Municipal Wastewater Treatment: A Review of Treatment Technologies

Water Resources Division

Department of Environment and Conservation

Province of Newfoundland and Labrador

Outline of Presentation

- Municipal Wastewater
- Wastewater Collection Systems
- Wastewater Treatment Methods
  - Off-site Systems - Centralized Systems
  - On-site Systems
- New and Innovative Technologies
- Emerging Issues and Challenges
- Conclusions: Q&A

Municipal Wastewater

Municipal Sanitary Wastewater

Sanitary domestic wastewater discharged from residences and from commercial, institutional, industrial and similar facilities in the municipality. The general term “wastewater” also includes surface and groundwater infiltration. This discussion does not include combined, storm, or industrial/commercial process water.

How Much Sewage is Water?

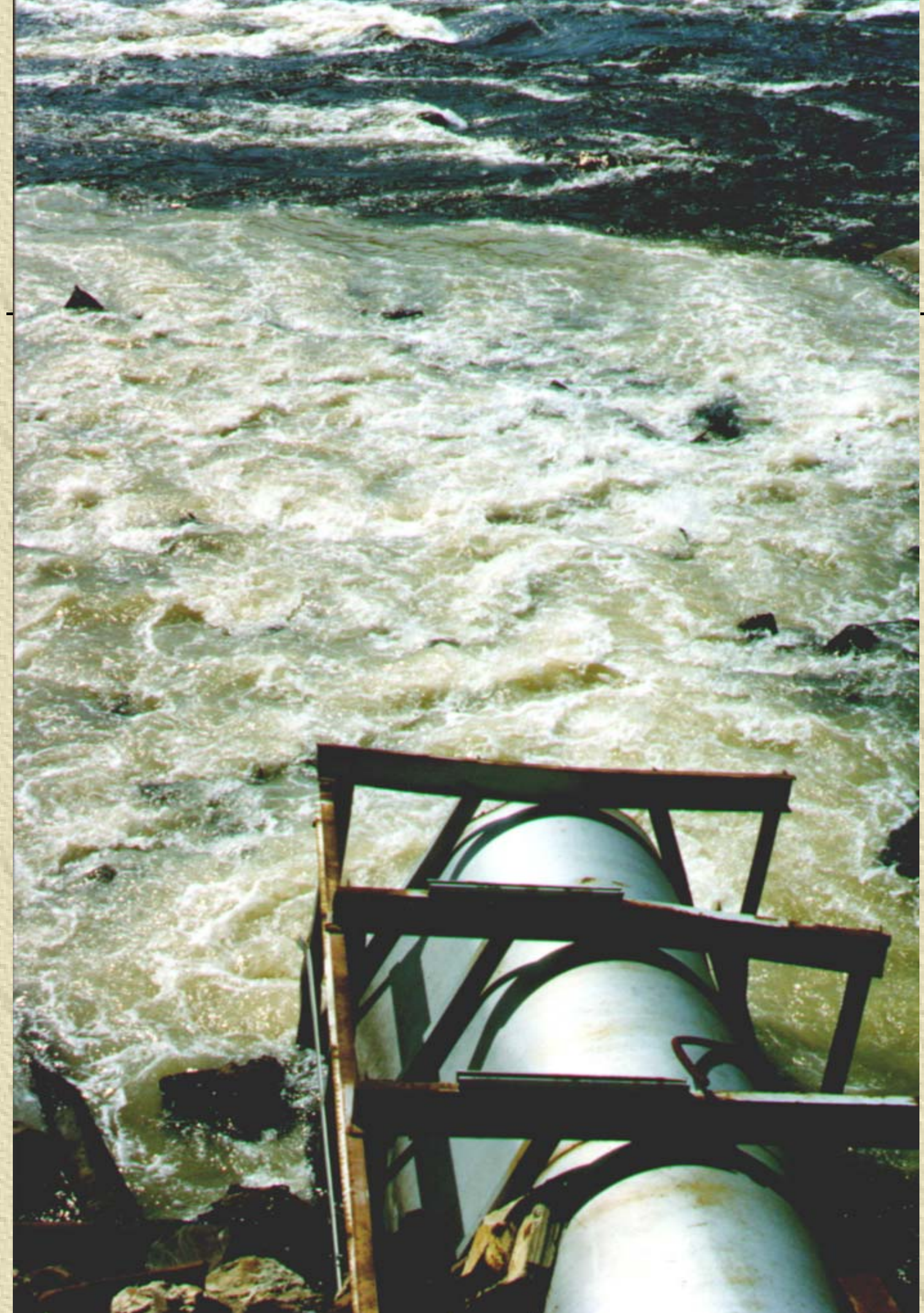
Normal domestic sewage will average less than 0.1% total solids in soft water regions.

