

WASTEWATER MANAGEMENT IN THE 21ST CENTURY: ISSUES FOR THE DESIGN OF SMALL TREATMENT SYSTEMS

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DISCUSSION TOPICS

- A Paradigm Shift and Fundamental Question
- 21st Century Challenges and Issues
- Decentralized Non-Potable Water Systems
- New Technologies for the 21st Century
- Treatment for Different Endpoints
- Probabilistic Process Design
- Urine Separation and Processing
- Closing Thoughts

A PARADIGM SHIFT AND FUNDAMENTAL QUESTION

A PARADIGM SHIFT: A NEW VIEW OF WASTEWATER

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

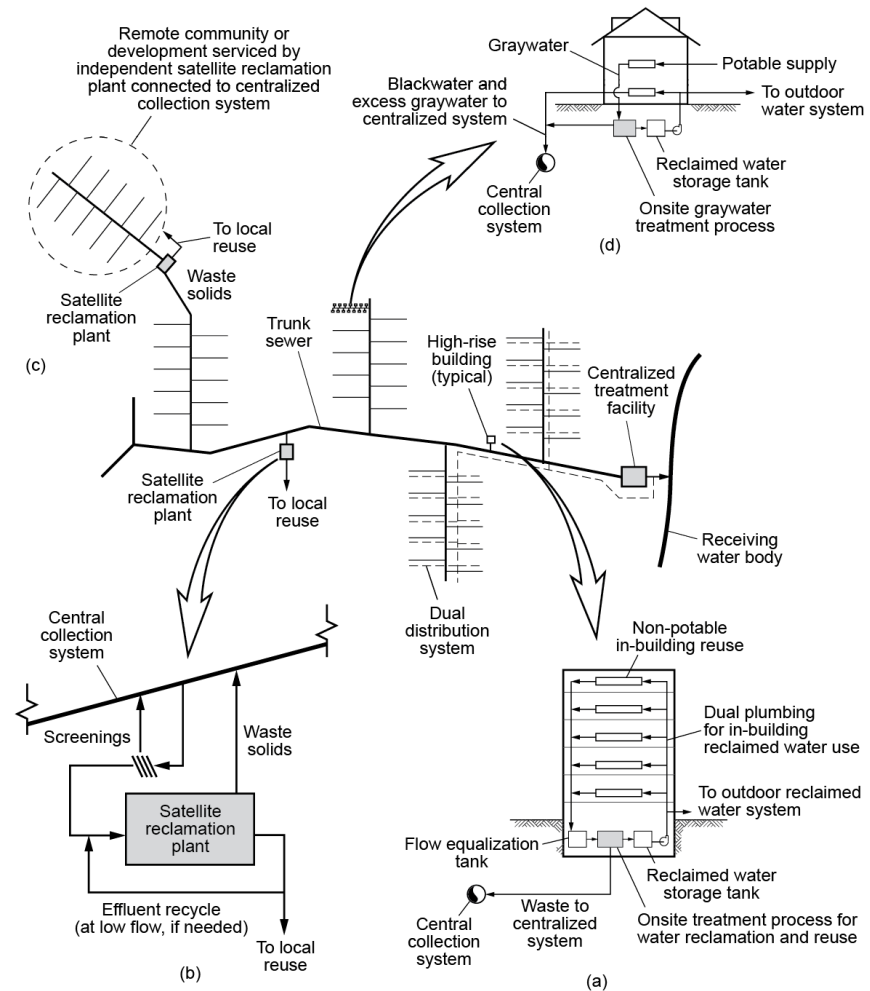
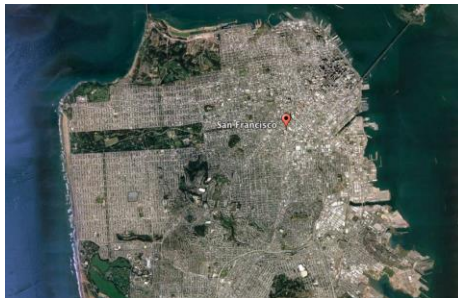
A FUNDAMENTAL QUESTION

What is the optimal use of the carbon in wastewater?

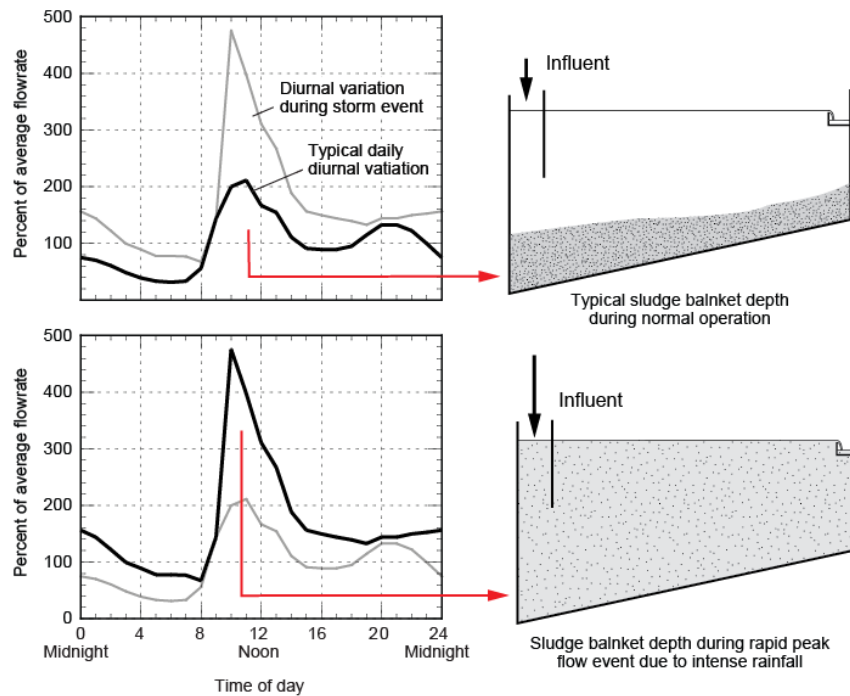
21ST CENTURY CHALLENGES AND ISSUES FOR SMALL WASTEWATER MANAGEMENT SYSTEMS

- *Population demographics*
- *Impact of climate change*
- *Decreasing per capita flowrates*
- *Decentralized non-potable
water sources*

