

# ***WASTEWATER MANAGEMENT IN THE 21<sup>ST</sup> CENTURY: ISSUES FOR THE DESIGN OF SMALL TREATMENT SYSTEMS***

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**Presented at the**

***13<sup>th</sup> IWA Specialized Conference on  
Small Water and Wastewater Systems***

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## ***DISCUSSION TOPICS***

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- A Paradigm Shift and Fundamental Question
- 21<sup>st</sup> Century Challenges and Issues
- New Technologies for the 21<sup>st</sup> Century
- Treatment for Different Endpoints
- Probabilistic Process Design
- Urine Separation and Processing
- Closing Thoughts

## ***A PARADIGM SHIFT AND FUNDAMENTAL QUESTION***

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### ***A PARADIGM SHIFT: A NEW VIEW OF WASTEWATER***

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

### ***A FUNDAMENTAL QUESTION***

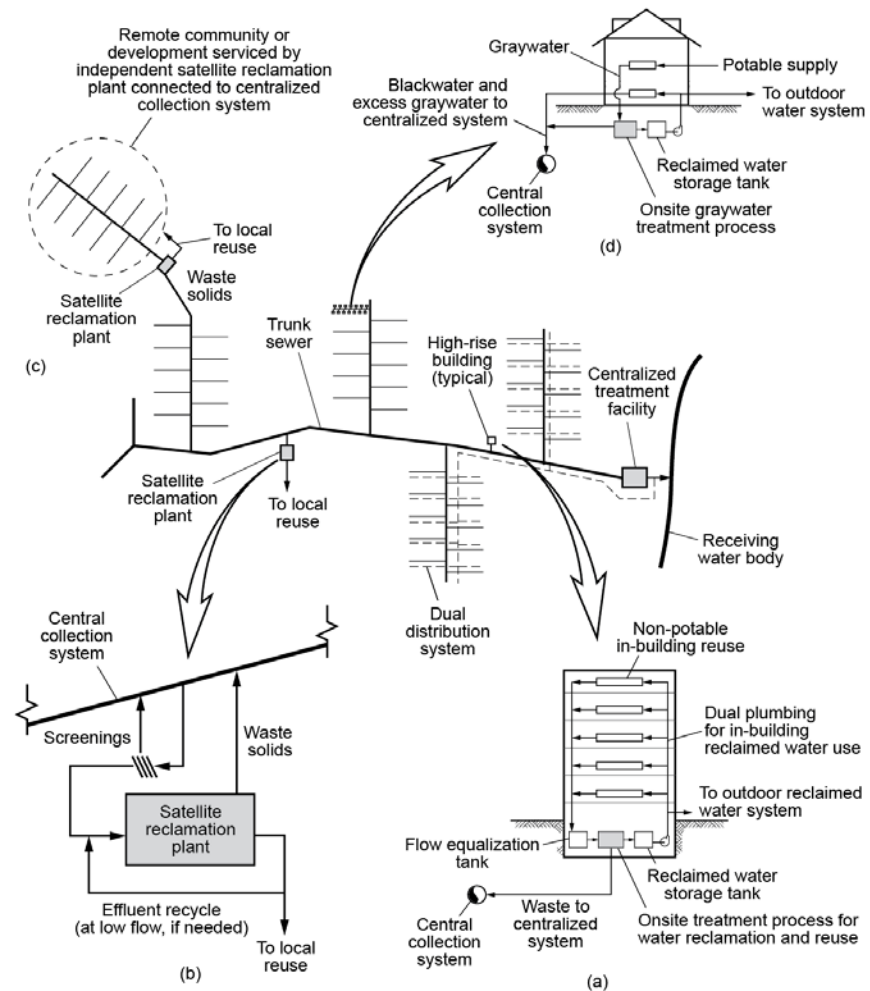
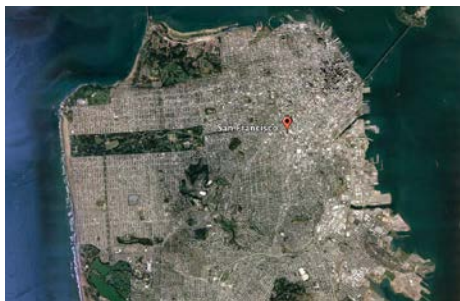
What is the optimal use of the carbon in wastewater?

## **21<sup>ST</sup> CENTURY CHALLENGES AND ISSUES FOR SMALL WASTEWATER MANAGEMENT SYSTEMS**

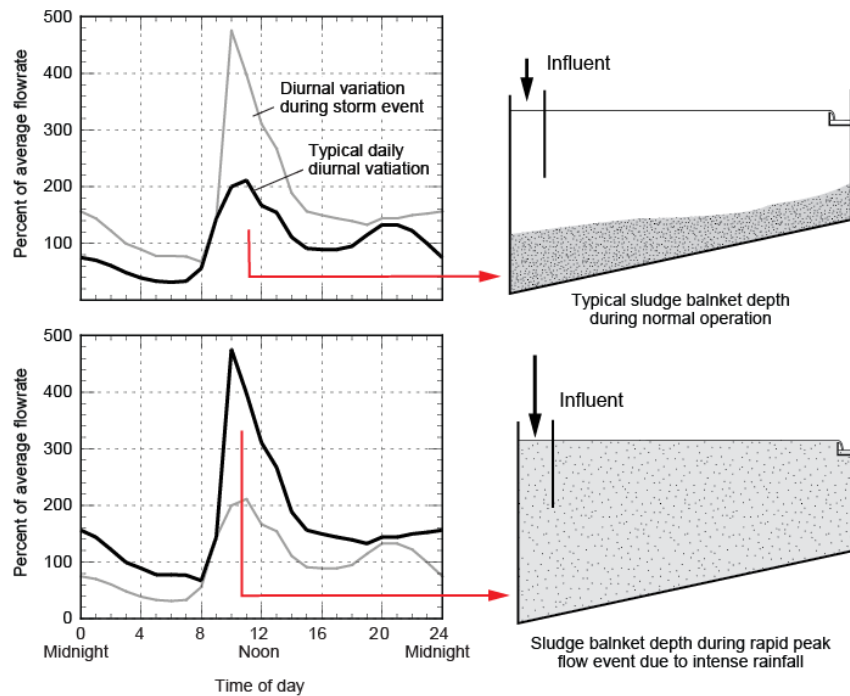
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- *Population demographics*
- *Impact of climate change*
- *Decreasing per capita flowrates*
  - *Decentralized non-potable  
water sources*