J. S. Salvato “Environmental Engineering and Sanitation”

or

99.9% domestic sewage is water


Ivory
Snow



Designed Treatment

Nature’s Treatment

What is Wastewater Treatment?

Designed Wastewater Treatment Technology is an attempt to accomplish in less time and space what the environment does naturally. Adequate treatment will reduce public exposure, minimize public health risk, promote environmental protection by minimizing environmental impacts, and promote economic development.

Outfall to Marine Environment

Nature's Dilution/Dispersion Forces


2002 09 04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Municipal Wastewater

Main Constituents

- Physical Properties
  - Colour, odour, solids, temperature
- Chemical Constituents
  - Organic, inorganic, gases
- Biological Constituents
  - Animal, plants, bacteria, viruses, protozoa

Municipal Wastewater

Common Contaminants of Concern in Wastewater

- Suspended solids
- Biodegradable organics
- Pathogens
- Nutrients
- Priority pollutants (CEPA Toxins List)
- Refractory organics (surfactants, phenols, agricultural pesticides, etc.)
- Heavy metals
- Dissolved inorganics
- Pharmaceuticals
- Radiological

Municipal Wastewater Characterization

Contaminants	Unit	Weak	Medium	Strong
Solids, total (TS)	mg/L	350	720	1200
Dissolved, total (TDS)	mg/L	250	500	850
Fixed	mg/L	145	300	525
Volatile	mg/L	105	200	325
Suspended solids (SS)	mg/L	100	220	350
Fixed	mg/L	20	55	75
Volatile	mg/L	80	165	275
Settleable solids	mg/L	5	10	20
BOD_5, 20^{o}C	mg/L	110	220	400
Total organic carbon (TOC)	mg/L	80	160	290

Municipal Wastewater Characterization (cont'd)

Contaminants	**Unit**	**Weak**	**Medium**	**Strong**
Chemical oxygen demand (COD)	mg/L	250	500	1000
Nitrogen (total as N)	mg/L	20	40	85
Organic	mg/L	8	15	35
Free ammonia	mg/L	12	25	50
Nitrites	mg/L	0	0	0
Nitrates	mg/L	0	0	0
Phosphorus (total as P)	mg/L	4	8	15
Organics	mg/L	1	3	5
Inorganics	mg/L	3	5	10

