質および他の有機物が分解および酸化されて一層安定した化合物になる。

【0104】

RCASによって供給される大量の大気を利用し、溶存酸素を従来の曝気システムで維持

されているレベル（ 2.0 mg/L から 3.0 mg/L ）よりも高めのレベル（ 3.5 mg/L よりもかなり上）に維持することで、MCRTが長いことも相まって、微生物コロニーは内生呼吸（ER）として知られる生物学的ライフサイクルモードに入る。このERモードでは、生きている微生物は自分たちが周囲環境から吸収または吸着した新たな有機物と一緒に自己の細胞塊の一部を代謝しはじめる。このため、食物対微生物比（F/M）を調節することで微生物コロニーを維持しながら固形物の減量を促進しやすくなり、内生呼吸プロセスによって微生物コロニーの死滅率を微生物コロニーの増殖率と等しくすることができる。

【0105】

この反応槽内で強烈な曝気を供給することによるもうひとつの利点として、微生物による多量のリンの消費量が増えることがあげられる。上述したように、微生物が取り込むリンの量は微生物がタンク8内で放出するリンの量よりも多い。微生物は新たに獲得したリンを使って新しい細胞壁を発達させ、他のエネルギー需要を満たす。

【0106】

濃度が予め定められたレベルに達したら、蓄積された不活性固形物をライン5経由でタンク18（好気性反応槽No. 1）から除去する。これは本発明のすべての実施例に当てはまることである。この予め定められたレベルは、タンク18内の蒸発残留物濃度の実質的に50%であるか、あるいはプロセスでプロセス排水に栄養塩を通すことができるようになるレベルである。

【0107】

フローはライン54を介してタンク18から出て、スプリッタボックス56に供給され、続いて以後のプロセッシング用にライン60を介してタンク58に供給される。

【0108】

ポンプ62によって、2時間毎に実質的に1時間、タンク58（無酸素性セクター領域V No. 3）の中身を容量単位で再循環させる。タンク58は、タンク18（好気性反応槽No. 1の領域）内で行われる、硝化として知られるアンモニア変換プロセスに主に由来する、硝酸窒素（ NO_3 ）および亜硝酸窒素（ NO_2 ）の形で窒素分子に結合した元素酸素を受入れる。タンク58内の溶存酸素（DO）の量については 0.3 mg/L から 0.5 mg/L の範囲に維持する。タンク58の廃水中に含まれる微生物は呼吸するための酸素を探している。溶存酸素が少ししか利用できなければ、必然的に微生物は窒素と結合した NO_3 の元素酸素を使うことになる。このプロセスは一般に脱硝化と呼ばれている。窒素と酸素との間の結合が崩れると、微生物は呼吸のために元素酸素を消費するため、窒素が大気中に放出される。依然として廃水中にある有機物の消費を続けるために、微生物は必要な呼吸にこの酸素を利用する。

【0109】

このような無酸素条件の間、溶存酸素の可用性が低い間のエネルギーを保存する方法として微生物によるリンの自然放出が起こるが、タンク8（嫌気性コンディショナー領域V No. 1）で起こる場合より量的には少ない。これによって一時的にリンが増加するが、同時に以後のプロセスでさらに多くの量のリンを微生物によって代謝できるようになる。このプロセスの排水は、以後の処理用にライン64を介してタンク20（好気性反応槽No. 2の領域-V No. 4）に供給される。

【0110】

タンク20は動的好気性反応槽として用いられる。ポンプ66から動力を得る再循環導管曝気システム（RCAS）を利用して、2時間毎に実質的に1時間、タンク20の中身を容量単位で再循環させ、強烈に曝気する。タンク20では、溶存酸素を少なくとも 3.0 mg/L に維持することで、溶存した有機物ならびに懸濁した有機物の両方が酸化される。微生物コロニーに住むバクテリアであるニトロソモナスおよびニトロバクターが、有機窒素を酸化してアンモニア（ NH_3 ）に変え、さらに亜硝酸塩（ NO_2 ）に変えて最後に硝酸塩（ NO_3 ）にすることになる。タンク20（動的好気性反応槽No. 2の領域）の微生物コロニーを含む水溶液が曝気され、溶存酸素が増えると、微生物は自己の生命を維

持するのに必要な量よりも多くのリンを消費しはじめる。消費されるリンの量は、嫌気性コンディショナー領域および無酸素性セクター領域（タンク 8 および 58）内で処理されつつ微生物が水溶液中に放出するリンの量を大幅に上回る。この効果が「ぜいたくなリン摂取」と呼ばれるものである。以後の消化用にポンプ 24 を使ってタンク 20 からの混合液体懸濁物質（MLSS）の一部をライン 22 経由でタンク 18（動的好気性反応槽 No. 1 の領域）にリサイクルし、最後にライン 26 を介して排出する。一方、排水は浄化領域の分流器ボックス 72（SB Clar Inf）に流入する前にタンク 20 からライン 68 を介してライン 70 に入る。

【0111】

ライン 70 からの原水が浄化領域の分流器ボックス 72（SB Clar Inf）に流入する際、このフローを 4 つの等しい部分に分流し、清澄装置 No. 1 に相当するタンク 76 ではライン 74、清澄装置 No. 2 に相当するタンク 80 ではライン 78、清澄装置 No. 3 に相当するタンク 84 ではライン 82、清澄装置 No. 4 に相当するタンク 88 ではライン 86 をそれぞれ介して、4 つの清澄装置各々に送るようにすると好ましい。各清澄装置にフローが流入する際にはフロー速度を落とし、固形物が各清澄装置の底の部分に沈殿するようにする。続いて、タンク 76（清澄装置 No. 1）では水圧式固形物濃度インデューサ 90、タンク 80（清澄装置 No. 2）では水圧式固形物濃度インデューサ 92、タンク 84（清澄装置 No. 3）では水圧式固形物濃度インデューサ 94、タンク 88（清澄装置 No. 4）では水圧式固形物濃度インデューサ 96 を用いて沈殿固形物を清澄装置の壁面から取り除き、各清澄装置の RAS ポンプ（28、30、32、34）および RAS ライン（36、38、40、42）を介して除去して以後の処理用にタンク 18（動的好気性反応槽 No. 1）に送る前に固形物をさらに濃縮できるようにする。浄化プロセスから分離された液体は、ライン 98 を介してタンク 76 から、ライン 100 を介してタンク 80 から、ライン 102 を介してタンク 84 から、ライン 104 を介してタンク 88 から流出し、収集ボックス 106（CB Clar Eff）に合流する。この清澄装置によって、排水が最終処理排水としてライン 108 経由で得られる。

【0112】

本発明の実施例では、従来の好気性処理システムよりも動作の柔軟性を高めることができる。

【0113】

本発明の第 1 の別の実施例を図 5 に示す。同図では図 4 に示す装置の実施例のラインおよび設備のうち未利用のものを省いてある。しかしながら、プロセスの実施例を用いて廃水流を処理するのに必要な利用ラインおよび設備については図示してある。特定のフロー構成の設置を企図し、図 No. 4 で得られる柔軟性が不必要な場合に、図 No. 5 に示す別の実施例を用いる。一般的な都市廃水である原水を、ライン 2 経由で、嫌気性コンディショナー領域（V No. 1）として用いられるタンク 8 に送ることで、ポンプ 10 を用いて 2 時間毎に実質的に 1 時間この領域の中身を容量単位で再循環させる。実施例の場合と同様に、ライン 10 からのタンク 58（無酸素性セクター領域）からポンプ 12 を介して低酸素濃度の MLSS を制御下で導入し、ライン 14 経由でタンク 8 に供給することで、このタンクの中身を低溶存酸素濃度状態に維持することができる。

【0114】

タンク 8（嫌気性コンディショナー領域）からの含水蒸発残留物はライン 16 を通って動的好気性反応槽 No. 1 の領域（V No. 2）であるタンク 18 に流入する。また、タンク 18 は、別のフローである MLSS リサイクル流も受入れる。このフローは動的好気性反応槽 No. 2 の領域として用いられているタンク 20 からのものである。タンク 20 からのフローはライン 22 からポンプ 24 を経由し、最後にライン 26 を経由して送られてくる。清澄装置（後述するタンク 76、80、84、88）各々からのもうひとつのフローが、戻り汚泥（RAS）の形でタンク 18 に入る。この戻り汚泥は、RAS ポンプ 28、30、32、34 を経由し、さらにライン 36、38、40、42 をそれぞれ経由して、最後にライン 44、46、48、50 をそれぞれ経由してタンク 18 に入る。ポンプ

52から動力を得る、後述する再循環導管曝気システム(RCASS)を利用して、2時間毎に実質的に1時間、タンク18の中身を容量単位で再循環させる。再循環手順では、この領域のRCASSシステムを通る際に細断することによって、沈殿性固形物であるタンク18の中身を可溶化する。細断については、微生物の個体群によって一層容易に消費されるように、RCASSシステムのトロイダル渦作用によってRCASSシステムで水溶液内の固形物が処理される際に行う。また、再循環手順では、溶存酸素レベルが実質的に1リットルあたり3.5mg以上の濃度で維持されるように、RCASSシステムによって強烈な曝気も適用する。

【0115】

フローはライン110を介してタンク18(好気性反応槽No.1の領域)から出てタンク58(無酸素性セクター領域-V No.3)に供給される。2時間毎に実質的に1時間、ポンプ62によってタンク58の中身を再循環させる。タンク58の動作は図4を参照して説明したものと同様である。タンク58からの排水を以後の処理用にライン64経由でタンク20に送る。

【0116】

タンク20は動的好気性反応槽(V No.4)である。ポンプ66から動力を得る再循環導管曝気システム(RCASS)を用いて、2時間毎に実質的に1時間、タンク20の中身を再循環させ、強烈に曝気する。タンク20の動作は図4を参照して説明したものと同様である。上述したように、以後のプロセッシング用にポンプ24を使ってタンク20からのMLSSの一部をライン22経由でタンク18にリサイクルし、最後にライン26を介して排出する。一方、タンク20の排水については、浄化領域の分流器ボックス72(SBClar Inf)に流入する前にライン68を介して排出され、ライン70に入る。

【0117】

ライン70からの原水が浄化領域の分流器ボックス72に流入する際、このフローを4つの等しい部分に分流し、清澄装置No.1に相当するタンク76ではライン74、清澄装置No.2に相当するタンク80ではライン78、清澄装置No.3に相当するタンク84ではライン82、清澄装置No.4に相当するタンク88ではライン86をそれぞれ介して、4つの清澄装置(V No.5、V No.6、V No.7、V No.8)各々に送るようにすると好ましい。

各清澄装置にフローが流入する際にはフロー速度を落とし、固形物が各清澄装置の底の部分に沈殿するようにする。続いて、タンク76では水圧式固形物濃度インデューサ90、タンク80では水圧式固形物濃度インデューサ92、タンク84では水圧式固形物濃度インデューサ94、タンク88では水圧式固形物濃度インデューサ96を用いてこれらの沈殿固形物をタンクの壁面から取り除き、各清澄装置のRASポンプ(28、30、32、34)およびRASライン(36、38、40、42)を介して除去して以後の処理用にライン44、46、48、50経由でタンク18に送る前に固形物をさらに濃縮できるようにする。浄化プロセスから分離された液体は、ライン98を介してタンク76から、ライン100を介してタンク80から、ライン102を介してタンク84から、ライン104を介してタンク88から流出し、収集ボックス106(CBClar Eff)に合流する。清澄装置の排水は最終処理排水としてライン108経由で排出される。

【0118】

図18は、清澄装置(ライン108)の出力に連結された濾過領域89をさらに含む、図5に示すプロセスの簡略図である。濾過領域は以後のプロセッシング用にライン108を介して水溶液(図4では排水)を受ける。この水溶液は、水溶液の液体分から固形物が分離および沈殿される場である濾過領域に供給される。液体分から沈殿および分離された固形物は、システムでの再プロセッシングおよび再処理用に、ライン109を介して原水ライン2に送られる。図18に示す濾過領域は、図4に示すシステムまたは後述する本発明の他のいずれの実施例にも含めることが可能なものである。

【0119】

図6に示す本発明の第2の別の実施例では、本発明の別のプロセスの実施例No.1を用

いて、プラグ流れタイプの流量特性に関して硝化および脱硝化のプロセッシング特性を得る。別の装置の実施例 No. 2 を別のプロセスの実施例 No. 1 と併用する。本発明の別のプロセッシングの実施例 No. 1 は、領域に特有であるがタンクに特有のものではないプロセッシング方法である。

【0120】

別のプロセスの実施例 No. 1 では、一般的な都市廃水で代表される原水を、ライン 120 経由で、無酸素性セクター領域 (V No. 1) として用いられるタンク 122 に送ることで、ポンプ 124 を用いて 2 時間毎に実質的に 1 時間、このタンクの中身を容量単位で再循環させる。タンク 122 に入る他のフローは、タンク 122 内での酸素不足を補うために使われる M L S S リサイクル流の形で、ライン 128 経由でタンク 126 (好気性反応槽 No. 1 の領域 - V No. 2) から、ライン 132 経由でタンク 130 (好気性反応槽 No. 2 の領域 - V No. 3) から送られてくる。タンク 122 に入るもうひとつのフローは、戻り汚泥 (R A S) の形で、R A S ポンプ 142、144、146、148 を介し、最後にライン 150、152、154、156 をそれぞれ介して、4 つの澄清装置 (タンク 134、136、138、140) の各々から送られてくる。タンク 122 は、タンク 126 および 130 (好気性反応槽 No. 1 の領域および好気性反応槽 No. 2 の領域) 内で行われる、大半が硝化として知られるアンモニア変換プロセスに由来する、硝酸窒素 (NO_3) および亜硝酸窒素 (NO_2) の形で窒素分子に結合した元素酸素を受入れる。タンク 122 内の溶存酸素量については 0.3 mg/l から 0.5 mg/l の範囲に維持する。これは、ポンプ 158 を用いてタンク 126 (好気性反応槽 No. 1 の領域) からリサイクルしてライン 128 を介してポンプで送り、ポンプ 160 を用いてタンク 130 (好気性反応槽 No. 2 の領域) からリサイクルしてライン 132 を介してポンプで送る形で、M L S S をタンク 122 に送ることで可能になる。

【0121】

タンク 122 (無酸素性セクター領域) の廃水中に含まれる微生物は呼吸するための酸素を探している。溶存酸素が少ししか利用できなければ、必然的に微生物は窒素ガスと結合した NO_3 の元素酸素を使うことになる。このプロセスは一般に脱硝化と呼ばれている。窒素と酸素との間の結合が崩れると、微生物は呼吸のために元素酸素を消費するため、窒素が大気中に放出される。

【0122】

酸素を消費している間、タンク 122 (無酸素性セクター領域) の脱硝化プロセスでの呼吸によって、微生物は、微生物の個体群によって一層容易に消費されるようにタンク 126、130 (好気性反応槽領域 No. 1 および No. 2) の再循環プロセスで細断および可溶化された全懸濁物質での有機物の一部も消費する。

【0123】

継続して処理を行うために、タンク 122 (無酸素性セクター領域) からの含水蒸発残留物 (T S) が重力によってライン 162 を介してタンク 126 (好気性反応槽 No. 1 の領域) に流入する。ポンプ 164 から動力を得る再循環導管曝気システム (R C A S) を用いて、2 時間毎に実質的に 1 時間、タンク 126 の中身を容量単位で再循環させる。再循環手順では、タンクの R C A S システムで細断することによって、タンク 126 の中身すなわち沈殿性固形物を可溶化する。細断については、微生物の個体群によって一層容易に消費されるように、R C A S システムのトロイダル渦作用によって R C A S システムで水溶液内の固形物が処理される際に行う。また、再循環では、溶存酸素レベルが実質的に 3.5 mg/L 以上の濃度で維持されるように、R C A S システムによって強烈な曝気も適用する。溶存酸素濃度をこれらのレベルに保つことで、微生物コロニーに住むバクテリアであるニトロソモナスおよびニトロバクターがアンモニア (NH_3) を酸化して亜硝酸塩 (NO_2) に変え、最後に硝酸塩 (NO_3) にすることになる。当業者であればこのプロセスを硝化として知っている。この領域の溶存酸素濃度を 3.5 mg/L 以上に維持しておく、懸濁物質および他の有機物が分解および酸化されて一層安定した化合物になる。

【0124】

R C A S システムによって供給される大量の大気を利用し、溶存酸素を従来のシステムで維持されているレベル（ 2.0 mg/L から 3.0 mg/L ）よりも高めのレベル（ 3.5 mg/L よりもかなり上）に維持することで、M C R T が長いことも相まって、微生物コロニーは内生呼吸（E R）として知られる生物学的ライフサイクルモードに入る。この E R モードでは、生きている微生物は自分たちが周囲環境から吸収または吸着した新たな有機物と一緒に自己の細胞塊の一部を酸化しはじめる。このため、食物対微生物（F/M）比を調節することで微生物コロニーを維持しながら固形物の減量を促進しやすくなり、E R プロセスによって微生物の死滅率を微生物の増殖率と等しくすることができる。

【0125】

この反応槽内で強烈な曝気を供給することによるもうひとつの利点として、微生物によってリンがいくらか消費されることがあげられる。

【0126】

タンク 126（好気性反応槽 No. 1 の領域）から流出するフローは、ライン 166 を介してタンク 130 に送られる。タンク 130 は好気性反応槽 No. 2 の領域（V No. 3）として用いられ、これによって、ポンプ 168 から動力を得る再循環導管曝気システム（R C A S）を利用して、2 時間毎に実質的に 1 時間、このタンクの中身を容量単位で再循環させ、強烈に曝気する。このタンクでは、D O レベルを少なくとも 3.0 mg/l に維持することで、溶存した有機物ならびに懸濁した有機物の両方が酸化される。このタンクでは、微生物コロニーに住むバクテリアであるニトロソモナスおよびニトロバクターが、有機窒素を酸化してアンモニア（ NH_3 ）に変え、さらに亜硝酸塩（ NO_2 ）に変えて最後に硝酸塩（ NO_3 ）にすることになる。脱硝化プロセスで窒素を減少させるために、硝酸塩含有量の高い M L S S の一部を、ポンプ 160 を用いてライン 132 経由でタンク 122（無酸素性セクター領域）にリサイクルする。

【0127】

また、廃水の液体分から固形物を沈殿させるために浄化領域の分流ボックス 174（S B C l a r I n f）に入る前に重力によってライン 170 経由でライン 172 にフローが流出する。

【0128】

この別の実施例には、実施例に存在するタンク（V No. 4）が含まれていないことに注意されたい。このタンクは別の好気性反応槽での必要性が実質的に避けられなくなって流量が増えるまで使用されることはない。

【0129】

ライン 172 からの原水が浄化領域のスプリットボックス 174（S B C l a r I n f）に入る際、このフローを 4 つの等しい部分に分流し、タンク 134（清澄装置 No. 1）ではライン 176、タンク 136（清澄装置 No. 2）ではライン 178、タンク 138（清澄装置 No. 3）ではライン 180、タンク 140（清澄装置 No. 4）ではライン 182 を介して、4 つの清澄装置タンク（134、136、138、140）各々に送る。各清澄装置にフローが流入する際にはフロー速度を落とし、固形物が各清澄装置タンクの底に沈殿するようにする。続いて、タンク 134 では水圧式固形物濃度インデューサ 184、タンク 136 では水圧式固形物濃度インデューサ 186、タンク 138 では水圧式固形物濃度インデューサ 188、タンク 140 では水圧式固形物濃度インデューサ 190 を用いて沈殿固形物を円錐側面から取り除き、各清澄装置の R A S ポンプ（142、144、146、148）および R A S ライン（150、152、154、156）を介して除去し、以後の処理用にタンク 122（無酸素反応槽領域）に送る前に固形物をさらに濃縮できるようにする。浄化プロセスから分離された液体は、ライン 192 を介してタンク 134（清澄装置 No. 1）から、ライン 194 を介してタンク 136（清澄装置 No. 2）から、ライン 196 を介してタンク 138（清澄装置 No. 3）から、ライン 198 を介してタンク 140（清澄装置 No. 4）から流出し、収集ボックス 200（C B C l a r E f f）に合流する。清澄装置の排水はライン 202 を経由して最終処理排水

10

20

30

40

50

として排出される。

【0130】

図7を参照すると、プラグ流れタイプの流量特性に関して別のプロセスの実施例No. 2を用いて硝化のプロセッシング特性を得る、本発明によるもうひとつの別の装置の実施例が示されている。この別の装置の実施例は、別のプロセスの実施例No. 2と併用される。本発明の別のプロセスの実施例No. 2は、領域に特有であるがタンクに特有のものではないプロセッシング方法である。

【0131】

図7に示す本発明によれば、一般的な都市廃水に代表される原水を、ライン210経由で、好気性反応槽No. 1の領域であるタンク212に送る。タンク212に入る他のフローは、戻り汚泥(RAS)の形でRASポンプ(222、224、226、228)によって4つの清澄装置(214、216、218、220)から送出され、それぞれライン230、232、234、236を介してタンク212に供給される。 10

【0132】

ポンプ238から動力を得る再循環導管曝気システム(RCAS)を用いて、2時間毎に実質的に1時間、タンク212(好気性反応槽No. 1の領域)の中身を容量単位で再循環させる。再循環手順では、RCASシステムで細断することによって、タンク212の中身すなわち沈殿性固形物を可溶化する。細断については、微生物の個体群によって一層容易に消費されるように、RCASシステムのトロイダル渦作用によってRCASシステムで水溶液内の固形物が処理される際に行う。また、再循環では、溶存酸素レベルが実質的に3.5mg/L以上の濃度で維持されるように、RCASシステムによって強烈な曝気も適用する。溶存酸素濃度をこれらのレベルに保つことで、微生物コロニーに住むバクテリアであるニトロソモナスおよびニトロバクターがアンモニア(NH_3)を酸化して亜硝酸塩(NO_2)に変え、最後に硝酸塩(NO_3)にすることになる。当業者であればこのプロセスを硝化として知っている。この領域の溶存酸素濃度を3.5mg/L以上に維持しておく、懸濁物質および他の有機物が分解および酸化されて一層安定した化合物になる。 20

【0133】

RCASシステムによって供給される大量の大気を利用し、溶存酸素を従来のシステムで維持されているレベル(2.0mg/Lから3.0mg/L)よりも高めのレベル(3.5mg/Lよりもかなり上)に維持することで、MCRTが長いことも相まって、微生物コロニーは内生呼吸(ER)として知られる生物学的ライフサイクルモードに入る。このERモードでは、生きている微生物は自分たちが周囲環境から吸収または吸着した新たな有機物と一緒に自己の細胞塊の一部を酸化しはじめる。このため、食物対微生物比(F/M)を調節することで微生物コロニーを維持しながら固形物の減量を促進しやすくなり、ERプロセスによって微生物の死滅率を微生物の増殖率と等しくすることができる。 30

【0134】

この反応槽内で強烈な曝気を供給することによるもうひとつの利点として、微生物によってリンがいくらか消費されることがあげられる。

【0135】

さらに好気性の処理を行うために、フローはタンク212(好気性反応槽No. 1の領域)から出てライン239を経由し、タンク240(好気性反応槽No. 2の領域-V No. 2)に流入する。ポンプ242から動力を得る再循環導管曝気システム(RCAS)を用いて、2時間毎に実質的に1時間、タンク240の中身を容量単位で再循環させる。タンク240の中身を再循環させている間、別の強烈な曝気を適用し、溶存酸素レベルを実質的に濃度3.0mg/L以上に維持する。溶存酸素濃度をこれらのレベルに保つことで、全BODを含むがこれに限定されるものではない有機物、さらには有機窒素をまずアンモニアに変換し、次いで亜硝酸塩、最後に硝酸塩に変換する機能を微生物に持たせることができる。このプロセスによって、全窒素の濃度が有害性の低い化合物まで低下する。 40

【0136】

フローは、廃水の液体分から固形物を沈殿させるべく浄化領域の分流ボックス246 (S B C l a r I n f)に入る前に、好ましくは重力によってタンク240から流出し、ライン243を経由してライン244に入る。

【0137】

この実施例では、別の好気性反応槽での必要性が実質的に避けられなくなって流量が増えるまで上記の実施例で説明した別の好気性反応槽タンクを使用しない点に注意されたい。

【0138】

ライン244からの原水が浄化領域のスプリッタボックス246 (S B C l a r I n f)に入る際、このフローを4つの等しい部分に分流し、タンク214 (清澄装置No. 1)ではライン248、タンク216 (清澄装置No. 2)ではライン250、タンク218 (清澄装置No. 3)ではライン252、タンク220 (清澄装置No. 4)ではライン254を介して、4つの清澄装置タンク (タンク214、216、218、220) 各々に送るようにすると好ましい。各清澄装置にフローが流入する際にはフロー速度を落とし、固形物が各清澄装置の底に沈殿するようにする。続いて、タンク214では水圧式固形物濃度インデューサ256、タンク216では水圧式固形物濃度インデューサ258、タンク218では水圧式固形物濃度インデューサ260、タンク220では水圧式固形物濃度インデューサ262を用いて沈殿固形物を壁面から取り除き、各清澄装置のRASポンプ (222、224、226、228) およびRASライン (230、232、234 および236) を介して除去し、以後の処理用にタンク212 (好気性反応槽No. 1の領域) に送る前に固形物をさらに濃縮できるようにする。浄化プロセスから分離された液体は、ライン264を介してタンク214から、ライン266を介してタンク216から、ライン268を介してタンク218から、ライン270を介してタンク220から流出し、収集ボックス272 (C B C l a r E f f) に合流する。清澄装置の排水はライン274を経由して最終処理排水として排出される。

【0139】

図8を参照すると、動作の柔軟性を改善しつつ、段階フィードフロータイプの流量特性を用いることに関して、本発明の別のプロセッシングの実施例No. 3を用いて、硝化、脱硝化およびリンの低減のプロセッシング特性を得る、本発明のもうひとつの別の実施例が示されている。この別の実施例と別のプロセッシングの実施例No. 3との併用は、供給性能が変動したりパラメータの変更があり、かつ、排水品質を改善する必要があるような場合に好ましいであろう。これは、原水流の特性が同一でありながら原水の栄養塩負荷が変動する場合にもあてはまるであろう。本発明の別のプロセッシングの実施例No. 3は、領域に特有であるがタンクに特有のものではないプロセッシング方法である。

【0140】

別のプロセスの実施例No. 3では、原水は、主力産業の廃棄物の流れの原水濃度によって示す必要があるとおり、硝化、脱硝化およびリンの低減を必要とする一方で、TSS濃度が高く全BOD濃度も高い、高濃度でNH₃を含有することがある非常に強い廃棄物である。

【0141】

図8に示す別の実施例では、懸濁物質および生物分解性有機物質を含む原水がライン280を経由してスプリッタボックス282 (S B P L T I n f) に達し、ここで全原水流の60%をライン286経由でタンク284 (嫌気性コンディショナー領域-V No. 1) に、全原水流の30%をライン288経由でタンク290 (好気性反応槽No. 1の領域-V No. 2) に転流し、5%をライン292経由でタンク294 (無酸素性セクター領域V No. 3) に転流し、他の5%をライン296経由でタンク298 (好気性反応槽No. 2の領域-V No. 4) に転流する。

【0142】

タンク284はプラント原水流の60%を受入れ、さらにポンプ302およびライン304を用いて、タンク294からのフローをライン300経由で受入れる。ポンプ306を用いて、2時間毎に実質的に1時間、タンク284の中身を容量単位で再循環させる。

【0143】

タンク284（嫌気性コンディショナー領域）は、生物学的リン（Bio-P）の放出である、ぜいたくなリン摂取の第1段階を開始する。このぜいたくなリン摂取は、タンク284内を酸素欠乏状態に維持することで達成される。溶存酸素濃度を0.10mg/L以下に維持し、微生物によるBio-Pを引き起こす。このようにBio-Pを放出することで、一時的にリンが増加するが、同時に以後のプロセスでさらに多くの量のリンを微生物によって代謝できるようになる。ライン300からのタンク294（無酸素性セクター領域）からポンプ302を用いてライン304経由でタンク284に低酸素濃度のMLSSを制御下で導入することで、この領域の中身を低溶存酸素濃度で維持することができる。続いて処理用にフローをライン308経由でタンク290（好気性反応槽No. 1の領域）に送り続ける。

【0144】

上述したように、タンク290はライン288を介してプラント原水流の30%を受入れ、好気性反応槽No. 1の領域として利用される。このタンクに入るもうひとつのフローは、ポンプ312を用いてライン310経由でタンク298から送られてきた後、ライン314を介してタンク290に送られる。タンク298（好気性反応槽No. 2の領域）からのフローはMLSSリサイクル流の形である。タンク290に入るさらにもうひとつのフローは、戻り汚泥（RAS）の形で、RASポンプ324、326、328および330を介し、最後にそれぞれライン332、334、336および338を介して、4つの清澄装置タンク（316、318、320、322）の各々から送られてくる。ポンプ340から動力を得る再循環導管曝気システム（RCAS）を用いて、2時間毎に実質的に1時間、タンク290の中身を容量単位で再循環させる。再循環手順では、タンクのRCASシステムを通過する際に細断することによって、タンク284の中身すなわち沈殿性固形物を可溶化する。細断については、微生物の個体群によって一層容易に消費されるように、RCASシステムのトロイダル渦作用によってRCASシステムで水溶液内の固形物が処理される際に行う。また、再循環手順では、溶存酸素レベルが実質的に3.5mg/L以上の濃度で維持されるように、強烈な曝気も適用する。溶存酸素濃度をこれらのレベルに保つことで、微生物コロニーに住むバクテリアであるニトロソモナスおよびニトロバクターがアンモニア（NH₃）を酸化して亜硝酸塩（NO₂）に変え、最後に硝酸塩（NO₃）にすることになる。この領域の溶存酸素濃度が3.5mg/L以上であると、懸濁物質および他の有機物が分解および酸化されて一層安定した化合物になる。RCASシステムによって供給される大量の大気を利用し、溶存酸素を従来の曝気システムで維持されているレベルよりも高めのレベル（3.0mg/Lよりも上）に維持することで、MCRTが長いことも相まって、微生物コロニーは内生呼吸（ER）として知られる生物学的ライフサイクルモードに入る。このERモードでは、生きている微生物は自分たちが周囲環境から吸収または吸着した新たな有機物と一緒に自己の細胞塊の一部を酸化しはじめる。このため、食物対微生物（F/M）比を調節することで微生物コロニーを維持しながら固形物の減量を促進しやすくなり、ERプロセスによって微生物コロニーの死滅率を微生物コロニーの増殖率と等しくすることができる。

【0145】

この反応槽内で強烈な曝気を供給することによるもうひとつの利点として、微生物による多量のリンの消費量が増えることがあげられる。上述したように、微生物が取り込むリンの量は微生物がタンク284（嫌気性コンディショナー領域）内で放出するリンの量よりも多い。微生物は新たに獲得したリンを使って新しい細胞壁を発達させ、他のエネルギー需要を満たす。

【0146】

続いて、さらにプロセッシングを行うべく、フローはタンク290（好気性反応槽No. 1の領域）を出てライン342を経由し、タンク294（無酸素性セクター領域）に流入する。タンク290からライン342を経由してのフローだけでなく、タンク294は、ライン292を介してプラント原水の5%の別のフローも受入れる。2時間毎に実質的に

1 時間、ポンプ 3 4 4 によって、このタンクの中身を容量単位で再循環させる。この無酸素性セレクター領域は、タンク 2 9 0（好気性反応槽 No. 1 の領域）内で行われる、硝化として知られるアンモニア変換プロセスに主に由来する、硝酸窒素（ NO_3 ）および亜硝酸窒素（ NO_2 ）の形で窒素分子に結合した元素酸素を受入れる。タンク 2 9 4 内の溶存酸素（DO）の量については 0.3 mg/l から 0.5 mg/l の範囲に維持する。タンク 2 9 4 の廃水中に含まれる微生物は呼吸するための酸素を探している。DO が少ししか利用できなければ、必然的に微生物は窒素と結合した NO_3 の元素酸素を使うことになる。このプロセスは一般に脱硝化と呼ばれている。窒素と酸素との間の結合が崩れると、微生物は呼吸のために元素酸素を消費するため、窒素が大気中に放出される。依然として廃水中にある有機物の消費を続けるために、微生物は必要な呼吸にこの酸素を利用する。 10

【0 1 4 7】

このような無酸素条件の間、溶存酸素の可用性が低い間のエネルギーを保存する方法として微生物によるリンの自然放出が起こるが、タンク 2 8 4（嫌気性コンディショナー領域）で起こる場合より量的には少ない。これによってリンが一時的に若干増加するが、同時に以後のプロセスでさらに多くの量のリンを微生物によって代謝できるようになる。このプロセスの排水は、以後の処理用にライン 3 4 6 を介してタンク 2 9 8（好気性反応槽 No. 2 の領域）に供給され続ける。

【0 1 4 8】

ライン 3 4 6 を介してタンク 2 9 8（好気性反応槽 No. 2 の領域）に入るフローに加えて、プラント原水の 5 % のフローがライン 2 9 6 を介してタンク 2 9 8 に流入する。ポンプ 3 4 8 から動力を得る再循環導管曝気システム（RCAS）を利用して、2 時間毎に実質的に 1 時間、この領域の中身を容量単位で再循環させ、強烈に曝気する。このタンクでは、溶存酸素を少なくとも 3.5 mg/l に維持することで、溶存した有機物ならびに懸濁した有機物の両方が酸化される。このタンクでは、微生物コロニーに住むバクテリアであるニトロソモナスおよびニトロバクターが、有機窒素を酸化してアンモニア（ NH_3 ）に変え、さらに亜硝酸塩（ NO_2 ）に変えて最後に硝酸塩（ NO_3 ）にすることになる。タンク 2 9 8 の微生物コロニーを含む水溶液が曝気され、溶存酸素が増えると、微生物は自己の生命を維持するのに必要な量よりも多くのリンを消費しはじめる。消費されるリンの量は、タンク 2 8 4 および 2 9 4（嫌気性コンディショナー領域および無酸素性セレクター領域）内で処理されつつ微生物が水溶液中に放出するリンの量を大幅に上回る。これが業界で「ぜいたくなリン摂取」と呼ばれるものである。ポンプ 3 1 2 を使ってタンク 2 9 8 からの MLSS の一部をライン 3 1 0 経由でタンク 2 9 0（好気性反応槽 No. 1 の領域）にリサイクルし、最後にライン 3 1 4 を介して排出する。一方、排水は浄化領域の分流器ボックス 3 5 4（SB Clar Inf）に流入する前にライン 3 5 0 を介してライン 3 5 2 に送られ続ける。 20 30

【0 1 4 9】

ライン 3 5 2 からの原水が浄化領域のスプリッタボックス 3 5 4 に流入する際、このフローを 4 つの等しい部分に分流し、タンク 3 1 6（清澄装置 No. 1）ではライン 3 5 6、タンク 3 1 8（清澄装置 No. 2）ではライン 3 5 8、タンク 3 2 0（清澄装置 No. 3）ではライン 3 6 0、タンク 3 2 2（清澄装置 No. 4）ではライン 3 6 2 を介して、4 つの清澄装置（3 1 6、3 1 8、3 2 0、3 2 2）各々に送るようにすると好ましい。各清澄装置にフローが流入する際にはフロー速度を落とし、固形物が各清澄装置の底に沈殿するようにする。続いて、タンク 3 1 6（清澄装置 No. 1）では水圧式固形物濃度インデューサ 3 6 4、タンク 3 1 8（清澄装置 No. 2）では水圧式固形物濃度インデューサ 3 6 6、タンク 3 2 0（清澄装置 No. 3）では水圧式固形物濃度インデューサ 3 6 8、タンク 3 2 2（清澄装置 No. 4）では水圧式固形物濃度インデューサ 3 7 0 を用いて沈殿固形物を各清澄装置タンクの壁面から取り除き、各清澄装置のRASポンプ（3 2 4、3 2 6、3 2 8、3 3 0）およびRASライン（3 3 2、3 3 4、3 3 6、3 3 8）を介して除去して以後の処理用にタンク 2 9 0（好気性反応槽 No. 1 の領域）に送る前に固形物をさらに濃縮できるようにする。浄化プロセスから分離された液体は、ライン 3 7 2 40 50

を介してタンク 316 (清澄装置 No. 1) から、ライン 374 を介してタンク 318 (清澄装置 No. 2) から、ライン 376 を介してタンク 320 (清澄装置 No. 3) から、ライン 378 を介してタンク 322 (清澄装置 No. 4) から流出し、収集ボックス 380 (C B C l a r E f f) に合流する。この清澄装置の排水はライン 382 を介して最終処理排水として流出する。

【0150】

図 9 を参照すると、ステップフィードフロータイプの流量特性を用いることに関して、別のプロセスの実施例 No. 4 を用いて、硝化および脱硝化のプロセッシング特性を得る、本発明のもうひとつの別の実施例が示されている。本発明の別のプロセッシングの実施例 No. 4 は、領域に特有であるがタンクに特有のものではないプロセッシング方法である。

10

【0151】

別のプロセスの実施例 No. 4 では、原水は非常に強い廃棄物である。この廃棄物は、主力産業の廃棄物の流れの原水濃度によって示す必要があるような、高濃度の NH_3 を含有することがあり、TSS 濃度が高く全 BOD 濃度も高い一方で全窒素を減少させるために硝化および脱硝化を必要とするものである。

【0152】

ここで図 9 を参照すると、懸濁物質と生物分解性有機物質とを含む原水を、ライン 390 経由でスプリッタボックス 392 (S B P L T I n f) に送り、ここで転流して全原水流の 75% をライン 394 経由でタンク 396 (無酸素性セクター領域 - V No. 1) に送り、全原水流の 15% をスプリッタボックス 392 によって転流してライン 398 経由でタンク 400 (好気性反応槽 No. 1 の領域 V No. 2) に送り、全原水流の残りの 10% をスプリッタボックス 392 によって転流してライン 402 経由でタンク 404 (好気性反応槽 No. 2 の領域 V No. 3) に送る本発明の別の実施例が示されている。

20

【0153】

タンク 396 (V No. 1) は、ライン 394 を介して原水流の 75% を受ける無酸素性セクター領域として用いられる。MLSS リサイクル流の形での別のフローが、ライン 406、ポンプ 408 およびライン 410 を介してタンク 404 (V No. 3) から受入られる。タンク 396 中の溶存酸素は脱硝化のために 0.5 mg/L 未満のレベルに保たれる。タンク 396 の中には、タンク 404 から送られた硝酸塩の形での結合酸素と好気性微生物とが豊富に含まれている。溶存酸素のレベルを 0.5 mg/L の範囲にすることで、好気性微生物は強制的に硝酸塩を使って呼吸をさせられることになり、さらにプロセッシングを続ける前に廃水の脱硝化の目的でこれを利用できるのである。

30

【0154】

ライン 390 経由で送られてくる原水流は栄養塩を豊富に含み、一方ライン 410 経由でタンク 404 から送られてくるフローは硝酸塩と微生物を豊富に含む。したがって、ステップフィードでは、本発明の装置の実施例の現在の設計に何ら変更を加えることなく、このタンクへの原水流の一部すなわちプラントに流入する有機負荷を増やすことができる。ポンプ 412 によって、2 時間毎に 1 時間、タンク 396 の中身を容量単位で再循環させる。フローはライン 414 を介してタンク 396 から流出し、以後の処理のためにタンク 400 に流入する。

40

【0155】

タンク 400 (V No. 2) は、ライン 398 を介して全原水流の 15% を受入れ、かつ、ライン 414 を介してタンク 396 からのフローを受入れる好気性反応槽 No. 1 の領域として用いられる。各清澄装置 (416、418、420、422) から戻り汚泥 (RAS) の形で別のフローが送られてくる。ポンプ「424」から動力を得る再循環導管曝気システム (RCAS) を用いて、2 時間毎に実質的に 1 時間、このタンクの中身を容量単位で再循環させる。再循環手順では、この領域の RCAS システムを通る際に細断することによって、タンク 400 の中身すなわち沈殿性固形物を可溶化する。細断については、微生物の個体群によって一層容易に消費されるように、RCAS システムのトロイダ

50

ル渦作用によってR C A Sシステムで水溶液内の固形物が処理される際に行う。また、再循環手順では、溶存酸素レベルが実質的に3.5 mg/L以上の濃度で維持されるように、強烈な曝気も適用する。溶存酸素濃度をこれらのレベルに保つことで、微生物コロニーに住むバクテリアであるニトロソモナスおよびニトロバクターがアンモニア (NH_3) を酸化して亜硝酸塩 (NO_2) に変え、最後に硝酸塩 (NO_3) にすることになる。当業者であればこのプロセスを硝化として知っている。

【0156】

この領域の溶存酸素濃度が3.5 mg/L以上であると、懸濁物質および他の有機物が分解および酸化されて一層安定した化合物になる。この最初の有機物の分解は、有機物が複雑な形態から単純な形態へと分解されるものであり、主に好気性バクテリア消化作用によるものである。 10

【0157】

R C A Sシステムによって供給される大量の大気を利用し、溶存酸素を従来の曝気システムで維持されているレベルよりも高めのレベル (3.5 mg/L よりも上) に維持することで、M C R Tが長いことも相まって、微生物コロニーは内生呼吸 (E R) として知られる生物学的ライフサイクルモードに入る。このE Rモードでは、生きている微生物は自分たちが周囲環境から吸収または吸着した新たな有機物と一緒に自己の細胞塊の一部を酸化しはじめる。このため、食物対微生物 (F/M) 比を調節することで微生物コロニーを維持しながら固形物の減量を促進しやすくなり、E Rプロセスによって微生物コロニーの死滅率を微生物コロニーの増殖率と等しくすることができる。フローはタンク400 (好気性反応槽No. 1の領域) から流出し、ライン426を介してタンク404 (好気性反応槽No. 2の領域V No. 3) に流入する。原水流の別の10%がスプリッタボックス392 (S B P L T I n f) からライン402を介してタンク404 (V No. 3) に入る。 20

【0158】

ポンプ428から動力を得る再循環導管曝気システム (R C A S) を用いて、2時間毎に実質的に1時間、タンク404の中身を容量単位で再循環させ、強烈に曝気する。タンク404の中身を再循環させている間、領域の再循環ポンピングによって細断することで沈殿性固形物をさらに可溶化し、微生物個体群がさらに消費できるようにする。再循環時には溶存酸素レベルが実質的に3.0 mg/L以上の濃度で維持されるように強烈な曝気も適用する。この領域では、微生物コロニーに住むバクテリアであるニトロソモナスおよびニトロバクターが有機窒素を酸化してアンモニア (NH_3) に変え、さらに亜硝酸塩 (NO_2) に変え、最後に硝酸塩 (NO_3) にすることになる。 30

【0159】

溶存酸素濃度を3.5 mg/Lより高いレベルに保つことで、別の有機窒素に加えて、別の全BODを含むがこれに限定されるものではない有機物を、最初にアンモニアに変換し、次いで亜硝酸塩、最後に硝酸塩および他の有害性の低い化合物に変換する機能を微生物コロニーに持たせることができる。このプロセスによって、脱硝化プロセスで水性環境に放出される全窒素の濃度が抑えられる。タンク404 (好気性反応槽No. 2の領域) 中の溶存酸素は少なくとも3.5 mg/Lの濃度を維持し、廃棄物の流れに含まれる有機栄養塩を完全に分解および酸化できるようにする。 40

【0160】

タンク404の中身の一部をライン406でポンプ408を介してM L S Sリサイクル流の形でリサイクルしてタンク396 (無酸素性セクター領域) に送り、最後にライン410に送る。好気性微生物と結合酸素とを多く含むM L S Sを、残っている栄養塩を処理し続けるためにタンク400、404に戻す前にタンク396で脱硝化する。

【0161】

このプロセスでの排水は、タンク404から出てライン430を經由し、浄化プロセスのためにライン432に流入する。ライン432からの原水が浄化領域のスプリッタボックス434 (S B C l a r I n f) に流入する際、このフローを4つの等しい部分に分流 50

し、タンク416（清澄装置No. 1）ではライン436、タンク418（清澄装置No. 2）ではライン438、タンク420（清澄装置No. 3）ではライン440、タンク422（清澄装置No. 4）ではライン442を介して4つの清澄装置（416、418、420、422）各々に送るようにすると好ましい。各清澄装置にフローが流入する際にはフロー速度を落とし、固形物が各清澄装置の底に沈殿するようにする。続いて、タンク416では水圧式固形物濃度インデューサ444、タンク418では水圧式固形物濃度インデューサ446、タンク420では水圧式固形物濃度インデューサ448、タンク422では水圧式固形物濃度インデューサ450を用いて沈殿固形物を円錐壁から取り除き、各清澄装置のRASポンプ（452、454、456、458）およびRASライン（460、462、464、466）を介して除去して以後の処理用にタンク400（好気性反応槽No. 1の領域）に送る前に固形物をさらに濃縮できるようにする。浄化プロセスから分離された液体は、ライン468を介してタンク416から、ライン470を介してタンク418から、ライン472を介してタンク420から、ライン474を介してタンク422から流出し、収集ボックス476（C B C l a r E f f）に合流する。この清澄装置の排水はライン478を介して最終処理排水として排出される。

10

【0162】

図10に示される別の実施例では、装置の実施例の未利用のライン、タンクおよび設備が省略されている。しかしながら、別のプロセスの実施例No. 4を用いて廃水フローを処理するのに必要な利用されているライン、タンクおよび設備については図示してある。

【0163】

20

図10を参照すると、ステップフィードフロータイプの流量特性を用いることに関して、本発明の別のプロセスの実施例No. 5を用いて、硝化および脱硝化のプロセッシング特性を得る、本発明の別の装置の実施例が示されている。本発明の別のプロセッシングの実施例No. 5は、領域に特有であるがタンクに特有のものではないプロセッシング方法である。

【0164】

別のプロセスの実施例No. 5では、原水は非常に強い廃棄物を代表するものである。この廃棄物は、主力産業の廃棄物の流れの原水濃度によって示す必要があるような、高濃度の NH_3 を含有することがあり、TSS濃度が高く全BOD濃度も高い一方で硝化も必要とするものである。

【0165】

30

図10の現在の別の実施例では、懸濁物質と生物分解性有機物質とを含む原水をライン500に通してスプリッタボックス502（S B P L T I n f）に送り、ここで転流する。全原水流の50%をライン506経由でタンク504（好気性反応槽No. 1の領域－V No. 1）に送り、全原水流の30%をスプリッタボックス502（S B P L T I n f）で転流してライン508経由でタンク510（好気性反応槽No. 2の領域－V No. 2）に送り、原水の残りの20%をスプリッタボックス502（S B P L T I n f）で転流してライン512経由でタンク532（好気性反応槽No. 3領域－V No. 3）に送る。

【0166】

上述したように、タンク504は全原水流の50%を受け、好気性反応槽No. 1の領域として用いられる。各清澄装置（516、518、520、522）から戻り汚泥（RAS）の形で別のフローが送られてくる。ポンプ524から動力を得る再循環導管曝気システム（RCAS）を用いて、2時間毎に実質的に1時間、タンク504の中身を容量単位で再循環させる。再循環手順では、このタンクのRCASシステムを通る際に細断することによって、タンク504の中身すなわち沈殿性固形物を可溶化する。細断については、微生物の個体群によって一層容易に消費されるように、RCASシステムのトロイダル渦作用によってRCASシステムで水溶液内の固形物が処理される際に行う。また、再循環手順では、溶存酸素レベルが実質的に3.5 mg/L以上の濃度で維持されるように、強烈な曝気も適用する。溶存酸素濃度をこれらのレベルに保つことで、微生物コロニーに住むバクテリアであるニトロソモナスおよびニトロバクターがアンモニア（ NH_3 ）を酸化

50

して亜硝酸塩（ NO_2 ）に変え、最後に硝酸塩（ NO_3 ）にすることになる。当業者であればこのプロセスを硝化として知っている。

【0167】

この領域の溶存酸素濃度レベルが 3.5 mg/L 以上であると、懸濁物質と、炭素質 BOD を含むがこれに限定されるものではない他の有機物とが分解および酸化され、一層安定した化合物になる。この最初の有機物の分解は、有機物が複雑な形態から単純な形態へと分解されるものであり、主に好気性バクテリア消化作用によって発生する。

【0168】

RCA S システムによって供給される大量の大気を利用し、溶存酸素を従来の曝気システムで維持されているレベルよりも高めのレベル（ 3.5 mg/L よりも上）に維持することで、MCRT が長いことも相まって、微生物コロニーは内生呼吸（ER）として知られる生物学的ライフサイクルモードに入る。この ER モードでは、生きている微生物は自分たちが周囲環境から吸収または吸着した新たな有機物と一緒に自己の細胞塊の一部を酸化しはじめる。このため、食物対微生物比を調節することでコロニーを維持しながら固形物の減量を促進しやすくなり、ER によって微生物の死滅率を微生物の増殖率と等しくすることができる。

10

【0169】

このタンク内での強烈な曝気によるもうひとつの利点として、微生物によってリンがいくらか消費されることがあげられる。

【0170】

さらに好気性処理を行うために、フローはタンク 504（好気性反応槽 No. 1 の領域）を出てライン 526 を経由し、タンク 510 に送られる。

20

【0171】

このフローは、ライン 508 によって供給されるプラントの原水流の 30% と一緒にタンク 504 からタンク 510 に流入する。タンク 510 は好気性反応槽 No. 2 の領域として用いられる。ポンプ 528 から動力を得る再循環導管曝気システム（RCA S）を用いて、2 時間毎に実質的に 1 時間、このタンクの中身を容量単位で再循環させる。再循環手順では、RCA S を通る際に細断することによって、タンク 510（好気性反応槽 No. 2 の領域）の中身すなわち沈殿性固形物を可溶化する。タンク 510（好気性反応槽 No. 2 の領域）の RCA S システムのもうひとつの利点として、別の強烈な曝気を適用し、溶存酸素レベルを実質的に 3.5 mg/L 以上の濃度で維持することがあげられる。溶存酸素濃度をこれらのレベルに保つことで、全 BOD を含むがこれに限定されるものではない有機物を変換する機能を微生物コロニーに持たせることができる。また、有機窒素は、まずアンモニアに変換され、次に亜硝酸塩、最後に硝酸塩に変換される。このプロセスによって全窒素および全 BOD の濃度が有害性の低い化合物まで低下する。繰り返すが、微生物は増えた分のリンも消費するためシステム内のリン濃度が下がる。