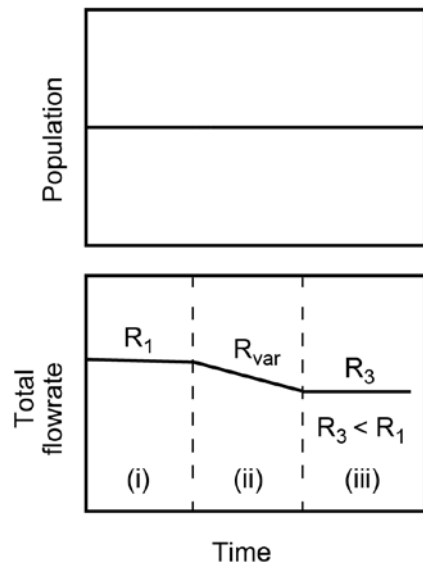
# POPULATION DEMOGRAPHICS FAVOR DECENTRALIZED WATER SYSTEMS



# Impact of Climate Change on Rainfall Intensity and Operation of WWTPs



## **CURRENT AND PROJECTED PER CAPITA WATER USE IN THE UNITED STATES**



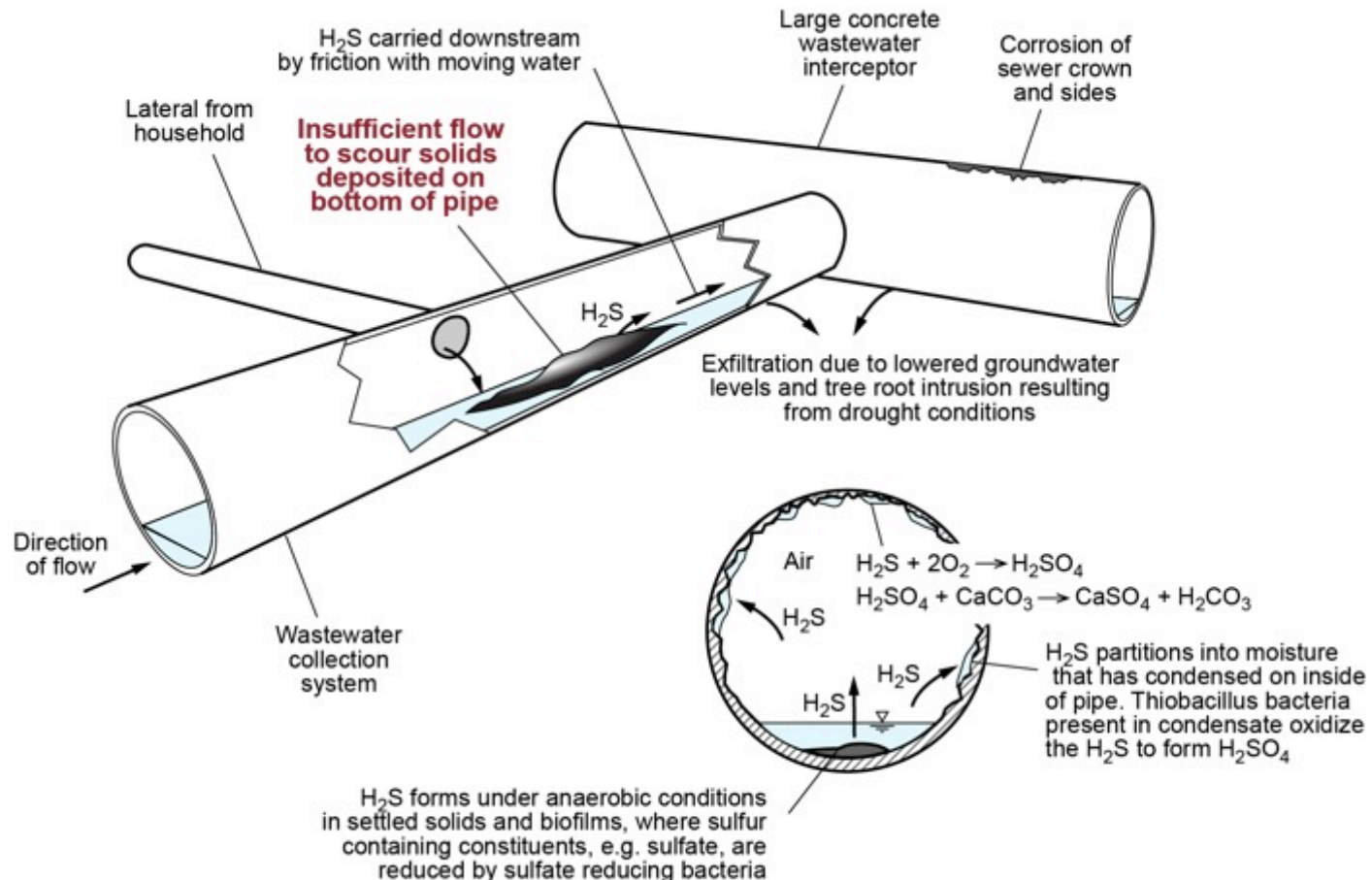
(i) Pre-1992

(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, H<sub>2</sub>S FORMATION, AND DOWNSTREAM CORROSION DUE TO REDUCED FLOWS





## DECENTRALIZED NON-POTABLE WATER SYSTEMS

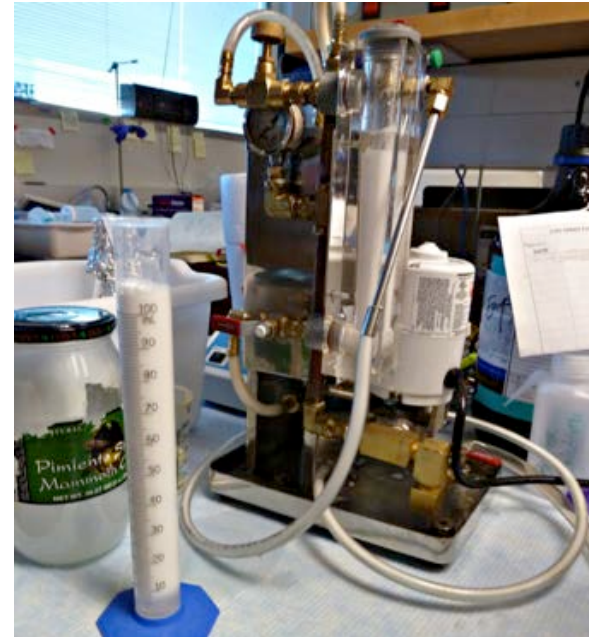
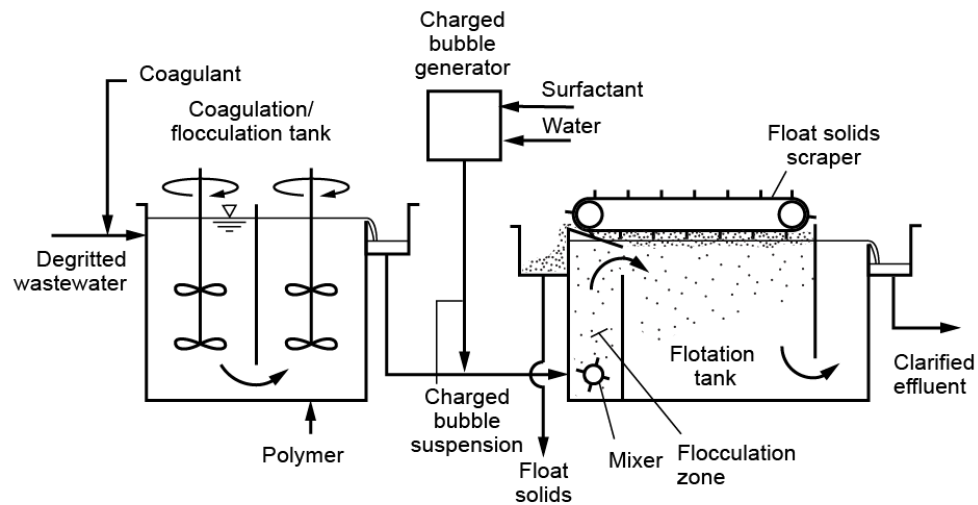
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Water Source	Definition
Blackwater	Wastewater originating from toilets and/or kitchen sources
Graywater	Wastewater collected from non-blackwater sources
Wastewater	Water that is collected from combined graywater and blackwater sources
Roof runoff	Precipitation 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 21<sup>ST</sup> CENTURY***

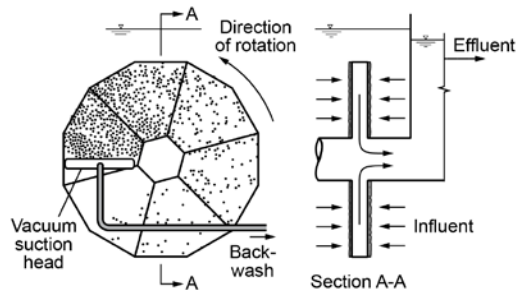
- ***Alternative primary treatment processes***
- ***Enhanced primary treatment***
- ***Enhanced primary-secondary treatment***
- ***Approaching closed loop***
- ***Algae removal of algae with charged bubble flotation***

# ALTERNATIVE TECHNOLOGIES FOR ENHANCED PRIMARY TREATMENT: CHARGED BUBBLE FLOTATION



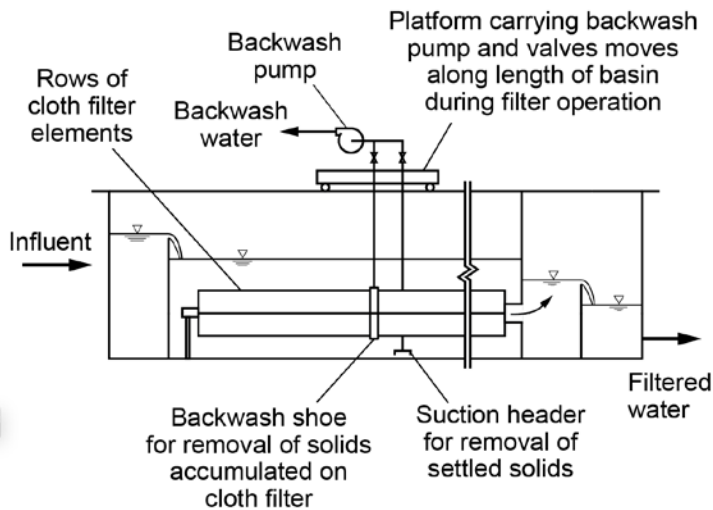
- 1/5<sup>th</sup> the size of conventional clarifiers
- Nanoparticles can be added to charged bubble for removal of specific constituents