Solids in Wastewater

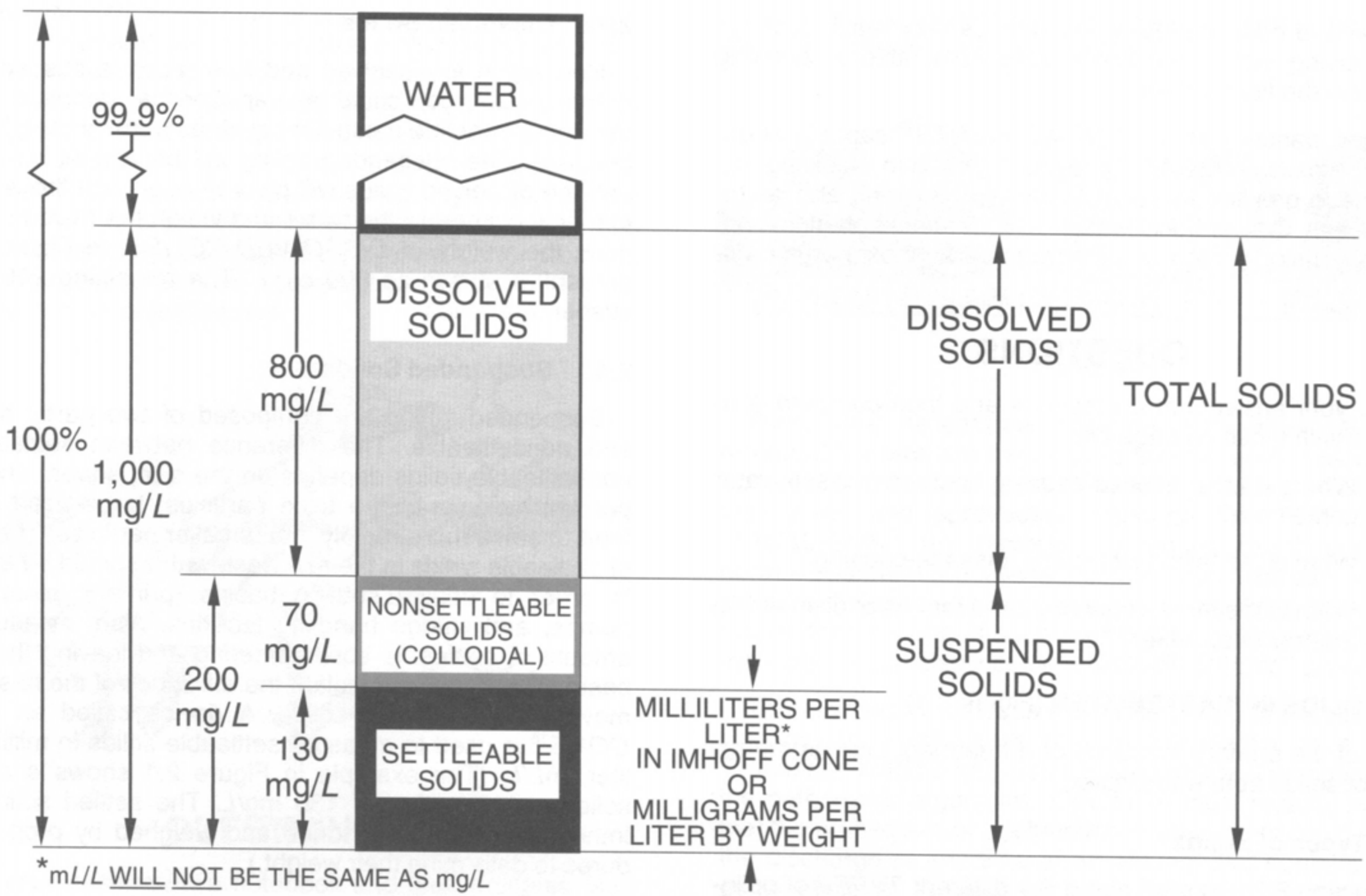


Fig. 2.1 Typical composition of solids in raw wastewater (floatable solids not shown)

Municipal Wastewater Characterization (cont'd)

Contaminants	**Unit**	**Weak**	**Medium**	**Strong**
Chlorides[a]	mg/L	30	50	100
Sulfate[a]	mg/L	20	30	50
Alkalinity (as $CaCO^3$)	mg/L	50	100	200
Grease	mg/L	50	100	150
Total coliform	no./ 100 ml	10^6-10^7	10^7-10^8	10^8-10^9
Volatile organic compounds (VOCs)	µg/L	<100	100-400	>400

[a]Values should be increased by amount present in domestic water supply.

Municipal Wastewater Sources

- Domestic
- Residential
- Commercial
- Institutional
- Industrial

Municipal Wastewater Discharge

Residential Source	**Unit**	**Flow (L/unit/d)**
High-rise apartment	Person	190
Low-rise apartment	Person	250
Individual Residence:		
Typical home	Person	265
Better home	Person	305
Luxury home	Person	360
Older home	Person	170
Summer cottage	Person	155
Trailer park	Person	155

Municipal Wastewater Discharge (cont’d)

Typical distribution of residential interior water use:

USE	**% of Total**
Baths	8.9
Dishwashers	3.1
Faucets	11.7
Showers	21.2
Toilets	28.4
Toilet Leakage	5.5
Washing Machines	21.2
TOTAL	100.0

Municipal Wastewater Discharge (cont’d)

Commercial Source	Unit	Flow (L/unit/d)
Airport	Passenger	45
Bar	Customer	12
Department store	Toilet Room	1900
Hotel	Guest	182
Laundry	Machine	2100
Office	Employee	50
Restaurant	Meal	12
Shopping center:	Employee	38
	Parking space	8

Municipal Wastewater Discharge (cont'd)

Institutional Source	**Unit**	**Flow (L/unit/d)**
Hospital, medical	Bed	625
Hospital, mental	Bed	380
Prison	Inmate	435
Rest home	Resident	322
School, day:		
With cafeteria, gym, showers	Student	95
With cafeteria only	Student	58
Without cafeteria and gym	Student	42
School, boarding	Student	285

Design Flow Guidelines for Municipal Systems

	Average Design Flow (L/capita/day)	Peaking Factor using the Harmon Formula
Wastewater Treatment System / Collection System	450 (dry weather)	1+(14/(4+P)^0.5)) or 5/(P^0.2) note: P = population/1000