30

【0172】

フローはタンク 510（好気性反応槽 No. 2 の領域）から出てライン 530 を経由し、タンク 532（好気性反応槽 No. 3 領域）に送られる。また、スプリッタボックス 502（ライン 512 を経由したプラントの原水流の 10%）からのフローがタンク 532 に入る。ポンプ 534 から動力を得る再循環導管曝気システム（RCA S）を用いて、2 時間毎に実質的に 1 時間、タンク 532 の中身を容量単位で再循環させる。再循環手順では、RCA S システムを通る際に細断することによって、タンク 532 の中身すなわち沈殿性固形物を可溶化する。タンク 532 の RCA S システムのもうひとつの利点として、別の強烈な曝気を適用し、溶存酸素レベルを実質的に 3.5 mg/L 以上の濃度で維持することがあげられる。溶存酸素濃度をこれらのレベルに保つことで、全 BOD を含むがこれに限定されるものではない有機物を変換する機能を微生物コロニーに持たせることができる。このプロセスによって全 BOD の濃度が有害性の低い化合物まで低下する。繰り返すが、不可避免的に、微生物は増えた分のリンも消費する。

40

【0173】

50

このフローは、固形物分を廃水の液体分から沈殿させるために浄化領域の分流器ボックス 540 (S B C l a r I n f .) に入る前に重力によってタンク 532 から流出し、ライン 536 を経由してライン 538 に流入する。

【0174】

ライン 538 からの原水が浄化領域のスプリッタボックス 540 (S B C l a r I n f .) に流入する際、このフローを 4 つの等しい部分に分流し、タンク 516 (清澄装置 No. 1) ではライン 542、タンク 518 (清澄装置 No. 2) ではライン 544、タンク 520 (清澄装置 No. 3) ではライン 546、タンク 522 (清澄装置 No. 4) ではライン 548 をそれぞれ介して、4 つの清澄装置 (516、518、520、522) 各々に送るようにすると好ましい。各清澄装置タンクにフローが流入する際にはフロー速度を落とし、固形物が各清澄装置タンクの底に沈殿するようにする。続いて、タンク 516 (清澄装置 No. 1) では水圧式固形物濃度インデューサ 550、タンク 518 (清澄装置 No. 2) では水圧式固形物濃度インデューサ 552、タンク 520 (清澄装置 No. 3) では水圧式固形物濃度インデューサ 554、タンク 522 (清澄装置 No. 4) では水圧式固形物濃度インデューサ 556 を用いて沈殿固形物を円錐形の壁面から取り除き、各清澄装置の R A S ポンプ (558、560、562、564) および R A S ライン (566、568、570、572) を介して除去して以後の処理用にタンク 504 (好気性反応槽 No. 1 の領域) に送る前に固形物をさらに濃縮できるようにする。浄化プロセスから分離された液体は、ライン 574 を介してタンク 516 から、ライン 576 を介してタンク 518 から、ライン 578 を介してタンク 520 から、ライン 580 を介してタンク 522 から流出し、収集ボックス 582 (C B C l a r E f f) と合流する。清澄装置の排水はライン 584 経由で最終処理排水として排出される。

【0175】

再循環曝気システム (R C A S)

図 15 を参照すると、本発明による促進された固形物の減量廃水処理方法の主な構成要素のうちのひとつが示されている。R C A S は、必要に応じて上述したものをを用いて、廃水を細断し、混合し、攪拌し、循環させ、曝気し、均質化し、飽和させる上での効率的な手段である。R C A S は、保守管理がしやすいように好ましくは各タンクの外側部分に配置された差動インジェクタ (d i f f e r e n t i a l i n j e c t o r) によってタンク中身の高速フローを生み出しす機械的なポンプでタンクの中身を取る一種の導管搬送システムである。差動インジェクタを通る空気を廃水処理フローに注入し、これをタンクに戻す。タンクの中身が R C A S システムを通過する際、微生物が消化しやすいように有機固形物を可溶化して均質化するような方法で有機固形物を細断する。R C A S システムのもうひとつの利点として、攪拌を行っている装置の排出部分 (インラインインジェクタ／ミキサ／曝気装置) でのトロイダル渦作用によって病原体を破壊する点があげられる。

【0176】

R C A S は、ポンプ 602 の吸入側に連結された吸入側の導管 600 と、米国特許第 5, 893, 641 号 (その開示内容全体を本願明細書に援用する) に記載されているものなどのインラインインジェクタ／ミキサ／曝気装置 606 を内部に含む排出側の導管 604 と、空気／酸素供給源の導管 608 と、供給用導管 610 とを含む。ポンプ 602 は、水溶液の入ったタンク 612 から廃水を汲み出し、混合、曝気、攪拌を行うために導管 600 を介してこれを曝気装置 606 まで運ぶ。次に、導管 610 によって廃水をタンク 612 に戻し、ここで導管 610 内の廃水と一緒に移動する気泡に捕捉された余分な大気を放出して、タンク 612 内に入った廃水に二次曝気、攪拌および混合作用をほどこす。廃水の移動時、図 15 に示すようにこれを曝気装置 606 に通し、ここで大気を真空によって引き抜く (ベンチュリ作用)。インライン曝気装置 608 の排出口で廃水と大気とを混合し、この廃水と大気とが導管 610 内にある間に廃水を酸素で飽和させる。曝気装置 606 は米国特許第 5, 893, 641 号明細書に示すような曝気装置であってもよいし、係属中の国際特許出願第 P C T / U S 0 1 / 1 1 9 3 6 号または米国特許出願第 0 9 / 5 4 7, 4 4 7 号明細書 (その開示内容全体を本願明細書に援用する) に記載されたいずれか

の曝気装置など、同等の性能を持つ他の曝気装置であってもよい。

【0177】

酸素飽和させた混合廃水は導管610を通して移動し、タンク612に戻される。導管610内では、導管610内を移動している廃水の完全飽和に必要な量を超えて廃水の流れに注入された大気余分な気泡が飽和廃水と一緒に運ばれる。余分な空気を導管610からタンクに排出する際、飽和廃水と一緒に、余分な空気がタンク612の中身に供給される別の空気源になり、まだ再循環されていないタンクの中身によって吸収されることになる酸素をさらに供給することで、タンクの中身全体の曝気プロセスが助長される。

【0178】

導管614を通る廃水の一部または全部の別のフローによって、システムの混合機能を維持したまま曝気を抑えるための制御ができるようになる場合もある。 10

【0179】

特定の条件下では、拘束または摩擦損失（すなわち導管サイズ縮小）、結合金具、バルブ、ノズルなどを用いて、供給用導管に抵抗を加えて人為的に圧力を発生させることができる。

【0180】

導管のサイズに特定の要件があったり導管の長さに特定の要件があるなど、R C A Sシステムを設置できるのが曝気または混合プロセスの設計要件を満たさない限られたパラメータに制約される場合の導管610に関する特定の条件については、導管610内の環境を補正する人為的な圧力を導管610内で発生させることが可能である。こうした導管610の設計上の補正によって、所望の特定の曝気基準になるように、直径、長さ、あるいは導管内での所望の圧力が異なる導管の特性を等しくすることができる。ここで企図される補正は、バルブ、結合金具、インラインミキサの追加、導管直径の縮小または拡大、オリフィスなどの拘束部の導管610への導入などで表される。 20

【0181】

再循環作業によって、送風機とコンプレッサとを用いる従来の曝気システムと比較して、R C A Sシステムの酸素移動能および微小気泡が得られ、電力消費量が削減される。こうしたR C A Sの有効性によって、本発明を総合的なプラント設計に必要な敷地面積を小さくすることができる。

【0182】

気泡 30

水溶液の曝気は生物学的栄養塩の好気性消化にとって重要なものである。気泡が小さくなればなるほど、容易に利用できる溶存酸素の呼吸によるバクテリアおよび他の微生物の好気性消化活性が高くなる。これらの2つの事実を念頭におくと、供給するのに最善の気泡の形態は微小気泡になる。この気泡は本発明のR C A Sシステムによって得られる。

【0183】

水性環境中での酸化生物学的および化学的プロセスは、水に対する酸素の可溶性が低いことで制限される。ヘンリーの法則によって定義されているように、この物理的な制約によれば、温度を一定に保つと、液体に溶解する気体の量は気体によって液体に加えられる圧力に比例する。R C A Sシステムの使用時には、廃水に溶解できる気体状酸素の量を増やすために気体と液体の圧力を大気圧よりも高くする。 40

【0184】

純水に対する酸素の可溶性は、周囲温度で1気圧にてわずかに約10 ppmである。

【0185】

ほとんどの好気性バイオプロセスでは、溶存酸素は短時間で消費されるため、その補充がプロセスの比率を制限する要因になる。したがって、バイオプロセス設計の最も重要な構成要素のひとつが、プロセスの液相に酸素を物質移動するための手段である。活発に呼吸している細菌培養についてみると、液体培地中の酸素を必要に応じて十分な比率で交換し、バクテリアの酸素要求量に対応していかなければならない。本発明で使用するR C A Sシステムでは、バクテリアの酸素要求量を上回る比率で溶存酸素を補充している。 50

【0186】

水は一般に、気相と液相との間に接触表面を作ることによって曝気される。これは、酸素源をバルク液相に導入するか、あるいはバルク気体（空気）相中に分散水を流動させることによって行うことができる。気相と液相のどちらが酸素化プロセスを左右するかとは無関係に、気泡を液相に導入して酸素または他の気体を物質移動させる。気体－液体間の物質移動の効率は、かなりの部分が気泡の特性に左右される。気泡の挙動は以下の物質移動パラメータに大きく影響する。

【0187】

- (a) 気泡内部から気体－液体界面への酸素の移動
- (b) 気体－液体界面を横切った酸素の運動
- (c) 気泡を囲む比較的よどんだ液膜を通しての酸素の拡散。

10

【0188】

一般に、バイオプロセスにおける気泡の最も重要な性質はそのサイズであると言われている。一定体積の気体についてみると、気体を大きな若干数の気泡ではなく多くの小さな気泡で分散させた場合に、気相と液相との間の界面面積が増える。1～3 mmの小さな気泡は、大きな気泡にはない以下の有利な特性を持つことが明らかになっている。

【0189】

小さな気泡は大きな気泡よりゆっくりと上昇するため、気体が水性相に溶解する時間が長く得られる。この性質はガスホールドアップと呼ばれ、ヘンリーの法則による可溶性の限界を超えて水中の酸素濃度を二倍以上にすることができる。たとえば、酸素の飽和限界の10 ppmに達した後、小さな気泡中の少なくともさらに10 ppmの酸素を利用して酸素を補充することができる。

20

【0190】

気泡が形成された後は、液相に対する酸素移動の主な障壁となるのは気泡を囲む液膜である。生化学工学の研究では、この膜を通しての移動は完全なプロセスでの速度を制限する段階であり、全体の物質移動比率を制御するという結論に至っている。しかしながら、気泡が小さくなれば、この液体の膜厚が薄くなり、バルク液相への気体の移動が妨げられることはなくなる。

【0191】

R C A S システムの場合と同様に、ポンプによる水溶液のフローと同じ速度および容量で真空によって空気を導入すると、微小気泡が形成される。これらの微小気泡はガスホールドアップの作用によって懸濁液中で保持されるのに必要な大きさのものであり、よってバクテリアが必要とする以上に溶存酸素濃度が高くなる。

30

【0192】

本発明の独自性

1) 本発明は、従来の廃水処理システムとは異なる生物学的プロセッシング範囲で動作する。

【0193】

本発明では30日間から150日間を超える範囲にわたる平均細胞滞留時間(M C R T)を利用しているのに対し、従来のシステムではこのような高い冗長性を達成することはできない。

40

【0194】

さまざまな従来のシステムを用いて記録された制限された比の範囲に対する、その有効値を裏付ける、本発明が立証した食物対微生物(F/M)比が、実質的に0.05から0.80の範囲である。

【0195】

本発明では、プラントのプロセッシング動作によるエネルギーを抑えて廃水の全B O D部分を処理するために独特な設計の廃水処理プラントを利用している。この処理は、あらゆる生物分解性固形物を除去しないまでも大幅に削減するように設計されている。処理サイクル全体を通して導入される曝気および再循環プロセッシングの有効性がゆえに、この独特なプ

50

ロセスを上記のような効率的なレベルで実施することが可能なのである。

【0196】

従来の廃水処理プラントの設計目的のひとつに、できるだけ多くの固形物質を原水流から物理的に除去し、最終的には処理システムから取り除いた固形物を外で処分または廃棄することがあげられる。さまざまな手段によって、さまざまな浄化度で廃水のバランスを処理し、排水に必要なレベルをほぼ満たすようにする。

【0197】

2) 本発明では、タンク底が円錐形をした浄化タンクのデザインを使用し、機械的な手段を使わずにこの中に沈殿固形物を回収して沈殿固形物を凝縮している。

【0198】

タンク内の廃水は、スラッジが円錐形の底の側面に付着することがないようにしつつスラッジを沈殿させることができるだけの十分に遅い速度で回転される。固形物を回転させる速度は、この固形物を沈殿させ、懸濁液中に残さずにすむだけの十分な低速に維持される。これは、タンクの液体を制御下で回転移動させるために清澄装置で使用する固形物アキュムレータ誘導システム (solids accumulator induction system) によって達成される。

【0199】

従来の清澄装置には、除去すべきスラッジをスラッジポンプのサンプルエリアに送るための機械的な装置がある。この機械的な手段は、モータ、ギア減速機、レーキアーム、ブレード、スクレーパスキージー、スキマーアームからなるものである。

【0200】

3) (装置の実施例において) 実質的に、本発明は典型的なタンク構成および設備一式を利用している。このようにすることで、異なるプロセスに対するタンク用途の変更に対応することができる。タンクはいずれも実質的に同一のサイズおよび形状であるため、タンクを単一のプロセッシング領域として利用することができる。単一のプロセッシング領域としての使用例のひとつとして、操業手順の間にすべてのタンクを好気性反応槽として用いることがあげられる。すべてのタンクは実質的に同じように給排水設備が施され、(必要な場合は) 実質的に同じ機能を有している。このシステムには、各タンクが同じサイズおよび形状であって、どのタンクをどのプロセスに使うこともできるという点で備え付けの冗長性があるが、これは保守管理時に望ましいことである。タンクおよび給排水構成は、どのプロセッシング領域にもプロセスタンクと給排水とを必要に応じて単に複製するだけで徐々に拡張し、性能および/または排水許可要件を満たすことができる機能があるようなものである。給排水およびタンク構成を用いることで、ほとんどまたは全く動作を停止させることなく、タンクプロセッシングの活用法の選択肢に幅が生まれる。単純なバルブの変更でこれが可能になる。

【0201】

4) 本発明では、タンクへの排水点でR C A Sシステムの速度、容積および流動方向を利用し、各領域での固形物の混合および/または沈殿のための回転速度と移動時間とを調節している。たとえば、

好気性反応槽をシステムから切り離し、固形物を完全に消化できるように中身を保持しつつ中身を曝気する

嫌気性コンディショナーに移動させるために固形物が沈殿するように無酸素性セクターにおける回転速度を遅くする

好気性消化装置に移動させるために固形物が沈殿するように嫌気性コンディショナーにおける回転速度を遅くする

有機物をほぼ完全に消化できるように曝気しながら好気性消化装置の中身を保持する

好気性消化作用を停止し、無機物を円錐底に沈殿させた後、無機物をすべて除去して廃棄する

有機固形物の消化を続けるためにプロセスを再開する

ことによって、好気性反応槽を好気性消化装置に変換することができる。

10

20

30

40

50

【0202】

すべての有機消化が終了した時点で、好気性消化装置を好気性反応槽としての作業に戻すことができる。

【0203】

5) 本発明では、R C A Sシステムを用いることで廃水中の病原体数を減らしている。これは、R C A S装置のトロイダル渦内での乱流および攪拌によって極端な作用が発生したときに起こり、これによってe. c o l iや糞便性大腸菌などのバクテリアの細胞膜の向きが変わり、バクテリアを酸化する酵素がこれを殺すバクテリアの電子受容体を利用できるようになる。

【0204】

以上、添付の図面を参照して実例としての本発明の実施例について説明したが、本発明はこれらの明確な実施例に限定されるものではなく、当業者であれば本発明の範囲または趣旨から逸脱することなく当該実施例にさまざまな他の変更および修正を施し得ることを理解できよう。たとえば、従来のプロセッシングタンクの場合と同様に、底が平坦または傾斜した正方形または長方形のプロセッシングタンクを使用してR C A Sシステムの効果を得ることができる。本発明の生物学的プロセスは、R C A Sシステム以外にも、十分な循環、攪拌、曝気および均質性を達成するものである。

10

【図面の簡単な説明】

【図1】

さまざまな廃水処理工程におけるバイオマスの相対濃度、可溶性有機食物、全酸素摂取量を、時間の関数として示すグラフである。

20

【図2】

廃水処理工程での代謝率を F/M （餌：微生物）比の関数として示すグラフである。

【図3】

多様な廃水処理システムについての比較データを示す図である。

【図4】

フレックスフロー、硝化、脱硝化およびリンの低減を示す、本発明の実施例による8段タンク型プラント配置の概略図である。

【図5】

本発明の別の実施例による8段タンク型プラント配置の概略図である。

30

【図6】

プラグ流れ、硝化、脱硝化での特有の流量特性を示す、本発明の別の実施例による7段タンク型プラント配置の概略図である。

【図7】

プラグ流れおよび硝化での特有の流量特性を示す、本発明の別の実施例による6段タンク型プラント配置の概略図である。

【図8】

ステップフィード、硝化、脱硝化およびリンの低減での具体的な流量特性を示す、本発明の別の実施例による8段タンク型プラント配置の概略図である。

【図9】

ステップフィード、硝化および脱硝化での特有の流量特性を示す、本発明の別の実施例による7段タンク型プラント配置の概略図である。

40

【図10】

ステップフィードおよび硝化での特有の流量特性を示す、本発明の別の実施例による7段タンク型プラント配置の概略図である。

【図11】

各々が複数のタンクを含む複数の処理領域で構成される廃水処理システムの概略図である。

【図12】

領域の流れ図を含む、本発明のタンク構造の概略図である。

50

【図 1 3】

典型的な都市廃水における未処理の原水の固体組成物である。

【図 1 4】

廃水窒素サイクルを示す図である。

【図 1 5】

任意の曝気装置バイパスを含む再循環曝気システム（R C A S）の概略図である。

【図 1 6】

30 分間の固形物沈殿状態を M C R T との関連で示す図である。

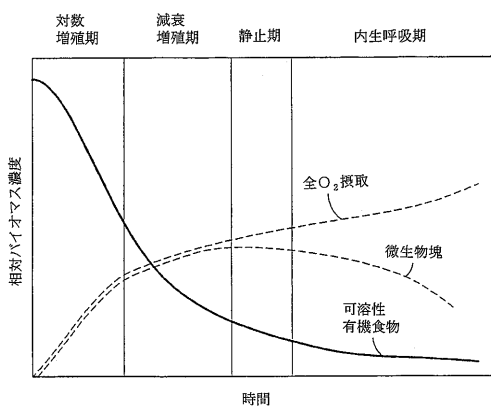
【図 1 7】

M C R T および F/M 比に対して減衰係数 k_d をどのようにして算出するかを示す図である。 10

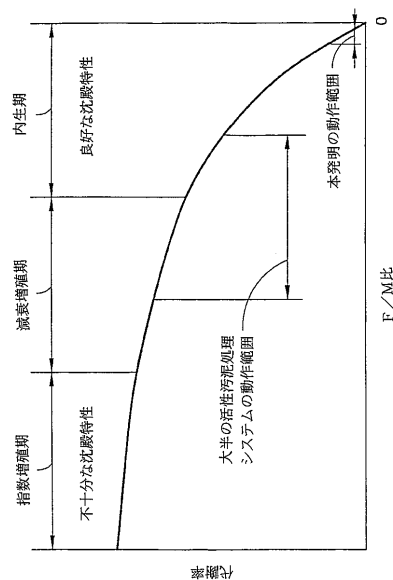
【図 1 8】

図 5 に示す処理を、捕捉した固形物を再プロセッシング用に戻すために濾過領域を清澄装置に連結した状態で示す簡略図である。

【図 1】



【図 2】

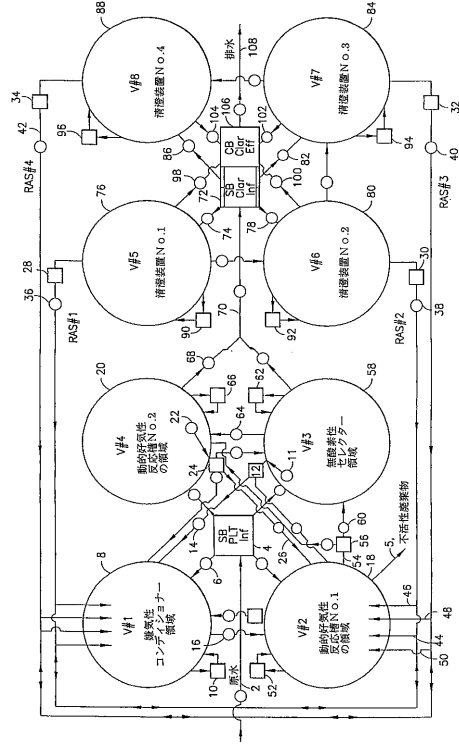


【図 3】

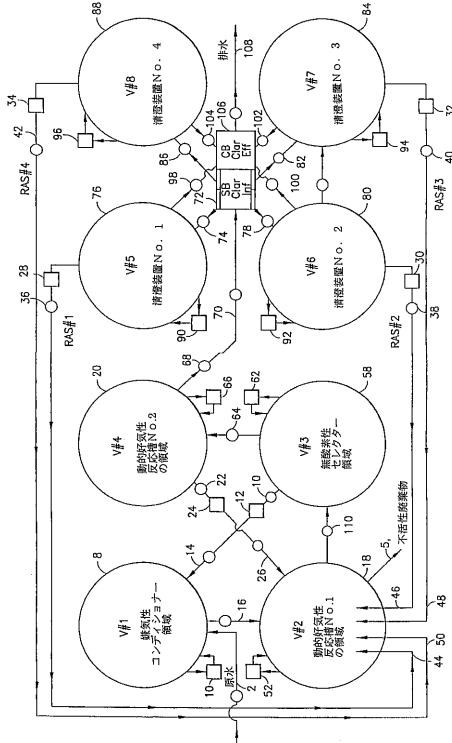
	本発明	完全混合	栓流	接触安定化	ステップ フィード	長時間曝気
曝気時間 (時間)	4-8	3-5	4-8	.5-1.0	3-5	18-36
MCRT (日)	30->150	15-30	15-30	5-15	5-15	15-30
F/MLB (BOD (g/L) / B / MLVSS (g/L))	0.05-0.80	0.05-0.20	0.05-0.20	0.20-0.40	0.20-0.4	0.05-0.2
MLSS	2,000-10,000	3,000-6,000	1,500-3,000	1,000-3,000	2,000-3,500	3,000-6,000
RAS再循環率 RAS / (Q)	25-100	25-100	25-50	25-100	25-75	75-150
プロセッシング再循環率	500-2000	N/A	N/A	N/A	N/A	N/A

排水処理システム比較

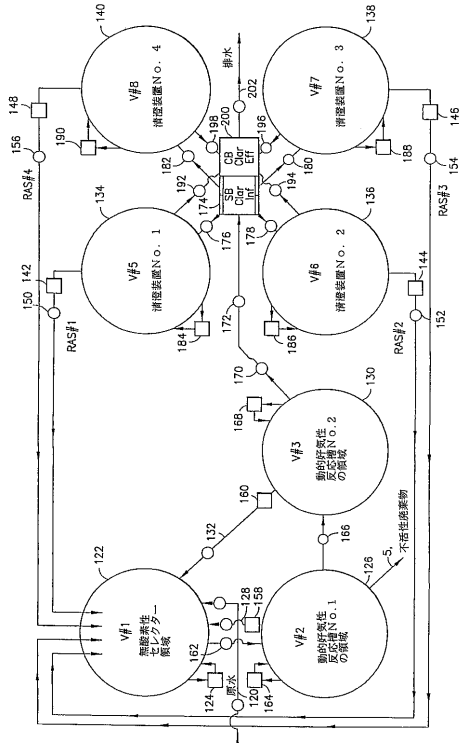
【図 4】



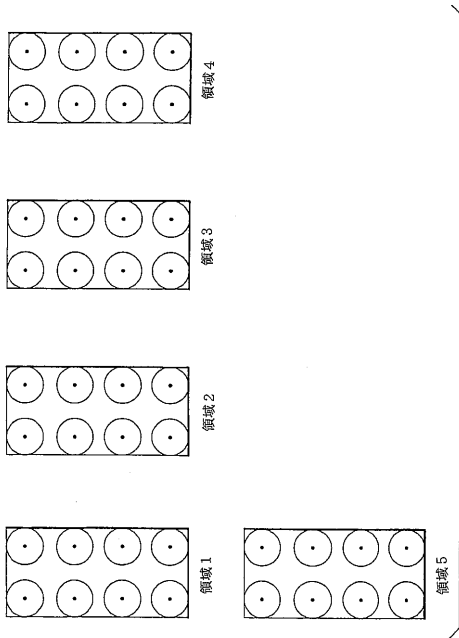
【図 5】



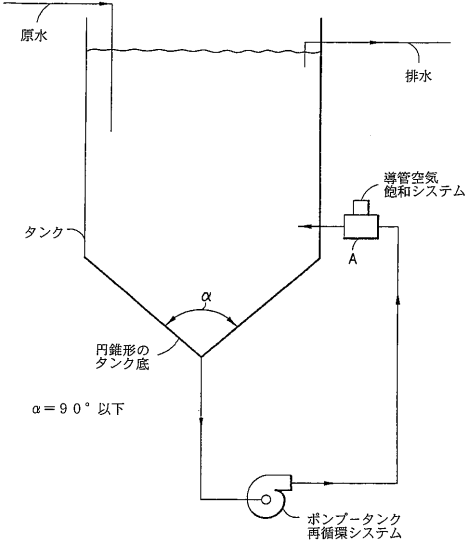
【図 6】



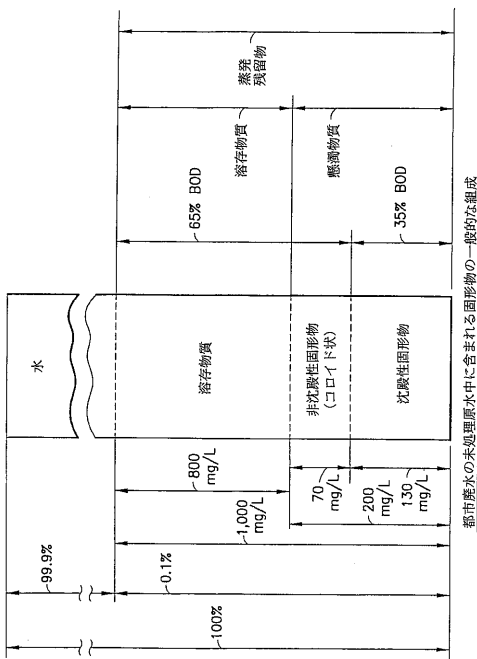
【図 1 1】



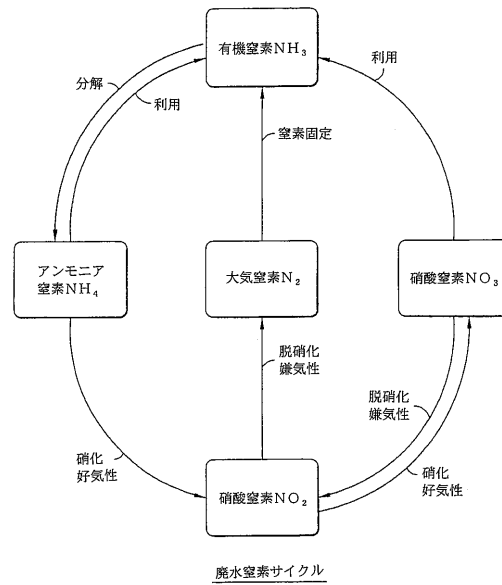
【図 1 2】



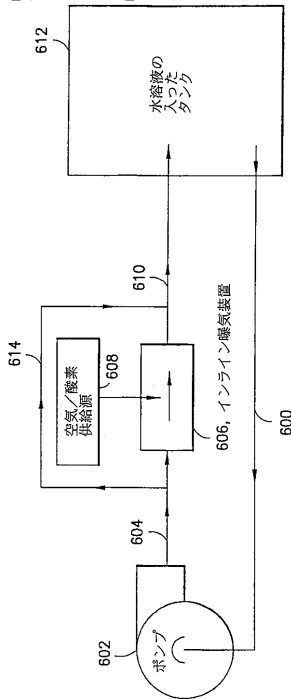
【図 1 3】



【図 1 4】



【図 15】



再循環曝気システム (RCAS)
(任意の曝気装置バイパスを含む)

【図 17】

破壊係数

MCRT は平均細胞滞留時間である

Y は展性である

F/M は食物対微生物比である

BOD REM EFFCY は BOD 除去効率である

K_a は減衰係数K_a を求める

$$K_a = (Y) (F/M) (BOD \text{ REM EFFCY}) - \frac{1}{MCRT}$$

式中:

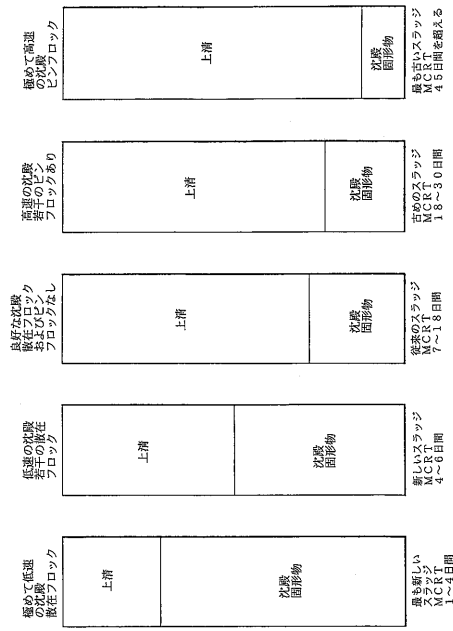
Y = 除去される BOD の 1 ポンドあたりで生成される VSS 0.55 ポンド

$$F/M = \frac{\text{毎日適用される BOD のポンド数}}{\text{在庫の VSS のポンド数}}$$

BOD REM EFFCY = プロセスでの BOD 除去率 (%) を小数で表記

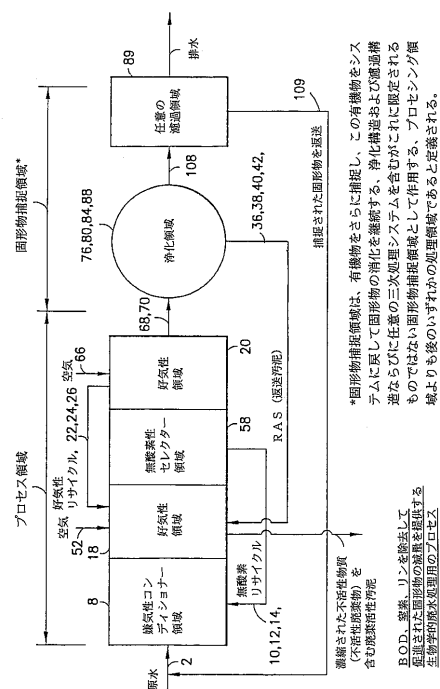
$$MCR = \frac{\text{曝気システム内の MLVSS のポンド数}}{\text{曝気システムから出る MLVSS のポンド数}}$$

【図 16】



MCRT に関連した 3.0 分間の固形物沈殿

【図 18】



【国際公開パンフレット】

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
11 April 2002 (11.04.2002)

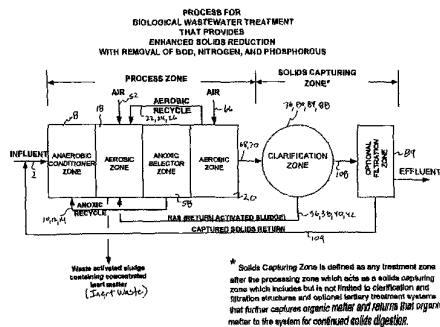
PCT

(10) International Publication Number
WO 02/28780 A2

- (51) International Patent Classification: C02F 1700 E, Jeanne Avenue, Pahrump, NV 89048 (US). GARCIA, Paul, F. [US/US]; 34 Church Street, Henderson, NV 89015 (US).
- (21) International Application Number: PCT/US01/31411
- (22) International Filing Date: 5 October 2001 (05.10.2001)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 60/238,878 6 October 2000 (06.10.2000) US
- (71) Applicant (for all designated States except US): PREMIER WASTEWATER INTERNATIONAL, LLC [US/US]; 4340 S. Procyon, Las Vegas, NV 89118 (US).
- (72) Inventors; and
- (73) Inventors/Applicants (for US only): GARCIA, Paul, G. [US/US]; 1500 Stardust-163, Unit B-3078, Las Vegas, NV 89109 (US). DAVIDSON, Leonard [US/US]; 2444 Tour Edition Drive, Henderson, NV 89014 (US). RUSSELL, H., Matthew [US/US]; 2305 Calle De Nuevo, Las Vegas, NV 89102 (US). JOHNSON, Martin, Perry [US/US]; 1700 E. Jeanne Avenue, Pahrump, NV 89048 (US). GARCIA, Paul, F. [US/US]; 34 Church Street, Henderson, NV 89015 (US).
- (74) Agents: MICHAL, Robert et al.; Frishauf, Holtz, Goodman, Langer & Chick, P.C., 767 Third Avenue, New York, NY 10017-2023 (US).
- (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR WASTEWATER TREATMENT WITH ENHANCED SOLIDS REDUCTION (ESR)



(57) Abstract: A wastewater treatment process that provides improved reduction of total solids through endogenous respiration while reducing biochemical oxygen demand and utilizing biological nutrient reduction. The wastewater treatment process uses an efficient aeration delivery system to drastically reduce the time needed to oxidize organic matter, and re-circulates, shreds and homogenizes the organic matter and microorganisms and oxygenates the entire mass many more times than traditional systems resulting in a greater biological solids digestion rate.

WO 02/28780 A2

WO 02/28780 A2

**Published:**

— without international search report and to be republished
upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 02/28780

PCT/US01/31411

APPARATUS AND METHOD FOR WASTEWATER TREATMENT
WITH ENHANCED SOLIDS REDUCTION (ESR)

5

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims priority under 35 USC
119(e) of U.S. Provisional Application Serial No. 60/238,878,
10 the entire disclosure of which is incorporated herein by
reference.

BACKGROUND OF THE INVENTION

Field of the Invention

15 The present invention relates to an aqueous waste
treatment method and apparatus that provides improved
treatment of aqueous waste and, more particularly, to a method
and apparatus which employs improved functionality, ease of
operation and aeration techniques to provide improvement in
20 the treatment of aqueous waste.

Background Information

Currently, the processes used in wastewater treatment
plants follow traditional methods that expend energy,
25 materials and labor at a relatively high rate along with a
large use of land. The high costs associated with traditional
methods of wastewater treatment are due to the treatment,

WO 02/28780

PCT/US01/31411

handling, and monitoring of all of the wastewater flow's components with equipment such as pumps, blowers, air compressors, scrapers, filters, chemicals, heat, presses, coagulants, flocculants, precipitants and dewatering, among
5 others. In traditional wastewater treatment systems, the wastewater is treated using high energy consuming methods. These methods include, but are not limited to, aerobic digestion, anaerobic digestion, sludge thickening and solids dewatering processes. The costs associated with these
10 treatments amount to approximately 85% of the plant operating energy budget.

In a typical influent wastewater stream which is subject to wastewater treatment, 99.9% of the entire wastewater stream is water and about 0.1% is organic, inorganic and dissolved
15 solids. The typical influent wastewater stream also contains nutrients in varying concentrations. Nutrients within the wastewater stream which need removal have an oxygen demand which must be met for decomposition. In the industry, this oxygen demand is referred to as biochemical oxygen demand
20 (BOD). Of the approximately 0.1% solids, about 10% to 20% are settleable solids containing about 35% of the BOD. The remaining 65% of the BOD is contained within the dissolved organic matter portion of municipal waste. See Figure 13.

In the solids (sludge) handling systems of traditional
25 wastewater treatment systems, processing energy is expended

WO 02/28780

PCT/US01/31411

for organic matter to be reduced by digestion to a level of about 50% reduction in volume while the remaining 50% volume of organic matter is disposed of by a number of means including, but not limited to, land fill disposal, incineration and land application. This results in the expenditure of additional energy and expense for the handling of solids. It would be beneficial to have a system and method which eliminates most of the need for disposal of organic matter.

10

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the present invention to provide an apparatus and method for treating aqueous waste containing organic matter and chemicals.

15 It is another object of the present invention to use an activated sludge process with recirculation of a treatment zone and greater aerator effectiveness to decrease the time and energy necessary for decomposition of organic matter.

It is yet another object of the present invention to substantially reduce the wasting of organic matter in the form of waste activated sludge (WAS) which is the intentional removal of organic settled solids from the system and thus reduce the effort and cost of solids handling facilities.

20

WO 02/28780

PCT/US01/31411

It is another object of the present invention to provide an apparatus and method for treating aqueous wastewater which contains high concentrations of industrial type nutrients.

It is yet a further object of the present invention to
5 treat municipal waste which has typical concentrations of chemical oxygen demand (COD), BOD, ammonia and phosphorous.

It is yet a further object of the present invention to treat industrial strength waste which has high concentration levels of COD, BOD, ammonia and phosphorous typically found in
10 animal type wastes.

It is still another object of the present invention to provide an apparatus and method for pre-treating wastewater from on-site facilities such as might occur from industrial manufacturers or animal wastes facilities.

15 It is another object of the present invention to utilize an efficient re-circulating aeration system (RCAS), which provides a combination of aeration, mixing, homogenizing and shredding that is superior to and which is more affordable than conventional aeration systems.

20 It is still another object of the present invention to provide an apparatus and method which is easier to design, operate, construct, initialize, manage, expand and maintain than conventional treatment systems.

It is still another object of the present invention to
25 provide an apparatus and method which is easier to adapt to

WO 02/28780

PCT/US01/31411

changes in processing and flow conditions, and which is easier to automate, monitor and control than conventional treatment systems.

It is still another object of the present invention to
5 provide an apparatus and method which when compared with similar wastewater treatment requirements, uses an overall smaller footprint (land area) than that which is found with conventional wastewater treatment plants.

It is still another object of the present invention to
10 provide an apparatus and method which is more economical to operate than conventional wastewater treatment systems.

It is still another object of the present invention to provide an apparatus and method which is less expensive to build and operate than conventional wastewater treatment
15 systems.

It is still another object of the present invention to provide an apparatus and method which increases the ability of the process vessels to treat larger quantities of wastewater in aeration basins by not being limited by vessel floor
20 surface area for placement of diffusers with regard to the ability to deliver intense aeration.

It is still another object of the present invention to provide an apparatus and method which provides a significantly increased decay coefficient (k_d).

WO 02/28780

PCT/US01/31411

It is still another object of the present invention to provide an apparatus and method which increases the mean cell residence time (MCRT) beyond that of conventional treatment systems, thereby providing for increased volatile solids
5 destruction and subsequent reduced solids handling efforts.

It is still another object of the present invention to provide an apparatus and method which allows for a highly flexible food to microorganism (F/M) ratio range above and below the ratio ranges of conventional treatment systems.

10 It is still another object of the present invention to provide an apparatus and method which reduces start-up costs, which include, but are not limited to, more rapidly increasing the mixed liquid suspended solids (MLSS) concentration, lower power costs for initial start-up and reduced costs for hauling
15 of seed sludge, thereby achieving design flow capacity with increased efficiency.

It is still another object of the present invention to provide an apparatus and method which uses cone bottom shaped vessels for a type of sequential batch reaction system during
20 start-up conditions for faster initial plant start-up.

It is still another object of the present invention to provide an apparatus and method which uses cone bottom shaped vessels for a type of sequential batch reaction that allows micro colonies to grow rapidly following conditions that have

WO 02/28780

PCT/US01/31411

upset a process, so as to quickly grow microorganisms which recover from the upset conditions.

It is still another object of the present invention is to provide a treatment plant that contains less apparatus and
5 processes to treat the wastewater to the desired effluent quality than conventional wastewater treatment systems.

It is still another object of the present invention to provide a device that separates solids from liquid through clarification without the need for scraping, raking or
10 brushing devices in clarifiers.

It is still another object of the present invention to provide a device which acts as a solids capturing zone which includes, but is not limited to clarifiers, filtration structures and optional tertiary treatment systems that
15 further capture organic matter, and that return the organic matter to aerobic zones for continued solids digestion.

It is still another object of the present invention to provide a device which decreases total nitrogen in a waste stream through oxidation of organic nitrogen into the more
20 stable compound of nitrate, which is then reduced in the waste stream by the denitrification process.

It is still another object of the present invention to provide a device which reduces phosphorous in a waste stream through microorganism digestion and use for the growing of new
25 cells in the decomposition of organic matter.

WO 02/28780

PCT/US01/31411

It is still another object of the present invention to provide a treatment process that is zone specific and not vessel specific.

It is still another object of the present invention to provide a system design that accommodates a specific flow and specific treatment process.

It is still another object of the present invention to use the toroidal vortex action of the RCAS system for the reduction of the number of pathogenic organisms within wastewater.

It is still another object of the present invention to provide an apparatus and method which allows for chemical oxidation of an aqueous solution.

It is still another object of the present invention to provide a means for the homogenization of a microorganism colony and the substrate that the colony feeds on.

It is still another object of the present invention to provide for the disbursements of a large microorganism floc into a smaller microorganism floc.

It is still another object of the present invention to cause the entire microorganism floc including the center to remain aerobic.

It is still another object of the present invention to provide a high concentration of dissolved oxygen in an aerobic process.

WO 02/28780

PCT/US01/31411

It is still another object of the present invention to provide an alternative to the cost and need for wastewater lagoons.

It is yet a further object of the present invention to
5 overcome the deficiencies of known wastewater treatment systems and methods.

In order to represent the applications for, and capabilities of, the present invention, raw influent of municipal wastewater is exemplified as the aqueous waste to be
10 treated. However the embodiments of the apparatus and method of the present invention can be implemented to treat a variety of wastes.

The term aeration as it pertains to the present invention means the addition of a secondary fluid flow (liquid or gas)
15 into a primary fluid flow (liquid or gas).

The present invention is able to treat organic matter of wastewater by providing intense aeration by means of an RCAS (Re-Circulating Aeration System) which gives increased oxygen transfer efficiencies that results in increased microorganism
20 oxygen uptake rates and functionalizing, shredding and homogenizing organic matter causing virtually 100% digestion of the organic matter. This is a significantly more effective use of processing energy as compared with traditional treatment methods using traditional aeration such as diffused
25 aeration. The present invention also reduces or eliminates

WO 02/28780

PCT/US01/31411

many traditional energy consuming devices such as primary clarification equipment, anaerobic digestion equipment, aerobic digestion equipment, primary treatment lagoons, incineration furnaces and related equipment, sludge thickening
5 equipment and sludge hauling equipment.

The present invention enables a more efficient and complete digestion of organic matter in the wastewater. The organic matter portions of the wastewater total BOD are treated in a first aerobic reactor zone and a second aerobic
10 reactor zone by use of aeration, and in an anaerobic conditioner zone and anoxic selector zone where the wastewater is kept in a condition in which the aquatic environment does not contain sufficient dissolved molecular oxygen for easy microorganism respiration, which can also be called an oxygen
15 deficient condition. This oxygen deficient condition generally refers to an environment in which chemically bound oxygen, such as nitrate, is present. Aggressive digestion of the organic matter is accomplished in the zones of the anaerobic conditioner, first aerobic reactor zone, anoxic
20 selector and second aerobic reactor zone.

In accordance with one form of the present invention a process for the treatment of an aqueous solution containing waste includes the steps of:

WO 02/28780

PCT/US01/31411

providing an influent wastewater stream to an anaerobic conditioner zone within which aqueous total solids are re-circulated, mixed and kept in suspension;

providing low oxygen level mixed liquor suspended solids
5 from an anoxic selector zone to the anaerobic conditioner zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;

providing an outflow from the anaerobic conditioner zone to a first aerobic reactor zone, the anaerobic conditioner
10 zone outflow being mixed in the first aerobic reactor zone with return activated sludge from a clarification zone whereby contents of the first aerobic reactor zone are re-circulated and aerated, and whereby settleable solids present in the contents of the first aerobic reactor zone are fractionalized,
15 thereby decomposing and oxidizing the solids and other organic matter and accumulating inert solids;

discharging the accumulated inert solids from the first aerobic reactor zone;

providing an outflow of aqueous solution from the first
20 aerobic reactor zone to the anoxic selector zone wherein the aqueous solution in the anoxic selector zone is re-circulated and mixed;

transferring a first portion of the anoxic selector zone aqueous solution corresponding to the low oxygen level/mixed
25 liquor suspended solids to the anaerobic conditioner zone, and

WO 02/28780

PCT/US01/31411

a second portion of the anoxic selector zone aqueous solution
to a second aerobic reactor zone;

recirculating and aerating aqueous solution contained in
the second aerobic reactor zone whereby settleable solids

5 become fractionalized thereby decomposing and oxidizing
suspended solids and other organic matter;

providing a first portion of the second aerobic reactor
zone aqueous solution to the first aerobic reactor zone;

providing a second portion of the second aerobic reactor
10 zone aqueous solution to the clarification zone to settle or
separate solids from the aqueous solution contained therein;

providing the settled or separated solids from the
clarification zone, corresponding to return activated sludge,
to the first aerobic reactor zone;

15 providing aqueous solution of the clarification zone to a
filtration zone to settle or separate solids from the aqueous
solution provided thereto; and

transferring a liquid portion of an outflow of the
filtration zone to a discharge receptacle, and the settled or
20 separated solids portion of the outflow of the filtration zone
to the influent wastewater stream for re-processing.

In accordance with another form of the present invention,
a process for the biological treatment of an aqueous solution
containing waste to reduce organic material, nitrogen and
25 phosphorous, includes the steps of:

WO 02/28780

PCT/US01/31411

providing an influent wastewater stream, which includes microorganisms, to an anaerobic conditioner zone within which aqueous total solids are re-circulated, mixed and kept in suspension, wherein a first stage of luxury phosphorous uptake
5 is accomplished by regulating a flow of low oxygen level mixed liquor suspended solids from an anoxic selector zone to the anaerobic conditioner zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;

providing an outflow from the anaerobic conditioner zone
10 to a first aerobic reactor zone, the anaerobic conditioner zone outflow being mixed in the first aerobic reactor zone with return activated sludge received from a clarification zone whereby contents of the first aerobic reactor zone are re-circulated and aerated and whereby nitrification occurs and
15 settleable solids present in the contents of the first aerobic reactor zone are fractionalized, thereby decomposing and oxidizing suspended solids and other organic matter along with enhancing a second stage of luxury phosphorous uptake and accumulating inert solids;

20 discharging the accumulated inert solids from the first aerobic reactor zone;

providing an outflow of aqueous solution from the first aerobic reactor zone to the anoxic selector zone wherein the aqueous solution in the anoxic selector zone is re-circulated
25 and mixed, and causing a low oxygen environment to exist

WO 02/28780

PCT/US01/31411

within the anoxic selector zone such that denitrification and release of biological phosphorous occurs along with the consumption of organic matter contained within the aqueous solution;

5 transferring a first portion of anoxic selector zone aqueous solution corresponding to low oxygen level/mixed liquor suspended solids to the anaerobic conditioner zone and a second portion of the anoxic selector zone aqueous solution to a second aerobic zone, at least the second portion of the
10 anoxic selector zone aqueous solution being rich in microorganisms and nutrients;

re-circulating and aerating aqueous solution contained in the second aerobic reactor zone whereby nitrification occurs and settleable solids become fractionalized and shredded
15 thereby decomposing and oxidizing suspended solids and other organic matter, and further enhancing the second stage of luxury phosphorous uptake resulting in a consumption of a large amount of phosphorous by the microorganisms;

providing a first portion of the second aerobic reactor
20 zone aqueous solution to the first aerobic reactor zone;
providing a second portion of the second aerobic reactor zone aqueous solution to the clarification zone to settle or separate solids from the aqueous solution provided thereto;

WO 02/28780

PCT/US01/31411

providing the settled or separated solids from the clarification zone to the first aerobic reactor zone as return activated sludge;

providing aqueous solution of the clarification zone to a
5 filtration zone to settle or separate solids from the aqueous solution provided thereto; and

transferring a liquid portion of an outflow of the filtration zone to a discharge receptacle and the settled or separated solids portion of the outflow of the filtration zone
10 to the influent wastewater stream for re-processing.

In accordance with another form of the present invention, apparatus for the treatment of an aqueous solution containing waste includes:

an anaerobic conditioner zone fluidly coupled to an
15 inlet, the anaerobic conditioner zone receiving an influent wastewater stream through the inlet, the anaerobic conditioner zone re-circulating the wastewater contained therein such that aqueous total solids are kept in suspension, the anaerobic conditioner zone receiving a flow of low oxygen level mixed
20 liquor suspended solids from an anoxic selector zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;

a first aerobic reactor zone fluidly coupled to the anaerobic conditioner zone, the first aerobic reactor zone
25 receiving an outflow of the anaerobic conditioner zone which

WO 02/28780

PCT/US01/31411

is mixed with return activated sludge received from a clarification zone whereby contents of the first aerobic reactor zone are re-circulated and aerated and whereby settleable solids become fractionalized thereby decomposing and oxidizing suspended solids and other organic matter, the first aerobic reactor zone accumulating inert solids, the accumulated inert solids being discharged from the first aerobic reactor zone;

an anoxic selector zone fluidly coupled to the anaerobic conditioner zone and the first aerobic reactor zone, the anoxic selector zone receiving an outflow of aqueous solution from the first aerobic reactor zone, aqueous solution within the anoxic selector zone being re-circulated and mixed, a first portion of the anoxic selector zone aqueous solution, corresponding to the low oxygen level/mixed liquor suspended solids, being provided to the anaerobic conditioner zone;

a second aerobic reactor zone fluidly coupled to the anoxic selector zone and the first aerobic reactor zone, the second aerobic reactor zone receiving a second portion of the anoxic selector zone aqueous solution wherein the aqueous solution within the second aerobic zone is re-circulated and aerated whereby settleable solids become fractionalized, a first portion of the aqueous solution of the second aerobic reactor zone being provided to the first aerobic reactor zone;

WO 02/28780

PCT/US01/31411

a clarification zone fluidly coupled to the second aerobic zone and the first aerobic zone, the clarification zone receiving a second portion of the second aerobic reactor zone aqueous solution, whereby settling or separating and
5 capturing of solids from the aqueous solution occurs, and the settled solids, corresponding to return activated sludge, are provided to the first aerobic reactor zone; and

a filtration zone fluidly coupled to the clarification zone, the inlet, and an outlet, the filtration zone receiving
10 an outflow from the clarification zone to separate solids from the liquid portion of the contents of the clarification zone, a first portion of the contents of the filtration zone, which corresponds to effluent, being provided to the outlet, and a second portion of the contents of the filtration zone, which
15 corresponds to separated solids, being provided to the inlet and being combined with the influent wastewater stream for re-processing.

