WASTEWATER TREATMENT DEVELOPMENTS AND TRENDS IN THE 21ST CENTURY

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EDEYA Workshop on Small Wastewater Systems

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George Tchobanoglous and Harold Leverenz
Department of Civil and Environmental Engineering
University of California, Davis

DISCUSSION TOPICS

- Paradigm Shift/Fundamental Question
- 21^{st} Century Challenges and Issues
- New Technologies for the 21^{st} Century
- Application of New Technologies
- Design of WWTPs for Potable Reuse
- Probabilistic Process Design
- Urine Separation and Processing
- Closing Thoughts

WASTEWATER MANAGEMENT IN THE 21ST CENTURY

A PARADIGM SHIFT: A NEW VIEW OF WASTEWATER

Wastewater is a renewable recoverable source of potable water, resources, and energy.

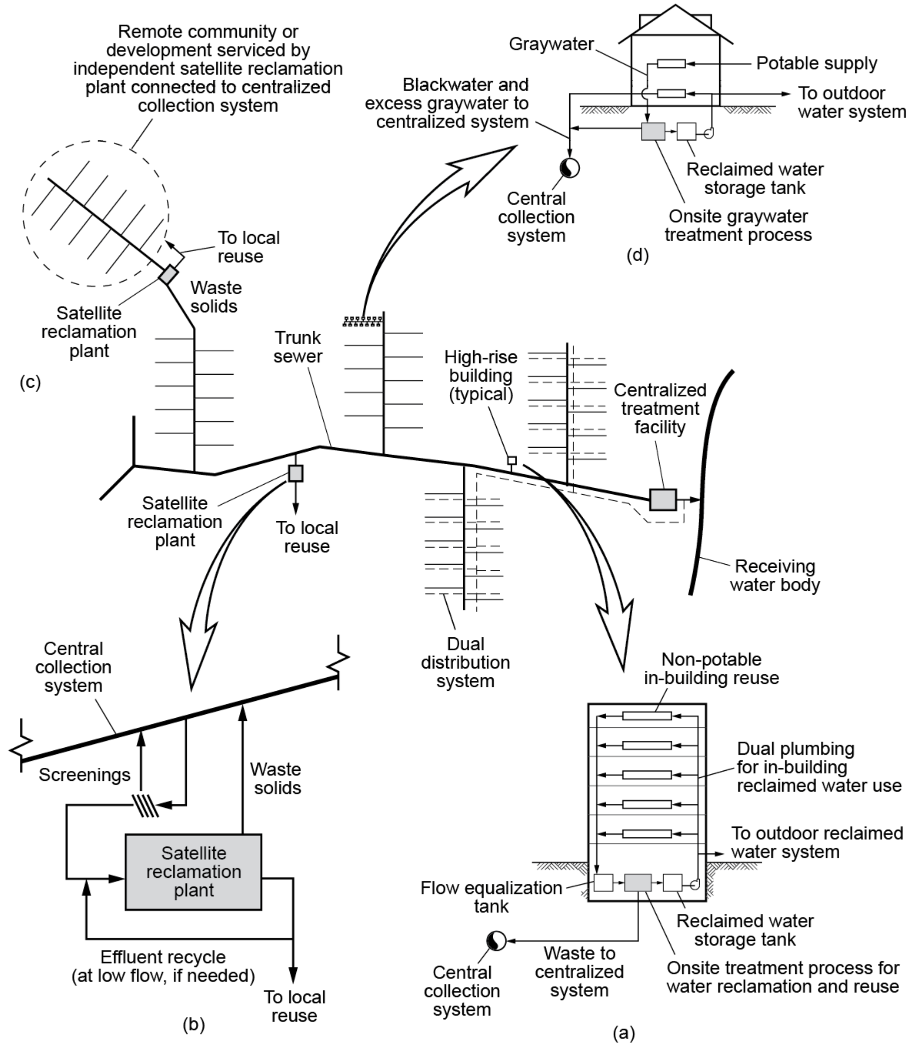
A FUNDAMENTAL QUESTION

What is the optimal use of the carbon in wastewater?

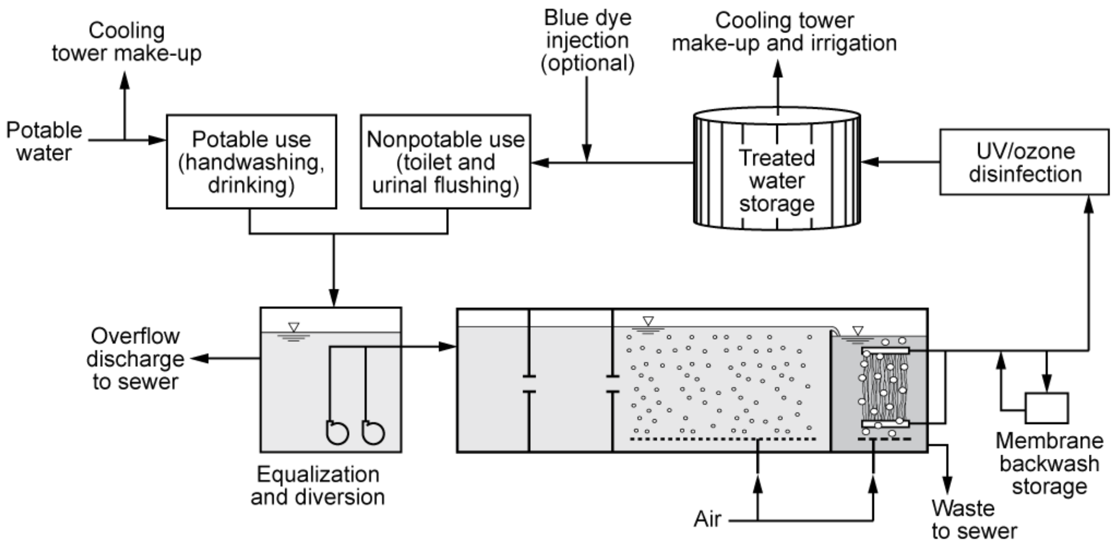
21ST CENTURY CHALLENGES AND ISSUES FOR WASTEWATER MANAGEMENT

- *POPULATION DEMOGRAPHICS*
- *IMPACT OF CLIMATE CHANGE*
- *DECREASING PER CAPITA FLOWRATES*
- *AGING INFRASTRUCTURE*

IMPACT OF POPULATION DEMOGRAPHICS ON ON WATER REUSE

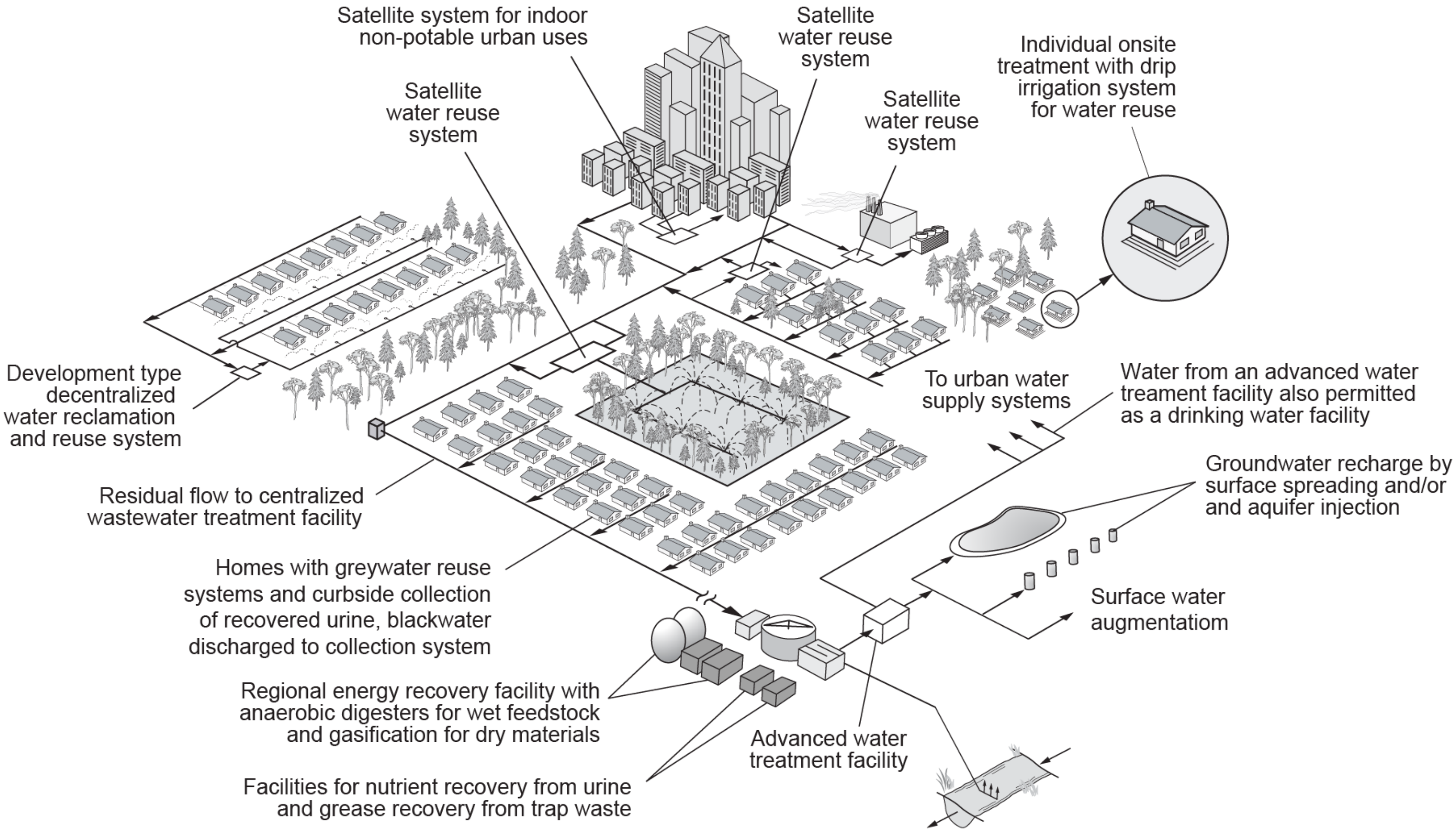


INTERCEPTED IN-BUILDING SELF-CONTAINED WATER RECYCLE SYSTEM

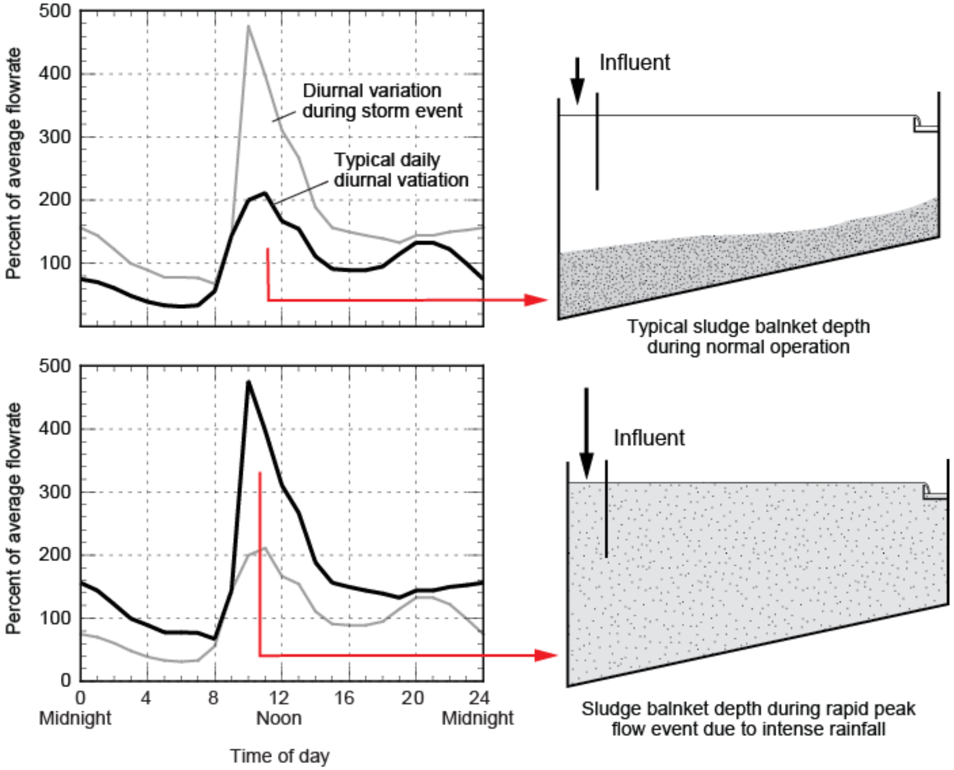


Reclaimed water is used for toilet flushing, landscape irrigation, and cooling water