Sewage Collection Systems

- Private homes
- Cluster system
- Centralized collection system

Wastewater Treatment Methods

- Centralized Systems / Off-site Systems
- On-site Systems

Centralized Systems / Off-Site Systems – Pretreatment

- Bar Racks and Screens
- Communitors / Grinders
- Grit Chambers / Removal

Bar Screens (Screening Devices)

- Bar Racks
  - Composed of parallel bars or rods with opening greater than 15mm.
  - Used for protection of pumps, valves, pipelines, etc.
- Screens
  - Composed of perforated plates, wedge wire elements, and wire cloth with openings less than 15mm.
  - Its application ranges from primary treatment to removal of residual suspended solids from biological treatment processes.

Bar Screens (Screening Devices)

Type of Screening Device	**Size Classification**	**Application**
Bar Rack	Coarse	Pretreatment
Screening:		
Inclined (fixed)	Medium	Primary Treatment
Inclined (rotary)	Coarse	Pretreatment
Drum (rotary)	Coarse	Pretreatment
	Medium	Primary Treatment
	Fine	Removal of residual secondary suspended solids
Rotary Disk	Medium	Primary Treatment
	Fine	Primary Treatment
Centrifugal	Fine	Primary Treatment

Communitors / Grinders

OPERATING PRINCIPLES

- Used as an alternative to coarse screening.
- Used to grind up coarse material without removing from the flow.
- Types of communitors:
  - Vertical revolving-drum screen.
  - Stationary semicircular cutting disks.
  - Unit containing two large-diameter vertical rotating shafts equipped with cutting blades.
  - Unit containing a conical-shaped screen grid, the axis of which is located parallel to the channel flow.

Communitors / Grinders

DESIGN CRITERIA

- May be preceded by grit chambers.
- Should be constructed with a bypass arrangement so that manual bar screen is used in case flowrates exceed the capacity of the communitor.
- Stop gates and provisions for draining should be included into design.
- Should be equipped with rock traps upstream.
- Headloss through communitor ranges from 0.3m – 0.9m.
- The capacity rating should be decreased by 20 – 25% to account for partial clogging due to wastewater flows instead of clean water flows.

Communitors / Grinders

Advantages

- Reduced coarse material to fine particles that are easier to handle downstream.

Disadvantages

- Returns material to the wastewater flow.
- Returned material can cause problems downstream if flow is agitated.

In Stream Grinders

Grit Chambers / Removal

OPERATING PRINCIPLES

- Grit chambers are provided to:
  - Protect moving mechanical equipment from abrasion and accompanying abnormal wear.
  - Reduce formation of heavy deposits in pipelines, channels, and conduits.
  - Reduce the frequency of digester cleaning caused by excessive accumulation of grit.

Grit Chambers / Removal

DESIGN CRITERIA

- Commonly based on removal of specific gravity of 2.65 and water temperature of 15.5^{o}C.
- There are three major types of grit chambers:
  - Horizontal-flow Grit Chambers
  - Aerated Grit Chambers
  - Vortex-type Grit Chambers

Grit Chambers / Removal

Horiz-Flow Grit Chamber	**Range**	**Typ**
Detention Time, seconds	45-90	60
Horizontal Velocity, m/min	0.2-0.4	0.3
Settling Velocity for removal of:		
65-mesh material, m/min	1.0-1.3	1.2
100-mesh material, m/min	0.6-0.9	0.8
Headloss in control section (% of depth in channel)	30-40	36
Allowance for inlet and outlet turbulence	$2D_m$- 0.5L	

D_m=maximum depth in chamber; L=theoretical length of chamber

Grit Chambers / Removal

Aerated Grit Chamber	Range	Typical
Detention Time @ Peak Flowrates, min	2-5	3
Dimensions:		
Depth, m	2.1-4.9	
Length, m	7.6-19.8	
Width, m	2.4-7.0	
Width-depth ratio	1:1-5:1	1.5:1
Length-width ratio	3:1-5:1	4:1
Air Supply, $m^3/min \cdot m$ of length	0.2-0.5	
Grit Quantities, $m^3/10^3 m^3$	0.003-0.2	0.015

Grit Chambers / Removal

Vortex-Type Grit Chamber	**Range**	**Typical**
Detention Time @ Average Flowrates, seconds		30
Dimensions:		
Diameter		
Upper Chamber, ft	1.2-7.3	
Lower Chamber, ft	0.9-1.8	
Height, ft	2.7- 4.9	
Removal rate, %		
50 mesh (0.3mm)		95+
70 mesh (0.24mm)		85+
100 mesh (0.15mm)		65+

Grit Chambers / Removal

ADVANTAGES

- Protect moving mechanical equipment from abrasion.
- Reduce formation of heavy deposits in pipelines, channels, etc.
- Reduce the frequency of digester cleaning caused by excessive accumulations of grit.

