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

Presented at the

13th IWA Specialized Conference on Small Water and Wastewater Systems

Athens, Greece

September 14–16, 2016

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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.

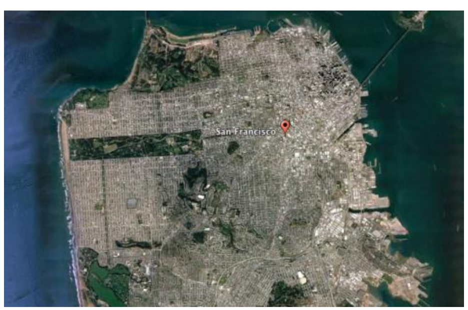
A FUNDAMENTAL QUESTION

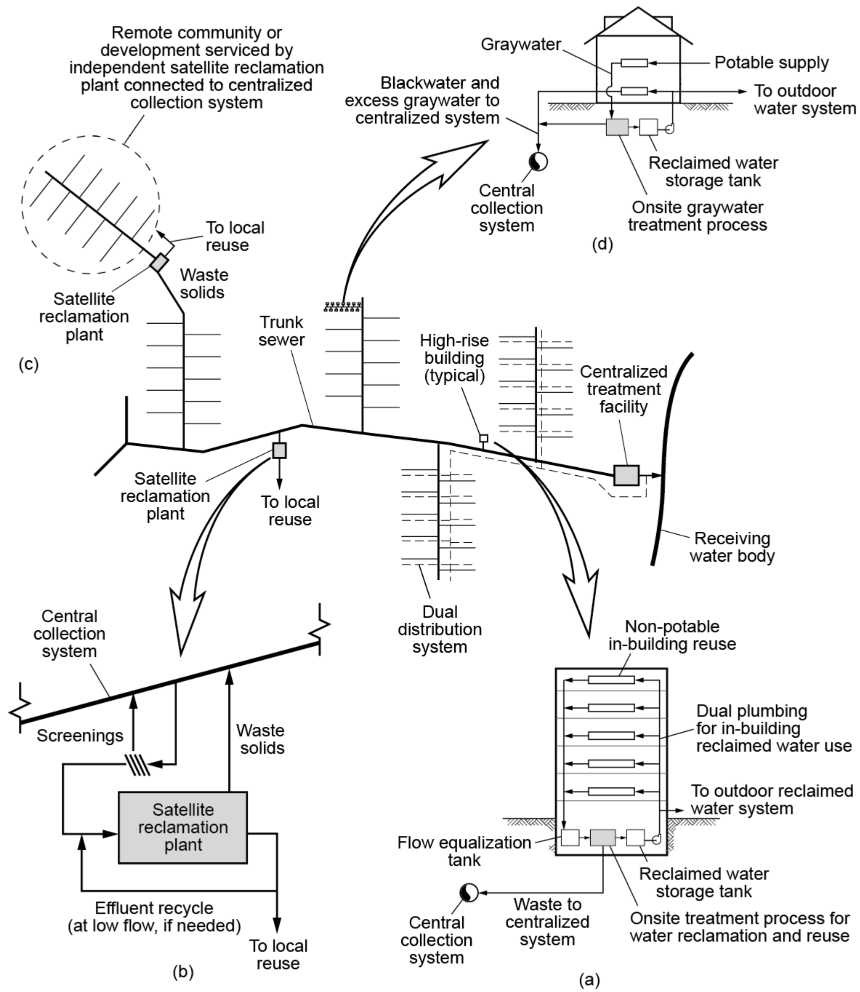
What is the optimal use of the carbon in wastewater?

21^{ST} CENTURY CHALLENGES AND ISSUES FOR SMALL WASTEWATER MANAGEMENT SYSTEMS

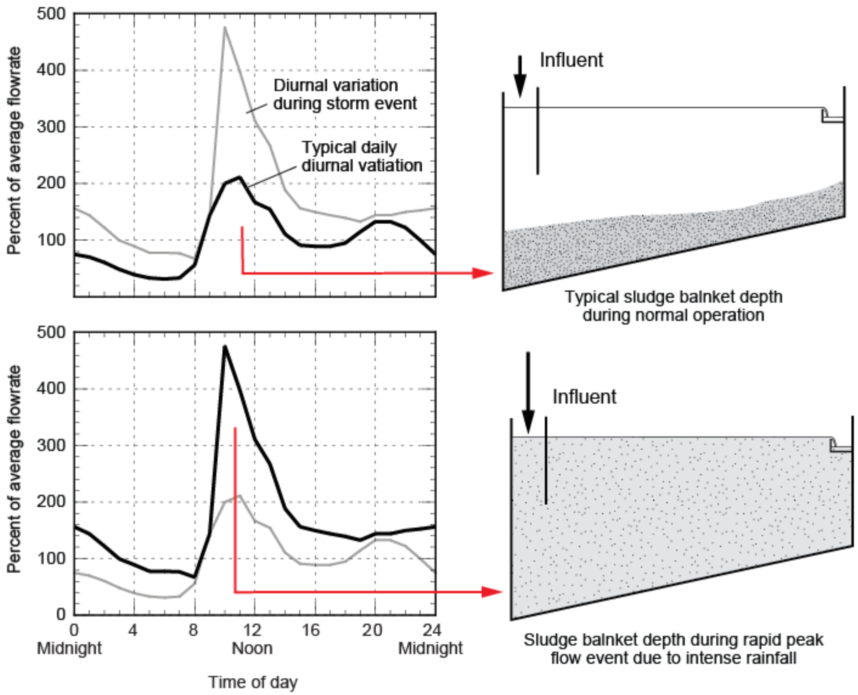
- *Population demographics*
- *Impact of climate change*
- *Decreasing per capita flowrates*
- *Decentralized non-potable water sources*

