Treatment	Achievable Effluent Characteristics (mg/L)						Critical Design Parameters	Estimated Costs[17] ($ per million gallons treated)		Benefits	Limitations	Examples
	Ammonia Nitrogen	Total Nitrogen	Nitrate-N	BOD	TSS	Phosphorus		Capital ($/mgd)	Operation and Maintenance ($/million gallons treated)			
Typical Wastewater Constituent Influent Characteristics	12-50[13]	20-85[13]	0[14]	180-300	180-300	3-7[13]						
Medium Systems (10,000 gpd - 1 mgd)												
Non-discharging Alternatives												
Dedicated Land Application	ref[16]	ref[16]	ref[16]	30	30	ref[16]	Hydraulic and nutrient loading of the site. Follows conventional secondary systems Pre-treatment Land Area	$0.70 mil. per mgd or $70 per person per mgd (land (160 Ac): $400K (irr sys with 1/4 sect center pivot) + $150K (holding pond) + $150K	$500+ [2] (annual) $1096 (annual 2006-08 Muskegon, MI irrigation system cost only)	Savings on potable water Nutrients recycled to plants groundwater recharge preservation of in stream water quality	Large land area may be required Requires significant pre-treatment Requires buffer area Potential nitrogen leaching	Often use center pivot irrigation. Pauls Valley, Oklahoma and Muskegon County, MI (11,000 acres).
Seasonal Land Application	ref[16]	ref[16]	ref[16]	30	30	ref[16]	Hydraulic and nutrient loading of the site. Follows conventional secondary systems Pre-treatment Land Area	$1.0 mil. per mgd or $100 per person per mgd (land (160 Ac): $400K (irr sys with 1/4 sect center pivot) + $150K (holding pond) + $450 k (excav costs)	$500+[2] (annual) $1096 (annual 2006-08 Muskegon, MI irrigation system cost only)	Savings on potable water Nutrients recycled to plants	Large land area may be required Requires significant pre-treatment Requires buffer area Potential nitrogen leaching	Often use center pivot irrigation. Pauls Valley, Oklahoma and Muskegon County, MI (11,000 acres); Fox Mills, IL; City of Plano, IL; Village of Cortland, IL
Advanced Innovative Treatment Technologies												
Modified Ludzack Ettinger (MLE)	0-2 (Ammonium converted to nitrates by nitrification)	5-8	3-6 (Limited reduction of nitrates by denitrification)	10-20[2]	10-20[2]	2-6 (15 to 35% reduction)	Recycle ratio for control over nitrogen removal Pre-treatment Effluent requirements	$2.5 - 5.0 mil. per mgd or $250 - $500 per person per mgd[8] (upgrade to plant)	$773,000 - per year per mgd or $78 per person per year[8]	Provides control over amount of nitrogen removal through recycle ratio. Removes some Nitrate, thus total nitrogen is reduced more than just a nitrification system.	Requires more energy because of mixed liquor recycle	Orlando, Fl (>1 mgd) Maryland- Cambridge, Seneca, Freedom District, Conococheaque, Cox Creek, Back River and Aberdeen, Ref[21]
Bardenpho Process	0-1	3-6	1-7	10-20[2]	10-20[2]	2-6 (15 to 35% reduction)	Needs to have an adequate amount of carbon (food) in the influent to obtain high denitrification	$2.2 mil. per mgd or $220 per person per mgd[8] (upgrade to plant)	$930,000 - per year per mgd or $93 per person per year[8]	Proven process, excellent ammonia reduction with good total nitrogen removal with denitrification.	Often limited by amount of carbon (food) available in the influent. This can be overcome with methanol addition, thus added costs.	Maryland: Maryland Correctional Institute
A^2/O	0-1	6-8	1-7	10-20[2]	10-20[2]	1-2 without metal salt addition	Must be properly sized and may need a fermentor to provide volatile fatty acids (VFAs)	$17 mil. per mgd or $1700 per person per mgd[9] (50K gpd package plant)	$1.2 mil. per year per mgd or $1200 per person per mgd[9] (50K gpd package plant)	Proven process, can achieve total N < 3 mg/l with careful operation and methanol addition. When combined with effluent filtration and metal salt addition, Total P can achieve very low values.	Often need to add methanol and install fermenters. Solids upsets will discharge total P[18]. Often post filtration needed to achieve consistent P discharge.	Maryland: Frederick, Ballenger, Westminster, and Sod Run.