These and other objects, features and advantages of the present invention will become apparent from the following
20 detailed description of preferred embodiments which is to be read in connection with the accompanying drawings.

WO 02/28780

PCT/US01/31411

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph showing the relative concentrations of biomass, soluble organic food and total oxygen uptake vs. time of various wastewater treatment processes;

5 Fig. 2 is a graph showing the rate of metabolism vs. F/M (Food to Microorganism) ratio of wastewater treatment processes;

Fig. 3 is a chart showing comparative data for a variety of wastewater treatment systems;

10 Fig. 4 is a schematic diagram of an eight-vessel plant layout according to the preferred embodiment of the present invention showing flex-flow, nitrification, de-nitrification and phosphorous reduction;

Fig. 5 is a schematic diagram of an eight-vessel plant layout according to an alternate embodiment of the present invention;

Fig. 6 is a schematic diagram of a seven-vessel plant layout according to an alternate embodiment of the present invention showing specific flow characteristics of plug flow, nitrification, de-nitrification;

20 Fig. 7 is a schematic diagram of a six-vessel plant layout according to an alternate embodiment of the present invention showing specific flow characteristics of plug flow and nitrification;

WO 02/28780

PCT/US01/31411

Fig. 8 is a schematic diagram of an eight-vessel plant layout according to an alternate embodiment of the present invention showing specific flow characteristics of step feed, nitrification, de-nitrification and phosphorous reduction;

5 Fig. 9 is a schematic diagram of a seven-vessel plant layout according to an alternate embodiment of the present invention showing specific flow characteristics of step feed, nitrification and de-nitrification;

10 Fig. 10 is a schematic diagram of a seven-vessel plant layout according to an alternate embodiment of the present invention showing specific flow characteristics of step feed and nitrification;

Fig. 11 is a schematic illustration of a wastewater treatment system made up of a number of treatment zones, each
15 of which includes a number of vessels;

Fig. 12 is a schematic illustration of a vessel structure of the present invention, including a zone flow diagram;

Fig. 13 illustrates the solids composition of raw influent in typical municipal wastewater;

20 Fig. 14 shows a wastewater nitrogen cycle;

Fig. 15 is a schematic illustration of the Re-Circulation Aeration System (RCAS) with an optional aerator by-pass;

Fig. 16 is a chart showing the 30 minute solids settling as related to MCRT;

WO 02/28780

PCT/US01/31411

Fig. 17 illustrates how the Decay Co-efficient k_d is calculated in relation to the MCRT and F/M Ratio; and

Fig. 18 is a simplified representation of the process shown in Fig. 5 with a filtration zone coupled to the clarifiers for returning captured solids for reprocessing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Treatment of chemical and biological aqueous waste can be performed through utilization and implementation of the method and apparatus of the present invention. The present invention cleans aqueous wastes in an aqueous solution by means of various strictly aerobic treatment methods and combinations of treatment methods such as aerobic biological decomposition, biological oxidation, chemical oxidation and physical separation of solids. The present invention is efficient in its use of aerobic treatment methods in that there is a reduction in the reliance on chemicals for nutrient removal. These methods exist in various stages of stabilization within the treatment process.

The approximate levels of performance (influent vs. effluent) within the treatment process of the present invention are as follows:

Reduction of 90% to 99.5% influent total BOD (biochemical oxygen demand) concentrations through oxidation and subsequent gravity settling.

WO 02/28780

PCT/US01/31411

Reduction of organic nitrogen through oxidation into first ammonia, second nitrite and third nitrate.

Reductions of 95% to 99.5% influent ammonia nitrogen concentrations through nitrification.

5 Reductions through de-nitrification of 50% to 99.5% nitrite and nitrate nitrogen concentrations that have resulted through the nitrification process referenced above.

Reduction of 90% to 99.5% influent total phosphorous concentrations through luxury "P" uptake.

10 Destruction of up to 99.5% total organic suspended solids concentrations through intense oxidation.

The following description explains the processes of the present invention that achieve these levels of performance as the aqueous solutions proceed from process zone to process
15 zone for treatment. The design of the present invention prefers a total hydraulic detention time for nutrient oxidation within the processing zones of about 4 to 8 hours.

PROCESS PERFORMANCE

20 Treatment of chemical and organic matter that occurs as an aqueous waste is stabilized through either oxidation or biological means. Stabilization is actually a group of processes. For example, in the treatment of municipal wastewater, the stabilization of ammonia as it is converted
25 into nitrogen gas is a several step process. Ammonia (NH₃) is

WO 02/28780

PCT/US01/31411

biologically oxidized into nitrite (NO_2) and then it is organically stabilized into nitrate (NO_3). The next and final stage is known as de-nitrification. Once this stage is attained, the presence of oxygen is reduced to very low levels
5 and the elemental bound oxygen in the form of NO_3 is utilized for respiration while the nitrogen gas, N_2 , is released into the atmosphere.

Another form of treatment is oxidation of chemical compounds which is accomplished by aeration. The reaction
10 occurring from oxidation causes a chemical element or compound to lose electrons. This loss of electrons makes the element or compound more stable.

Biological treatment is one of the most important steps in processing municipal wastewater, and a brief explanation of
15 that treatment is helpful in understanding the present invention and its apparatus and processes. During biological treatment, microorganisms eat, convert or consume nutrients (BOD) in the wastewater. These nutrients can be biodegradable organics or chemical in nature. With traditional systems,
20 physical treatment of raw wastewater by sedimentation and wasting removes only about 35% of the BOD, due to the high percentage (about 65% of the BOD) of BOD contained in the non-settleable and dissolved solids contained in wastes. The present invention uses aerobic digestion treatment through a

WO 02/28780

PCT/US01/31411

suspended growth treatment method to treat the total BOD within the aqueous solution to levels at or above 95% removal.

There are two types of solids in liquid wastes, 1) organic, and 2) inorganic. Inorganic solids do not break down or decompose by biological treatment. Therefore, as the inorganic or inert solids begin to accumulate in the processing system, the removal or wasting of inert solids should occur. This wasting is set on a predetermined concentration ratio of inert to organic solids. With the percentage of inorganic or inert solids content in most municipal type wastewater being small compared to the entire solids load entering the system, the time frame for inert wasting could range substantially between 90 days and 360 days or more. Organic solids content of the typical municipal waste stream makes up approximately 70% to 85% of the solids in the wastewater. Around 80% to 85% of these solids are typically dissolved solids and are not settleable, but 15% to 20% of these solids are settleable. However, these settleable solids are shredded during the recirculation process of each of the aerobic processing zones used in the present invention which allows for easier consumption by the microorganisms.

This shredding enhances the aerobic digestion treatment process of the current invention by allowing the microorganism colony and settleable solids to become homogenized. This homogenization of settleable solids causes all of the food

WO 02/28780

PCT/US01/31411

substrate to become almost a dissolved solid allowing for easier consumption by the microorganism colony.

As the floc of the microorganism colony passes through the RCAS system of the present invention, the large floc portions are disbursed into smaller floc particles. The reduction in floc size aids the consumption of substrate by the microorganism colony by increasing the surface area of the floc and causing more intimate contact with needed food and oxygen.

Digestion of a substrate and microorganism colony occurs with increased speed when a microorganism colony remains aerobic throughout its contents. The RCAS system increases the digestion of a substrate by keeping microorganism colonies in disbursed small floc particles so as to maintain an aerobic condition in the center of the floc particles. As the floc particles become smaller, the concentration of dissolved oxygen within the aerobic zone is easily accessible to the center of the floc particles. This also allows for a high concentration of dissolved oxygen to be maintained within an aerobic zone.

The processing and aerobic digestion treatment system of the present invention are provided by living systems that rely on mixed biological culture to break down the organic wastes. The present invention's aerobic digestion treatment system grows and maintains in suspension a high population of non-

WO 02/28780

PCT/US01/31411

photosynthetic microorganisms, i.e., a biomass, which consumes the organic waste. Under aerobic digestion conditions, the reduced organic compounds are oxidized to end products of carbon dioxide and water.

5 The growth and survival of non-photosynthetic microorganisms depends on the microorganisms ability to obtain energy by metabolizing the organic matter. A traditional aerobic treatment process results in complete metabolism and synthesis of organic matter, producing biological growth in
10 large quantities which must be removed from the system to keep the process from becoming biologically overloaded compromising the quality of the effluent. The present invention makes use of a complete aerobic digestion treatment of the biomass with which the microorganism environment is kept to the far right
15 of the "endogenous respiration phase" of Fig. 2 by controlling and balancing the F/M (food-to-microorganism) ratio (in a range of .05 to .80) and the oxygen delivery. This results in not only the complete metabolism and synthesis of the organic matter but also in the significant reduction of biological
20 solids at the end of the process.

Another feature of the present invention is the use of the nitrification cycle for the conversion of large amounts of organic nitrogen into ammonia, ammonia into nitrite and nitrite into nitrate. The nitrate is then de-nitrified

WO 02/28780

PCT/US01/31411

releasing nitrogen into the atmosphere, resulting in a reduction of total nitrogen within the waste stream.

Still another feature of the present invention is the consumption of phosphorous entering the system by microorganisms as a food source for cell wall development and new cell growth during high oxygen concentration times such as that which occurs in the aerobic reactor zones.

Referring now to Fig. 1, the characteristic growth pattern for microorganisms is shown where the relative biomass concentration (on the vertical axis) is charted as a function of time (on the horizontal axis). After a short time period for adaptation to the new environment, the microorganisms consume the organic matter and reproduce by binary fission, exponentially increasing the number of viable cells and biomass in the culture medium. This is the "log growth phase" shown in the left most portion of the chart in Fig. 1. The rate of metabolism in the "log growth phase" is limited by both the ability of the microorganisms to process the organic matter, and the amount of dissolved oxygen available to the microorganisms for respiration.

The "declining growth phase" shown in Fig. 1 is caused by an increasing shortage of the organic matter necessary for growth of the microorganisms. In the "declining growth phase", the rate of reproduction of the microorganisms decreases. The growth of microorganisms in the "declining

WO 02/28780

PCT/US01/31411

growth phase" is a function of both the concentration of the microorganisms and concentration of the growth-limiting organic matter.

The "declining growth phase" is followed by a "stationary phase". In the "stationary phase", the biomass concentration reaches a maximum value, and the low concentration of remaining organic matter substantially limits the biomass growth rate which becomes relatively constant.

The "endogenous respiration phase" follows the "stationary phase". In the "endogenous respiration phase", viable microorganisms compete for the small amount of organic matter which is still in the wastewater that is undergoing treatment. Eventually, starvation of the microorganisms occurs, such that the rate of death exceeds the rate of reproduction. Thus, the concentration of biomass in the aqueous solution declines during the "endogenous respiration phase". In the current invention the endogenous respiration (ER) is controlled such that the rate of death of the microorganisms is equal to the rate of growth of the microorganisms as verified by a mixed liquid suspended solids (MLSS) concentration that is kept at a constant concentration relative to the processing criteria.

Wastewater treatment according to the present invention will now be described in detail. In the present invention, wastewater treatment processing takes place in three stages:

WO 02/28780

PCT/US01/31411

- (1) Mass biological aerobic digestion to consume the organic waste, including but not limited to total organic nitrogen and total phosphorous reductions;
- (2) Solids capturing zone clarification/sedimentation;
- 5 and
- (3) Re-treatment of solids capturing zones settled solids by returning solids back to the aerobic reactor process.

In the processing method of the present invention, consumption of organic waste is accomplished by maintaining an environment consisting of high mean cell residence time (MCRT), a moderate food to microorganism (F/M) ratio and intense aeration, wherein the microorganisms are forced to live in the endogenous respiration phase.

15 The clarification/sedimentation stage of the process is used to separate solids from the supernatant (the remaining liquid) through gravity settling. Once the aqueous solution containing suspended solids enter the clarification zone (vessels 76, 80, 84 and 88 corresponding (Clarifier #'s 1, 2, 20 3 and 4 of Fig. 4) from the aerobic reactor zone #2 (vessel 20 of Fig. 4), the specifics of which are explained in detail below, the velocity of the supernatant is slowed to allow the solids to settle by gravity. As the settled solids slightly concentrate at the bottom of the clarification vessels, they 25 are frequently and quickly removed and sent back to vessel

WO 02/28780

PCT/US01/31411

aerobic reactor #1 zone (vessel 18) for further treatment.

The supernatant (clearer aqueous solution) continues through the process where it may be further treated with optional tertiary treatments such as tertiary clarification or

5 filtration for the nearly complete removal of biological and inert matter before being discharged. A receiving stream, evaporation ponds, landscape irrigation, crop irrigation or to some other type of disposal may be the recipient of such a discharge.

10 Aerobic digestion treatment systems such as that of the present invention must grow and maintain in suspension a population of microorganisms in order to consume the organic waste. Although, as illustrated in Fig. 1, individual microorganisms grow rapidly, it takes time at startup or where
15 major load changes are occurring to increase the original low concentration of microorganisms to levels high enough to rapidly degrade the organic waste. It therefore becomes important to use methods for increasing the concentration of MLSS in a rapid fashion. Plant startup time, in regard to
20 traditional systems, range as long as 30 to 45 days for MLSS concentrations to reach acceptable operational levels. Using the present invention, plant start-up time can be reduced to as little as 14 days or less with the present invention. The time required for plant re-starts due to a toxic shock load to

WO 02/28780

PCT/US01/31411

the microorganisms are reduced as compared with traditional plant time requirements. These methods are discussed below.

A common design concept for aerobic digestion systems is mean cell residence time (MCRT), which is the average time the microorganisms spend in the system. The MCRT of traditional treatment systems relates to the quantity of microbial solids in an activated sludge process, relative to the quantity of solids lost in the effluent and the excess solids withdrawn from the processing cycle in the waste sludge. With the present invention the MCRT relates to the quantity of microbial solids in the aerobic treatment process, relative to the quantity of solids lost in the effluent only, which is unintentional wasting, as there are virtually no volatile solids withdrawn as waste activated sludge. Typical MCRT values for traditional systems are from 15 to 30 days. However, MCRT values for the present invention begin at 30 days and reach numbers of 150 to 250 days or greater (see Fig. 3). MCRT values for conventional aerobic treatment systems of greater than 30 days may produce operational problems. The excessive build up of solids in the system caused by inadequate wasting of solids is a common cause of a poor effluent quality due to the retention of higher concentrations of suspended solids, turbidity, etc. Other reasons for poor effluent quality include extremely old slow settling solids, over-oxidation of the solids and de-flocculation of the solids. Consequently,

WO 02/28780

PCT/US01/31411

for traditional aerobic treatment systems it is desirable to intentionally waste excessive solids from time to time to keep the MCRT within the ranges shown in Fig. 3. As in the present invention, the removal of excessive solids is not necessary
5 due to its ability to nearly complete the digestion of all organic solids.

Quantities of solids are expressed as concentrations of MLSS (mixed liquid suspended solids) with values for a conventional system shown in Fig. 3. These typical MLSS
10 values for conventional systems range from 1,000 mg/L at the low end of the range for contact stabilization systems to 6,000 mg/L for complete mix and extended aeration systems. The quantity of microbial solids (MLSS) in the anaerobic conditioner zone, anoxic selector zone and aerobic reactor
15 zones of the present invention (see, e.g. Fig. 4 explained in detail below) range from 2,000 - 8,000 mg/L or more. The apparatus and method of the present invention is able to maintain the MLSS concentrations shown in Fig. 3 for near complete digestion of organic matter of a typical municipal
20 type waste, to the elevated MLSS concentration shown in Fig. 3 for near complete digestion of organic matter of non-typical industrial type waste by using an efficient aeration delivery system device such as the one used in the present invention (re-circulating aeration system or "RCAS"). The aeration
25 device used in the present invention is the one described in

WO 02/28780

PCT/US01/31411

USP 5,893,641 (Garcia), the entire disclosure of which is incorporated herein by reference.

The process implemented by the present invention also achieves the results of total organic solids digestion by using the above-mentioned efficient aeration delivery system (RCAS) to deliver atmospheric air necessary for oxygen transfer, circulation, homogenization and deep mixing. An additional benefit of the implemented process that uses an aeration system of the type mentioned above is the mixing and secondary oxygenation of the MLSS residing within the aerobic reactor zones. This mixing and secondary oxygenation is accomplished by the removal of the MLSS contents from the aerobic reactor zones at their lowest point and discharging the re-oxygenated MLSS back into each respective vessel at an elevation of substantially two thirds of the way below the surface of the side water depth. The secondary oxygenation of the MLSS is accomplished by allowing the excess entrained air, injected by the RCAS, carried along with the aerated MLSS to flow via a conduit into and through the contents of the aerobic reactor zones. The primary and secondary oxygenation of the aerobic reactor zones MLSS enables the dissolved oxygen (DO) concentration to achieve levels in a range substantially between 3.0 and 5.0 mg/L. The dissolved oxygen concentration in the aerobic reactor zones is kept at an operational level that exceeds the upper range for traditional aerobic digestion

WO 02/28780

PCT/US01/31411

systems, which is 2.0 mg/L. For this reason, inter alia, the present invention achieves a higher degree of organic solids digestion through its efficient oxygenation treatment process.

With the higher than normal dissolved oxygen concentrations and intimate mixing as achieved with the present invention, a higher rate decay co-efficient (k_d) of organic matter occurs than is achieved with traditional aeration systems. The word "decay" is the term used to express destruction (digestion) of volatile (organic) suspended solids in the formula relating F/M to MCRT. Traditional aeration systems have a k_d value of between 0.04 to 0.06 for an average of 0.05, whereas in the present invention, k_d is substantially 0.10 or twice that for traditional aeration systems, thus yielding a greater digestion rate. See Fig. 17 for the formulas used for determining the decay co-efficient.

Traditional oxygen transfer efficiency is expressed as the percentage of mass of oxygen that reaches the biological cell compared to the applied mass of gaseous oxygen supplied to the reactor. The rate of oxygen transfer from air bubbles admitted by the RCAS is a function of several factors which vary according to the wastewater characteristics, including but not limited to, the oxygen transfer coefficient of the wastewater within a conduit and the oxygen transfer coefficient within a vessel, the oxygen saturation coefficient of the wastewater, and the present dissolved oxygen

WO 02/28780

PCT/US01/31411

concentration and saturation concentrations of oxygen within the aqueous solution.

In a traditional aerobic biological treatment system the metabolism of organic matter in the wastewater results in an increased biological mass (growth) of microorganisms in the system. Excess microorganisms are removed or wasted from the system to maintain a proper balance between food supply and the mass of microorganisms that exist in the aeration basin where the oxygen is being delivered. This balance is referred to as food-to-microorganism (F/M) ratio. One familiar in the art knows that an F/M ratio of 0.05 to 0.20 that is maintained in traditional aeration basins defines the operation of extended aeration systems. Fig. 2 illustrates how an increasing F/M ratio affects the rate of metabolism. Although the "exponential growth phase" shown in Fig. 2 is desirable for maximum rate of removal of organic matter, in this phase the microorganisms are in dispersed growth and experience difficulty in settling out of solution by gravity. Moreover, there is excess unconsumed organic matter in solution, which cannot be removed by a dispersed growth microorganism colony of a traditional aeration system and thus passes out of the system in the effluent. Operation of traditional aeration treatment systems at a high F/M ratio thus results in inefficient and insufficient BOD removal.

WO 02/28780

PCT/US01/31411

At a low F/M ratio, the overall metabolic activity in the aeration basin is endogenous. In this phase the metabolism of the organic matter is nearly complete and the microorganisms flocculate rapidly and settle out of solution by gravity.

5 Operation in the endogenous phase is desirable where a high BOD removal efficiency is desired.

Typical traditional aeration treatment systems F/M ratios range from 0.05 to 0.2 for the low rate needed for extended aeration, 0.2 to 0.4 for conventional rate of treatment to the
10 upper range of 0.4 to 1.5 for high rate treatment. However, in the present invention, the F/M ratio is kept in the range of 0.05 to 0.8 to encompass all of the low rate, all of the conventional rate and a portion of the high rate treatment processes allowing for a significant amount of flexibility
15 within a single treatment plant design. This flexibility is evident in that as the flow of a treatment system increases and the concentrations of organic matter remains the same, the recirculation rate is able to be increased by simply modulating the aerator to increase the speed of the
20 recirculating pumps, which in turn increases the aeration delivery rate. Therefore, with a sufficient amount of available oxygen as achieved by using an aeration delivery system such as the one described herein and in USP 5,893,641, the ranges of F/M ratio listed above for the current invention
25 allow the microorganisms not only to completely metabolize the

WO 02/28780

PCT/US01/31411

organic matter, but through intense aeration the food source diminishes as the microorganisms consume it and thus the competition for food increases. Microorganisms consume themselves and each other in order to survive as in the
5 endogenous respiration treatment process, even at the higher F/M ratio of 0.8. The long-term cannibalistic state of endogenous respiration ensures the mass reduction of solids accumulation that occurs with the aerobic digestion process of the current invention. Maintaining F/M ratios such as with
10 the current invention along with maintaining high amounts of dissolved oxygen as is economically possible using the aeration device and delivery system mentioned above, the oxidation of organic matter is rapidly completed.

As the MCRT of the microorganisms increases, the
15 promotion of rapid settling of the microorganisms increases, benefitting the clarification process, as shown in Figs. 2 and 16.

In order to better understand the term "wasting" as used in the present invention, the following explanation is given.
20 As the concentration of inert solids increases, a removal or wasting of these solids should occur so as to allow a sufficient volume of biological microorganisms to reside within the biological processing zones. For this reason provisions have been made for the removal of inorganic or
25 inert solids from aerobic reactor #1 as illustrated in figures

WO 02/28780

PCT/US01/31411

4, 5, 6, 7, 8, 9, 10 and 18. When the inert concentration reaches the removal level a predetermined amount of solids are removed. The concentration of inert solids prior to this wasting has steadily risen from the extremely low concentrations (approximately 0.001% of the settleable solids as indicated in figure 13) in the influent flow, to levels that can reach substantially 50% of the total solids concentration residing in the biological processing zones. While there are organic solids intermixed with inert solids, the total weight of organic solids wasted out of the biological processing zones are substantially between 0.01% and 0.5% as compared to the total weight of organic solids that have entered the biological processing zone. This wasting of inert and organic solids should continue periodically until the inert solids concentrations within the biological processing zone have dropped to acceptable processing levels.

Clarification may be defined as separating the biomass from the treated aqueous solution. Traditional aerobic treatment and solids separation systems attempt to retain the bulk of the microorganisms in the system by coagulation and flocculation, however, wasting occurs due to the nature of traditional process and apparatus along with operational energy cost limitations. The biological solids then settle to the bottom of a clarifier. The majority of the biological

WO 02/28780

PCT/US01/31411

solids are then returned to the aeration basin while intentionally wasting (removing) from the system a portion of the biological solids (activated sludge), which is an amount of activated sludge that exceeds the system's designed treatment digestion ability. The current invention retains the microorganisms in the system by settling the biological solids along with all inorganic solids in a clarification zone (Clarifiers #1, 2, 3 and 4 of Fig. 4), and returning them to the aerobic reactor #1 zone (vessel 18 of Fig. 4) for further processing. Care is taken so as to regulate the blanket depth (accumulated sludge in the bottom of a clarifier) to a minimum by the frequency and number of gallons of return activated sludge (RAS) evacuated and returned to the aerobic reactor #1 zone. This frequency of evacuation of RAS eliminates long detention times of biological solids in the clarification zone, which would otherwise become septic, gasify and float to the surface of the clarification zone. Observation and adjustments are made to the evacuation of RAS flows so as to minimize the hydraulic velocities in the clarification zone. Higher hydraulic velocities can cause inefficient settling in the clarification zone resulting in biological solids carry over in its effluent.

With the present invention, the hydraulic detention time within the aeration cycles are in the ranges of the complete mix and plug flow processes, and partially in the high purity

WO 02/28780

PCT/US01/31411

oxygen process range, while deriving the benefits of the extended aeration process. The extended aeration process typically uses 18 to 36 hours to almost completely oxidize (treat) organic matter as shown on Fig.3 (see the right-most column thereof). The present invention obtains the same results on the organic matter in substantially 4 to 8 hours time. By using an efficient aeration delivery system, the current invention drastically reduces the time needed to oxidize the organic matter. This is accomplished by the aeration delivery systems located at each of the aerobic reactor zones (vessels 18, 20 of Fig. 4), the anaerobic conditioner zone (vessel 8 of Fig. 4) and the anoxic selector zone (vessel 58 of Fig. 4) re-circulating, by volume, each of their respective contents substantially 100% every two hours. When combining the anaerobic conditioner zone along with both aerobic reactor zone and the anoxic selector zone recirculation percentage rates, the total processing recirculation percentage rate is equal to or greater than 200% of the influent flow entering the treatment process in a 24 hour period. The aeration system re-circulates, shreds and homogenizes the organic matter and microorganisms, and oxygenates the entire mass many more times than traditional systems resulting in a greater biological solids digestion rate in a shorter time period than traditional systems. Typical re-circulation rates in conventional treatment systems

WO 02/28780

PCT/US01/31411

range from 25 to 100 percent per day of the influent flow for complete mix systems, 25 to 50 percent per day of the influent flow for plug flow systems and 75 to 150 percent per day of the influent flow for extended aeration systems.

5 Recirculation percentage rates as they pertain to traditional activated sludge treatment systems refer only to the percentage of recirculation of the Return Activated Sludge (RAS) as compared to the influent flow. While the present invention uses this same type of RAS recirculation percentage
10 the present invention also utilizes the previously described processing recirculation percentage achieving a greater solids digestion rate than is possible with traditional activated sludge treatment systems.

The biological treatment technique according to the
15 present invention will now be described. The composition of microorganism cells consist of 70 to 90 percent water with 10 to 30 percent dry material by weight. Of this dry material, 70 to 95 percent is organic and 5 to 30 percent is inorganic. Ninety-five percent of the organic dry material consists of
20 carbon, oxygen, nitrogen, hydrogen and phosphorus, and other trace materials respectively. The present invention takes advantage of the large percent of organics available to the microorganisms by maintaining an extremely long MCRT for not only the complete oxidation of organic compounds but also for
25 the consumption of biomass (the mass of organic material

WO 02/28780

PCT/US01/31411

consisting of living organisms feeding on the wastes in the wastewater, dead organisms and other debris), which also contains these same elements. In the activated sludge process, carbon, oxygen, 5 nitrogen and hydrogen are used as the main constituent of cellular material, with phosphorus being used as the constituent of nucleic acids, phospholipids and nucleotides. Compounds are taken up by microorganisms from their environment to carry out two basic primary metabolic 10 activities: energy production through bioenergetics, and synthesis of new cell material through biosynthesis. Microorganisms produce energy for themselves from light, organic and inorganic compounds. The main inorganic compounds used by the microorganisms as a source of energy are, ammonium 15 (NH₄), nitrite (NO₂), dissolved sulfide (H₂S), and elemental sulfur. These compounds are oxidized and the energy released is used for cell maintenance, synthesis of new cell material and movement of the microorganism if they are mobile. There are two types of microorganisms: autotrophic microorganisms 20 which use inorganic carbon for biosynthesis and heterotrophic microorganisms which use organic carbon for biosynthesis.

Carbon makes up approximately 50 percent of the dry mass of the microorganism cell. Therefore carbon is the main element used during biosynthesis. The microorganisms use as 25 one of their sources of energy for new cell development either

WO 02/28780

PCT/US01/31411

organic compounds such as fatty acids, amino acids, sugars, organic acids, or carbon dioxide (CO₂). Through biological processes, organic carbon is converted into microorganism biosynthesis material and gases such as carbon dioxide, which
5 can escape into the atmosphere. Through the 200% recirculation by volume of the contents of the aerobic reactor by the RCAS of the present invention, the microorganisms are enabled to come into contact with their carbon source more times and more efficiently than in traditional systems.

10 Oxygen and hydrogen are the main gas elements used in cellular material. The source of oxygen for the cellular material of microorganisms is found in molecular oxygen, organic compounds or even carbon dioxide. The present invention delivers oxygen through the aerobic reactor's
15 aeration delivery system (RCAS) directly into the aqueous solution of nutrients and microorganisms. This offers the microorganisms the opportunity to respire in the easiest manner and with the most available oxygen source for bioenergetics and biosynthesis. The source of hydrogen for
20 the cellular material of microorganisms is found in molecular hydrogen and organic compounds. Oxygen as an electron acceptor is used in the classification of microorganisms. Microorganisms, which use oxygen are referred to as aerobes, and those that do not use oxygen are referred as anaerobes.

WO 02/28780

PCT/US01/31411

The present invention uses aerobes for organic compound stabilization and decomposition in the aerobic reactor.

Nitrogen is the major source for proteins and nucleic acids for the microorganisms and includes 14 percent of the cellular material. Microorganisms can use inorganic nitrogen in the form of nitrogen gas (N_2), ammonia-nitrogen ($NH_3 + NH_4$), nitrite (NO_2) and nitrate (NO_3). Nitrogen gas to be used must first be converted into ammonium (NH_4) and then converted into organic nitrogen as in nitrogen fixing in soils, however ammonia-nitrogen (NH_3) can be considered as 100 percent ready and available for nutritional use by microorganisms. Conversion of ammonia (NH_3) into nitrite (NO_2) and nitrate (NO_3) opens the door for microorganisms that use NO_2 and NO_3 as their sole nitrogen source. However there is a large amount of energy needed for microorganisms to be able to use this nitrogen as a source for growth. These microorganisms must oxidize larger amounts of organic compounds to have the energy needed for using NO_2 and NO_3 as their nitrogen source. This results in a lower microorganism growth rate than when using NH_3 as a source for nitrogen. The current invention uses this lower growth rate to its advantage when maintaining an extremely long MCRT and variable F/M ratio to reduce the amount of microorganism growth. In combination, the microorganisms must consume greater amounts of organic compounds and are unable to reproduce as rapidly. There are

WO 02/28780

PCT/US01/31411

three biological removal processes used to remove nitrogen, they are ammonification followed by nitrification and denitrification. Ammonification and nitrification occur in the aerobic reactors while denitrification occurs in the anoxic selector. Ammonification is carried out by heterotrophic microorganisms, which take organic nitrogen in the form of proteins and peptides and decomposes them into ammonia and ammonium. Autotrophic microorganisms that convert ammonia into NO_2 and then NO_3 carry out nitrification. The third stage in the process is denitrification where another group of heterotrophic microorganisms reduce the NO_3 to NO_2 and then to NO and finally to N_2 for release into the atmosphere.

Microorganisms use phosphorus during cell synthesis, cell maintenance and as energy transport. Due to this, about 10 to 30 percent of an influent's phosphorus is consumed by microorganisms and used for their metabolic processes. However there are three microorganisms with the ability to store phosphorus in larger amounts than is needed for growth requirements. This is referred to as luxury phosphorus uptake. The three microorganisms, acinetobacter, pseudomonas and moraxella, are collectively referred to as poly-P bacteria because of their ability to store phosphorus in the form of polyphosphate granules. The poly-P bacteria are able to use the polyphosphate as an energy source when under stressed conditions. Since these bacteria are only able to store this

WO 02/28780

PCT/US01/31411

extra amount of phosphorus when under aerobic conditions, the current invention maintains dissolved oxygen in sufficient quantities to ensure luxury phosphorus uptake within the aerobic reactor zones. The present invention uses an
5 anaerobic conditioner zone as an area for microorganisms to reach the necessary stressed conditions to enable these poly-P bacteria to use the polyphosphate as energy, thus reducing the amount of phosphorus in the effluent stream.

In summary, carbon, nitrogen and phosphorus are reduced
10 through bioenergetics and biosynthesis by the microorganisms. The amount of removal of these nutrients is directly related to the concentration of the nutrients and the amount of time these nutrients are exposed to microorganisms. Increasing the number of times nutrients come into contact with the
15 microorganisms and oxygen through homogenization, as is the case with the current invention, can accelerate the organic digestion process. By designing zones to substantially meet a 2-hour hydraulic detention time and by re-circulation and re-aerating the entire content, by volume, of the aerobic reactor
20 zones 100% every 2 hours before it flows out of the zones, an environment for the microorganisms to accelerate the biological digestion process is provided. All biological solids removed from the solids capturing zone and returned to the processing zones are subject to this accelerated
25 biological digestion as well. The present invention, as

WO 02/28780

PCT/US01/31411

outlined above, produces this effect, and henceforth utilizes a smaller footprint design as compared to traditional treatment systems while performing as if there is more hydraulic detention capacity available.

5 By using an extended MCRT, a flexible F/M ratio and increasing the re-circulation as described above, the consumption of biomass also occurs, achieving an enhanced organic solids reduction in the process through digestion. Only after a predetermined concentration of inorganic solids
10 is reached is intentional wasting initiated of substantially only those inorganic solids, with possible high concentrations of phosphorous.

Another component of the "enhanced solids reduction" (ESR) wastewater treatment system of the present invention are
15 the zones (vessels), as being a part of an entire system. The zones consist of a vessel or group of vessels, which contains the wastewater for treatment. These vessels are preferred to be of a particular shape consisting of a vertical cylinder having a conical bottom. However, the processing of said
20 wastewater with the present invention is not limited to the preferred vessels. Effective treatment with the process of the present invention is attainable in square or rectangular vessels, with flat or sloped bottoms. The zones are unique to the process designated for that zone. The vessel design and
25 construction of the process zones are a component of the ESR

WO 02/28780

PCT/US01/31411

wastewater treatment system that permits the modularization of the system. The zones illustrated in Fig. 4, the preferred apparatus embodiment, are of a single vessel per zone design. Alternate apparatus embodiments could resemble a zone having
5 one or more vessels performing the unique process function of that zone. Alternately, as an example of a large capacity ESR wastewater treatment system, the number vessels shown in Fig. 11, could be classified as one zone, and additional modules resembling the number of vessels in Fig. 11 could be
10 added for each additional treatment zone required until such time that the design criteria of a large volume treatment plant is satisfied. Alternate designs could incorporate various sized vessels that utilize the same treatment processing techniques as described herein.

15 Vessel design incorporates the vertical cylinder with a depressed-shaped bottom, but preferably cone-shaped bottom (see Fig. 12) in order to create the environment to enhance the desired path of the wastewater stream during treatment. The use of the cone bottom vessel is essential for the
20 settling and concentrating of solids within the clarification zone and is used effectively in the process zones in the settling and concentrating of phosphorous rich inorganic solids for periodic removal. Keeping solids in suspension is accomplished by the RCAS system as it receives flow into the
25 pump from the bottom of the aerobic reactor zone. The aerobic

WO 02/28780

PCT/US01/31411

reactor zone contents are then pumped, aerated and recirculated, generating velocities during the RCAS conduit discharge back into the aerobic reactor so that the aerobic reactor zone contents are well mixed.

5 With the use of cylindrical shapes during clarification, and with the prompting of flow via the inflow's direction and its positioned reference point, and the re-circulation discharge direction and its positioned reference point, the wastewater is directed to travel in a particular direction, preferably rotational, at a particular speed and for a particular distance so as to allow the settling solids to arrive at the lower portion of the vessel, and remain within the vessel for a particular period of time so as to accumulate, concentrate and process, in order to facilitate the treatment desired. The conical bottom along with the flow characteristics of the traveling wastewater, promotes the settling solids to accumulate at a central point of reference at the lowest point within the cone shaped bottom (referred to as solids concentrator). These accumulated settled solids are then available to be evacuated by way of a port exiting at that lowest point.

15 The embodiment of Fig. 4 is utilized to illustrate the preferred flow characteristics when the influent contains normal BOD, TSS (Total Suspended Solids) & NH₃ loading, and requiring normal nitrification, denitrification and

25

WO 02/28780

PCT/US01/31411

phosphorous reduction, as demonstrated by the influent concentrations of a municipal wastewater treatment plant. In Fig. 4, pre-screened influent wastewater containing suspended solids and biodegradable organic substances passes through the influent feeder line, which flows into an influent splitter box, which then has take-off feeders to each of the vessels. This enables Fig. 4 to represent a universal configuration that would be used as a representative for all possible flow characteristics sought after for varying treatment specifications.

FLOW AND PROCESSES

Referring now to Fig. 4, a preferred embodiment of the enhanced solids reduction (ESR) wastewater treatment system in accordance with the present invention is shown which provides complete operational flexibility in the processing characteristics of nitrification, de-nitrification and phosphorous reduction in conjunction with using a plug flow type flow characteristic (the preferred process embodiment). Due to the efficiency of the preferred embodiment of the present invention and particularly of the RCAS system, an economic and treatability improvement in the processing of wastewater is achieved over and above traditional wastewater treatment processes. The preferred embodiment corresponds to a four-zone biological process and a solids capturing

WO 02/28780

PCT/US01/31411

treatment zone. The biological processing zones consist of, but are not limited to, 1) an anaerobic zone, 2) an aerobic zone, 3) an anoxic zone and 4) an additional aerobic zone. The solids capturing zone consists of but is not limited to
5 secondary clarification, tertiary clarification, filtration and chemical addition. However, by altering the flow characteristics by valve changes, any of the alternate processing embodiments (described below) can be implemented and used. The preferred processing embodiment of the present
10 invention is a method of processing that is zone specific and not vessel specific.

For the preferred plug flow characteristic, the influent, which in this embodiment is foreseen as typical municipal wastewater, is directed through line 2 into a flow splitter
15 box 4 which regulates and/or splits the flow of the influent to the treatment vessels. In this embodiment the entire flow of influent is then directed via line 6 to vessel 8 (V # 1) which is used as an anaerobic conditioner zone, whereby the contents, by volume, of this zone are recirculated
20 substantially one time every two hours using pump 10 and the above-mentioned RCAS. The size of the vessel 8 depends on the volume of influent being processed.

Vessel 8 (anaerobic conditioner zone) begins the first stage of luxury phosphorous uptake, which is biological
25 phosphorous (Bio-P) release. This first stage of luxury

WO 02/28780

PCT/US01/31411

phosphorous uptake is accomplished by maintaining an oxygen deficient state within the vessel. The anaerobic conditioner zone's dissolved oxygen levels are maintained at or below 0.10 mg/L allowing a formation of volatile fatty acids (VFA's) used
5 by microorganisms in the release of Bio-P. While this Bio-P release creates a temporary increase of phosphorous, it also forces the microorganisms to metabolize greater amounts of phosphorous during a later process. The contents of this zone are able to be maintained with low dissolved oxygen levels by
10 the controlled introduction of low oxygen level mixed liquid suspended solids (MLSS) from vessel 58 (anoxic selector zone - V #3) from line 11 through pump 12 and through line 14 into vessel 8 (anaerobic conditioner zone).

Aqueous total solids (TS) from vessel 8 (V # 1) flows
15 through line 16 into vessel 18 (V # 2) which is a dynamic aerobic reactor # 1 zone. The vessel 18 also receives another flow, MLSS re-cycle, which comes from vessel 20 (V # 4), which is a dynamic aerobic reactor # 2 zone. The flow from vessel 20 comes from line 22 through pump 24 and finally through line
20 26. Another flow enters vessel 18 from each of the four clarifiers (vessels 76, 80, 84, 88) - (V #5, V#6, V#7 and V#8) in the form of return activated sludge (RAS) through RAS pumps 28, 30, 32 and 34 then through the lines 36, 38, 40 and 42, and finally entering vessel 18 through lines 44, 46, 48 and 50
25 respectively. The contents, by volume, of vessel 18 are

WO 02/28780

PCT/US01/31411

recirculated substantially one time every two hours, using a re-circulation conduit aeration system (RCAS), explained below, which is powered by pump 52. During the recirculation procedure the contents of vessel 18 the settleable solids, become solubilized by means of shredding as they pass through the RCAS system of pump 52. Shredding occurs as the solids within the aqueous solution are processed through the RCAS system by the toroidal vortex action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied through the RCAS system during the recirculation procedure so that the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or higher. Keeping the dissolved oxygen concentration at these levels allows bacteria nitrosomonas and nitrobactor, residing in the microorganism colony, to oxidize ammonia (NH_3) into nitrite (NO_2) and finally into nitrate (NO_3) respectively. With dissolved oxygen concentrations of this zone maintained at or above 3.5 mg/L, suspended solids and other organic matter are decomposed and oxidized into more stable compounds.

By using large volumes of atmospheric air delivered by the RCAS and maintaining the dissolved oxygen at higher levels (well above 3.5 mg/L) than that which would be maintained by traditional aeration systems (2.0 mg/L to 3.0 mg/L), along with long MCRT's, the microorganism colony will enter the

WO 02/28780

PCT/US01/31411

biological life cycle mode known as endogenous respiration (ER). In this ER mode, the living microorganisms begin to metabolize some of their own cellular mass along with any new organic matter they absorb or adsorb from their environment.

5 This aids in the enhancement of solids reduction while maintaining a microorganism colony through the adjustment of the food to microorganism ratio (F/M) to allow the rate of death of the microorganism colony to equal the rate of growth of the microorganism colony through the endogenous respiration
10 process.

Another benefit of the delivery of intense aeration within this reactor is the enhanced consumption of large amounts of phosphorous by the microorganisms. The amount of phosphorous taken up by the microorganisms is greater than the
15 amount of phosphorous the microorganisms released in vessel 8 as described previously. The microorganisms then use this newly acquired phosphorous for new cell wall development and other energy needs.

Accumulation of inert solids are removed via line 5, from
20 vessel 18 (aerobic reactor #1) when the concentrations reach a predetermined level. This holds true for all embodiments of the present invention. This predetermined level could be substantially 50% of the concentration of total solids in vessel 18 or a level at which the process begins to allow
25 nutrients to pass through to the process effluent.

WO 02/28780

PCT/US01/31411

The flow exits vessel 18 via line 54, is provided to splitter box 56 and is then provided to vessel 58 via line 60 for further processing.

The contents, by volume, of vessel 58 (anoxic selector zone V#3) are recirculated substantially one time every two hours by the pump 62. Vessel 58 receives elemental oxygen attached to nitrogen molecules in the form of nitrate nitrogen (NO_3) and nitrite nitrogen (NO_2), which was derived primarily from the ammonia conversion process known as nitrification, occurring within vessel 18 (aerobic reactor # 1 zone). The amount of dissolved oxygen (DO) in vessel 58 is maintained in the range of 0.3mg/L to 0.5mg/L. The microorganisms contained within the wastewater of vessel 58 look for oxygen to respire. With little dissolved oxygen available, the microorganisms are forced to use the elemental oxygen in the NO_3 that is tied up with nitrogen. This process is commonly called denitrification. Once the bond between the nitrogen and oxygen is broken, the microorganisms consume the elemental oxygen for respiration, allowing the nitrogen to be released into the atmosphere. The microorganisms use this oxygen for necessary respiration in order to continue consumption of organic matter still within the wastewater.

During this anoxic condition, a natural release of phosphorous by the microorganisms occurs, as a way to conserve energy during the time of low dissolved oxygen availability,

WO 02/28780

PCT/US01/31411

but in lesser quantities than that which occurs in vessel 8
(the anaerobic conditioner zone V #1). While this creates a
temporary increase of phosphorous, it also forces the
microorganisms to metabolize greater amounts of phosphorous in
5 a later process. The effluent from this process is provided
via line 64 on to vessel 20 (aerobic reactor # 2 zone-V#4) for
further treatment.

Vessel 20 is used as a dynamic aerobic reactor. The
contents, by volume, of vessel 20 are recirculated and
10 intensely aerated substantially one time every two hours using
the re-circulation conduit aeration system (RCAS), which is
powered by pump 66. The oxidation of both dissolved and
suspended organic matter occur in vessel 20 by maintaining a
dissolved oxygen of at least 3.0 mg/L. The bacteria
15 nitrosomonas and nitrobactor, residing in the microorganism
colony, will oxidize organic nitrogen into ammonia (NH_3) then
into nitrite (NO_2) and finally into nitrate (NO_3) respectively.
As the aqueous solution containing the microorganism colony of
vessel 20 (dynamic aerobic reactor # 2 zone) is aerated and
20 the dissolved oxygen increases, the microorganisms begin
consuming phosphorous in larger quantities than is necessary
for them to sustain life. The amount of phosphorous consumed
far exceeds the amount of phosphorous the microorganisms
released into the aqueous solution while being processed
25 within the anaerobic conditioner zone and anoxic selector

WO 02/28780

PCT/US01/31411

zones (vessel 8 and 58). This effect is what is referred to as "luxury phosphorous uptake". Portions of the mixed liquid suspended solids (MLSS) from vessel 20 are recycled for further digestion to vessel 18 (dynamic aerobic reactor # 1 zone) through line 22, using pump 24 and is finally discharged through line 26, while the effluent is discharged from vessel 20 through line 68 and into line 70 before entering a clarification zone flow splitter box 72 (SB Clar Inf).

As the influent from line 70 enters the clarification zone flow splitter box 72 (SB Clar Inf), the flow is preferably split into four equal portions and sent to each of the four clarifiers through line 74 for vessel 76 corresponding to Clarifier # 1, line 78 for vessel 80 corresponding to Clarifier # 2, line 82 for vessel 84 corresponding to Clarifier # 3 and line 86 for vessel 88 corresponding to Clarifier # 4. The flow velocity is diminished as the flow enters each of the clarifiers, allowing the solids to settle into the bottom portion of each of the clarifiers. The settling solids are then dislodged from the walls of the clarifiers by using a hydraulically operated solids concentration inducer 90 for vessel 76 (Clarifier # 1), hydraulically operated solids concentration inducer 92 for vessel 80 (Clarifier # 2) hydraulically operated solids concentration inducer 94 for vessel 84 (Clarifier # 3), and hydraulically operated solids concentration inducer 96 for

WO 02/28780

PCT/US01/31411

vessel 88 (Clarifier # 4), allowing the solids to further thicken before being removed through each of the clarifier RAS pumps (28, 30, 32 and 34) and RAS lines (36, 38, 40 and 42) and sent to the vessel 18 (dynamic aerobic reactor # 1) for further treatment. Separated liquid from the clarification process exits vessel 76 through line 98, vessel 80 through line 100, vessel 84 through line 102 and vessel 88 through line 104, and join in the collection box 106 (CB Clar Eff). This clarifier provides effluent through line 108 as the final processed effluent.

The preferred embodiment of the present invention allows for an improvement in operational flexibility over traditional aerobic treatment systems.

A first alternate embodiment of the present invention is shown in Fig. 5 wherein the unutilized lines and equipment of the preferred apparatus embodiment of Fig. 4 are removed. However, all the utilized lines and equipment required to process the wastewater flow using the preferred process embodiment are shown. The alternative embodiment depicted in Fig. # 5 is utilized when the specific flow configuration is contemplated for the installation and where the flexibility offered in Fig. #4 is not required. The influent, which is typical municipal waste water, is directed through line 2 into vessel 8 which is used as an anaerobic conditioner zone (V#1), whereby the contents, by volume, of the zone are recirculated

WO 02/28780

PCT/US01/31411

substantially one time every two hours using pump 10. Similar to that of the preferred embodiment, the contents of this vessel are able to be maintained with low dissolved oxygen levels by the controlled introduction of low oxygen level MLSS from vessel 58 (anoxic selector zone) from line 10 through pump 12 and fed through line 14 into vessel 8.

Aqueous total solids from vessel 8 (anaerobic conditioner zone) flows through line 16 into vessel 18 which is a dynamic aerobic reactor #1 zone (V#2). Vessel 18 also receives another flow, MLSS re-cycle, which comes from vessel 20 which is being used as dynamic aerobic reactor #2 zone. The flow from vessel 20 comes from line 22 through pump 24 and finally through line 26. Another flow enters vessel 18 from each of the four clarifiers (vessels 76, 80, 84, 88 described below) in the form of return activated sludge (RAS) through the RAS pumps 28, 30, 32 and 34, then through the lines 36, 38, 40 and 42 respectively, and finally entering vessel 18 through lines 44, 46, 48 and 50 respectively. The contents, by volume, of vessel 18 are re-circulated substantially one time every two hours, using a re-circulation conduit aeration system (RCAS), explained below, which is powered by pump 52. During the re-circulation procedure, the contents of vessel 18, that is the settleable solids, become solubilized by means of shredding as it passes through the RCAS system of the zone. Shredding occurs as the solids within the aqueous solution are processed

WO 02/28780

PCT/US01/31411

through the RCAS system by the toroidal vortex action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied through the RCAS system during the re-circulation procedures
5 so that the level of the dissolved oxygen is substantially maintained at a concentration of 3.5mg per liter or higher.

The flow exits vessel 18 (aerobic reactor #1 zone) via line 110 to vessel 58 (anoxic selector zone - V#3). The contents of vessel 58 are recirculated substantially one time
10 every two hours by pump 62. The operation of vessel 58 is similar to that described in connection with Fig. 4. The effluent from vessel 58 is provided via line 64 to vessel 20 for further treatment.

Vessel 20 is a dynamic aerobic reactor (V#4). The
15 contents of vessel 20 are re-circulated and intensely aerated substantially one time every two hours using the re-circulation conduit aeration system (RCAS), which is powered by pump 66. The operation of vessel 20 is similar to that described in connection with Fig. 4. As explained above,
20 portions of the MLSS from vessel 20 are recycled for further processing to vessel 18 through line 22, using pump 24 and finally discharged through line 26, while the effluent of vessel 20 is discharged through line 68 and into line 70 before entering a clarification zone flow splitter box 72 (SB
25 Clar Inf).

WO 02/28780

PCT/US01/31411

As the influent from line 70 enters the clarification zone flow splitter box 72, the flow is preferably split into four equal portions and sent to each of the four clarifiers (V#5, V#6, V#7, V#8) through line 74 for vessel 76

5 corresponding to clarifier #1, line 78 for vessel 80 corresponding to clarifier #2, line 82 for vessel 84 corresponding to clarifier #3 and line 86 for vessel 88 corresponding to clarifier #4. The flow velocity is diminished as the flow enters each of the clarifiers, allowing

10 the solids to settle into the bottom of each of the clarifiers. These settling solids are then dislodged from the vessel walls by a hydraulically operated solid concentrations inducer 90 for vessel 76, hydraulically operated solids concentration inducer 92 for vessel 80, hydraulically operated

15 solids concentration inducer 94 for vessel 84, and hydraulically operated solids concentration inducer 96 for vessel 88, allowing the solids to further thicken before being removed through each of the clarifier RAS pumps (28, 30, 32 and 34) and RAS lines (36, 38, 40 and 42) and sent via lines

20 44, 46, 48 and 50 to the vessel 18 for further treatment. Separated liquid from the clarification process exists vessel 76 through line 98, vessel 80 through line 100, vessel 84 through line 102 and vessel 88 through line 104, and joined in collection box 106 (CB Clar Eff). The clarifier effluent

25 exists through line 108 as the final processed effluent.