# ALTERNATIVE TECHNOLOGIES FOR ENHANCED PRIMARY TREATMENT: CLOTH DISK FILTER (5-10 $\mu\text{m}$ )



Vacuum  
suction head

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

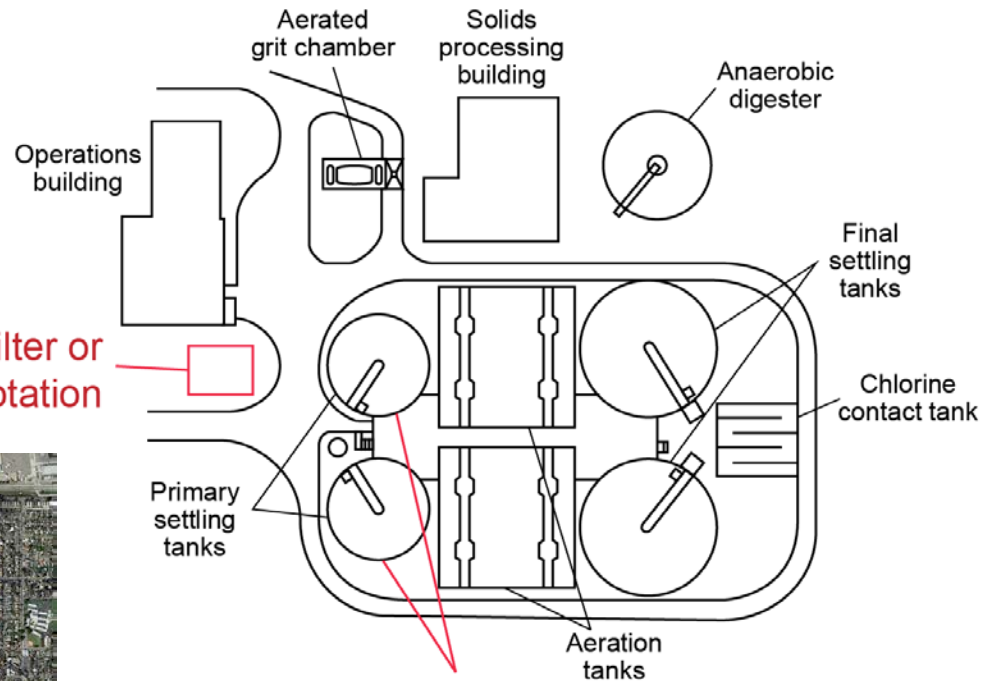


Parameter	Unit	Average influent	Average effluent	Average removal, %
BOD	mg/L	169	59	64.2
COD	mg/L	417	147	62.8
TSS	mg/L	221	26	87.5
VSS	mg/L	116	36	69.0
Turbidity	NTU	143	37	73.5
TKN	mg/L	39	36	7.7
FOG	mg/L	14	10	28.6
UVT	%	28	44	+59.9

# *Replace and Repurpose Existing Primary Clarifiers*



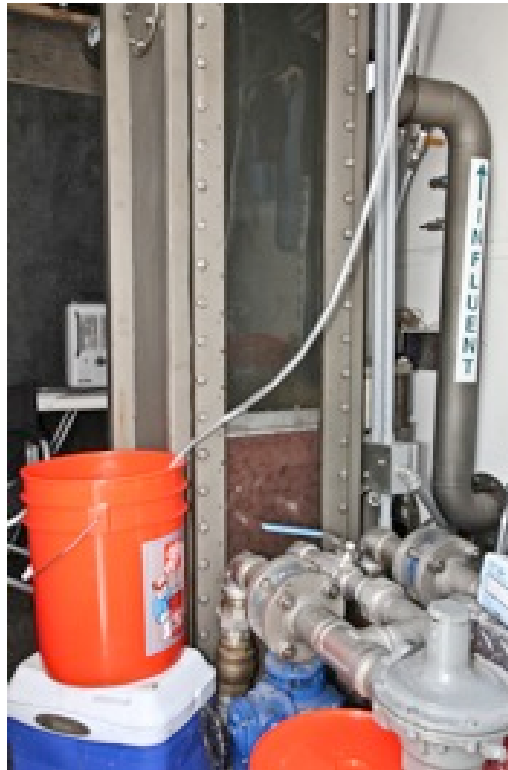
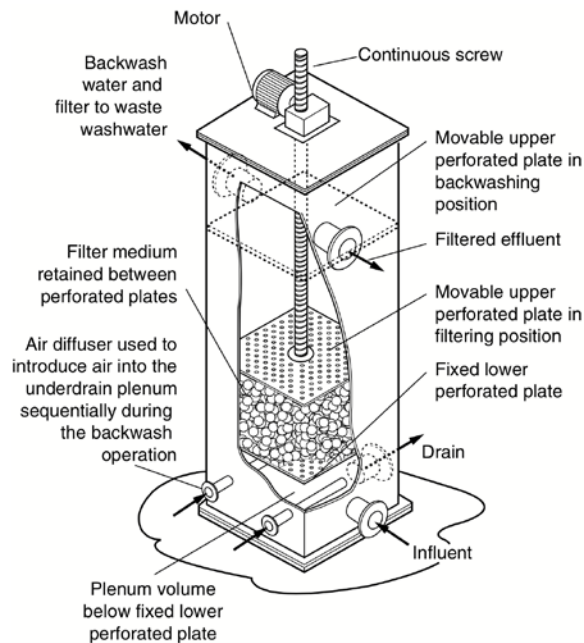
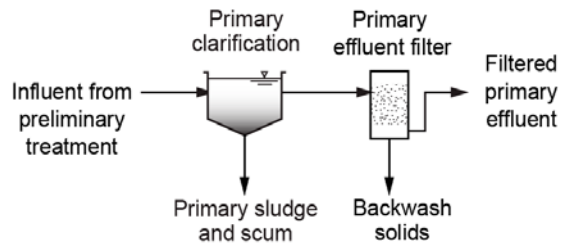
Cloth disk filter or  
charged-bubble flotation



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

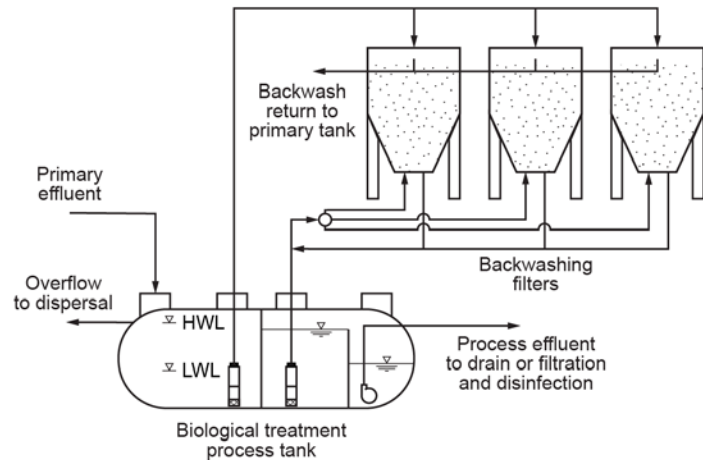


# ENHANCED PRIMARY TREATMENT WITH PRIMARY EFFLUENT FILTRATION (PEF) BEFORE BIOLOGICAL TREATMENT



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<sup>2</sup>·d (3,000 L/m<sup>2</sup>·d) with septic tank effluent

Specific weight = 640 kg/m<sup>3</sup>

Average porosity = 90 %

Particle size = 2- 4 mm

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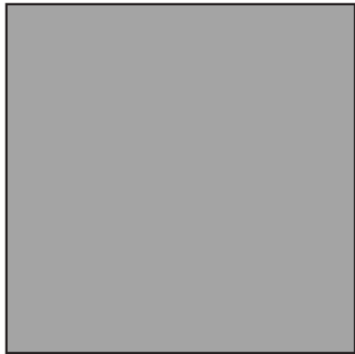







## ***ADVANTAGES OF PUMICE FILTER***

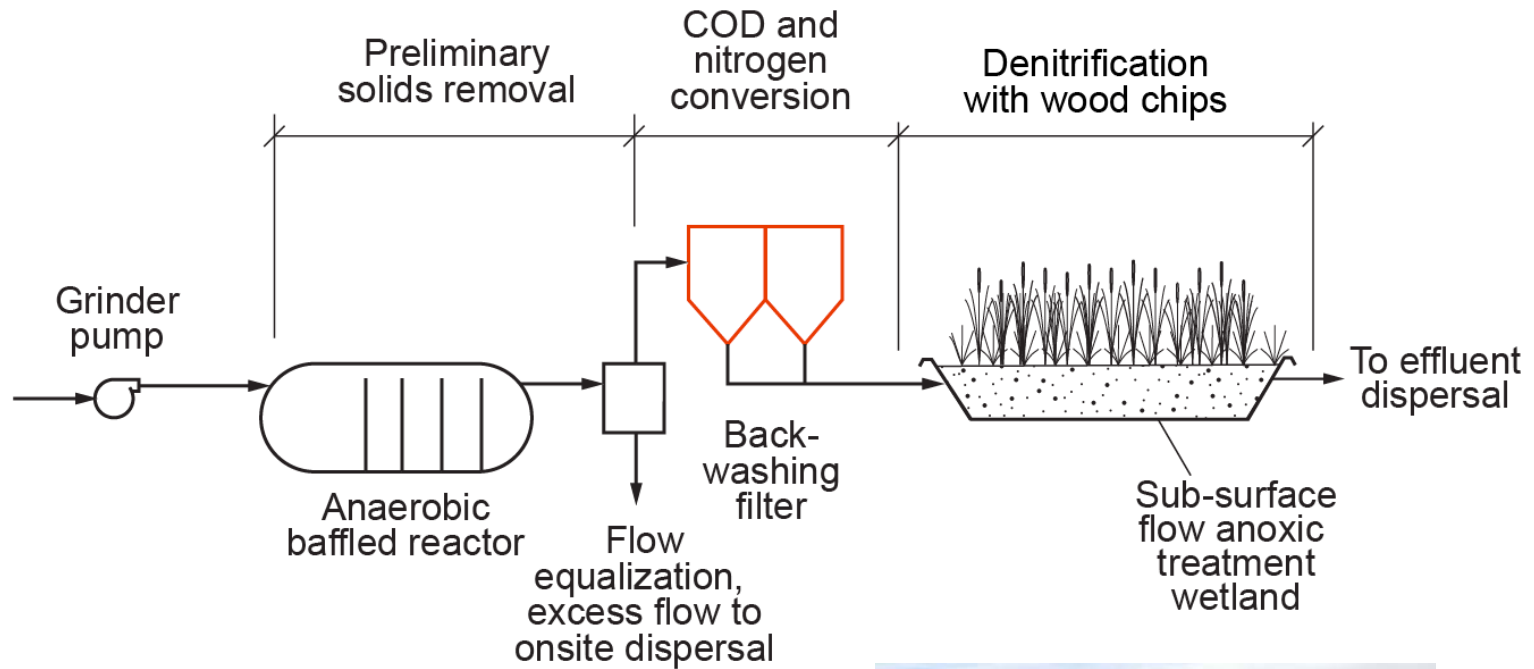
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- High organic loading rate
- Single or multi-pass operation
- The filter is located above ground
- Easy to prefabricate and plumb at treatment site
- Being above ground, filter is easy to maintain
- Filter is easy to aerate
- Lower energy input