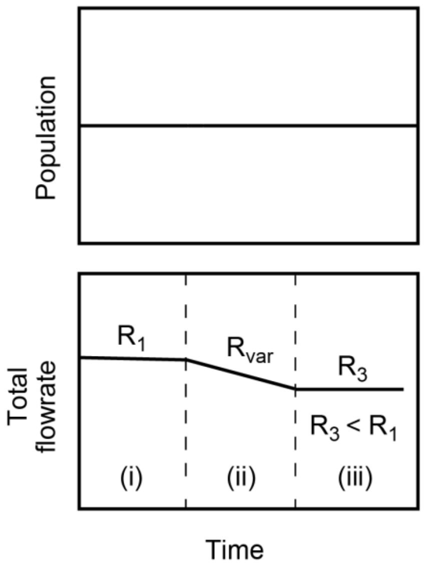
INTEGRATED WASTEWATER MANAGEMENT



IMPACT OF CLIMATE CHANGE ON RAINFALL INTENSITY AND OPERATION OF WWTPS



CURRENT AND PROJECTED PER CAPITA WATER USE IN THE UNITED STATES



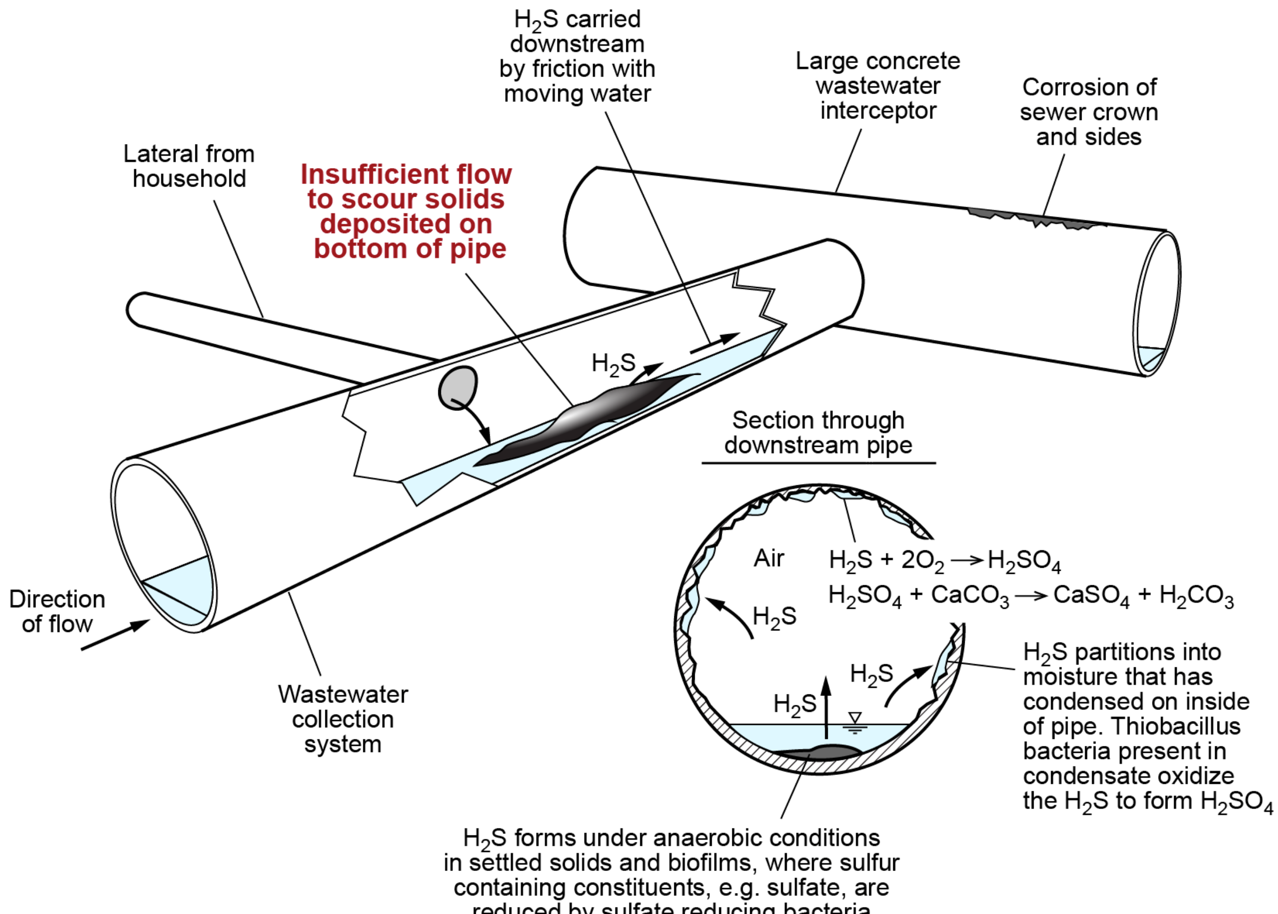
(i) Pre-1992

(ii) Improved water conservation

(iii) Maximum water conservation

Use	Flow, gal/capita•d					
	2013		2020		2030	
	Range	Typical	Range	Typical	Range	Typical
Domestic						
Indoor use	40 - 80	60	35 - 65	55	30 - 60	45
Outdoor use	16 - 50	35	16 - 50	35	16 - 50	35
Commercial	10 - 75	40	10 - 70	35	10 - 65	30
Public	15 - 25	20	15 - 25	18	15 - 25	15
Loss and waste	15 - 25	20	15 - 25	18	15 - 25	15
Total	96 - 255	175		161		138

IMPACT OF WATER CONSERVATION AND DROUGHT: SOLIDS DEPOSITION, H_2S FORMATION, AND DOWNSTREAM CORROSION DUE TO REDUCED FLOWS

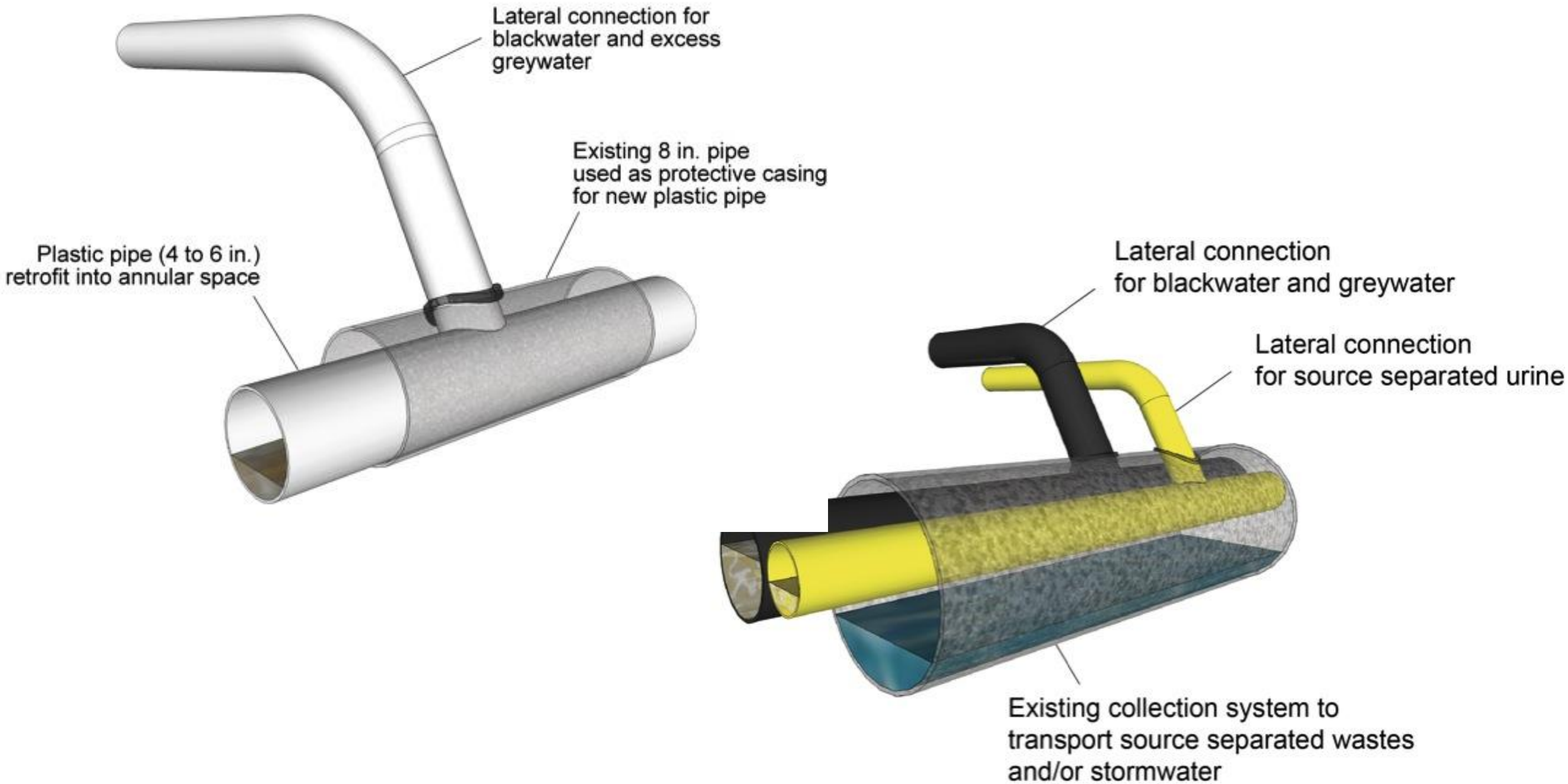


THE IMPACT OF CONSERVATION: ENHANCED CORROSION AND INCREASED MASS LOADINGS

- Reduced flow results in solids deposition
- Solids undergo decomposition and produce H_2S
- H_2S is transported with the water
- Downstream H_2S increases the rate of corrosion

- Per capita wastewater flow rates decreasing
- Flow rates will not increase beyond current values
- Mass loadings of constituents will increase with population growth without a flowrate increase

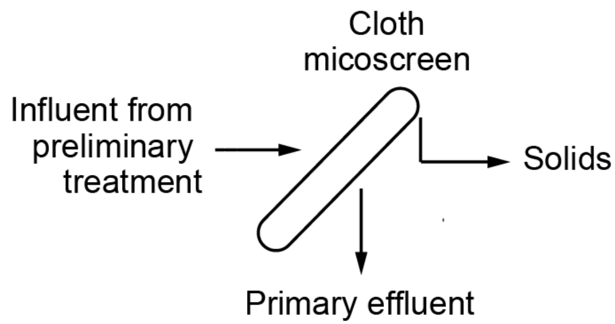
Use of Existing Collection System For Source Separated Resource Streams

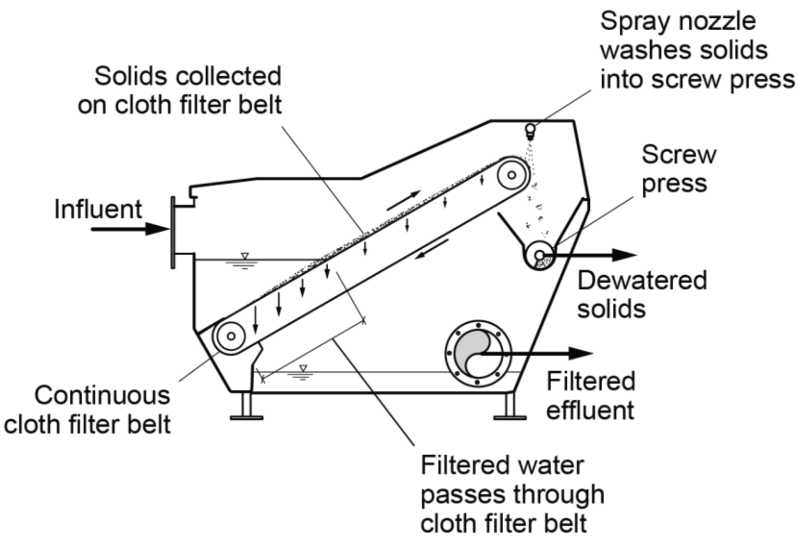


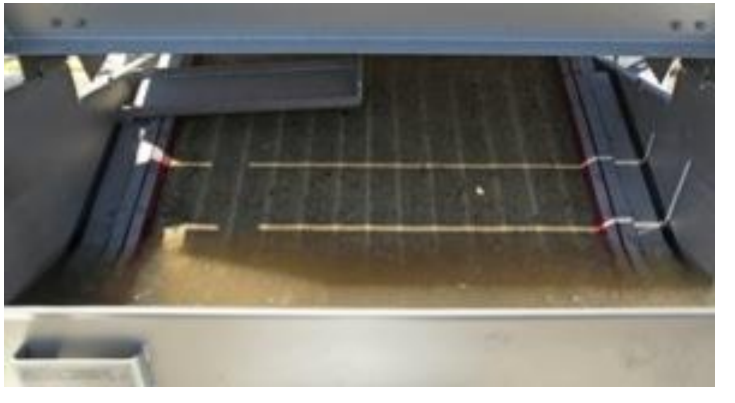
NEW TECHNOLOGIES FOR THE 21ST CENTURY

- ***Alternative primary treatment processes***
- ***Enhanced primary treatment***
- ***Enhanced primary-secondary treatment***
- ***Enhanced removal of algae***
- ***Enhanced wetland systems***

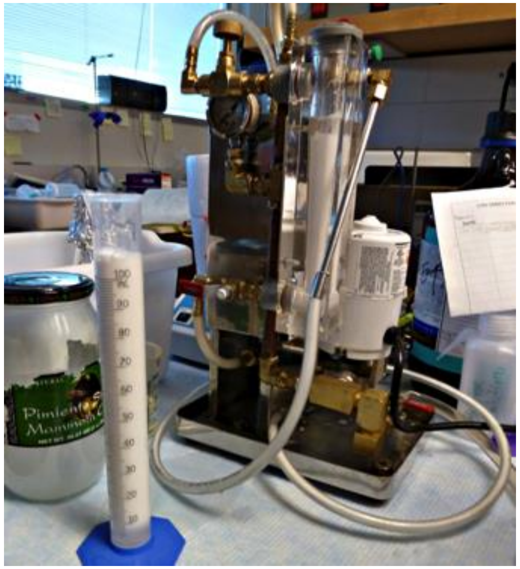
ALTERNATIVE TECHNOLOGIES FOR ENHANCED PRIMARY TREATMENT: CLOTH SCREEN (250-300 MM)

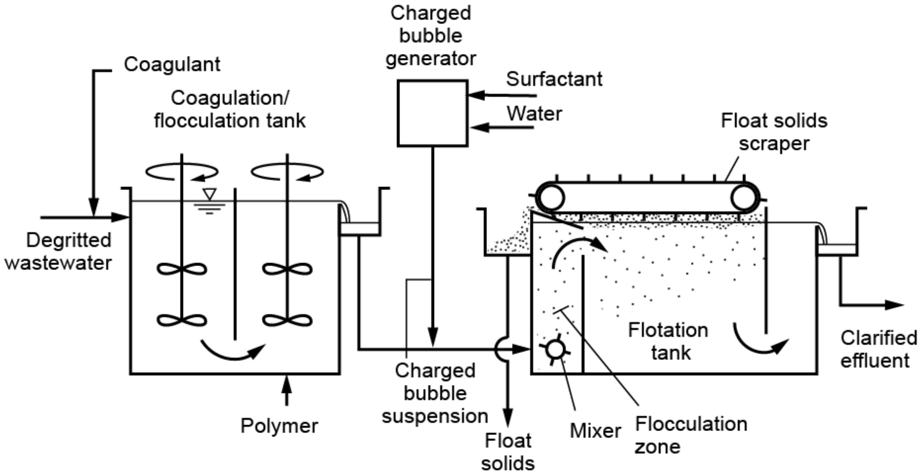






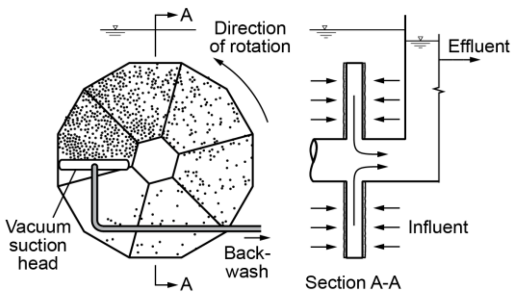
ALTERNATIVE TECHNOLOGIES FOR ENHANCED PRIMARY TREATMENT: CHARGED BUBBLE FLOTATION