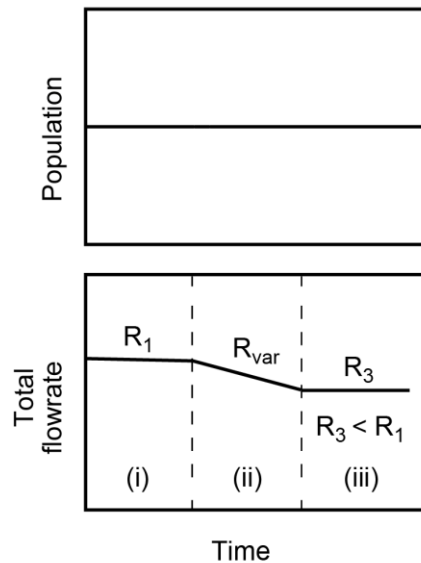
POPULATION DEMOGRAPHICS FAVOR DECENTRALIZED WATER SYSTEMS



Impact of Climate Change on Rainfall Intensity and Operation of WWTPs



CURRENT AND PROJECTED PER CAPITA WATER USE IN THE UNITED STATES



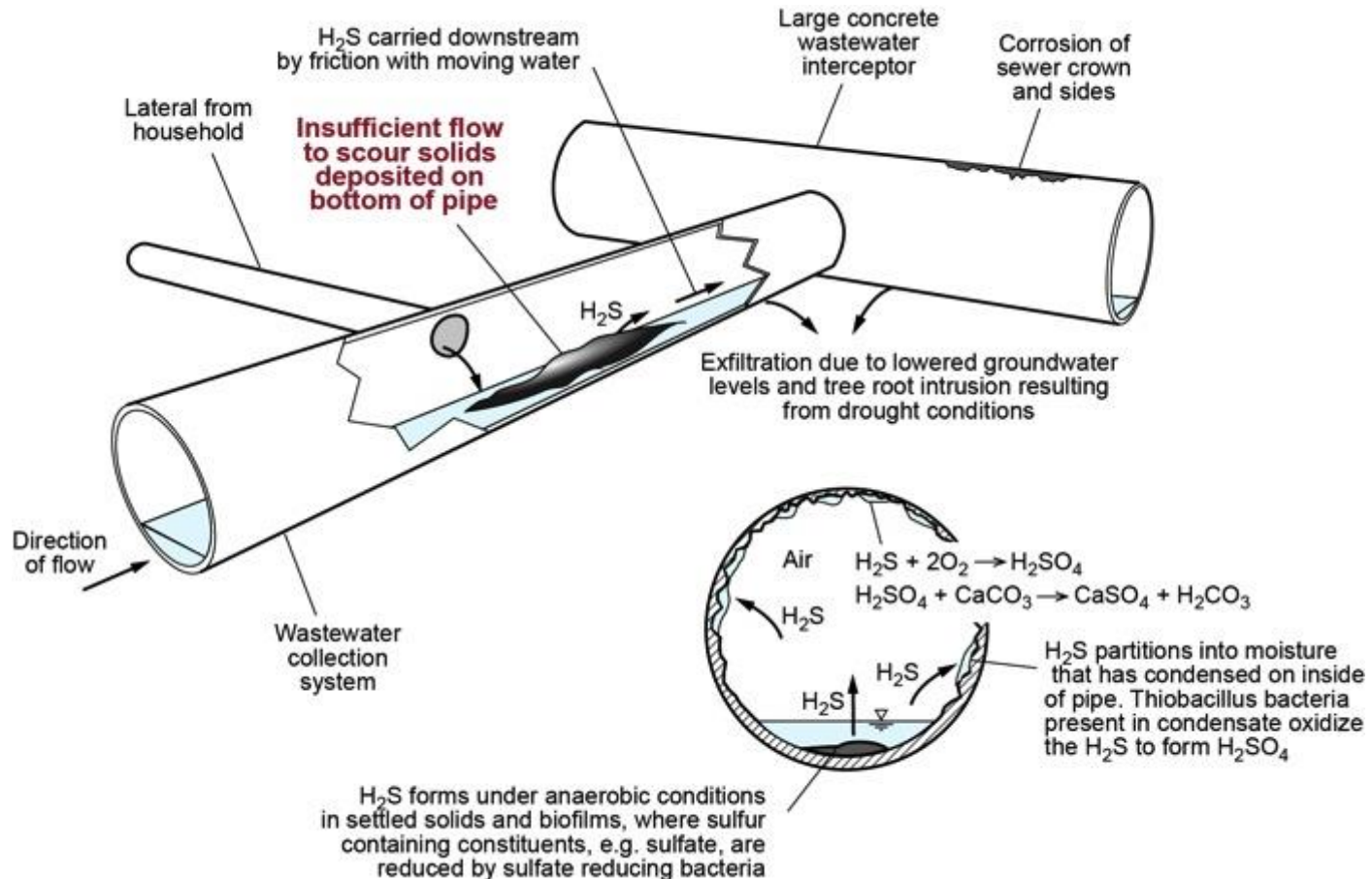
(i) Pre-1992

(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, H₂S FORMATION, AND DOWNSTREAM CORROSION DUE TO REDUCED FLOWS



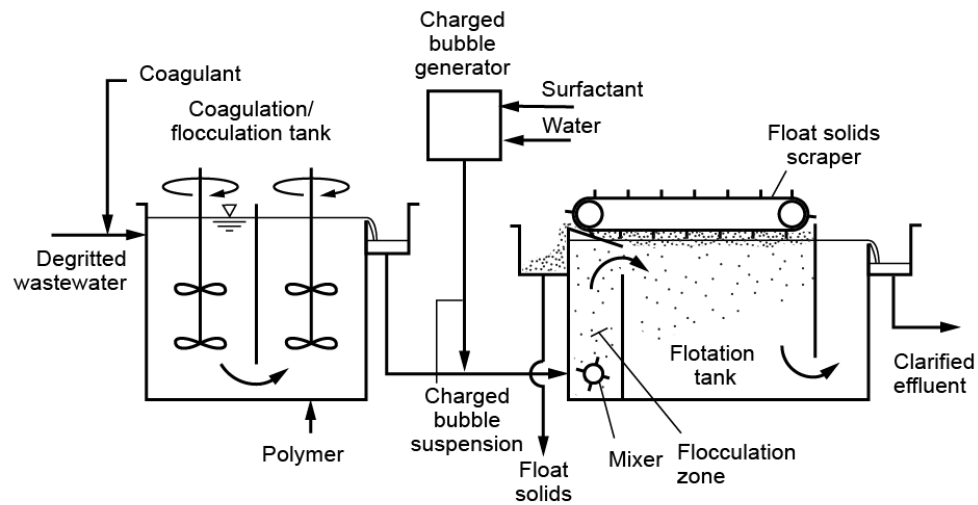
DECENTRALIZED NON-POTABLE WATER SYSTEMS

Water Source	Definition
Blackwater	Wastewater originating from toilets and/or kitchen sources
Graywater	Wastewater collected from non-blackwater sources
Wastewater	Water that is collected from combined graywater and blackwater sources
Roof runoff	Precipitation from rain or snowmelt events, directly collected off of a roof surface
Stormwater	Precipitation runoff from rain or snowmelt events that flows over land and/or impervious surfaces
Condensate	Water vapor that is converted to a liquid and collected from HVAC systems
Shallow groundwater	Groundwater located near the ground surface in an unconfined aquifer
Foundation water	Groundwater that is collected from drainage around building foundations or sumps
Blended water	Various combinations of water derived originally from blackwater, graywater, wastewater, roof runoff, stormwater, condensate, or foundation water.

NEW TECHNOLOGIES FOR THE 21ST CENTURY

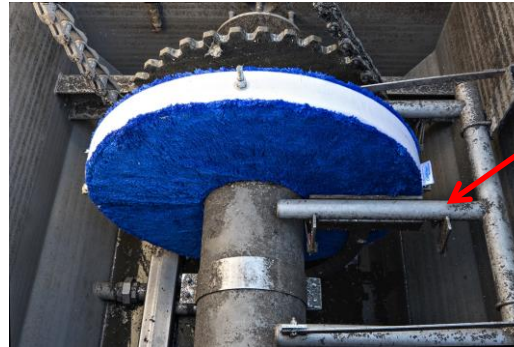
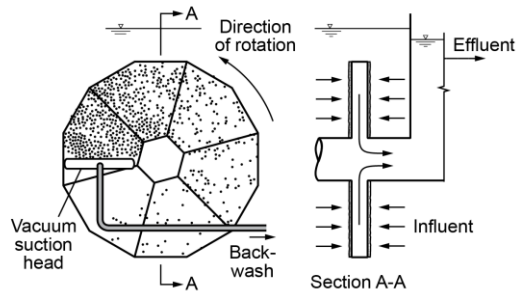
- ***Alternative primary treatment processes***
- ***Enhanced primary treatment***
- ***Enhanced primary-secondary treatment***
- ***Approaching closed loop***
- ***Algae removal of algae with charged bubble flotation***

ALTERNATIVE TECHNOLOGIES FOR ENHANCED PRIMARY TREATMENT: CHARGED BUBBLE FLOTATION



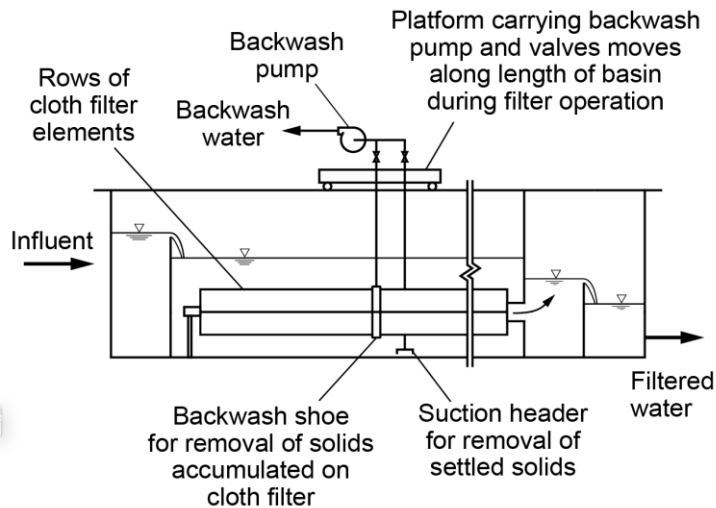
- 1/5th the size of conventional clarifiers
- Nanoparticles can be added to charged bubble for removal of specific constituents