POPULATION DEMOGRAPHICS FAVOR DECENTRALIZED WATER SYSTEMS

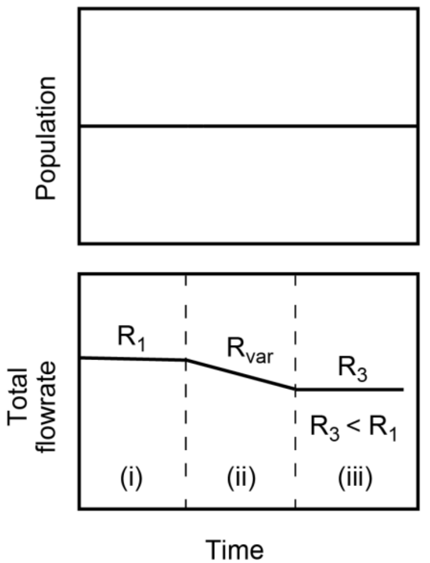




Impact of Climate Change on Rainfall Intensity and Operation of WWTPs



CURRENT AND PROJECTED PER CAPITA WATER USE IN THE UNITED STATES



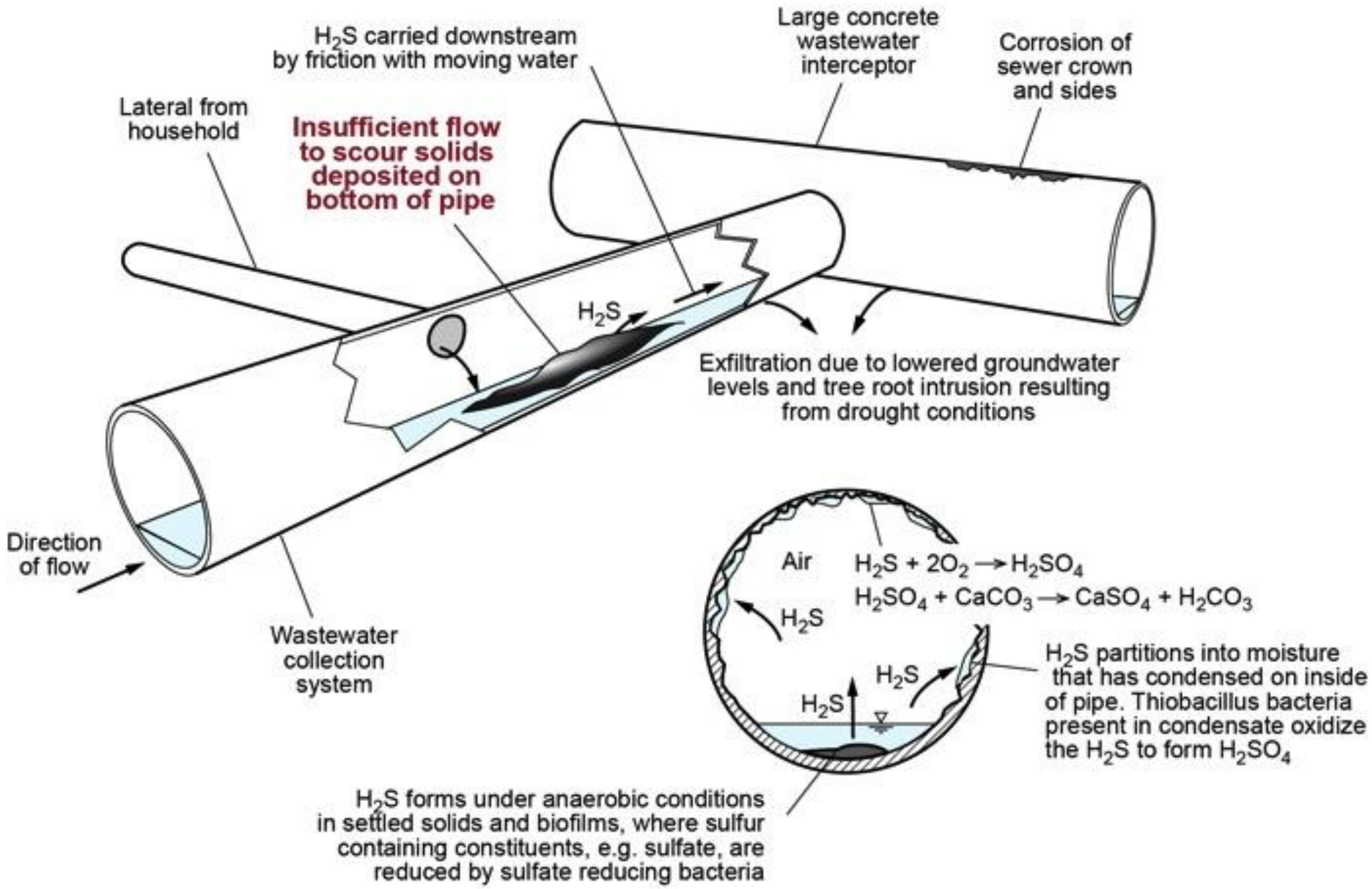
(i) Pre-1992

(ii) Improved water conservation

(iii) Maximum water conservation

	Flow, gal/capita•d					
	2013		2020		2030	
Use	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



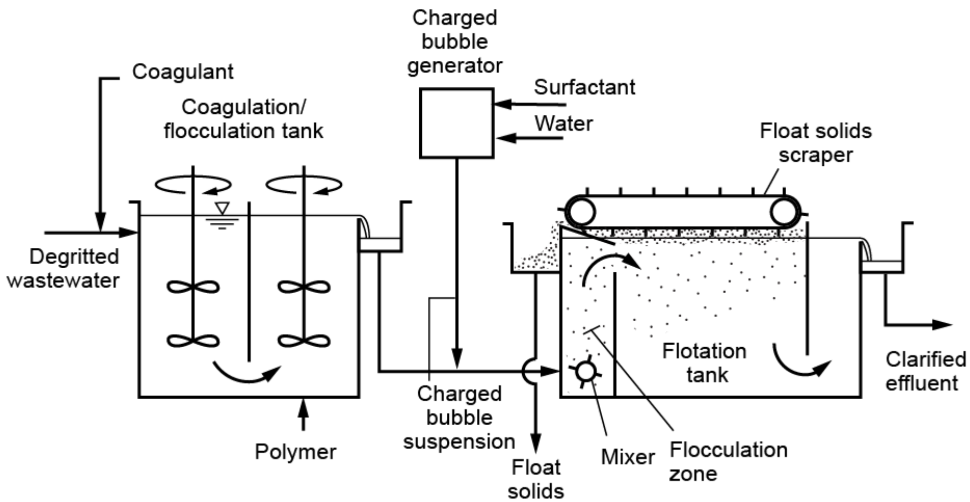
DECENTRALIZED NON-POTABLE WATER SYSTEMS

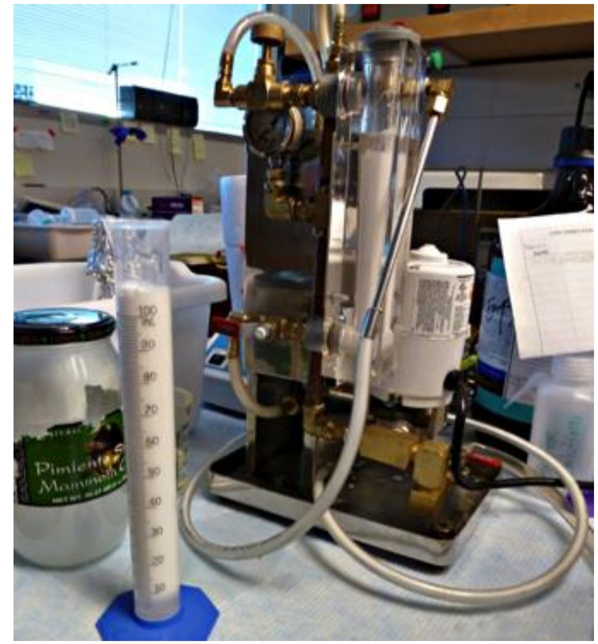
Water Source	Definition
Blackwater	Wastewater originating from toilets and/or kitchen sources
Graywater	Wastewater collected from non-blackwater sources
Wastewater	Water that is collected from combined graywater and blackwater sources
Roof runoff	Precipitation from rain or snowmelt events, directly collected 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***

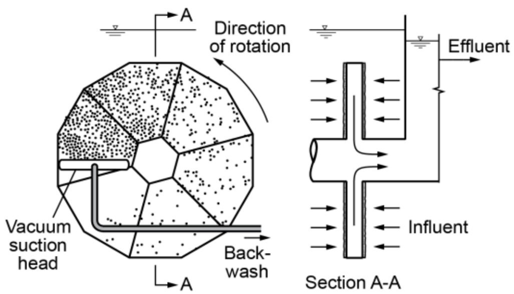
ALTERNATIVE TECHNOLOGIES FOR ENHANCED PRIMARY TREATMENT: CHARGED BUBBLE FLOTATION

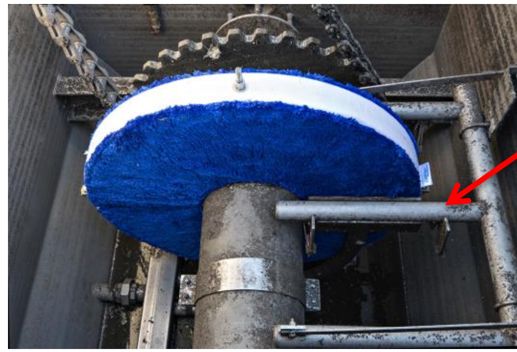




- 1/5th the size of conventional clarifiers
- Nanoparticles can be added to charged bubble for removal of specific constituents

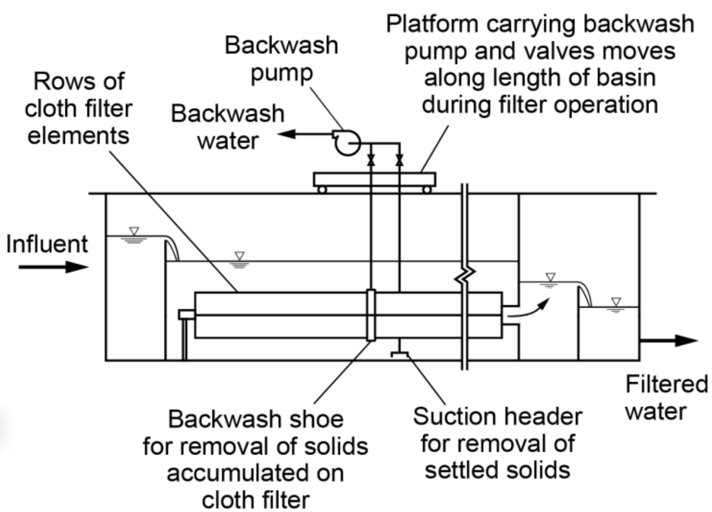
ALTERNATIVE TECHNOLOGIES FOR ENHANCED PRIMARY TREATMENT: CLOTH DISK FILTER (5-10 μm)