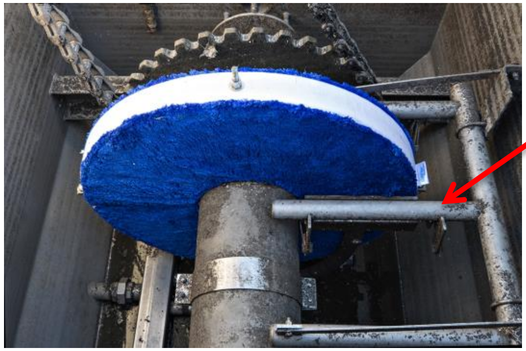




- 1/5th the size of conventional clarifiers
- Nanoparticles can be added to charged bubble for removal of specific constituents

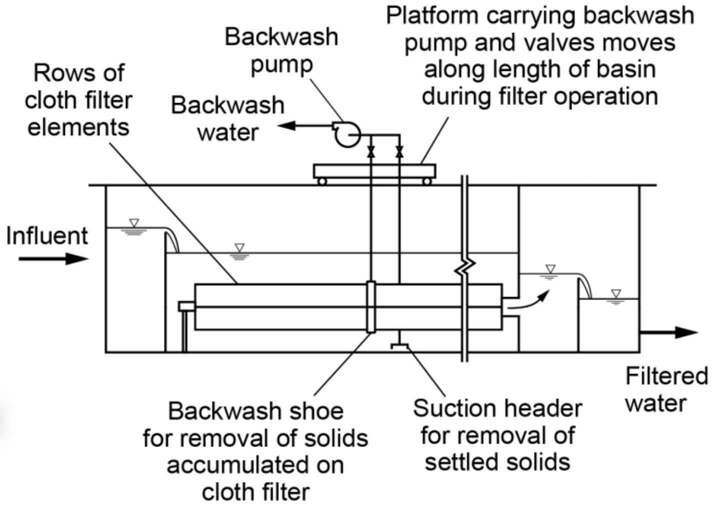
ALTERNATIVE TECHNOLOGIES FOR ENHANCED PRIMARY TREATMENT: CLOTH DISK FILTER (5-10 µm)





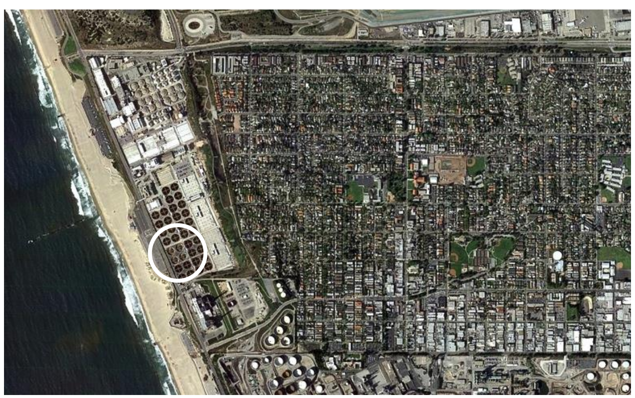
Vacuum suction head

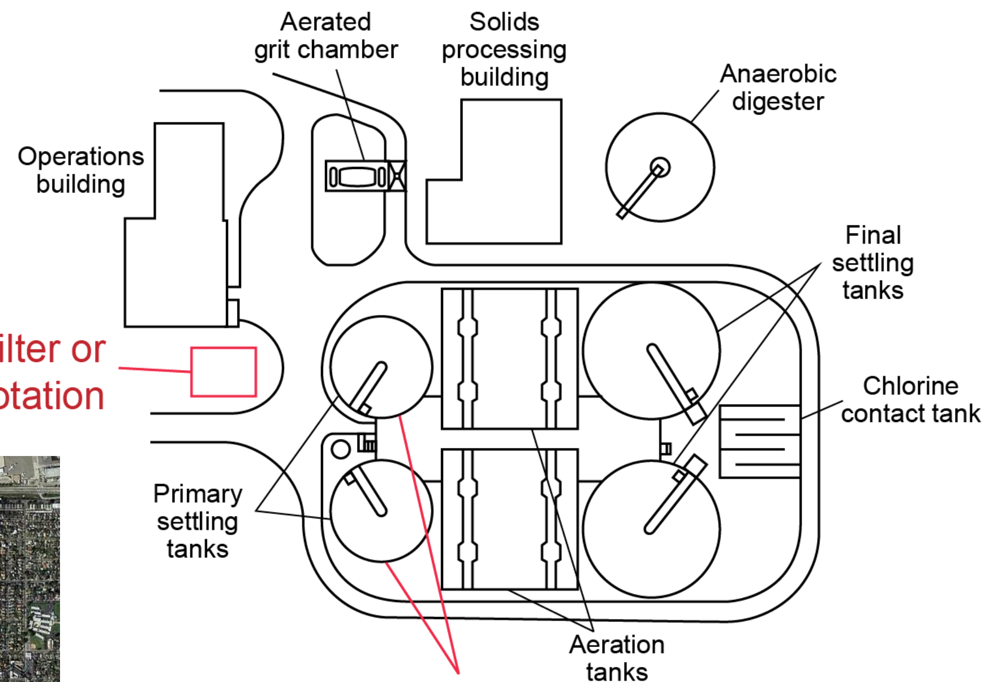
Fiber thickness = 0.007 mm
Depth filter L/D = 400 to 800
Cloth filter L/D = 425 to 725



Parameter	Unit	Average influent	Average effluent	Average removal, %
BOD	mg/L	169	59	64.2
COD	mg/L	417	147	62.8
TSS	mg/L	221	26	87.5
VSS	mg/L	116	36	69.0
Turbidity	NTU	143	37	73.5
TKN	mg/L	39	36	7.7
FOG	mg/L	14	10	28.6
UVT	%	28	44	+59.9

Replace and Repurpose Existing Primary Clarifiers





Cloth disk filter or charged-bubble flotation

Primary clarifiers can now be used for influent and/or return flow equalization

NEW TECHNOLOGIES FOR THE 21ST CENTURY

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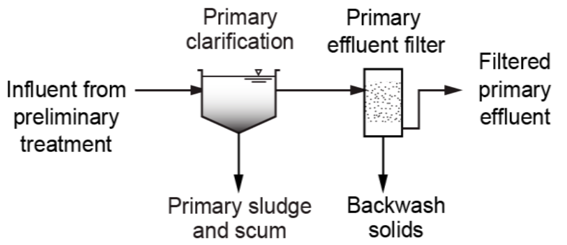
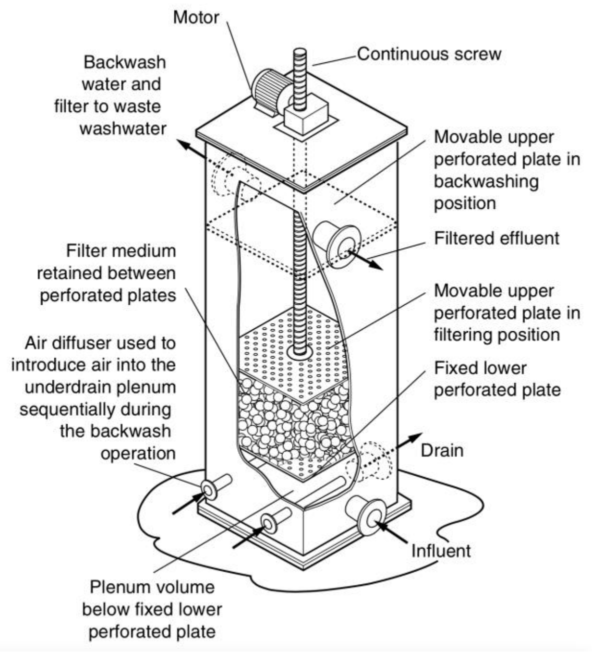
- *Enhanced primary-secondary treatment*
- *Enhanced removal of algae*
- *Enhanced wetland systems*

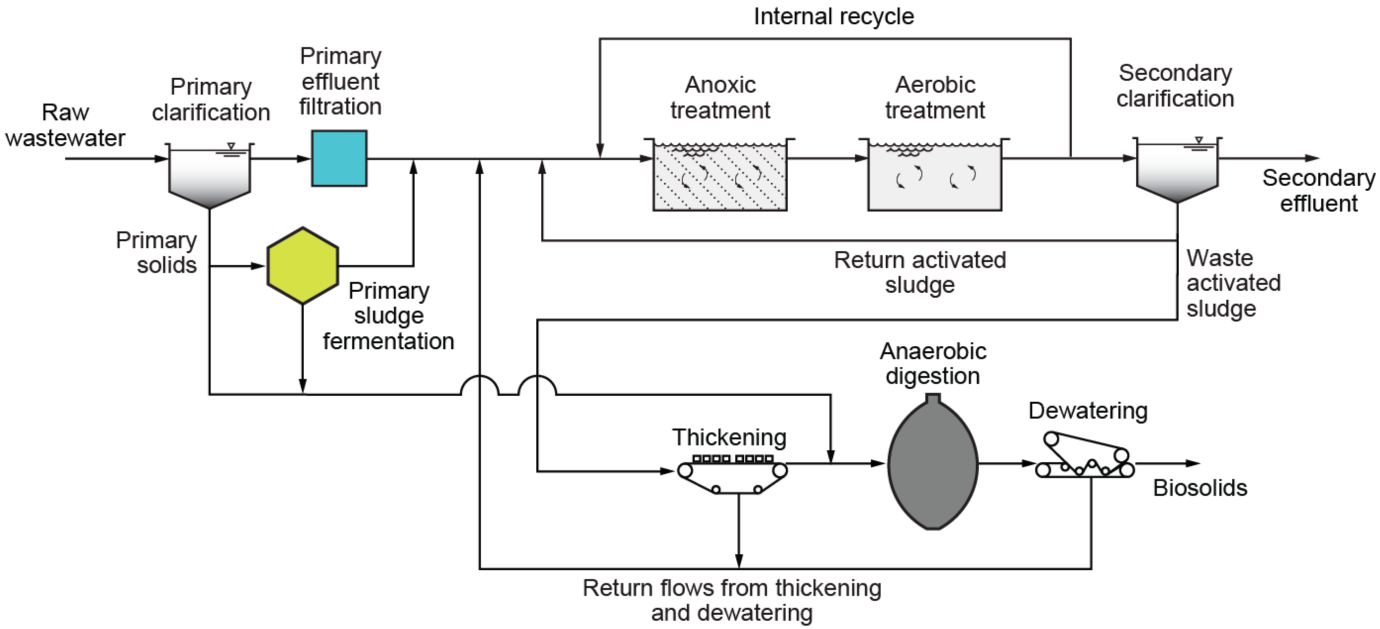
Primary Effluent Filtration (PEF) of Settled Raw Wastewater before Biological Treatment





Compressible medium filters

PEF and Primary Solids Fermentation for Enhanced Performance and Improved Energy Balance



Condition	*Effluent TN*	*Air demand*	*Biogas production*
PEF only	+ 53%	– 18%	+ 40%
25% PS to fermentation	– 20%	– 14%	+ 16%

Courtesy Onder Caliskaner

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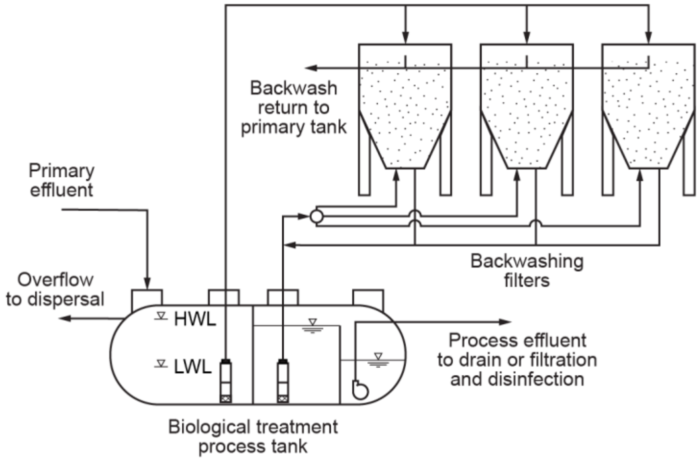
BACKWASHING UNSATURATED FLOW PUMICE FILTER

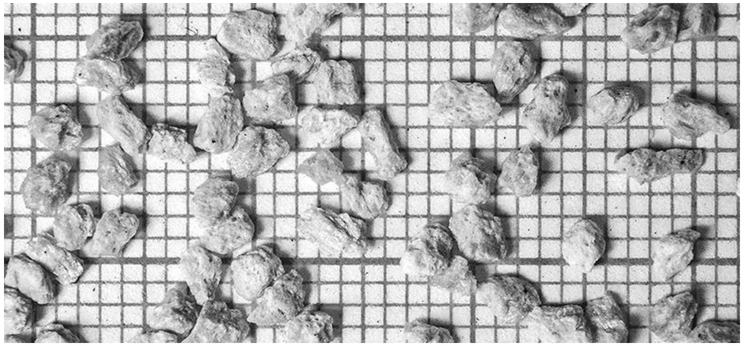


TYPICAL PERFORMANCE DATA FOR PUMICE FILTER

Parameter	Unit	Influent	Effluent
Chemical oxygen demand (COD)	mg/L	350	70
Biochemical oxygen demand (BOD)	mg/L	130	20
Total suspended solids (TSS)	mg/L	60	10
Turbidity	NTU	90	5
Total Kjeldahl nitrogen (TKN)	mg N/L	260	30
Ammonium nitrogen	mg N/L	200	20
Nitrate nitrogen	mg N/L	0	100
Dissolved oxygen	mg/L	0	6