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

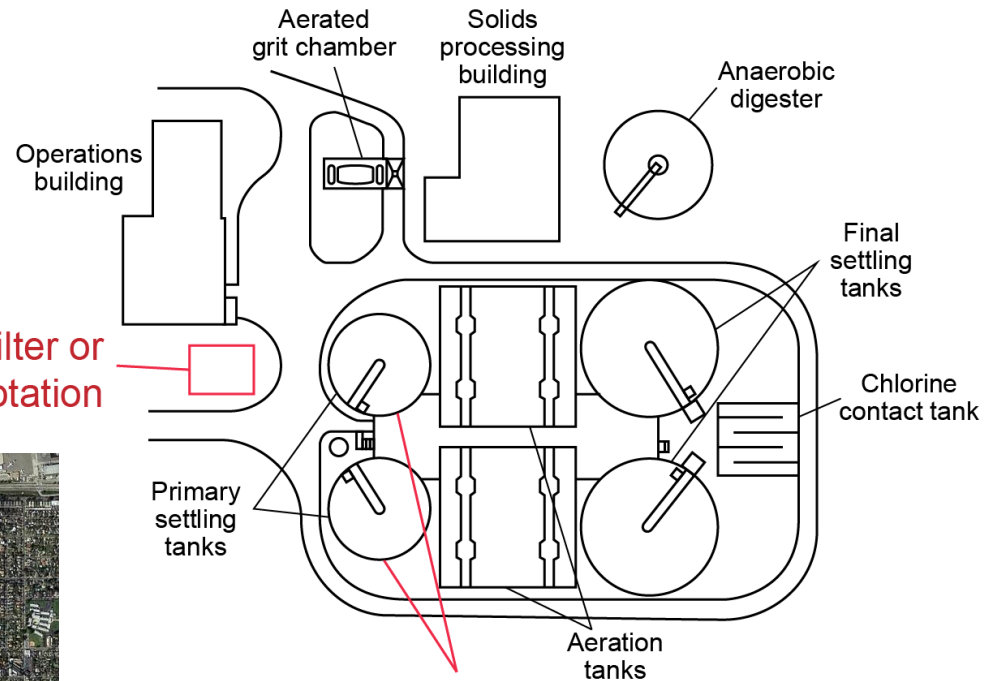
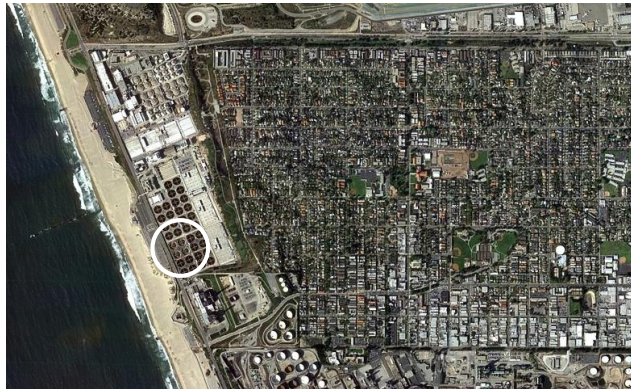


Parameter	Unit	Average influent	Average effluent	Average removal, %
BOD	mg/L	169	59	64.2
COD	mg/L	417	147	62.8
TSS	mg/L	221	26	87.5
VSS	mg/L	116	36	69.0
Turbidity	NTU	143	37	73.5
TKN	mg/L	39	36	7.7
FOG	mg/L	14	10	28.6
UVT	%	28	44	+59.9

Replace and Repurpose Existing Primary Clarifiers

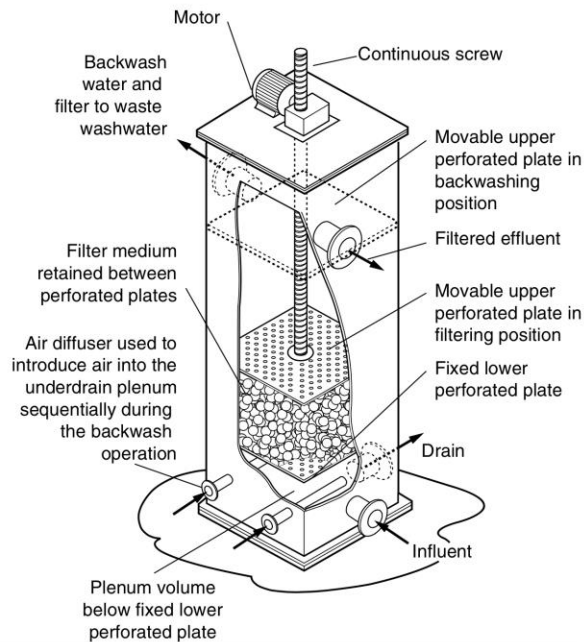
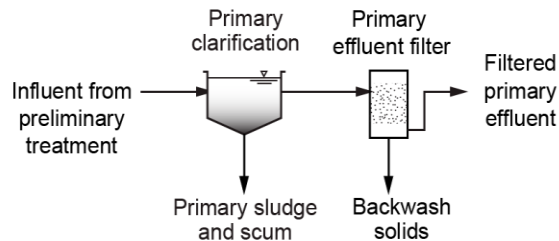


Cloth disk filter or
charged-bubble flotation



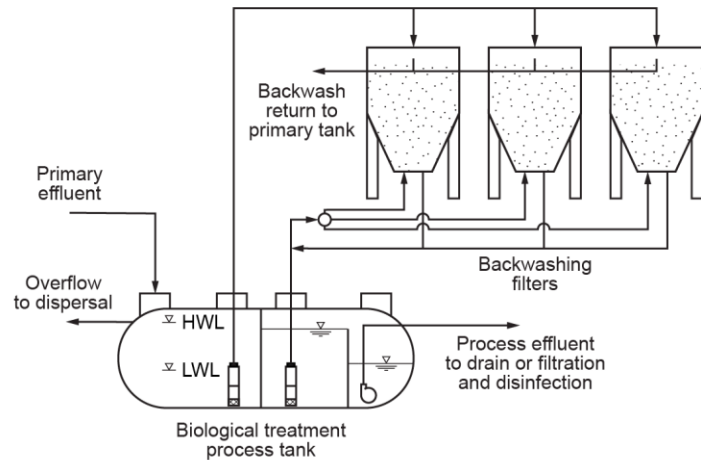
Primary clarifiers can now be used for
influent and/or return flow equalization

ENHANCED PRIMARY TREATMENT WITH PRIMARY EFFLUENT FILTRATION (PEF) BEFORE BIOLOGICAL TREATMENT



Compressible medium filters

ENHANCED PRIMARY-SECONDARY TREATMENT WITH 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/ft²·d (3,000 L/m²·d) with septic tank effluent

Specific weight = 640 kg/m³

Average porosity = 90 %

Particle size = 2- 4 mm

Contact:

Dr. Harold Leverenz

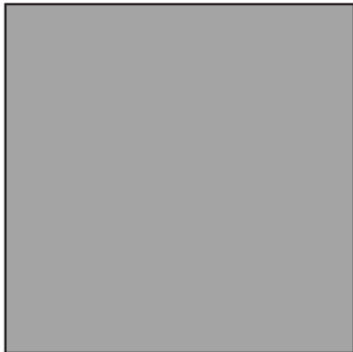





Email: harold.leverenz@gmail.com



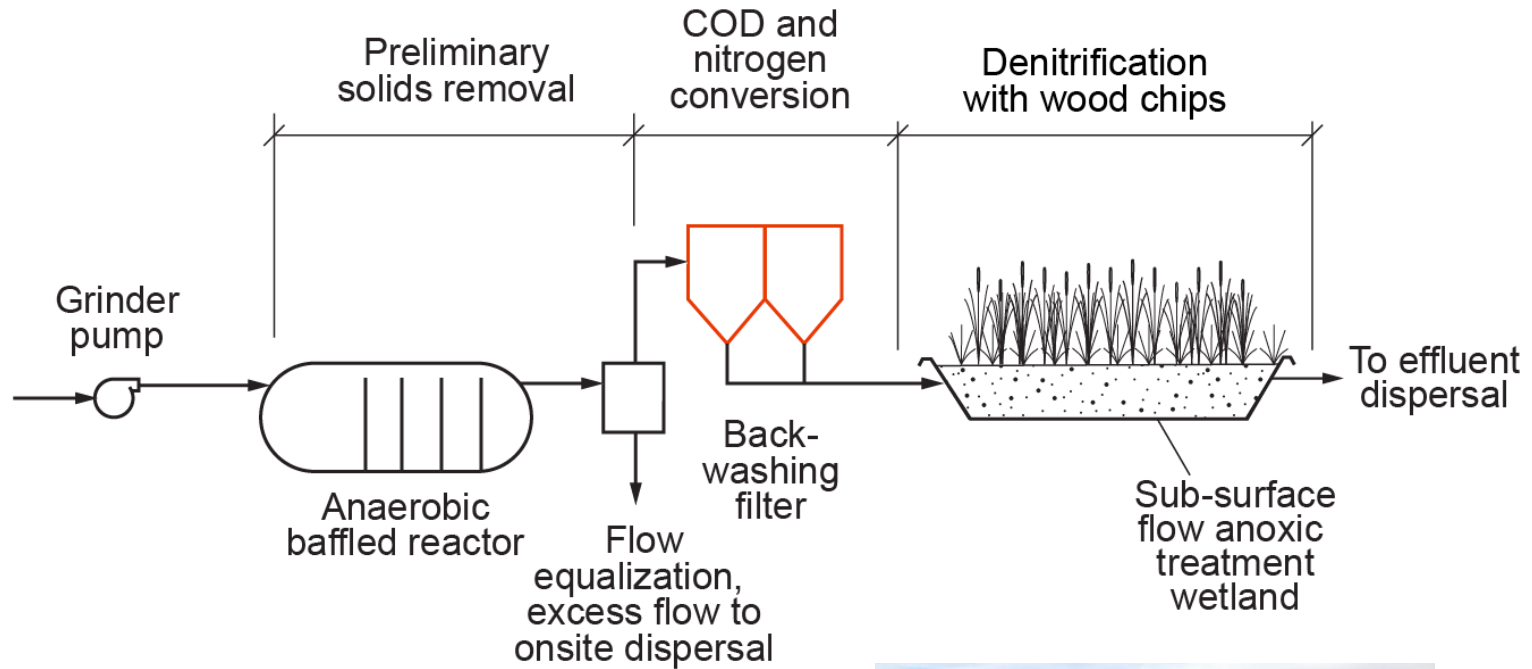
ADVANTAGES OF PUMICE FILTER

- High organic loading rate
- Single or multi-pass operation
- 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