WO 02/28780

PCT/US01/31411

Fig. 18 is a simplified representation of the process shown in Fig. 5 which further includes a filtration zone 89 coupled to the output of the clarifiers (line 108). The filtration zone receives the aqueous solution (in Fig. 4 the effluent) via line 108 for further processing. The aqueous solution is provided to the filtration zone where solids separate and settle from the liquid portion of the aqueous solution. The solids which have settled and separated from the liquid portion are provided via line 109 to the influent line 2 for re-processing and re-treatment through the system. The filtration zone shown in Fig. 18 can also be included in the system shown in Fig. 4 or any of the other embodiments of the present invention explained below.

The second alternate embodiment of the present invention depicted in Figure 6 uses alternate process embodiment # 1 of the present invention to provide the processing characteristic of nitrification and de-nitrification in conjunction with a plug flow type flow characteristic. Alternate apparatus embodiment #2 is to be used with alternate process embodiment # 1. Alternate processing embodiment # 1 of the present invention is a method of processing that is zone specific and not vessel specific.

For alternate process embodiment # 1, the influent, represented as typical municipal wastewater, is directed through line 120 into vessel 122 which is used as an anoxic

WO 02/28780

PCT/US01/31411

selector zone (V#1), whereby the contents, by volume, of this vessel are recirculated substantially one time every two hours using pump 124. Other flows that enter vessel 122 come from vessel 126 (aerobic reactor # 1 zone-V#2) via line 128 and
5 vessel 130 (aerobic reactor # 2 zone-V#3) via line 132 in the form of MLSS recycle, which is used to supplement the lack of oxygen within vessel 122. Another flow that enters vessel 122 comes from each of the four clarifiers (vessels 134, 136, 138, 140) in the form of return activated sludge (RAS) through the
10 RAS pumps 142, 144, 146 and 148, then finally through the lines 150, 152, 154 and 156 respectively. Vessel 122 receives elemental oxygen attached to nitrogen molecules in the form of nitrate nitrogen (NO_3) and nitrite nitrogen (NO_2), which were derived mostly from the ammonia conversion process known as
15 nitrification, occurring within vessels 126 and 130 (aerobic reactor # 1 zone and aerobic reactor # 2 zone). The amount of dissolved oxygen in vessel 122 is maintained in the range of 0.3mg/l to 0.5mg/l. This is made possible by the recycling of MLSS from vessel 126 (aerobic reactor # 1 zone) using pump 158
20 and pumping through line 128, and vessel 130 (aerobic reactor # 2 zone) using pump 160 and pumping through line 132 into vessel 122.

The microorganisms contained within the wastewater of vessel 122 (anoxic selector zone) look for oxygen to
25 respire. With little dissolved oxygen available, the

WO 02/28780

PCT/US01/31411

microorganisms are forced to use the elemental oxygen in the NO_3 that is tied up with the nitrogen gas. This process is commonly called denitrification. Once the bond between the nitrogen and oxygen is broken, the microorganisms consume the
5 elemental oxygen for respiration, allowing the nitrogen to be released into the atmosphere.

During the consumption of oxygen, through respiration in the denitrification process of vessel 122 (anoxic selector zone), the microorganisms also consume portions of organic
10 matter in the form of total suspended solids that have been shredded and solubilized in the recirculation process of vessels 126, 130 (the aerobic reactor zones # 1 and # 2) so as to become more easily consumed by the microorganism population.

15 Aqueous total solids (TS) from vessel 122 (anoxic selector zone) flows via gravity through line 162 to vessel 126 (aerobic reactor # 1 zone) for continued treatment. The contents, by volume, of vessel 126 are recirculated substantially one time every two hours, using the re-
20 circulation conduit aeration system (RCAS), which is powered by pump 164. During the recirculation procedure the contents of vessel 126, the settleable solids, become solubilized by the means of shredding through the RCAS system of the vessel. Shredding occurs as the solids within the aqueous solution are
25 processed through the RCAS system by the toroidal vortex

WO 02/28780

PCT/US01/31411

action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied through the RCAS system during recirculation so that the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or higher. Keeping the dissolved oxygen concentration at these levels allows the bacteria nitrosomonas and nitrobactor, residing in the microorganism colony, to oxidize ammonia (NH_3) into nitrite (NO_2) and finally into nitrate (NO_3) respectively. Individuals familiar in the art know this process as nitrification. With dissolved oxygen concentrations of this zone maintained at or above 3.5 mg/L, suspended solids and other organic matter are decomposed and oxidized into more stable compounds.

By using large volumes of atmospheric air delivered by the RCAS system and maintaining the dissolved oxygen at higher levels (well above 3.5 mg/L) than that which would be maintained by traditional systems (2.0 mg/L to 3.0 mg/L), along with long MCRT's, the microorganism colony will enter the biological life cycle mode known as endogenous respiration (ER). In this ER mode, the living microorganisms begin to oxidize some of their own cellular mass along with any new organic matter they absorb or adsorb from their environment. This aids in the enhancement of solids reduction while maintaining a microorganism colony through the adjustment of the food to microorganism (F/M) ratio to allow the rate of

WO 02/28780

PCT/US01/31411

death of the microorganisms to equal the rate of growth of the microorganisms through the ER process.

Another benefit of the delivery of intense aeration within this reactor is the consumption of some phosphorous by the microorganisms.

The flow exiting vessel 126 (aerobic reactor # 1 zone) exits through line 166 to vessel 130. Vessel 130 is used as an aerobic reactor # 2 zone (V#3), whereby the contents, by volume, of this vessel are recirculated and intensely aerated substantially one time every two hours using the recirculation conduit aeration system (RCAS), which is powered by pump 168. The oxidation of both dissolved and suspended organic matter occur in this vessel by maintaining a DO level of at least 3.0 mg/l. The bacteria nitrosomonas and nitrobactor, residing in the microorganism colony, will oxidize organic nitrogen into ammonia (NH_3) then into nitrite (NO_2) and finally into nitrate (NO_3) respectively in this vessel. A portion of the nitrate rich MLSS is recycled using pump 160 through line 132 into vessel 122 (anoxic selector zone) for nitrogen reduction through the de-nitrification process.

A flow also exits via gravity through line 170 into line 172 before entering the clarification zone flow split box 174 (SB Clar Inf) for the settling of solids from the liquid portion of the wastewater.

WO 02/28780

PCT/US01/31411

Note that this alternate embodiment does not include a vessel (V#4) present in the preferred embodiment. This vessel is not used until the flow increases substantially necessitating the need for an additional aerobic reactor.

5 As the influent from line 172 enters the clarification zone split box 174 (SB Clar Inf) the flow is split into four equal portions and sent to each of the four clarifier vessels (134, 136, 138, 140) through line 176 for vessel 134 (Clarifier # 1), line 178 for vessel 136 (Clarifier # 2), line 10 180 for vessel 138 (Clarifier # 3) and line 182 for vessel 140 (clarifier # 4). The flow velocity is diminished as the flow enters each of the clarifiers, allowing the solids to settle into the bottom of each of the clarifier vessels. The settling solids are then dislodged from the cone walls by 15 using a hydraulically operated solids concentration inducer 184 for vessel 134, hydraulically operated solids concentration inducer 186 for vessel 136, hydraulically operated solids concentration inducer 188 for vessel 138, and hydraulically operated solids concentration inducer 190 for 20 vessel 140, allowing the solids to further thicken before being removed through each of the clarifier RAS pumps (142, 144, 146 and 148) and RAS lines (150, 152, 154 and 156) be and sent to vessel 122 (anoxic reactor zone) for further treatment. Separated liquid from the clarification process 25 exits vessel 134 (Clarifier # 1) through line 192, vessel 136

WO 02/28780

PCT/US01/31411

(Clarifier # 2) through line 194, vessel 138 (Clarifier # 3) through line 196 and vessel 140 (Clarifier # 4) through line 198 and join in the collection box 200 (CB Clar Eff). The clarifier effluent exits via line 202 as the final processed
5 effluent.

Referring now to Fig. 7, another alternate apparatus embodiment of the present invention is shown which employs alternate process embodiment # 2 to provide the processing characteristic of nitrification in conjunction with a plug
10 flow type flow characteristic. This alternate apparatus embodiment is to be used with alternate process embodiment # 2. Alternate process embodiment # 2 of the present invention is a method of processing that is zone specific and not vessel specific.

15 In accordance with the present invention shown in Fig. 7, the influent, represented as typical municipal wastewater, is directed through line 210 into vessel 212, which is an aerobic reactor # 1 zone. Other flows entering vessel 212 come from four clarifiers (214, 216, 218, 220) in the form of return
20 activated sludge (RAS) through RAS pumps (222, 224, 226 and 228) and are delivered to vessel 212 through lines 230, 232, 234 and 236 respectively.

The contents, by volume, of vessel 212 (aerobic reactor #1 zone) are recirculated substantially one time every two
25 hours, using the re-circulation conduit aeration system

WO 02/28780

PCT/US01/31411

(RCAS), which is powered by pump 238. During the recirculation procedure the contents of vessel 212, the settleable solids, become solubilized by means of shredding through the RCAS system. Shredding occurs as the solids within the aqueous solution are processed through the RCAS system by the toroidal vortex action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied through the RCAS system during recirculation so that the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or above. Keeping the dissolved oxygen concentration at these levels allows the bacteria nitrosomonas and nitrobactor, residing in the microorganism colony, to oxidize ammonia (NH_3) into nitrite (NO_2) and finally into nitrate (NO_3) respectively. Individuals familiar in the art know this process as nitrification. With dissolved oxygen concentrations of this zone maintained at or above 3.5 mg/L, suspended solids and other organic matter are decomposed and oxidized into more stable compounds.

By using large volumes of atmospheric air delivered by the RCAS system and maintaining the dissolved oxygen at higher levels (well above 3.5 mg/L) than that which would be maintained by traditional systems (2.0 mg/L to 3.0 mg/L), along with long MCRT's, the microorganism colony will enter the biological life cycle mode known as Endogenous Respiration

WO 02/28780

PCT/US01/31411

(ER). In this ER mode, the living microorganisms begin to oxidize some of their own cellular mass along with any new organic matter they absorb or adsorb from their environment. This aids in the enhancement of solids reduction while

5 maintaining a microorganism colony through the adjustment of the food to microorganism ratio (F/M) to allow the rate of death of the microorganisms to equal the rate of growth of the microorganisms through the ER process.

Another benefit of the delivery of intense aeration
10 within this reactor is the consumption of some phosphorous by the microorganisms.

The flow exits vessel 212 (aerobic reactor #1 zone) through line 239 into vessel 240 (aerobic reactor #2 zone-V#2) for further aerobic treatment. The contents, by volume, of
15 vessel 240 are recirculated substantially one time every two hours, using the re-circulation conduit aeration system (RCAS), which is powered by pump 242. During recirculation of the contents of vessel 240, additional intense aeration is applied and the level of dissolved oxygen is substantially
20 maintained at a concentration of 3.0 mg/L or above. Keeping the dissolved oxygen concentration at these levels allows microorganisms the ability to convert organic matter, including but not limited to total BOD, and also organic nitrogen first into ammonia, then nitrite and finally into

WO 02/28780

PCT/US01/31411

nitrate. This process reduces the concentrations of total nitrogen into less harmful compounds.

The flow exits vessel 240, preferably via gravity, through line 243 into line 244 before entering clarification zone flow split box 246 (SB Clar Inf) for the settling of solids from the liquid portion of the wastewater.

Note that additional aerobic reactor vessels described in the previous embodiments are not used in this embodiment until the flow increases substantially necessitating the need for additional aerobic reactors.

As the influent from line 244 enters the clarification zone splitter box 246 (SB Clar Inf), the flow is preferably split into four equal portions and sent to each of the four clarifiers (vessels 214, 216, 218, 220) through line 248 for vessel 214 (Clarifier # 1), line 250 for vessel 216 (Clarifier # 2), line 252 for vessel 218 (Clarifier # 3) and line 254 for vessel 220 (Clarifier # 4). The flow velocity is diminished as the flow enters each of the clarifiers, allowing the solids to settle into the bottom of each of the clarifiers. The settling solids are then dislodged from the walls by using a hydraulically operated solids concentration inducer 256 for vessel 214, hydraulically operated solids concentration inducer 258 for vessel 216, hydraulically operated solids concentration inducer 260 for vessel 218 and hydraulically operated solids concentration inducer 262 for vessel 220,

WO 02/28780

PCT/US01/31411

allowing the solids to further thicken before being removed through each of the clarifier RAS pumps (222, 224, 226 and 228) and RAS lines (230, 232, 234 and 236) and sent to vessel 212 (aerobic reactor # 1 zone) for further treatment.

5 Separated liquid from the clarification process, exits vessel 214 through line 264, vessel 216 through line 266, vessel 218 through line 268 and vessel 220 through line 270 and joins in the collection box 272 (CB Clar Eff). The clarifier effluent exits through line 274 as the final processed effluent.

10 Referring now to Fig. 8, another alternate embodiment of the present invention is shown which utilizes the alternate processing embodiment # 3 of the present invention to provide the processing characteristics of nitrification, de-nitrification and phosphorous reduction in conjunction with
15 using a step feed flow type flow characteristic, giving improved operational flexibility. The use of this alternate embodiment in conjunction with alternate processing embodiment # 3 would be preferable when there is a change in feed preferences or the parameters change and the effluent quality
20 needs to be improved. This would also hold true for influent nutrient load variations while the influent flow characteristics remain the same. Alternate processing embodiment # 3 of the present invention is a method of processing that is zone specific and not vessel specific.

WO 02/28780

PCT/US01/31411

For alternate process embodiment # 3, the influent is a high strength waste, which could contain a high concentration of NH_3 , with a high TSS concentration and a high total BOD concentration, while requiring nitrification, de-nitrification and phosphorous reduction as might need to be demonstrated by the influent concentrations of an industrial strength waste stream.

In the alternate embodiment shown in Fig. 8, influent containing suspended solids and biodegradable organic substances passes through line 280 to splitter box 282 (SB PLT Inf), where it is diverted, sending 60% of the total influent flow into vessel 284 (anaerobic conditioner zone-V #1) via line 286, 30% of the total influent flow through line 288 into the vessel 290 (aerobic reactor #1 zone-V #2) and 5% being diverted through line 292 to vessel 294 (anoxic selector zone-V #3) while the other 5% is diverted thorough line 296 to vessel 298 (aerobic reactor # 2 zone-V #4).

Vessel 284 receives 60% of the plant influent flow and a flow from vessel 294 through line 300 using pump 302 and line 304. The contents, by volume, of vessel 284 are recirculated substantially one time every two hours using pump 306.

Vessel 284 (anaerobic conditioner zone) begins the first stage of luxury phosphorous uptake, which is biological phosphorous (Bio-P) release. Luxury phosphorous uptake is accomplished by maintaining an oxygen deficient state within

WO 02/28780

PCT/US01/31411

vessel 284. Dissolved oxygen levels are maintained at or below 0.10 mg/L causing Bio-P release by the microorganisms. While this Bio-P release creates a temporary increase of phosphorous, it also forces the microorganisms to metabolize greater amounts of phosphorous during a later process. The contents of this zone are able to maintain low dissolved oxygen levels by the controlled introduction low oxygen level MLSS from vessel 294 (anoxic selector zone) from line 300 through pump 302 and through line 304 into vessel 284. The flow then continues on through line 308 to vessel 290 (aerobic reactor # 1 zone) for treatment.

As mentioned above, vessel 290 receives 30% of the plant influent flow through line 288 and is used as aerobic reactor # 1 zone. Another flow that enters this vessel comes from vessel 298 through line 310 using pump 312 then through line 314 discharging into vessel 290. The flow from vessel 298 (aerobic reactor #2 zone) is in the form of MLSS recycle. Still another flow entering vessel 290 comes from each of the four clarifier vessels (316, 318, 320, 322) in the form of return activated sludge (RAS) through the RAS pumps 324, 326, 328 and 330, and then finally through the lines 332, 334, 336 and 338 respectively. The contents, by volume, of vessel 290 are recirculated substantially one time every two hours, using the re-circulation conduit aeration system (RCAS), which is powered by pump 340. During the recirculation procedure the

WO 02/28780

PCT/US01/31411

contents of vessel 284, the settleable solids, become
solubilized by means of shredding as they pass through the
RCAS system of the vessel. The shredding occurs as the solids
within the aqueous solution are processed through the RCAS
5 system by the toroidal vortex action of the RCAS system so as
to become more easily consumed by the microorganism
population. Intense aeration is also applied during the
recirculation procedure so that the level of dissolved oxygen
is substantially maintained at a concentration of 3.5 mg/L or
10 above. Keeping the dissolved oxygen concentration at these
levels allows the bacteria nitrosomonas and nitrobacter,
residing in the microorganism colony, to oxidize ammonia (NH_3)
into nitrite (NO_2) and finally into nitrate (NO_3) respectively.
With dissolved oxygen concentrations in this zone at or above
15 3.5 mg/L, suspended solids and other organic matter are
decomposed and oxidized into more stable compounds. By using
large volumes of atmospheric air delivered by the RCAS system
and maintaining the dissolved oxygen at higher levels (above
3.0 mg/L) than that which would be maintained by traditional
20 aeration systems, along with long MCRT's, the microorganism
colony will enter the biological life cycle mode known as
endogenous respiration (ER). In this ER mode, the living
microorganisms begin to oxidize some of their own cellular
mass along with any new organic matter they absorb or adsorb
25 from their environment. This aids in the enhancement of

WO 02/28780

PCT/US01/31411

solids reduction while maintaining a microorganism colony
through the adjustment of the food to microorganism (F/M)
ratio to allow the rate of death of the microorganism colony
to equal the rate of growth of the microorganism colony
5 through the ER process.

Another benefit of the delivery of intense aeration
within this reactor is the enhanced consumption of large
amounts of phosphorous by the microorganisms. The amount of
phosphorous taken up by the microorganisms is in greater
10 amounts than the amount of phosphorous the microorganisms
released in vessel 284 (anaerobic conditioner zone) as
described above. The microorganisms then use this newly
acquired phosphorous for new cell wall development and other
energy needs.

15 The flow then exits vessel 290 (aerobic reactor # 1 zone)
through line 342 into vessel 294 (anoxic selector zone) for
further processing. In addition to the flow through line 342
from vessel 290, vessel 294 also receives an additional flow
of 5% of the plant influent through line 292. The contents,
20 by volume, of this vessel are recirculated substantially one
time every two hours by pump 344. This anoxic selector zone
receives elemental oxygen attached to nitrogen molecules in
the form of nitrate nitrogen (NO_3) and nitrite nitrogen (NO_2),
which were derived mostly from the ammonia conversion process
25 known as nitrification occurring within vessel 290 (the

WO 02/28780

PCT/US01/31411

aerobic reactor # 1 zone). The amount of dissolved oxygen (DO) in vessel 294 is maintained in the range of 0.3mg/l to 0.5mg/l. The microorganisms contained within the wastewater of vessel 294 look for oxygen to respire. With little DO
5 available, the microorganisms are forced to use the elemental oxygen in the NO₃ that is tied up with nitrogen. This process is commonly called denitrification. Once the bond between the nitrogen and oxygen is broken, the microorganisms consume the elemental oxygen for respiration, allowing the nitrogen to be
10 released into the atmosphere. The microorganisms use this oxygen for the necessary respiration in order to continue consumption of organic matter still within the wastewater.

During this anoxic condition, a natural release of phosphorous by the microorganisms occurs, as a way to conserve
15 energy during the time of low dissolved oxygen availability, but in lesser quantities than occur in vessel 284 (anaerobic conditioner zone). While this creates a temporary, but slight, increase of phosphorous, it also forces the microorganisms to metabolize greater amounts of phosphorous in
20 a later process. The effluent from this process would continue through line 346 on to vessel 298 (aerobic reactor #2 zone) for further treatment.

In addition to the flow which enters the vessel 298 (aerobic reactor #2 zone) through line 346, a flow of 5% of
25 the plant influent is provided into vessel 298 through line

WO 02/28780

PCT/US01/31411

296. The contents, by volume, of this zone are recirculated and intensely aerated substantially one time every two hours using the re-circulation conduit aeration system (RCAS), which is powered by pump 348. The oxidation of both dissolved and suspended organic matter occur in this vessel by maintaining a dissolved oxygen of at least 3.5 mg/l. The bacteria nitrosomonas and nitrobactor, residing in the microorganism colony, will oxidize organic nitrogen into ammonia (NH_3) then into nitrite (NO_2) and finally into nitrate (NO_3) respectively in this vessel. As the aqueous solution containing the microorganism colony of vessel 298 is aerated and the dissolved oxygen increases, the microorganisms will also begin to consume phosphorous in larger quantities than is necessary for them to sustain life. The amount of phosphorous consumed far exceeds the amount of phosphorous the microorganisms released into the aqueous solution while being processed within vessels 284 and 294 (anaerobic conditioner zone and anoxic selector zone). This is what is referred to in the industry as "luxury phosphorous uptake". Portions of the MLSS from vessel 298 are recycled to vessel 290 (aerobic reactor # 1 zone), through line 310, using pump 312 and finally discharging through line 314, while the effluent continues on through line 350 and into line 352 before entering the clarification zone flow splitter box 354 (SB Clar Inf).

WO 02/28780

PCT/US01/31411

As the influent from line 352 enters the clarification zones splitter box 354, the flow is preferably split into four equal portions and sent to each of the four clarifiers (316, 318, 320, 322) through line 356 for vessel 316 (Clarifier # 1), line 358 for vessel 318 (Clarifier # 2), line 360 for vessel 320 (Clarifier # 3) and line 362 for vessel 322 (Clarifier # 4). The flow velocity is diminished as the flow enters each of the clarifiers, allowing the solids to settle into the bottom of each of the clarifiers. The settling solids are then dislodged from the walls of each clarifier vessel by using a hydraulically operated solids concentration inducer 364 for vessel 316 (Clarifier # 1), hydraulically operated solids concentration inducer 366 for vessel 318 (Clarifier # 2), hydraulically operated solids concentration inducer 368 for vessel 320, (Clarifier # 3), hydraulically operated solids concentration inducer 370 for vessel 322 (Clarifier # 4), allowing the solids to further thicken before being removed through each of the clarifier RAS pumps (324, 326, 328 and 330) and RAS lines (332, 334, 336 and 338) and sent to vessel 290 (aerobic reactor # 1 zone) for further treatment. Separated liquid from the clarification process, exits vessel 316 (Clarifier # 1) through line 372, vessel 318 (Clarifier # 2) through line 374, vessel 320 (Clarifier # 3) through line 376 and vessel 322 (Clarifier # 4) through line 378, and are combined in collection box 380 (CB Clar Eff).

WO 02/28780

PCT/US01/31411

The clarifier effluent exits through line 382 as the final processed effluent.

Referring now to Fig. 9, another alternate embodiment of the present invention is shown which utilizes an alternate process embodiment #4 to provide the processing characteristics of nitrification and de-nitrification in conjunction with using a step feed flow type flow characteristic. Alternate processing embodiment #4 of the present invention is a method of processing that is zone specific and not vessel specific.

For alternate process embodiment # 4, the influent is a high strength waste, which could contain a high NH_3 concentration, with a high TSS concentration and a high total BOD concentration, while requiring nitrification and de-nitrification for a total nitrogen reduction as might need to be demonstrated by the influent concentrations of an industrial strength waste stream.

Referring now to Fig. 9, an alternate embodiment of the present invention is shown wherein influent containing suspended solids and biodegradable organic substances, is passed through line 390 to splitter box 392 (SB PLT Inf), where it is diverted, sending 75% of the total influent flow through line 394 into vessel 396 (anoxic selector zone - V # 1), 15% of the total influent flow is diverted by splitter box 392 through line 398 into the vessel 400 (aerobic reactor #1

WO 02/28780

PCT/US01/31411

zone V # 2) and the remaining 10% of the total influent flow is diverted by splitter box 392 through line 402 to vessel 404 (aerobic reactor #2 zone V # 3).

Vessel 396 (V # 1) is used as an anoxic selector zone receiving 75% of the influent flow through line 394. An additional flow in the form of MLSS Recycle is received from vessel 404 (V # 3) through line 406, pump 408 and line 410. Dissolved oxygen in vessel 396 is kept at a level below 0.5 mg/L for denitrification. Vessel 396 is rich in aerobic microorganisms and combined oxygen in the form of nitrate received from vessel 404. With the levels of dissolved oxygen in the 0.5 mg/L range, the aerobic microorganisms are forced to use nitrate for respiration thus being used for the purpose of denitrification of the wastewater prior to continuing on to further processing.

The influent flow received through line 390 is rich in nutrients, while the flow received through line 410 from vessel 404 is rich in nitrate and microorganisms. Therefore, in step feeding a portion of the influent flow into this vessel, the organic load entering the plant can be increased without any alterations to the current design of the preferred apparatus embodiment of the present invention. The contents, by volume of vessel 396 are recirculated one time every two hours by pump 412. Flow exits vessel 396 through line 414 into vessel 400 for further treatment.

WO 02/28780

PCT/US01/31411

Vessel 400 (V # 2) is used as an aerobic reactor # 1 zone, receiving 15% of the total influent flow through line 398 and flow from vessel 396 through line 414. Additional flow comes from each of the clarifiers (416, 418, 420, 422) in the form of return activated sludge (RAS). The contents, by volume, of this vessel are recirculated substantially one time every two hours, using the re-circulation conduit aeration system (RCAS), which is powered by pump "424". During the recirculation procedure the contents of vessel 400, the settleable solids, become solubilized by means of shredding as they pass through the RCAS system of the zone. The shredding occurs as the solids within the aqueous solution are processed through the RCAS system by the toroidal vortex action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied during the recirculation procedure so that the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or above. Keeping the dissolved oxygen concentration at these levels allows the bacteria nitrosomonas and nitrobactor, residing in the microorganism colony, to oxidize ammonia (NH_3) into nitrite (NO_2) and finally into nitrate (NO_3) respectively. Individuals familiar in the art know this process as nitrification.

With dissolved oxygen concentrations in this zone at or above 3.5 mg/L, suspended solids and other organic matter are

WO 02/28780

PCT/US01/31411

decomposed and oxidized into more stable compounds. This initial decomposition of organic matter, which is the breaking down of organic matter from complex forms to more simple forms, mainly through the digestion action of aerobic bacteria.

By using large volumes of atmospheric air delivered by the RCAS system and maintaining the dissolved oxygen at higher levels (above 3.5 mg/L) than that which would be maintained by traditional aeration systems, along with long MCRT's, the microorganism colony will enter the biological life cycle mode known as endogenous respiration (ER). In this ER mode, the living microorganisms begin to oxidize some of their own cellular mass along with any new organic matter they absorb or adsorb from their environment. This aids in the enhancement of solids reduction while maintaining a microorganism colony through the adjustment of the food to microorganism (F/M) ratio to allow the rate of death of the microorganism colony to equal the rate of growth of the microorganism colony through the ER process. The flow exits vessel 400 (aerobic reactor # 1 zone) through line 426 to vessel 404 (aerobic reactor #2 zone V # 3). An additional 10% of the influent flow enters vessel 404 (V # 3) from the splitter box 392 (SB PLT Inf) through line 402.

The contents, by volume, of vessel 404 is recirculated and intensely aerated substantially one time every two hours

WO 02/28780

PCT/US01/31411

using the re-circulation conduit aeration system (RCAS), which is powered by pump 428. During the recirculation of the contents of vessel 404, the settleable solids become further solubilized by the means of shredding through the

5 recirculation pumping of the zone so as to become further consumed by the microorganism population. Intense aeration is also applied during recirculation so that the level of dissolved oxygen is substantially maintained at a concentration of 3.0 mg/L or above. The bacteria nitrosomonas

10 and nitrobacter, residing in the microorganism colony, will oxidize organic nitrogen into ammonia (NH_3) then into nitrite (NO_2) and finally into Nitrate (NO_3) respectively in this zone.

Keeping the dissolved oxygen concentration at levels above 3.5 mg/L allows the microorganism colony the ability to

15 convert organic matter, including but not limited to additional total BOD, along with additional organic nitrogen first into ammonia, then nitrite and finally into nitrate and other less harmful compounds. This process reduces the concentrations of total nitrogen released into the aquatic

20 environment through the denitrification process. The dissolved oxygen in vessel 404 (aerobic reactor # 2 zone) maintains a concentration of at least 3.5 mg/L to ensure complete decomposition and oxidation of the organic nutrients within the waste stream.

WO 02/28780

PCT/US01/31411

Portions of the contents of vessel 404 is recycled to vessel 396 (anoxic selector zone) in the form of MLSS recycle in line 406 using pump 408 and finally through in line 410. The MLSS, which is rich in aerobic microorganisms and combined oxygen, is denitrified in vessel 396 prior to returning to the vessels 400, 404 for continued treatment of remaining nutrients.

The Effluent from this processes exits vessel 404 through line 430 into line 432 for the clarification process. As the influent from line 432 enters the clarification zone splitter box 434 (SB Clar Inf) the flow is preferably split into four equal portions and sent to each of the four clarifiers (416, 418, 420, 422) through line 436 for vessel 416 (clarifier # 1), line 438 for vessel 418 (clarifier # 2), line 440 for vessel 420 (clarifier # 3) and line 442 for vessel 422 (clarifier # 4). The flow velocity is diminished as the flow enters each of the clarifiers, allowing the solids to settle into the bottom of each of the clarifiers. The settling solids are then dislodged from off of the cone walls by using a hydraulically operated solids concentration inducer 444 for vessel 416, hydraulically operated solids concentration inducer 446 for vessel 418, hydraulically operated solids concentration inducer 448 for vessel 420, hydraulically operated solids concentration inducer 450 for vessel 422 allowing the solids to further thicken before being removed

WO 02/28780

PCT/US01/31411

through each of the clarifiers RAS pumps (452, 454, 456, 458) and RAS lines (460, 462, 464, 466) and sent to vessel 400 (aerobic reactor # 1 zone) for further treatment. Separated liquid from the clarification process, exits vessel 416 through line 468, vessel 418 through line 470, vessel 420 through line 472 and vessel 422 through line 474 and join in the collection box 476 (CB Clar Eff). This clarifier effluent exits through line 478 as the final processed effluent.

The alternate embodiment as depicted in Fig. 10 shows the unutilized lines, vessels and equipment of the Preferred Apparatus Embodiment removed. However, all the utilized lines, vessels and equipment required to process the wastewater flow using alternate process embodiment # 4 are shown.

Referring now to Fig. 10, an alternate apparatus embodiment of the present invention is shown which utilizes the alternate process embodiment # 5 of the present invention to provide the processing characteristics of nitrification in conjunction with using a step feed flow type flow characteristic. Alternate processing embodiment # 5 of the present invention is a method of processing that is zone specific and not vessel specific.

For alternate process embodiment # 5, the influent is represented as a high strength waste which could contain a high NH_3 concentration, with a high TSS concentration and a

WO 02/28780

PCT/US01/31411

high total BOD concentration, while requiring nitrification as might need to be demonstrated by the influent concentrations of an industrial strength waste stream.

In the present alternate embodiment of Fig. 10 the
5 influent containing suspended solids and biodegradable organic substances passes through line 500 to splitter box 502 (SB PLT Inf), where it is diverted. 50% of the total influent flow is provided into the vessel 504 (aerobic reactor # 1 zone-V#1) via line 506, 30% of the total influent flow is diverted
10 through the splitter box 502 (SB PLT Inf) through line 508 into the vessel 510 (aerobic reactor # 2 zone-V#2) and the remaining 20% of the influent is diverted by the splitter box 502 (SB PLT Inf) through line 512 to vessel 532 (aerobic reactor # 3 zone-V#3).

15 As stated above, the vessel 504 is used as aerobic reactor # 1 zone, receiving 50% of the total influent flow. Additional flows come from each of the clarifiers (516, 518, 520, 522) in the form of return activated sludge (RAS). The contents, by volume, of vessel 504 are recirculated
20 substantially one time every two hours, using the re-circulation conduit aeration system (RCAS), which is powered by pump 524. During the recirculation procedure the contents of the vessel 504, the settleable solids, become solubilized by means of shredding as they pass through the RCAS system of
25 the vessel. The shredding occurs as the solids within the

WO 02/28780

PCT/US01/31411

aqueous solution are processed through the RCAS system by the
toroidal vortex action of the RCAS system so as to become more
easily consumed by the microorganism population. Intense
aeration is also applied during the recirculation procedure so
5 that the level of dissolved oxygen is substantially maintained
at a concentration of 3.5 mg/L or above. Keeping the
dissolved oxygen concentration at these levels allows the
bacteria nitrosomonas and nitrobacter, residing in the
microorganism colony, to oxidize ammonia (NH_3) into nitrite
10 (NO_2) and finally into nitrate (NO_3) respectively. Individuals
familiar in the art know this process as nitrification.

With dissolved oxygen concentration levels in this zone
at or above 3.5 mg/L, suspended solids and other organic
matter, including but not limited to carbonaceous BOD, are
15 decomposed and oxidized into more stable compounds. This
initial decomposition of organic matter, which is the breaking
down of organic matter from complex forms to simpler forms,
occurs mainly through the digestion action of aerobic
bacteria.

20 By using large volumes of atmospheric air delivered by
the RCAS system and maintaining the dissolved oxygen at higher
levels (above 3.5 mg/L) than that which would be maintained by
traditional aeration systems, along with long MCRT's, the
microorganism colony will enter the biological life cycle mode
25 known as Endogenous Respiration (ER). In this ER mode, the

WO 02/28780

PCT/US01/31411

living microorganisms begin to oxidize some of their own cellular mass along with any new organic matter they absorb or adsorb from their environment. This aids in the enhancement of solids reduction while maintaining a colony through
5 adjusting the food to microorganism ratio to allow the rate of death of the microorganisms to equal the rate of growth of the microorganisms through ER.

Another benefit of the intense aeration within this vessel is the consumption of some phosphorous by the
10 microorganisms.

The flow exits vessel 504 (the aerobic reactor # 1 zone) through line 526 and is provided into vessel 510 for further aerobic treatment.

The flow enters vessel 510 from vessel 504 along with 30%
15 of the plant influent flow which is provided by line 508. Vessel 510 is used as an aerobic reactor # 2 zone. The contents, by volume, of this vessel are recirculated substantially one time every two hours, using the recirculation conduit aeration system (RCAS), which is powered
20 by pump 528. During the recirculation procedure the contents of vessel 510 (the aerobic reactor # 2 zone), the settleable solids, become solubilized by means of shredding as they pass through the RCAS. Another benefit of the RCAS system of vessel 510 (aerobic reactor # 2 zone) is additional intense
25 aeration being applied and the level of dissolved oxygen is

WO 02/28780

PCT/US01/31411

substantially maintained at a concentration of 3.5 mg/L or above. Keeping the dissolved oxygen concentration at these levels gives the microorganism colony the ability to convert organic matter, including but not limited to total BOD.

5 Organic nitrogen is also converted, first into ammonia, then nitrite and finally into nitrate. This process reduces the concentrations of total nitrogen and total BOD into less harmful compounds. Once again, microorganisms consume additional amounts of phosphorous reducing the phosphorous
10 concentrations in the system.

The flow exits vessel 510 (aerobic reactor # 2 zone) through line 530 and is provided into vessel 532 (aerobic reactor #3 zone). Flow also enters vessel 532 from the splitter box 502 (10% of the plant influent flow via line
15 512). The contents, by volume, of vessel 532 are recirculated substantially one time every two hours, using the re-circulation conduit aeration system (RCAS), which is powered by pump 534. During the recirculation procedure the contents of vessel 532, the settleable solids, become solubilized by
20 means of shredding as they pass through the RCAS system. Another benefit of the RCAS system of vessel 532 is additional intense aeration being applied and the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or above. Keeping the dissolved oxygen concentration at
25 these levels gives the microorganism colony the ability to

WO 02/28780

PCT/US01/31411

convert organic matter, including but not limited to total BOD. This process reduces the concentrations total BOD into less harmful compounds. Once again, unavoidably, the microorganisms consume additional amounts of phosphorous.

5 The flow exits vessel 532 via gravity through line 536 into line 538 before entering the clarification zone flow splitter box 540 (SB Clar Inf.) for the settling of the solids portion from the liquid portion of the wastewater.

As the influent from line 538 enters the clarification zone splitter box 540 (SB Clar Inf) the flow is preferably split into four equal portions and sent to each of the four clarifiers (516, 518, 520, 522) through line 542 for vessel 516 (Clarifier # 1), line 544 for vessel 518 (Clarifier # 2), line 546 for vessel 520 (Clarifier # 3) and line 548 for vessel 522 (Clarifier # 4). The flow velocity is diminished as the flow enters each of the clarifier vessels, allowing the solids to settle into the bottom of each of the clarifier vessels. The settling solids are then dislodged from the cone walls by hydraulically operated solids concentration inducer 550 for vessel 516 (Clarifier # 1), hydraulically operated solids concentration inducer 552 for vessel 518 (Clarifier # 2), hydraulically operated solids concentration inducer 554 for vessel 520 (Clarifier # 3) and hydraulically operated solids concentration inducer 556 for vessel 522 (Clarifier # 4), allowing the solids to further thicken before being

WO 02/28780

PCT/US01/31411

removed through each of the clarifier RAS pumps (558, 560, 562, 564) and RAS lines (566, 568, 570, 572) and sent to vessel 504 (aerobic reactor # 1 zone) for further treatment. Separated liquid from the clarification process, exits vessel 516 through line 574, vessel 518 through line 576, vessel 520 through line 578 and vessel 522 through line 580 and join in the collection box 582 (CB Clar Eff). The clarifier effluent exits through line 584 as the final processed effluent.

10 Re-Circulation Aeration System (RCAS)

Referring now to Fig. 15, one of the main components of the enhanced solids reduction wastewater treatment process of the present invention is shown. The RCAS is an efficient means of shredding, mixing, agitating, circulating, aerating, 15 homogenizing and saturating the wastewater, with each of the aforementioned employed, as the demand requires. The RCAS is a type of conduit conveyance system that takes the contents of a vessel through a mechanical pump creating a high velocity flow of the vessel contents through a differential injector, 20 which is preferably located on the exterior portion of each vessel for ease of maintenance. The air passing through the differential injector is injected into the wastewater treatment flow which is then returned back to the vessel. As the contents of the vessel pass through the RCAS system, a 25 shredding of organic solids occurs such that the organic

WO 02/28780

PCT/US01/31411

solids become solubilized and homogenized for easier digestion by microorganisms. Another benefit of the RCAS system is the destruction of pathogenic microorganisms by the toroidal vortex action at the discharge of the device (in line injector/mixer/aerator) creating agitation.

The RCAS includes a suction side conduit 600 coupled to the suction side of a pump 602, a discharge side conduit 604 that contains within it an in-line injector/mixer/aerator 606 such as the one described in USP 5,893,641, (the entire disclosure of which is incorporated herein by reference), an air/oxygen supply source conduit 608 and a delivery conduit 610. The pump 602 evacuates the wastewater from the vessel 612 containing aqueous solution delivering it through the conduit 600 to the aerator 606 for mixing, aeration and agitation. The wastewater is then returned to vessel 612 via conduit 610 where the excess atmospheric air that is entrapped within the bubbles traveling along with the wastewater within conduit 610 are released causing a secondary aeration, agitation and mixing effect to the wastewater contained within vessel 612. During the wastewater's travel, it is passed through an aerator 606, as shown in FIG. 15, where atmospheric air is drawn in by vacuum (venturi effect). The wastewater and atmospheric air are mixed at the discharge of the in-line aerator 608 and while they are encapsulated within the conduit 610, saturating the wastewater with oxygen. The aerator 606

WO 02/28780

PCT/US01/31411

may be the aerator as shown in USP 5,893,641 or any other
aerator device of similar performance, such as any of the
aerators shown in pending PCT Application Serial No.
PCT/US01/11936, or U.S. Application Serial No. 09/547,447, the
5 entire disclosures of which are incorporated herein by
reference.

The oxygen saturated mixed wastewater travels through the
conduit 610, and then is discharged back into the vessel 612.
Carried along with the saturated wastewater within the conduit
10 610 are excess bubbles of atmospheric air that were injected
into the wastewater stream, over and above the quantity
required for the complete saturation of the wastewater
traveling within the conduit 610. When the excess air is
discharged from the conduit 610 into the vessel, along with
15 the saturated wastewater, the excess air becomes a source of
additional air delivered to the contents of vessel 612, and
thereby furthering the aeration process of the entire contents
of the vessel by providing additional oxygen supply to be
absorbed by the not as yet re-circulated contents of the
20 vessel.

An alternate flow of some or all of the wastewater
through conduit 614 would enable additional controls to be
available for diminishing the aeration while continuing with
the mixing capabilities of the system.

WO 02/28780

PCT/US01/31411

Under certain conditions, induced pressures can be produced by adding resistance to the delivery conduits with restrictions or friction losses (i.e. conduit size reductions) fittings, valves, nozzles, etc.

- 5 For certain conditions regarding conduit 610, such as in the case of specific conduit size requirements, specific conduit length requirements, where the installation of the RCAS system is limited to confined parameters that do not meet the design requirements for the aeration or mixing process,
- 10 induced pressures can be produced within the conduit 610 that would provide compensation to the environment within conduit 610. These compensations in the design of conduit 610 would equal characteristics of a conduit of different diameter, length or desired pressure contained within such conduit so as
- 15 to deliver the specific aeration criteria desired. The compensations that would be contemplated are represented by the addition of valves, fittings, in-line mixers, a reduction or increase of conduit diameter, or the inclusion of a restriction, such as an orifice, in the conduit 610.
- 20 Through the re-circulation events, oxygen transfer abilities and creation of micro-bubbles by the RCAS system, a reduction in power consumption is achieved over traditional aeration systems, which use blowers and compressors. These efficiencies of the RCAS allow the present invention to use a
- 25 smaller footprint for total plant design.

WO 02/28780

PCT/US01/31411

Bubbles

Aeration of an aqueous solution is important to aerobic digestion of biological nutrients. The smaller the bubble, the greater the aerobic digestion activity of the bacteria and other microorganisms, due to the respiration of easily accessible dissolved oxygen. With these two facts in mind, the best possible forms of bubbles to deliver are micro-bubbles. These are provided by the RCAS System of the present invention.

Oxidative biological and chemical processes in aqueous environments are limited by the low solubility of oxygen in water. This physical limitation as defined by Henry's Law states that when the temperature is kept constant, the amount of a gas that dissolves into a liquid is proportional to the pressure exerted by the gas on the liquid. In the use of the RCAS system, the pressure of the gas and liquid are increased beyond atmospheric pressure so as to increase the amount of gaseous oxygen able to be dissolved in wastewater.

The solubility of oxygen in pure water is only about 10 parts per million (ppm) at ambient temperatures and at one atmosphere pressure.

For most aerobic bioprocesses, dissolved oxygen is quickly consumed so that replenishing it becomes the factor that limits the rate of the process. Therefore, a most

WO 02/28780

PCT/US01/31411

critical component of a bioprocess design is the means for the mass transfer of oxygen into the liquid phase of the process. For an actively respiring culture of bacteria, oxygen in the liquid medium must be replaced as needed at a sufficient rate to keep up with the oxygen demand of the bacteria. With the RCAS system used in the present invention, the dissolved oxygen is replenished at a rate that exceeds the oxygen demand of the bacteria.

Water is typically aerated by providing contact surfaces between the gaseous and liquid phases. This can be done either by introducing a source of oxygen into a bulk liquid phase or by flowing dispersed water through a bulk gaseous (air) phases. Regardless of whether the gaseous or liquid phases dominate the oxygenation process, the mass transfer of oxygen, or other gas, is accomplished by introducing gas bubbles into the liquid phase. The efficiency of gas-liquid mass transfer depends to a large extent on the characteristics of the bubbles. Bubble behavior strongly affects the following mass-transfer parameters of:

- (a) Transfer of oxygen from the interior of the bubble to the gas-liquid interface;
- (b) Movement of oxygen across the gas-liquid interface; and
- (c) Diffusion of oxygen through the relatively stagnant liquid film surrounding the bubble.

WO 02/28780

PCT/US01/31411

It is generally agreed that a most important property of air bubbles in a bioprocess is their size. For a given volume of gas, more interfacial area between the gas phase and liquid phase is provided if the gas is dispersed into many small bubbles rather than a few large ones. Small bubbles, 1-3 mm, have been shown to have the following beneficial properties not shared by larger bubbles.

Small gas bubbles rise more slowly than large bubbles, allowing more time for a gas to dissolve in the aqueous phase. This property is referred to as gas hold-up, concentrations of oxygen in water can be more than doubled beyond Henry's Law solubility limits. For example, after a saturation limit of 10 ppm oxygen is attained, at least another 10 ppm oxygen within small bubbles would be available to replenish the oxygen.

Once a bubble has been formed, the major barrier for oxygen transfer to the liquid phase is the liquid film surrounding the bubble. Biochemical engineering studies have concluded that transport through this film becomes the rate-limiting step in the complete process, and controls the overall mass-transfer rate. However, as bubbles become smaller, this liquid film thickness decreases so that the transfer of gas into the bulk liquid phase is no longer impeded.

When air is introduced by means of a vacuum, as with the RCAS system, at a velocity and volume equal to the flow of an

WO 02/28780

PCT/US01/31411

aqueous solution through a pump, the formation of micro bubbles occurs. These micro bubbles have the size necessary to remain in suspension through the action of gas hold-up, thus increasing the dissolved oxygen concentration beyond the
5 needs of the bacteria.

Uniqueness of the Invention

1) The present invention operates in biological processing ranges that differ from traditional wastewater
10 treatment systems.

The present invention utilizes a Mean Cell Residence Time (MCRT) ranging from 30 days to over 150 days, while the traditional systems cannot achieve such high residency.

The Food to Microorganism (F/M) ratio sustained by the
15 current invention, supporting its efficiency values, are substantially in the 0.05 to 0.80 range, versus a restricted ratio range as recorded with various traditional systems.

The present invention uses a wastewater treatment plant with a unique design so as to treat the total BOD portion of
20 the wastewater using less energy by the plant's processing operation. This treatment is designed to significantly reduce, if not eliminate, all biodegradable solids. The unique process is able to perform at such an efficient level due to the effectiveness of the aeration and recirculation
25 processing introduced throughout the treatment cycles.

WO 02/28780

PCT/US01/31411

A traditional wastewater treatment plant's design objective is to physically remove as much of the solid materials from the influent flow as possible and to ultimately dispose or waste the solids removed from the treatment system off premises. The balance of the wastewater is treated by various means to varying degrees of cleanliness, appropriately meeting the levels required for the discharge.

2) The current invention uses a clarification vessel design with a conical shaped vessel bottom in which to collect the settled solids without the use of mechanical means to concentrate the settled solids.

Wastewater within the vessel is made to rotate at a sufficiently slow velocity to cause the sludge to settle, while not providing an opportunity for the sludge to adhere to the side of the cone shaped bottom. The velocity of the rotating solids remain slow enough to allow them to settle and not remain in suspension. This is accomplished by means of a solids accumulator induction system used in the clarifier for a controlled rotational travel of the vessels liquid.

A traditional clarifier has a mechanical device to transport the sludge into the sludge pump's sump area for removal. The mechanical means consist of a motor, gear reducer, rake arm, blade and scraper squeegees and a skimmer arm.

WO 02/28780

PCT/US01/31411

3) The present invention (in the preferred apparatus embodiment) substantially utilizes typical vessel construction and outfitting. This allows for changes in vessel utilization for different processes. All of the vessels are substantially of the same size and shape to allow the vessels to be used as a single processing zone. An example of use as a single processing zone would be using all the vessels as aerobic reactors during start-up procedures. All the vessels are substantially plumbed the same, and have substantially the same capabilities (if so desired). The system has built-in redundancy capabilities in that each of the vessels being of the same size and shape allows for any one of the vessels to be used for any process, which is desirable during times of maintenance. Vessel and plumbing configuration is such that any processing zone has the ability to be expanded incrementally by simply duplicating a process vessel and plumbing as necessary to satisfy performance and/or discharge permit requirements. With plumbing and vessel configuration, allowances are available for a choice of vessel processing utilization with little or no operational shutdowns. Simple valve changes make this possible.

4) The present invention utilizes the RCAS system's velocity, volume and direction of flow, at its discharge point into the vessel, to regulate the rotational speed and travel time for mixing and/or settling of solids in each zone. For

WO 02/28780

PCT/US01/31411

example, an aerobic reactor could be converted into an aerobic digester by:

Isolating the aerobic reactor from the system and aerating the contents while holding the contents for complete
5 digestion of solids.

Slowing the rotational velocity in the anoxic selector so as to allow solids to settle for transfer to the anaerobic conditioner.

Slowing the rotational velocity in the anaerobic
10 conditioner so as to allow solids to settle for transfer to the aerobic digester.

Holding the contents of the aerobic digester while aerating so as to nearly complete the digestion of organic matter.

15 Stopping the aerobic digestion action, allowing any inorganic matter to settle to the cone bottom and then removing any inorganic matter for disposal.

Starting the process once again for continued digestion of organic solids.

20 Upon completion of all organic digestion, the aerobic digester can be returned into service as an aerobic reactor.

5) The present invention reduces the number of pathogenic organisms within a wastewater through the use of the RCAS system. This occurs as the turbulence and agitation within
25 the toroidal vortex of the RCAS device creates a violent

WO 02/28780

PCT/US01/31411

action, sheering the cell membrane of bacteria such as e. coli and fecal coliform allowing the electron acceptors of the bacteria to be used by oxygen which then oxidizes the bacteria killing it.

5 Although illustrative embodiments of the present invention have been described herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to these precise embodiments, and that various other changes and modifications may be effected
10 therein by one of ordinary skill in the art without departing from the scope or spirit of the invention. For example, the use of square or rectangular processing vessels having flat or slopped bottoms, as is the case in traditional processing vessels are able to be used with effectiveness by the RCAS
15 system. The biological process of the present invention functions with sufficient circulation, agitation, aeration and homogenization apart from the RCAS system.