In single-pass mode at 75 gal/ft^2·d (3,000 L/m^2·d) with septic tank effluent

Specific weight = 640 kg/m^3
Average porosity = 90 %
Particle size = 2- 4 mm

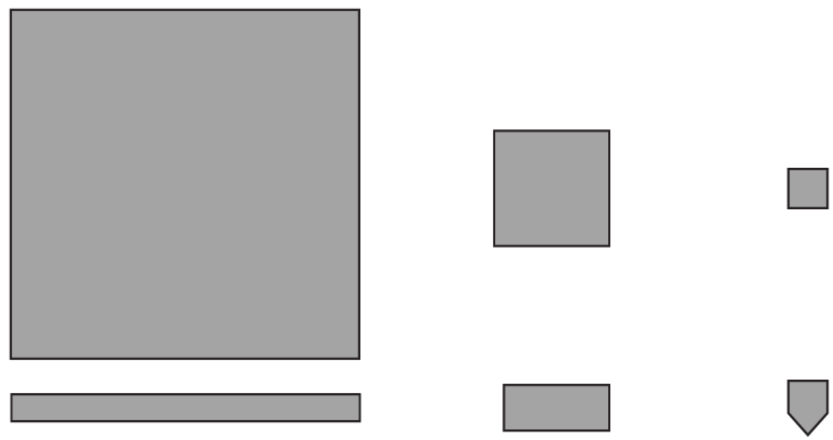


Contact:
Dr. Harold Leverenz
Email: harold.leverenz@gmail.com

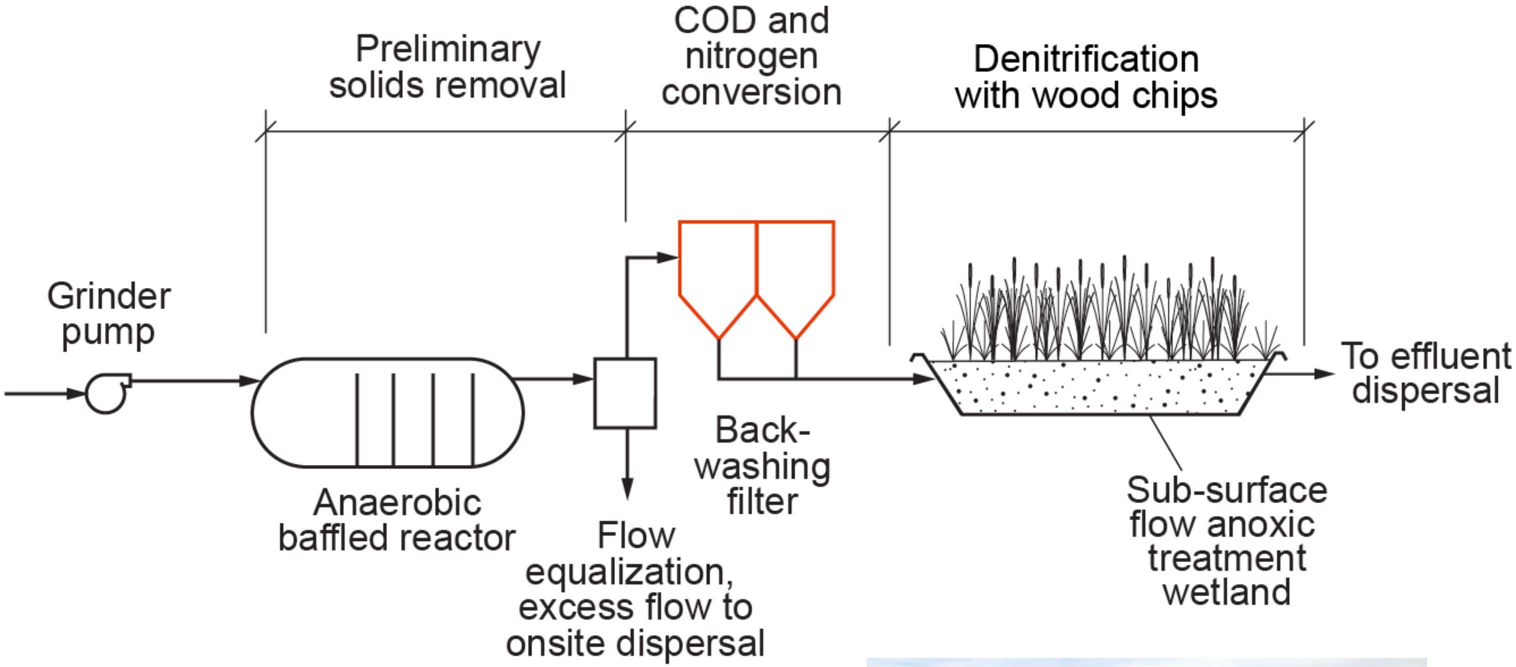
ADVANTAGES OF PUMICE FILTER

- High organic loading rate
- Single or multi-pass operation
- Small size can be located in an enclosure to protect from weather elements
- The filter is located above ground
- Easy to prefabricate and plumb at treatment site
- Being above ground, filter is easy to maintain
- Filter is easy to aerate
- Lower energy input

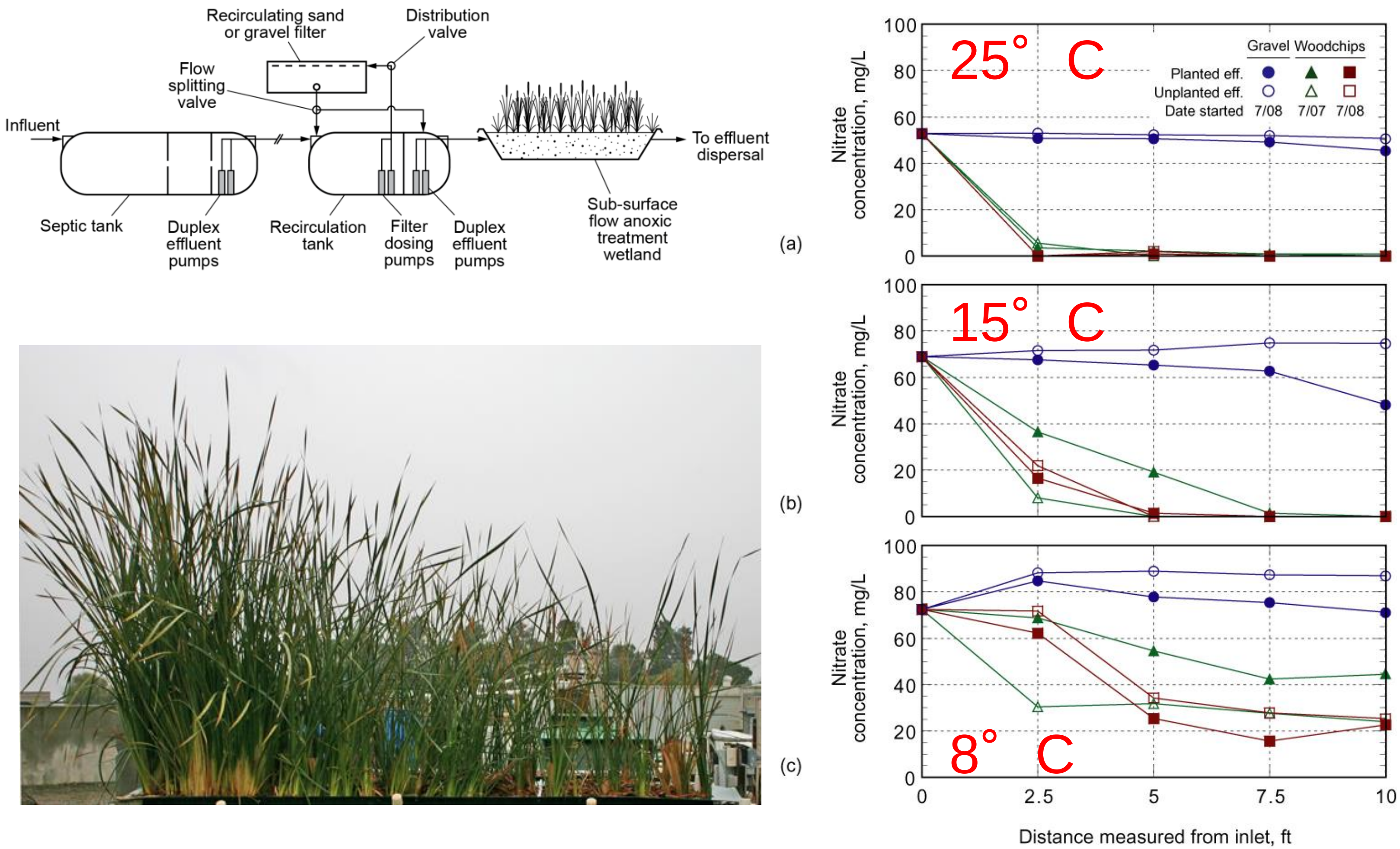
RELATIVE SIZE OF ALTERNATIVE TREATMENT PROCESSES BASED ON NITROGEN LOADING

Item	Technology		
	Recirculating gravel filter	Recirculating textile filter	Single-pass backwashing pumice filter
Nitrogen loading, g TN/m^2·d	8	70	600
Plan view (relative size) Profile view (relative size)			
Filter size for 1,000 persons, 13,000 g TN/d	1,625 m^2	185 m^2	22 m^2