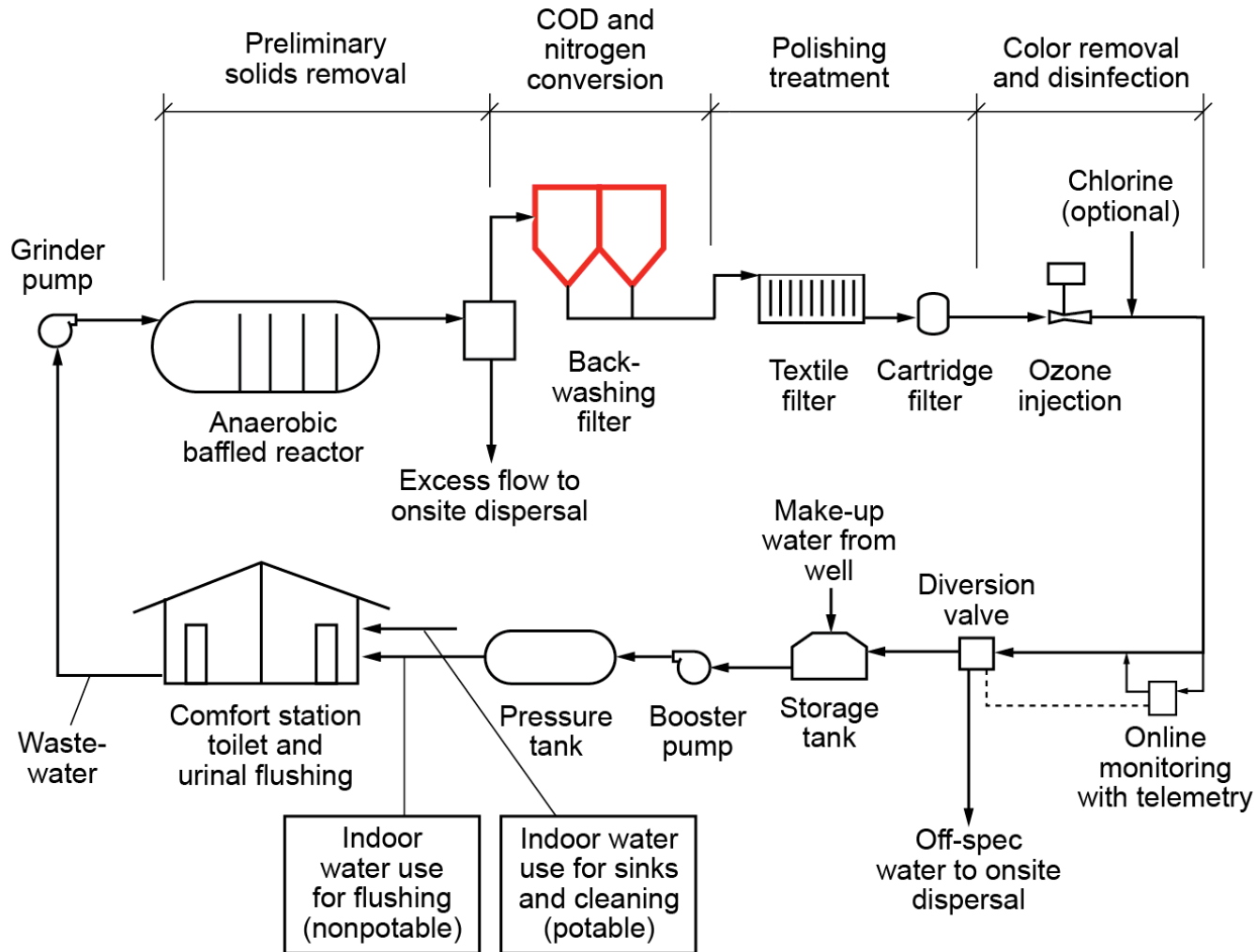
RELATIVE SIZE OF ALTERNATIVE TREATMENT PROCESSES BASED ON NITROGEN LOADING

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

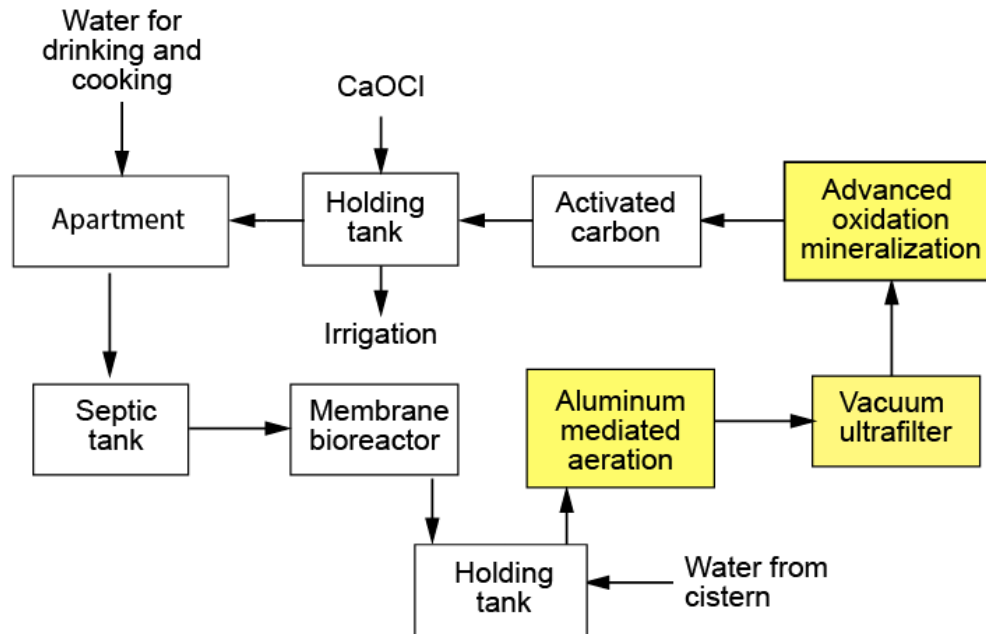
COMPLETE TREATMENT WITH PUMICE FILTER



RECYCLE SYSTEM FOR TOILET FLUSHING



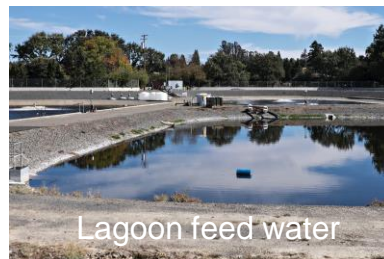
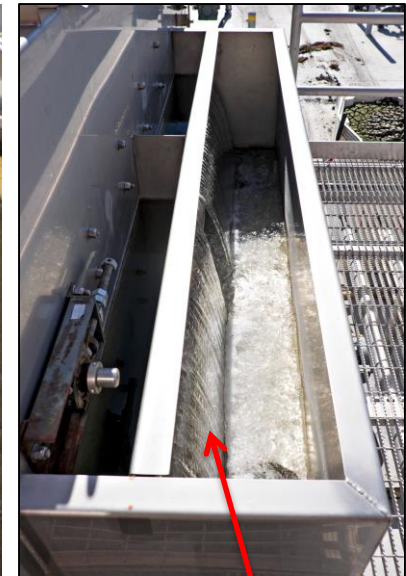
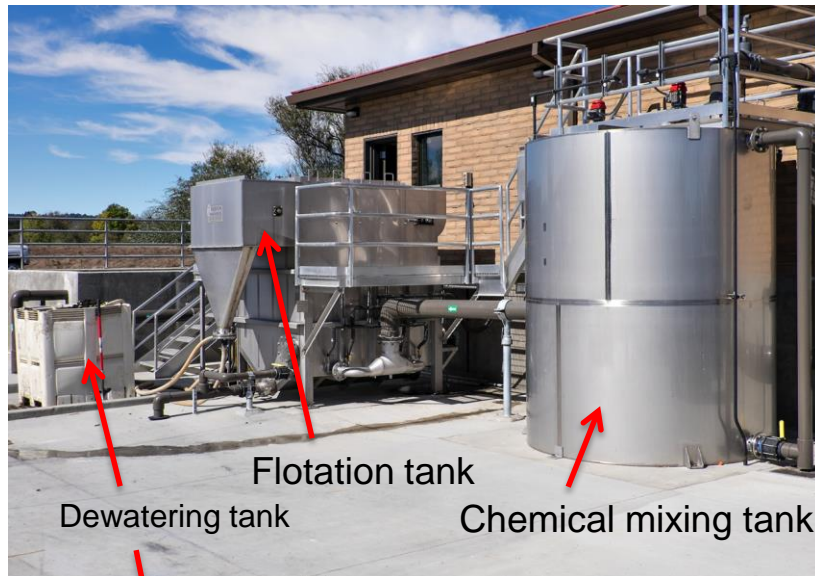
APPROACHING NET-ZERO WATER: ENERGY-POSITIVE MUNICIPAL WATER MANAGEMENT