DISADVANTAGES

- Collection and removal of grit

Centralized Systems / Off-Site Systems – Primary Treatment

- Communal Septic Tank (discussed in detail in On-site Systems section)
- Primary Clarifier
- Vortex Separator
- Magnetite Clarification

Primary Clarifier

<u>OPERATING PRINCIPLES</u>

- The primary clarifier is a sedimentation tank that is used for grit removal.
- The clarifier will remove the readily settable solids and floating materials to decrease the suspended solids content.
- The clarifier provides removal for:
  - Settleable solids capable of forming sludge deposits in receiving waters.
  - Free oil and grease and other floating material.
  - A portion of the organic load is discharged to the receiving waters.

Primary Clarifier

DESIGN CRITERIA

Design Parameter	Range	Typical
Detention time, hr	1.5-2.5	2.0
Overflow rate, gal/ft^2·d	1,000	1,000
Average flow, gal/ft^2·d	1,300 – 2,000	1,500
Peak hourly flow, gal/ft^2·d	1,500 – 3,000	2,200
Weir Loading, gal/ft·d	1,500 – 6,200	3,100

Primary Clarifier

ADVANTAGES

- Detention time is relatively short.
- Produces sludge with a solids concentration that is easily handled and treated.

DISADVANTAGES

- Sludge removal is required on a relatively frequent or continuous basis.
- Sludge requires additional treatment prior to discharge.

Vortex Separator

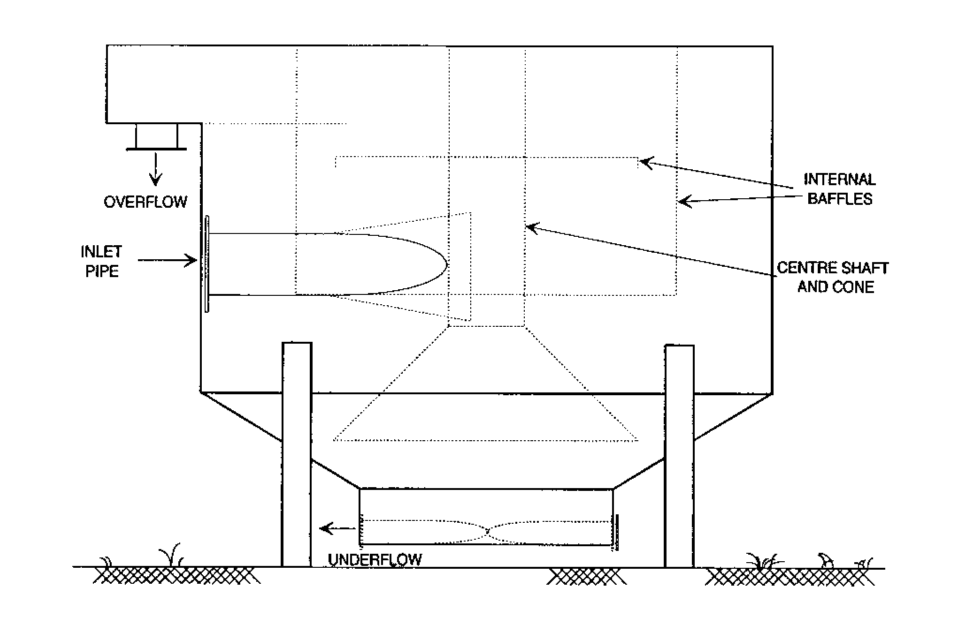
OPERATING PRINCIPLES

- Physical process which separates suspended solids from wastewater using gravity and hydraulic forces.
- Used primarily for grit removal and high rate treatment of combined sewer overflows.
- A vortex flow pattern is established in the tank which allows the settleable solids to move towards the center and bottom. The sludge is then removed with the underflow. The underflow requires additional treatment to remove the concentrated solids.

Vortex Separator

DESIGN CRITERIA

- Net efficiency of suspended solids removal is approximately 50% at a surface loading rate of 2m/hr.
- The removal efficiency decreases as the surface loading rate increases. The removal efficiency was negligible at a surface loading rate in excess of 10m/hr.