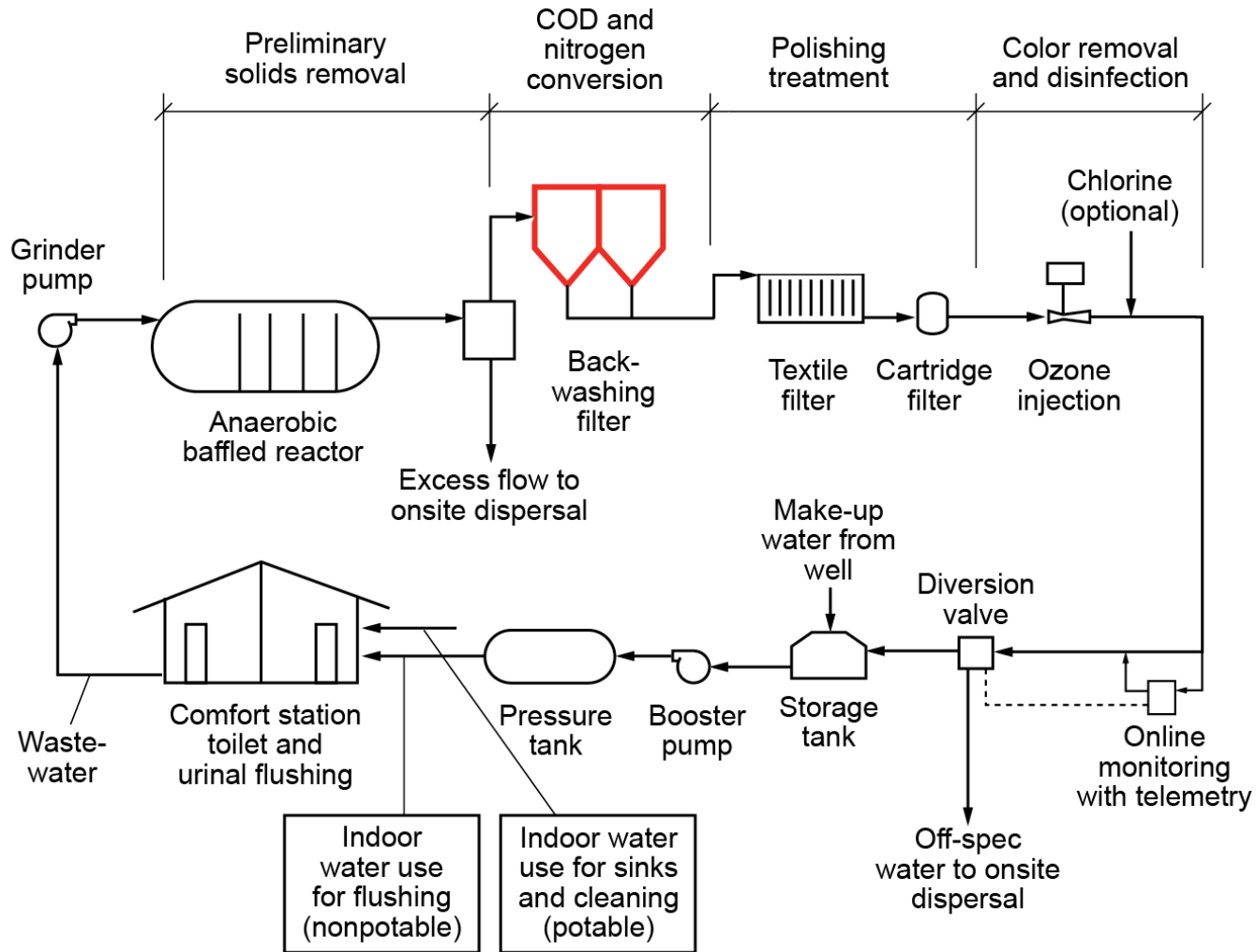
## ***RELATIVE SIZE OF ALTERNATIVE TREATMENT PROCESSES BASED ON NITROGEN LOADING***

Item	Technology		
	Recirculating gravel filter	Recirculating textile filter	Single-pass backwashing pumice filter
Nitrogen loading, g TN/m <sup>2</sup> .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 <sup>2</sup>	185 m <sup>2</sup>	22 m <sup>2</sup>

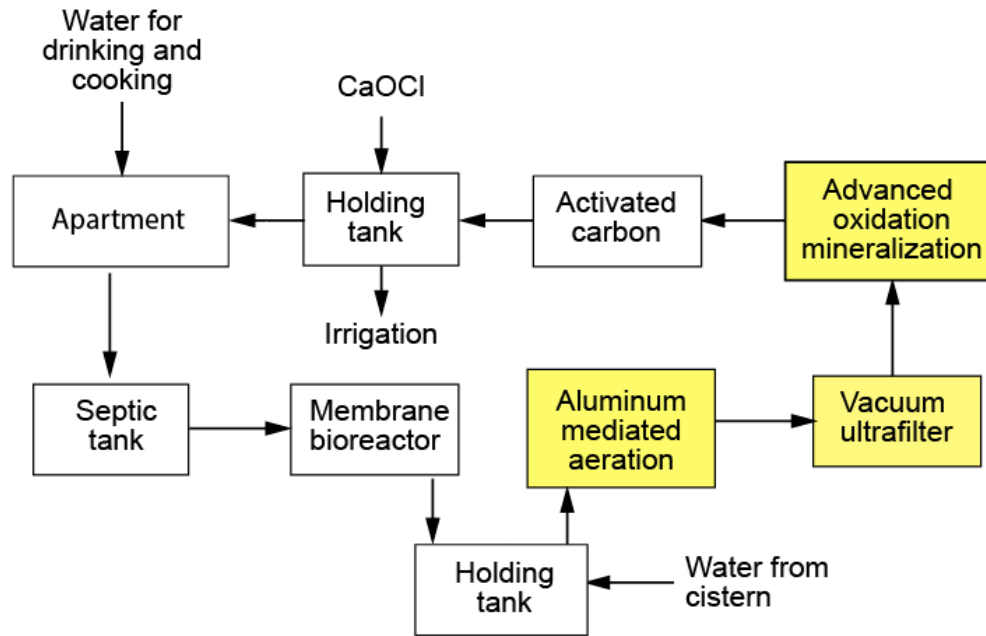
# COMPLETE TREATMENT WITH PUMICE FILTER



# RECYCLE SYSTEM FOR TOILET FLUSHING



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

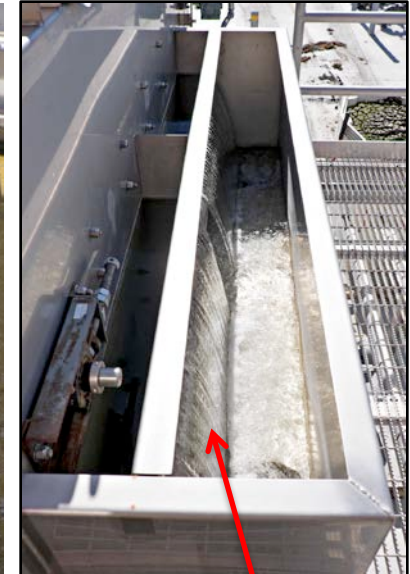
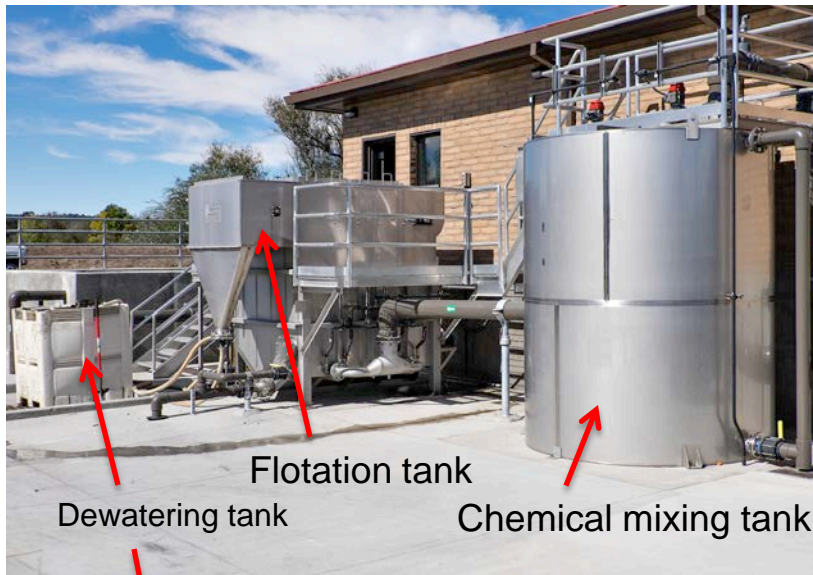