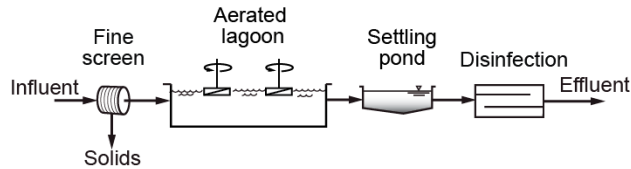
Source: Jim Englehardt
University of Miami
College of Engineering



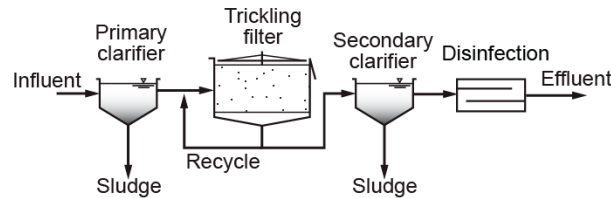
ALGAL REMOVAL WITH CHARGED BUBBLE FLOTATION PROCESS



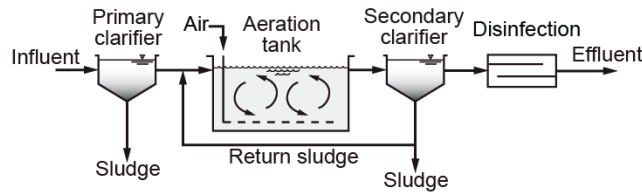
ARE ALL SECONDARY WASTEWATER TREATMENT PROCESSES SUITABLE FOR PR?