WO 02/28780

PCT/US01/31411

WHAT IS CLAIMED:

1. A process for the treatment of an aqueous solution containing waste comprising the steps of:
 - providing an influent wastewater stream to an anaerobic conditioner zone within which aqueous total solids are
 - 5 re-circulated, mixed and kept in suspension;
 - providing low oxygen level mixed liquor suspended solids from an anoxic selector zone to the anaerobic conditioner zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;
 - 10 providing an outflow from the anaerobic conditioner zone to a first aerobic reactor zone, the anaerobic conditioner zone outflow being mixed in the first aerobic reactor zone with return activated sludge from a clarification zone whereby contents of the first aerobic reactor zone are re-circulated and
 - 15 aerated, and whereby settleable solids present in the contents of the first aerobic reactor zone are fractionalized, thereby decomposing and oxidizing the solids and other organic matter and accumulating inert solids;
 - discharging the accumulated inert solids from the first
 - 20 aerobic reactor zone;

WO 02/28780

PCT/US01/31411

providing an outflow of aqueous solution from the first aerobic reactor zone to the anoxic selector zone wherein the aqueous solution in the anoxic selector zone is re-circulated and mixed;

25 transferring a first portion of the anoxic selector zone aqueous solution corresponding to the low oxygen level/mixed liquor suspended solids to the anaerobic conditioner zone, and a second portion of the anoxic selector zone aqueous solution to a second aerobic reactor zone;

30 recirculating and aerating aqueous solution contained in the second aerobic reactor zone whereby settleable solids become fractionalized thereby decomposing and oxidizing suspended solids and other organic matter;

 providing a first portion of the second aerobic reactor
35 zone aqueous solution to the first aerobic reactor zone;

 providing a second portion of the second aerobic reactor zone aqueous solution to the clarification zone to settle or separate solids from the aqueous solution contained therein;

 providing the settled or separated solids from the
40 clarification zone, corresponding to return activated sludge, to the first aerobic reactor zone;

WO 02/28780

PCT/US01/31411

providing aqueous solution of the clarification zone to a filtration zone to settle or separate solids from the aqueous solution provided thereto; and

45 transferring a liquid portion of an outflow of the filtration zone to a discharge receptacle, and the settled or separated solids portion of the outflow of the filtration zone to the influent wastewater stream for re-processing.

2. A process for the biological treatment of an aqueous solution containing waste to reduce organic material, nitrogen and phosphorous, comprising the steps of:

5 providing an influent wastewater stream, which includes microorganisms, to an anaerobic conditioner zone within which aqueous total solids are re-circulated, mixed and kept in suspension, wherein a first stage of luxury phosphorous uptake is accomplished by regulating a flow of low oxygen level mixed
10 liquor suspended solids from an anoxic selector zone to the anaerobic conditioner zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;

 providing an outflow from the anaerobic conditioner zone to a first aerobic reactor zone, the anaerobic conditioner zone
15 outflow being mixed in the first aerobic reactor zone with return activated sludge received from a clarification zone

WO 02/28780

PCT/US01/31411

whereby contents of the first aerobic reactor zone are re-circulated and aerated and whereby nitrification occurs and settleable solids present in the contents of the first aerobic reactor zone are fractionalized, thereby decomposing and oxidizing suspended solids and other organic matter along with enhancing a second stage of luxury phosphorous uptake and accumulating inert solids;

discharging the accumulated inert solids from the first aerobic reactor zone;

providing an outflow of aqueous solution from the first aerobic reactor zone to the anoxic selector zone wherein the aqueous solution in the anoxic selector zone is re-circulated and mixed, and causing a low oxygen environment to exist within the anoxic selector zone such that denitrification and release of biological phosphorous occurs along with the consumption of organic matter contained within the aqueous solution;

transferring a first portion of anoxic selector zone aqueous solution corresponding to low oxygen level/mixed liquor suspended solids to the anaerobic conditioner zone and a second portion of the anoxic selector zone aqueous solution to a second aerobic zone, at least the second portion of the anoxic selector zone aqueous solution being rich in microorganisms and nutrients;

WO 02/28780

PCT/US01/31411

40 re-circulating and aerating aqueous solution contained in
the second aerobic reactor zone whereby nitrification occurs and
settleable solids become fractionalized thereby decomposing and
oxidizing suspended solids and other organic matter, and further
enhancing the second stage of luxury phosphorous uptake
45 resulting in a consumption of a large amount of phosphorous by
the microorganisms;
providing a first portion of the second aerobic reactor
zone aqueous solution to the first aerobic reactor zone;
providing a second portion of the second aerobic reactor
50 zone aqueous solution to the clarification zone to settle or
separate solids from the aqueous solution provided thereto;
providing the settled or separated solids from the
clarification zone to the first aerobic reactor zone as return
activated sludge;
55 providing aqueous solution of the clarification zone to a
filtration zone to settle or separate solids from the aqueous
solution provided thereto; and
transferring a liquid portion of an outflow of the
filtration zone to a discharge receptacle and the settled or
60 separated solids portion of the outflow of the filtration zone
to the influent wastewater stream for re-processing.

WO 02/28780

PCT/US01/31411

3. Apparatus for the treatment of an aqueous solution containing waste comprising:

an anaerobic conditioner zone fluidly coupled to an inlet, the anaerobic conditioner zone receiving an influent wastewater stream through the inlet, the anaerobic conditioner zone re-circulating the wastewater contained therein such that aqueous total solids are kept in suspension, the anaerobic conditioner zone receiving a flow of low oxygen level mixed liquor suspended solids from an anoxic selector zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;

a first aerobic reactor zone fluidly coupled to the anaerobic conditioner zone, the first aerobic reactor zone receiving an outflow of the anaerobic conditioner zone which is mixed with return activated sludge received from a clarification zone whereby contents of the first aerobic reactor zone are re-circulated and aerated and whereby settleable solids become fractionalized thereby decomposing and oxidizing suspended solids and other organic matter, the first aerobic reactor zone accumulating inert solids, the accumulated inert solids being discharged from the first aerobic reactor zone;

an anoxic selector zone fluidly coupled to the anaerobic conditioner zone and the first aerobic reactor zone, the anoxic

WO 02/28780

PCT/US01/31411

selector zone receiving an outflow of aqueous solution from the first aerobic reactor zone, aqueous solution within the anoxic selector zone being re-circulated and mixed, a first portion of the anoxic selector zone aqueous solution, corresponding to the low oxygen level/mixed liquor suspended solids, being provided to the anaerobic conditioner zone;

a second aerobic reactor zone fluidly coupled to the anoxic selector zone and the first aerobic reactor zone, the second aerobic reactor zone receiving a second portion of the anoxic selector zone aqueous solution wherein the aqueous solution within the second aerobic zone is re-circulated and aerated whereby settleable solids become fractionalized, a first portion of the aqueous solution of the second aerobic reactor zone being provided to the first aerobic reactor zone;

a clarification zone fluidly coupled to the second aerobic zone and the first aerobic zone, the clarification zone receiving a second portion of the second aerobic reactor zone aqueous solution, whereby settling or separating and capturing of solids from the aqueous solution occurs, and the settled solids, corresponding to return activated sludge, are provided to the first aerobic reactor zone; and

a filtration zone fluidly coupled to the clarification zone, the inlet, and an outlet, the filtration zone receiving an

WO 02/28780

PCT/US01/31411

outflow from the clarification zone to separate solids from the liquid portion of the contents of the clarification zone, a first portion of the contents of the filtration zone, which corresponds to effluent, being provided to the outlet, and a
50 second portion of the contents of the filtration zone, which corresponds to separated solids, being provided to the inlet and being combined with the influent wastewater stream for re-processing.

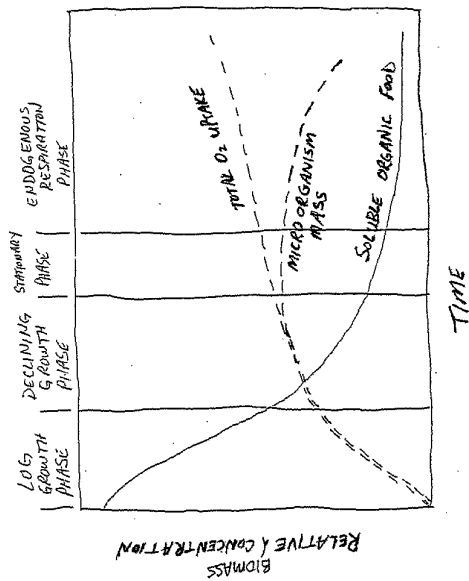


FIG. 1

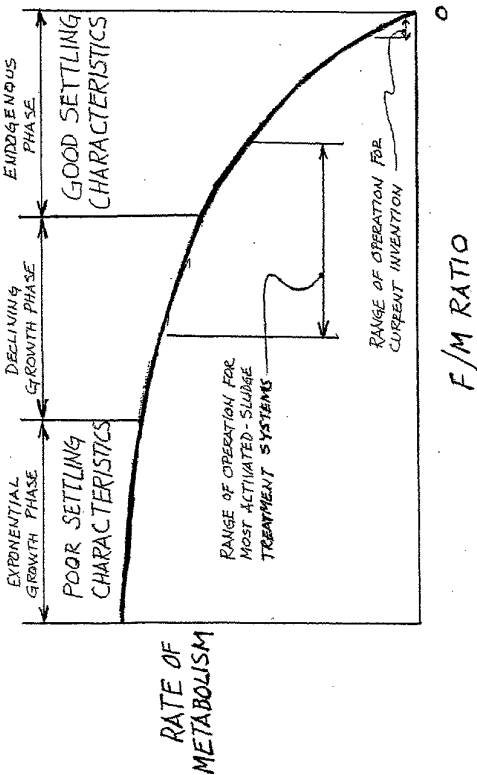


FIG.2

FIG. 3

		Percent Inactivation	Complete Mix	Plug Flow	Contact Stabilization	Step Feed	Extended Aeration
Aeration Time (hrs)		4 - 8	3 - 5	4 - 8	.5 - 1.0	3 - 5	18 - 36
MCRT (days)		30 - >160	15 - 30	15 - 30	5 - 15	5 - 15	15 - 30
F/M Ratio (lbs BOD/day/lb MLVSS)		0.05 - 0.80	0.05 - 0.20	0.05 - 0.20	0.20 - 0.40	0.20 - 0.40	0.05 - 0.2
MLSS		2,000 - 10,000	3,000 - 6,000	1,500 - 3,000	1,000 - 3,000	2,000 - 3,500	3,000 - 6,000
Recirculation % (RAS/Q)		25 - 100	25 - 100	25 - 50	25 - 100	25 - 75	75 - 150
PROCESSING RECIRCULATION %		500 - 2,000	N/A	N/A	N/A	N/A	N/A

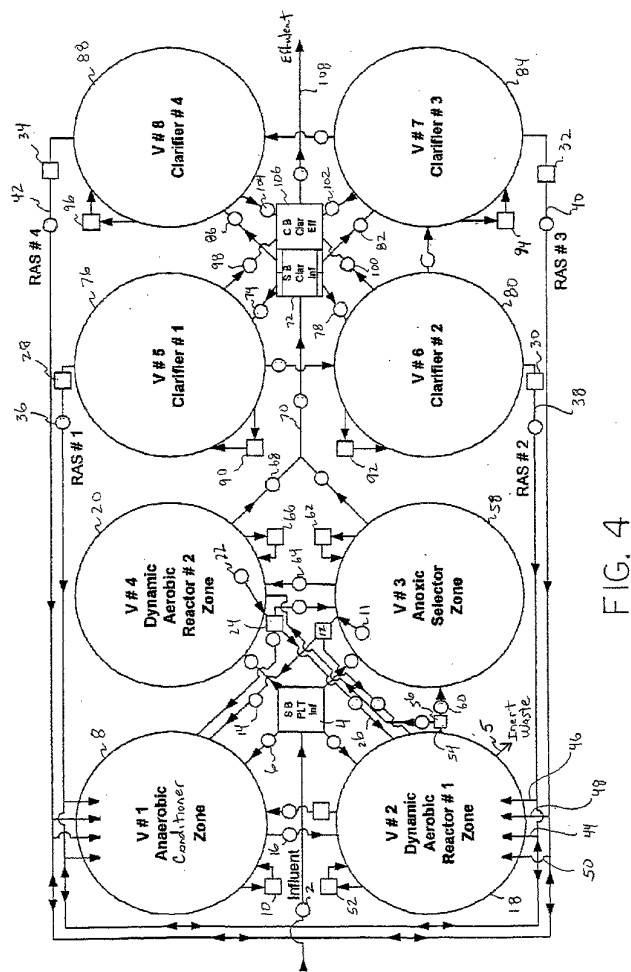


FIG. 4

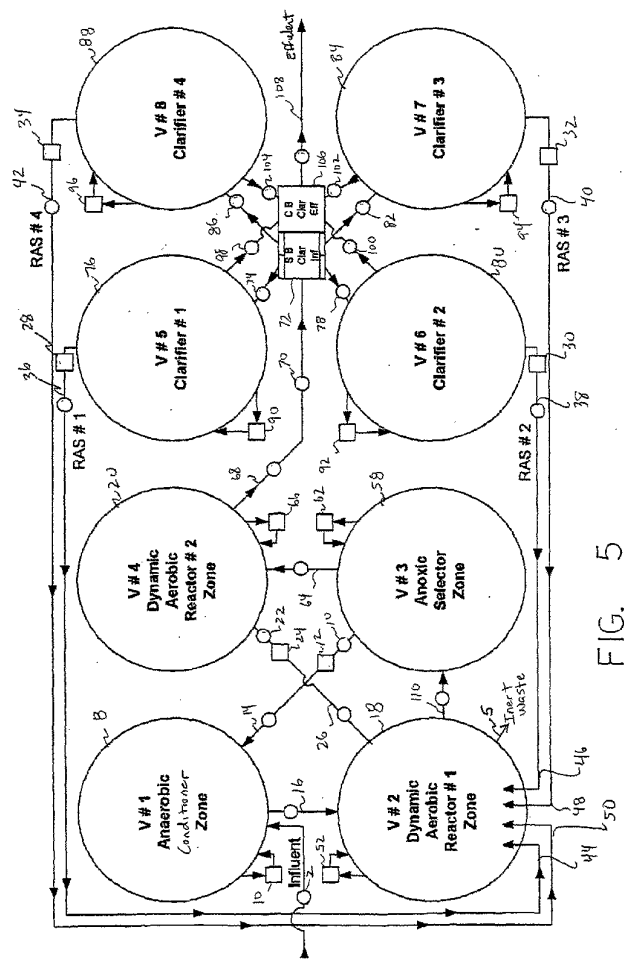


FIG. 5

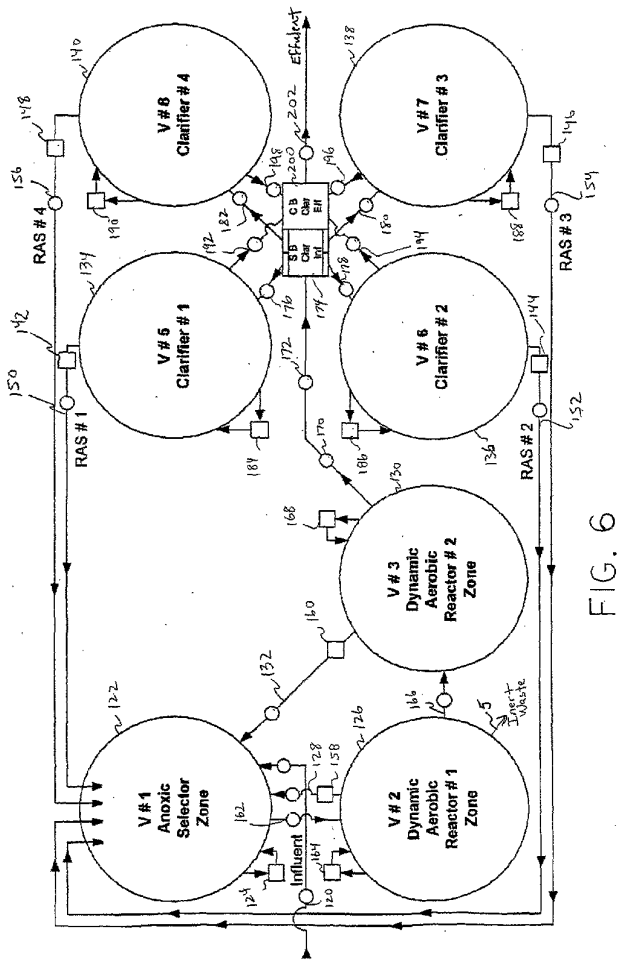
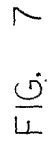


FIG. 6



WO 02/28780

PCT/US01/31411

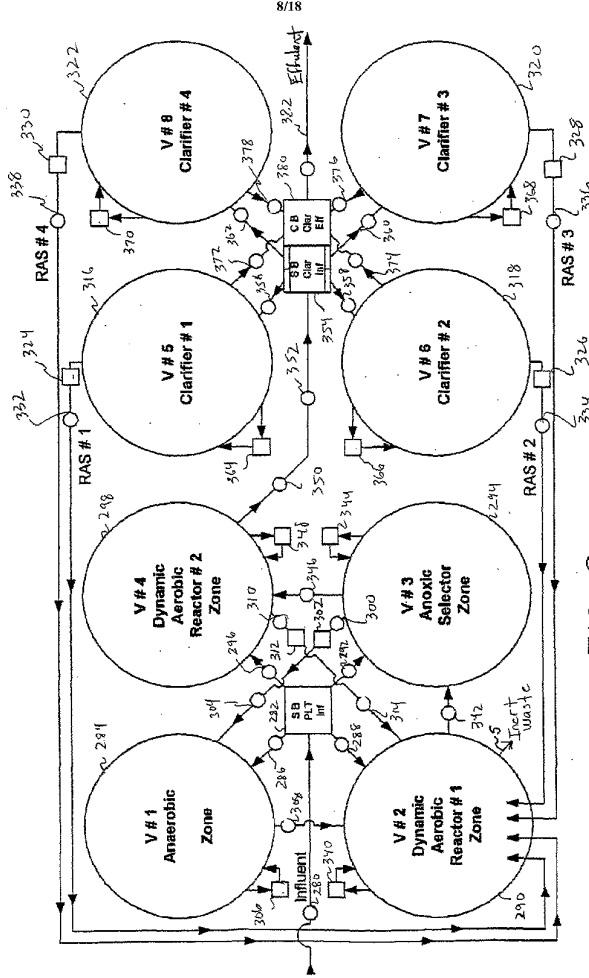
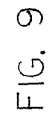


FIG. 8



F/G. 9

WO 02/28780

10/18

PCT/US01/31411

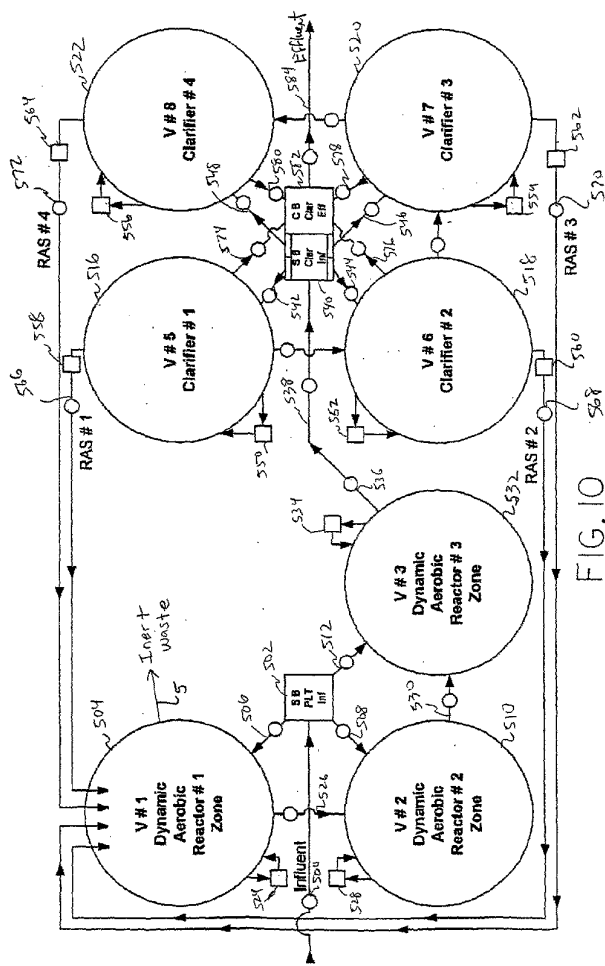


FIG. 10

WO 02/28780

11/18

PCT/US01/31411

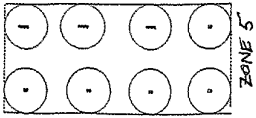
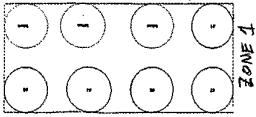
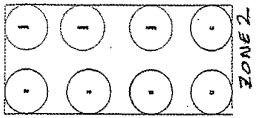
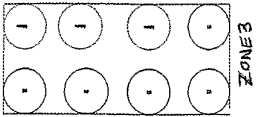
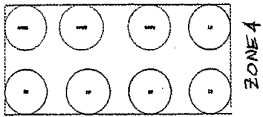
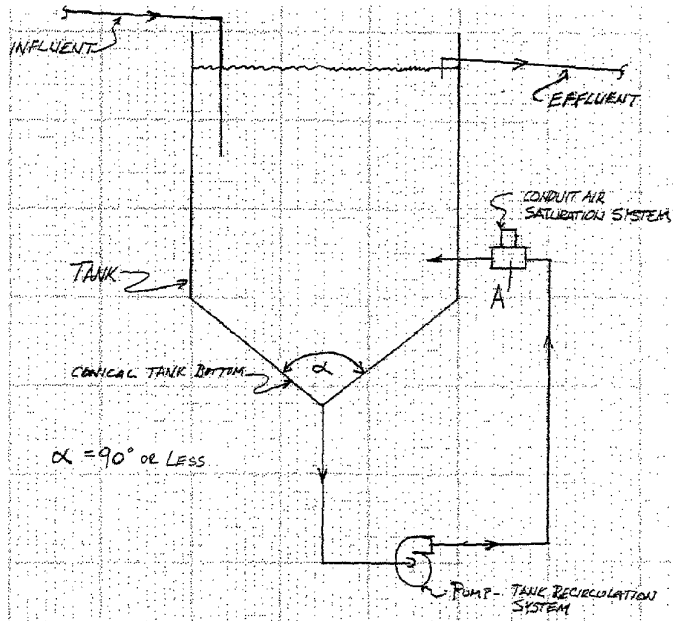


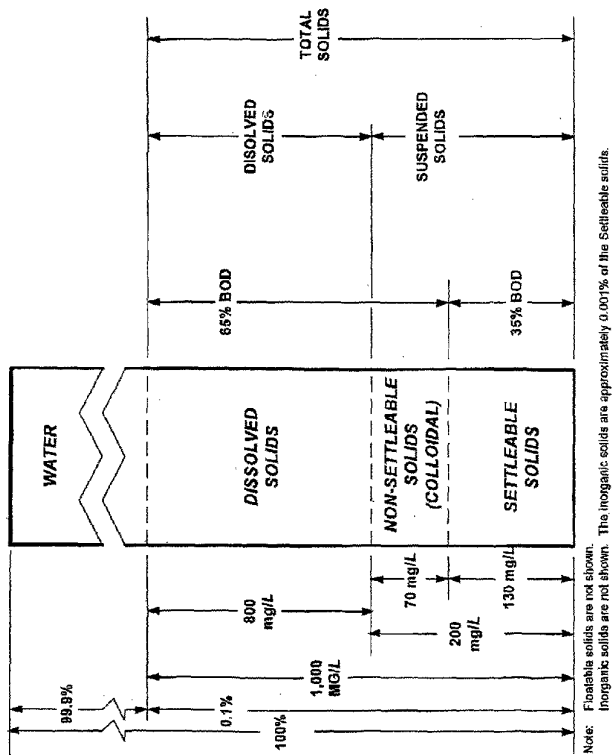
FIG. 11



TYPICAL ZONE FLOW DIAG.

FIG. 12

FIG.13
Typical Composition of Solids In Raw Influent of Municipal Wastewater



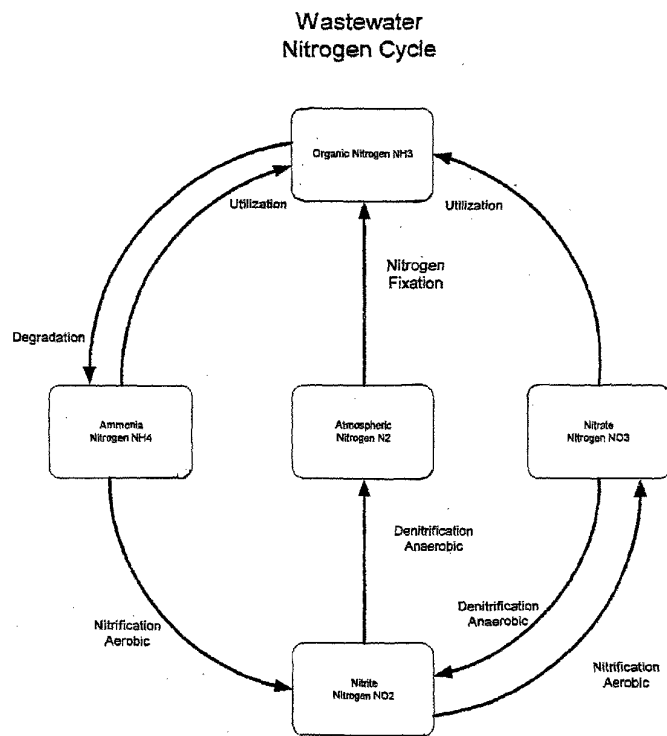
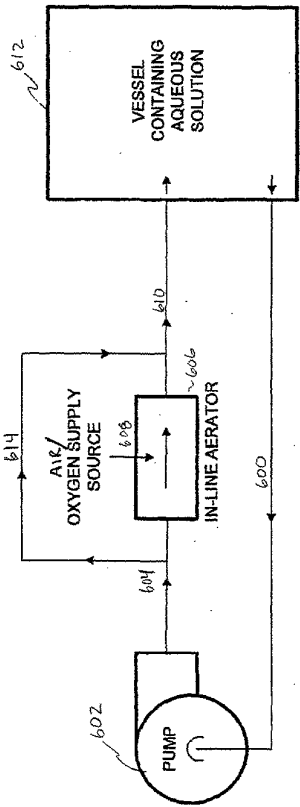


FIG. 14

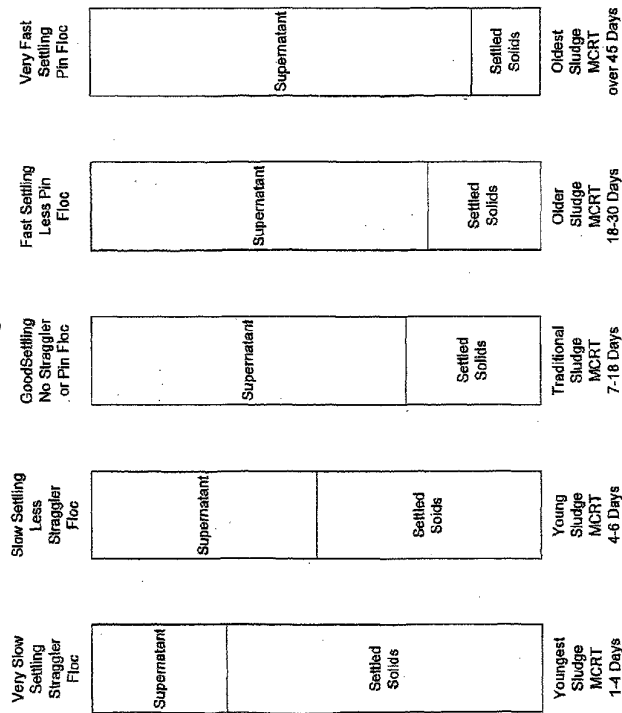


Re-Circulation Aeration System
(RCAS)
with optional aerator by-pass

FIG. 15

FIG. 16

30 Minute Solids Settling as Related to MCRT



WO 02/28780

17/18

PCT/US01/31411

Decay Coefficient

MCRT is Mean Cell Residence Time

Y is the Yield Coefficient

F/M is the Food to Microorganism Ratio

BOD REM EFFCY is the BOD Removal Efficiency

 K_d is the Decay CoefficientSolving for K_d

$$K_d = (Y) (F/M) (BOD \text{ REM EFFCY}) - \frac{1}{MCRT}$$

Where:

Y = 0.55 lbs of VSS produced per lb BOD removed

$$F/M = \frac{\text{lbs of BOD applied per day}}{\text{lbs of VSS in inventory}}$$

BOD REM EFFCY = % BOD removed in the process as a decimal

$$MCRT = \frac{\text{lbs MLVSS in aeration system}}{\text{lbs MLVSS leaving aeration system}}$$

FIG. 17

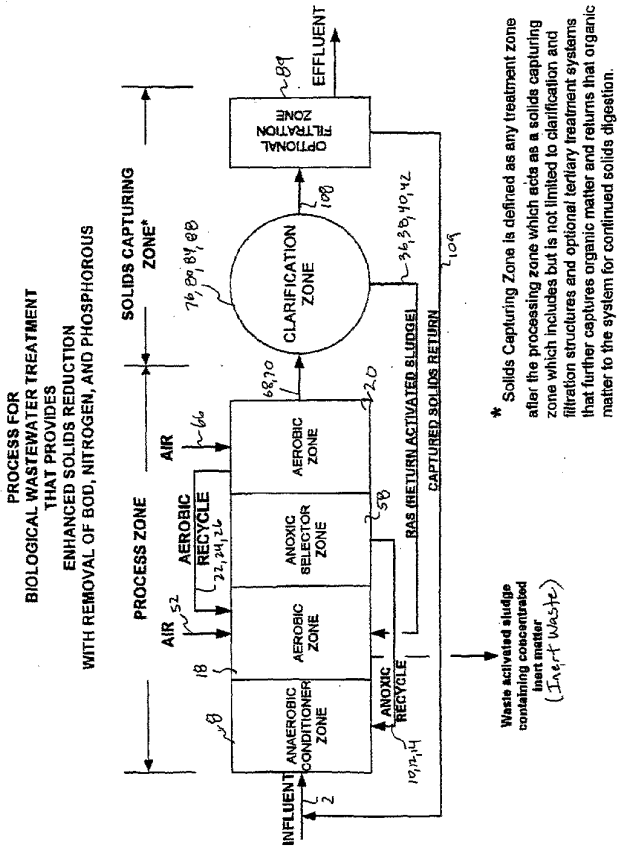


FIG. 18

【国際公開パンフレット（コレクトバージョン）】

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
11 April 2002 (11.04.2002)

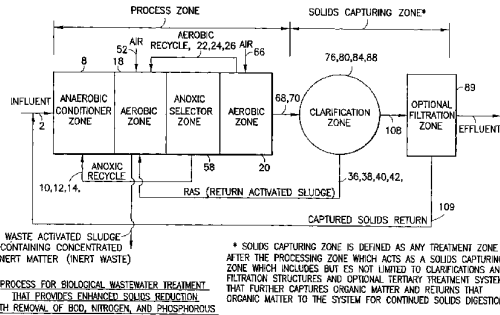
PCT

(10) International Publication Number
WO 02/028780 A2

- (51) International Patent Classification: C02F
Edition Drive, Henderson, NV 89014 (US); RUSSELL, H., Matthew [US/US]; 2305 Calle De Nuevo, Las Vegas, NV 89102 (US); JOHNSON, Martin, Perry [US/US]; 1700 E. Jeanne Avenue, Pahrump, NV 89048 (US); GARCIA, Paul, R. [US/US]; 34 Church Street, Henderson, NV 89015 (US).
- (21) International Application Number: PCT/US01/31411
- (22) International Filing Date: 5 October 2001 (05.10.2001)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 60/238,878 6 October 2000 (06.10.2000) US
- (71) Applicant (for all designated States except US): PREMIER WASTEWATER INTERNATIONAL, LLC [US/US]; 4340 S. Procyon, Las Vegas, NV 89118 (US).
- (72) Inventors; and
(75) Inventors/Applicants (for US only): GARCIA, Paul, G. [US/US]; 1500 Stardust-163, Unit 15-3078, Las Vegas, NV 89109 (US); DAVIDSON, Leonard [US/US]; 2444 Tour
- (74) Agents: MICHAL, Robert et al.; Trishauf, Holtz, Goodman, Langer & Chick, P.C., 767 Third Avenue, New York, NY 10017-2023 (US).
- (81) Designated States (national): AT, AG, AI, AM, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GI, GM, GR, HU, IL, IN, IS, JP, KL, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MY, NZ, NI, NO, NZ, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR WASTEWATER TREATMENT WITH ENHANCED SOLIDS REDUCTION (USR)



(57) Abstract: A wastewater treatment process that provides improved reduction of total solids through endogenous respiration while reducing biochemical oxygen demand and utilizing biological nutrient reduction. The wastewater treatment process uses an efficient aeration delivery system to drastically reduce the time needed to oxidize organic matter, and re-circulates, shreds and homogenizes the organic matter and microorganisms and oxygenates the entire mass many more times than traditional systems resulting in a greater biological solids digestion rate.

WO 02/028780 A2

WO 02/028780 A2



patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IL, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

(48) Date of publication of this corrected version:
20 February 2003

(15) Information about Correction:
see PCT Gazette No. 08/2003 of 20 February 2003, Section II

Published:

— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 02/028780

PCT/US01/31411

APPARATUS AND METHOD FOR WASTEWATER TREATMENT
WITH ENHANCED SOLIDS REDUCTION (ESR)

5

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims priority under 35 USC
119(e) of U.S. Provisional Application Serial No. 60/238,876,
10 the entire disclosure of which is incorporated herein by
reference.

BACKGROUND OF THE INVENTION

Field of the Invention

15 The present invention relates to an aqueous waste
treatment method and apparatus that provides improved
treatment of aqueous waste and, more particularly, to a method
and apparatus which employs improved functionality, ease of
operation and aeration techniques to provide improvement in
20 the treatment of aqueous waste.

Background Information

Currently, the processes used in wastewater treatment
plants follow traditional methods that expend energy,
25 materials and labor at a relatively high rate along with a
large use of land. The high costs associated with traditional
methods of wastewater treatment are due to the treatment,

WO 02/028780

PCT/US01/31411

handling, and monitoring of all of the wastewater flow's components with equipment such as pumps, blowers, air compressors, scrapers, filters, chemicals, heat, presses, coagulants, flocculants, precipitants and dewatering, among
5 others. In traditional wastewater treatment systems, the wastewater is treated using high energy consuming methods. These methods include, but are not limited to, aerobic digestion, anaerobic digestion, sludge thickening and solids dewatering processes. The costs associated with these
10 treatments amount to approximately 85% of the plant operating energy budget.

In a typical influent wastewater stream which is subject to wastewater treatment, 99.9% of the entire wastewater stream is water and about 0.1% is organic, inorganic and dissolved
15 solids. The typical influent wastewater stream also contains nutrients in varying concentrations. Nutrients within the wastewater stream which need removal have an oxygen demand which must be met for decomposition. In the industry, this oxygen demand is referred to as biochemical oxygen demand
20 (BOD). Of the approximately 0.1% solids, about 10% to 20% are settleable solids containing about 35% of the BOD. The remaining 65% of the BOD is contained within the dissolved organic matter portion of municipal waste. See Figure 13.

In the solids (sludge) handling systems of traditional
25 wastewater treatment systems, processing energy is expended

WO 02/028780

PCT/US01/31411

for organic matter to be reduced by digestion to a level of about 50% reduction in volume while the remaining 50% volume of organic matter is disposed of by a number of means including, but not limited to, land fill disposal, incineration and land application. This results in the expenditure of additional energy and expense for the handling of solids. It would be beneficial to have a system and method which eliminates most of the need for disposal of organic matter.

10

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the present invention to provide an apparatus and method for treating aqueous waste containing organic matter and chemicals.

15 It is another object of the present invention to use an activated sludge process with recirculation of a treatment zone and greater aerator effectiveness to decrease the time and energy necessary for decomposition of organic matter.

It is yet another object of the present invention to substantially reduce the wasting of organic matter in the form of waste activated sludge (WAS) which is the intentional removal of organic settled solids from the system and thus reduce the effort and cost of solids handling facilities.

20

WO 02/028780

PCT/US01/31411

It is another object of the present invention to provide an apparatus and method for treating aqueous wastewater which contains high concentrations of industrial type nutrients.

It is yet a further object of the present invention to
5 treat municipal waste which has typical concentrations of chemical oxygen demand (COD), BOD, ammonia and phosphorous.

It is yet a further object of the present invention to treat industrial strength waste which has high concentration levels of COD, BOD, ammonia and phosphorous typically found in
10 animal type wastes.

It is still another object of the present invention to provide an apparatus and method for pre-treating wastewater from on-site facilities such as might occur from industrial manufacturers or animal wastes facilities.

15 It is another object of the present invention to utilize an efficient re-circulating aeration system (RCAS), which provides a combination of aeration, mixing, homogenizing and shredding that is superior to and which is more affordable than conventional aeration systems.

20 It is still another object of the present invention to provide an apparatus and method which is easier to design, operate, construct, initialize, manage, expand and maintain than conventional treatment systems.

It is still another object of the present invention to
25 provide an apparatus and method which is easier to adapt to

WO 02/028780

PCT/US01/31411

changes in processing and flow conditions, and which is easier to automate, monitor and control than conventional treatment systems.

It is still another object of the present invention to
5 provide an apparatus and method which when compared with similar wastewater treatment requirements, uses an overall smaller footprint (land area) than that which is found with conventional wastewater treatment plants.

It is still another object of the present invention to
10 provide an apparatus and method which is more economical to operate than conventional wastewater treatment systems.

It is still another object of the present invention to provide an apparatus and method which is less expensive to build and operate than conventional wastewater treatment
15 systems.

It is still another object of the present invention to provide an apparatus and method which increases the ability of the process vessels to treat larger quantities of wastewater in aeration basins by not being limited by vessel floor
20 surface area for placement of diffusers with regard to the ability to deliver intense aeration.

It is still another object of the present invention to provide an apparatus and method which provides a significantly increased decay coefficient (k_d).

WO 02/028780

PCT/US01/31411

It is still another object of the present invention to provide an apparatus and method which increases the mean cell residence time (MCRT) beyond that of conventional treatment systems, thereby providing for increased volatile solids
5 destruction and subsequent reduced solids handling efforts.

It is still another object of the present invention to provide an apparatus and method which allows for a highly flexible food to microorganism (F/M) ratio range above and below the ratio ranges of conventional treatment systems.

10 It is still another object of the present invention to provide an apparatus and method which reduces start-up costs, which include, but are not limited to, more rapidly increasing the mixed liquid suspended solids (MLSS) concentration, lower power costs for initial start-up and reduced costs for hauling
15 of seed sludge, thereby achieving design flow capacity with increased efficiency.

It is still another object of the present invention to provide an apparatus and method which uses cone bottom shaped vessels for a type of sequential batch reaction system during
20 start-up conditions for faster initial plant start-up.

It is still another object of the present invention to provide an apparatus and method which uses cone bottom shaped vessels for a type of sequential batch reaction that allows micro colonies to grow rapidly following conditions that have

WO 02/028780

PCT/US01/31411

upset a process, so as to quickly grow microorganisms which
recover from the upset conditions.

It is still another object of the present invention is to
provide a treatment plant that contains less apparatus and
5 processes to treat the wastewater to the desired effluent
quality than conventional wastewater treatment systems.

It is still another object of the present invention to
provide a device that separates solids from liquid through
clarification without the need for scraping, raking or
10 brushing devices in clarifiers.

It is still another object of the present invention to
provide a device which acts as a solids capturing zone which
includes, but is not limited to clarifiers, filtration
structures and optional tertiary treatment systems that
15 further capture organic matter, and that return the organic
matter to aerobic zones for continued solids digestion.

It is still another object of the present invention to
provide a device which decreases total nitrogen in a waste
stream through oxidation of organic nitrogen into the more
20 stable compound of nitrate, which is then reduced in the waste
stream by the denitrification process.

It is still another object of the present invention to
provide a device which reduces phosphorous in a waste stream
through microorganism digestion and use for the growing of new
25 cells in the decomposition of organic matter.

WO 02/028780

PCT/US01/31411

It is still another object of the present invention to provide a treatment process that is zone specific and not vessel specific.

It is still another object of the present invention to provide a system design that accommodates a specific flow and specific treatment process.

It is still another object of the present invention to use the toroidal vortex action of the RCAS system for the reduction of the number of pathogenic organisms within wastewater.

It is still another object of the present invention to provide an apparatus and method which allows for chemical oxidation of an aqueous solution.

It is still another object of the present invention to provide a means for the homogenization of a microorganism colony and the substrate that the colony feeds on.

It is still another object of the present invention to provide for the disbursements of a large microorganism floc into a smaller microorganism floc.

It is still another object of the present invention to cause the entire microorganism floc including the center to remain aerobic.

It is still another object of the present invention to provide a high concentration of dissolved oxygen in an aerobic process.

WO 02/028780

PCT/US01/31411

It is still another object of the present invention to provide an alternative to the cost and need for wastewater lagoons.

It is yet a further object of the present invention to
5 overcome the deficiencies of known wastewater treatment systems and methods.

In order to represent the applications for, and capabilities of, the present invention, raw influent of municipal wastewater is exemplified as the aqueous waste to be
10 treated. However the embodiments of the apparatus and method of the present invention can be implemented to treat a variety of wastes.

The term aeration as it pertains to the present invention means the addition of a secondary fluid flow (liquid or gas)
15 into a primary fluid flow (liquid or gas).

The present invention is able to treat organic matter of wastewater by providing intense aeration by means of an RCAS (Re-Circulating Aeration System) which gives increased oxygen transfer efficiencies that results in increased microorganism
20 oxygen uptake rates and functionalizing, shredding and homogenizing organic matter causing virtually 100% digestion of the organic matter. This is a significantly more effective use of processing energy as compared with traditional treatment methods using traditional aeration such as diffused
25 aeration. The present invention also reduces or eliminates

WO 02/028780

PCT/US01/31411

many traditional energy consuming devices such as primary clarification equipment, anaerobic digestion equipment, aerobic digestion equipment, primary treatment lagoons, incineration furnaces and related equipment, sludge thickening
5 equipment and sludge hauling equipment.

The present invention enables a more efficient and complete digestion of organic matter in the wastewater. The organic matter portions of the wastewater total BOD are treated in a first aerobic reactor zone and a second aerobic
10 reactor zone by use of aeration, and in an anaerobic conditioner zone and anoxic selector zone where the wastewater is kept in a condition in which the aquatic environment does not contain sufficient dissolved molecular oxygen for easy microorganism respiration, which can also be called an oxygen
15 deficient condition. This oxygen deficient condition generally refers to an environment in which chemically bound oxygen, such as nitrate, is present. Aggressive digestion of the organic matter is accomplished in the zones of the anaerobic conditioner, first aerobic reactor zone, anoxic
20 selector and second aerobic reactor zone.

In accordance with one form of the present invention a process for the treatment of an aqueous solution containing waste includes the steps of:

WO 02/028780

PCT/US01/31411

providing an influent wastewater stream to an anaerobic conditioner zone within which aqueous total solids are re-circulated, mixed and kept in suspension;

providing low oxygen level mixed liquor suspended solids
5 from an anoxic selector zone to the anaerobic conditioner zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;

providing an outflow from the anaerobic conditioner zone to a first aerobic reactor zone, the anaerobic conditioner
10 zone outflow being mixed in the first aerobic reactor zone with return activated sludge from a clarification zone whereby contents of the first aerobic reactor zone are re-circulated and aerated, and whereby settleable solids present in the contents of the first aerobic reactor zone are fractionalized,
15 thereby decomposing and oxidizing the solids and other organic matter and accumulating inert solids;

discharging the accumulated inert solids from the first aerobic reactor zone;

providing an outflow of aqueous solution from the first
20 aerobic reactor zone to the anoxic selector zone wherein the aqueous solution in the anoxic selector zone is re-circulated and mixed;

transferring a first portion of the anoxic selector zone aqueous solution corresponding to the low oxygen level/mixed
25 liquor suspended solids to the anaerobic conditioner zone, and

WO 02/028780

PCT/US01/31411

a second portion of the anoxic selector zone aqueous solution
to a second aerobic reactor zone;

recirculating and aerating aqueous solution contained in
the second aerobic reactor zone whereby settleable solids

5 become fractionalized thereby decomposing and oxidizing
suspended solids and other organic matter;

providing a first portion of the second aerobic reactor
zone aqueous solution to the first aerobic reactor zone;

providing a second portion of the second aerobic reactor
10 zone aqueous solution to the clarification zone to settle or
separate solids from the aqueous solution contained therein;

providing the settled or separated solids from the
clarification zone, corresponding to return activated sludge,
to the first aerobic reactor zone;

15 providing aqueous solution of the clarification zone to a
filtration zone to settle or separate solids from the aqueous
solution provided thereto; and

transferring a liquid portion of an outflow of the
filtration zone to a discharge receptacle, and the settled or
20 separated solids portion of the outflow of the filtration zone
to the influent wastewater stream for re-processing.

In accordance with another form of the present invention,
a process for the biological treatment of an aqueous solution
containing waste to reduce organic material, nitrogen and
25 phosphorous, includes the steps of:

WO 02/028780

PCT/US01/31411

providing an influent wastewater stream, which includes microorganisms, to an anaerobic conditioner zone within which aqueous total solids are re-circulated, mixed and kept in suspension, wherein a first stage of luxury phosphorous uptake
5 is accomplished by regulating a flow of low oxygen level mixed liquor suspended solids from an anoxic selector zone to the anaerobic conditioner zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;

providing an outflow from the anaerobic conditioner zone
10 to a first aerobic reactor zone, the anaerobic conditioner zone outflow being mixed in the first aerobic reactor zone with return activated sludge received from a clarification zone whereby contents of the first aerobic reactor zone are re-circulated and aerated and whereby nitrification occurs and
15 settleable solids present in the contents of the first aerobic reactor zone are fractionalized, thereby decomposing and oxidizing suspended solids and other organic matter along with enhancing a second stage of luxury phosphorous uptake and accumulating inert solids;

20 discharging the accumulated inert solids from the first aerobic reactor zone;

providing an outflow of aqueous solution from the first aerobic reactor zone to the anoxic selector zone wherein the aqueous solution in the anoxic selector zone is re-circulated
25 and mixed, and causing a low oxygen environment to exist

WO 02/028780

PCT/US01/31411

within the anoxic selector zone such that denitrification and release of biological phosphorous occurs along with the consumption of organic matter contained within the aqueous solution;

5 transferring a first portion of anoxic selector zone aqueous solution corresponding to low oxygen level/mixed liquor suspended solids to the anaerobic conditioner zone and a second portion of the anoxic selector zone aqueous solution to a second aerobic zone, at least the second portion of the
10 anoxic selector zone aqueous solution being rich in microorganisms and nutrients;

re-circulating and aerating aqueous solution contained in the second aerobic reactor zone whereby nitrification occurs and settleable solids become fractionalized and shredded
15 thereby decomposing and oxidizing suspended solids and other organic matter, and further enhancing the second stage of luxury phosphorous uptake resulting in a consumption of a large amount of phosphorous by the microorganisms;

providing a first portion of the second aerobic reactor
20 zone aqueous solution to the first aerobic reactor zone;
providing a second portion of the second aerobic reactor zone aqueous solution to the clarification zone to settle or separate solids from the aqueous solution provided thereto;

WO 02/028780

PCT/US01/31411

providing the settled or separated solids from the clarification zone to the first aerobic reactor zone as return activated sludge;

providing aqueous solution of the clarification zone to a
5 filtration zone to settle or separate solids from the aqueous solution provided thereto; and

transferring a liquid portion of an outflow of the filtration zone to a discharge receptacle and the settled or separated solids portion of the outflow of the filtration zone
10 to the influent wastewater stream for re-processing.

In accordance with another form of the present invention, apparatus for the treatment of an aqueous solution containing waste includes:

an anaerobic conditioner zone fluidly coupled to an
15 inlet, the anaerobic conditioner zone receiving an influent wastewater stream through the inlet, the anaerobic conditioner zone re-circulating the wastewater contained therein such that aqueous total solids are kept in suspension, the anaerobic conditioner zone receiving a flow of low oxygen level mixed
20 liquor suspended solids from an anoxic selector zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;

a first aerobic reactor zone fluidly coupled to the anaerobic conditioner zone, the first aerobic reactor zone
25 receiving an outflow of the anaerobic conditioner zone which

WO 02/028780

PCT/US01/31411

is mixed with return activated sludge received from a clarification zone whereby contents of the first aerobic reactor zone are re-circulated and aerated and whereby settleable solids become fractionalized thereby decomposing and oxidizing suspended solids and other organic matter, the first aerobic reactor zone accumulating inert solids, the accumulated inert solids being discharged from the first aerobic reactor zone;

an anoxic selector zone fluidly coupled to the anaerobic conditioner zone and the first aerobic reactor zone, the anoxic selector zone receiving an outflow of aqueous solution from the first aerobic reactor zone, aqueous solution within the anoxic selector zone being re-circulated and mixed, a first portion of the anoxic selector zone aqueous solution, corresponding to the low oxygen level/mixed liquor suspended solids, being provided to the anaerobic conditioner zone;

a second aerobic reactor zone fluidly coupled to the anoxic selector zone and the first aerobic reactor zone, the second aerobic reactor zone receiving a second portion of the anoxic selector zone aqueous solution wherein the aqueous solution within the second aerobic zone is re-circulated and aerated whereby settleable solids become fractionalized, a first portion of the aqueous solution of the second aerobic reactor zone being provided to the first aerobic reactor zone;

WO 02/028780

PCT/US01/31411

a clarification zone fluidly coupled to the second aerobic zone and the first aerobic zone, the clarification zone receiving a second portion of the second aerobic reactor zone aqueous solution, whereby settling or separating and
5 capturing of solids from the aqueous solution occurs, and the settled solids, corresponding to return activated sludge, are provided to the first aerobic reactor zone; and

a filtration zone fluidly coupled to the clarification zone, the inlet, and an outlet, the filtration zone receiving
10 an outflow from the clarification zone to separate solids from the liquid portion of the contents of the clarification zone, a first portion of the contents of the filtration zone, which corresponds to effluent, being provided to the outlet, and a second portion of the contents of the filtration zone, which
15 corresponds to separated solids, being provided to the inlet and being combined with the influent wastewater stream for re-processing.

These and other objects, features and advantages of the present invention will become apparent from the following
20 detailed description of preferred embodiments which is to be read in connection with the accompanying drawings.