Source: Jim Englehardt  
University of Miami  
College of Engineering

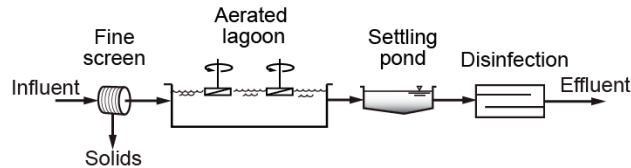




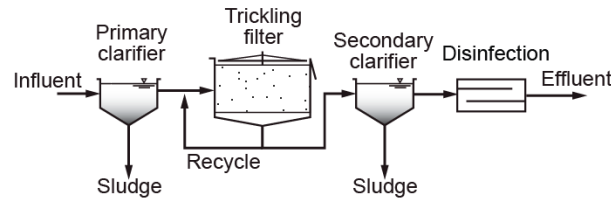
# ALGAL REMOVAL WITH CHARGED BUBBLE FLOTATION PROCESS



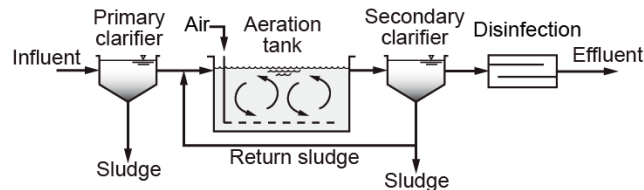
# ARE ALL SECONDARY WASTEWATER TREATMENT PROCESSES SUITABLE FOR PR?



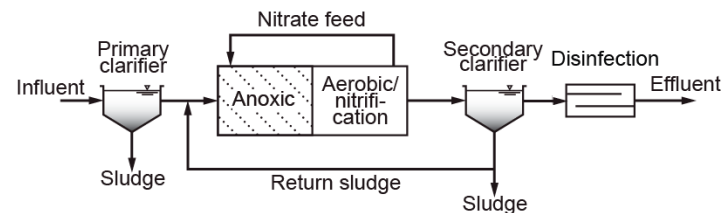
Aerated Lagoon



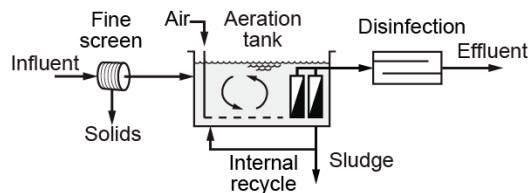
Trickling Filter



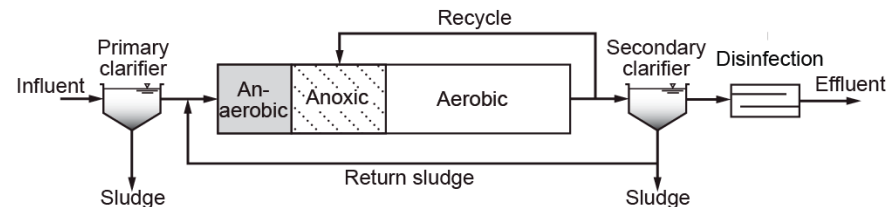
Conventional Activated Sludge



Preanoxic Nitrogen Removal



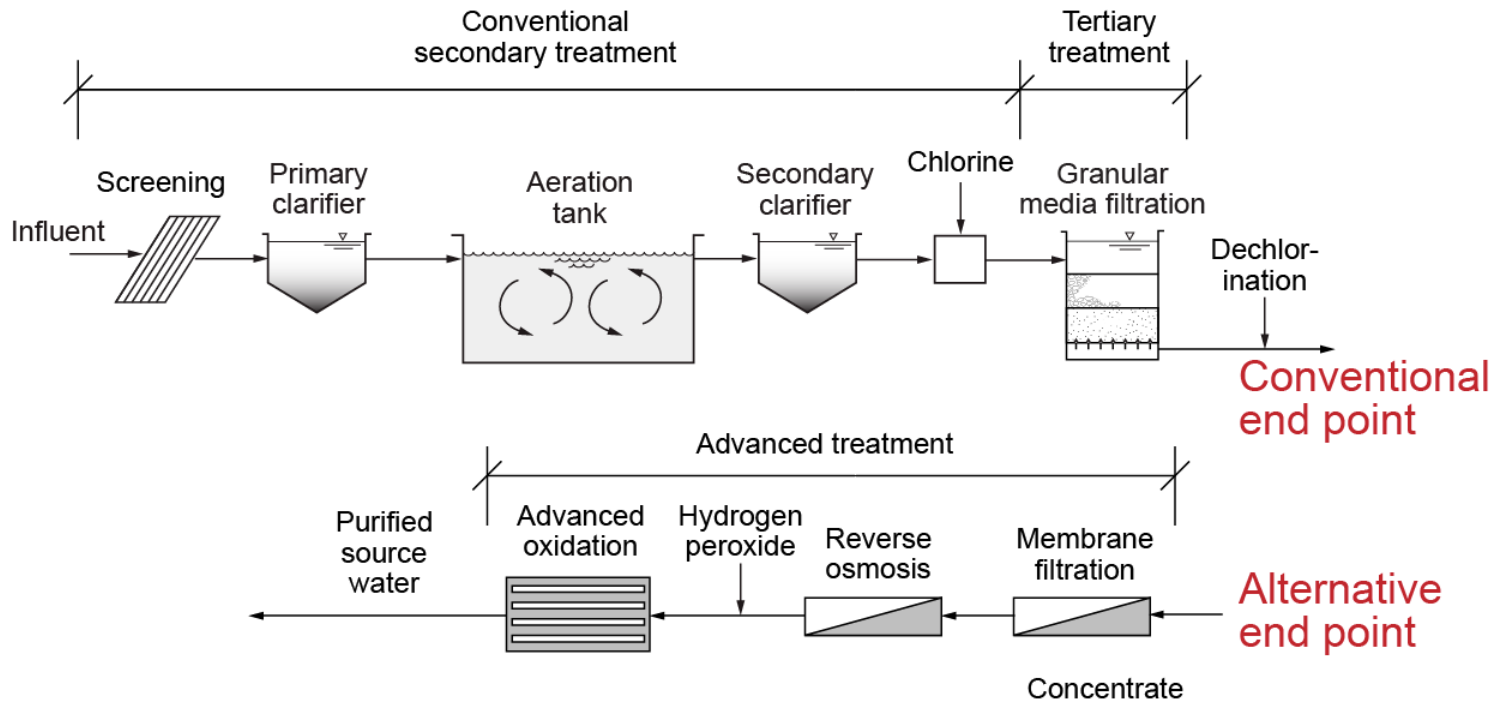
Membrane Bioreactor Activated Sludge



Anaerobic/Anoxic /Aerobic (A2O)