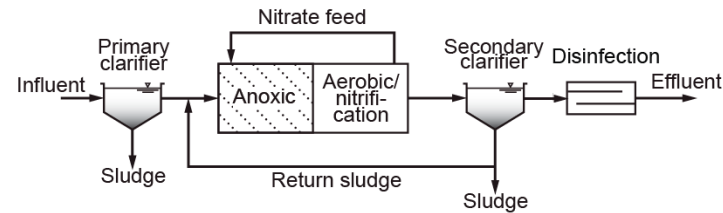
Aerated Lagoon



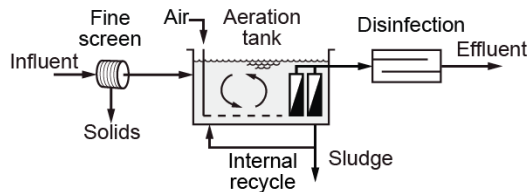
Trickling Filter



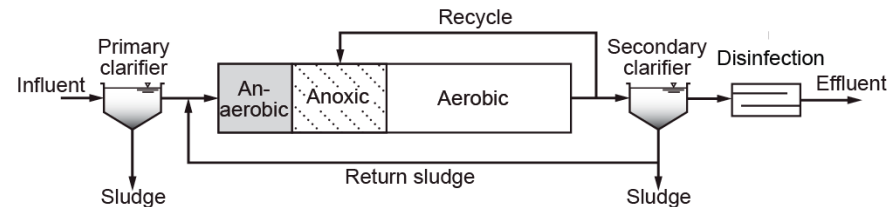
Conventional Activated Sludge



Preanoxic Nitrogen Removal

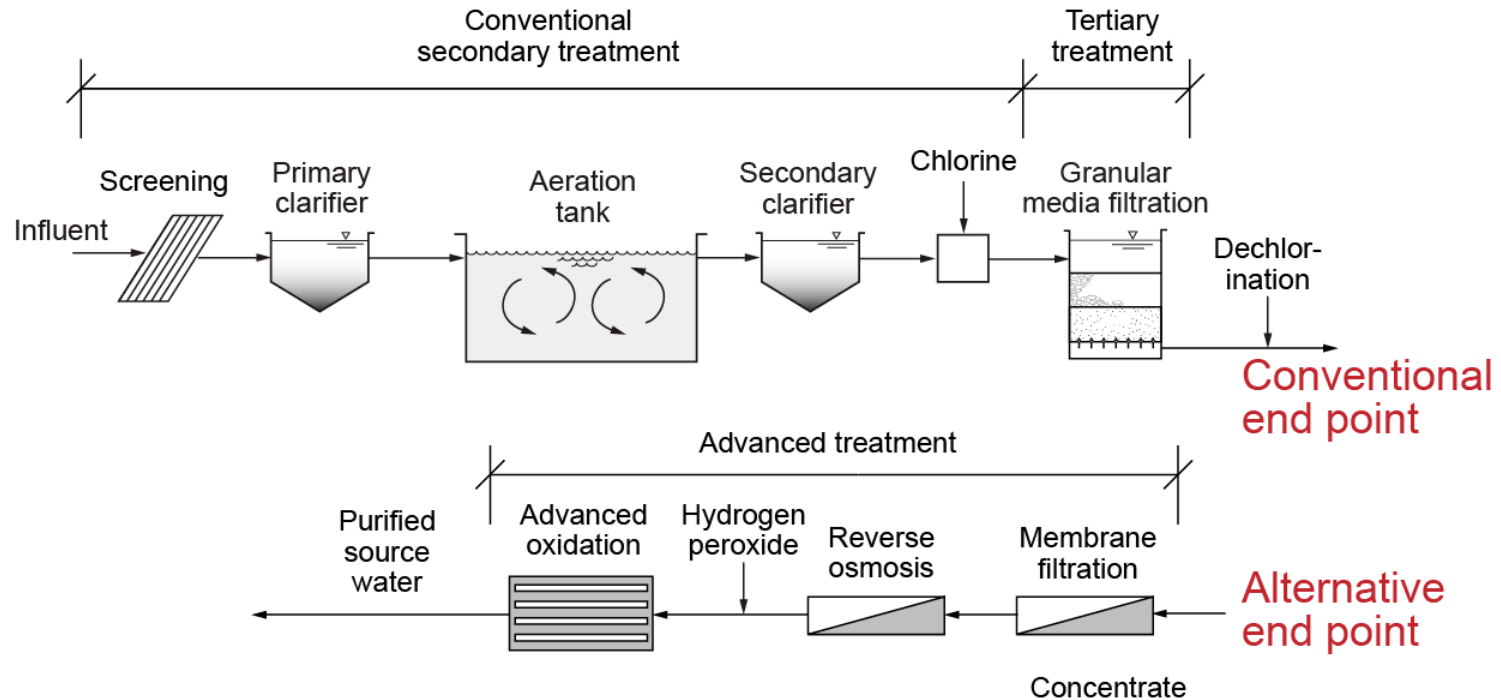


Membrane Bioreactor Activated Sludge



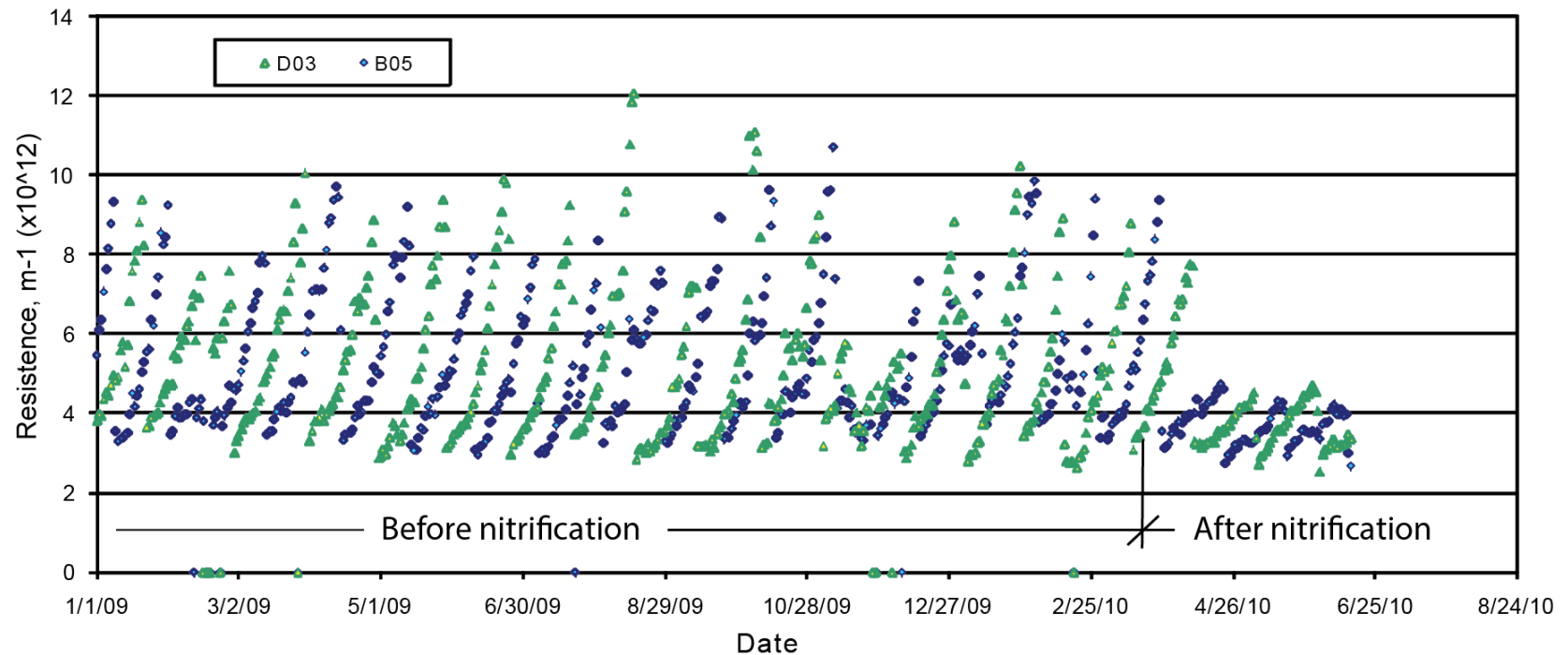
Anaerobic/Anoxic /Aerobic (A2O)

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 DECENTRALIZED
WASTEWATER MANAGEMENT
SYSTEMS FOR DIFFERENT USES***

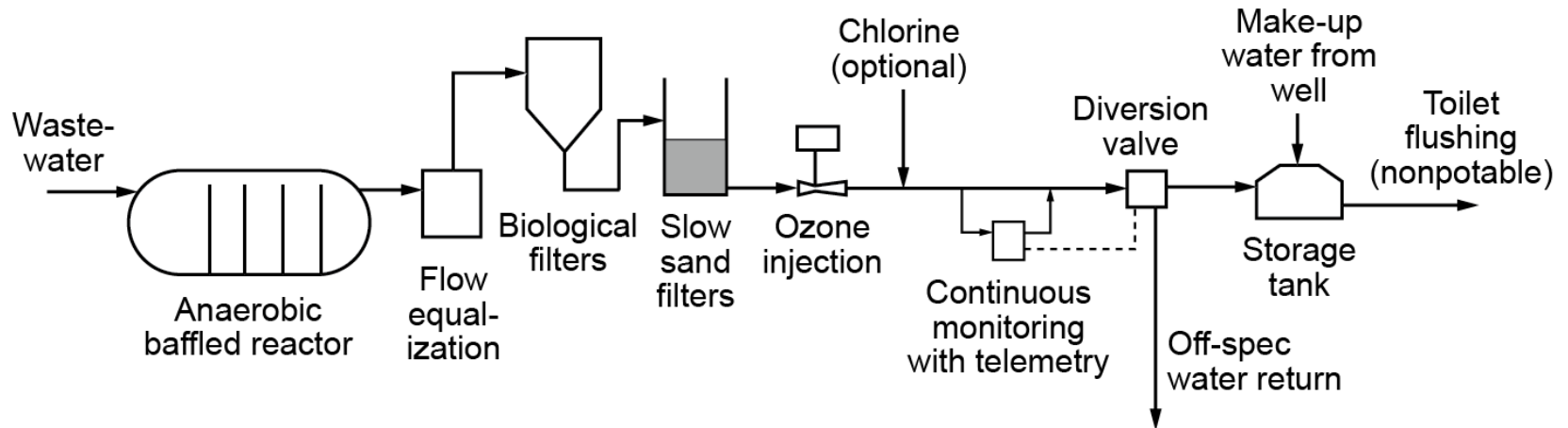
***DEVELOPMENT OF REQUIRED LOG₁₀ REDUCTION VALUES FOR
INDIRECT AND DIRECT POTABLE REUSE***

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 x 10 ⁻⁷ virus/L	6.8 x 10 ⁻⁶ cysts /L	1.7 x 10 ⁻⁶ oocysts /L
Ratio of TDWD to wastewater density	2.2 x 10 ⁻¹²	6.8 x 10 ⁻¹¹	1.7 x 10 ⁻¹⁰
Required log ₁₀ reduction value	12	10	10