Vortex Separator

ADVANTAGES

- Use of hydraulic forces provides improved performance over the use of primary clarification.
- Flow through the separator can be entirely by gravity flow.
- Head loss is minimal.

DISADVANTAGES

- The concentrated underflow is discharged at a lower elevation than the underflow, and a pump may be required to lift the underflow to a sludge storage facility
- Sludge requires stabilization and disposal.

Magnetite Clarification

<u>OPERATING PRINCIPLES</u>

- Process of rapid clarification which utilizes finely divided particles of magnetite combined with an inorganic coagulant to aid in the rapid separation of colloidal and suspended solids.

Magnetite Clarification

DESIGN CRITERIA

Design Parameter	**Removal**	**Residual**
TSS	90%	30 mg/L
Oil and Grease	90%	6 mg/L
Phosphate	90%	
BOD	50%	
COD	50%	
Total Coliforms	3 logarithms	

Magnetite Clarification

ADVANTAGES

- Results in high quality wastewater within 15 minutes of treatment.
- The magnetite and coagulant are recovered and reused.

DISADVANTAGES

- Not recommended for flows less than 5ML/day.

Centralized Systems / Off-Site Systems – Secondary Treatment

- Soil-Based Systems
  - Absorption Fields (discussed in detail in On-site Systems section)
- Non Soil-Based Systems
  - Activated Sludge
  - Oxidation Ditch
  - Rotating Biological Contactors
  - Sequence Batch Reactors
- Lagoons
  - Aerated lagoon
  - Facultative lagoon
  - Anaerobic lagoon
  - New Hamburg process
- Disinfection (Chlorine, Ultraviolet and Ozone)

Non Soil-Based Systems - Activated Sludge

OPERATING PRINCIPLES

- Involves the production of an activated mass of microorganisms capable of stabilizing a waste aerobically. There are many types of activated sludge process but they are all fundamentally the same.

Non Soil-Based Systems - Activated Sludge (cont’d)

OPERATING PRINCIPLES

- The primary effluent flows into an aeration tank where oxygen is added typically through one of two methods:
  - bubbling air through diffusers located at the bottom of the tank or;
  - by agitating the liquid surface using mechanical or turbine aerators.

Non Soil-Based Systems - Activated Sludge (cont’d)