WO 02/028780

PCT/US01/31411

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph showing the relative concentrations of biomass, soluble organic food and total oxygen uptake vs. time of various wastewater treatment processes;

5 Fig. 2 is a graph showing the rate of metabolism vs. F/M (Food to Microorganism) ratio of wastewater treatment processes;

Fig. 3 is a chart showing comparative data for a variety of wastewater treatment systems;

10 Fig. 4 is a schematic diagram of an eight-vessel plant layout according to the preferred embodiment of the present invention showing flex-flow, nitrification, de-nitrification and phosphorous reduction;

Fig. 5 is a schematic diagram of an eight-vessel plant layout according to an alternate embodiment of the present invention;

Fig. 6 is a schematic diagram of a seven-vessel plant layout according to an alternate embodiment of the present invention showing specific flow characteristics of plug flow, nitrification, de-nitrification;

20 Fig. 7 is a schematic diagram of a six-vessel plant layout according to an alternate embodiment of the present invention showing specific flow characteristics of plug flow and nitrification;

WO 02/028780

PCT/US01/31411

Fig. 8 is a schematic diagram of an eight-vessel plant layout according to an alternate embodiment of the present invention showing specific flow characteristics of step feed, nitrification, de-nitrification and phosphorous reduction;

5 Fig. 9 is a schematic diagram of a seven-vessel plant layout according to an alternate embodiment of the present invention showing specific flow characteristics of step feed, nitrification and de-nitrification;

Fig. 10 is a schematic diagram of a seven-vessel plant layout according to an alternate embodiment of the present invention showing specific flow characteristics of step feed and nitrification;

Fig. 11 is a schematic illustration of a wastewater treatment system made up of a number of treatment zones, each
15 of which includes a number of vessels;

Fig. 12 is a schematic illustration of a vessel structure of the present invention, including a zone flow diagram;

Fig. 13 illustrates the solids composition of raw influent in typical municipal wastewater;

20 Fig. 14 shows a wastewater nitrogen cycle;

Fig. 15 is a schematic illustration of the Re-Circulation Aeration System (RCAS) with an optional aerator by-pass;

Fig. 16 is a chart showing the 30 minute solids settling as related to MCRT;

WO 02/028780

PCT/US01/31411

Fig. 17 illustrates how the Decay Co-efficient k_d is calculated in relation to the MCRT and F/M Ratio; and

Fig. 18 is a simplified representation of the process shown in Fig. 5 with a filtration zone coupled to the clarifiers for returning captured solids for reprocessing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Treatment of chemical and biological aqueous waste can be performed through utilization and implementation of the method and apparatus of the present invention. The present invention cleans aqueous wastes in an aqueous solution by means of various strictly aerobic treatment methods and combinations of treatment methods such as aerobic biological decomposition, biological oxidation, chemical oxidation and physical separation of solids. The present invention is efficient in its use of aerobic treatment methods in that there is a reduction in the reliance on chemicals for nutrient removal. These methods exist in various stages of stabilization within the treatment process.

The approximate levels of performance (influent vs. effluent) within the treatment process of the present invention are as follows:

Reduction of 90% to 99.5% influent total BOD (biochemical oxygen demand) concentrations through oxidation and subsequent gravity settling.

WO 02/028780

PCT/US01/31411

Reduction of organic nitrogen through oxidation into first ammonia, second nitrite and third nitrate.

Reductions of 95% to 99.5% influent ammonia nitrogen concentrations through nitrification.

5 Reductions through de-nitrification of 50% to 99.5% nitrite and nitrate nitrogen concentrations that have resulted through the nitrification process referenced above.

Reduction of 90% to 99.5% influent total phosphorous concentrations through luxury "P" uptake.

10 Destruction of up to 99.5% total organic suspended solids concentrations through intense oxidation.

The following description explains the processes of the present invention that achieve these levels of performance as the aqueous solutions proceed from process zone to process

15 zone for treatment. The design of the present invention prefers a total hydraulic detention time for nutrient oxidation within the processing zones of about 4 to 8 hours.

PROCESS PERFORMANCE

20 Treatment of chemical and organic matter that occurs as an aqueous waste is stabilized through either oxidation or biological means. Stabilization is actually a group of processes. For example, in the treatment of municipal wastewater, the stabilization of ammonia as it is converted

25 into nitrogen gas is a several step process. Ammonia (NH_3) is

WO 02/028780

PCT/US01/31411

biologically oxidized into nitrite (NO_2) and then it is organically stabilized into nitrate (NO_3). The next and final stage is known as de-nitrification. Once this stage is attained, the presence of oxygen is reduced to very low levels
5 and the elemental bound oxygen in the form of NO_3 is utilized for respiration while the nitrogen gas, N_2 , is released into the atmosphere.

Another form of treatment is oxidation of chemical compounds which is accomplished by aeration. The reaction
10 occurring from oxidation causes a chemical element or compound to lose electrons. This loss of electrons makes the element or compound more stable.

Biological treatment is one of the most important steps in processing municipal wastewater, and a brief explanation of
15 that treatment is helpful in understanding the present invention and its apparatus and processes. During biological treatment, microorganisms eat, convert or consume nutrients (BOD) in the wastewater. These nutrients can be biodegradable organics or chemical in nature. With traditional systems,
20 physical treatment of raw wastewater by sedimentation and wasting removes only about 35% of the BOD, due to the high percentage (about 65% of the BOD) of BOD contained in the non-settleable and dissolved solids contained in wastes. The present invention uses aerobic digestion treatment through a

WO 02/028780

PCT/US01/31411

suspended growth treatment method to treat the total BOD within the aqueous solution to levels at or above 95% removal.

There are two types of solids in liquid wastes, 1) organic, and 2) inorganic. Inorganic solids do not break down or decompose by biological treatment. Therefore, as the inorganic or inert solids begin to accumulate in the processing system, the removal or wasting of inert solids should occur. This wasting is set on a predetermined concentration ratio of inert to organic solids. With the percentage of inorganic or inert solids content in most municipal type wastewater being small compared to the entire solids load entering the system, the time frame for inert wasting could range substantially between 90 days and 360 days or more. Organic solids content of the typical municipal waste stream makes up approximately 70% to 85% of the solids in the wastewater. Around 80% to 85% of these solids are typically dissolved solids and are not settleable, but 15% to 20% of these solids are settleable. However, these settleable solids are shredded during the recirculation process of each of the aerobic processing zones used in the present invention which allows for easier consumption by the microorganisms.

This shredding enhances the aerobic digestion treatment process of the current invention by allowing the microorganism colony and settleable solids to become homogenized. This homogenization of settleable solids causes all of the food

WO 02/028780

PCT/US01/31411

substrate to become almost a dissolved solid allowing for easier consumption by the microorganism colony.

As the floc of the microorganism colony passes through the RCAS system of the present invention, the large floc portions are disbursed into smaller floc particles. The reduction in floc size aids the consumption of substrate by the microorganism colony by increasing the surface area of the floc and causing more intimate contact with needed food and oxygen.

Digestion of a substrate and microorganism colony occurs with increased speed when a microorganism colony remains aerobic throughout its contents. The RCAS system increases the digestion of a substrate by keeping microorganism colonies in disbursed small floc particles so as to maintain an aerobic condition in the center of the floc particles. As the floc particles become smaller, the concentration of dissolved oxygen within the aerobic zone is easily accessible to the center of the floc particles. This also allows for a high concentration of dissolved oxygen to be maintained within an aerobic zone.

The processing and aerobic digestion treatment system of the present invention are provided by living systems that rely on mixed biological culture to break down the organic wastes. The present invention's aerobic digestion treatment system grows and maintains in suspension a high population of non-

WO 02/028780

PCT/US01/31411

photosynthetic microorganisms, i.e., a biomass, which consumes the organic waste. Under aerobic digestion conditions, the reduced organic compounds are oxidized to end products of carbon dioxide and water.

5 The growth and survival of non-photosynthetic microorganisms depends on the microorganisms ability to obtain energy by metabolizing the organic matter. A traditional aerobic treatment process results in complete metabolism and synthesis of organic matter, producing biological growth in
10 large quantities which must be removed from the system to keep the process from becoming biologically overloaded compromising the quality of the effluent. The present invention makes use of a complete aerobic digestion treatment of the biomass with which the microorganism environment is kept to the far right
15 of the "endogenous respiration phase" of Fig. 2 by controlling and balancing the F/M (food-to-microorganism) ratio (in a range of .05 to .80) and the oxygen delivery. This results in not only the complete metabolism and synthesis of the organic matter but also in the significant reduction of biological
20 solids at the end of the process.

Another feature of the present invention is the use of the nitrification cycle for the conversion of large amounts of organic nitrogen into ammonia, ammonia into nitrite and nitrite into nitrate. The nitrate is then de-nitrified

WO 02/028780

PCT/US01/31411

releasing nitrogen into the atmosphere, resulting in a reduction of total nitrogen within the waste stream.

Still another feature of the present invention is the consumption of phosphorous entering the system by microorganisms as a food source for cell wall development and new cell growth during high oxygen concentration times such as that which occurs in the aerobic reactor zones.

Referring now to Fig. 1, the characteristic growth pattern for microorganisms is shown where the relative biomass concentration (on the vertical axis) is charted as a function of time (on the horizontal axis). After a short time period for adaptation to the new environment, the microorganisms consume the organic matter and reproduce by binary fission, exponentially increasing the number of viable cells and biomass in the culture medium. This is the "log growth phase" shown in the left most portion of the chart in Fig. 1. The rate of metabolism in the "log growth phase" is limited by both the ability of the microorganisms to process the organic matter, and the amount of dissolved oxygen available to the microorganisms for respiration.

The "declining growth phase" shown in Fig. 1 is caused by an increasing shortage of the organic matter necessary for growth of the microorganisms. In the "declining growth phase", the rate of reproduction of the microorganisms decreases. The growth of microorganisms in the "declining

WO 02/028780

PCT/US01/31411

growth phase" is a function of both the concentration of the microorganisms and concentration of the growth-limiting organic matter.

The "declining growth phase" is followed by a "stationary phase". In the "stationary phase", the biomass concentration reaches a maximum value, and the low concentration of remaining organic matter substantially limits the biomass growth rate which becomes relatively constant.

The "endogenous respiration phase" follows the "stationary phase". In the "endogenous respiration phase", viable microorganisms compete for the small amount of organic matter which is still in the wastewater that is undergoing treatment. Eventually, starvation of the microorganisms occurs, such that the rate of death exceeds the rate of reproduction. Thus, the concentration of biomass in the aqueous solution declines during the "endogenous respiration phase". In the current invention the endogenous respiration (ER) is controlled such that the rate of death of the microorganisms is equal to the rate of growth of the microorganisms as verified by a mixed liquid suspended solids (MLSS) concentration that is kept at a constant concentration relative to the processing criteria.

Wastewater treatment according to the present invention will now be described in detail. In the present invention, wastewater treatment processing takes place in three stages:

WO 02/028780

PCT/US01/31411

- (1) Mass biological aerobic digestion to consume the organic waste, including but not limited to total organic nitrogen and total phosphorous reductions;
- (2) Solids capturing zone clarification/sedimentation;
- 5 and
- (3) Re-treatment of solids capturing zones settled solids by returning solids back to the aerobic reactor process.

In the processing method of the present invention,
10 consumption of organic waste is accomplished by maintaining an environment consisting of high mean cell residence time (MCRT), a moderate food to microorganism (F/M) ratio and intense aeration, wherein the microorganisms are forced to live in the endogenous respiration phase.

15 The clarification/sedimentation stage of the process is used to separate solids from the supernatant (the remaining liquid) through gravity settling. Once the aqueous solution containing suspended solids enter the clarification zone (vessels 76, 80, 84 and 88 corresponding (Clarifier #'s 1, 2,
20 3 and 4 of Fig. 4) from the aerobic reactor zone #2 (vessel 20 of Fig. 4), the specifics of which are explained in detail below, the velocity of the supernatant is slowed to allow the solids to settle by gravity. As the settled solids slightly concentrate at the bottom of the clarification vessels, they
25 are frequently and quickly removed and sent back to vessel

WO 02/028780

PCT/US01/31411

aerobic reactor #1 zone (vessel 18) for further treatment.
The supernatant (clearer aqueous solution) continues through
the process where it may be further treated with optional
tertiary treatments such as tertiary clarification or
5 filtration for the nearly complete removal of biological and
inert matter before being discharged. A receiving stream,
evaporation ponds, landscape irrigation, crop irrigation or to
some other type of disposal may be the recipient of such a
discharge.

10 Aerobic digestion treatment systems such as that of the
present invention must grow and maintain in suspension a
population of microorganisms in order to consume the organic
waste. Although, as illustrated in Fig. 1, individual
microorganisms grow rapidly, it takes time at startup or where
15 major load changes are occurring to increase the original low
concentration of microorganisms to levels high enough to
rapidly degrade the organic waste. It therefore becomes
important to use methods for increasing the concentration of
MLSS in a rapid fashion. Plant startup time, in regard to
20 traditional systems, range as long as 30 to 45 days for MLSS
concentrations to reach acceptable operational levels. Using
the present invention, plant start-up time can be reduced to
as little as 14 days or less with the present invention. The
time required for plant re-starts due to a toxic shock load to

WO 02/028780

PCT/US01/31411

the microorganisms are reduced as compared with traditional plant time requirements. These methods are discussed below.

A common design concept for aerobic digestion systems is mean cell residence time (MCRT), which is the average time the microorganisms spend in the system. The MCRT of traditional treatment systems relates to the quantity of microbial solids in an activated sludge process, relative to the quantity of solids lost in the effluent and the excess solids withdrawn from the processing cycle in the waste sludge. With the present invention the MCRT relates to the quantity of microbial solids in the aerobic treatment process, relative to the quantity of solids lost in the effluent only, which is unintentional wasting, as there are virtually no volatile solids withdrawn as waste activated sludge. Typical MCRT values for traditional systems are from 15 to 30 days. However, MCRT values for the present invention begin at 30 days and reach numbers of 150 to 250 days or greater (see Fig. 3). MCRT values for conventional aerobic treatment systems of greater than 30 days may produce operational problems. The excessive build up of solids in the system caused by inadequate wasting of solids is a common cause of a poor effluent quality due to the retention of higher concentrations of suspended solids, turbidity, etc. Other reasons for poor effluent quality include extremely old slow settling solids, over-oxidation of the solids and de-flocculation of the solids. Consequently,

WO 02/028780

PCT/US01/31411

for traditional aerobic treatment systems it is desirable to intentionally waste excessive solids from time to time to keep the MCRT within the ranges shown in Fig. 3. As in the present invention, the removal of excessive solids is not necessary
5 due to its ability to nearly complete the digestion of all organic solids.

Quantities of solids are expressed as concentrations of MLSS (mixed liquid suspended solids) with values for a conventional system shown in Fig. 3. These typical MLSS
10 values for conventional systems range from 1,000 mg/L at the low end of the range for contact stabilization systems to 6,000 mg/L for complete mix and extended aeration systems. The quantity of microbial solids (MLSS) in the anaerobic conditioner zone, anoxic selector zone and aerobic reactor
15 zones of the present invention (see, e.g. Fig. 4 explained in detail below) range from 2,000 - 8,000 mg/L or more. The apparatus and method of the present invention is able to maintain the MLSS concentrations shown in Fig. 3 for near complete digestion of organic matter of a typical municipal
20 type waste, to the elevated MLSS concentration shown in Fig. 3 for near complete digestion of organic matter of non-typical industrial type waste by using an efficient aeration delivery system device such as the one used in the present invention (re-circulating aeration system or "RCAS"). The aeration
25 device used in the present invention is the one described in

WO 02/028780

PCT/US01/31411

USP 5,893,641 (Garcia), the entire disclosure of which is incorporated herein by reference.

The process implemented by the present invention also achieves the results of total organic solids digestion by using the above-mentioned efficient aeration delivery system (RCAS) to deliver atmospheric air necessary for oxygen transfer, circulation, homogenization and deep mixing. An additional benefit of the implemented process that uses an aeration system of the type mentioned above is the mixing and secondary oxygenation of the MLSS residing within the aerobic reactor zones. This mixing and secondary oxygenation is accomplished by the removal of the MLSS contents from the aerobic reactor zones at their lowest point and discharging the re-oxygenated MLSS back into each respective vessel at an elevation of substantially two thirds of the way below the surface of the side water depth. The secondary oxygenation of the MLSS is accomplished by allowing the excess entrained air, injected by the RCAS, carried along with the aerated MLSS to flow via a conduit into and through the contents of the aerobic reactor zones. The primary and secondary oxygenation of the aerobic reactor zones MLSS enables the dissolved oxygen (DO) concentration to achieve levels in a range substantially between 3.0 and 5.0 mg/L. The dissolved oxygen concentration in the aerobic reactor zones is kept at an operational level that exceeds the upper range for traditional aerobic digestion

WO 02/028780

PCT/US01/31411

systems, which is 2.0 mg/L. For this reason, inter alia, the present invention achieves a higher degree of organic solids digestion through its efficient oxygenation treatment process.

With the higher than normal dissolved oxygen concentrations and intimate mixing as achieved with the present invention, a higher rate decay co-efficient (k_d) of organic matter occurs than is achieved with traditional aeration systems. The word "decay" is the term used to express destruction (digestion) of volatile (organic) suspended solids in the formula relating F/M to MCRT. Traditional aeration systems have a k_d value of between 0.04 to 0.06 for an average of 0.05, whereas in the present invention, k_d is substantially 0.10 or twice that for traditional aeration systems, thus yielding a greater digestion rate. See Fig. 17 for the formulas used for determining the decay co-efficient.

Traditional oxygen transfer efficiency is expressed as the percentage of mass of oxygen that reaches the biological cell compared to the applied mass of gaseous oxygen supplied to the reactor. The rate of oxygen transfer from air bubbles admitted by the RCAS is a function of several factors which vary according to the wastewater characteristics, including but not limited to, the oxygen transfer coefficient of the wastewater within a conduit and the oxygen transfer coefficient within a vessel, the oxygen saturation coefficient of the wastewater, and the present dissolved oxygen

WO 02/028780

PCT/US01/31411

concentration and saturation concentrations of oxygen within the aqueous solution.

In a traditional aerobic biological treatment system the metabolism of organic matter in the wastewater results in an increased biological mass (growth) of microorganisms in the system. Excess microorganisms are removed or wasted from the system to maintain a proper balance between food supply and the mass of microorganisms that exist in the aeration basin where the oxygen is being delivered. This balance is referred to as food-to-microorganism (F/M) ratio. One familiar in the art knows that an F/M ratio of 0.05 to 0.20 that is maintained in traditional aeration basins defines the operation of extended aeration systems. Fig. 2 illustrates how an increasing F/M ratio affects the rate of metabolism. Although the "exponential growth phase" shown in Fig. 2 is desirable for maximum rate of removal of organic matter, in this phase the microorganisms are in dispersed growth and experience difficulty in settling out of solution by gravity. Moreover, there is excess unconsumed organic matter in solution, which cannot be removed by a dispersed growth microorganism colony of a traditional aeration system and thus passes out of the system in the effluent. Operation of traditional aeration treatment systems at a high F/M ratio thus results in inefficient and insufficient BOD removal.

WO 02/028780

PCT/US01/31411

At a low F/M ratio, the overall metabolic activity in the aeration basin is endogenous. In this phase the metabolism of the organic matter is nearly complete and the microorganisms flocculate rapidly and settle out of solution by gravity.

5 Operation in the endogenous phase is desirable where a high BOD removal efficiency is desired.

Typical traditional aeration treatment systems F/M ratios range from 0.05 to 0.2 for the low rate needed for extended aeration, 0.2 to 0.4 for conventional rate of treatment to the
10 upper range of 0.4 to 1.5 for high rate treatment. However, in the present invention, the F/M ratio is kept in the range of 0.05 to 0.8 to encompass all of the low rate, all of the conventional rate and a portion of the high rate treatment processes allowing for a significant amount of flexibility
15 within a single treatment plant design. This flexibility is evident in that as the flow of a treatment system increases and the concentrations of organic matter remains the same, the recirculation rate is able to be increased by simply modulating the aerator to increase the speed of the
20 recirculating pumps, which in turn increases the aeration delivery rate. Therefore, with a sufficient amount of available oxygen as achieved by using an aeration delivery system such as the one described herein and in USP 5,893,641, the ranges of F/M ratio listed above for the current invention
25 allow the microorganisms not only to completely metabolize the

WO 02/028780

PCT/US01/31411

organic matter, but through intense aeration the food source diminishes as the microorganisms consume it and thus the competition for food increases. Microorganisms consume themselves and each other in order to survive as in the
5 endogenous respiration treatment process, even at the higher F/M ratio of 0.8. The long-term cannibalistic state of endogenous respiration ensures the mass reduction of solids accumulation that occurs with the aerobic digestion process of the current invention. Maintaining F/M ratios such as with
10 the current invention along with maintaining high amounts of dissolved oxygen as is economically possible using the aeration device and delivery system mentioned above, the oxidation of organic matter is rapidly completed.

As the MCRT of the microorganisms increases, the
15 promotion of rapid settling of the microorganisms increases, benefitting the clarification process, as shown in Figs. 2 and 16.

In order to better understand the term "wasting" as used in the present invention, the following explanation is given.
20 As the concentration of inert solids increases, a removal or wasting of these solids should occur so as to allow a sufficient volume of biological microorganisms to reside within the biological processing zones. For this reason provisions have been made for the removal of inorganic or
25 inert solids from aerobic reactor #1 as illustrated in figures

WO 02/028780

PCT/US01/31411

4, 5, 6, 7, 8, 9, 10 and 18. When the inert concentration reaches the removal level a predetermined amount of solids are removed. The concentration of inert solids prior to this wasting has steadily risen from the extremely low concentrations (approximately 0.001% of the settleable solids as indicated in figure 13) in the influent flow, to levels that can reach substantially 50% of the total solids concentration residing in the biological processing zones. While there are organic solids intermixed with inert solids, the total weight of organic solids wasted out of the biological processing zones are substantially between 0.01% and 0.5% as compared to the total weight of organic solids that have entered the biological processing zone. This wasting of inert and organic solids should continue periodically until the inert solids concentrations within the biological processing zone have dropped to acceptable processing levels.

Clarification may be defined as separating the biomass from the treated aqueous solution. Traditional aerobic treatment and solids separation systems attempt to retain the bulk of the microorganisms in the system by coagulation and flocculation, however, wasting occurs due to the nature of traditional process and apparatus along with operational energy cost limitations. The biological solids then settle to the bottom of a clarifier. The majority of the biological

WO 02/028780

PCT/US01/31411

solids are then returned to the aeration basin while intentionally wasting (removing) from the system a portion of the biological solids (activated sludge), which is an amount of activated sludge that exceeds the system's designed treatment digestion ability. The current invention retains the microorganisms in the system by settling the biological solids along with all inorganic solids in a clarification zone (Clarifiers #1, 2, 3 and 4 of Fig. 4), and returning them to the aerobic reactor #1 zone (vessel 18 of Fig. 4) for further processing. Care is taken so as to regulate the blanket depth (accumulated sludge in the bottom of a clarifier) to a minimum by the frequency and number of gallons of return activated sludge (RAS) evacuated and returned to the aerobic reactor #1 zone. This frequency of evacuation of RAS eliminates long detention times of biological solids in the clarification zone, which would otherwise become septic, gasify and float to the surface of the clarification zone. Observation and adjustments are made to the evacuation of RAS flows so as to minimize the hydraulic velocities in the clarification zone. Higher hydraulic velocities can cause inefficient settling in the clarification zone resulting in biological solids carry over in its effluent.

With the present invention, the hydraulic detention time within the aeration cycles are in the ranges of the complete mix and plug flow processes, and partially in the high purity

WO 02/028780

PCT/US01/31411

oxygen process range, while deriving the benefits of the extended aeration process. The extended aeration process typically uses 18 to 36 hours to almost completely oxidize (treat) organic matter as shown on Fig.3 (see the right-most column thereof). The present invention obtains the same results on the organic matter in substantially 4 to 8 hours time. By using an efficient aeration delivery system, the current invention drastically reduces the time needed to oxidize the organic matter. This is accomplished by the aeration delivery systems located at each of the aerobic reactor zones (vessels 18, 20 of Fig. 4), the anaerobic conditioner zone (vessel 8 of Fig. 4) and the anoxic selector zone (vessel 58 of Fig. 4) re-circulating, by volume, each of their respective contents substantially 100% every two hours. When combining the anaerobic conditioner zone along with both aerobic reactor zone and the anoxic selector zone recirculation percentage rates, the total processing recirculation percentage rate is equal to or greater than 200% of the influent flow entering the treatment process in a 24 hour period. The aeration system re-circulates, shreds and homogenizes the organic matter and microorganisms, and oxygenates the entire mass many more times than traditional systems resulting in a greater biological solids digestion rate in a shorter time period than traditional systems. Typical re-circulation rates in conventional treatment systems

WO 02/028780

PCT/US01/31411

range from 25 to 100 percent per day of the influent flow for complete mix systems, 25 to 50 percent per day of the influent flow for plug flow systems and 75 to 150 percent per day of the influent flow for extended aeration systems.

5 Recirculation percentage rates as they pertain to traditional activated sludge treatment systems refer only to the percentage of recirculation of the Return Activated Sludge (RAS) as compared to the influent flow. While the present invention uses this same type of RAS recirculation percentage
10 the present invention also utilizes the previously described processing recirculation percentage achieving a greater solids digestion rate than is possible with traditional activated sludge treatment systems.

The biological treatment technique according to the
15 present invention will now be described. The composition of microorganism cells consist of 70 to 90 percent water with 10 to 30 percent dry material by weight. Of this dry material, 70 to 95 percent is organic and 5 to 30 percent is inorganic. Ninety-five percent of the organic dry material consists of
20 carbon, oxygen, nitrogen, hydrogen and phosphorus, and other trace materials respectively. The present invention takes advantage of the large percent of organics available to the microorganisms by maintaining an extremely long MCRT for not only the complete oxidation of organic compounds but also for
25 the consumption of biomass (the mass of organic material

WO 02/028780

PCT/US01/31411

consisting of living organisms feeding on the wastes in the wastewater, dead organisms and other debris), which also contains these same elements. In the activated sludge process, carbon, oxygen, nitrogen and hydrogen are used as the main constituent of cellular material, with phosphorus being used as the constituent of nucleic acids, phospholipids and nucleotides. Compounds are taken up by microorganisms from their environment to carry out two basic primary metabolic activities: energy production through bioenergetics, and synthesis of new cell material through biosynthesis. Microorganisms produce energy for themselves from light, organic and inorganic compounds. The main inorganic compounds used by the microorganisms as a source of energy are, ammonium (NH_4), nitrite (NO_2), dissolved sulfide (H_2S), and elemental sulfur. These compounds are oxidized and the energy released is used for cell maintenance, synthesis of new cell material and movement of the microorganism if they are mobile. There are two types of microorganisms: autotrophic microorganisms which use inorganic carbon for biosynthesis and heterotrophic microorganisms which use organic carbon for biosynthesis.

Carbon makes up approximately 50 percent of the dry mass of the microorganism cell. Therefore carbon is the main element used during biosynthesis. The microorganisms use as one of their sources of energy for new cell development either

WO 02/028780

PCT/US01/31411

organic compounds such as fatty acids, amino acids, sugars,
organic acids, or carbon dioxide (CO₂). Through biological
processes, organic carbon is converted into microorganism
biosynthesis material and gases such as carbon dioxide, which
5 can escape into the atmosphere. Through the 200%
recirculation by volume of the contents of the aerobic reactor
by the RCAS of the present invention, the microorganisms are
enabled to come into contact with their carbon source more
times and more efficiently than in traditional systems.

10 Oxygen and hydrogen are the main gas elements used in
cellular material. The source of oxygen for the cellular
material of microorganisms is found in molecular oxygen,
organic compounds or even carbon dioxide. The present
invention delivers oxygen through the aerobic reactor's
15 aeration delivery system (RCAS) directly into the aqueous
solution of nutrients and microorganisms. This offers the
microorganisms the opportunity to respire in the easiest
manner and with the most available oxygen source for
bioenergetics and biosynthesis. The source of hydrogen for
20 the cellular material of microorganisms is found in molecular
hydrogen and organic compounds. Oxygen as an electron
acceptor is used in the classification of microorganisms.
Microorganisms, which use oxygen are referred to as aerobes,
and those that do not use oxygen are referred as anaerobes.

WO 02/028780

PCT/US01/31411

The present invention uses aerobes for organic compound stabilization and decomposition in the aerobic reactor.

Nitrogen is the major source for proteins and nucleic acids for the microorganisms and includes 14 percent of the
5 cellular material. Microorganisms can use inorganic nitrogen in the form of nitrogen gas (N_2), ammonia-nitrogen ($NH_3 + NH_4$), nitrite (NO_2) and nitrate (NO_3). Nitrogen gas to be used must first be converted into ammonium (NH_4) and then converted into organic nitrogen as in nitrogen fixing in soils, however
10 ammonia-nitrogen (NH_3) can be considered as 100 percent ready and available for nutritional use by microorganisms. Conversion of ammonia (NH_3) into nitrite (NO_2) and nitrate (NO_3) opens the door for microorganisms that use NO_2 and NO_3 as their sole nitrogen source. However there is a large amount
15 of energy needed for microorganisms to be able to use this nitrogen as a source for growth. These microorganisms must oxidize larger amounts of organic compounds to have the energy needed for using NO_2 and NO_3 as their nitrogen source. This results in a lower microorganism growth rate than when using
20 NH_3 as a source for nitrogen. The current invention uses this lower growth rate to its advantage when maintaining an extremely long MCRT and variable F/M ratio to reduce the amount of microorganism growth. In combination, the microorganisms must consume greater amounts of organic
25 compounds and are unable to reproduce as rapidly. There are

WO 02/028780

PCT/US01/31411

three biological removal processes used to remove nitrogen, they are ammonification followed by nitrification and denitrification. Ammonification and nitrification occur in the aerobic reactors while denitrification occurs in the anoxic selector. Ammonification is carried out by heterotrophic microorganisms, which take organic nitrogen in the form of proteins and peptides and decomposes them into ammonia and ammonium. Autotrophic microorganisms that convert ammonia into NO_2 and then NO_3 carry out nitrification. The third stage in the process is denitrification where another group of heterotrophic microorganisms reduce the NO_3 to NO_2 and then to NO and finally to N_2 for release into the atmosphere.

Microorganisms use phosphorus during cell synthesis, cell maintenance and as energy transport. Due to this, about 10 to 30 percent of an influent's phosphorus is consumed by microorganisms and used for their metabolic processes. However there are three microorganisms with the ability to store phosphorus in larger amounts than is needed for growth requirements. This is referred to as luxury phosphorus uptake. The three microorganisms, acinetobacter, pseudomonas and moraxella, are collectively referred to as poly-P bacteria because of their ability to store phosphorus in the form of polyphosphate granules. The poly-P bacteria are able to use the polyphosphate as an energy source when under stressed conditions. Since these bacteria are only able to store this

WO 02/028780

PCT/US01/31411

extra amount of phosphorus when under aerobic conditions, the current invention maintains dissolved oxygen in sufficient quantities to ensure luxury phosphorus uptake within the aerobic reactor zones. The present invention uses an
5 anaerobic conditioner zone as an area for microorganisms to reach the necessary stressed conditions to enable these poly-P bacteria to use the polyphosphate as energy, thus reducing the amount of phosphorus in the effluent stream.

In summary, carbon, nitrogen and phosphorus are reduced
10 through bioenergetics and biosynthesis by the microorganisms. The amount of removal of these nutrients is directly related to the concentration of the nutrients and the amount of time these nutrients are exposed to microorganisms. Increasing the number of times nutrients come into contact with the
15 microorganisms and oxygen through homogenization, as is the case with the current invention, can accelerate the organic digestion process. By designing zones to substantially meet a 2-hour hydraulic detention time and by re-circulation and re-aerating the entire content, by volume, of the aerobic reactor
20 zones 100% every 2 hours before it flows out of the zones, an environment for the microorganisms to accelerate the biological digestion process is provided. All biological solids removed from the solids capturing zone and returned to the processing zones are subject to this accelerated
25 biological digestion as well. The present invention, as

WO 02/028780

PCT/US01/31411

outlined above, produces this effect, and henceforth utilizes a smaller footprint design as compared to traditional treatment systems while performing as if there is more hydraulic detention capacity available.

5 By using an extended MCRT, a flexible F/M ratio and increasing the re-circulation as described above, the consumption of biomass also occurs, achieving an enhanced organic solids reduction in the process through digestion. Only after a predetermined concentration of inorganic solids
10 is reached is intentional wasting initiated of substantially only those inorganic solids, with possible high concentrations of phosphorous.

Another component of the "enhanced solids reduction" (ESR) wastewater treatment system of the present invention are
15 the zones (vessels), as being a part of an entire system. The zones consist of a vessel or group of vessels, which contains the wastewater for treatment. These vessels are preferred to be of a particular shape consisting of a vertical cylinder having a conical bottom. However, the processing of said
20 wastewater with the present invention is not limited to the preferred vessels. Effective treatment with the process of the present invention is attainable in square or rectangular vessels, with flat or sloped bottoms. The zones are unique to the process designated for that zone. The vessel design and
25 construction of the process zones are a component of the ESR

WO 02/028780

PCT/US01/31411

wastewater treatment system that permits the modularization of the system. The zones illustrated in Fig. 4, the preferred apparatus embodiment, are of a single vessel per zone design. Alternate apparatus embodiments could resemble a zone having

5 one or more vessels performing the unique process function of that zone. Alternately, as an example of a large capacity ESR wastewater treatment system, the number vessels shown in Fig. 11, could be classified as one zone, and additional modules resembling the number of vessels in Fig. 11 could be

10 added for each additional treatment zone required until such time that the design criteria of a large volume treatment plant is satisfied. Alternate designs could incorporate various sized vessels that utilize the same treatment processing techniques as described herein.

15 Vessel design incorporates the vertical cylinder with a depressed-shaped bottom, but preferably cone-shaped bottom (see Fig. 12) in order to create the environment to enhance the desired path of the wastewater stream during treatment. The use of the cone bottom vessel is essential for the

20 settling and concentrating of solids within the clarification zone and is used effectively in the process zones in the settling and concentrating of phosphorous rich inorganic solids for periodic removal. Keeping solids in suspension is accomplished by the RCAS system as it receives flow into the

25 pump from the bottom of the aerobic reactor zone. The aerobic

WO 02/028780

PCT/US01/31411

reactor zone contents are then pumped, aerated and recirculated, generating velocities during the RCAS conduit discharge back into the aerobic reactor so that the aerobic reactor zone contents are well mixed.

- 5 With the use of cylindrical shapes during clarification, and with the prompting of flow via the inflow's direction and its positioned reference point, and the re-circulation discharge direction and its positioned reference point, the wastewater is directed to travel in a particular direction,
- 10 preferably rotational, at a particular speed and for a particular distance so as to allow the settling solids to arrive at the lower portion of the vessel, and remain within the vessel for a particular period of time so as to accumulate, concentrate and process, in order to facilitate
- 15 the treatment desired. The conical bottom along with the flow characteristics of the traveling wastewater, promotes the settling solids to accumulate at a central point of reference at the lowest point within the cone shaped bottom (referred to as solids concentrator). These accumulated settled solids are
- 20 then available to be evacuated by way of a port exiting at that lowest point.

The embodiment of Fig. 4 is utilized to illustrate the preferred flow characteristics when the influent contains normal BOD, TSS (Total Suspended Solids) & NH₃ loading, and

25 requiring normal nitrification, denitrification and

WO 02/028780

PCT/US01/31411

phosphorous reduction, as demonstrated by the influent concentrations of a municipal wastewater treatment plant. In Fig. 4, pre-screened influent wastewater containing suspended solids and biodegradable organic substances passes through the influent feeder line, which flows into an influent splitter box, which then has take-off feeders to each of the vessels. This enables Fig. 4 to represent a universal configuration that would be used as a representative for all possible flow characteristics sought after for varying treatment specifications.

FLOW AND PROCESSES

Referring now to Fig. 4, a preferred embodiment of the enhanced solids reduction (ESR) wastewater treatment system in accordance with the present invention is shown which provides complete operational flexibility in the processing characteristics of nitrification, de-nitrification and phosphorous reduction in conjunction with using a plug flow type flow characteristic (the preferred process embodiment). Due to the efficiency of the preferred embodiment of the present invention and particularly of the RCAS system, an economic and treatability improvement in the processing of wastewater is achieved over and above traditional wastewater treatment processes. The preferred embodiment corresponds to a four-zone biological process and a solids capturing

WO 02/028780

PCT/US01/31411

treatment zone. The biological processing zones consist of, but are not limited to, 1) an anaerobic zone, 2) an aerobic zone, 3) an anoxic zone and 4) an additional aerobic zone. The solids capturing zone consists of but is not limited to
5 secondary clarification, tertiary clarification, filtration and chemical addition. However, by altering the flow characteristics by valve changes, any of the alternate processing embodiments (described below) can be implemented and used. The preferred processing embodiment of the present
10 invention is a method of processing that is zone specific and not vessel specific.

For the preferred plug flow characteristic, the influent, which in this embodiment is foreseen as typical municipal wastewater, is directed through line 2 into a flow splitter
15 box 4 which regulates and/or splits the flow of the influent to the treatment vessels. In this embodiment the entire flow of influent is then directed via line 6 to vessel 8 (V # 1) which is used as an anaerobic conditioner zone, whereby the contents, by volume, of this zone are recirculated
20 substantially one time every two hours using pump 10 and the above-mentioned RCAS. The size of the vessel 8 depends on the volume of influent being processed.

Vessel 8 (anaerobic conditioner zone) begins the first stage of luxury phosphorous uptake, which is biological
25 phosphorous (Bio-P) release. This first stage of luxury

WO 02/028780

PCT/US01/31411

phosphorous uptake is accomplished by maintaining an oxygen deficient state within the vessel. The anaerobic conditioner zone's dissolved oxygen levels are maintained at or below 0.10 mg/L allowing a formation of volatile fatty acids (VFA's) used
5 by microorganisms in the release of Bio-P. While this Bio-P release creates a temporary increase of phosphorous, it also forces the microorganisms to metabolize greater amounts of phosphorous during a later process. The contents of this zone are able to be maintained with low dissolved oxygen levels by
10 the controlled introduction of low oxygen level mixed liquid suspended solids (MLSS) from vessel 58 (anoxic selector zone - V #3) from line 11 through pump 12 and through line 14 into vessel 8 (anaerobic conditioner zone).

Aqueous total solids (TS) from vessel 8 (V # 1) flows
15 through line 16 into vessel 18 (V # 2) which is a dynamic aerobic reactor # 1 zone. The vessel 18 also receives another flow, MLSS re-cycle, which comes from vessel 20 (V # 4), which is a dynamic aerobic reactor # 2 zone. The flow from vessel 20 comes from line 22 through pump 24 and finally through line
20 26. Another flow enters vessel 18 from each of the four clarifiers (vessels 76, 80, 84, 88) - (V #5, V#6, V#7 and V#8) in the form of return activated sludge (RAS) through RAS pumps 28, 30, 32 and 34 then through the lines 36, 38, 40 and 42, and finally entering vessel 18 through lines 44, 46, 48 and 50
25 respectively. The contents, by volume, of vessel 18 are

WO 02/028780

PCT/US01/31411

recirculated substantially one time every two hours, using a re-circulation conduit aeration system (RCAS), explained below, which is powered by pump 52. During the recirculation procedure the contents of vessel 18 the settleable solids, become solubilized by means of shredding as they pass through the RCAS system of pump 52. Shredding occurs as the solids within the aqueous solution are processed through the RCAS system by the toroidal vortex action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied through the RCAS system during the recirculation procedure so that the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or higher. Keeping the dissolved oxygen concentration at these levels allows bacteria nitrosomonas and nitrobactor, residing in the microorganism colony, to oxidize ammonia (NH_3) into nitrite (NO_2) and finally into nitrate (NO_3) respectively. With dissolved oxygen concentrations of this zone maintained at or above 3.5 mg/L, suspended solids and other organic matter are decomposed and oxidized into more stable compounds.

By using large volumes of atmospheric air delivered by the RCAS and maintaining the dissolved oxygen at higher levels (well above 3.5 mg/L) than that which would be maintained by traditional aeration systems (2.0 mg/L to 3.0 mg/L), along with long MCRT's, the microorganism colony will enter the

WO 02/028780

PCT/US01/31411

biological life cycle mode known as endogenous respiration (ER). In this ER mode, the living microorganisms begin to metabolize some of their own cellular mass along with any new organic matter they absorb or adsorb from their environment.

5 This aids in the enhancement of solids reduction while maintaining a microorganism colony through the adjustment of the food to microorganism ratio (F/M) to allow the rate of death of the microorganism colony to equal the rate of growth of the microorganism colony through the endogenous respiration
10 process.

Another benefit of the delivery of intense aeration within this reactor is the enhanced consumption of large amounts of phosphorous by the microorganisms. The amount of phosphorous taken up by the microorganisms is greater than the
15 amount of phosphorous the microorganisms released in vessel 8 as described previously. The microorganisms then use this newly acquired phosphorous for new cell wall development and other energy needs.

Accumulation of inert solids are removed via line 5, from
20 vessel 18 (aerobic reactor #1) when the concentrations reach a predetermined level. This holds true for all embodiments of the present invention. This predetermined level could be substantially 50% of the concentration of total solids in vessel 18 or a level at which the process begins to allow
25 nutrients to pass through to the process effluent.

WO 02/028780

PCT/US01/31411

The flow exits vessel 18 via line 54, is provided to splitter box 56 and is then provided to vessel 58 via line 60 for further processing.

The contents, by volume, of vessel 58 (anoxic selector zone V#3) are recirculated substantially one time every two hours by the pump 62. Vessel 58 receives elemental oxygen attached to nitrogen molecules in the form of nitrate nitrogen (NO_3) and nitrite nitrogen (NO_2), which was derived primarily from the ammonia conversion process known as nitrification, occurring within vessel 18 (aerobic reactor # 1 zone). The amount of dissolved oxygen (DO) in vessel 58 is maintained in the range of 0.3mg/L to 0.5mg/L. The microorganisms contained within the wastewater of vessel 58 look for oxygen to respire. With little dissolved oxygen available, the microorganisms are forced to use the elemental oxygen in the NO_3 that is tied up with nitrogen. This process is commonly called denitrification. Once the bond between the nitrogen and oxygen is broken, the microorganisms consume the elemental oxygen for respiration, allowing the nitrogen to be released into the atmosphere. The microorganisms use this oxygen for necessary respiration in order to continue consumption of organic matter still within the wastewater.

During this anoxic condition, a natural release of phosphorous by the microorganisms occurs, as a way to conserve energy during the time of low dissolved oxygen availability,

WO 02/028780

PCT/US01/31411

but in lesser quantities than that which occurs in vessel 8
(the anaerobic conditioner zone V #1). While this creates a
temporary increase of phosphorous, it also forces the
microorganisms to metabolize greater amounts of phosphorous in
5 a later process. The effluent from this process is provided
via line 64 on to vessel 20 (aerobic reactor # 2 zone-V#4) for
further treatment.

Vessel 20 is used as a dynamic aerobic reactor. The
contents, by volume, of vessel 20 are recirculated and
10 intensely aerated substantially one time every two hours using
the re-circulation conduit aeration system (RCAS), which is
powered by pump 66. The oxidation of both dissolved and
suspended organic matter occur in vessel 20 by maintaining a
dissolved oxygen of at least 3.0 mg/L. The bacteria
15 nitrosomonas and nitrobactor, residing in the microorganism
colony, will oxidize organic nitrogen into ammonia (NH₃) then
into nitrite (NO₂) and finally into nitrate (NO₃) respectively.
As the aqueous solution containing the microorganism colony of
vessel 20 (dynamic aerobic reactor # 2 zone) is aerated and
20 the dissolved oxygen increases, the microorganisms begin
consuming phosphorous in larger quantities than is necessary
for them to sustain life. The amount of phosphorous consumed
far exceeds the amount of phosphorous the microorganisms
released into the aqueous solution while being processed
25 within the anaerobic conditioner zone and anoxic selector

WO 02/028780

PCT/US01/31411

zones (vessel 8 and 58). This effect is what is referred to as "luxury phosphorous uptake". Portions of the mixed liquid suspended solids (MLSS) from vessel 20 are recycled for further digestion to vessel 18 (dynamic aerobic reactor # 1 zone) through line 22, using pump 24 and is finally discharged through line 26, while the effluent is discharged from vessel 20 through line 68 and into line 70 before entering a clarification zone flow splitter box 72 (SB Clar Inf).

As the influent from line 70 enters the clarification zone flow splitter box 72 (SB Clar Inf), the flow is preferably split into four equal portions and sent to each of the four clarifiers through line 74 for vessel 76 corresponding to Clarifier # 1, line 78 for vessel 80 corresponding to Clarifier # 2, line 82 for vessel 84 corresponding to Clarifier # 3 and line 86 for vessel 88 corresponding to Clarifier # 4. The flow velocity is diminished as the flow enters each of the clarifiers, allowing the solids to settle into the bottom portion of each of the clarifiers. The settling solids are then dislodged from the walls of the clarifiers by using a hydraulically operated solids concentration inducer 90 for vessel 76 (Clarifier # 1), hydraulically operated solids concentration inducer 92 for vessel 80 (Clarifier # 2) hydraulically operated solids concentration inducer 94 for vessel 84 (Clarifier # 3), and hydraulically operated solids concentration inducer 96 for

WO 02/028780

PCT/US01/31411

vessel 88 (Clarifier # 4), allowing the solids to further thicken before being removed through each of the clarifier RAS pumps (28, 30, 32 and 34) and RAS lines (36, 38, 40 and 42) and sent to the vessel 18 (dynamic aerobic reactor # 1) for further treatment. Separated liquid from the clarification process exits vessel 76 through line 98, vessel 80 through line 100, vessel 84 through line 102 and vessel 88 through line 104, and join in the collection box 106 (CB Clar Eff). This clarifier provides effluent through line 108 as the final processed effluent.

The preferred embodiment of the present invention allows for an improvement in operational flexibility over traditional aerobic treatment systems.

A first alternate embodiment of the present invention is shown in Fig. 5 wherein the unutilized lines and equipment of the preferred apparatus embodiment of Fig. 4 are removed. However, all the utilized lines and equipment required to process the wastewater flow using the preferred process embodiment are shown. The alternative embodiment depicted in Fig. # 5 is utilized when the specific flow configuration is contemplated for the installation and where the flexibility offered in Fig. #4 is not required. The influent, which is typical municipal waste water, is directed through line 2 into vessel 8 which is used as an anaerobic conditioner zone (V#1), whereby the contents, by volume, of the zone are recirculated

WO 02/028780

PCT/US01/31411

substantially one time every two hours using pump 10. Similar to that of the preferred embodiment, the contents of this vessel are able to be maintained with low dissolved oxygen levels by the controlled introduction of low oxygen level MLSS from vessel 58 (anoxic selector zone) from line 10 through pump 12 and fed through line 14 into vessel 8.

Aqueous total solids from vessel 8 (anaerobic conditioner zone) flows through line 16 into vessel 18 which is a dynamic aerobic reactor #1 zone (V#2). Vessel 18 also receives another flow, MLSS re-cycle, which comes from vessel 20 which is being used as dynamic aerobic reactor #2 zone. The flow from vessel 20 comes from line 22 through pump 24 and finally through line 26. Another flow enters vessel 18 from each of the four clarifiers (vessels 76, 80, 84, 88 described below) in the form of return activated sludge (RAS) through the RAS pumps 28, 30, 32 and 34, then through the lines 36, 38, 40 and 42 respectively, and finally entering vessel 18 through lines 44, 46, 48 and 50 respectively. The contents, by volume, of vessel 18 are re-circulated substantially one time every two hours, using a re-circulation conduit aeration system (RCAS), explained below, which is powered by pump 52. During the re-circulation procedure, the contents of vessel 18, that is the settleable solids, become solubilized by means of shredding as it passes through the RCAS system of the zone. Shredding occurs as the solids within the aqueous solution are processed

WO 02/028780

PCT/US01/31411

through the RCAS system by the toroidal vortex action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied through the RCAS system during the re-circulation procedures
5 so that the level of the dissolved oxygen is substantially maintained at a concentration of 3.5mg per liter or higher.

The flow exits vessel 18 (aerobic reactor #1 zone) via line 110 to vessel 58 (anoxic selector zone - V#3). The contents of vessel 58 are recirculated substantially one time
10 every two hours by pump 62. The operation of vessel 58 is similar to that described in connection with Fig. 4. The effluent from vessel 58 is provided via line 64 to vessel 20 for further treatment.

Vessel 20 is a dynamic aerobic reactor (V#4). The
15 contents of vessel 20 are re-circulated and intensely aerated substantially one time every two hours using the re-circulation conduit aeration system (RCAS), which is powered by pump 66. The operation of vessel 20 is similar to that described in connection with Fig. 4. As explained above,
20 portions of the MLSS from vessel 20 are recycled for further processing to vessel 18 through line 22, using pump 24 and finally discharged through line 26, while the effluent of vessel 20 is discharged through line 68 and into line 70 before entering a clarification zone flow splitter box 72 (SB
25 Clar Inf).

WO 02/028780

PCT/US01/31411

As the influent from line 70 enters the clarification zone flow splitter box 72, the flow is preferably split into four equal portions and sent to each of the four clarifiers (V#5, V#6, V#7, V#8) through line 74 for vessel 76
5 corresponding to clarifier #1, line 78 for vessel 80 corresponding to clarifier #2, line 82 for vessel 84 corresponding to clarifier #3 and line 86 for vessel 88 corresponding to clarifier #4. The flow velocity is diminished as the flow enters each of the clarifiers, allowing
10 the solids to settle into the bottom of each of the clarifiers. These settling solids are then dislodged from the vessel walls by a hydraulically operated solid concentrations inducer 90 for vessel 76, hydraulically operated solids concentration inducer 92 for vessel 80, hydraulically operated
15 solids concentration inducer 94 for vessel 84, and hydraulically operated solids concentration inducer 96 for vessel 88, allowing the solids to further thicken before being removed through each of the clarifier RAS pumps (28, 30, 32 and 34) and RAS lines (36, 38, 40 and 42) and sent via lines
20 44, 46, 48 and 50 to the vessel 18 for further treatment. Separated liquid from the clarification process exists vessel 76 through line 98, vessel 80 through line 100, vessel 84 through line 102 and vessel 88 through line 104, and joined in collection box 106 (CB Clar Eff). The clarifier effluent
25 exists through line 108 as the final processed effluent.

WO 02/028780

PCT/US01/31411

Fig. 18 is a simplified representation of the process shown in Fig. 5 which further includes a filtration zone 89 coupled to the output of the clarifiers (line 108). The filtration zone receives the aqueous solution (in Fig. 4 the effluent) via line 108 for further processing. The aqueous solution is provided to the filtration zone where solids separate and settle from the liquid portion of the aqueous solution. The solids which have settled and separated from the liquid portion are provided via line 109 to the influent line 2 for re-processing and re-treatment through the system. The filtration zone shown in Fig. 18 can also be included in the system shown in Fig. 4 or any of the other embodiments of the present invention explained below.

The second alternate embodiment of the present invention depicted in Figure 6 uses alternate process embodiment # 1 of the present invention to provide the processing characteristic of nitrification and de-nitrification in conjunction with a plug flow type flow characteristic. Alternate apparatus embodiment #2 is to be used with alternate process embodiment # 1. Alternate processing embodiment # 1 of the present invention is a method of processing that is zone specific and not vessel specific.