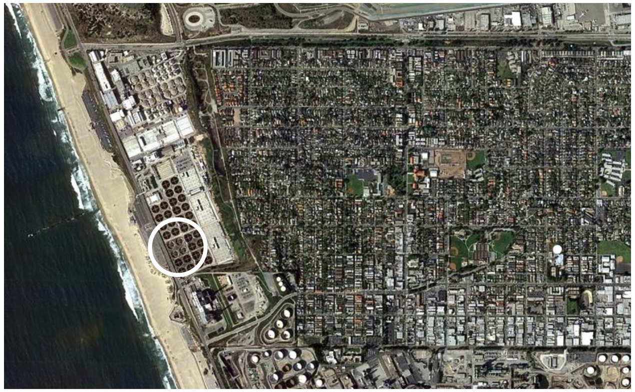
Vacuum suction head

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

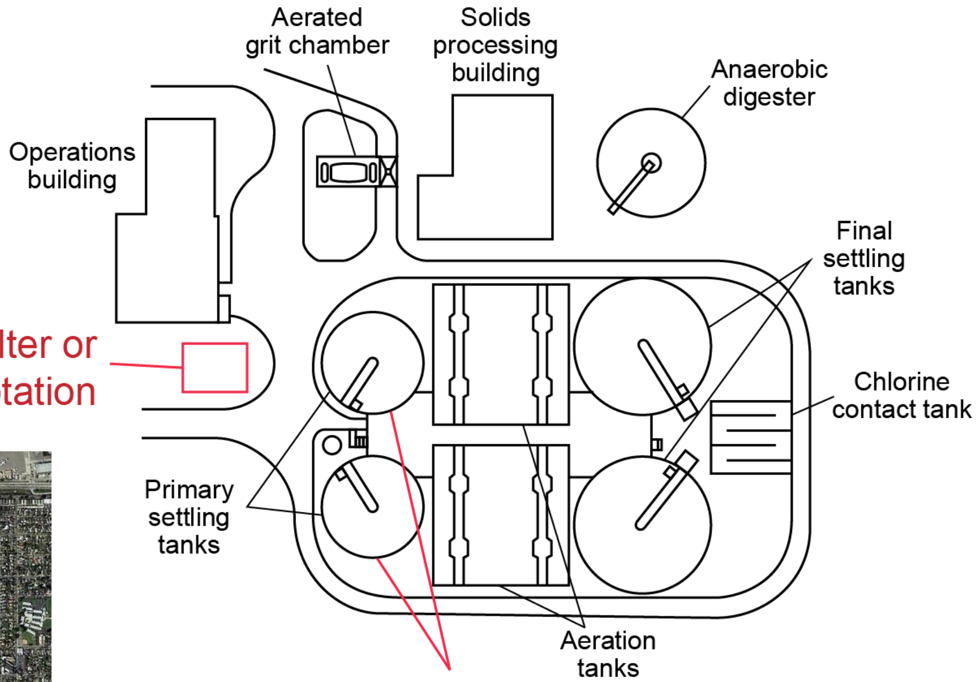


Parameter	Unit	Average influent	Average effluent	Average removal, %
BOD	mg/L	169	59	64.2
COD	mg/L	417	147	62.8
TSS	mg/L	221	26	87.5
VSS	mg/L	116	36	69.0
Turbidity	NTU	143	37	73.5
TKN	mg/L	39	36	7.7
FOG	mg/L	14	10	28.6
UVT	%	28	44	+59.9

Replace and Repurpose Existing Primary Clarifiers

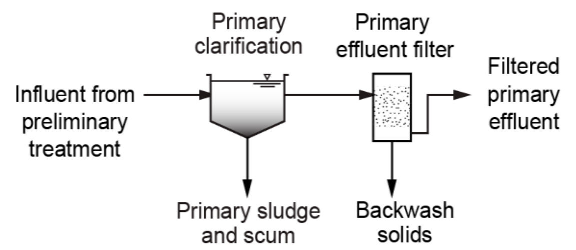


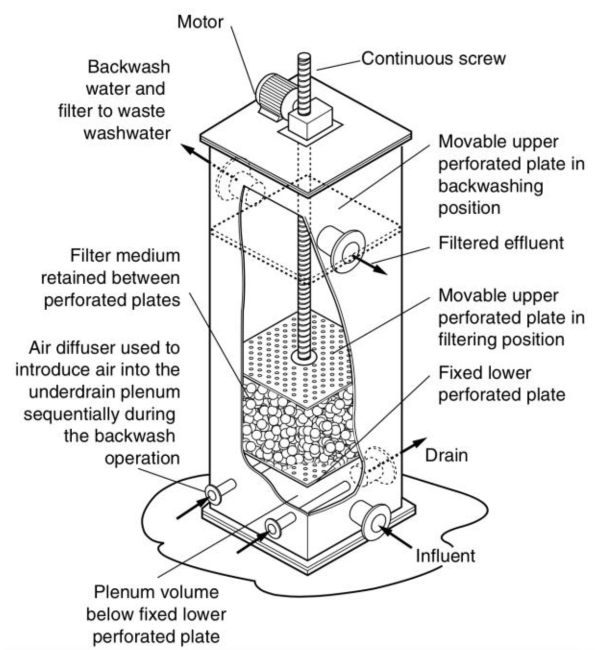
Cloth disk filter or charged-bubble flotation



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

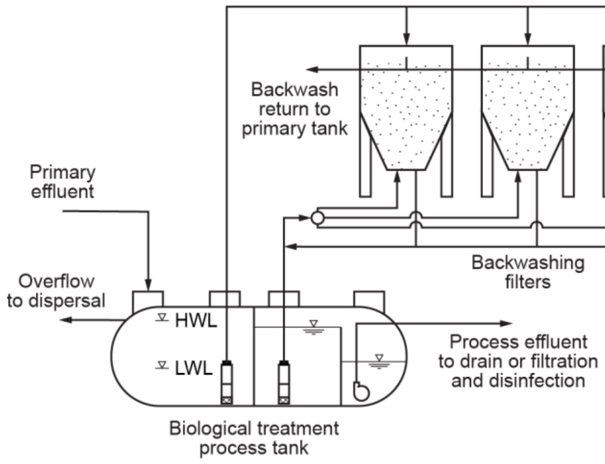
ENHANCED PRIMARY TREATMENT WITH PRIMARY EFFLUENT FILTRATION (PEF) BEFORE BIOLOGICAL TREATMENT





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/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:
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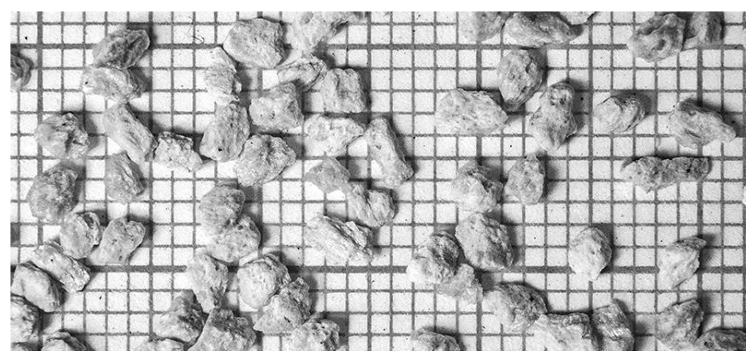
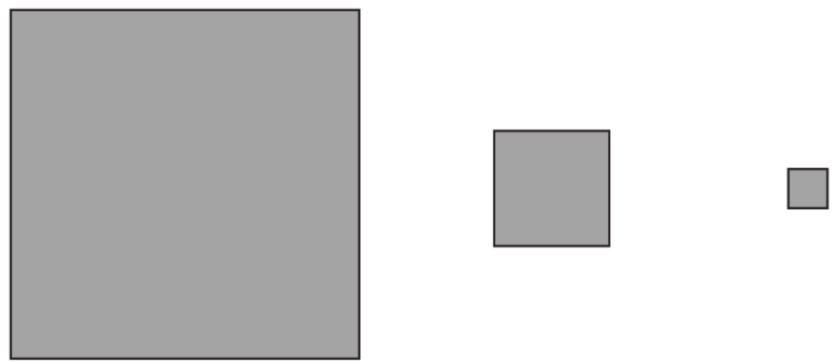