Oxidation Ditch with Nitrogen Removal	0-1	3-6 (< 5 Tot N if mixed liquor recycle employed)	2-5	10-20[2]	10-20[2]	2-6 (15 to 35% reduction)	Retention Time BOD loading may require mixed liquor recycle	$8 mil. per mgd or $800 per person per mgd	$850,000 per year per mgd or $85 per person per year	low operational and maintenance requirements (compared to other conventional treatments) produces less sludge than other systems	requires large land area TSS concentrations can be high compared to other systems requires more electricity than conventional	Hartland, MI, Cedarburg, WI
Sequencing Batch Reactor (Sanitaire's ICEAS process)	0.5-5	3-5	3-6 (requires anoxic system and mixer to get low numbers)	<10[1]	<10[1]	0.3-2[1] (requires metal salt addition)	Influent characteristics Effluent requirements Number of basins Number of cycles Aeration equipment	$5.8 mil. per mgd or $583 per person per mgd (Cedar Grove)	$0.5 mil. per year per mgd or $50 per person per year	Clarification, Treatment and Secondary clarification achieved in one reactor Minimal footprint Easily modified for nutrient removal Operator control	Sophisticated timing and controls (more maintenance) Potential for discharging sludge with clear water	Harmony Grove-Okee, WI Cedar Grove, WI
Post filtration with metal salt addition (after advanced innovative above)	ref[19]	ref[19]	ref[19]	2-5	2-5	0.03-1	Multi media filter with backflush (solids removal)	$1.5 mil. - $5.1 mil. per mgd or $150-$510 per person per mgd	$22,700-$69,000 per year per mgd or $2.70-$6.90 per person per year[9]	Proven Technology and well understood	Need the differential head to support hydraulic flow, often added as a retrofit to meet more stringent standards, thus low lift pumps are often necessary to elevate the water flow	Hillsboro, Oregon; Rock Creek, TX (includes tertiary Alum addition followed by filtration).[9]
Post Denitrification Filter (after advanced innovative above with full nitrification)	0-1	3-5	1-2	10	10	ref[20]	Anoxic Environment, carefully controlled, phosphoric acid addition if required and methanol addition as required	$1.46 - $3.2 mil. per mgd or $146 - $320 per person per mgd[11,12]	$286,000 (100K gpd) - $800,000 (25K gpd) per year per mgd or $28.60 - $80.00 per person per year[12]	Allow for good control of denitrification and results in very low BOD and TSS effluent. Often used in Chesapeake Bay area to achieve stringent requirements	Need the differential head to support hydraulic flow, often added as a retrofit to meet more stringent standards, thus low lift pumps are often necessary to elevate the water flow. Post denitrification system filter uses larger media and doesn't hold solids as effectively as smaller media systems.	Arlington County, VA (large plant), Maryland analyses and case study[11]

Medium Systems (10,000 gpd - 1 mgd)

Treatment	Achievable Effluent Characteristics (mg/L)						Critical Design Parameters	Estimated Costs[17] ($ per million gallons treated)		Benefits	Limitations	Examples
	Ammonia Nitrogen	Total Nitrogen	Nitrate-N	BOD	TSS	Phosphorus		Capital ($/mgd)	Operation and Maintenance ($/million gallons treated)			
Typical Wastewater Constituent Influent Characteristics	12-50[13]	20-85[13]	0[14]	180-300	180-300	3-7[13]						
Enhanced Treatment Technologies (above Conventional)												
Modified Activated Sludge Plants	< 2	ref[14] Little change	ref[14] Little change	10-30	10-30	2.5-6 (15 to 20% reduction)	Mean cell residence time (sludge age) generally >15 days, good solids settling or removal, temperature sensitive. Usually aeration hydraulic retention time >16 hours, often 24 to 36 hours.	$0.42 mil. - $ 1.45 mil. per mgd or $42 - $145 per person per mgd9	$46,000 - $145,000 per year per mgd or $73 per person per year[9]	Proven technology and well understood	Soft water may need alkalinity added, will need about 4 times as much aeration than a non-nitrifying plant.	City of LaSalle, IL (1 mgd); Pingree Grove, IL using MBR; Traverse City, MI using MBR;
Seasonal Discharging Alternatives												