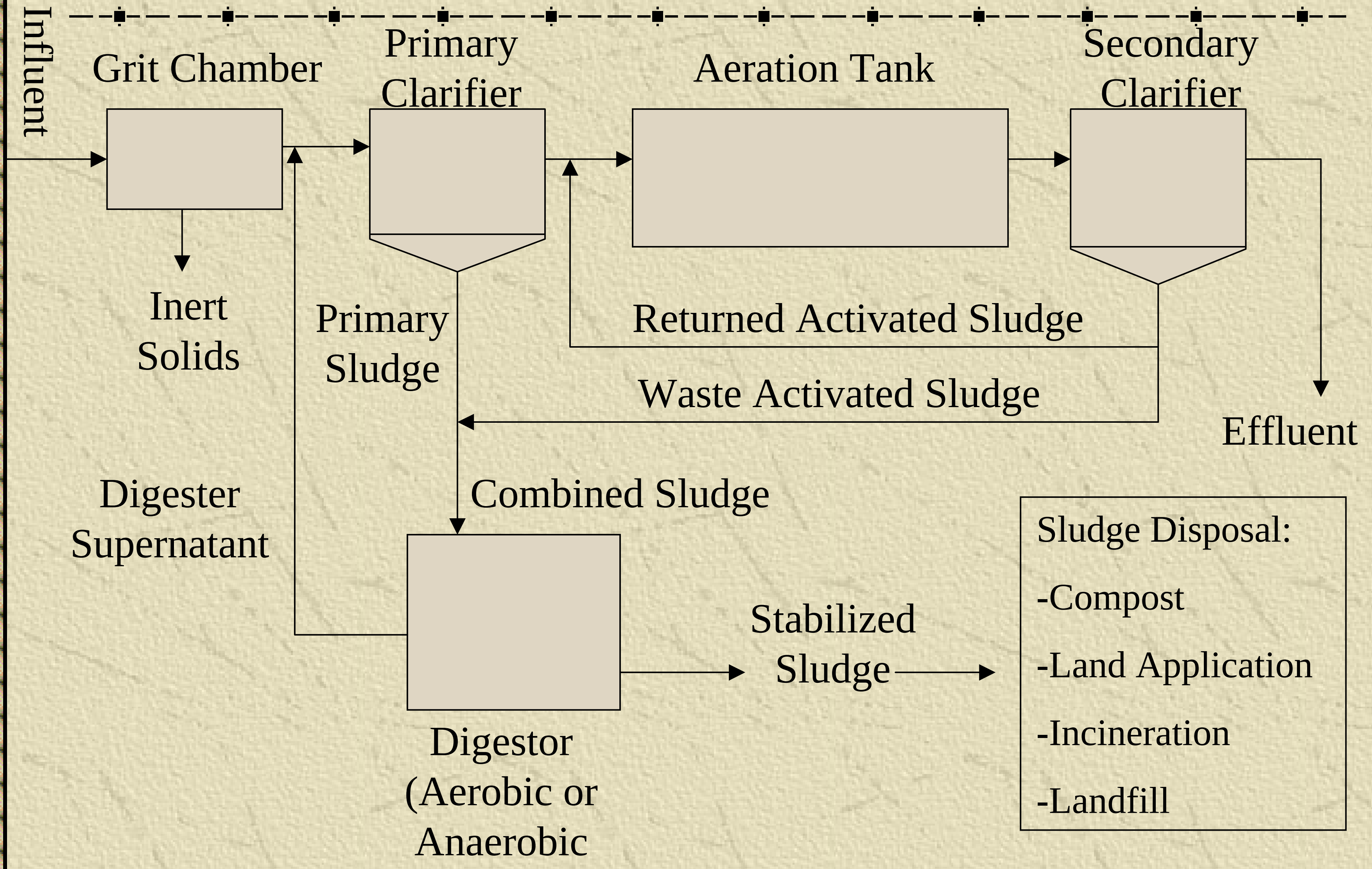
OPERATING PRINCIPLES

- The primary effluent is combined with the returned activated sludge and results in a “mixed liquor” which consists of wastewater, microorganisms and solids. This liquid converts the colloidal and soluble organic matter into new microbes, stable compounds, carbon dioxide and water. It is then send to a secondary clarifier to settle the solids.

Mechanical Aerator

Aeration Chamber – Lakeshore STP

Non Soil-Based Systems - Activated Sludge



Secondary Clarifier - Lakeshore

Non Soil-Based Systems - Activated Sludge

DESIGN CRITERIA

- Considerations must be given to:
  - Selection of the reactor type
  - Loading criteria
  - Sludge production
  - Oxygen requirements and transfer
  - Nutrient requirements
  - Control of filamentous organisms
  - Effluent characteristics
- Greater than 85% BOD and TSS removal is achieved.

30 minute settling test

Non Soil-Based Systems - Activated Sludge

Design Parameter	**Conventional Plug Flow**	**Complete-mix**
θ_c, d	3 - 15	1 – 15
F/M, kg BOD_5 applied / kg MLVSS · d	0.2 - 0.5	0.2 - 1.0
Volumetric loading, kg BOD_5 / m^3 · d	0.32 - 0.64	0.80 - 1.92
MLSS, mg/L	1,000 - 3,000	1,000 - 6,500
V/Q, h	4 - 8	3 – 5
Q_r/Q	0.25-0.75	0.25-1.0

Non Soil-Based Systems - Activated Sludge

ADVANTAGES

- Suitable for a wide range of flows and a variety of applications.
- Process can be modified with additions to the design to suit a wide range of parameters of concern.

DISADVANTAGES

- Requires daily attendance to the biological process and maintenance to the equipment.
- Excavation is required because systems are typically below grade.
- Waste sludge requires stabilization and disposal.