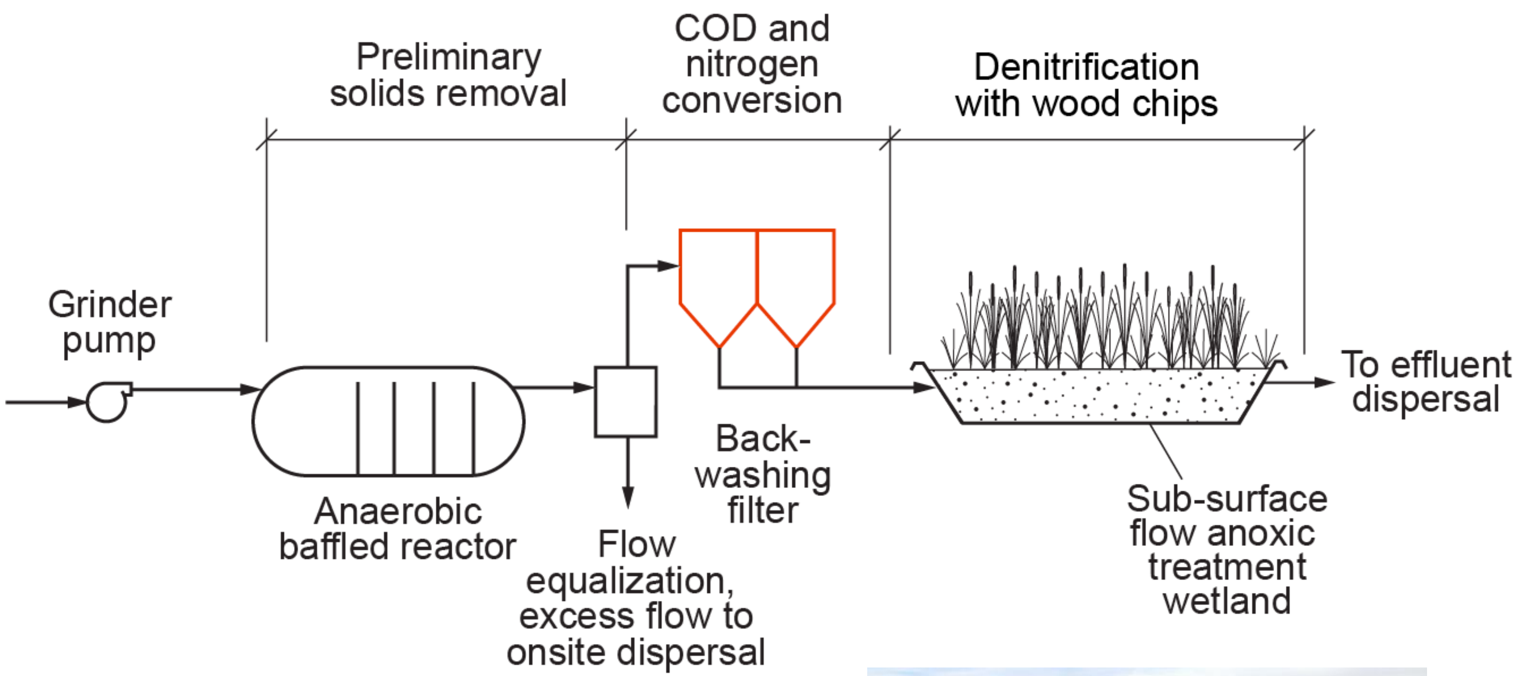
ADVANTAGES OF PUMICE FILTER

- 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

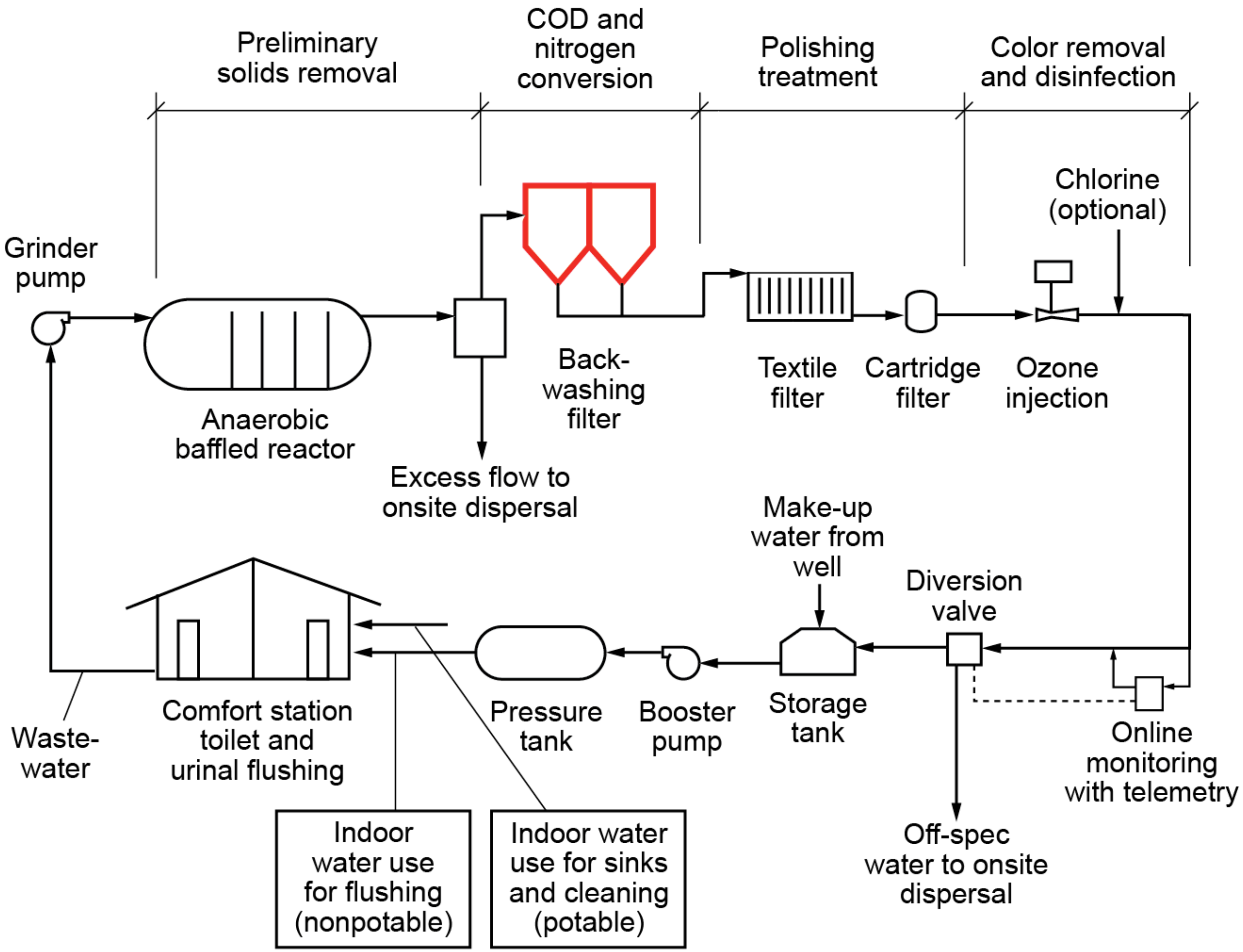
RELATIVE SIZE OF ALTERNATIVE TREATMENT PROCESSES BASED ON NITROGEN LOADING

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

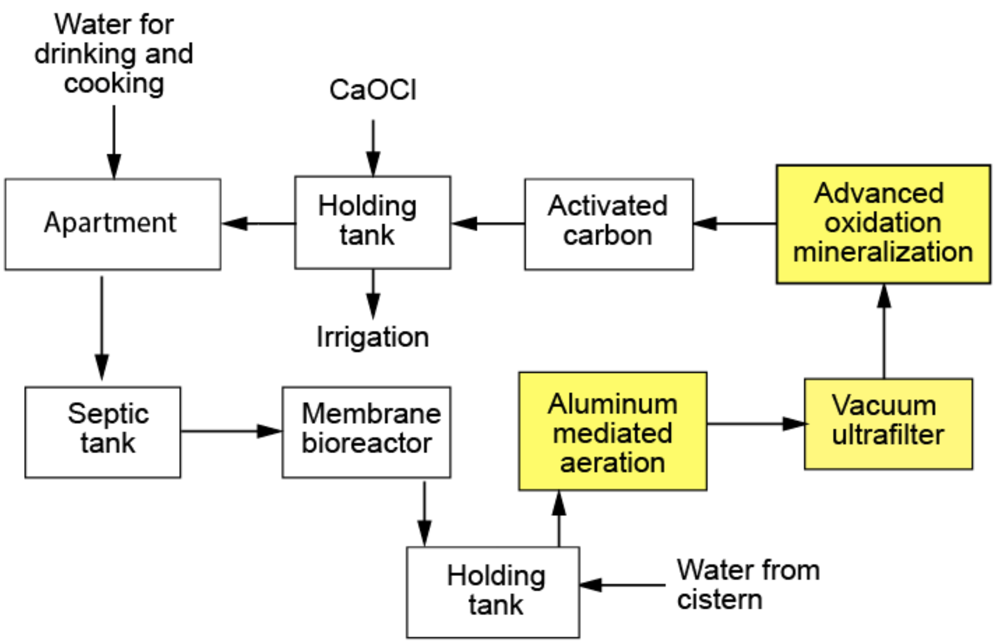
COMPLETE TREATMENT WITH PUMICE FILTER



RECYCLE SYSTEM FOR TOILET FLUSHING

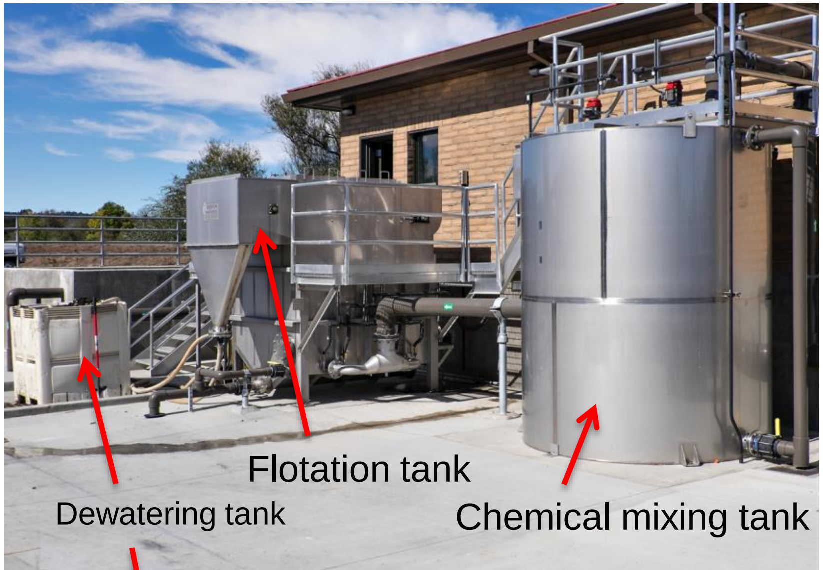


APPROACHING NET-ZERO WATER: ENERGY-POSITIVE MUNICIPAL WATER MANAGEMENT