Lagoons- Facultative	2.4-10[6]	ref[14] Little change	ref[14] Little change	30[6]	150[6]	1.5-3.5[6]	Liner based on soil conditions Number of cells for effectiveness Detention time based on climate	$4.4 mil. per 1 mgd or $440 per person per mgd	$175,000 per year per mgd or $17.50 per person per year	Inexpensive alternative for small rural towns Easy operation	Large area required Potential odors Seasonal discharge Mosquitoes and burrowing animals a concern Long detention times	Lagoons are used throughout the US and Canada primarily for medium or small systems. Fewer are being constructed because of their poor cold weather performance. Barneveld, Merrimac, and Brownsville, Wisconsin
Lagoons- Aerated and Mixed	More effective than facultative	ref[14] Little change	ref[14] Little change	15 (<95% [5])	20-60[5]	less effective than facultative	Liner based on soil conditions Number of cells for effectiveness Detention time and aeration intensity Downstream polishing required	$6.8 mil. per 1 mgd or $684 per person per mgd (19000 gpd WWTP)	$200,000 per year per mgd or $20.00 per person per year (19000 gpd WWTP)	Can discharge throughout the winter in colder climates	Large area required, though not as much as facultative Mosquitoes and burrowing animals a concern Requires energy input long detention times	
Rapid Infiltration Basin (RIB) (Seasonal method of returning treated wastewater to the ground water environment)	ref[16]	ref[16]	ref[16]	ref[16]	ref[16]	ref[16]	Soils are critical, typically sand and gravels, or otherwise porous soil structures. Typically sized for so many gallons per square foot of surface area. Requires berm of several feet in height. Requires several units so that they may be dosed	$1.5 mil. per 1 mgd or $150 per person per mgd [9]	$25,000 per year per mgd or $2.50 per person per year	This is a sustainable (seasonal) means of returning water back to the ground water where most water is drawn, if soils will allow and wastewater effluent to infiltrate meets State Discharge Standards for Total Nitrogen (varies from State to State, typically 3 to 5 mg/l Total N) and Total P (varies from State to State, but can be from 0.03 to 0.5 mg/l). Valuable method to combat salt water intrusion into ground water in coastal areas.	Requires very high treatment standards for both N and P, along with a discharge of typical advanced treatment effluent standards for TSS. BOD, and fecal coliform reduction. UV would be the preferred disinfection method	Hartland, MI, Orlando, Fl
Conventional Alternatives												
Activated Sludge Plants	ref[14] Little to some reduction	ref[14] Little change	ref[14] Little change	10-50[2]	15-60[2]	2.5-6 (15 to 20% reduction)	Hydraulic detention time, aeration & clarification capacity	$7.2 mil. per mgd or $722 per person per mgd	$730,000 per year per mgd or $73 per person per year	Cost Effective, well understood, can often take short term overloading during wet weather.	Cannot take long term overloads.	Many Locations throughout the US and the world.
Sequencing Batch Reactors (SBR)	5-8[1]	ref[14] Little to some reduction	ref[14] Little change	10 [1]	10 [1]	1-2[1]	Influent characteristics Effluent requirements Number of basins Number of cycles Aeration equipment	$6.5 mil. per mgd or $650 per person per mgd	$292,000 - $730,000 per year per mgd or $29 to $73 per person per yr[1]	Clarification, Treatment and Secondary clarification achieved in one reactor Minimal footprint Easily modified for nutrient removal Operator control	Sophisticated timing and controls (more maintenance) Potential for discharging sludge with clear water	Aqua Aerobics Design in Abilene, KS (1.5 mgd capacity, 2008 construction cost = $9.4 million) and Marissa, IL (0.6 mgd).
Oxidation Ditch	5-8	ref[14] Little to some reduction	ref[14] little to no change, may increase	10-30	10-30	2.5-6 (15 to 20% reduction)	Retention Time; BOD Loading; Hydraulic retention time (HRT) of aeration basin.	$7.2 mil. per mgd or $722 per person per mgd	$730,000 per year per mgd or $73 per person per year	low operational and maintenance requirements (compared to other conventional treatments) produces less sludge than other systems	requires large land area TSS concentrations can be high compared to other systems	Many Locations throughout the US and the world. Hartland, MI and Cedarburg, WI.