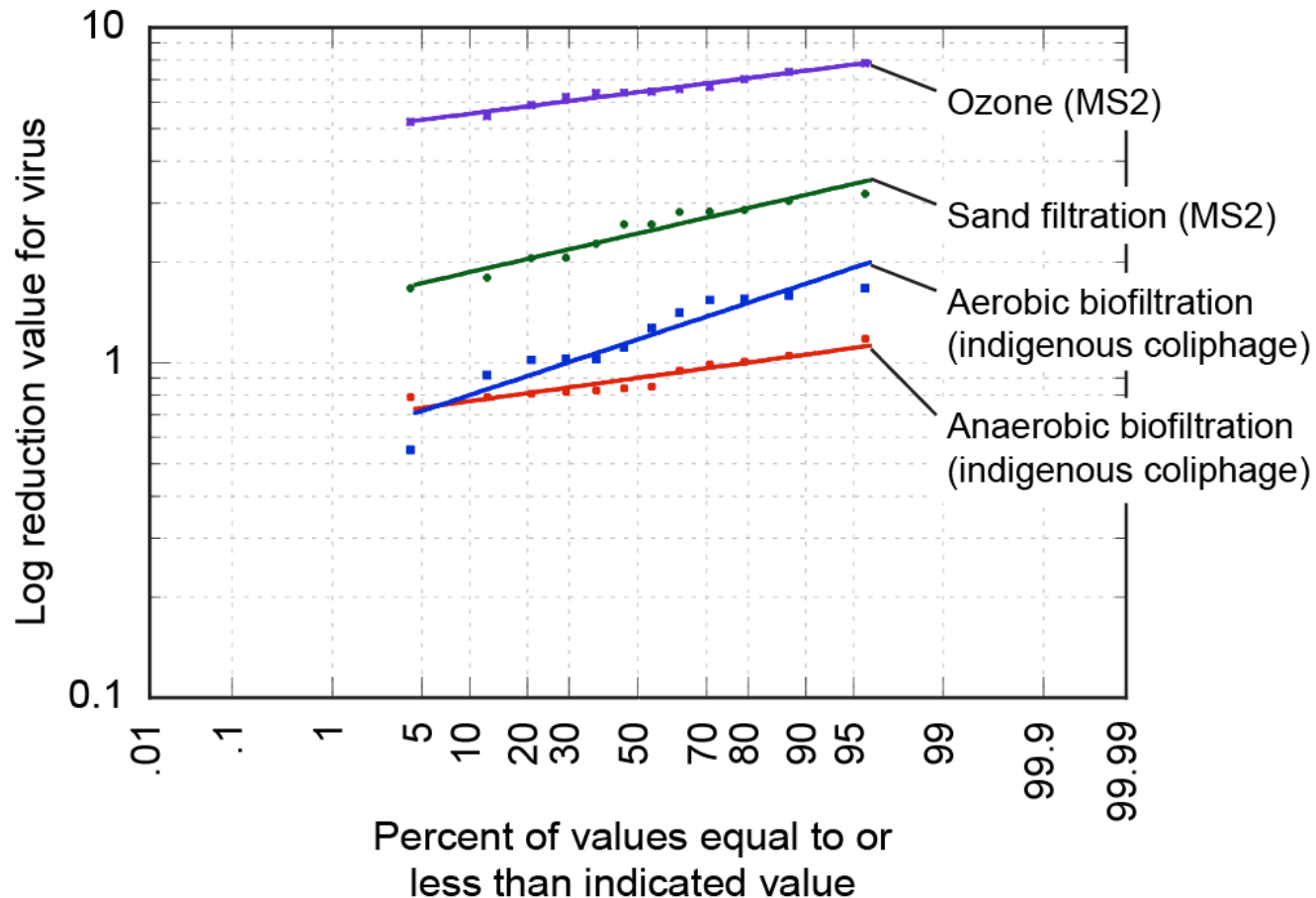
LOG_{10} PATHOGEN REDUCTION TARGETS (LRT_{05}) FOR VARIOUS WATERS AND USES

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

UNIT PROCESSES IN RECYCLE SYSTEM FOR TOILET FLUSHING



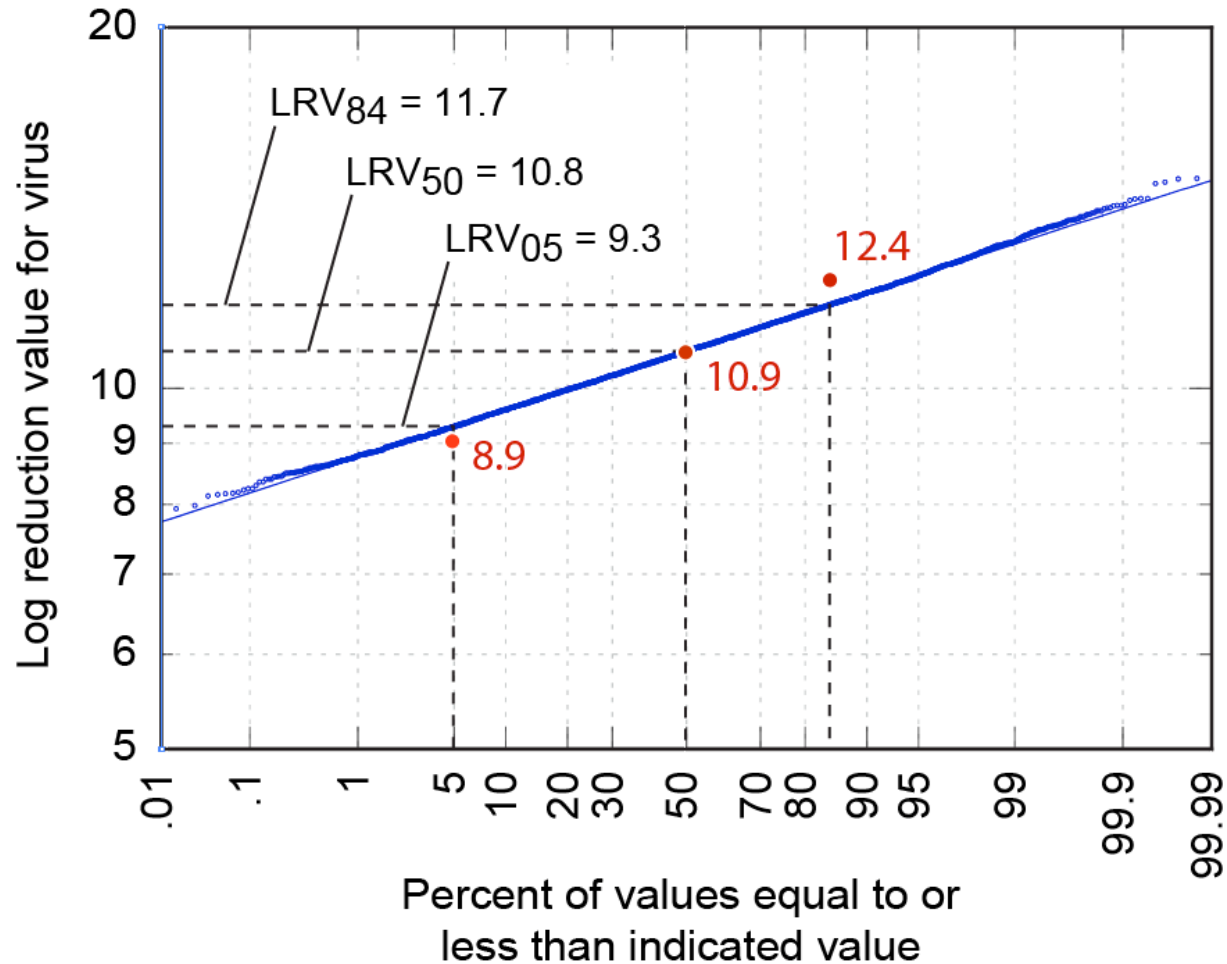
PERFORMANCE OF UNIT PROCESSES IN RECYCLE SYSTEM FOR TOILET FLUSHING



STATISTICAL 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 from urine

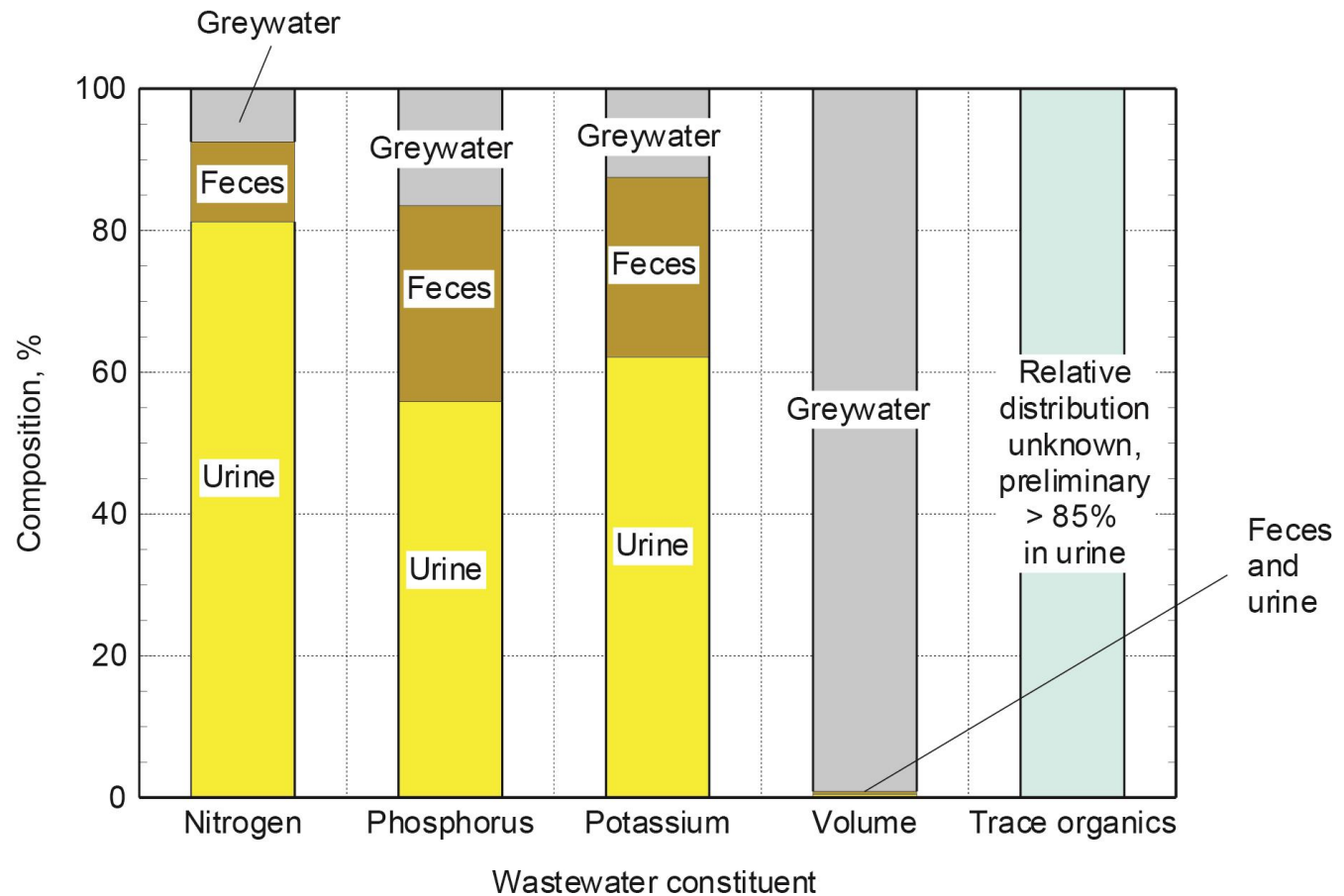
IT'S A NEW WORLD

UNLEASH YOUR IMAGINATION!