Source: Jim Englehardt
University of Miami
College of Engineering

ALGAL REMOVAL WITH CHARGED BUBBLE FLOTATION PROCESS

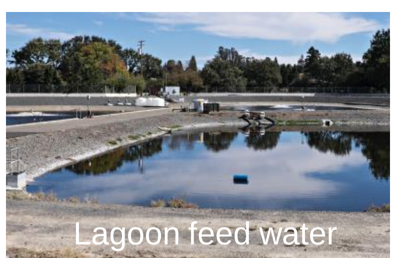


Thickened algae ~4-5%

Effluent turbidity typically, <1 NTU

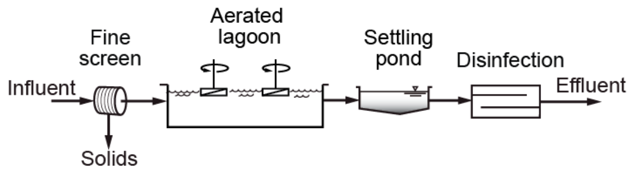
Pasteurization for disinfection

Compressible medium effluent filtration

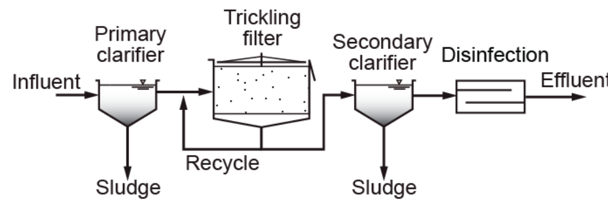


Algae dewatered on straw bed

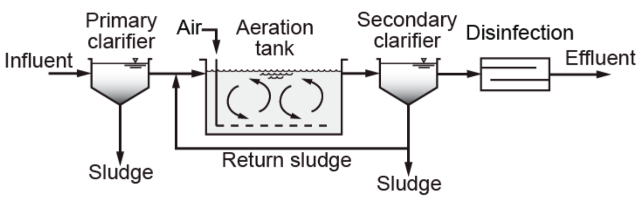
ARE ALL SECONDARY WASTEWATER TREATMENT PROCESSES SUITABLE FOR PR?