Metal Salt Precipitation (incorporated in secondary system)	ref[19] Little change	ref[19] Little change	ref[19] Little change	15	15	0.5-1.0 (<0.3 with Bio P removal + chemical phosphate removal + effluent filter)	Activated Sludge treatment with a metal salt (chemical phosphate removal) being used. Often added to aeration tank, settling in secondary clarifier.	$0.25 mil. per mgd or $25 per person per mgd	$31,000 per year per mgd or $3.10 per person per year	Well established technology Chemicals can be inexpensive Can be low maintenance	Difficult to obtain low phosphorus concentrations with chemical treatment alone Can increase the amount of sludge Operator safety can be a concern and personal protection equipment is used, training is required	Many Locations throughout the US and the world. Collinsville, IL, Racine, WI, and Bayfield, WI.
Disinfection	ref[15]	ref[15]	ref[15]	ref[15]	ref[15]	ref[15]	Retention time; Dosage; if UV- Lamp Intensity	500 gpm ozone contact vessel system - capital cost = $400,000[23]	500 gpm ozone contact vessel system - annual O&M cost = $20,000[23]	Use of chlorine for disinfection and sulfur dioxide for disinfection are proven technologies but are slowly losing favor (see limitations). Ozone is rarely used (see limitations). UV uses less space on a plant site, uses electricity only, and is effective with disinfecting a wastewater that is clear and <30 mg/l TSS. Easy to operate and maintain.	Chorine and Sulfur Dioxide are chemicals that require special handling, storage, and personnel protection measures. Ozone is a strong oxidant and like above, requires personnel protection measures. Emergency plans are costly and public notification required. UV requires clear effluent and some problems have occurred from overuse of ferric chloride (coats lamps).	UV: Cedarburg, WI; Wayne County- Wyandotte, MI ; UV: Stookey TWP Main STP, IL

Large Systems (> 1 mgd)

Treatment	Achievable Effluent Characteristics (mg/L)						Critical Design Parameters	Estimated Costs[17] ($ per million gallons treated)		Benefits	Limitations	Examples
	Ammonia Nitrogen	Total Nitrogen	Nitrate-N	BOD	TSS	Phosphorus		Capital ($/mgd)	Operation and Maintenance ($/million gallons treated)			
Typical Wastewater Constituent Influent Characteristics	12-50[13]	20-85[13]	0[14]	180-300	180-300	3-7[13]						
Non Discharging Alternatives												
Dedicated Land Application	ref[16]	ref[16]	ref[16]	30	30	ref[16]	Hydraulic and nutrient loading of the site. Follows conventional secondary systems Pre-treatment Land Area	$0.70 mil. per mgd or $70 per person per mgd (land (160 Ac) = $400K, irr sys (1/4 sect center pivot) = $150K, holding pond excav= $150K)	$500+2 (annual) $1096 (annual 2006-08 Muskegon, MI irrigation system cost only)	Savings on potable water Nutrients recycled to plants groundwater recharge preservation of in stream water quality	Large land area may be required Requires significant pre-treatment Requires buffer area Potential nitrogen leaching	Often use center pivot irrigation. More prevalent in drier areas and areas with sandy subsoil. Pauls Valley, Oklahoma and Muskegon County, MI (11,000 acres).