For alternate process embodiment # 1, the influent, represented as typical municipal wastewater, is directed through line 120 into vessel 122 which is used as an anoxic

WO 02/028780

PCT/US01/31411

selector zone (V#1), whereby the contents, by volume, of this vessel are recirculated substantially one time every two hours using pump 124. Other flows that enter vessel 122 come from vessel 126 (aerobic reactor # 1 zone-V#2) via line 128 and
5 vessel 130 (aerobic reactor # 2 zone-V#3) via line 132 in the form of MLSS recycle, which is used to supplement the lack of oxygen within vessel 122. Another flow that enters vessel 122 comes from each of the four clarifiers (vessels 134, 136, 138, 140) in the form of return activated sludge (RAS) through the
10 RAS pumps 142, 144, 146 and 148, then finally through the lines 150, 152, 154 and 156 respectively. Vessel 122 receives elemental oxygen attached to nitrogen molecules in the form of nitrate nitrogen (NO_3) and nitrite nitrogen (NO_2), which were derived mostly from the ammonia conversion process known as
15 nitrification, occurring within vessels 126 and 130 (aerobic reactor # 1 zone and aerobic reactor # 2 zone). The amount of dissolved oxygen in vessel 122 is maintained in the range of 0.3mg/l to 0.5mg/l. This is made possible by the recycling of MLSS from vessel 126 (aerobic reactor # 1 zone) using pump 158
20 and pumping through line 128, and vessel 130 (aerobic reactor # 2 zone) using pump 160 and pumping through line 132 into vessel 122.

The microorganisms contained within the wastewater of vessel 122 (anoxic selector zone) look for oxygen to
25 respire. With little dissolved oxygen available, the

WO 02/028780

PCT/US01/31411

microorganisms are forced to use the elemental oxygen in the NO_3 that is tied up with the nitrogen gas. This process is commonly called denitrification. Once the bond between the nitrogen and oxygen is broken, the microorganisms consume the elemental oxygen for respiration, allowing the nitrogen to be released into the atmosphere.

During the consumption of oxygen, through respiration in the denitrification process of vessel 122 (anoxic selector zone), the microorganisms also consume portions of organic matter in the form of total suspended solids that have been shredded and solubilized in the recirculation process of vessels 126, 130 (the aerobic reactor zones # 1 and # 2) so as to become more easily consumed by the microorganism population.

Aqueous total solids (TS) from vessel 122 (anoxic selector zone) flows via gravity through line 162 to vessel 126 (aerobic reactor # 1 zone) for continued treatment. The contents, by volume, of vessel 126 are recirculated substantially one time every two hours, using the recirculation conduit aeration system (RCAS), which is powered by pump 164. During the recirculation procedure the contents of vessel 126, the settleable solids, become solubilized by the means of shredding through the RCAS system of the vessel. Shredding occurs as the solids within the aqueous solution are processed through the RCAS system by the toroidal vortex

WO 02/028780

PCT/US01/31411

action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied through the RCAS system during recirculation so that the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or higher. Keeping the dissolved oxygen concentration at these levels allows the bacteria nitrosomonas and nitrobacter, residing in the microorganism colony, to oxidize ammonia (NH_3) into nitrite (NO_2) and finally into nitrate (NO_3) respectively. Individuals familiar in the art know this process as nitrification. With dissolved oxygen concentrations of this zone maintained at or above 3.5 mg/L, suspended solids and other organic matter are decomposed and oxidized into more stable compounds.

By using large volumes of atmospheric air delivered by the RCAS system and maintaining the dissolved oxygen at higher levels (well above 3.5 mg/L) than that which would be maintained by traditional systems (2.0 mg/L to 3.0 mg/L), along with long MCRT's, the microorganism colony will enter the biological life cycle mode known as endogenous respiration (ER). In this ER mode, the living microorganisms begin to oxidize some of their own cellular mass along with any new organic matter they absorb or adsorb from their environment. This aids in the enhancement of solids reduction while maintaining a microorganism colony through the adjustment of the food to microorganism (F/M) ratio to allow the rate of

WO 02/028780

PCT/US01/31411

death of the microorganisms to equal the rate of growth of the microorganisms through the ER process.

Another benefit of the delivery of intense aeration within this reactor is the consumption of some phosphorous by the microorganisms.

The flow exiting vessel 126 (aerobic reactor # 1 zone) exits through line 166 to vessel 130. Vessel 130 is used as an aerobic reactor # 2 zone (V#3), whereby the contents, by volume, of this vessel are recirculated and intensely aerated substantially one time every two hours using the re-circulation conduit aeration system (RCAS), which is powered by pump 168. The oxidation of both dissolved and suspended organic matter occur in this vessel by maintaining a DO level of at least 3.0 mg/l. The bacteria nitrosomonas and nitrobacter, residing in the microorganism colony, will oxidize organic nitrogen into ammonia (NH_3) then into nitrite (NO_2) and finally into nitrate (NO_3) respectively in this vessel. A portion of the nitrate rich MLSS is recycled using pump 160 through line 132 into vessel 122 (anoxic selector zone) for nitrogen reduction through the de-nitrification process.

A flow also exits via gravity through line 170 into line 172 before entering the clarification zone flow split box 174 (SB Clar Inf) for the settling of solids from the liquid portion of the wastewater.

WO 02/028780

PCT/US01/31411

Note that this alternate embodiment does not include a vessel (V#4) present in the preferred embodiment. This vessel is not used until the flow increases substantially necessitating the need for an additional aerobic reactor.

5 As the influent from line 172 enters the clarification zone split box 174 (SB Clar Inf) the flow is split into four equal portions and sent to each of the four clarifier vessels (134, 136, 138, 140) through line 176 for vessel 134 (Clarifier # 1), line 178 for vessel 136 (Clarifier # 2), line 10 180 for vessel 138 (Clarifier # 3) and line 182 for vessel 140 (clarifier # 4). The flow velocity is diminished as the flow enters each of the clarifiers, allowing the solids to settle into the bottom of each of the clarifier vessels. The settling solids are then dislodged from the cone walls by 15 using a hydraulically operated solids concentration inducer 184 for vessel 134, hydraulically operated solids concentration inducer 186 for vessel 136, hydraulically operated solids concentration inducer 188 for vessel 138, and hydraulically operated solids concentration inducer 190 for 20 vessel 140, allowing the solids to further thicken before being removed through each of the clarifier RAS pumps (142, 144, 146 and 148) and RAS lines (150, 152, 154 and 156) be and sent to vessel 122 (anoxic reactor zone) for further treatment. Separated liquid from the clarification process 25 exits vessel 134 (Clarifier # 1) through line 192, vessel 136

WO 02/028780

PCT/US01/31411

(Clarifier # 2) through line 194, vessel 138 (Clarifier # 3) through line 196 and vessel 140 (Clarifier # 4) through line 198 and join in the collection box 200 (CB Clar Eff). The clarifier effluent exits via line 202 as the final processed
5 effluent.

Referring now to Fig. 7, another alternate apparatus embodiment of the present invention is shown which employs alternate process embodiment # 2 to provide the processing characteristic of nitrification in conjunction with a plug
10 flow type flow characteristic. This alternate apparatus embodiment is to be used with alternate process embodiment # 2. Alternate process embodiment # 2 of the present invention is a method of processing that is zone specific and not vessel specific.

15 In accordance with the present invention shown in Fig. 7, the influent, represented as typical municipal wastewater, is directed through line 210 into vessel 212, which is an aerobic reactor # 1 zone. Other flows entering vessel 212 come from four clarifiers (214, 216, 218, 220) in the form of return
20 activated sludge (RAS) through RAS pumps (222, 224, 226 and 228) and are delivered to vessel 212 through lines 230, 232, 234 and 236 respectively.

The contents, by volume, of vessel 212 (aerobic reactor #1 zone) are recirculated substantially one time every two
25 hours, using the re-circulation conduit aeration system

WO 02/028780

PCT/US01/31411

(RCAS), which is powered by pump 238. During the recirculation procedure the contents of vessel 212, the settleable solids, become solubilized by means of shredding through the RCAS system. Shredding occurs as the solids within the aqueous solution are processed through the RCAS system by the toroidal vortex action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied through the RCAS system during recirculation so that the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or above. Keeping the dissolved oxygen concentration at these levels allows the bacteria nitrosomonas and nitrobacter, residing in the microorganism colony, to oxidize ammonia (NH_3) into nitrite (NO_2) and finally into nitrate (NO_3) respectively. Individuals familiar in the art know this process as nitrification. With dissolved oxygen concentrations of this zone maintained at or above 3.5 mg/L, suspended solids and other organic matter are decomposed and oxidized into more stable compounds.

By using large volumes of atmospheric air delivered by the RCAS system and maintaining the dissolved oxygen at higher levels (well above 3.5 mg/L) than that which would be maintained by traditional systems (2.0 mg/L to 3.0 mg/L), along with long MCRT's, the microorganism colony will enter the biological life cycle mode known as Endogenous Respiration

WO 02/028780

PCT/US01/31411

(ER). In this ER mode, the living microorganisms begin to oxidize some of their own cellular mass along with any new organic matter they absorb or adsorb from their environment. This aids in the enhancement of solids reduction while

5 maintaining a microorganism colony through the adjustment of the food to microorganism ratio (F/M) to allow the rate of death of the microorganisms to equal the rate of growth of the microorganisms through the ER process.

Another benefit of the delivery of intense aeration
10 within this reactor is the consumption of some phosphorous by the microorganisms.

The flow exits vessel 212 (aerobic reactor #1 zone) through line 239 into vessel 240 (aerobic reactor #2 zone-V#2) for further aerobic treatment. The contents, by volume, of
15 vessel 240 are recirculated substantially one time every two hours, using the re-circulation conduit aeration system (RCAS), which is powered by pump 242. During recirculation of the contents of vessel 240, additional intense aeration is applied and the level of dissolved oxygen is substantially
20 maintained at a concentration of 3.0 mg/L or above. Keeping the dissolved oxygen concentration at these levels allows microorganisms the ability to convert organic matter, including but not limited to total BOD, and also organic nitrogen first into ammonia, then nitrite and finally into

WO 02/028780

PCT/US01/31411

nitrate. This process reduces the concentrations of total nitrogen into less harmful compounds.

The flow exits vessel 240, preferably via gravity, through line 243 into line 244 before entering clarification zone flow split box 246 (SB Clar Inf) for the settling of solids from the liquid portion of the wastewater.

Note that additional aerobic reactor vessels described in the previous embodiments are not used in this embodiment until the flow increases substantially necessitating the need for additional aerobic reactors.

As the influent from line 244 enters the clarification zone splitter box 246 (SB Clar Inf), the flow is preferably split into four equal portions and sent to each of the four clarifiers (vessels 214, 216, 218, 220) through line 248 for vessel 214 (Clarifier # 1), line 250 for vessel 216 (Clarifier # 2), line 252 for vessel 218 (Clarifier # 3) and line 254 for vessel 220 (Clarifier # 4). The flow velocity is diminished as the flow enters each of the clarifiers, allowing the solids to settle into the bottom of each of the clarifiers. The settling solids are then dislodged from the walls by using a hydraulically operated solids concentration inducer 256 for vessel 214, hydraulically operated solids concentration inducer 258 for vessel 216, hydraulically operated solids concentration inducer 260 for vessel 218 and hydraulically operated solids concentration inducer 262 for vessel 220,

WO 02/028780

PCT/US01/31411

allowing the solids to further thicken before being removed through each of the clarifier RAS pumps (222, 224, 226 and 228) and RAS lines (230, 232, 234 and 236) and sent to vessel 212 (aerobic reactor # 1 zone) for further treatment.

5 Separated liquid from the clarification process, exits vessel 214 through line 264, vessel 216 through line 266, vessel 218 through line 268 and vessel 220 through line 270 and joins in the collection box 272 (CB Clar Eff). The clarifier effluent exits through line 274 as the final processed effluent.

10 Referring now to Fig. 8, another alternate embodiment of the present invention is shown which utilizes the alternate processing embodiment # 3 of the present invention to provide the processing characteristics of nitrification, de-nitrification and phosphorous reduction in conjunction with
15 using a step feed flow type flow characteristic, giving improved operational flexibility. The use of this alternate embodiment in conjunction with alternate processing embodiment # 3 would be preferable when there is a change in feed preferences or the parameters change and the effluent quality
20 needs to be improved. This would also hold true for influent nutrient load variations while the influent flow characteristics remain the same. Alternate processing embodiment # 3 of the present invention is a method of processing that is zone specific and not vessel specific.

WO 02/028780

PCT/US01/31411

For alternate process embodiment # 3, the influent is a high strength waste, which could contain a high concentration of NH_3 , with a high TSS concentration and a high total BOD concentration, while requiring nitrification, de-nitrification and phosphorous reduction as might need to be demonstrated by the influent concentrations of an industrial strength waste stream.

In the alternate embodiment shown in Fig. 8, influent containing suspended solids and biodegradable organic substances passes through line 280 to splitter box 282 (SB PLT Inf), where it is diverted, sending 60% of the total influent flow into vessel 284 (anaerobic conditioner zone-V #1) via line 286, 30% of the total influent flow through line 288 into the vessel 290 (aerobic reactor #1 zone-V #2) and 5% being diverted through line 292 to vessel 294 (anoxic selector zone-V #3) while the other 5% is diverted thorough line 296 to vessel 298 (aerobic reactor # 2 zone-V #4).

Vessel 284 receives 60% of the plant influent flow and a flow from vessel 294 through line 300 using pump 302 and line 304. The contents, by volume, of vessel 284 are recirculated substantially one time every two hours using pump 306.

Vessel 284 (anaerobic conditioner zone) begins the first stage of luxury phosphorous uptake, which is biological phosphorous (Bio-P) release. Luxury phosphorous uptake is accomplished by maintaining an oxygen deficient state within

WO 02/028780

PCT/US01/31411

vessel 284. Dissolved oxygen levels are maintained at or below 0.10 mg/L causing Bio-P release by the microorganisms. While this Bio-P release creates a temporary increase of phosphorous, it also forces the microorganisms to metabolize greater amounts of phosphorous during a later process. The contents of this zone are able to maintain low dissolved oxygen levels by the controlled introduction low oxygen level MLSS from vessel 294 (anoxic selector zone) from line 300 through pump 302 and through line 304 into vessel 284. The flow then continues on through line 308 to vessel 290 (aerobic reactor # 1 zone) for treatment.

As mentioned above, vessel 290 receives 30% of the plant influent flow through line 288 and is used as aerobic reactor # 1 zone. Another flow that enters this vessel comes from vessel 298 through line 310 using pump 312 then through line 314 discharging into vessel 290. The flow from vessel 298 (aerobic reactor #2 zone) is in the form of MLSS recycle. Still another flow entering vessel 290 comes from each of the four clarifier vessels (316, 318, 320, 322) in the form of return activated sludge (RAS) through the RAS pumps 324, 326, 328 and 330, and then finally through the lines 332, 334, 336 and 338 respectively. The contents, by volume, of vessel 290 are recirculated substantially one time every two hours, using the re-circulation conduit aeration system (RCAS), which is powered by pump 340. During the recirculation procedure the

WO 02/028780

PCT/US01/31411

contents of vessel 284, the settleable solids, become
solubilized by means of shredding as they pass through the
RCAS system of the vessel. The shredding occurs as the solids
within the aqueous solution are processed through the RCAS
5 system by the toroidal vortex action of the RCAS system so as
to become more easily consumed by the microorganism
population. Intense aeration is also applied during the
recirculation procedure so that the level of dissolved oxygen
is substantially maintained at a concentration of 3.5 mg/L or
10 above. Keeping the dissolved oxygen concentration at these
levels allows the bacteria nitrosomonas and nitrobactor,
residing in the microorganism colony, to oxidize ammonia (NH_3)
into nitrite (NO_2) and finally into nitrate (NO_3) respectively.
With dissolved oxygen concentrations in this zone at or above
15 3.5 mg/L, suspended solids and other organic matter are
decomposed and oxidized into more stable compounds. By using
large volumes of atmospheric air delivered by the RCAS system
and maintaining the dissolved oxygen at higher levels (above
3.0 mg/L) than that which would be maintained by traditional
20 aeration systems, along with long MCRT's, the microorganism
colony will enter the biological life cycle mode known as
endogenous respiration (ER). In this ER mode, the living
microorganisms begin to oxidize some of their own cellular
mass along with any new organic matter they absorb or adsorb
25 from their environment. This aids in the enhancement of

WO 02/028780

PCT/US01/31411

solids reduction while maintaining a microorganism colony through the adjustment of the food to microorganism (F/M) ratio to allow the rate of death of the microorganism colony to equal the rate of growth of the microorganism colony through the ER process.

Another benefit of the delivery of intense aeration within this reactor is the enhanced consumption of large amounts of phosphorous by the microorganisms. The amount of phosphorous taken up by the microorganisms is in greater amounts than the amount of phosphorous the microorganisms released in vessel 284 (anaerobic conditioner zone) as described above. The microorganisms then use this newly acquired phosphorous for new cell wall development and other energy needs.

The flow then exits vessel 290 (aerobic reactor # 1 zone) through line 342 into vessel 294 (anoxic selector zone) for further processing. In addition to the flow through line 342 from vessel 290, vessel 294 also receives an additional flow of 5% of the plant influent through line 292. The contents, by volume, of this vessel are recirculated substantially one time every two hours by pump 344. This anoxic selector zone receives elemental oxygen attached to nitrogen molecules in the form of nitrate nitrogen (NO_3) and nitrite nitrogen (NO_2), which were derived mostly from the ammonia conversion process known as nitrification occurring within vessel 290 (the

WO 02/028780

PCT/US01/31411

aerobic reactor # 1 zone). The amount of dissolved oxygen (DO) in vessel 294 is maintained in the range of 0.3mg/l to 0.5mg/l. The microorganisms contained within the wastewater of vessel 294 look for oxygen to respire. With little DO
5 available, the microorganisms are forced to use the elemental oxygen in the NO₃ that is tied up with nitrogen. This process is commonly called denitrification. Once the bond between the nitrogen and oxygen is broken, the microorganisms consume the elemental oxygen for respiration, allowing the nitrogen to be
10 released into the atmosphere. The microorganisms use this oxygen for the necessary respiration in order to continue consumption of organic matter still within the wastewater.

During this anoxic condition, a natural release of phosphorous by the microorganisms occurs, as a way to conserve
15 energy during the time of low dissolved oxygen availability, but in lesser quantities than occur in vessel 284 (anaerobic conditioner zone). While this creates a temporary, but slight, increase of phosphorous, it also forces the microorganisms to metabolize greater amounts of phosphorous in
20 a later process. The effluent from this process would continue through line 346 on to vessel 298 (aerobic reactor #2 zone) for further treatment.

In addition to the flow which enters the vessel 298 (aerobic reactor #2 zone) through line 346, a flow of 5% of
25 the plant influent is provided into vessel 298 through line

WO 02/028780

PCT/US01/31411

296. The contents, by volume, of this zone are recirculated and intensely aerated substantially one time every two hours using the re-circulation conduit aeration system (RCAS), which is powered by pump 348. The oxidation of both dissolved and
5 suspended organic matter occur in this vessel by maintaining a dissolved oxygen of at least 3.5 mg/l. The bacteria nitrosomonas and nitrobactor, residing in the microorganism colony, will oxidize organic nitrogen into ammonia (NH_3) then into nitrite (NO_2) and finally into nitrate (NO_3) respectively
10 in this vessel. As the aqueous solution containing the microorganism colony of vessel 298 is aerated and the dissolved oxygen increases, the microorganisms will also begin to consume phosphorous in larger quantities than is necessary for them to sustain life. The amount of phosphorous consumed
15 far exceeds the amount of phosphorous the microorganisms released into the aqueous solution while being processed within vessels 284 and 294 (anaerobic conditioner zone and anoxic selector zone). This is what is referred to in the industry as "luxury phosphorous uptake". Portions of the MLSS
20 from vessel 298 are recycled to vessel 290 (aerobic reactor # 1 zone), through line 310, using pump 312 and finally discharging through line 314, while the effluent continues on through line 350 and into line 352 before entering the clarification zone flow splitter box 354 (SB Clar Inf).

WO 02/028780

PCT/US01/31411

As the influent from line 352 enters the clarification zones splitter box 354, the flow is preferably split into four equal portions and sent to each of the four clarifiers (316, 318, 320, 322) through line 356 for vessel 316 (Clarifier # 1), line 358 for vessel 318 (Clarifier # 2), line 360 for vessel 320 (Clarifier # 3) and line 362 for vessel 322 (Clarifier # 4). The flow velocity is diminished as the flow enters each of the clarifiers, allowing the solids to settle into the bottom of each of the clarifiers. The settling solids are then dislodged from the walls of each clarifier vessel by using a hydraulically operated solids concentration inducer 364 for vessel 316 (Clarifier # 1), hydraulically operated solids concentration inducer 366 for vessel 318 (Clarifier # 2), hydraulically operated solids concentration inducer 368 for vessel 320, (Clarifier # 3), hydraulically operated solids concentration inducer 370 for vessel 322 (Clarifier # 4), allowing the solids to further thicken before being removed through each of the clarifier RAS pumps (324, 326, 328 and 330) and RAS lines (332, 334, 336 and 338) and sent to vessel 290 (aerobic reactor # 1 zone) for further treatment. Separated liquid from the clarification process, exits vessel 316 (Clarifier # 1) through line 372, vessel 318 (Clarifier # 2) through line 374, vessel 320 (Clarifier # 3) through line 376 and vessel 322 (Clarifier # 4) through line 378, and are combined in collection box 380 (CB Clar Eff).

WO 02/028780

PCT/US01/31411

The clarifier effluent exits through line 382 as the final processed effluent.

Referring now to Fig. 9, another alternate embodiment of the present invention is shown which utilizes an alternate process embodiment #4 to provide the processing characteristics of nitrification and de-nitrification in conjunction with using a step feed flow type flow characteristic. Alternate processing embodiment #4 of the present invention is a method of processing that is zone specific and not vessel specific.

For alternate process embodiment # 4, the influent is a high strength waste, which could contain a high NH_3 concentration, with a high TSS concentration and a high total BOD concentration, while requiring nitrification and de-nitrification for a total nitrogen reduction as might need to be demonstrated by the influent concentrations of an industrial strength waste stream.

Referring now to Fig. 9, an alternate embodiment of the present invention is shown wherein influent containing suspended solids and biodegradable organic substances, is passed through line 390 to splitter box 392 (SB PLT Inf), where it is diverted, sending 75% of the total influent flow through line 394 into vessel 396 (anoxic selector zone - V # 1), 15% of the total influent flow is diverted by splitter box 392 through line 398 into the vessel 400 (aerobic reactor #1

WO 02/028780

PCT/US01/31411

zone V # 2) and the remaining 10% of the total influent flow is diverted by splitter box 392 through line 402 to vessel 404 (aerobic reactor #2 zone V # 3).

Vessel 396 (V # 1) is used as an anoxic selector zone receiving 75% of the influent flow through line 394. An additional flow in the form of MLSS Recycle is received from vessel 404 (V # 3) through line 406, pump 408 and line 410. Dissolved oxygen in vessel 396 is kept at a level below 0.5 mg/L for denitrification. Vessel 396 is rich in aerobic microorganisms and combined oxygen in the form of nitrate received from vessel 404. With the levels of dissolved oxygen in the 0.5 mg/L range, the aerobic microorganisms are forced to use nitrate for respiration thus being used for the purpose of denitrification of the wastewater prior to continuing on to further processing.

The influent flow received through line 390 is rich in nutrients, while the flow received through line 410 from vessel 404 is rich in nitrate and microorganisms. Therefore, in step feeding a portion of the influent flow into this vessel, the organic load entering the plant can be increased without any alterations to the current design of the preferred apparatus embodiment of the present invention. The contents, by volume of vessel 396 are recirculated one time every two hours by pump 412. Flow exits vessel 396 through line 414 into vessel 400 for further treatment.

WO 02/028780

PCT/US01/31411

Vessel 400 (V # 2) is used as an aerobic reactor # 1 zone, receiving 15% of the total influent flow through line 398 and flow from vessel 396 through line 414. Additional flow comes from each of the clarifiers (416, 418, 420, 422) in the form of return activated sludge (RAS). The contents, by volume, of this vessel are recirculated substantially one time every two hours, using the re-circulation conduit aeration system (RCAS), which is powered by pump "424". During the recirculation procedure the contents of vessel 400, the settleable solids, become solubilized by means of shredding as they pass through the RCAS system of the zone. The shredding occurs as the solids within the aqueous solution are processed through the RCAS system by the toroidal vortex action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied during the recirculation procedure so that the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or above. Keeping the dissolved oxygen concentration at these levels allows the bacteria nitrosomonas and nitrobacter, residing in the microorganism colony, to oxidize ammonia (NH_3) into nitrite (NO_2) and finally into nitrate (NO_3) respectively. Individuals familiar in the art know this process as nitrification.

With dissolved oxygen concentrations in this zone at or above 3.5 mg/L, suspended solids and other organic matter are

WO 02/028780

PCT/US01/31411

decomposed and oxidized into more stable compounds. This
initial decomposition of organic matter, which is the breaking
down of organic matter from complex forms to more simple
forms, mainly through the digestion action of aerobic
5 bacteria.

By using large volumes of atmospheric air delivered by
the RCAS system and maintaining the dissolved oxygen at higher
levels (above 3.5 mg/L) than that which would be maintained by
traditional aeration systems, along with long MCRT's, the
10 microorganism colony will enter the biological life cycle mode
known as endogenous respiration (ER). In this ER mode, the
living microorganisms begin to oxidize some of their own
cellular mass along with any new organic matter they absorb or
adsorb from their environment. This aids in the enhancement
15 of solids reduction while maintaining a microorganism colony
through the adjustment of the food to microorganism (F/M)
ratio to allow the rate of death of the microorganism colony
to equal the rate of growth of the microorganism colony
through the ER process. The flow exits vessel 400 (aerobic
20 reactor # 1 zone) through line 426 to vessel 404 (aerobic
reactor #2 zone V # 3). An additional 10% of the influent
flow enters vessel 404 (V # 3) from the splitter box 392 (SB
PLT Inf) through line 402.

The contents, by volume, of vessel 404 is recirculated
25 and intensely aerated substantially one time every two hours

WO 02/028780

PCT/US01/31411

using the re-circulation conduit aeration system (RCAS), which is powered by pump 428. During the recirculation of the contents of vessel 404, the settleable solids become further solubilized by the means of shredding through the

5 recirculation pumping of the zone so as to become further consumed by the microorganism population. Intense aeration is also applied during recirculation so that the level of dissolved oxygen is substantially maintained at a concentration of 3.0 mg/L or above. The bacteria nitrosomonas

10 and nitrobacter, residing in the microorganism colony, will oxidize organic nitrogen into ammonia (NH_3) then into nitrite (NO_2) and finally into Nitrate (NO_3) respectively in this zone.

Keeping the dissolved oxygen concentration at levels above 3.5 mg/L allows the microorganism colony the ability to

15 convert organic matter, including but not limited to additional total BOD, along with additional organic nitrogen first into ammonia, then nitrite and finally into nitrate and other less harmful compounds. This process reduces the concentrations of total nitrogen released into the aquatic

20 environment through the denitrification process. The dissolved oxygen in vessel 404 (aerobic reactor # 2 zone) maintains a concentration of at least 3.5 mg/L to ensure complete decomposition and oxidation of the organic nutrients within the waste stream.

WO 02/028780

PCT/US01/31411

Portions of the contents of vessel 404 is recycled to vessel 396 (anoxic selector zone) in the form of MLSS recycle in line 406 using pump 408 and finally through in line 410. The MLSS, which is rich in aerobic microorganisms and combined oxygen, is denitrified in vessel 396 prior to returning to the vessels 400, 404 for continued treatment of remaining nutrients.

The Effluent from this processes exits vessel 404 through line 430 into line 432 for the clarification process. As the influent from line 432 enters the clarification zone splitter box 434 (SB Clar Inf) the flow is preferably split into four equal portions and sent to each of the four clarifiers (416, 418, 420, 422) through line 436 for vessel 416 (clarifier # 1), line 438 for vessel 418 (clarifier # 2), line 440 for vessel 420 (clarifier # 3) and line 442 for vessel 422 (clarifier # 4). The flow velocity is diminished as the flow enters each of the clarifiers, allowing the solids to settle into the bottom of each of the clarifiers. The settling solids are then dislodged from off of the cone walls by using a hydraulically operated solids concentration inducer 444 for vessel 416, hydraulically operated solids concentration inducer 446 for vessel 418, hydraulically operated solids concentration inducer 448 for vessel 420, hydraulically operated solids concentration inducer 450 for vessel 422 allowing the solids to further thicken before being removed

WO 02/028780

PCT/US01/31411

through each of the clarifiers RAS pumps (452, 454, 456, 458) and RAS lines (460, 462, 464, 466) and sent to vessel 400 (aerobic reactor # 1 zone) for further treatment. Separated liquid from the clarification process, exits vessel 416
5 through line 468, vessel 418 through line 470, vessel 420 through line 472 and vessel 422 through line 474 and join in the collection box 476 (CB Clar Eff). This clarifier effluent exits through line 478 as the final processed effluent.

The alternate embodiment as depicted in Fig. 10 shows the
10 unutilized lines, vessels and equipment of the Preferred Apparatus Embodiment removed. However, all the utilized lines, vessels and equipment required to process the wastewater flow using alternate process embodiment # 4 are shown.

15 Referring now to Fig. 10, an alternate apparatus embodiment of the present invention is shown which utilizes the alternate process embodiment # 5 of the present invention to provide the processing characteristics of nitrification in conjunction with using a step feed flow type flow
20 characteristic. Alternate processing embodiment # 5 of the present invention is a method of processing that is zone specific and not vessel specific.

For alternate process embodiment # 5, the influent is represented as a high strength waste which could contain a
25 high NH_3 concentration, with a high TSS concentration and a

WO 02/028780

PCT/US01/31411

high total BOD concentration, while requiring nitrification as might need to be demonstrated by the influent concentrations of an industrial strength waste stream.

In the present alternate embodiment of Fig. 10 the
5 influent containing suspended solids and biodegradable organic substances passes through line 500 to splitter box 502 (SB PLT Inf), where it is diverted. 50% of the total influent flow is provided into the vessel 504 (aerobic reactor # 1 zone-V#1) via line 506, 30% of the total influent flow is diverted
10 through the splitter box 502 (SB PLT Inf) through line 508 into the vessel 510 (aerobic reactor # 2 zone-V#2) and the remaining 20% of the influent is diverted by the splitter box 502 (SB PLT Inf) through line 512 to vessel 532 (aerobic reactor # 3 zone-V#3).

15 As stated above, the vessel 504 is used as aerobic reactor # 1 zone, receiving 50% of the total influent flow. Additional flows come from each of the clarifiers (516, 518, 520, 522) in the form of return activated sludge (RAS). The contents, by volume, of vessel 504 are recirculated
20 substantially one time every two hours, using the recirculation conduit aeration system (RCAS), which is powered by pump 524. During the recirculation procedure the contents of the vessel 504, the settleable solids, become solubilized by means of shredding as they pass through the RCAS system of
25 the vessel. The shredding occurs as the solids within the

WO 02/028780

PCT/US01/31411

aqueous solution are processed through the RCAS system by the toroidal vortex action of the RCAS system so as to become more easily consumed by the microorganism population. Intense aeration is also applied during the recirculation procedure so
5 that the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or above. Keeping the dissolved oxygen concentration at these levels allows the bacteria nitrosomonas and nitrobacter, residing in the microorganism colony, to oxidize ammonia (NH_3) into nitrite
10 (NO_2) and finally into nitrate (NO_3) respectively. Individuals familiar in the art know this process as nitrification.

With dissolved oxygen concentration levels in this zone at or above 3.5 mg/L, suspended solids and other organic matter, including but not limited to carbonaceous BOD, are
15 decomposed and oxidized into more stable compounds. This initial decomposition of organic matter, which is the breaking down of organic matter from complex forms to simpler forms, occurs mainly through the digestion action of aerobic bacteria.

20 By using large volumes of atmospheric air delivered by the RCAS system and maintaining the dissolved oxygen at higher levels (above 3.5 mg/L) than that which would be maintained by traditional aeration systems, along with long MCRT's, the microorganism colony will enter the biological life cycle mode
25 known as Endogenous Respiration (ER). In this ER mode, the

WO 02/028780

PCT/US01/31411

living microorganisms begin to oxidize some of their own cellular mass along with any new organic matter they absorb or adsorb from their environment. This aids in the enhancement of solids reduction while maintaining a colony through
5 adjusting the food to microorganism ratio to allow the rate of death of the microorganisms to equal the rate of growth of the microorganisms through ER.

Another benefit of the intense aeration within this vessel is the consumption of some phosphorous by the
10 microorganisms.

The flow exits vessel 504 (the aerobic reactor # 1 zone) through line 526 and is provided into vessel 510 for further aerobic treatment.

The flow enters vessel 510 from vessel 504 along with 30%
15 of the plant influent flow which is provided by line 508. Vessel 510 is used as an aerobic reactor # 2 zone. The contents, by volume, of this vessel are recirculated substantially one time every two hours, using the recirculation conduit aeration system (RCAS), which is powered
20 by pump 528. During the recirculation procedure the contents of vessel 510 (the aerobic reactor # 2 zone), the settleable solids, become solubilized by means of shredding as they pass through the RCAS. Another benefit of the RCAS system of vessel 510 (aerobic reactor # 2 zone) is additional intense
25 aeration being applied and the level of dissolved oxygen is

WO 02/028780

PCT/US01/31411

substantially maintained at a concentration of 3.5 mg/L or above. Keeping the dissolved oxygen concentration at these levels gives the microorganism colony the ability to convert organic matter, including but not limited to total BOD.

5 Organic nitrogen is also converted, first into ammonia, then nitrite and finally into nitrate. This process reduces the concentrations of total nitrogen and total BOD into less harmful compounds. Once again, microorganisms consume additional amounts of phosphorous reducing the phosphorous
10 concentrations in the system.

The flow exits vessel 510 (aerobic reactor # 2 zone) through line 530 and is provided into vessel 532 (aerobic reactor #3 zone). Flow also enters vessel 532 from the splitter box 502 (10% of the plant influent flow via line
15 512). The contents, by volume, of vessel 532 are recirculated substantially one time every two hours, using the recirculation conduit aeration system (RCAS), which is powered by pump 534. During the recirculation procedure the contents of vessel 532, the settleable solids, become solubilized by
20 means of shredding as they pass through the RCAS system.

Another benefit of the RCAS system of vessel 532 is additional intense aeration being applied and the level of dissolved oxygen is substantially maintained at a concentration of 3.5 mg/L or above. Keeping the dissolved oxygen concentration at
25 these levels gives the microorganism colony the ability to

WO 02/028780

PCT/US01/31411

convert organic matter, including but not limited to total BOD. This process reduces the concentrations total BOD into less harmful compounds. Once again, unavoidably, the microorganisms consume additional amounts of phosphorous.

5 The flow exits vessel 532 via gravity through line 536 into line 538 before entering the clarification zone flow splitter box 540 (SB Clar Inf.) for the settling of the solids portion from the liquid portion of the wastewater.

As the influent from line 538 enters the clarification zone splitter box 540 (SB Clar Inf) the flow is preferably split into four equal portions and sent to each of the four clarifiers (516, 518, 520, 522) through line 542 for vessel 516 (Clarifier # 1), line 544 for vessel 518 (Clarifier # 2), line 546 for vessel 520 (Clarifier # 3) and line 548 for vessel 522 (Clarifier # 4). The flow velocity is diminished as the flow enters each of the clarifier vessels, allowing the solids to settle into the bottom of each of the clarifier vessels. The settling solids are then dislodged from the cone walls by hydraulically operated solids concentration inducer 550 for vessel 516 (Clarifier # 1), hydraulically operated solids concentration inducer 552 for vessel 518 (Clarifier # 2), hydraulically operated solids concentration inducer 554 for vessel 520 (Clarifier # 3) and hydraulically operated solids concentration inducer 556 for vessel 522 (Clarifier # 4), allowing the solids to further thicken before being

WO 02/028780

PCT/US01/31411

removed through each of the clarifier RAS pumps (558, 560, 562, 564) and RAS lines (566, 568, 570, 572) and sent to vessel 504 (aerobic reactor # 1 zone) for further treatment. Separated liquid from the clarification process, exits vessel 5 516 through line 574, vessel 518 through line 576, vessel 520 through line 578 and vessel 522 through line 580 and join in the collection box 582 (CB Clar Eff). The clarifier effluent exits through line 584 as the final processed effluent.

10 Re-Circulation Aeration System (RCAS)

Referring now to Fig. 15, one of the main components of the enhanced solids reduction wastewater treatment process of the present invention is shown. The RCAS is an efficient means of shredding, mixing, agitating, circulating, aerating, 15 homogenizing and saturating the wastewater, with each of the aforementioned employed, as the demand requires. The RCAS is a type of conduit conveyance system that takes the contents of a vessel through a mechanical pump creating a high velocity flow of the vessel contents through a differential injector, 20 which is preferably located on the exterior portion of each vessel for ease of maintenance. The air passing through the differential injector is injected into the wastewater treatment flow which is then returned back to the vessel. As the contents of the vessel pass through the RCAS system, a 25 shredding of organic solids occurs such that the organic

WO 02/028780

PCT/US01/31411

solids become solubilized and homogenized for easier digestion by microorganisms. Another benefit of the RCAS system is the destruction of pathogenic microorganisms by the toroidal vortex action at the discharge of the device (in line injector/mixer/aerator) creating agitation.

The RCAS includes a suction side conduit 600 coupled to the suction side of a pump 602, a discharge side conduit 604 that contains within it an in-line injector/mixer/aerator 606 such as the one described in USP 5,893,641, (the entire disclosure of which is incorporated herein by reference), an air/oxygen supply source conduit 608 and a delivery conduit 610. The pump 602 evacuates the wastewater from the vessel 612 containing aqueous solution delivering it through the conduit 600 to the aerator 606 for mixing, aeration and agitation. The wastewater is then returned to vessel 612 via conduit 610 where the excess atmospheric air that is entrapped within the bubbles traveling along with the wastewater within conduit 610 are released causing a secondary aeration, agitation and mixing effect to the wastewater contained within vessel 612. During the wastewater's travel, it is passed through an aerator 606, as shown in FIG. 15, where atmospheric air is drawn in by vacuum (venturi effect). The wastewater and atmospheric air are mixed at the discharge of the in-line aerator 608 and while they are encapsulated within the conduit 610, saturating the wastewater with oxygen. The aerator 606

WO 02/028780

PCT/US01/31411

may be the aerator as shown in USP 5,893,641 or any other
aerator device of similar performance, such as any of the
aerators shown in pending PCT Application Serial No.
PCT/US01/11936, or U.S. Application Serial No. 09/547,447, the
5 entire disclosures of which are incorporated herein by
reference.

The oxygen saturated mixed wastewater travels through the
conduit 610, and then is discharged back into the vessel 612.
Carried along with the saturated wastewater within the conduit
10 610 are excess bubbles of atmospheric air that were injected
into the wastewater stream, over and above the quantity
required for the complete saturation of the wastewater
traveling within the conduit 610. When the excess air is
discharged from the conduit 610 into the vessel, along with
15 the saturated wastewater, the excess air becomes a source of
additional air delivered to the contents of vessel 612, and
thereby furthering the aeration process of the entire contents
of the vessel by providing additional oxygen supply to be
absorbed by the not as yet re-circulated contents of the
20 vessel.

An alternate flow of some or all of the wastewater
through conduit 614 would enable additional controls to be
available for diminishing the aeration while continuing with
the mixing capabilities of the system.

WO 02/028780

PCT/US01/31411

Under certain conditions, induced pressures can be produced by adding resistance to the delivery conduits with restrictions or friction losses (i.e. conduit size reductions) fittings, valves, nozzles, etc.

- 5 For certain conditions regarding conduit 610, such as in the case of specific conduit size requirements, specific conduit length requirements, where the installation of the RCAS system is limited to confined parameters that do not meet the design requirements for the aeration or mixing process,
- 10 induced pressures can be produced within the conduit 610 that would provide compensation to the environment within conduit 610. These compensations in the design of conduit 610 would equal characteristics of a conduit of different diameter, length or desired pressure contained within such conduit so as
- 15 to deliver the specific aeration criteria desired. The compensations that would be contemplated are represented by the addition of valves, fittings, in-line mixers, a reduction or increase of conduit diameter, or the inclusion of a restriction, such as an orifice, in the conduit 610.
- 20 Through the re-circulation events, oxygen transfer abilities and creation of micro-bubbles by the RCAS system, a reduction in power consumption is achieved over traditional aeration systems, which use blowers and compressors. These efficiencies of the RCAS allow the present invention to use a
- 25 smaller footprint for total plant design.

WO 02/028780

PCT/US01/31411

Bubbles

Aeration of an aqueous solution is important to aerobic digestion of biological nutrients. The smaller the bubble, the greater the aerobic digestion activity of the bacteria and other microorganisms, due to the respiration of easily accessible dissolved oxygen. With these two facts in mind, the best possible forms of bubbles to deliver are micro-bubbles. These are provided by the RCAS System of the present invention.

Oxidative biological and chemical processes in aqueous environments are limited by the low solubility of oxygen in water. This physical limitation as defined by Henry's Law states that when the temperature is kept constant, the amount of a gas that dissolves into a liquid is proportional to the pressure exerted by the gas on the liquid. In the use of the RCAS system, the pressure of the gas and liquid are increased beyond atmospheric pressure so as to increase the amount of gaseous oxygen able to be dissolved in wastewater.

The solubility of oxygen in pure water is only about 10 parts per million (ppm) at ambient temperatures and at one atmosphere pressure.

For most aerobic bioprocesses, dissolved oxygen is quickly consumed so that replenishing it becomes the factor that limits the rate of the process. Therefore, a most

WO 02/028780

PCT/US01/31411

critical component of a bioprocess design is the means for the mass transfer of oxygen into the liquid phase of the process. For an actively respiring culture of bacteria, oxygen in the liquid medium must be replaced as needed at a sufficient rate to keep up with the oxygen demand of the bacteria. With the RCAS system used in the present invention, the dissolved oxygen is replenished at a rate that exceeds the oxygen demand of the bacteria.

Water is typically aerated by providing contact surfaces between the gaseous and liquid phases. This can be done either by introducing a source of oxygen into a bulk liquid phase or by flowing dispersed water through a bulk gaseous (air) phases. Regardless of whether the gaseous or liquid phases dominate the oxygenation process, the mass transfer of oxygen, or other gas, is accomplished by introducing gas bubbles into the liquid phase. The efficiency of gas-liquid mass transfer depends to a large extent on the characteristics of the bubbles. Bubble behavior strongly affects the following mass-transfer parameters of:

- (a) Transfer of oxygen from the interior of the bubble to the gas-liquid interface;
- (b) Movement of oxygen across the gas-liquid interface; and
- (c) Diffusion of oxygen through the relatively stagnant liquid film surrounding the bubble.

WO 02/028780

PCT/US01/31411

It is generally agreed that a most important property of air bubbles in a bioprocess is their size. For a given volume of gas, more interfacial area between the gas phase and liquid phase is provided if the gas is dispersed into many small
5 bubbles rather than a few large ones. Small bubbles, 1-3 mm, have been shown to have the following beneficial properties not shared by larger bubbles.

Small gas bubbles rise more slowly than large bubbles, allowing more time for a gas to dissolve in the aqueous phase.
10 This property is referred to as gas hold-up, concentrations of oxygen in water can be more than doubled beyond Henry's Law solubility limits. For example, after a saturation limit of 10 ppm oxygen is attained, at least another 10 ppm oxygen within small bubbles would be available to replenish the oxygen.

15 Once a bubble has been formed, the major barrier for oxygen transfer to the liquid phase is the liquid film surrounding the bubble. Biochemical engineering studies have concluded that transport through this film becomes the rate-limiting step in the complete process, and controls the
20 overall mass-transfer rate. However, as bubbles become smaller, this liquid film thickness decreases so that the transfer of gas into the bulk liquid phase is no longer impeded.

When air is introduced by means of a vacuum, as with the
25 RCAS system, at a velocity and volume equal to the flow of an

WO 02/028780

PCT/US01/31411

aqueous solution through a pump, the formation of micro bubbles occurs. These micro bubbles have the size necessary to remain in suspension through the action of gas hold-up, thus increasing the dissolved oxygen concentration beyond the
5 needs of the bacteria.

Uniqueness of the Invention

1) The present invention operates in biological processing ranges that differ from traditional wastewater
10 treatment systems.

The present invention utilizes a Mean Cell Residence Time (MCRT) ranging from 30 days to over 150 days, while the traditional systems cannot achieve such high residency.

The Food to Microorganism (F/M) ratio sustained by the
15 current invention, supporting its efficiency values, are substantially in the 0.05 to 0.80 range, versus a restricted ratio range as recorded with various traditional systems.

The present invention uses a wastewater treatment plant with a unique design so as to treat the total BOD portion of
20 the wastewater using less energy by the plant's processing operation. This treatment is designed to significantly reduce, if not eliminate, all biodegradable solids. The unique process is able to perform at such an efficient level due to the effectiveness of the aeration and recirculation
25 processing introduced throughout the treatment cycles.

WO 02/028780

PCT/US01/31411

A traditional wastewater treatment plant's design objective is to physically remove as much of the solid materials from the influent flow as possible and to ultimately dispose or waste the solids removed from the treatment system off premises. The balance of the wastewater is treated by various means to varying degrees of cleanliness, appropriately meeting the levels required for the discharge.

2) The current invention uses a clarification vessel design with a conical shaped vessel bottom in which to collect the settled solids without the use of mechanical means to concentrate the settled solids.

Wastewater within the vessel is made to rotate at a sufficiently slow velocity to cause the sludge to settle, while not providing an opportunity for the sludge to adhere to the side of the cone shaped bottom. The velocity of the rotating solids remain slow enough to allow them to settle and not remain in suspension. This is accomplished by means of a solids accumulator induction system used in the clarifier for a controlled rotational travel of the vessels liquid.

A traditional clarifier has a mechanical device to transport the sludge into the sludge pump's sump area for removal. The mechanical means consist of a motor, gear reducer, rake arm, blade and scraper squeegees and a skimmer arm.

WO 02/028780

PCT/US01/31411

3) The present invention (in the preferred apparatus embodiment) substantially utilizes typical vessel construction and outfitting. This allows for changes in vessel utilization for different processes. All of the vessels are substantially of the same size and shape to allow the vessels to be used as a single processing zone. An example of use as a single processing zone would be using all the vessels as aerobic reactors during start-up procedures. All the vessels are substantially plumbed the same, and have substantially the same capabilities (if so desired). The system has built-in redundancy capabilities in that each of the vessels being of the same size and shape allows for any one of the vessels to be used for any process, which is desirable during times of maintenance. Vessel and plumbing configuration is such that any processing zone has the ability to be expanded incrementally by simply duplicating a process vessel and plumbing as necessary to satisfy performance and/or discharge permit requirements. With plumbing and vessel configuration, allowances are available for a choice of vessel processing utilization with little or no operational shutdowns. Simple valve changes make this possible.

4) The present invention utilizes the RCAS system's velocity, volume and direction of flow, at its discharge point into the vessel, to regulate the rotational speed and travel time for mixing and/or settling of solids in each zone. For

WO 02/028780

PCT/US01/31411

example, an aerobic reactor could be converted into an aerobic digester by:

Isolating the aerobic reactor from the system and aerating the contents while holding the contents for complete digestion of solids.

Slowing the rotational velocity in the anoxic selector so as to allow solids to settle for transfer to the anaerobic conditioner.

Slowing the rotational velocity in the anaerobic conditioner so as to allow solids to settle for transfer to the aerobic digester.

Holding the contents of the aerobic digester while aerating so as to nearly complete the digestion of organic matter.

Stopping the aerobic digestion action, allowing any inorganic matter to settle to the cone bottom and then removing any inorganic matter for disposal.

Starting the process once again for continued digestion of organic solids.

Upon completion of all organic digestion, the aerobic digester can be returned into service as an aerobic reactor.

5) The present invention reduces the number of pathogenic organisms within a wastewater through the use of the RCAS system. This occurs as the turbulence and agitation within the toroidal vortex of the RCAS device creates a violent

WO 02/028780

PCT/US01/31411

action, sheering the cell membrane of bacteria such as e. coli and fecal coliform allowing the electron acceptors of the bacteria to be used by oxygen which then oxidizes the bacteria killing it.

5 Although illustrative embodiments of the present invention have been described herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to these precise embodiments, and that various other changes and modifications may be effected
10 therein by one of ordinary skill in the art without departing from the scope or spirit of the invention. For example, the use of square or rectangular processing vessels having flat or slopped bottoms, as is the case in traditional processing vessels are able to be used with effectiveness by the RCAS
15 system. The biological process of the present invention functions with sufficient circulation, agitation, aeration and homogenization apart from the RCAS system.

WO 02/028780

PCT/US01/31411

WHAT IS CLAIMED:

1. A process for the treatment of an aqueous solution containing waste comprising the steps of:
 - providing an influent wastewater stream to an anaerobic conditioner zone within which aqueous total solids are
 - 5 re-circulated, mixed and kept in suspension;
 - providing low oxygen level mixed liquor suspended solids from an anoxic selector zone to the anaerobic conditioner zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;
 - 10 providing an outflow from the anaerobic conditioner zone to a first aerobic reactor zone, the anaerobic conditioner zone outflow being mixed in the first aerobic reactor zone with return activated sludge from a clarification zone whereby contents of the first aerobic reactor zone are re-circulated and
 - 15 aerated, and whereby settleable solids present in the contents of the first aerobic reactor zone are fractionalized, thereby decomposing and oxidizing the solids and other organic matter and accumulating inert solids;
 - discharging the accumulated inert solids from the first
 - 20 aerobic reactor zone;

WO 02/028780

PCT/US01/31411

providing an outflow of aqueous solution from the first aerobic reactor zone to the anoxic selector zone wherein the aqueous solution in the anoxic selector zone is re-circulated and mixed;

25 transferring a first portion of the anoxic selector zone aqueous solution corresponding to the low oxygen level/mixed liquor suspended solids to the anaerobic conditioner zone, and a second portion of the anoxic selector zone aqueous solution to a second aerobic reactor zone;

30 recirculating and aerating aqueous solution contained in the second aerobic reactor zone whereby settleable solids become fractionalized thereby decomposing and oxidizing suspended solids and other organic matter;

 providing a first portion of the second aerobic reactor
35 zone aqueous solution to the first aerobic reactor zone;

 providing a second portion of the second aerobic reactor zone aqueous solution to the clarification zone to settle or separate solids from the aqueous solution contained therein;

 providing the settled or separated solids from the
40 clarification zone, corresponding to return activated sludge, to the first aerobic reactor zone;

WO 02/028780

PCT/US01/31411

providing aqueous solution of the clarification zone to a filtration zone to settle or separate solids from the aqueous solution provided thereto; and

45 transferring a liquid portion of an outflow of the filtration zone to a discharge receptacle, and the settled or separated solids portion of the outflow of the filtration zone to the influent wastewater stream for re-processing.