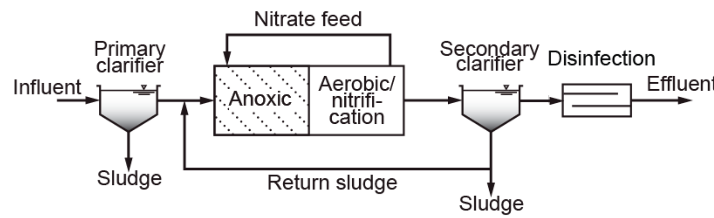
Aerated Lagoon



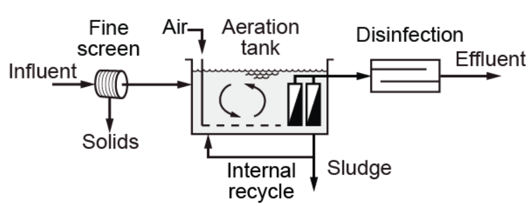
Tricklig Filter



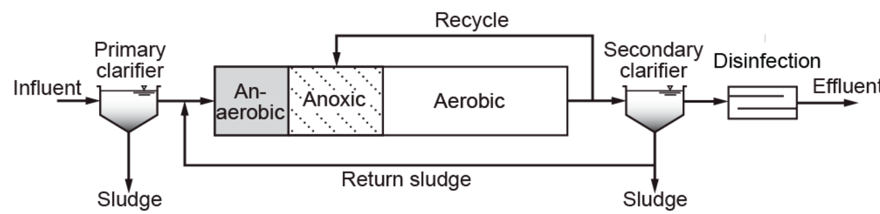
Conventional Activated Sludge



Preanoxic Nitrogen Removal

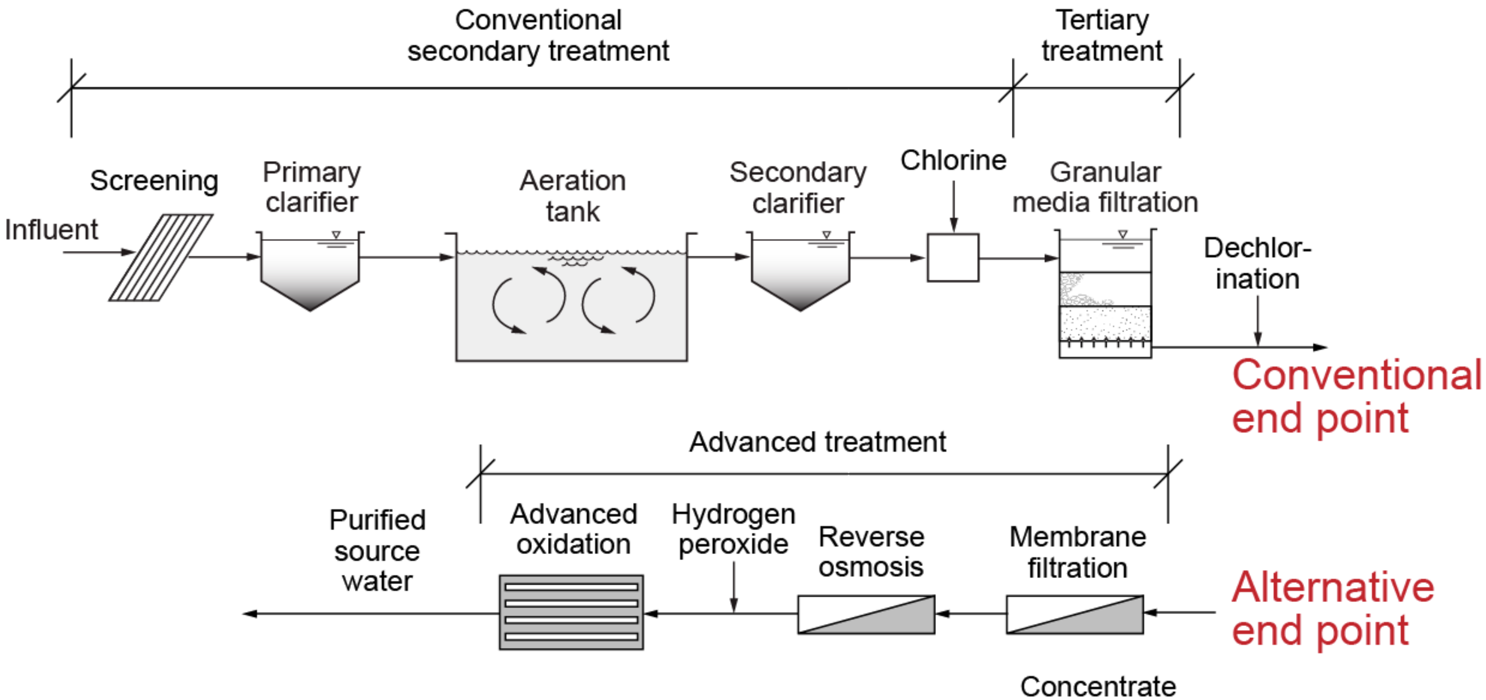


Membrane Bioreactor Activated Sludge



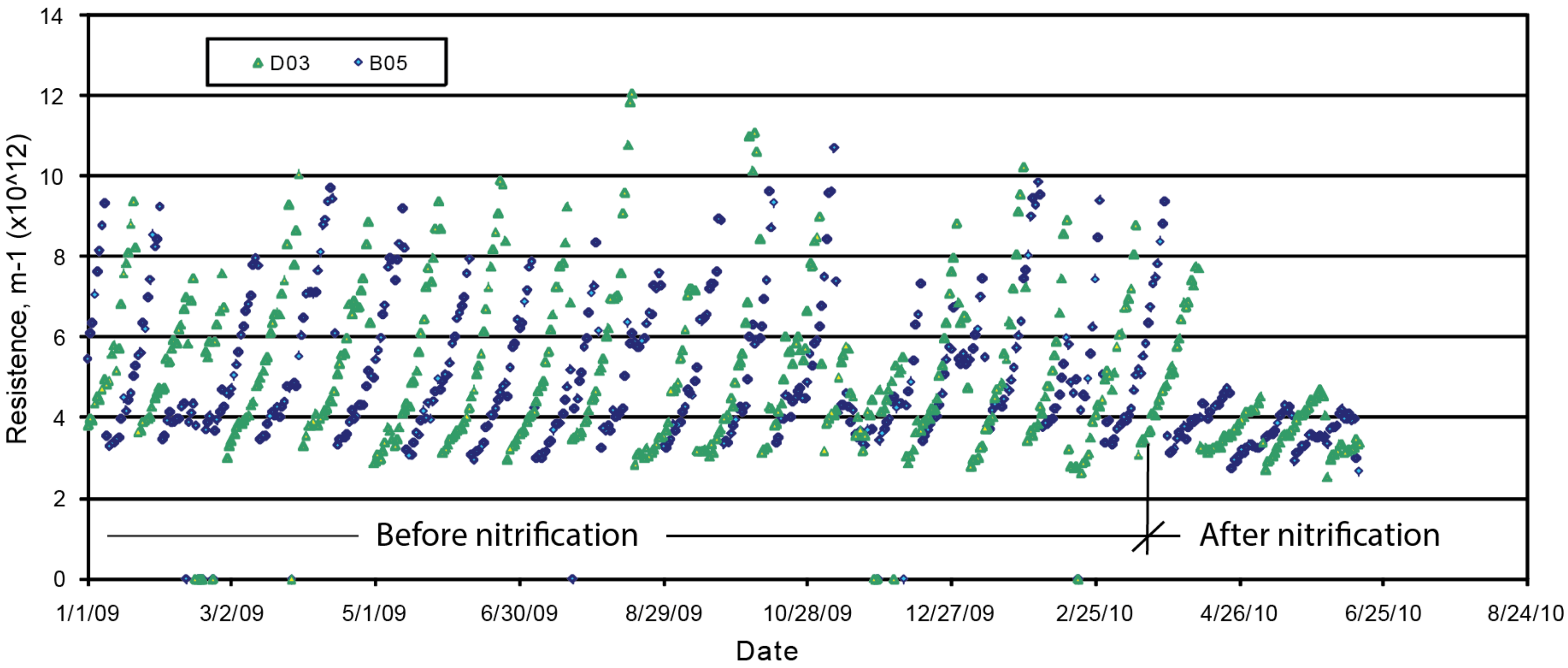
Anaerobic/Anoxic /Aerobic (A2O)

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

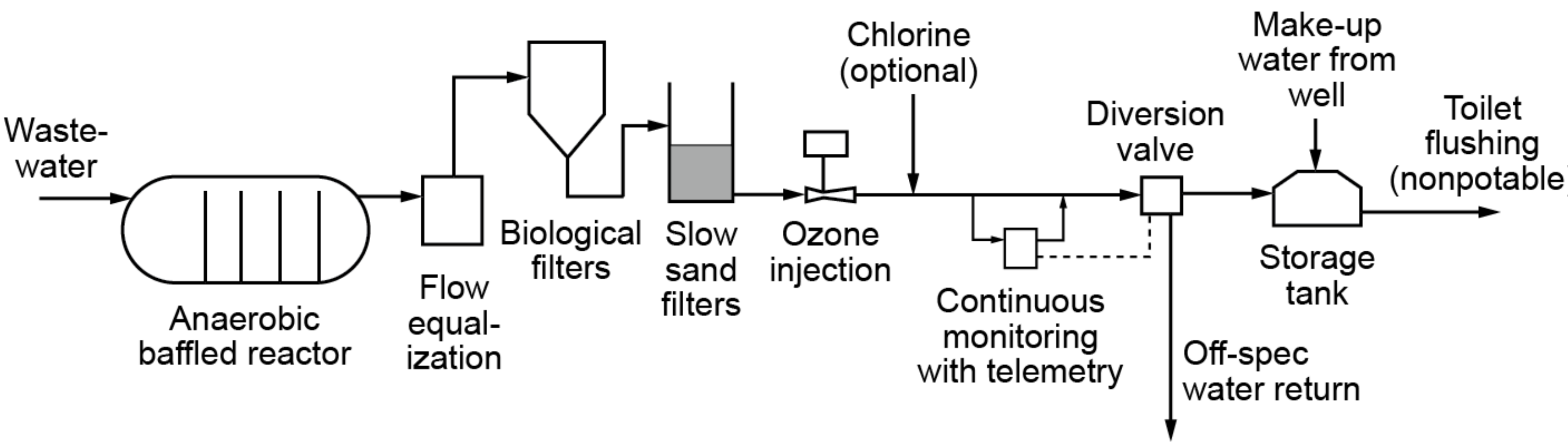
DEVELOPMENT OF REQUIRED LOG_{10} REDUCTION VALUES FOR INDIRECT AND DIRECT POTABLE REUSE