Advanced Innovative Treatment Technologies												
Modified Ludzack Ettinger (MLE)	0-2 (Ammonium converted to nitrates by nitrification)	5-8	3-6 (Limited reduction of nitrates by denitrification)	10-20[2]	10-20[2]	2-6 (15 to 35% reduction)	Recycle ratio for control over nitrogen removal Pre-treatment Effluent requirements	$1.4 mil. per mgd or $140 per person per mgd[10] (140 mgd plant)	$92,000 per year per mgd or $9 per person per mgd[10] (140 mgd)	Provides control over amount of nitrogen removal through recycle ratio, Removes some Nitrate, thus total nitrogen is reduced more than just a nitrification system.	Requires more energy because of mixed liquor recycle	Orlando, Fl (>1 mgd); Maryland- Cambridge, Seneca, Freedom District, Conococheaque, Cox Creek, Back River and Aberdeen. Denver, CO[10]
Bardenpho Process	0-1	3-6	1-7	10-20[2]	10-20[2]	2-6 (15 to 35% reduction)	Needs to have an adequate amount of carbon (food) in the influent to obtain high denitrification	$1.4 - $2.6 mil. per mgd or $140 - $220 per person per mgd[8]	$180,000 - per year per mgd or $18 per person per year[8]	Proven process, excellent ammonia reduction with good total nitrogen removal with denitrification.	Often limited by amount of carbon (food) available in the influent. This can be overcome with methanol addition, thus added costs.	Maryland: Ballenger and Hurlock
A^2/O	0-1	6-8	1-7	10-20[2]	10-20[2]	1-2 without metal salt addition	Must be properly sized and may need a fermentor to provide volatile fatty acids (VFAs)	$400,000 per year per mgd or $400 per person per mgd[8] (upgrade to plant)	$30,000 - per year per mgd or $3 per person per year[8]	Proven process, can achieve total N < 3 mg/l with careful operation and methanol addition. When combined with effluent filtration and metal salt addition, Total P can achieve very low values.	Often need to add methanol and install fermenters. Solids upsets will discharge total P. Often post filtration needed to achieve consistent P discharge.	Maryland: Frederick, Ballenger, Westminster, and Sod Run. Village of Mokean, IL. Triangle WWTP Durham, NC. Little Patuxent, MD[8]
Oxidation Ditch with Nitrogen Removal	0-1	3-6 (< 5 Tot N if mixed liquor recycle employed)	2-5	10-20[2]	10-20[2]	2-6 (15 to 35% reduction)	Retention Time BOD loading	$1.7 mil. per mgd or $170 per person per mgd[8]	$165,000 - per year per mgd or $16.5 per person per year[8]	low operational and maintenance requirements (compared to other conventional treatments) produces less sludge than other systems	requires large land area TSS concentrations can be high compared to other systems	Ashland, OR and Princeton, IN.
Sequencing Batch Reactor (Sanitaire's ICEAS process)	0.5-5	3-5	3-6 (requires anoxic system and mixer for low numbers)	<10 [1]	<10 [1]	0.3-2[1] (requires metal salt addition)	Influent characteristics Effluent requirements Number of basins Number of cycles Aeration equipment	$2.3 mil. per mgd or $227 per person per mgd (Jefferson City, MO)	$0.5 mil. per year per mgd or $50 per person per year	Clarification, Treatment and Secondary clarification achieved in one reactor Minimal footprint Easily modified for nutrient removal Operator control	Sophisticated timing and controls (more maintenance) potential for discharging sludge with clear water Need metal salt addition to achieve total P removal	Jefferson City, MO
Post filtration with metal salt addition (after advanced innovative above)	ref[19]	ref[19]	ref[19]	2-5	2-5	0.03-1	Multi media filter with backflush (solids removal)	$1.5 mil. - $5.1 mil. per mgd or $150-$510 per person per mgd. [9]	$22,700-$69,000 per year per mgd or $2.70-$6.90 per person per year[9]	Proven Technology and well understood	Need the differential head to support hydraulic flow, often added as a retrofit to meet more stringent standards, thus low lift pumps are often necessary to elevate the water flow	Hillsboro, Oregon; Rock Creek, TX (includes tertiary Alum addition followed by filtration). [9]
Post Denitrification Filter (after advanced innovative above with full nitrification)	0-1	3-5	1-2	10	10	ref[20]	Anoxic Environment, carefully controlled, phosphoric acid addition if required and methanol addition as required	$1.46 - $3.2 mil. per mgd or $146 - $320 per person per mgd[11,12]	$286,000 (100K gpd) - $800,000 (25K gpd) per year per mgd or $28.60 - $80.00 per person per year[12]	Allows for good control of denitrification and results in very low BOD and TSS effluent. Often used in Chesapeake Bay area	Need the differential head to support hydraulic flow, often added as a retrofit to meet more stringent standards, thus low lift pumps are often necessary to elevate the water flow	Arlington County, VA (large plant), Maryland analyses and case study[11]
Enhanced Treatment Technologies (above Conventional)												
Modified Activated Sludge Plants	<2	ref[14] Little change	ref[14] Little change	10-30	10-30	2.5-6 (15 to 20% reduction)	Mean cell residence time (sludge age) generally >15 days, good solids settling or removal, temperature sensitive. Usually aeration hydraulic retention time >16 hours. Could have MBR instead of clarifiers.	$1.45 mil. per mgd or $145 per person per mgd[8], $3 mil. per mgd or $300 per person per mgd (Delphos)	$180,000 - per year per mgd or $18 per person per year[8]	Proven technology and well understood	Soft water may need alkalinity added, will need about 4 times as much aeration than a non-nitrifying plant.	Delphos, OH. MBR plant (Enviroquip).