# ***DESIGN OF BIOLOGICAL TREATMENT PROCESS FOR ALTERNATIVE END POINT***

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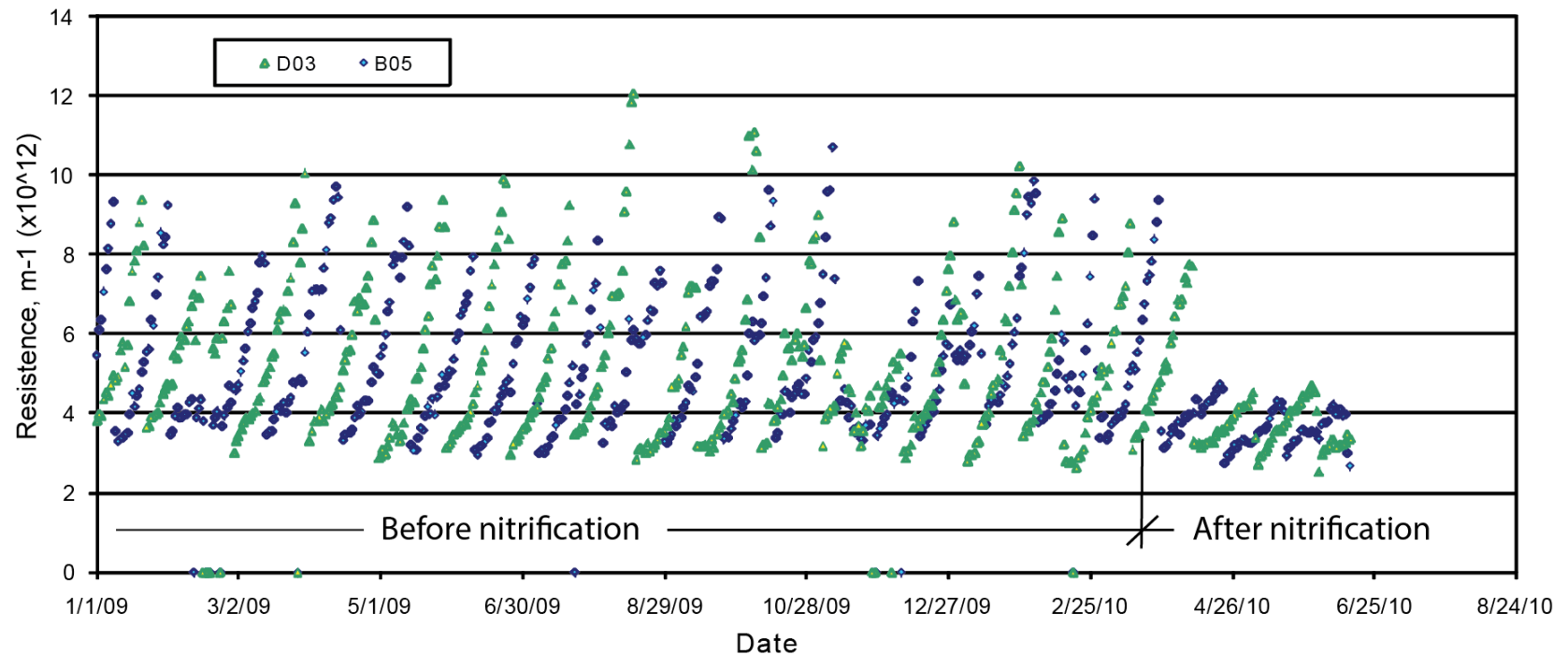


**It is time to rethink wastewater treatment**



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

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***PROBABALISTIC ANALYSIS AND  
DESIGN OF DECENTRALIZED  
WASTEWATER MANAGEMENT  
SYSTEMS FOR DIFFERENT USES***

## ***DEVELOPMENT OF REQUIRED LOG<sub>10</sub> REDUCTION VALUES FOR INDIRECT AND DIRECT POTABLE REUSE***

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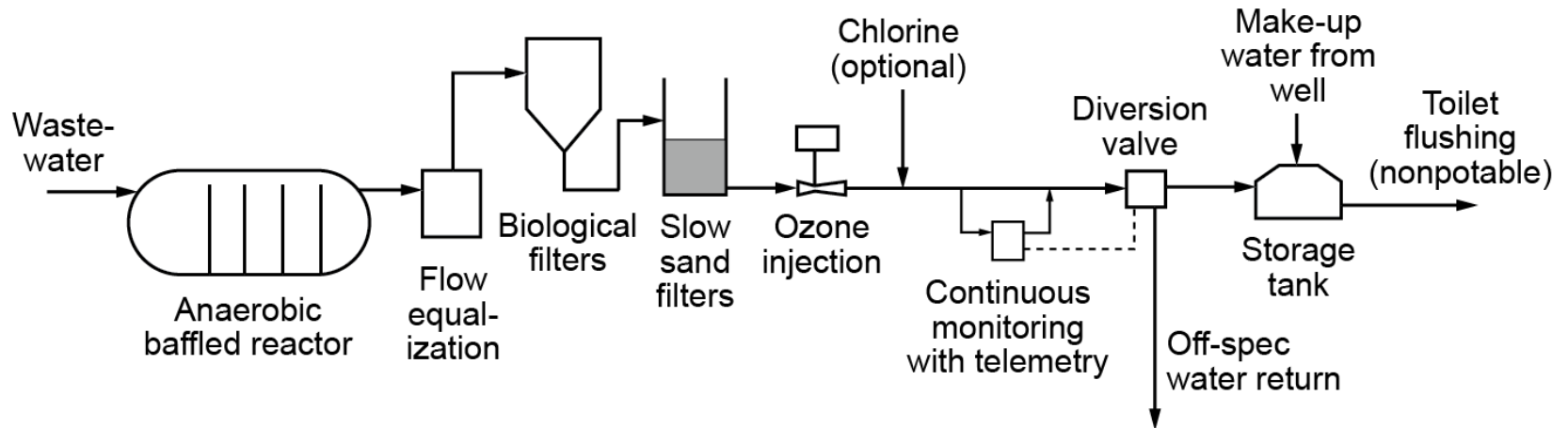
Item	Enteric virus	Giardia	Cryptosporidium
Untreated wastewater maximum density	10 <sup>5</sup> virus/L	10 <sup>5</sup> cysts/L	10 <sup>4</sup> oocysts/L
Tolerable drinking water density (TDWD)	2.2 x 10 <sup>-7</sup> virus/L	6.8 x 10 <sup>-6</sup> cysts /L	1.7 x 10 <sup>-6</sup> oocysts /L
Ratio of TDWD to wastewater density	2.2 x 10 <sup>-12</sup>	6.8 x 10 <sup>-11</sup>	1.7 x 10 <sup>-10</sup>
Required log <sub>10</sub> reduction value	12	10	10

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

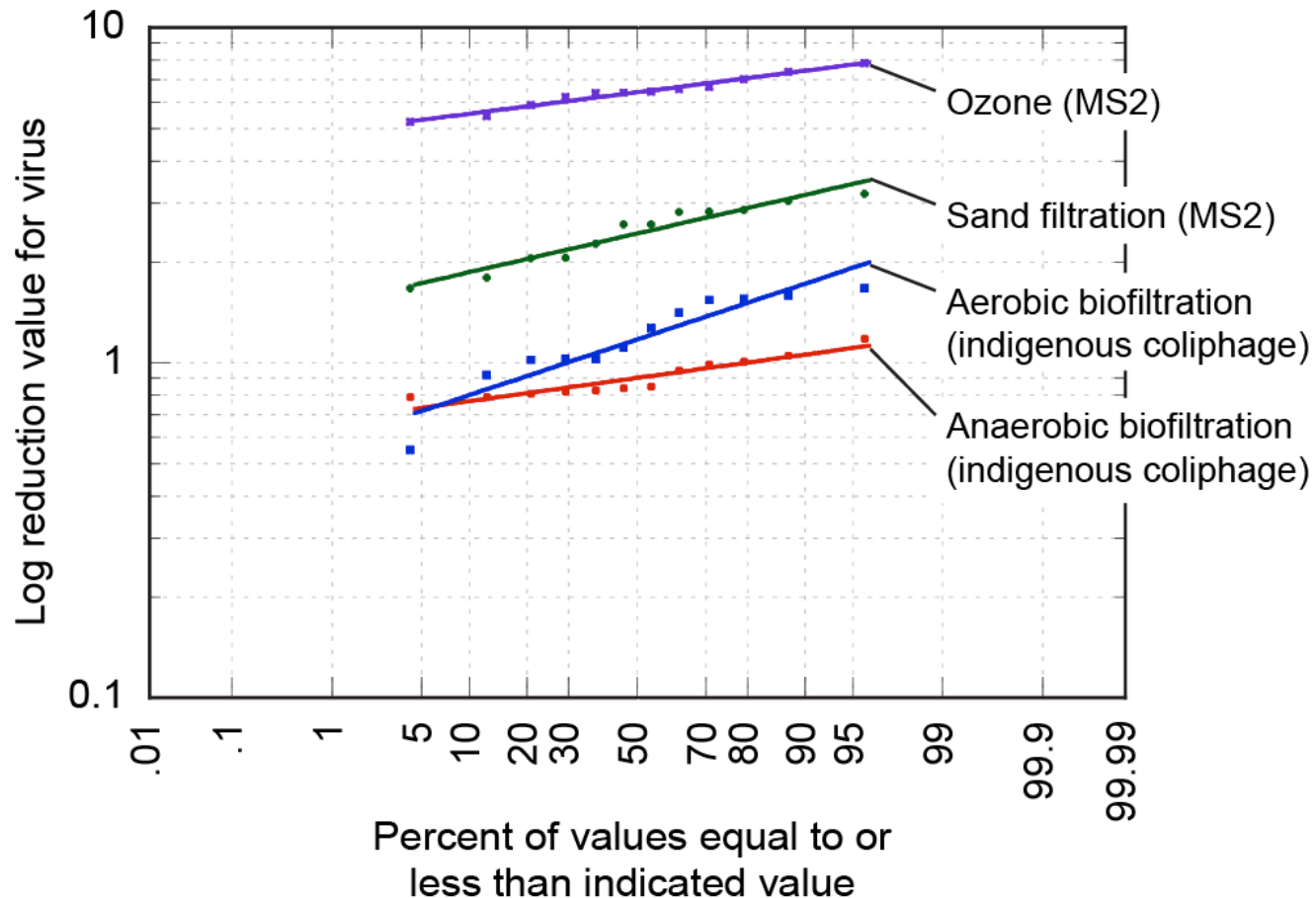
Water use	Log reduction targets for $10^{-4}$		
	Enteric viruses	Parasitic protozoa	Enteric bacteria
<b><i>Municipal wastewater</i></b>			
Unrestricted irrigation	6.0	6.5	5.0
Indoor use	6.5	7.5	6.0
<b><i>Graywater</i></b>			
Unrestricted irrigation	5.5	4.5	3.5
Indoor use	6.0	4.5	3.5
<b><i>Stormwater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