COMPLETE TREATMENT WITH PUMICE FILTER

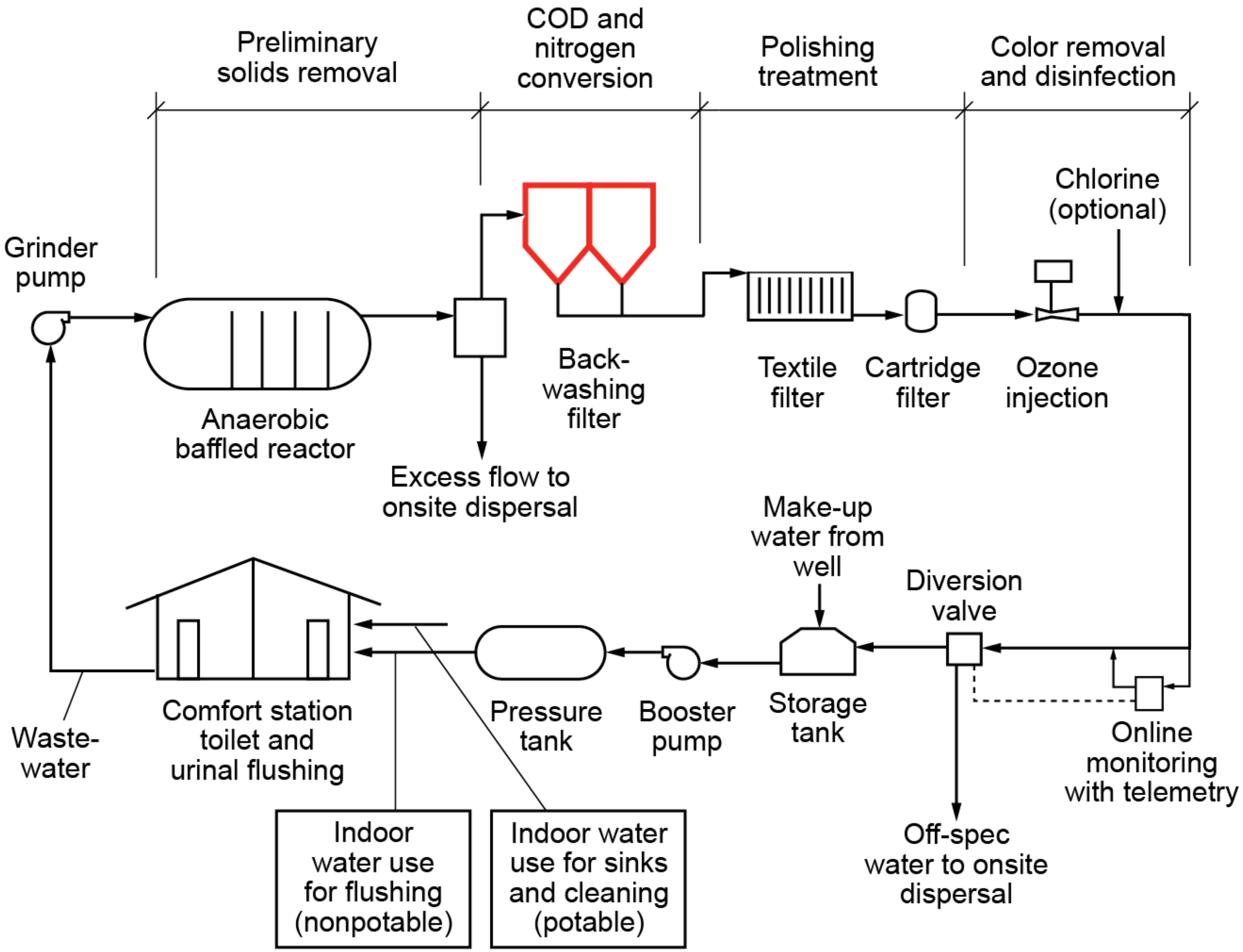


HORIZONTAL SUB-SURFACE FLOW ANOXIC WETLAND FOR NITROGEN REMOVAL

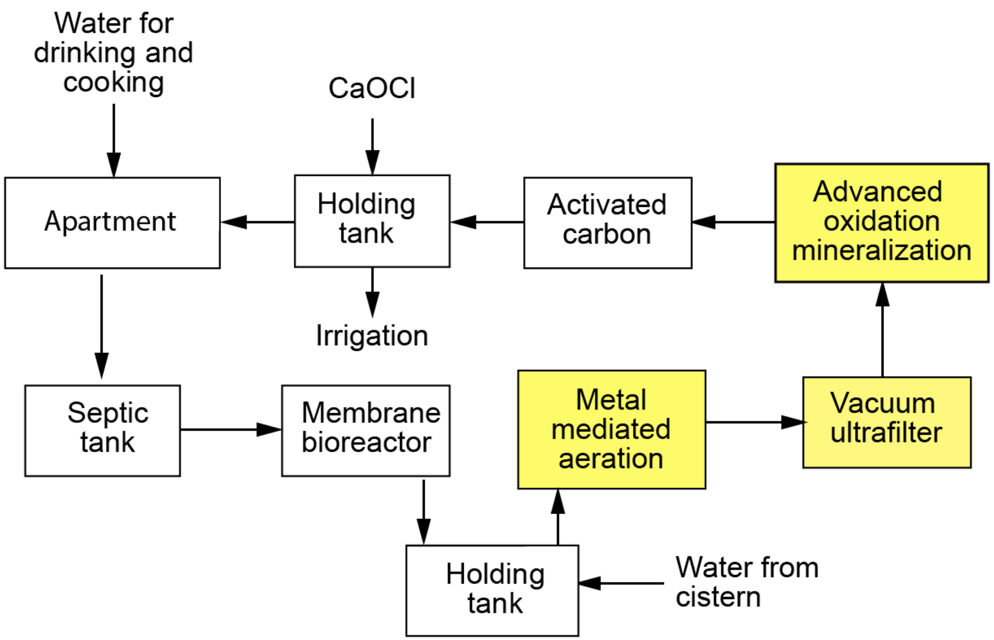


Courtesy Harold Leverenz

RECYCLE SYSTEM FOR TOILET FLUSHING



APPROACHING NET-ZERO WATER: ENERGY-POSITIVE MUNICIPAL WATER MANAGEMENT



Source: Jim Englehardt
University of Miami
College of Engineering

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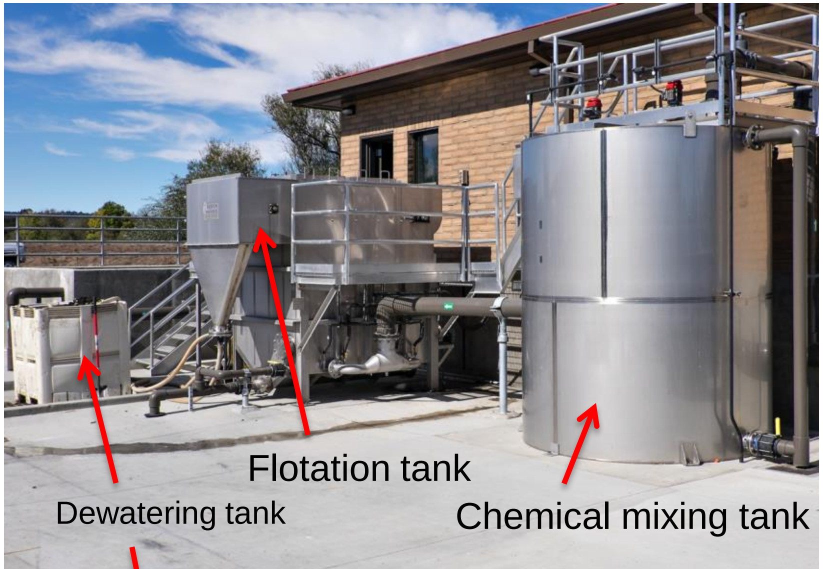
ALGAL REMOVAL WITH CHARGED BUBBLE FLOTATION PROCESS

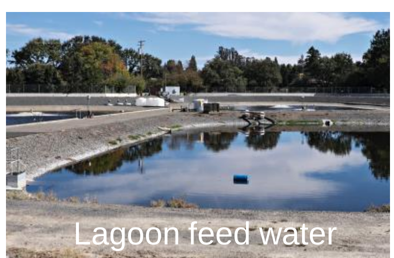


Thickened algae ~4-5%

Effluent turbidity typically, <1 NTU

Pasteurization for disinfection

Compressible medium effluent filtration



Algae dewatered on straw bed

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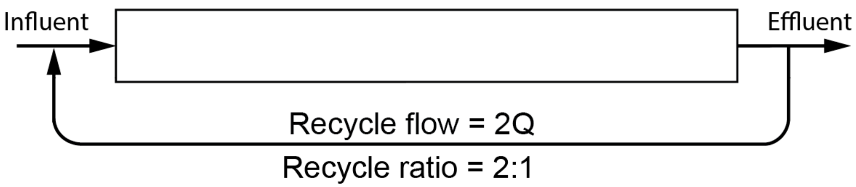
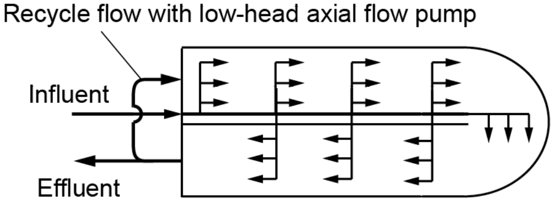
INTENSIFICATION OF WETLAND TREATMENT

- Surface flow wetland with step-feed and recycle flow in linear or wrap around design
- Surface flow wetland with step-feed, aeration, and recycle flow
- Surface flow wetland with side-stream pure oxygen aeration
- Horizontal sub-surface flow aerated wetland
- Horizontal sub-surface flow anoxic wetland
- Tidal flow (fill and draw) reciprocating flow wetland
- Single pass high ammonia exchange capacity
- Surface flow with side-stream zeolite anammox treatment

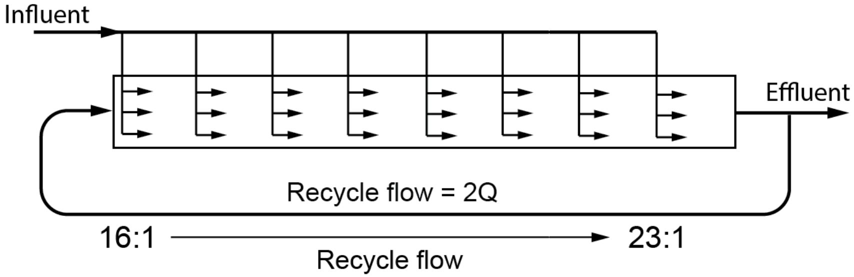
INTENSIFICATION WITH STEP-FEED AND LOW-HEAD RECYCLE



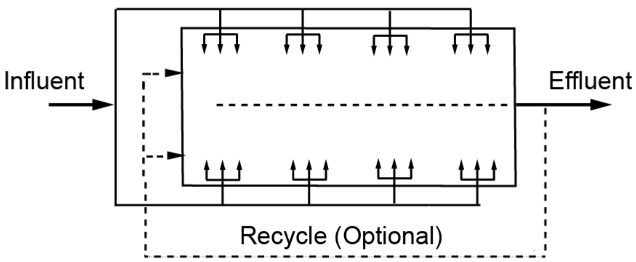
Plug-flow reactor with recycle



Wrap around step-feed plug-flow reactor with low-head recycle

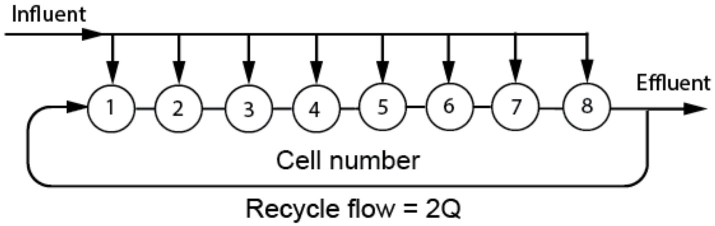


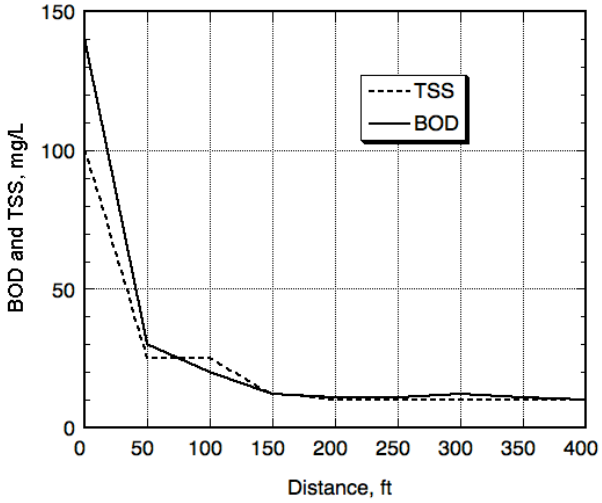
Step-feed plug-flow reactor with recycle