***THANK YOU
FOR LISTENING***

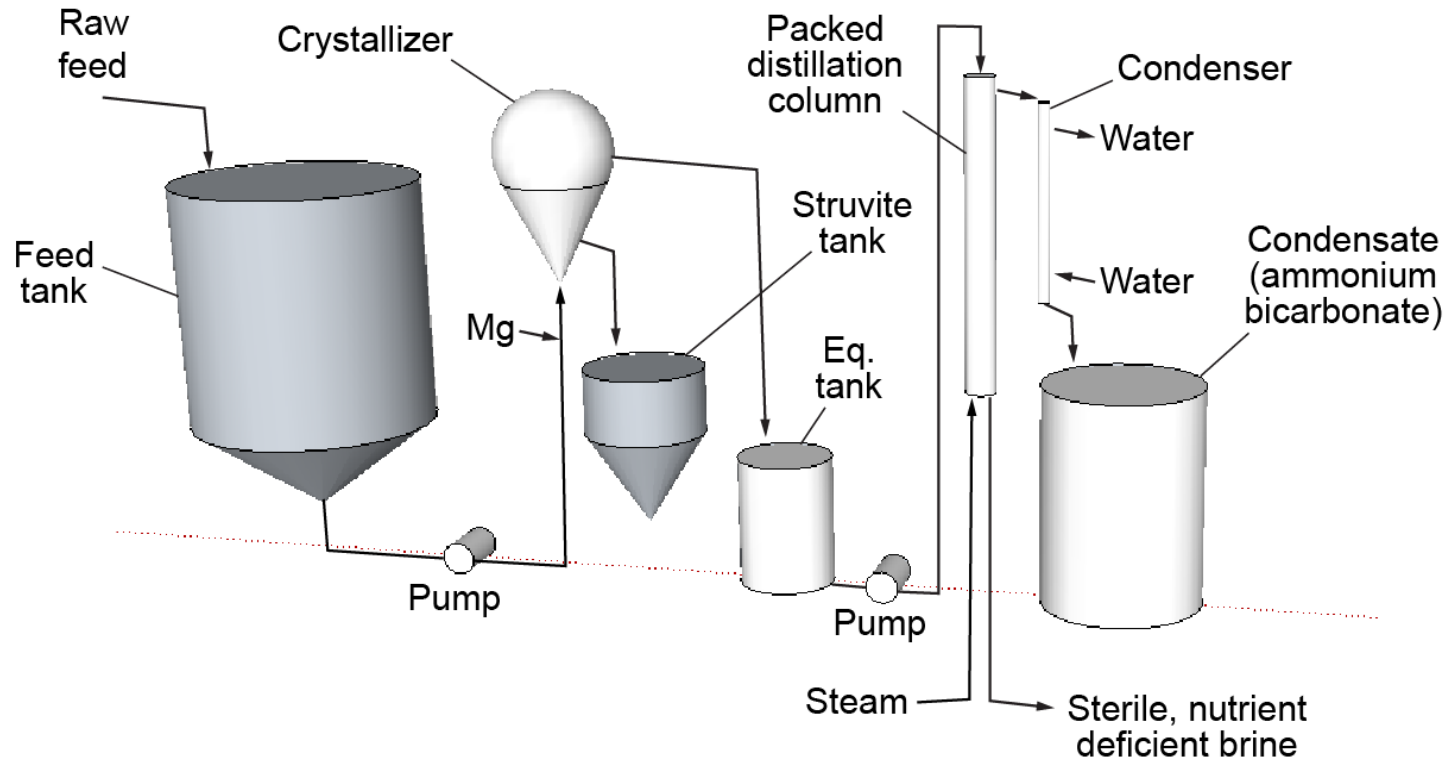
URINE SEPARATION AND NUTRIENT RECOVERY

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



UC DAVIS Sustainable Fertilizer Recovery from Urine
 Jessica Hazard, Harold Leverenz, Ph.D. PE and Rue Adams, PE
 University of California, Davis
 Advanced Environmental Methods LLC

Problems with Urine

Eutrophication
 Nitrogen is a critical nutrient for the nitrogen, phosphorus, potassium and other elements. These nutrients are very hard to remove from wastewater and end up in rivers, lakes, and bays. The nutrient exchange again grows that can cause severe environmental consequences that SR SR and shows the water only for human consumption. Extreme cases of eutrophication can cause dead zones and will severely damage aquatic ecosystems.

Drought
 The US is suffering from historic drought years and the consumption of water is critical in certain regions. The average household uses 27% of the water currently used for toilets can be used for flushing. Urine is a valuable resource that can be used for flushing. Urine is a valuable resource that can be used for flushing. Urine is a valuable resource that can be used for flushing.

2,000 gallons of the highest quality drinking water is wasted per person per year by flushing urine.

Alternative uses for Urine

Fertilizer
 Urine can be applied directly to a fertilizer in the home scale. Human urine does not generally contain pathogens that will be transmitted through the environment. The highest risk associated with diluted urine are mainly a result of contamination by feces.

For large quantities of urine, collection and its use capacity is an issue. Instead of using urine directly as a fertilizer, the nutrients in urine can be extracted and provide Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), Calcium (Ca), and other nutrients. These nutrients are easily stored, transported and perform comparably to the commercial grade ammonium phosphate (DAP) fertilizers.

Separating urine from wastewater has the potential to eliminate 80% of the nitrogen and 60% of the phosphorus from wastewater without making any changes to treatment plants.

Urine Chaining Toilet (wastewater Urine, Micro-Rinse and Dual Flush)

UC Davis Research Project
 The Urine Recovery Research Group (URRG) is developing and optimizing a technology that recovers ammonium, phosphate and potassium from urine by precipitation and distillation. Specifically, the distillation of concentrated ammonium bicarbonate and the crystallization of urea.

Goals of this project include:

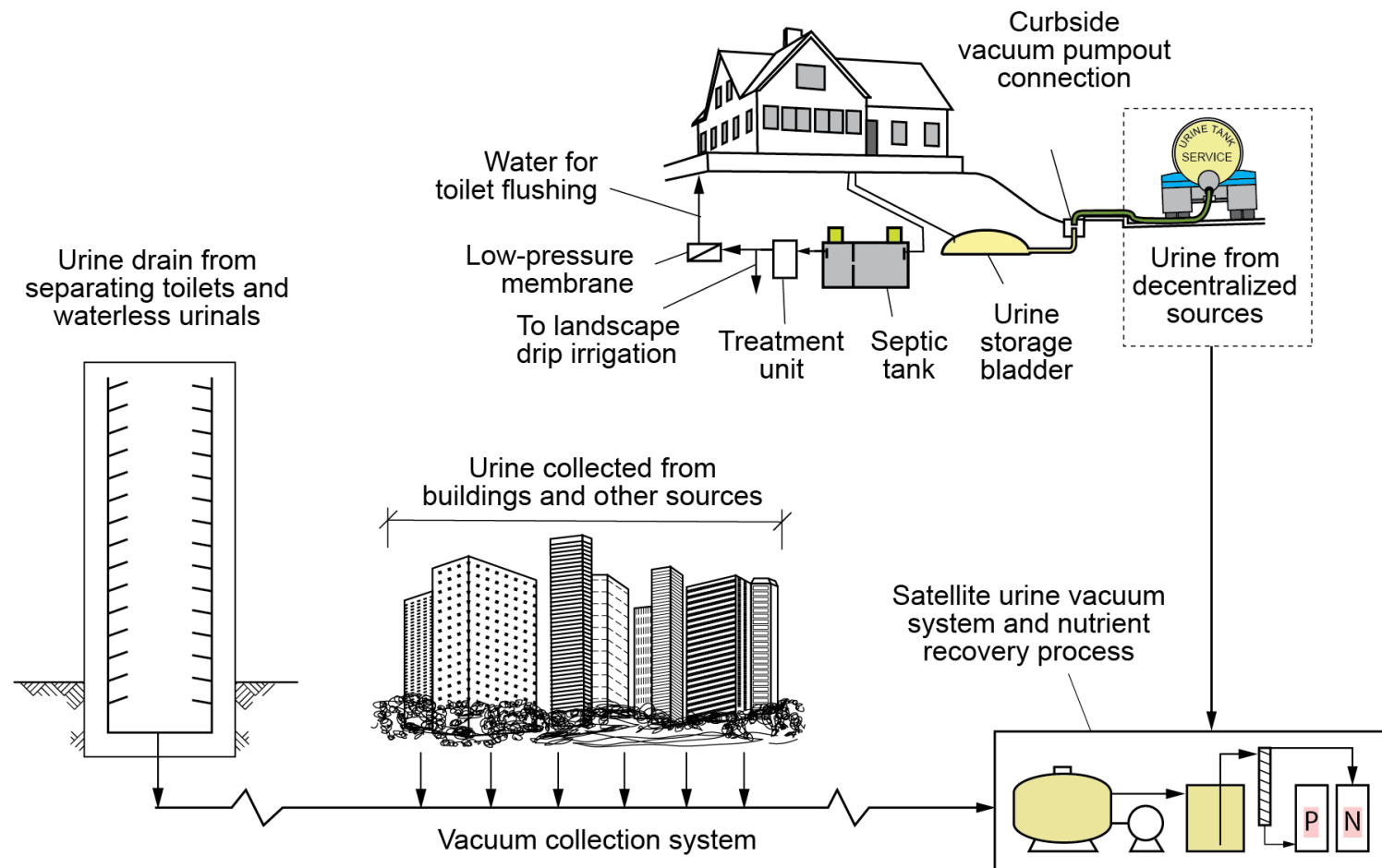
- Reduce the nutrient loading to wastewater treatment systems
- Low energy and commercially valuable fertilizer production
- Simple design and small footprint allowing for decentralized treatment of urine
- Support the developing green building movement

UC Davis Prototype

Collecting and recycling urine can conserve water, reduce wastewater treatment costs, produce sustainable fertilizer, improve water quality and protect the ecosystem.



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



***THANK YOU
FOR LISTENING***