# ***UNIT PROCESSES IN RECYCLE SYSTEM FOR TOILET FLUSHING***

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# PERFORMANCE OF UNIT PROCESSES IN RECYCLE SYSTEM FOR TOILET FLUSHING



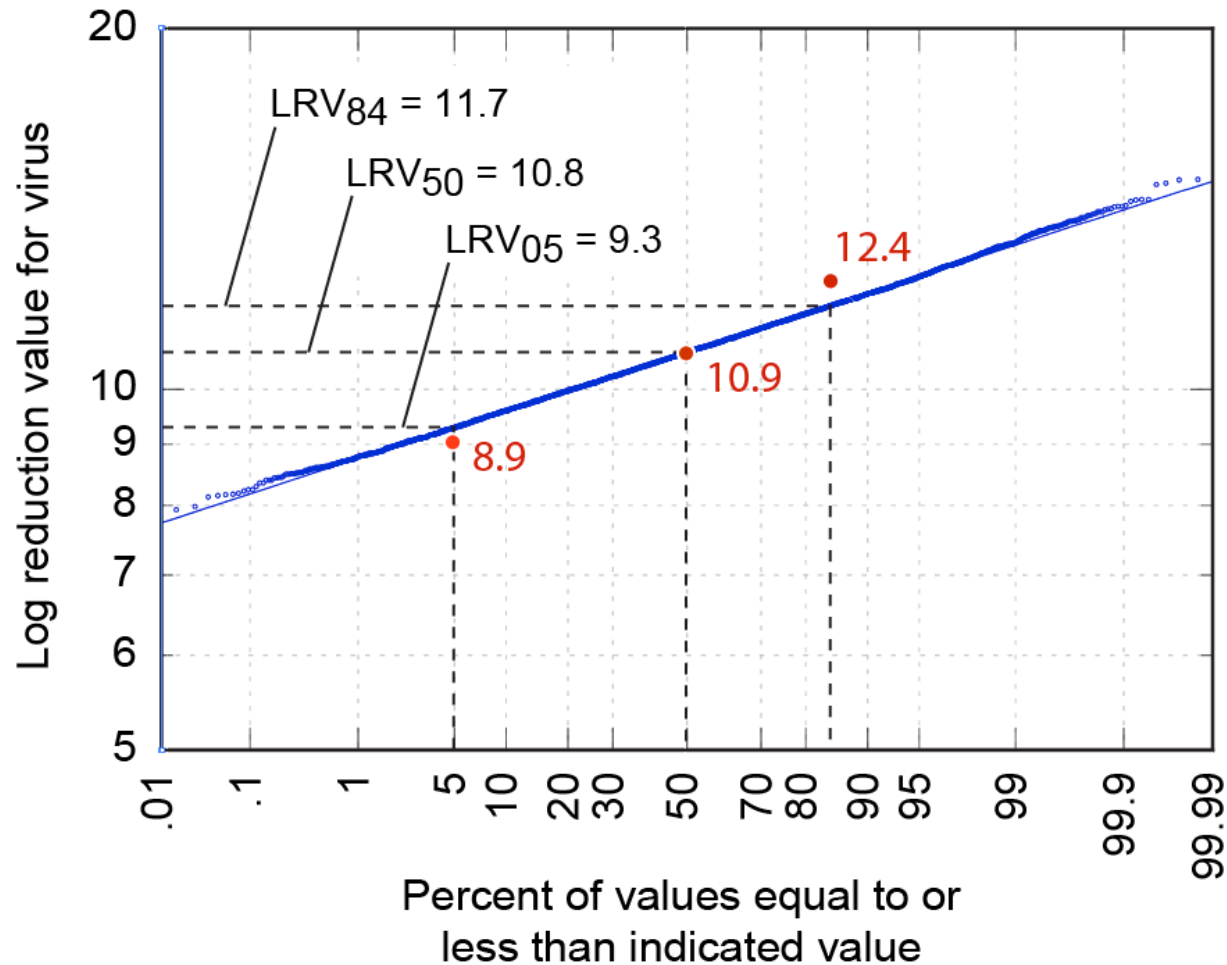
## ***STATISTICAL DATA FOR UNIT PROCESSES IN RECYCLE SYSTEM FOR TOILET FLUSHING***

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Disinfectant	Surrogate	Log reduction values				S <sub>g</sub>
		Lowest observed	LRV <sub>05</sub>	LRV <sub>50</sub>	LRV <sub>84</sub>	
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**