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

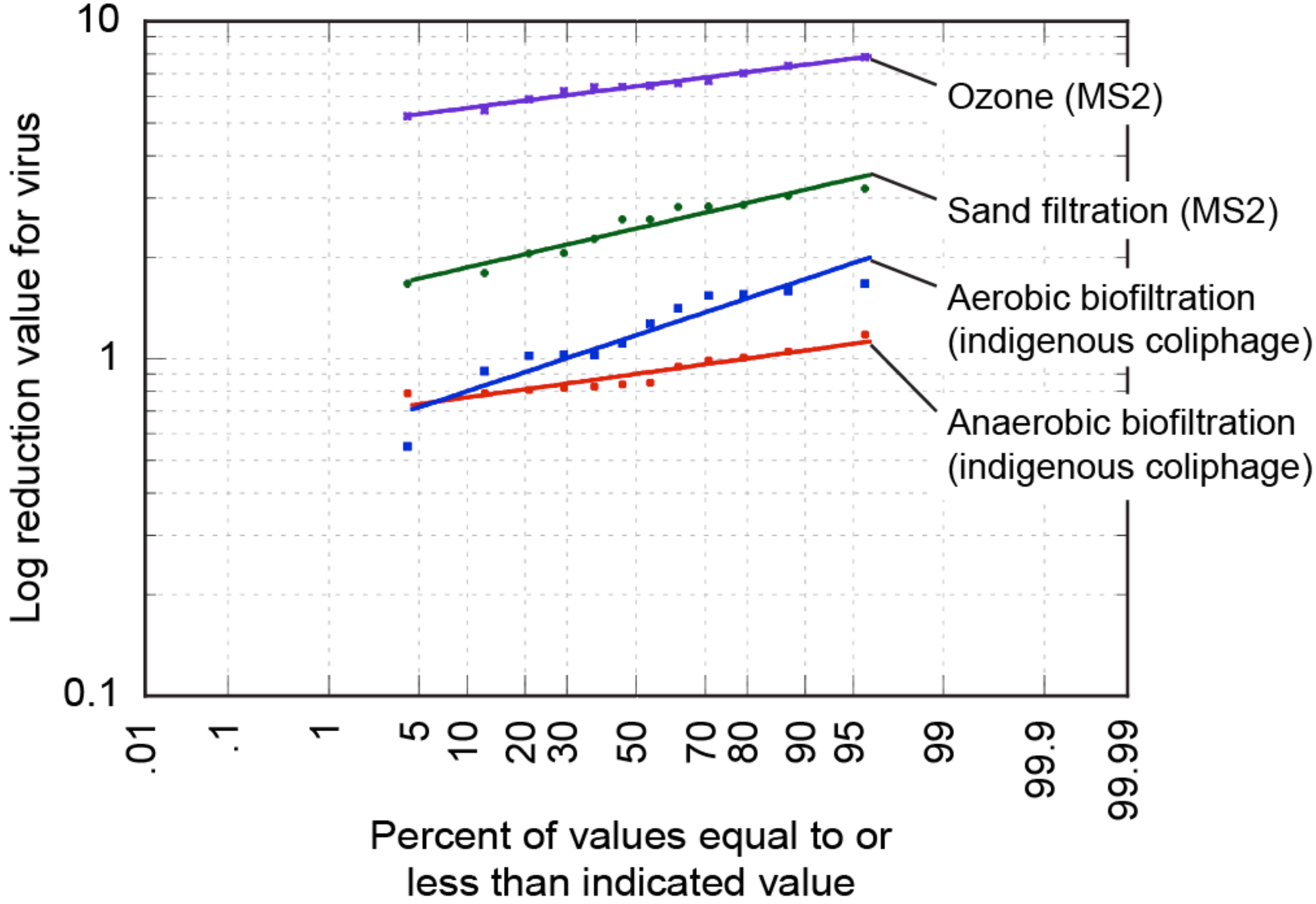
LOG_{10} PATHOGEN REDUCTION TARGETS (LRT_{05}) FOR VARIOUS WATERS AND USES

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



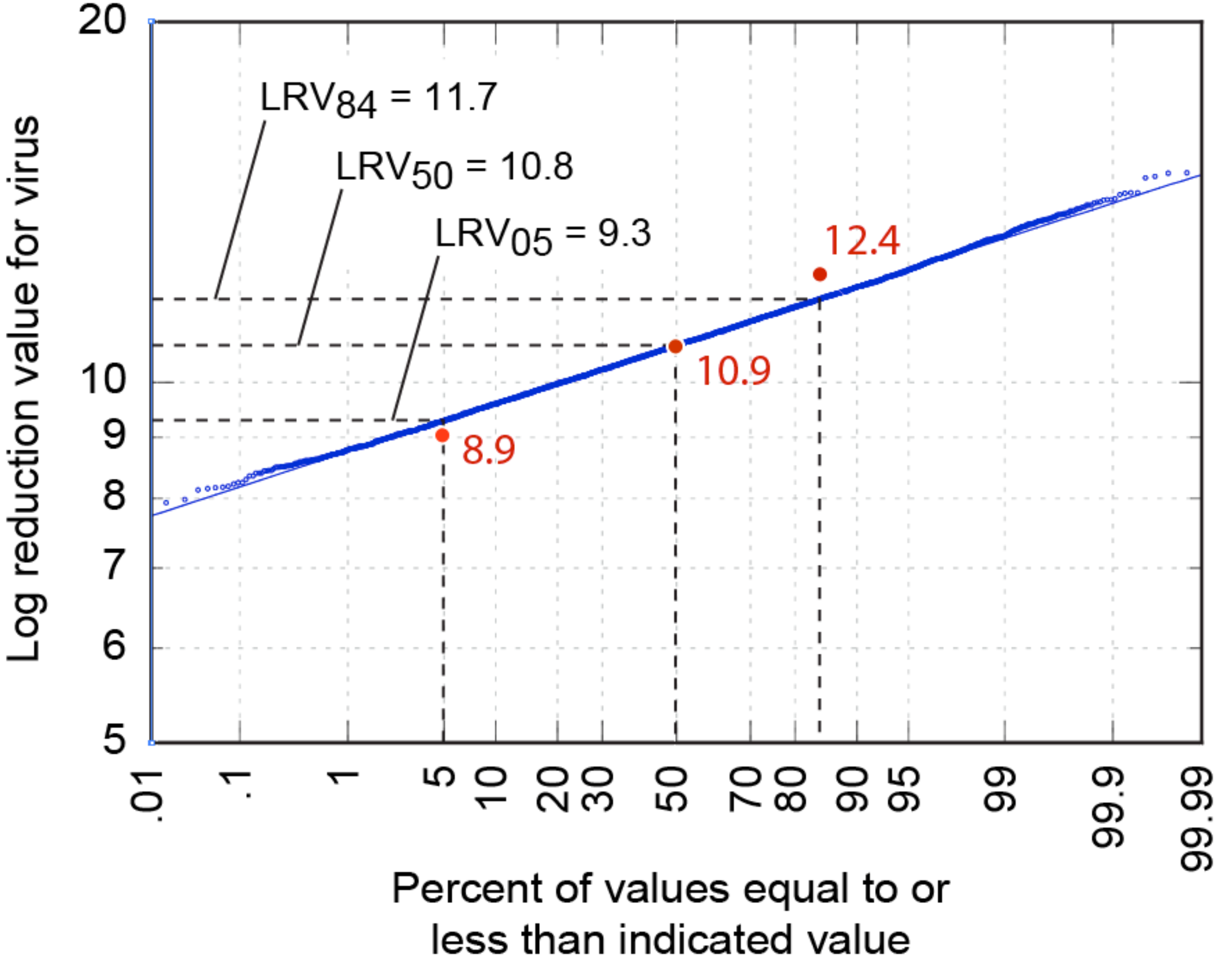
PERFORMANCE OF UNIT PROCESSES IN RECYCLE SYSTEM FOR TOILET FLUSHING



STASTICAL DATA FOR UNIT PROCESSES IN RECYCLE SYSTEM FOR TOILET FLUSHING

Disinfectant	Surrogate	Log reduction values: Lowest observed	LRV_{05}	LRV_{50}	LRV_{84}	s_g
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