Periferal feed with center drawoff with optional recycling

SURFACE FLOW WETLAND WITH STEP-FEED, AERATION, AND RECYCLE FLOW

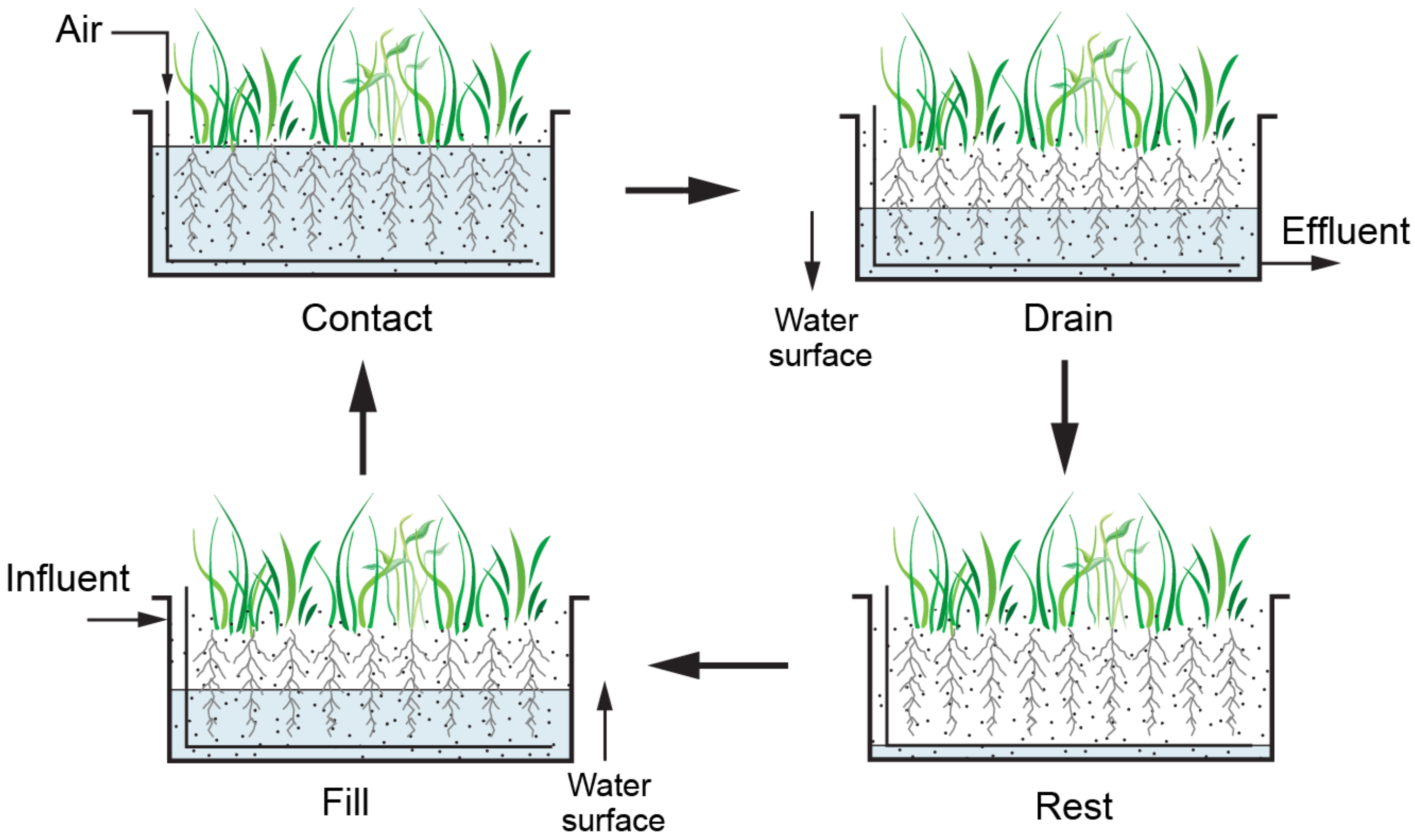




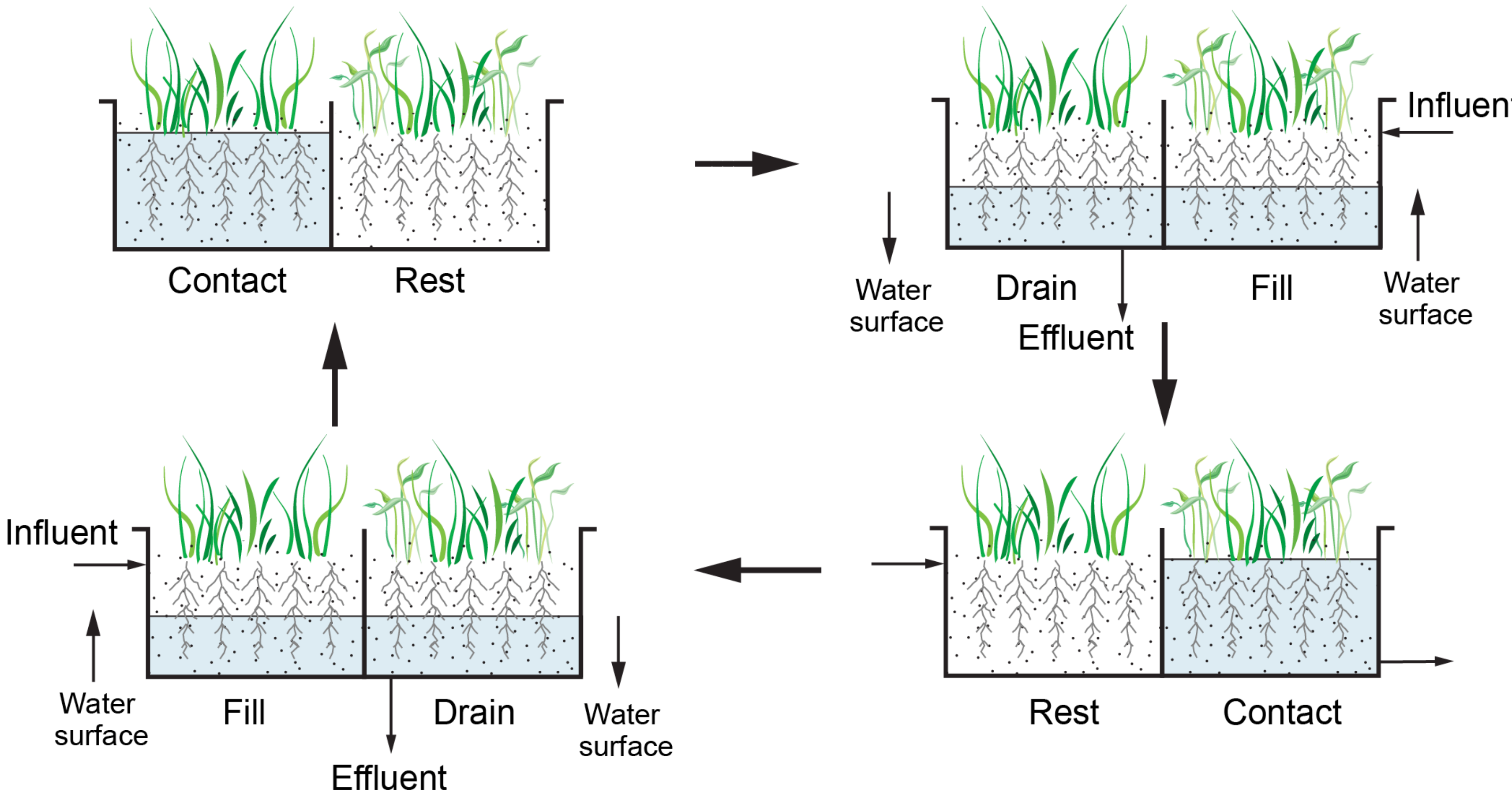
TYPICAL HORIZONTAL SUB-SURFACE FLOW AERATED WETLAND

Courtesy David Austin, CH2M

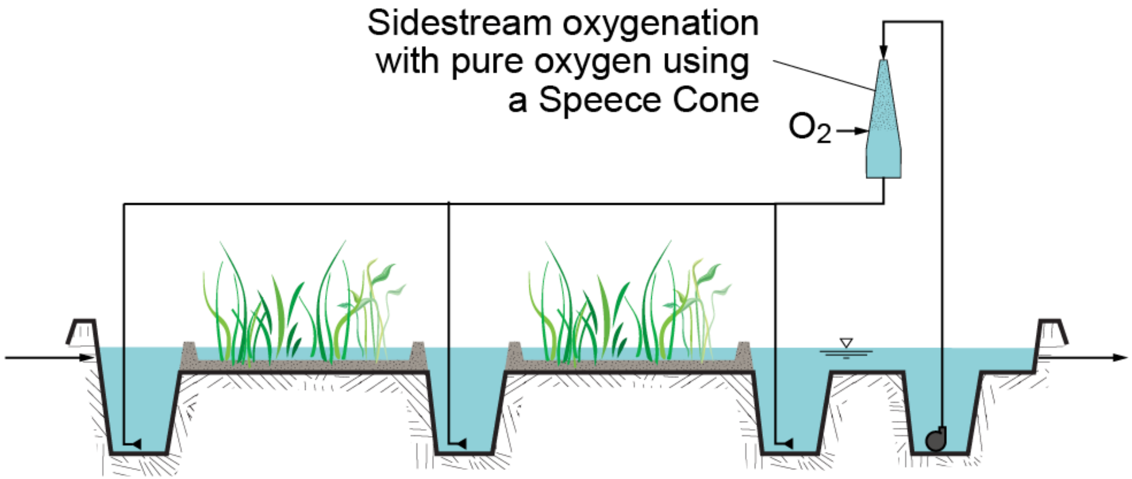
FILL AND DRAIN (TIDAL) WETLAND WITHOUT OR WITH AERATION



RECIPROCATING FILL AND DRAIN (TIDAL) WETLAND WITHOUT OR WITH AERATION AND ADSORPTIVE MEDIUM



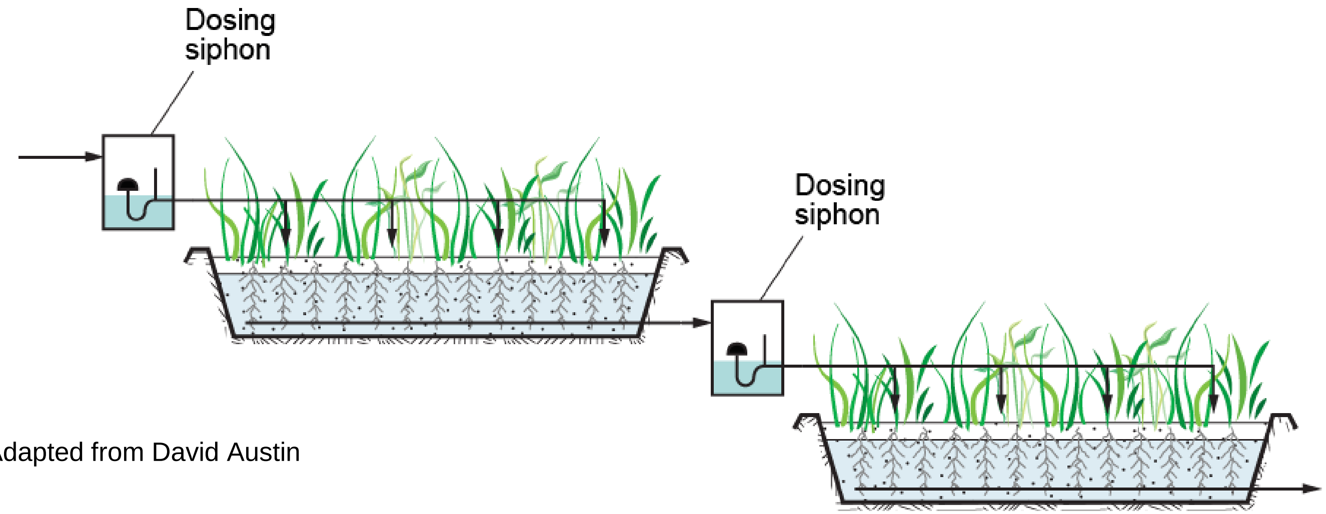
SURFACE FLOW WETLAND WITH SIDESTREAM OXYGENATION FOR NITRIFICATION



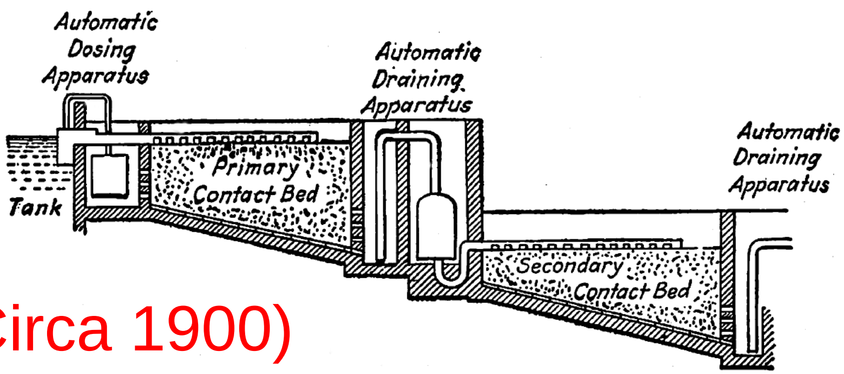
Dick Speece

Adapted from David Austin

TWO-STAGE FILL AND DRAIN (TIDAL) WETLAND WITH ADSORPTIVE MEDIM



Adapted from David Austin

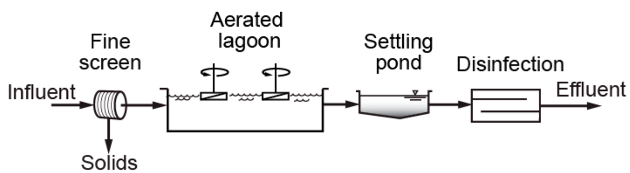


(Circa 1900)

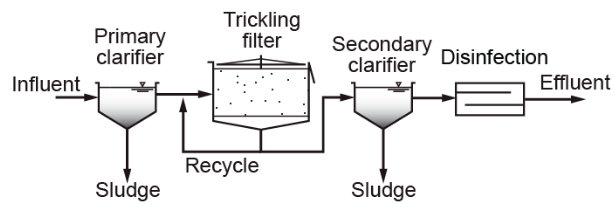
FIG. 115.—Arrangement of double contact beds.

DESIGN OF WASTEWATER TREATMENT SYSTEMS FOR POTABLE REUSE

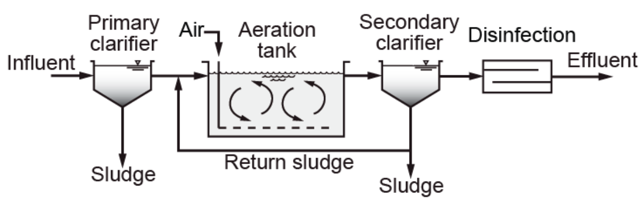
ARE ALL SECONDARY WASTEWATER TREATMENT PROCESSES SUITABLE FOR PR?