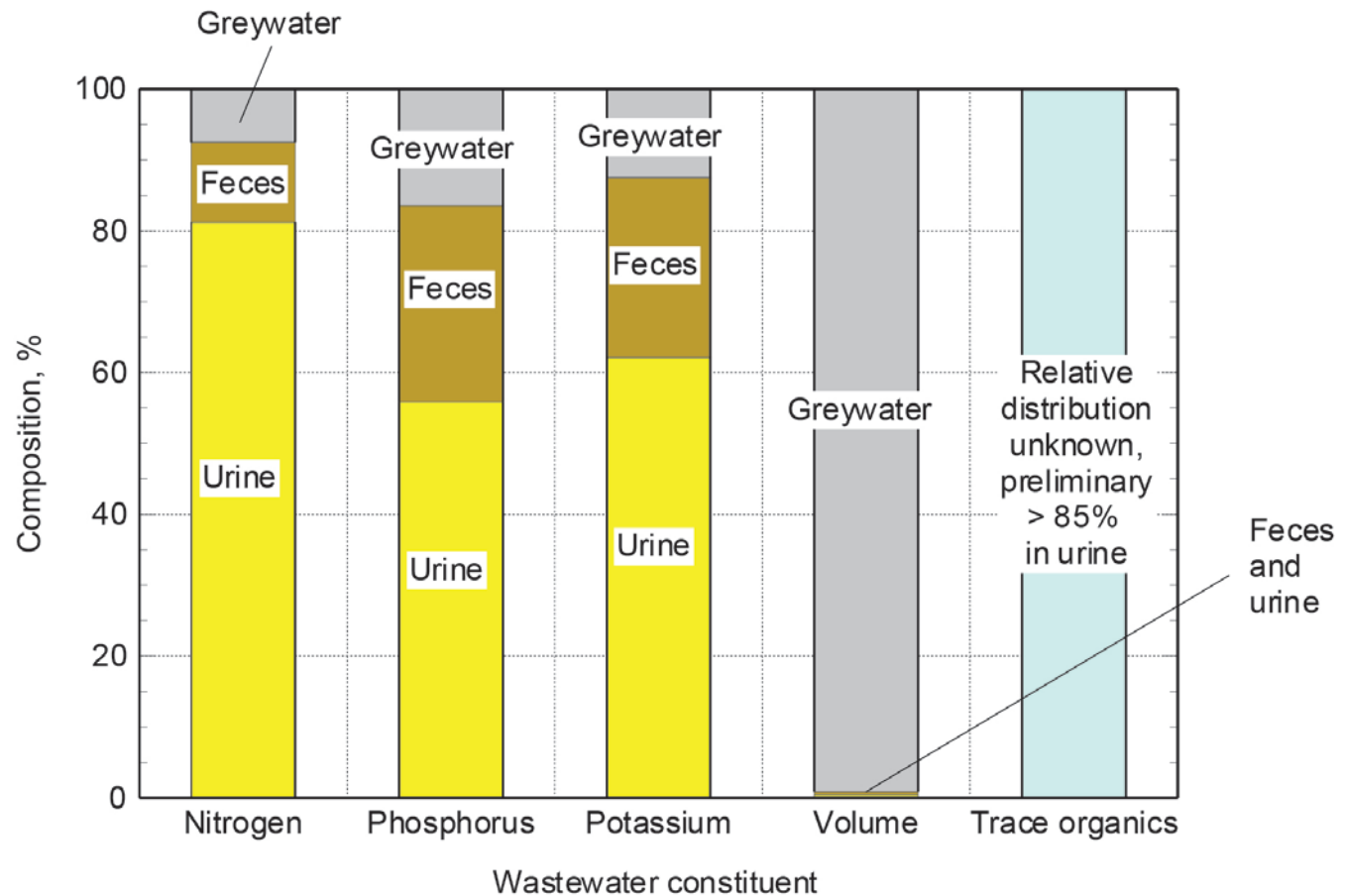
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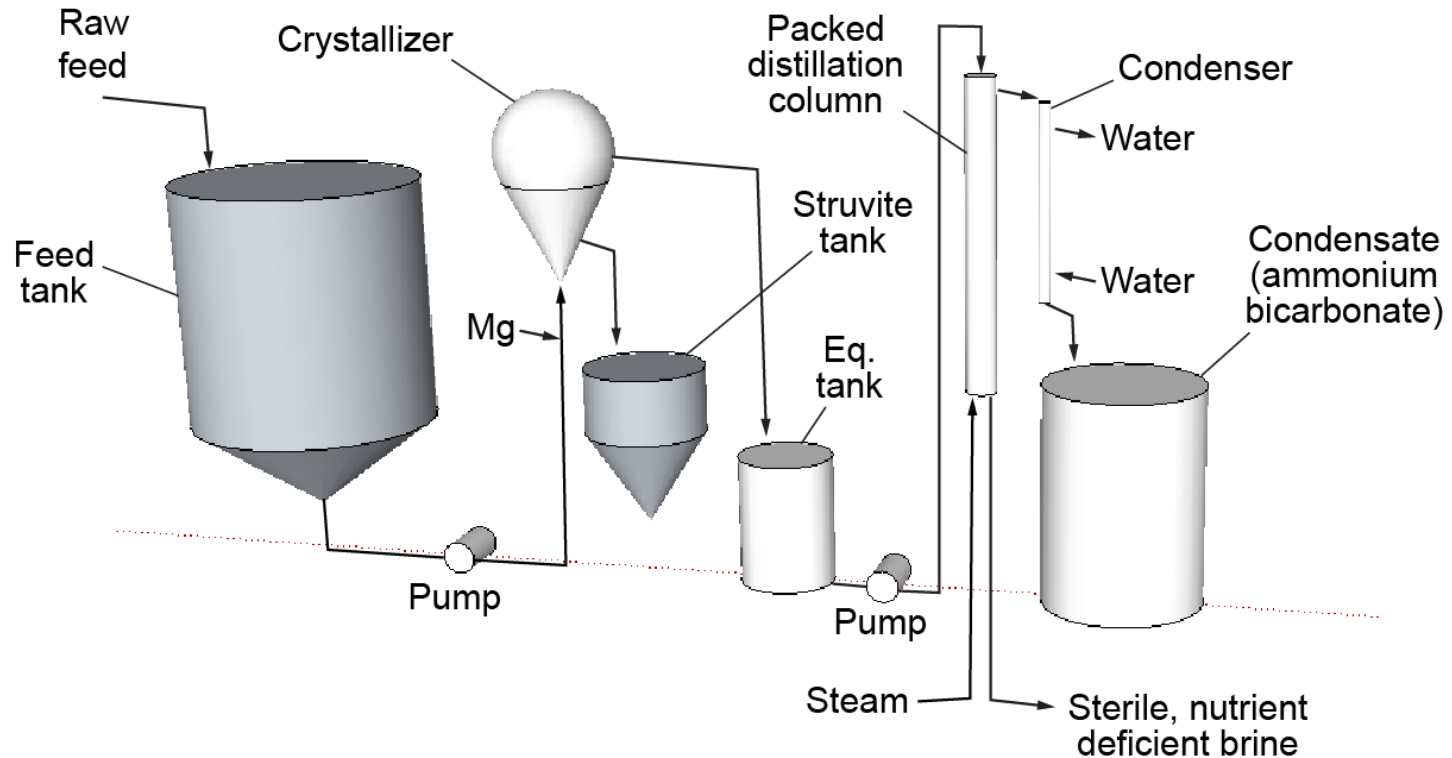
# ***URINE SEPARATION AND NUTRIENT RECOVERY***

# ***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)***

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# URINE SEPARATION FACILITY AT MICROBREWERY, DAVIS, CALIFORNIA



**UC DAVIS Sustainable Fertilizer Recovery from Urine**  
 JUSTUS HAZARD, MARCO LIVERINO, PH.D., PE, AND RUS ADAMS, PE  
 University of California, Davis  
 Advanced Environmental Methods LLC

**Problems with Urine**

**Eutrophication**  
 Urine is a nutrient-rich liquid that contains high concentrations of nitrogen and phosphorus. When urine is flushed into the sewer system, it can contribute to eutrophication, a process that can lead to oxygen depletion and the death of aquatic life.

**Groundwater Contamination**  
 Urine can seep into the ground and contaminate groundwater, which is a source of drinking water for many communities.

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

**Alternative uses for Urine**

**Fertilizer**  
 Urine is a natural fertilizer that can be used to grow a variety of crops. It is rich in nitrogen and phosphorus, which are essential nutrients for plant growth. Urine can be used to fertilize lawns, gardens, and agricultural fields.

**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.**

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

**Goals of the project include:**

- Reduce the nutrient loading to wastewater treatment facilities
- Save energy and chemicals by using fertilizer production
- Improve design and control strategies for decentralized treatment of urine
- Support the developing green building movement

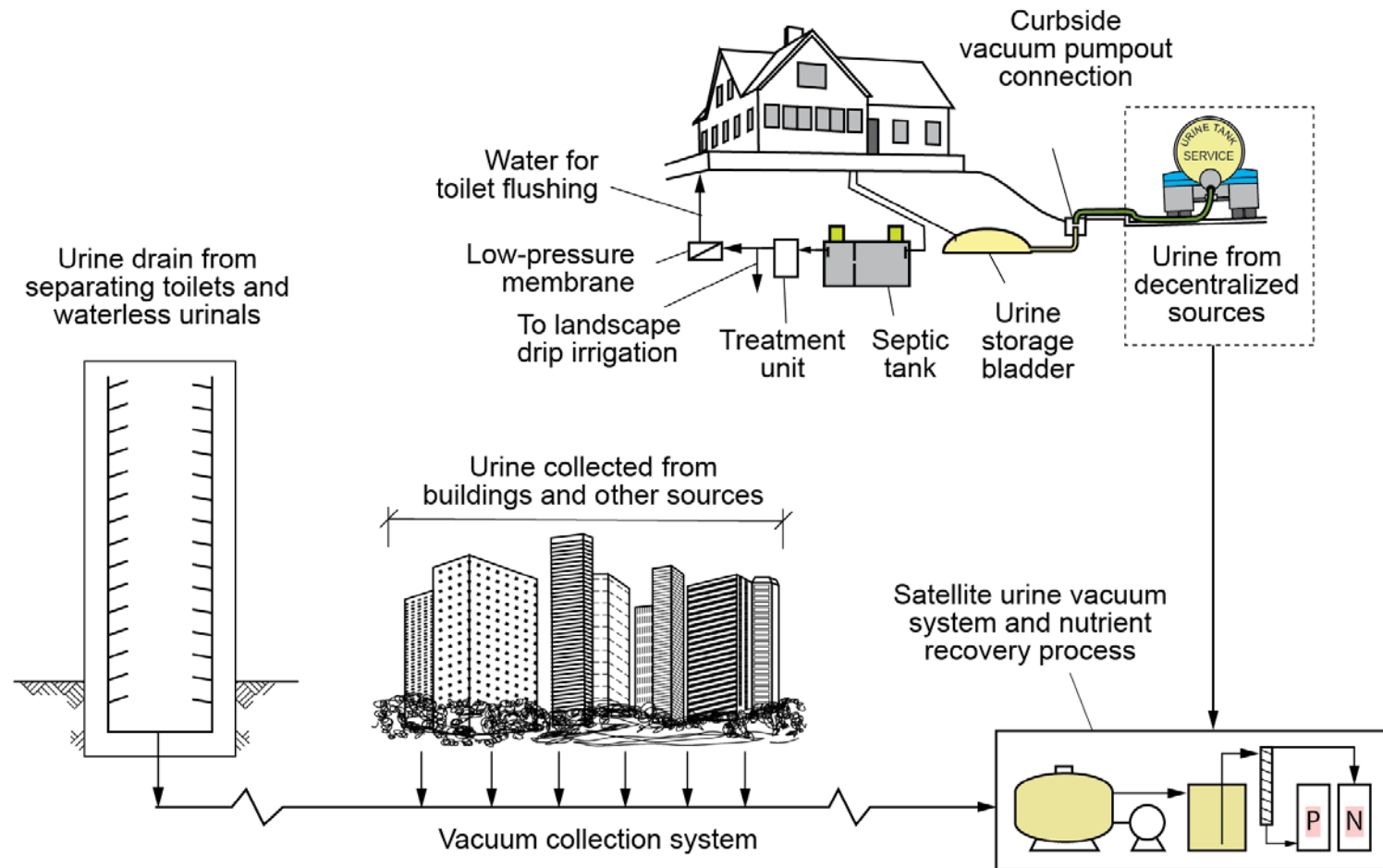
**UC Davis Prototype**

**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



## ***CLOSING THOUGHTS***

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- 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***