	Treatment	Achievable Effluent Characteristics (mg/L)						Critical Design Parameters	Estimated Costs[17] ($ per million gallons treated)		Benefits	Limitations	Examples
		Ammonia Nitrogen	Total Nitrogen	Nitrate-N	BOD	TSS	Phosphorus		Capital ($/mgd)	Operation and Maintenance ($/million gallons treated)			
	Typical Wastewater Constituent Influent Characteristics	12-50[13]	20-85[13]	0[14]	180-300	180-300	3-7[13]						
Large Systems (> 1 mgd)	**Conventional Alternatives**												
	Activated Sludge Plants	ref[14] Little to some reduction	ref[14] Little change	ref[14] Little change	10-50 [2]	15-60 [2]	2.5-6 (15 to 20% reduction)	Design for wet weather flow. Hydraulic detention time, aeration & clarification capacity	$6 mil. per mgd or $600 per person per mgd	$292,000 - $730,000 per year per mgd or $29 to $73 per person per year[1]	Cost Effective, well understood, can often take short term overloading during wet weather.	Cannot take long term overloads.	Many Locations throughout the US and the world. Edwardsville, IL, Waukesha, WI, Beaver Dam, WI, and Decatur, IL.
	Sequencing Batch Reactors (SBR)	5-8[1]	ref[14] Little to some reduction	ref[14] Little change	10 [1]	10 [1]	1-2[1]	Influent characteristics Effluent requirements Number of basins Number of cycles Aeration equipment	$1.2 mil. per mgd or $120 per person per mgd[8]	$130,000 - per year per mgd or $13 per person per year[8]	Clarification, Treatment and Secondary clarification achieved in one reactor Minimal footprint Easily modified for nutrient removal Operator control	Sophisticated timing and controls (more maintenance) Potential for discharging sludge with clear water	Many Locations throughout the US and the world. Pima, AZ, Pekin, IL, and Madison, WI.
	Oxidation Ditch	5-8	ref[14] Little to some reduction	ref[14] Little to no change, may increase	10-30	10-30	2.5-6 (15 to 20% reduction)	Retention Time; BOD Loading; HRT of aeration basin.	$6 mil. per mgd or $600 per person per mgd	$292,000 - $730,000 per year per mgd or 29.20 to 73 per person per year[1]	low operational and maintenance requirements (compared to other conventional treatments) produces less sludge than other systems	requires large land area TSS concentrations can be high compared to other systems	Many Locations throughout the US and the world. Hartland, MI and Cedarburg, WI.
	Metal Salt Precipitation (incorporated in secondary system)	ref[19] Little change	ref[19] Little change	ref[19] Little change	15	15	1	Activated Sludge treatment with a metal salt (chemical phosphate removal) being used. Often added to aeration tank, settling in secondary clarifier.	$0.25 mil. per mgd or $25 per person per mgd	$31,000 per year for 1 mgd or $3.10 per person per year	Well established technology Chemicals can be inexpensive Can be low maintenance	Difficult to obtain low phosphorus concentrations with chemical treatment alone Can increase the amount of sludge Operator safety can be a concern	Wyandotte, MI and Collinsville, IL.