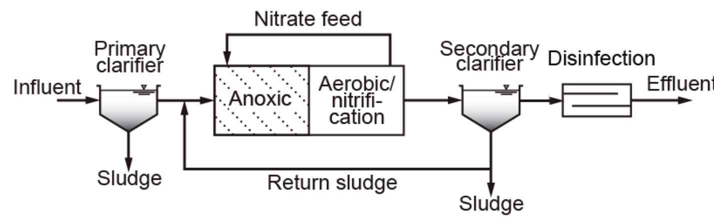
Aerated Lagoon



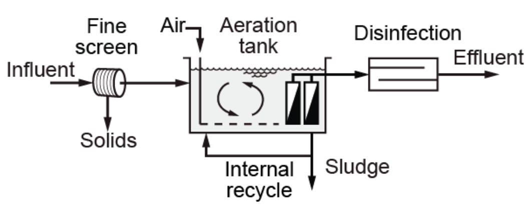
Tricklig Filter



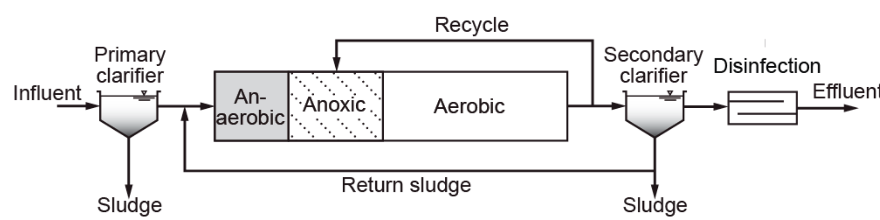
Conventional Activated Sludge



Preanoxic Nitrogen Removal

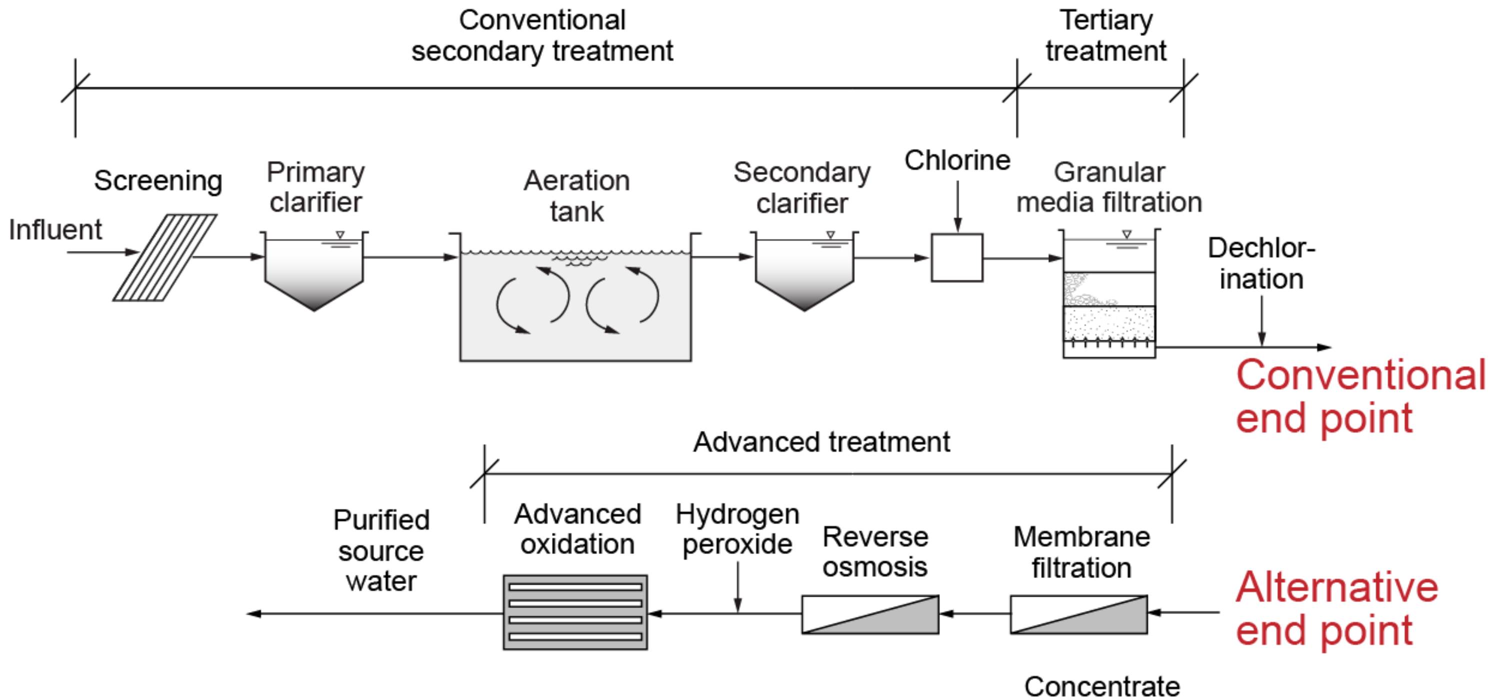


Membrane Bioreactor Activated Sludge



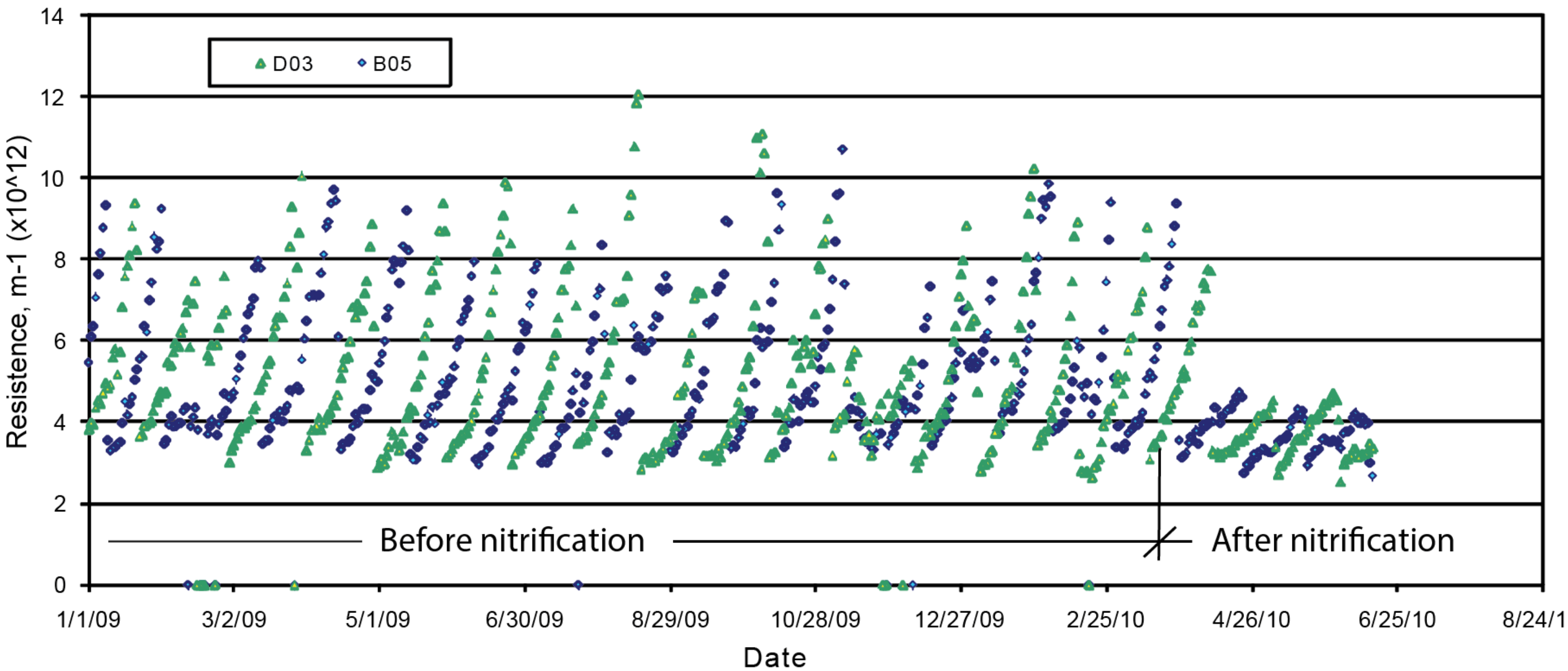
Anaerobic/Anoxic /Aerobic (A2O)

DESIGN OF BIOLOGICAL TREATMENT PROCESS FOR ALTERNATIVE END POINT



It is time to rethink wastewater treatment

IMPACT OF CHANGE IN OPERATION OF BIOLOGICAL TREATMENT PROCESS ON OCWD MF RESISTANCE



PROBABALISTIC ANALYSIS AND DESIGN OF DECENTALIZED WASTEWATER MANAGEMENT SYSTEMS FOR DIFFERENT USES

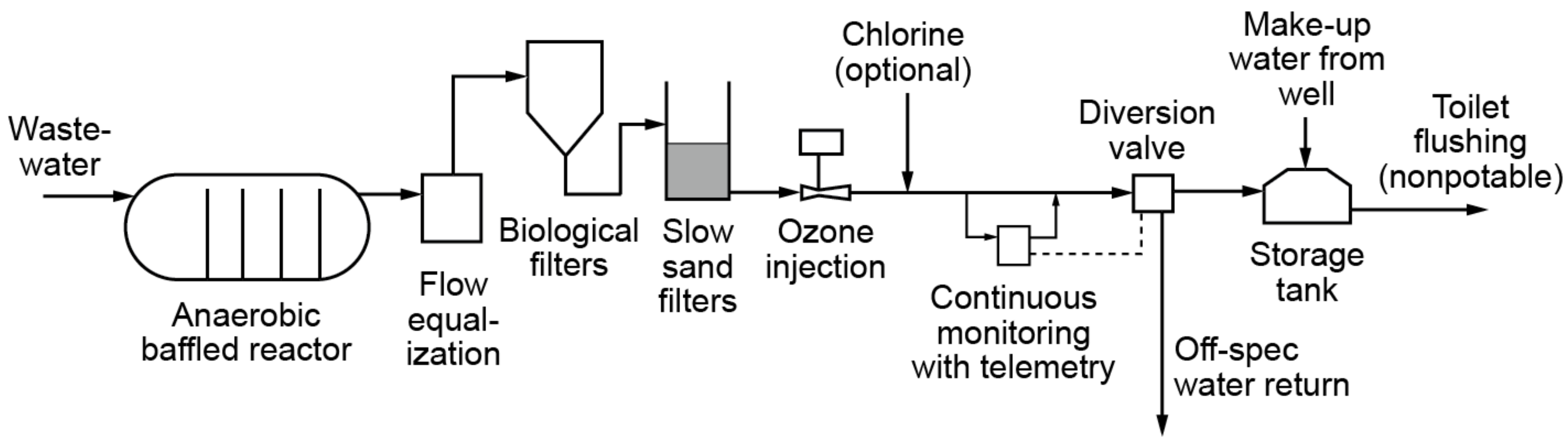
DEVELOPMENT OF REQUIRED LOG_{10} REDUCTION VALUES FOR INDIRECT AND DIRECT POTABLE REUSE

Item	Enteric virus	Giardia	Cryptosporidium
Untreated wastewater maximum density	10^5 virus/L	10^5 cysts/L	10^4 oocysts/L
Tolerable drinking water density (TDWD)	2.2×10^{-7} virus/L	6.8×10^{-6} cysts /L	1.7×10^{-6} oocysts /L
Ratio of TDWD to wastewater density	2.2×10^{-12}	6.8×10^{-11}	1.7×10^{-10}
Required $\log_{10}$ reduction value	12	10	10

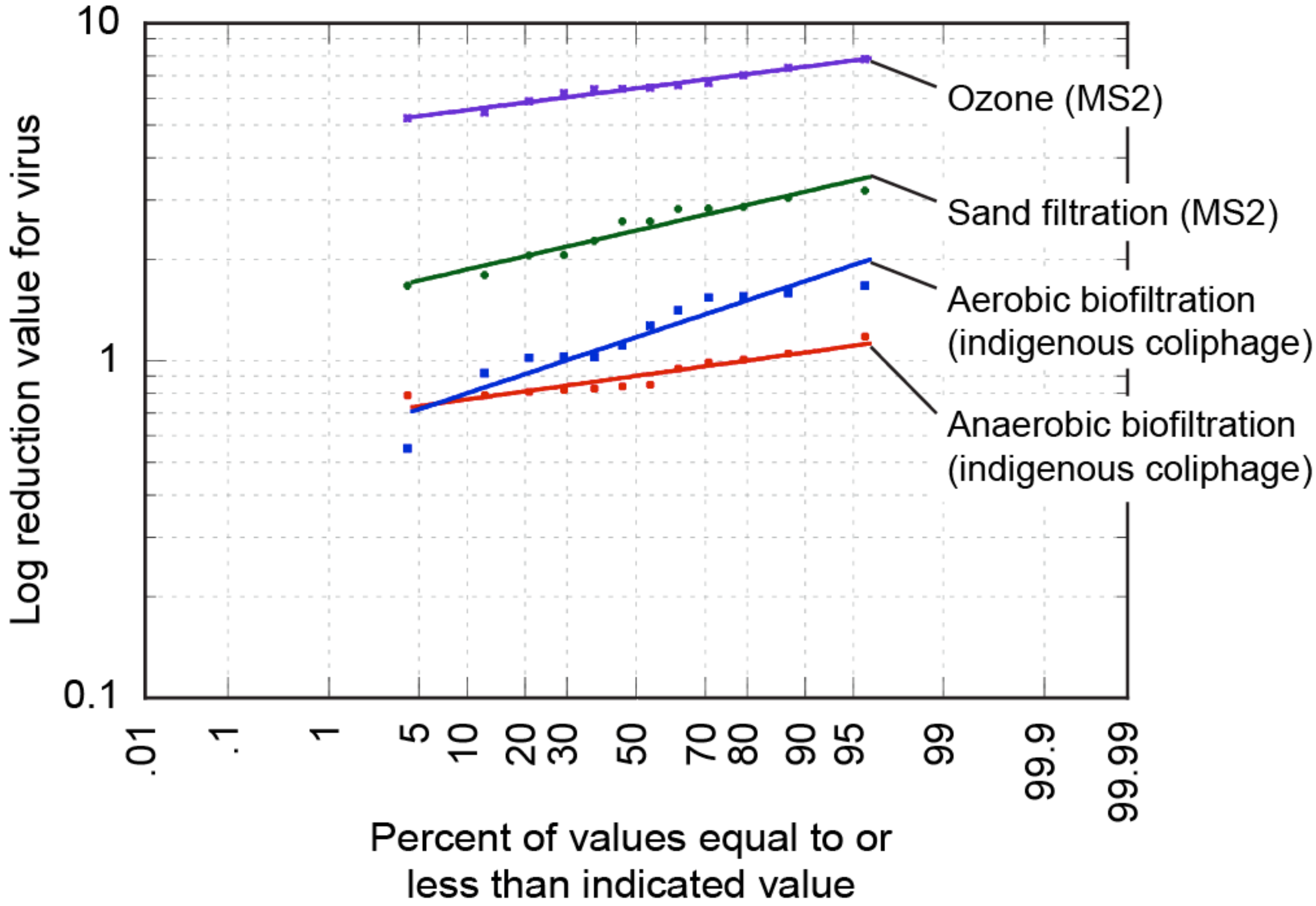
LOG$_{10}$ PATHOGEN REDUCTION TARGETS (LRT$_{05}$) FOR VARIOUS WATERS AND USES

Water use	Log reduction targets for 10^{-4}		
	Enteric viruses	Parasitic protozoa	Enteric bacteria
Municipal wastewater			
Unrestricted irrigation	6.0	6.5	5.0
Indoor use	6.5	7.5	6.0
Graywater			
Unrestricted irrigation	5.5	4.5	3.5
Indoor use	6.0	4.5	3.5
Stormwater – 10^{-1} dilution			
Unrestricted irrigation	5.0	5.5	4.0
Indoor use	5.5	6.5	5.0

UNIT PROCESSES IN RECYCLE SYSTEM FOR TOILET FLUSHING



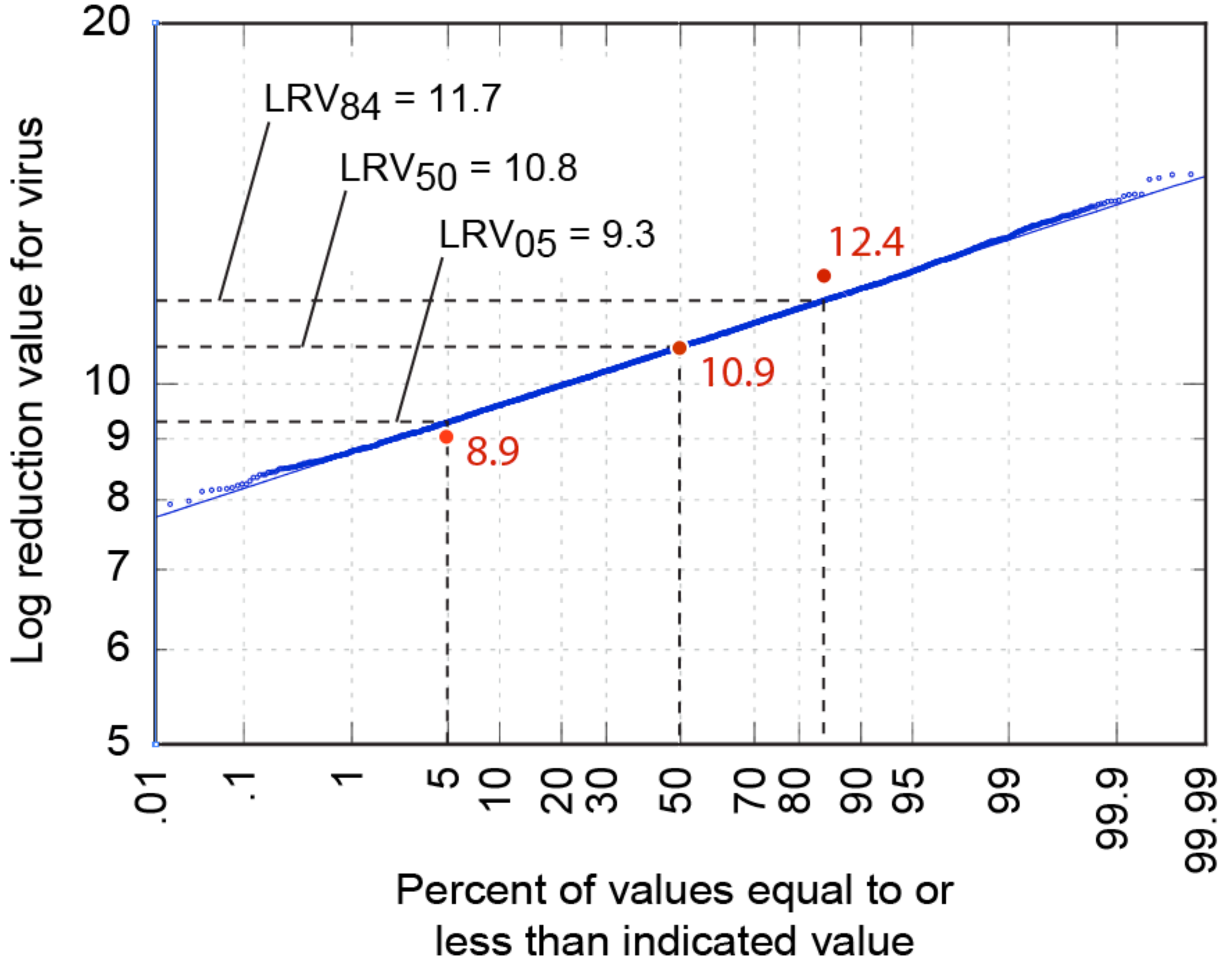
PERFORMANCE OF UNIT PROCESSES IN RECYCLE SYSTEM FOR TOILET FLUSHING



STASTICAL DATA FOR UNIT PROCESSES IN RECYCLE SYSTEM FOR TOILET FLUSHING

Disinfectant	Surrogate	Log reduction values				s_g
		Lowest observed	LRV_{05}	LRV_{50}	LRV_{84}	
Anaerobic biofiltration	Indigenous coliphage	0.8	0.73	0.90	1.02	1.13
Aerobic biofiltration	Indigenous coliphage	0.6	0.72	1.17	1.58	1.35
Sand filtration	MS2	1.7	1.73	2.43	2.99	1.23
Ozonation	MS2	5.2	5.71	6.42	6.80	1.06
Treatment train total		8.3	8.9	10.9	12.4	