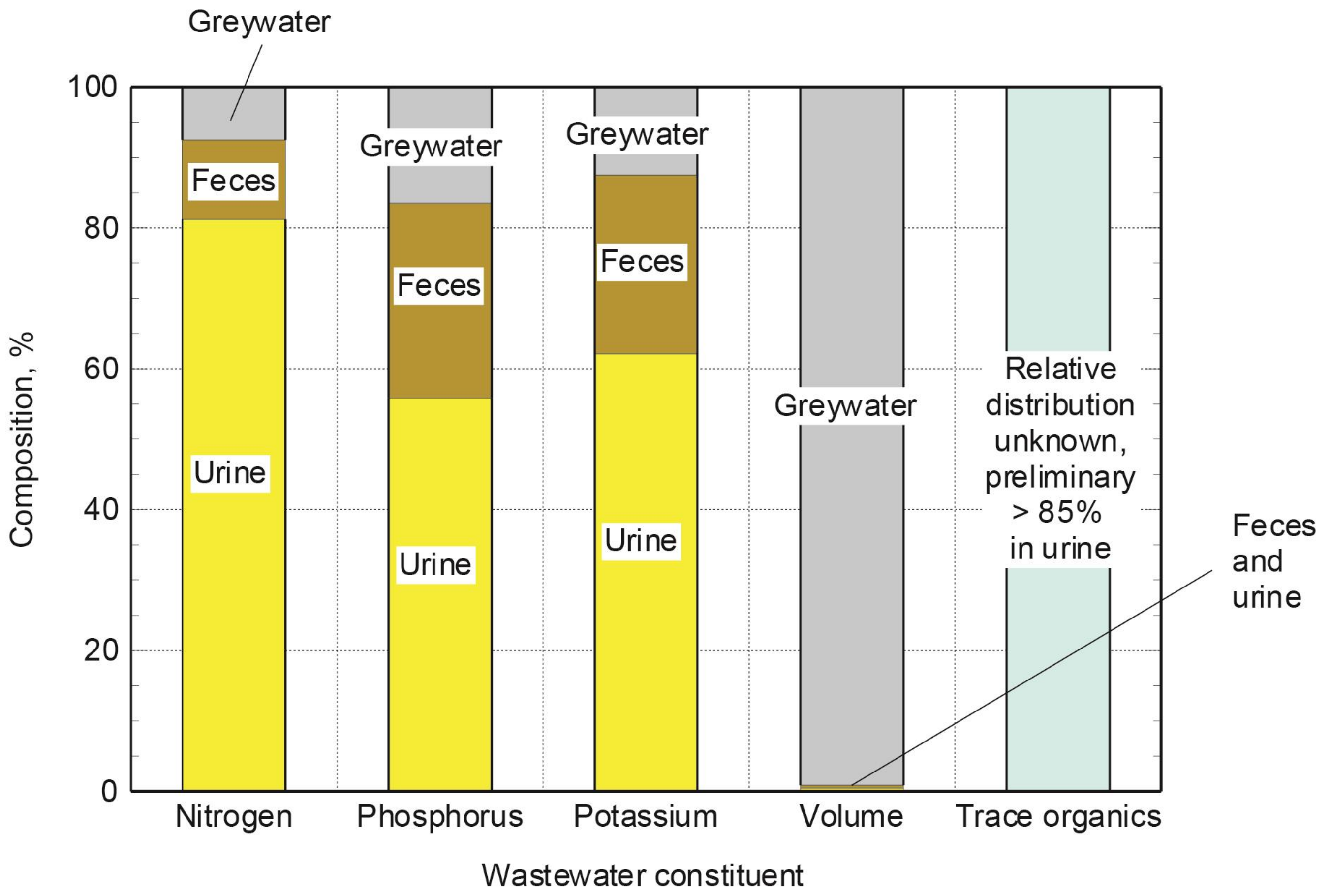
***UNLEASH YOUR IMAGINATION*!**

THANK YOU

FOR LISTENING

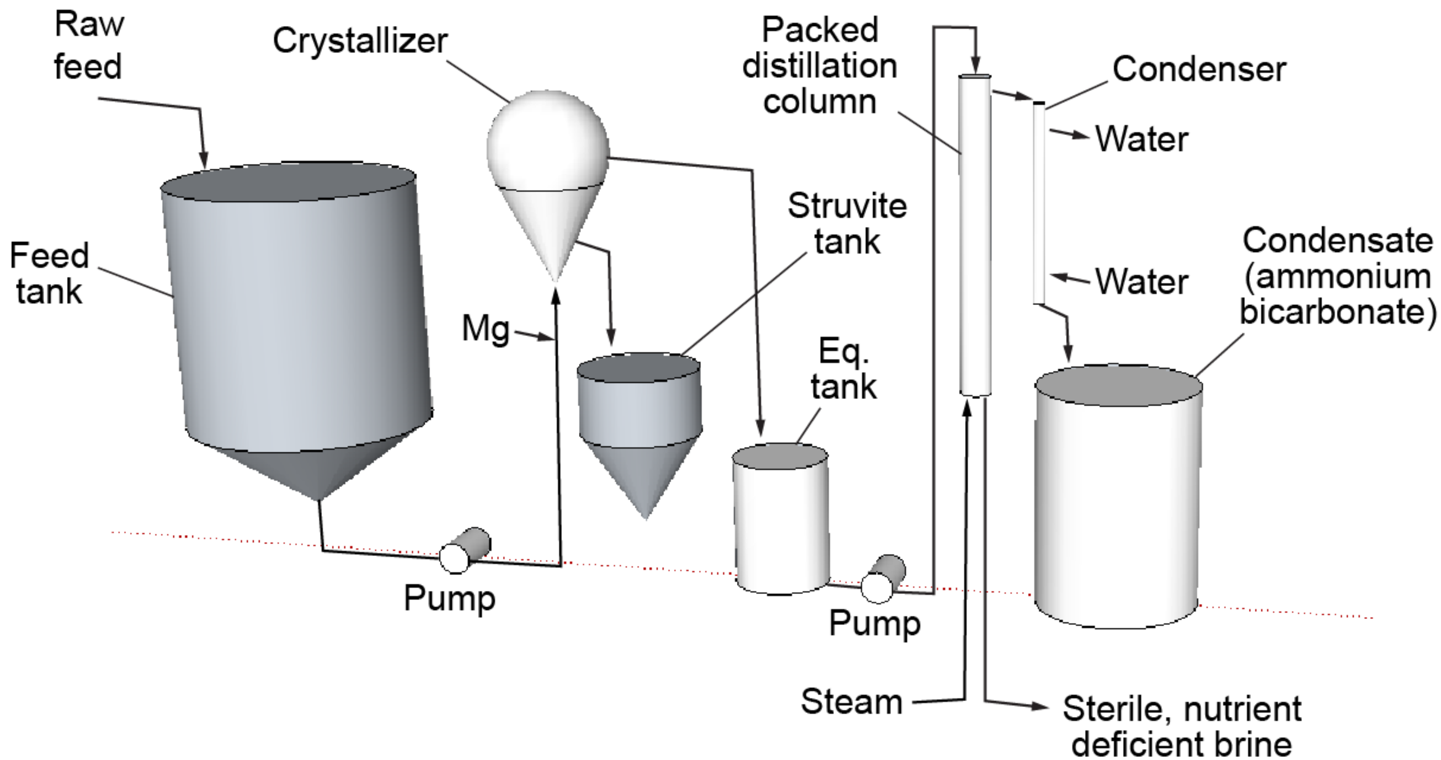
URINE SEPARATION AND NUTRIENT RECOVERY

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



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

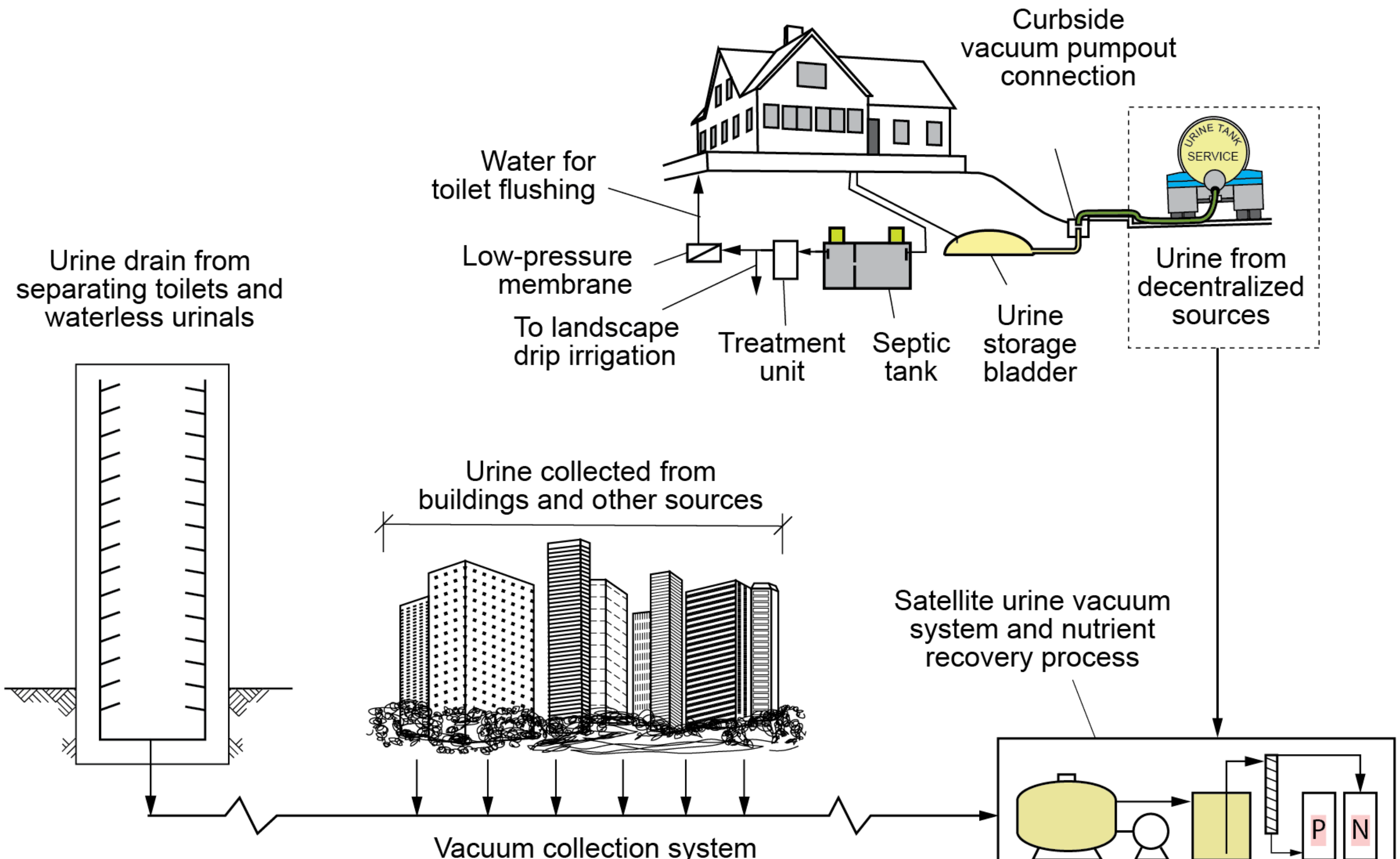
SCHEMATIC OF SEPARATION PROCESS FOR THE RECOVERY OF NUTRIENTS FROM URINE



URINE SEPARATION PROCESS AND PRODUCTS (Ammonium bicarbonate and struvite)

URINE SEPARATION FACILITY AT MICROBREWERY, DAVIS, CALIFORNIA

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



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