1. EPA (1999). Wastewater Technology Fact Sheet Sequencing Batch Reactors. Office of Water. Washington, D.C. EPA 832-F-99-073
2. EPA (2002). Onsite Wastewater Treatment Systems Manual. Office of Water and Office of Research and Development. Washington, D.C. EPA 625-R-00-008. BOD and TSS achievable limits referenced in the manual are 20 mg/L each. Various operators have been able to achieve limits approaching 10 mg/L for their particular system.
3. EPA (2000). Wastewater Technology Fact Sheet Oxidation Ditches. Office of Water. Washington, D.C. EPA 832-F-00-013
4. EPA (1981). Process Design Manual for Land Treatment of Municipal Wastewater. Center for Environmental Research Information. Cincinnati, OH EPA 625-1-81-013
5. EPA (2002). Wastewater Technology Fact Sheet Aerated, Partial Mix Lagoons. Office of Water. Washington, D.C. EPA 832-F-02-008
6. EPA (2002). Wastewater Technology Fact Sheet Facultative Lagoons. Office of Water. Washington, D.C. EPA 832-F-02-014
7. EPA (2009). Nutrient Control Design Manual State of Technology Review Report. Office of Water and Office of Research and Development. Washington, D.C. EPA 625-R-09-012
8. EPA (2007). Biological Nutrient Removal Processes and Costs. Office of Water and Office of Research and Development. Washington, D.C. EPA 823-R-07-002
9. Hartman, P. and Cleland, J.(2007). Wastewater Treatment Performance and Cost Data to Support an Affordability Analysis for Water Quality Standards. Prepared by ICF international for Montana Department of Environmental Quality. May 31, 2007.
10. University of Colorado Boulder(2009). The Robert W. Hite Treatment Facility South Complex Secondary Treatment Upgrade Evaluation. Denver, CO. October 12, 2009.
11. EPA (2007). Wastewater Technology Fact Sheet Denitrifying Filters. Office of Water. Washington, D.C. EPA 832-F-07-014
12. Foess, G. W., Steinbrecher, P., Williams, K., and Garrett, G. (1998). Cost and Performance Evaluation of BNR Processes. Florida Water Resources Journal. December, 1998.
13. Sedlak, R., Phosphorus and Nitrogen Removal from Municipal Wastewater, Principles and Practice, Second Edition (1991)
14. Nitrate is typically zero entering a municipal wastewater treatment facility. Aeration and biologic activity (nitrification) converts ammonium nitrogen to nitrates.
15. Disinfection typically has little effect on nutrients and wastewater characteristics. Common practice today is chlorination followed by dechlorination, Ultraviolet Light (UV), and on occasion ozone addition. Main objective is the reduction of pathogenic microorganisms (disease causing).
16. This is a method of returning the treated water to the environment. This includes groundwater as well as evaporation, even evapotranspiration. Thus the removal or alteration of nutrients is not the primary objective and in some cases the values may go down, up or remain unchanged. But see Antideg Alternaties for Municipal Sewage Treatment.
17. Capital costs cover the cost of materials & labor to construct the facily and bring it on-line. Generally it does not factor in the land costs for the treatment site O&M costs include repair items, labor, expendables, utilities, any chemicals.
18. The biomass that makes up the activated sludge has retained phosphorus in the cell wall and inner cell contents. Thus if a plant upset caused solids to pass through to the effluent, a P excursion is likely.
19. The addition of metal salts does not change the soluble ammonium or nitrate present in the effluent. The additional biomass settled by the metal salt would remove some additional organic nitrogen in the BOD and TSS resulting in a slightly lower total nitrogen concentration.
20. Denitrification does not change the phosphorus present in the biomass.
21. NRDC, et al before US EPA. (2007). Petition for Rulemaking under Clean Water Act. Secondary Treatment Standards for Nutrient Removal.
22. Clarkson, W. (1991) Land Treatment of Wastewater. Civil Engineering Class Text Oklahoma State University, Stillwater, OK.
Calculation assumptions - application 4"/week, nitrogen leaching >10mg/L, dedicated and seasonal system applies 30 weeks/year, 160 acres with center pivot req'd for 1 MGD, hold pond - dedicated system 6 month capacity, holding pond seasonal requires 1 month capacity
23. EPA (1999). Wastewater Technology Fact Sheet Ozone Disinfection. Office of Water. Washington, D.C. EPA 832-F-99-063