MONTE CARLO PERFORMANCE SIMULATION (10,000 SAMPLEs) OF RECYCLE SYSTEM FOR TOILET FLUSHING



CLOSING THOUGHTS

- Must think differently about wastewater
- Must embrace new technologies
- Must consider different treatment endpoints
- Must consider probabilistic design
- Must consider alternatives methods for resource recovery

IT'S A NEW WORLD

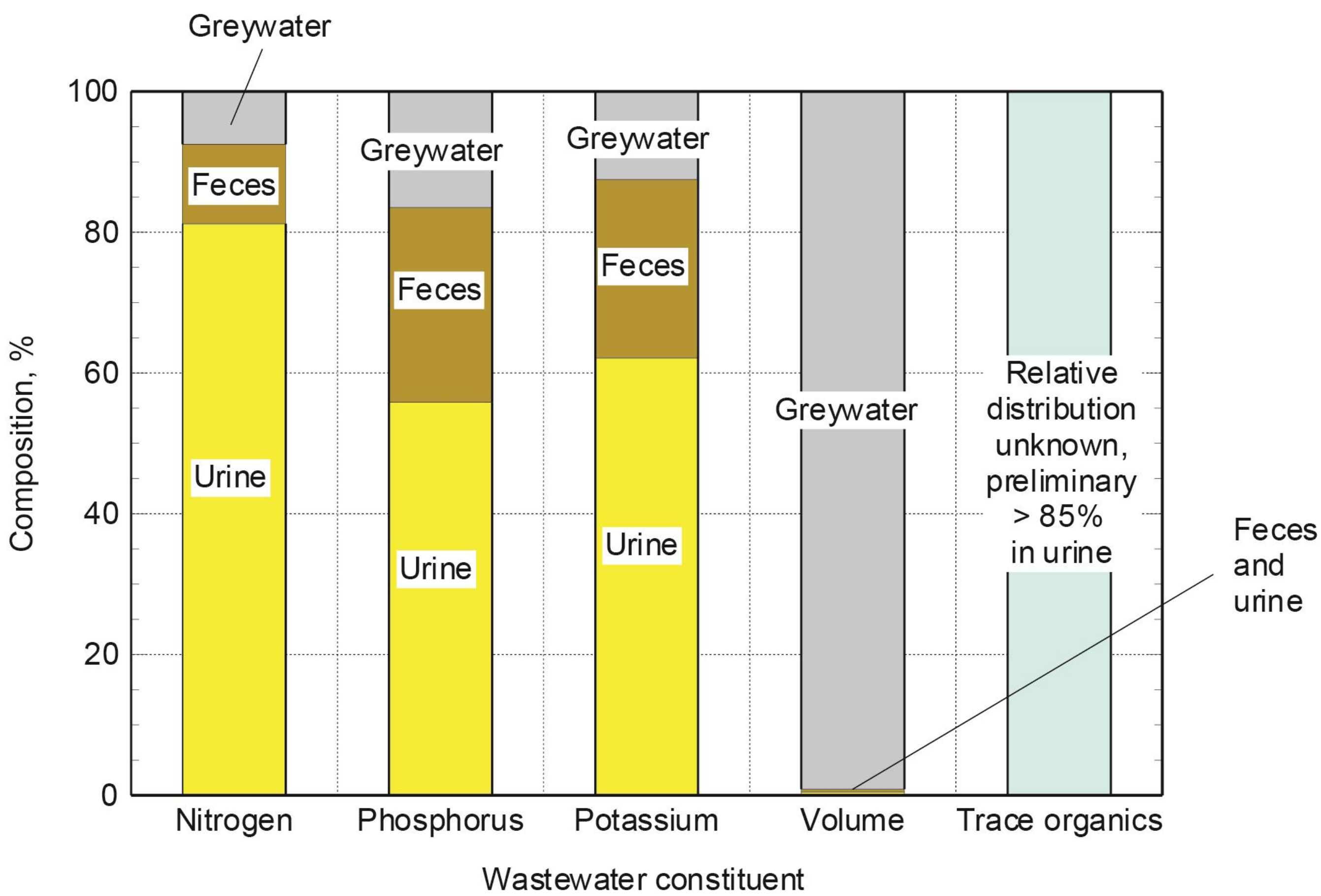
***UNLEASH YOUR IMAGINATION*!**

THANK YOU

FOR LISTENING

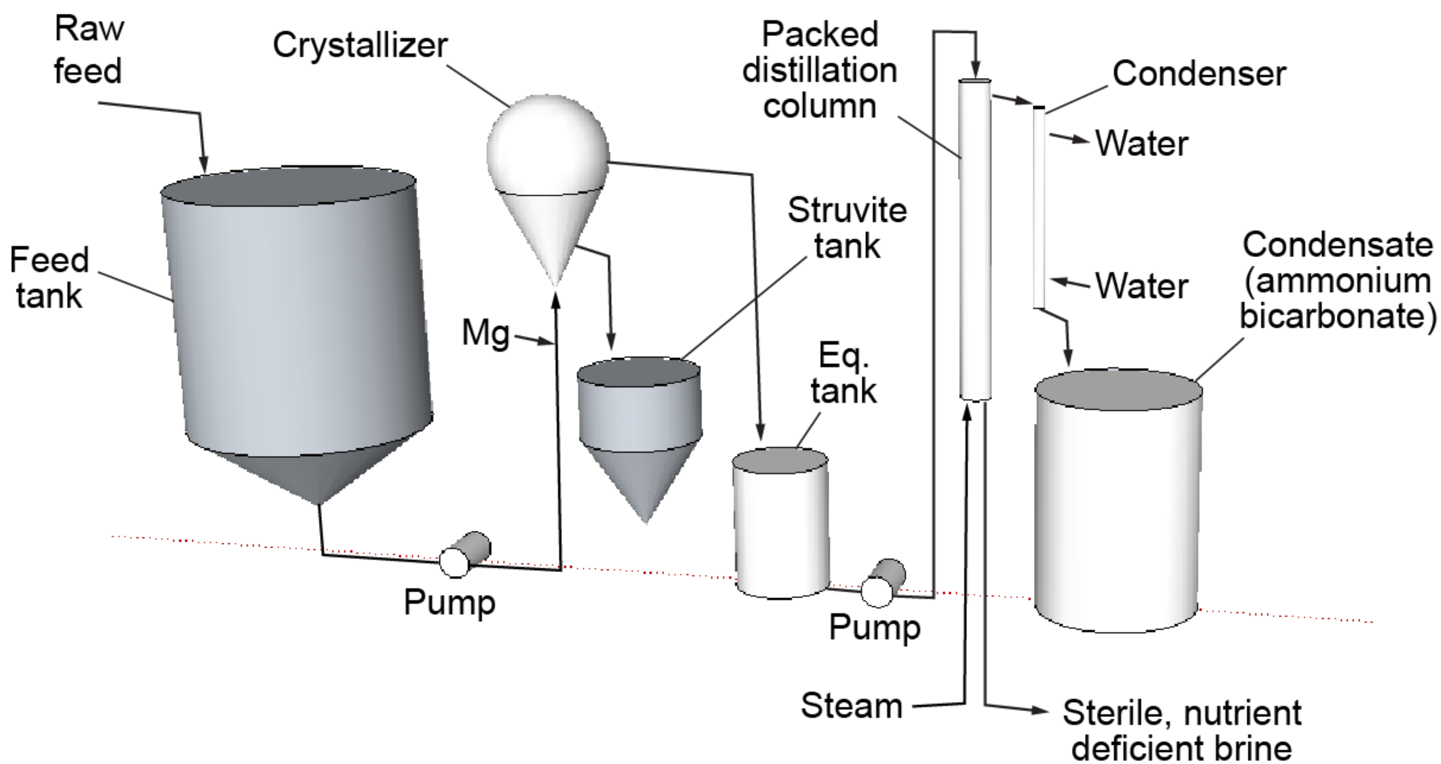
URINE SEPARATION AND NUTRIENT RECOVERY

NUTRIENTS AND TRACE ORGANICS IN DOMESTIC WASTEWATER: A CASE FOR URINE SEPARATION



Source: Jönsson et al.(2000) Recycling Source Separated Human Urine.

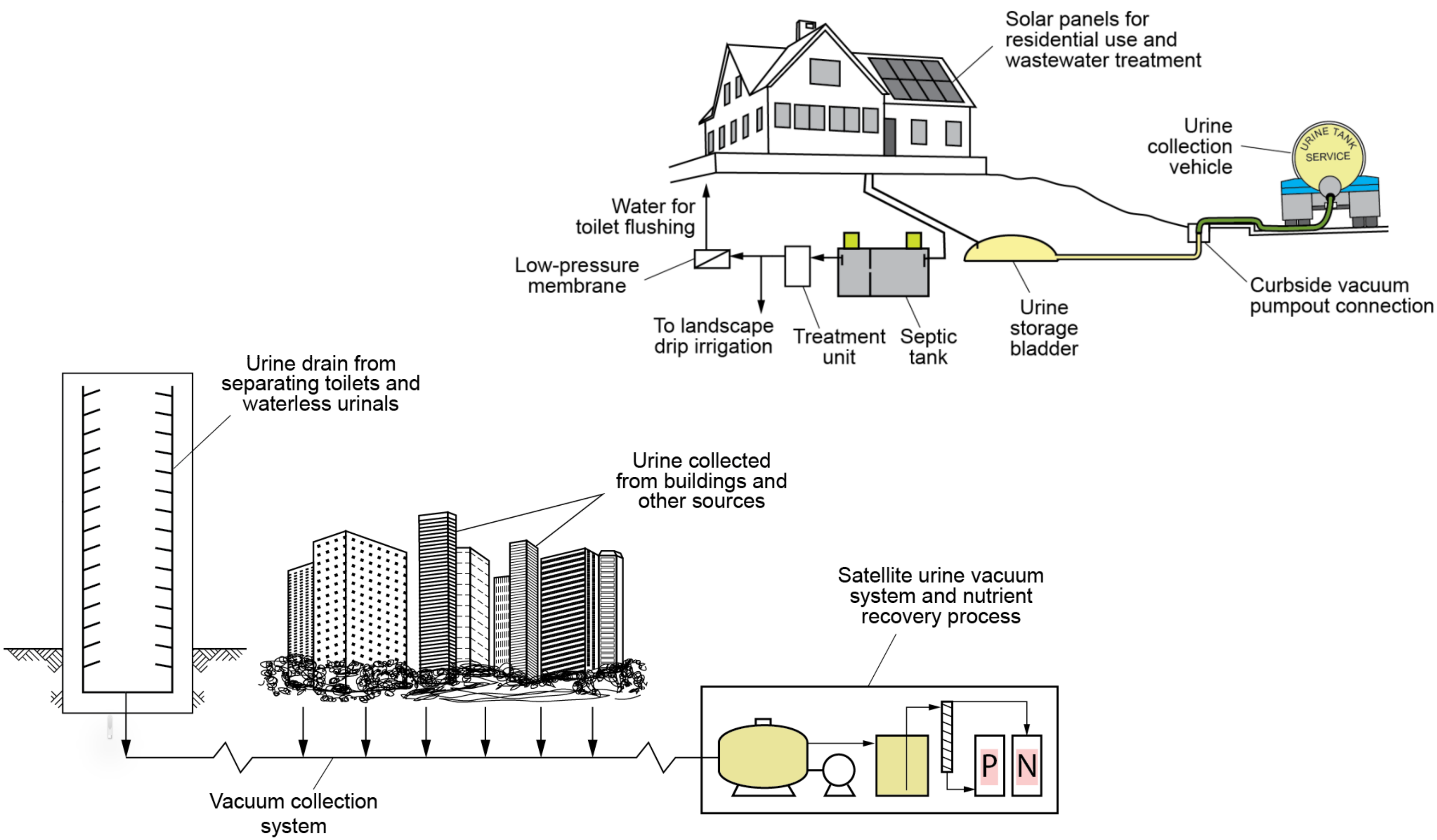
SCHEMATIC OF SEPARATION PROCESS FOR THE RECOVERY OF NUTRIENTS FROM URINE



URINE SEPARATION PROCESS AND PRODUCTS (Ammonium bicarbonate and struvite)

URINE SEPARATION FACILITY AT MICROBREWERY, DAVIS, CALIFORNIA

URINE SEPARATION, STORAGE, AND NUTRIENT RECOVERY FROM BUILDINGS AND INDIVIDUAL RESIDENCE



THANK YOU

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