2. A process for the biological treatment of an aqueous solution containing waste to reduce organic material, nitrogen and phosphorous, comprising the steps of:

5 providing an influent wastewater stream, which includes microorganisms, to an anaerobic conditioner zone within which aqueous total solids are re-circulated, mixed and kept in suspension, wherein a first stage of luxury phosphorous uptake is accomplished by regulating a flow of low oxygen level mixed
10 liquor suspended solids from an anoxic selector zone to the anaerobic conditioner zone to maintain a low dissolved oxygen level within the anaerobic conditioner zone;

providing an outflow from the anaerobic conditioner zone to a first aerobic reactor zone, the anaerobic conditioner zone
15 outflow being mixed in the first aerobic reactor zone with return activated sludge received from a clarification zone

WO 02/028780

PCT/US01/31411

whereby contents of the first aerobic reactor zone are re-circulated and aerated and whereby nitrification occurs and settleable solids present in the contents of the first aerobic reactor zone are fractionalized, thereby decomposing and oxidizing suspended solids and other organic matter along with enhancing a second stage of luxury phosphorous uptake and accumulating inert solids;

discharging the accumulated inert solids from the first aerobic reactor zone;

providing an outflow of aqueous solution from the first aerobic reactor zone to the anoxic selector zone wherein the aqueous solution in the anoxic selector zone is re-circulated and mixed, and causing a low oxygen environment to exist within the anoxic selector zone such that denitrification and release of biological phosphorous occurs along with the consumption of organic matter contained within the aqueous solution;

transferring a first portion of anoxic selector zone aqueous solution corresponding to low oxygen level/mixed liquor suspended solids to the anaerobic conditioner zone and a second portion of the anoxic selector zone aqueous solution to a second aerobic zone, at least the second portion of the anoxic selector zone aqueous solution being rich in microorganisms and nutrients;

WO 02/028780

PCT/US01/31411

40 re-circulating and aerating aqueous solution contained in
the second aerobic reactor zone whereby nitrification occurs and
settleable solids become fractionalized thereby decomposing and
oxidizing suspended solids and other organic matter, and further
enhancing the second stage of luxury phosphorous uptake
45 resulting in a consumption of a large amount of phosphorous by
the microorganisms;
providing a first portion of the second aerobic reactor
zone aqueous solution to the first aerobic reactor zone;
providing a second portion of the second aerobic reactor
50 zone aqueous solution to the clarification zone to settle or
separate solids from the aqueous solution provided thereto;
providing the settled or separated solids from the
clarification zone to the first aerobic reactor zone as return
activated sludge;
55 providing aqueous solution of the clarification zone to a
filtration zone to settle or separate solids from the aqueous
solution provided thereto; and
transferring a liquid portion of an outflow of the
filtration zone to a discharge receptacle and the settled or
60 separated solids portion of the outflow of the filtration zone
to the influent wastewater stream for re-processing.

WO 02/028780

PCT/US01/31411

3. Apparatus for the treatment of an aqueous solution
containing waste comprising:

an anaerobic conditioner zone fluidly coupled to an inlet,
the anaerobic conditioner zone receiving an influent wastewater
5 stream through the inlet, the anaerobic conditioner zone re-
circulating the wastewater contained therein such that aqueous
total solids are kept in suspension, the anaerobic conditioner
zone receiving a flow of low oxygen level mixed liquor suspended
solids from an anoxic selector zone to maintain a low dissolved
10 oxygen level within the anaerobic conditioner zone;

a first aerobic reactor zone fluidly coupled to the
anaerobic conditioner zone, the first aerobic reactor zone
receiving an outflow of the anaerobic conditioner zone which is
mixed with return activated sludge received from a clarification
15 zone whereby contents of the first aerobic reactor zone are re-
circulated and aerated and whereby settleable solids become
fractionalized thereby decomposing and oxidizing suspended
solids and other organic matter, the first aerobic reactor zone
accumulating inert solids, the accumulated inert solids being
20 discharged from the first aerobic reactor zone;

an anoxic selector zone fluidly coupled to the anaerobic
conditioner zone and the first aerobic reactor zone, the anoxic

WO 02/028780

PCT/US01/31411

selector zone receiving an outflow of aqueous solution from the first aerobic reactor zone, aqueous solution within the anoxic selector zone being re-circulated and mixed, a first portion of the anoxic selector zone aqueous solution, corresponding to the low oxygen level/mixed liquor suspended solids, being provided to the anaerobic conditioner zone;

a second aerobic reactor zone fluidly coupled to the anoxic selector zone and the first aerobic reactor zone, the second aerobic reactor zone receiving a second portion of the anoxic selector zone aqueous solution wherein the aqueous solution within the second aerobic zone is re-circulated and aerated whereby settleable solids become fractionalized, a first portion of the aqueous solution of the second aerobic reactor zone being provided to the first aerobic reactor zone;

a clarification zone fluidly coupled to the second aerobic zone and the first aerobic zone, the clarification zone receiving a second portion of the second aerobic reactor zone aqueous solution, whereby settling or separating and capturing of solids from the aqueous solution occurs, and the settled solids, corresponding to return activated sludge, are provided to the first aerobic reactor zone; and

a filtration zone fluidly coupled to the clarification zone, the inlet, and an outlet, the filtration zone receiving an

WO 02/028780

PCT/US01/31411

outflow from the clarification zone to separate solids from the liquid portion of the contents of the clarification zone, a first portion of the contents of the filtration zone, which corresponds to effluent, being provided to the outlet, and a
50 second portion of the contents of the filtration zone, which corresponds to separated solids, being provided to the inlet and being combined with the influent wastewater stream for re-processing.

WO 02/028780

PCT/US01/31411

1/25

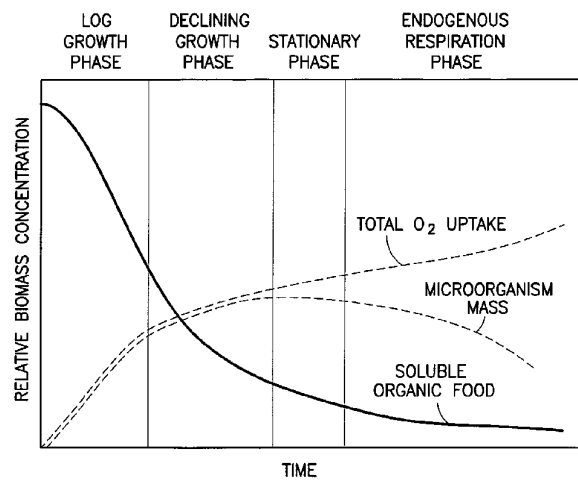


FIG.1

SUBSTITUTE SHEET (RULE 26)

WO 02/028780

PCT/US01/31411

2/25

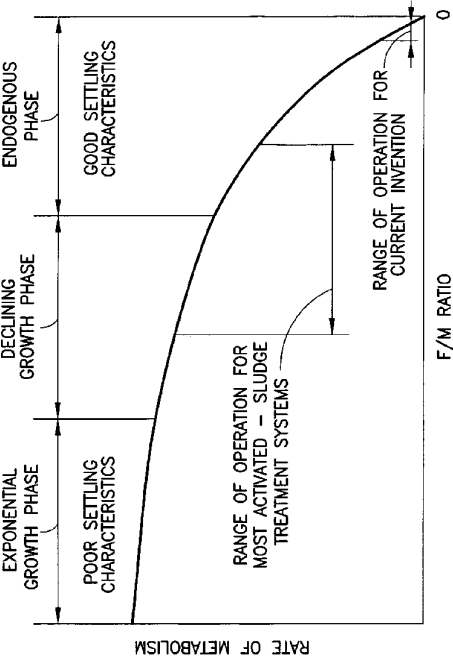


FIG.2

WO 02/028780

PCT/US01/31411

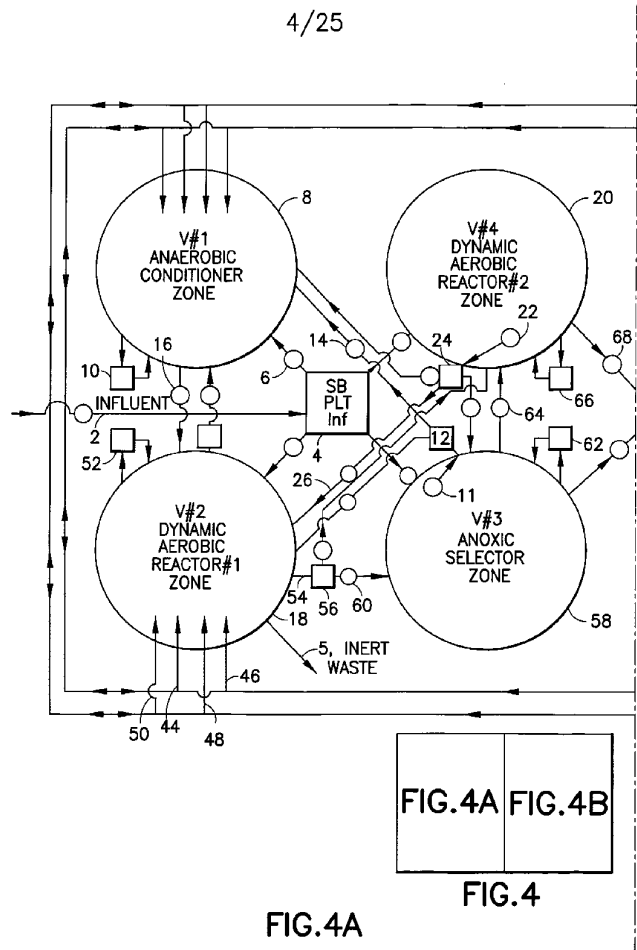
3/25

	PRESENT INVENTION	COMPLETE MIX	PLUG FLOW	CONTACT STABILIZATION	STEP FEED	EXTENDED AERATION
AERATION TIME (hrs)	4-8	3-5	4-8	.5-1.0	3-5	18-36
MCRT (days)	30->150	15-30	15-30	5-15	5-15	15-30
F/M RATIO (lbs BOD/day/lb MLVSS)	0.05-0.80	0.05-0.20	0.05-0.20	0.20-0.40	0.20-0.4	0.05-0.2
MLSS	2,000-10,000	3,000-6,000	1,500-3,000	1,000-3,000	2,000-3,500	3,000-6,000
RAS RECIRCULATION % RAS/(Q)	25-100	25-100	25-50	25-100	25-75	75-150
PROCESSING RECIRCULATION %	500-2000	N/A	N/A	N/A	N/A	N/A

WASTEWATER TREATMENT SYSTEMS COMPARATIVE

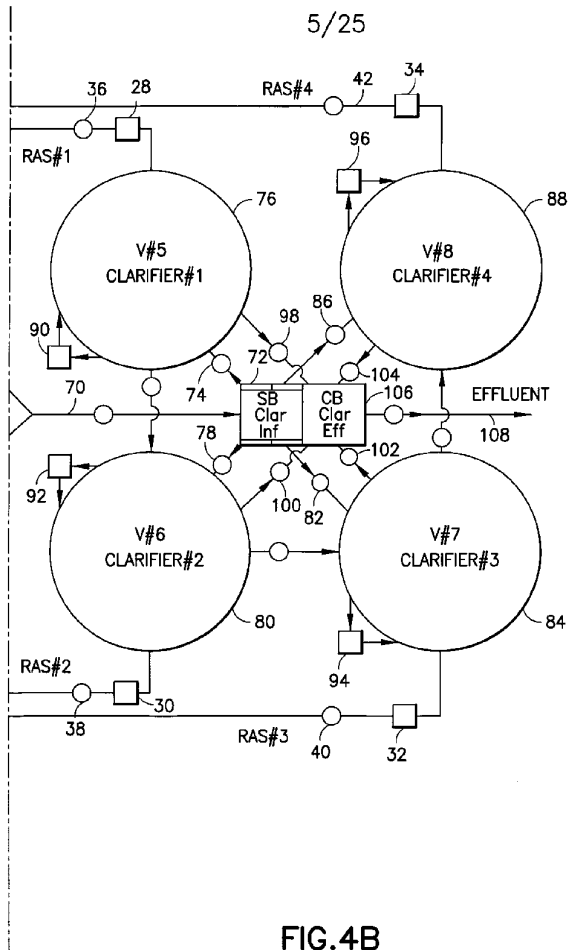
FIG.3

4/25



WO 02/028780

PCT/US01/31411



SUBSTITUTE SHEET (RULE 26)

6/25

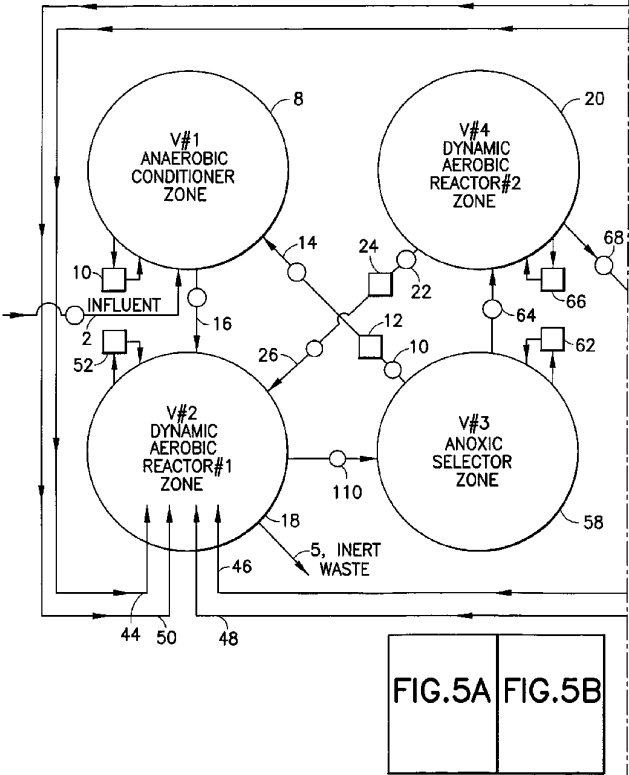


FIG.5A

FIG.5

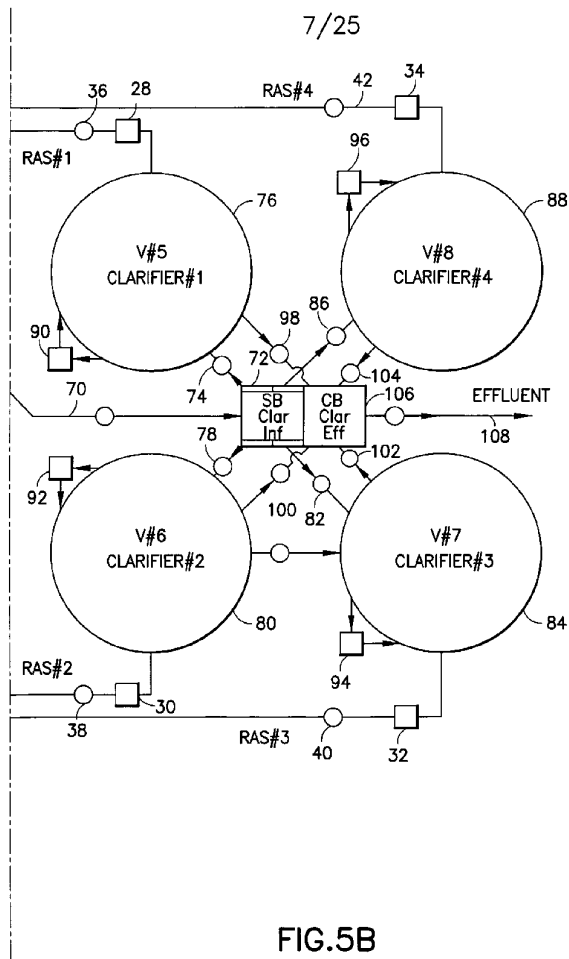


FIG.5B

SUBSTITUTE SHEET (RULE 26)

8/25

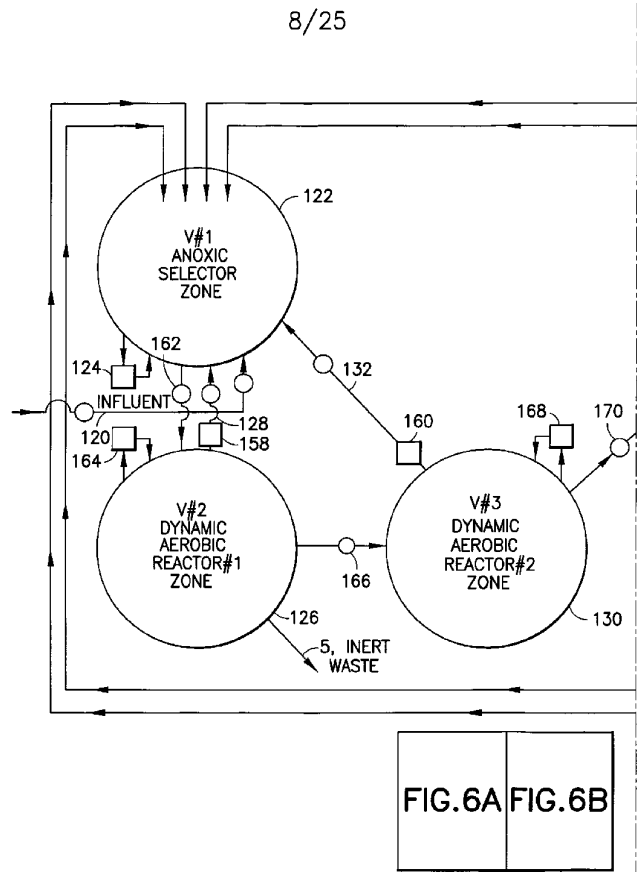


FIG.6A

FIG.6

WO 02/028780

PCT/US01/31411

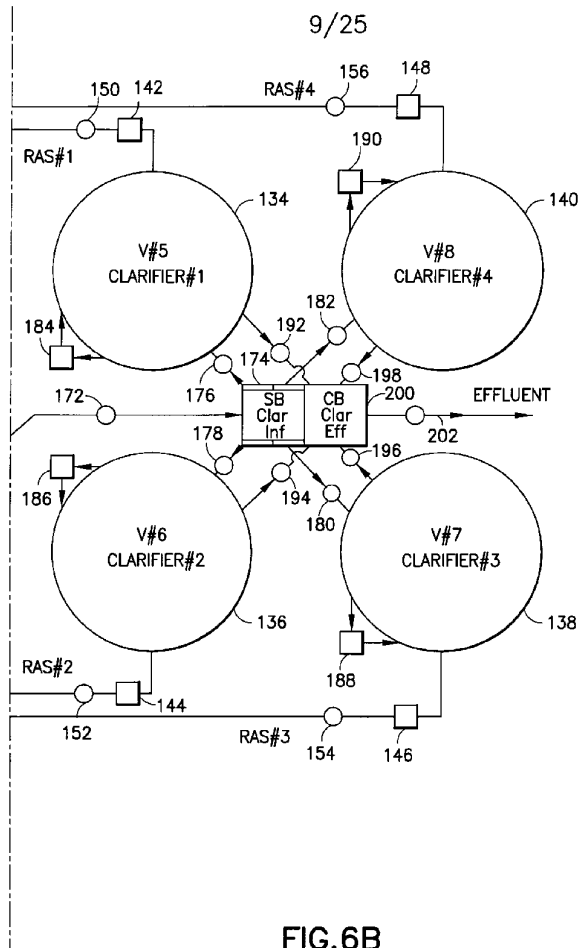
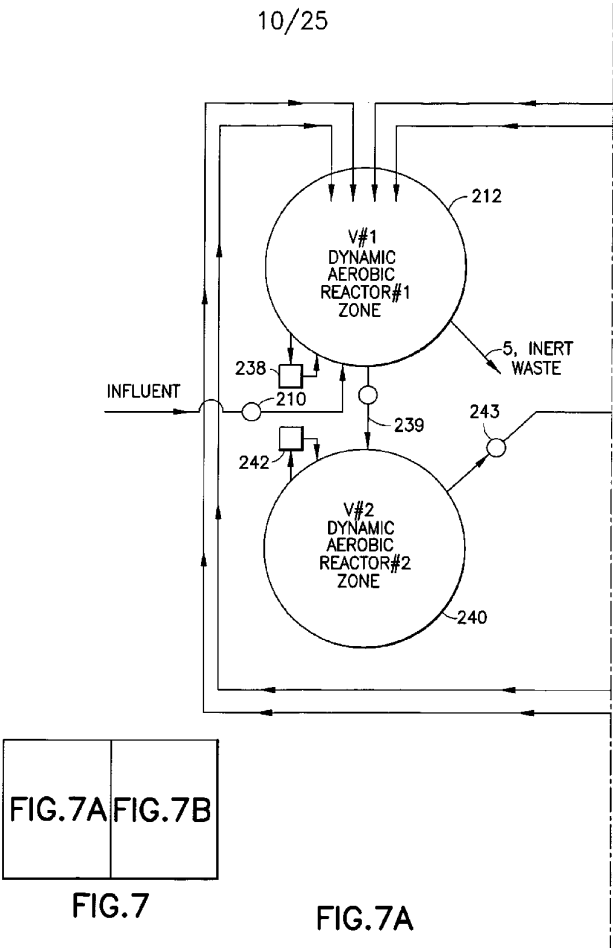


FIG.6B

SUBSTITUTE SHEET (RULE 26)

WO 02/028780

PCT/US01/31411



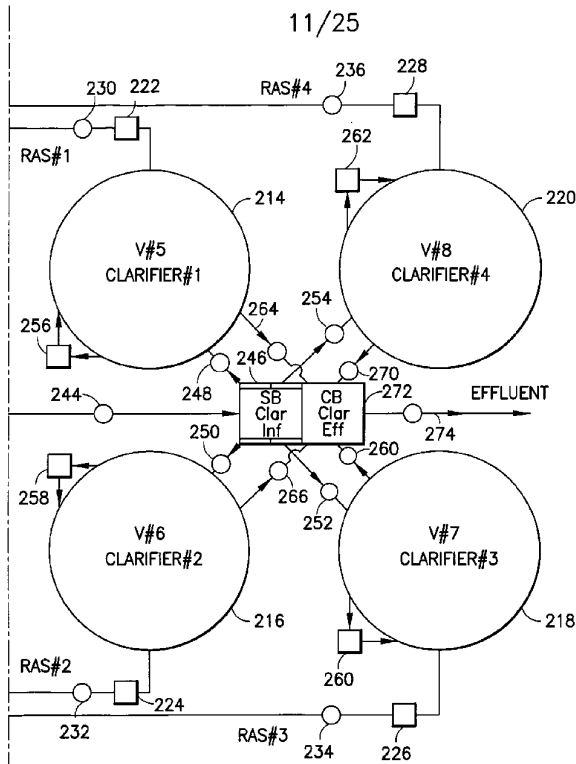


FIG.7B

SUBSTITUTE SHEET (RULE 26)

12/25

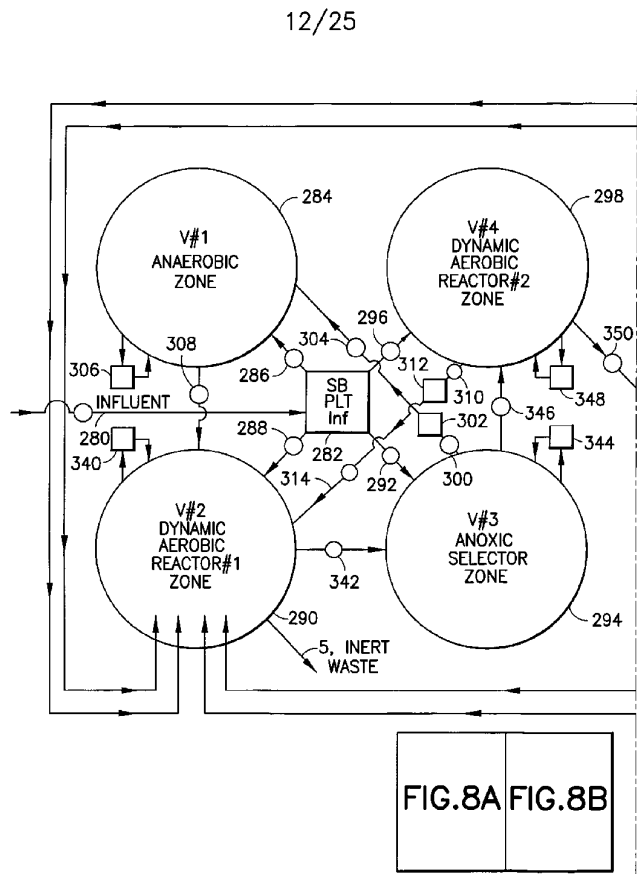
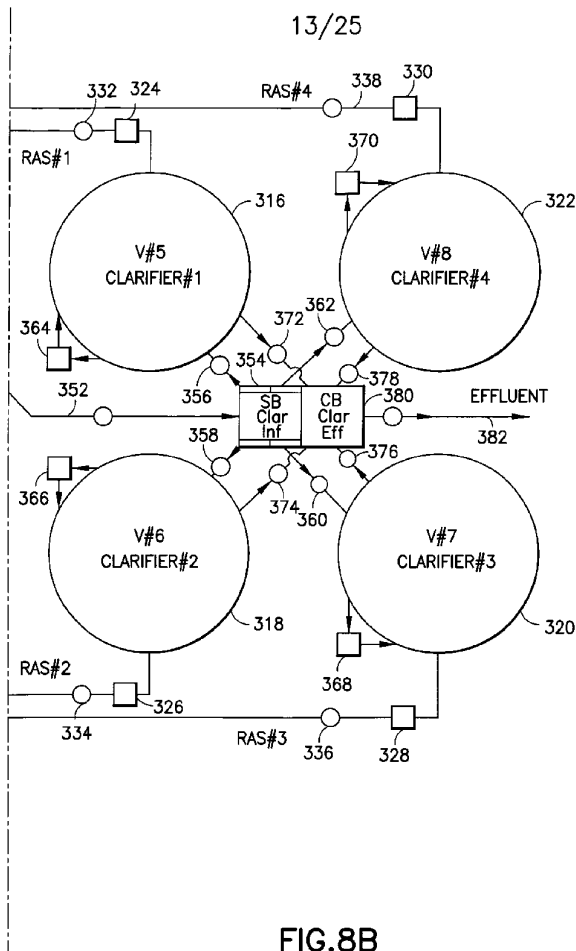


FIG.8A

FIG.8



14/25

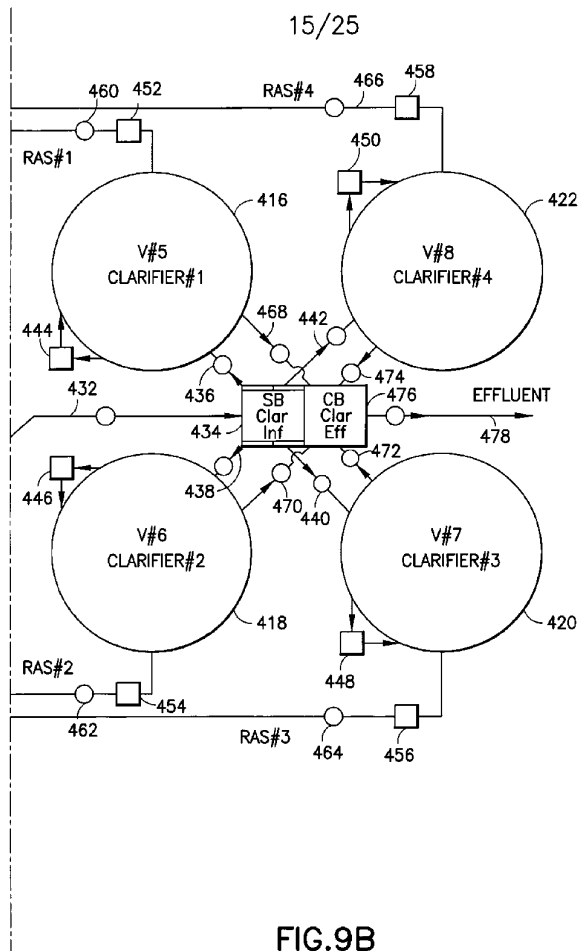
FIG. 9A

FIG. 9A	FIG. 9B

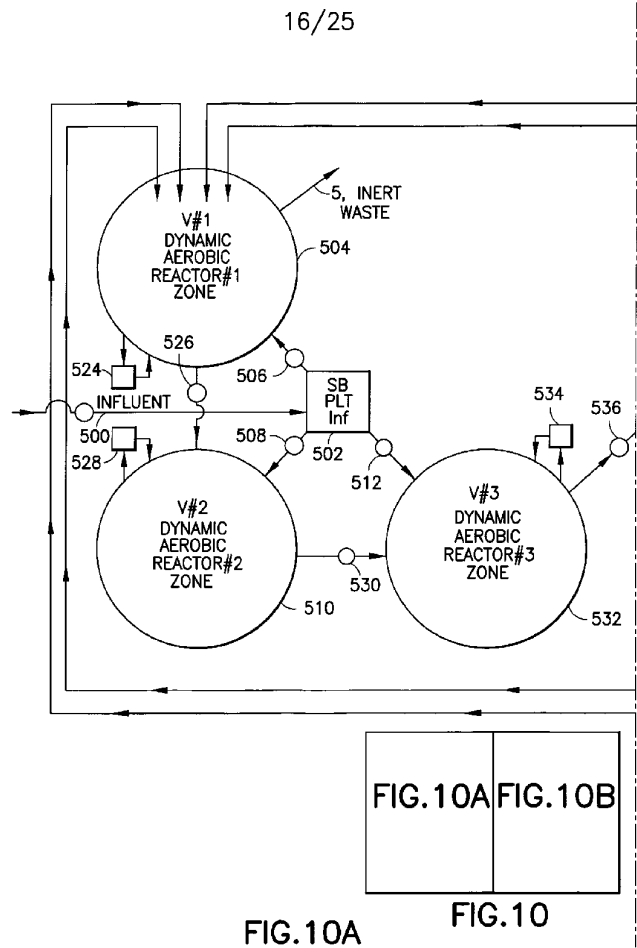
FIG. 9

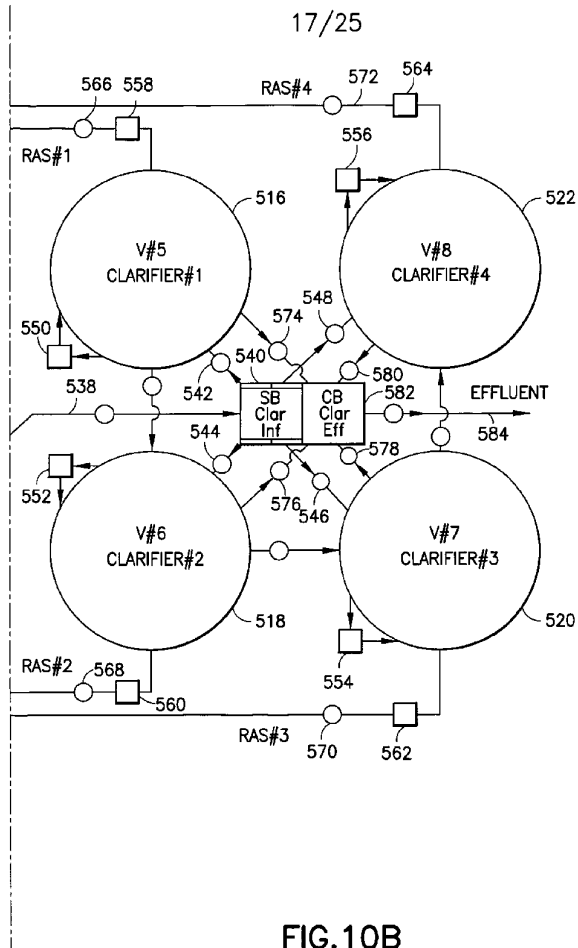
FIG.9A

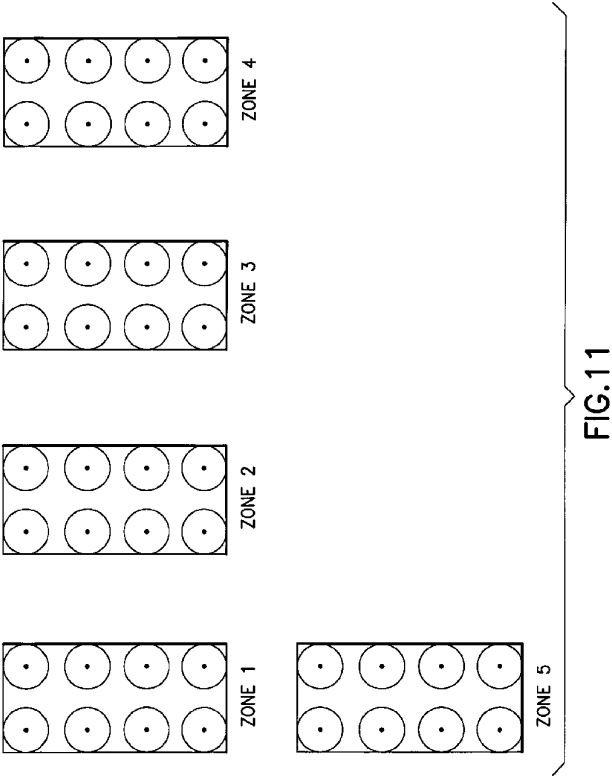
FIG.9



16/25







19/25

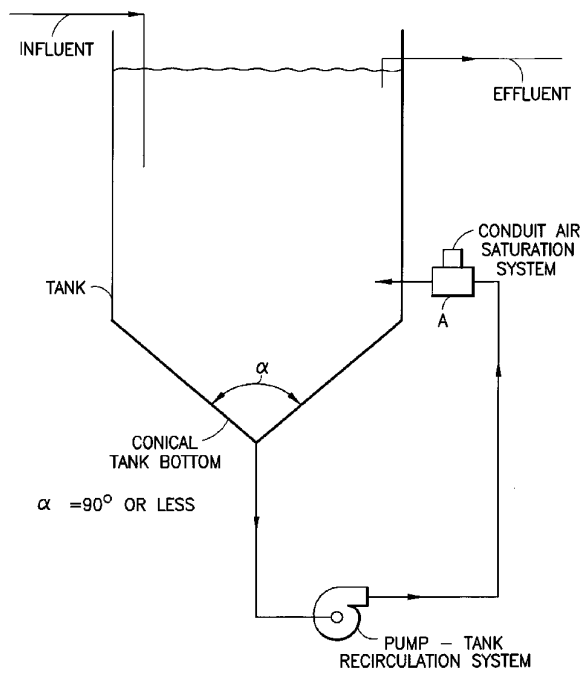


FIG.12

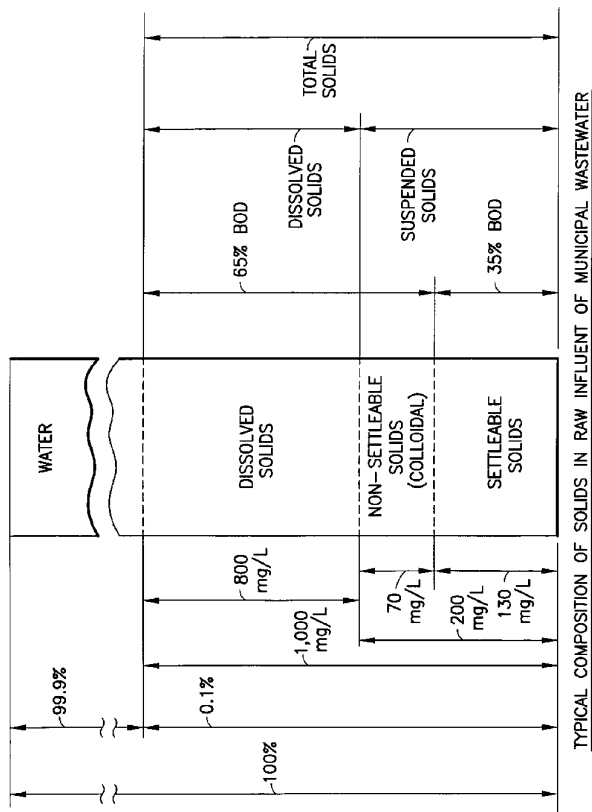
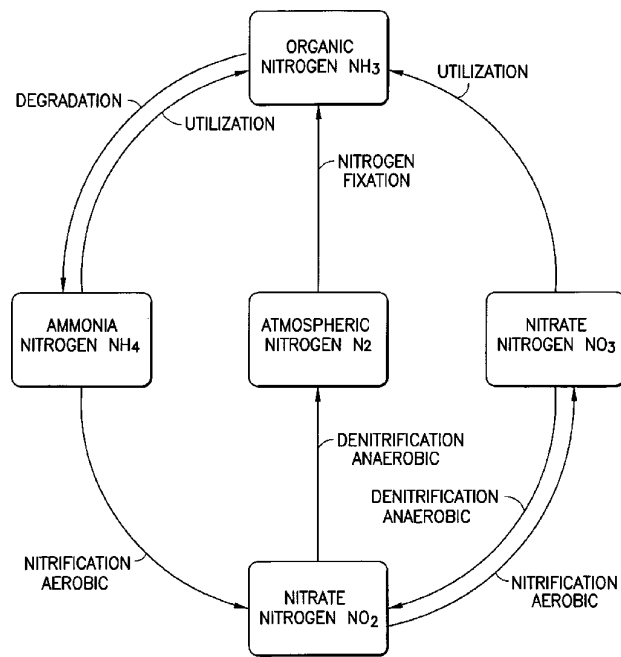


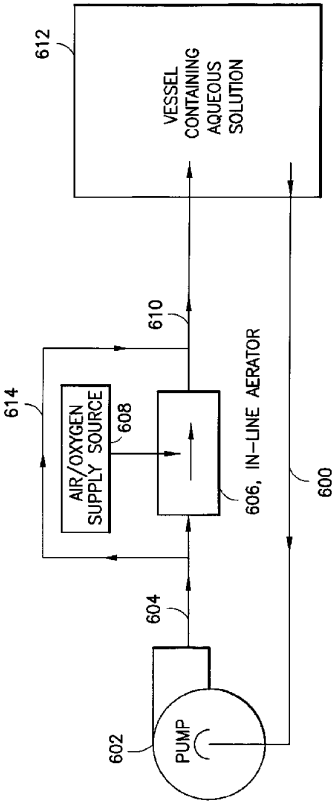
FIG.13

WO 02/028780

PCT/US01/31411

21/25

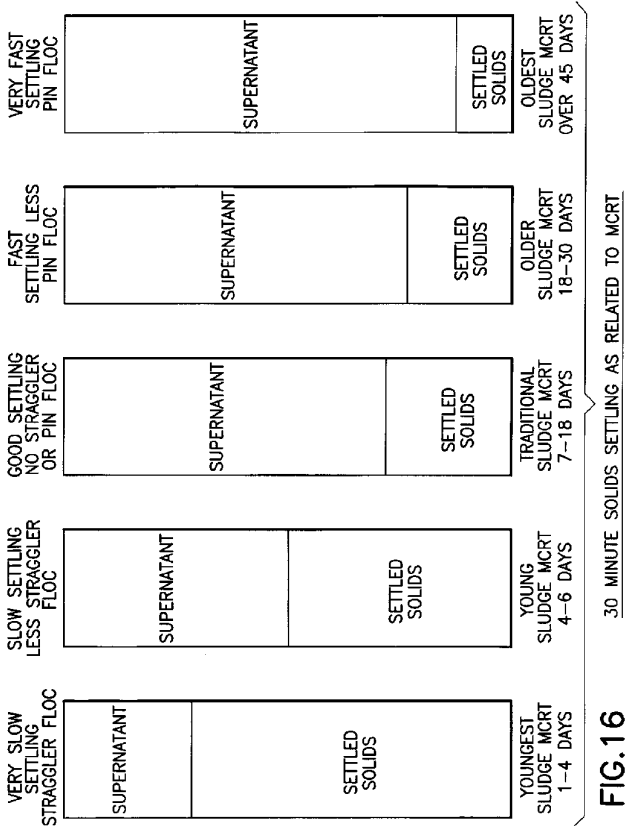
WASTEWATER NITROGEN CYCLE**FIG.14**



RE-CIRCULATION AERATION SYSTEM (RCAS)
(WITH OPTIONAL AERATOR BY-PASS)

FIG.15

23/25



WO 02/028780

PCT/US01/31411

24/25

DECAY COEFFICIENT

MCRT IS MEAN CELL RESIDENCE TIME

Y IS THE YIELD COEFFICIENT

F/M IS THE FOOD TO MICROORGANISM RATIO

BOD REM EFFCY IS THE BOD REMOVAL EFFICIENCY

 K_d IS THE DECAY COEFFICIENTSOLVING FOR K_d

$$K_d = (Y)(F/M)(BOD\ REM\ EFFCY) - \frac{1}{MCRT}$$

WHERE:

Y = 0.55 lbs OF VSS PRODUCED PER lb BOD REMOVED

$$F/M = \frac{\text{lbs OF BOD APPLIED PER DAY}}{\text{lbs OF VSS IN INVENTORY}}$$

BOD REM EFFCY = % BOD REMOVED IN THE PROCESS AS A DECIMAL

$$MCRT = \frac{\text{lbs MLVSS IN AERATION SYSTEM}}{\text{lbs MLVSS LEAVING AERATION SYSTEM}}$$

FIG.17

SUBSTITUTE SHEET (RULE 26)

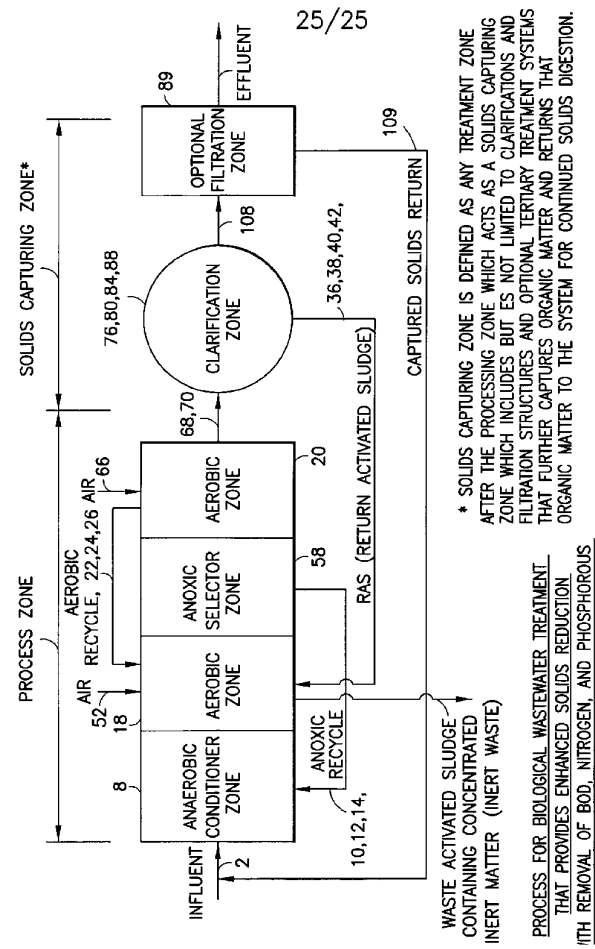


FIG.18

【国際公開パンフレット（コレクトバージョン）】

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
11 April 2002 (11.04.2002)

PCT

(10) International Publication Number
WO 02/028780 A3

(51) International Patent Classification: C02F 3/30

(21) International Application Number: PCT/US01/31411

(22) International Filing Date: 5 October 2001 (05.10.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/238,878 6 October 2000 (06.10.2000) US(71) Applicant (for all designated States except US): **PREMIER WASTEWATER INTERNATIONAL, LLC** [US/US]; 5340 S. Procyon, Las Vegas, NV 89118 (US).

(72) Inventors: and

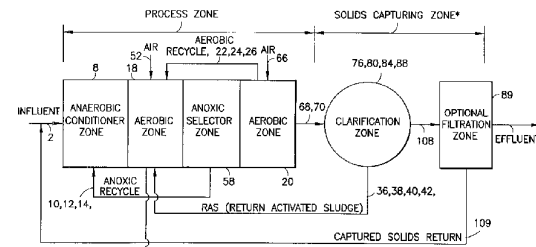
(75) Inventors/Applicants (for US only): **GARCIA, Paul, G.** [US/US]; 1500 Stardust 0-163, Unit E-3078, Las Vegas, NV 89109 (US); **DAVIDSON, Leonard** [US/US]; 2444 Tour Edition Drive, Henderson, NV 89014 (US); **RUSSELL, H., Matthew** [US/US]; 2305 Calle De Nuevo, Las Vegas,NV 89102 (US); **JOHNSON, Martin, Perry** [US/US]; 1700 E. Jean Avenue, Palmump, NV 89048 (US); **GARCIA, Paul, F.** [US/US]; 34 Church Street, Henderson, NV 89015 (US).(74) Agents: **MICHAL, Robert et al.**; Frislauf, Holtz, Goodman, Langer & Chick, P.C., 767 Third Avenue, New York, NY 10017-2023 (US).

(81) Designated States (national): AI, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MY, NO, NZ, PL, PT, RO, RU, SD, SI, SG, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KI, LS, MW, MZ, SD, SI, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR WASTEWATER TREATMENT WITH ENHANCED SOLIDS REDUCTION (USK)

WASTE ACTIVATED SLUDGE
CONTAINING CONCENTRATED
INERT MATTER (WERT WASTE)PROCESS FOR BIOLOGICAL WASTEWATER TREATMENT
THAT PROVIDES ENHANCED SOLIDS REDUCTION
WITH REMOVAL OF BOD, NITROGEN, AND PHOSPHORUS* SOLIDS CAPTURING ZONE IS DEFINED AS ANY TREATMENT ZONE
AFTER THE PROCESSING ZONE WHICH ACTS AS A SOLIDS CAPTURING
ZONE WHICH INCLUDES BUT IS NOT LIMITED TO CLARIFICATIONS AND
FILTRATION STRUCTURES AND OPTIONAL TERTIARY TREATMENT SYSTEMS
THAT FURTHER CAPTURES ORGANIC MATTER AND RETURNS THAT
ORGANIC MATTER TO THE SYSTEM FOR CONTINUED SOLIDS DIGESTION.

(57) Abstract: A wastewater treatment process that provides improved reduction of total solids through endogenous respiration while reducing biochemical oxygen demand and utilizing biological nutrient reduction. The wastewater treatment process uses an efficient aeration delivery system to drastically reduce the time needed to oxidize organic matter, and re-circulates, shreds and homogenizes the organic matter and microorganisms and oxygenates the entire mass many more times than traditional systems resulting in a greater biological solids digestion rate.

WO 02/028780 A3 

Published:
— with international search report

Previous Correction:
see PCT Gazette No. 08/2003 of 20 February 2003, Section II

(88) Date of publication of the international search report:
24 December 2003

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(15) Information about Correction:

【国際調査報告】

INTERNATIONAL SEARCH REPORT		International application No. PCT/US01/31411										
A. CLASSIFICATION OF SUBJECT MATTER IPC(7) : C02F 3/30 US CL : 210/605 According to International Patent Classification (IPC) or to both national classification and IPC												
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 210/605 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)												
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category *</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>WO 99/16717 A (NIELSEN et al) 8 April 1999 (08.04.1999), Fig. 4</td> <td>1-3</td> </tr> </tbody> </table>			Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	A	WO 99/16717 A (NIELSEN et al) 8 April 1999 (08.04.1999), Fig. 4	1-3				
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.										
A	WO 99/16717 A (NIELSEN et al) 8 April 1999 (08.04.1999), Fig. 4	1-3										
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.												
Special categories of cited documents: <table border="1"> <tbody> <tr> <td>*A* documents defining the general state of the art which is not considered to be of particular relevance</td> <td>*T* later documents published after the international filing date or priority date and not in conflict with the application as filed or underlying the principle or theory underlying the invention</td> </tr> <tr> <td>*E* earlier application or patent published on or after the international filing date</td> <td>*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step without the document in which it is disclosed</td> </tr> <tr> <td>*L* document which may throw doubts on priority claimed or which is cited to establish the publication date of another claim or other special reason (to specify)</td> <td>*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>*O* document referring to an oral disclosure, use, exhibition or other means</td> <td>*Z* document member of the same patent family</td> </tr> <tr> <td>*P* document published prior to the international filing date but later than the priority date claimed</td> <td></td> </tr> </tbody> </table>			*A* documents defining the general state of the art which is not considered to be of particular relevance	*T* later documents published after the international filing date or priority date and not in conflict with the application as filed or underlying the principle or theory underlying the invention	*E* earlier application or patent published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step without the document in which it is disclosed	*L* document which may throw doubts on priority claimed or which is cited to establish the publication date of another claim or other special reason (to specify)	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	*O* document referring to an oral disclosure, use, exhibition or other means	*Z* document member of the same patent family	*P* document published prior to the international filing date but later than the priority date claimed	
A documents defining the general state of the art which is not considered to be of particular relevance	*T* later documents published after the international filing date or priority date and not in conflict with the application as filed or underlying the principle or theory underlying the invention											
E earlier application or patent published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step without the document in which it is disclosed											
L document which may throw doubts on priority claimed or which is cited to establish the publication date of another claim or other special reason (to specify)	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art											
O document referring to an oral disclosure, use, exhibition or other means	*Z* document member of the same patent family											
P document published prior to the international filing date but later than the priority date claimed												
Date of the actual completion of the international search 28 December 2001 (28.12.2001)		Date of mailing of the international search report 13 FEB 2002										
Name and mailing address of the ISA/US Chief Examiner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230		Authorized officer Chester T. Barry Telephone No. 703-308-0651										

フロントページの続き

(81)指定国 AP(GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZW),EA(AM,AZ,BY,KG,KZ,MD,RU,TJ,TM),EP(AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE,TR),OA(BF,BJ,CF,CG,CI,CM,GA,GN,GQ,GW,ML,MR,NE,SN,TD,TG),AE,AG,AL,AM,AT,AU,AZ,BA,BB,BG,BR,BY,BZ,CA,CH,CN,CO,CR,CU,CZ,DE,DK,DM,DZ,EE,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KP,KR,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,MZ,NO,NZ,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,US,UZ,VN,YU,ZA,ZW

(72)発明者 デービッドソン, レオナード

アメリカ合衆国, ネバダ 89014, ヘンダーソン, ツアー エディション ドライヴ 2444

(72)発明者 ラッセル, エイチ. マシュー

アメリカ合衆国, ネバダ 89102, ラスベガス, カレ デ ヌエボ 2305

(72)発明者 ジョンソン, マーティン ペリー

アメリカ合衆国, ネバダ 89048, パーランプ, イー. ジーン アヴェニュー 1700

(72)発明者 ガルシア, ポール エフ.

アメリカ合衆国, ネバダ 89015, ヘンダーソン, チャーチ ストリート 34

Fターム(参考) 4D040 BB04 BB05 BB32 BB56 BB57 BB72