Non Soil-Based Systems – Oxidation Ditch

OPERATION PRINCIPLES

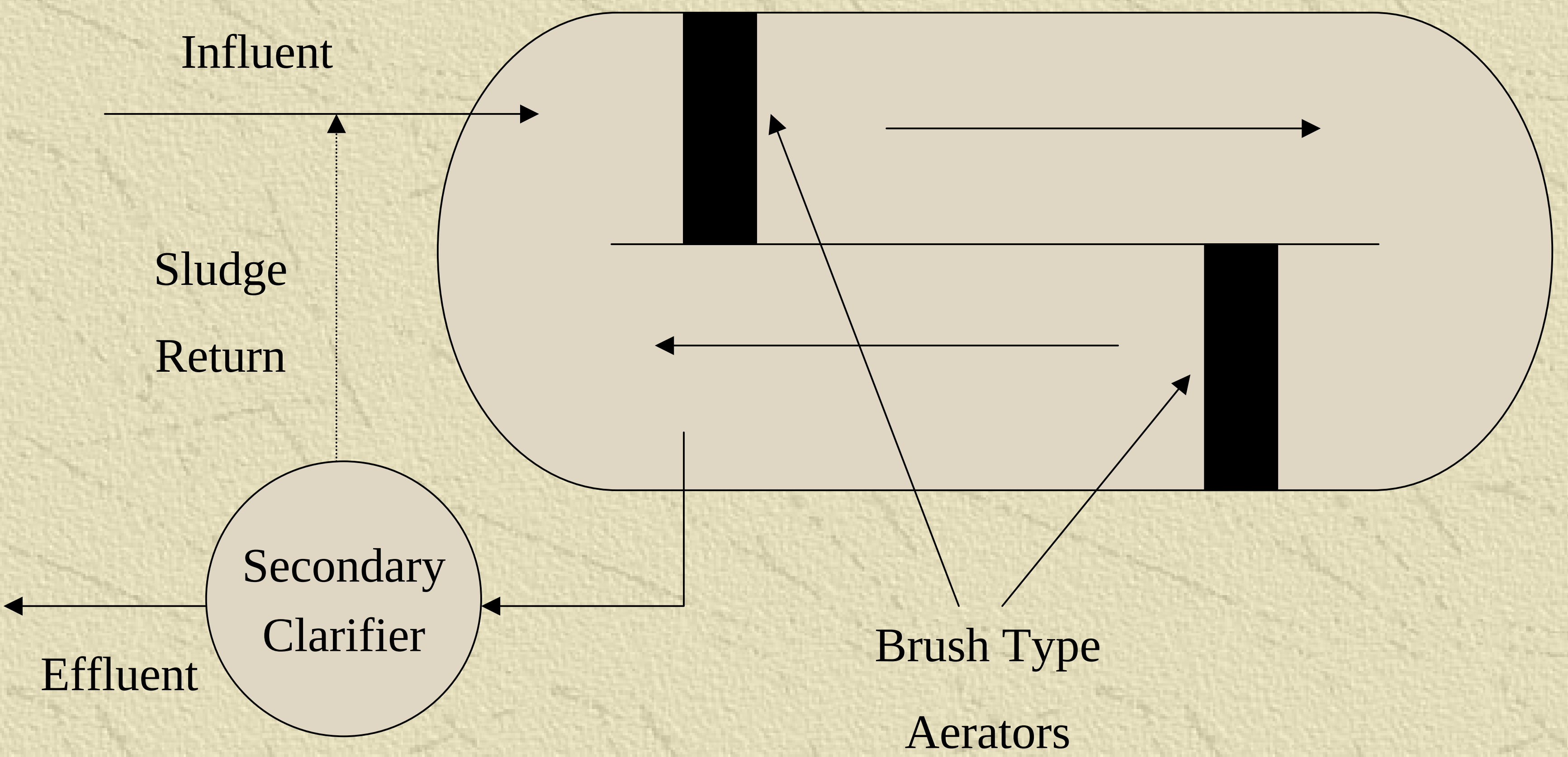
- Oxidation ditches are a type of suspended growth biological treatment process and are a modification of the activated sludge process.
- Consists of a ring- or oval-shaped channel and is equipped with mechanical aeration devices for aeration and circulation of fluids.

Non Soil-Based Systems – Oxidation Ditch (cont'd)

OPERATION PRINCIPLES

- BOD5 removal rates of approximately 90-95%.
- Suspended solids removal rates of approximately 90-95%.
- Ammonia nitrogen removal rates in the range of 40-80%.

Non Soil-Based Systems – Oxidation Ditch



Non Soil-Based Systems – Oxidation Ditch

DESIGN CRITERIA

Design Parameter	Typical Values
Depth, m	0.9 – 5.5
Flow rate, m/s	0.25 – 0.35
Hydraulic detention time, hrs	24
Solids retention time, days	20 - 30

Holyrood Oxidation Ditch

Non Soil-Based Systems – Oxidation Ditch

ADVANTAGES

- Suitable in a wide variety of small community applications.
- Sufficient for carbon (BOD) removal.
- Sufficient for suspended solids removal.

DISADVANTAGES

- Consideration to site constraints are required because ditches are typically below grade.
- Requires daily attendance to the biological process and maintenance to the equipment.

Non Soil-Based Systems – Rotating Biological Contactors

OPERATION PRINCIPLES

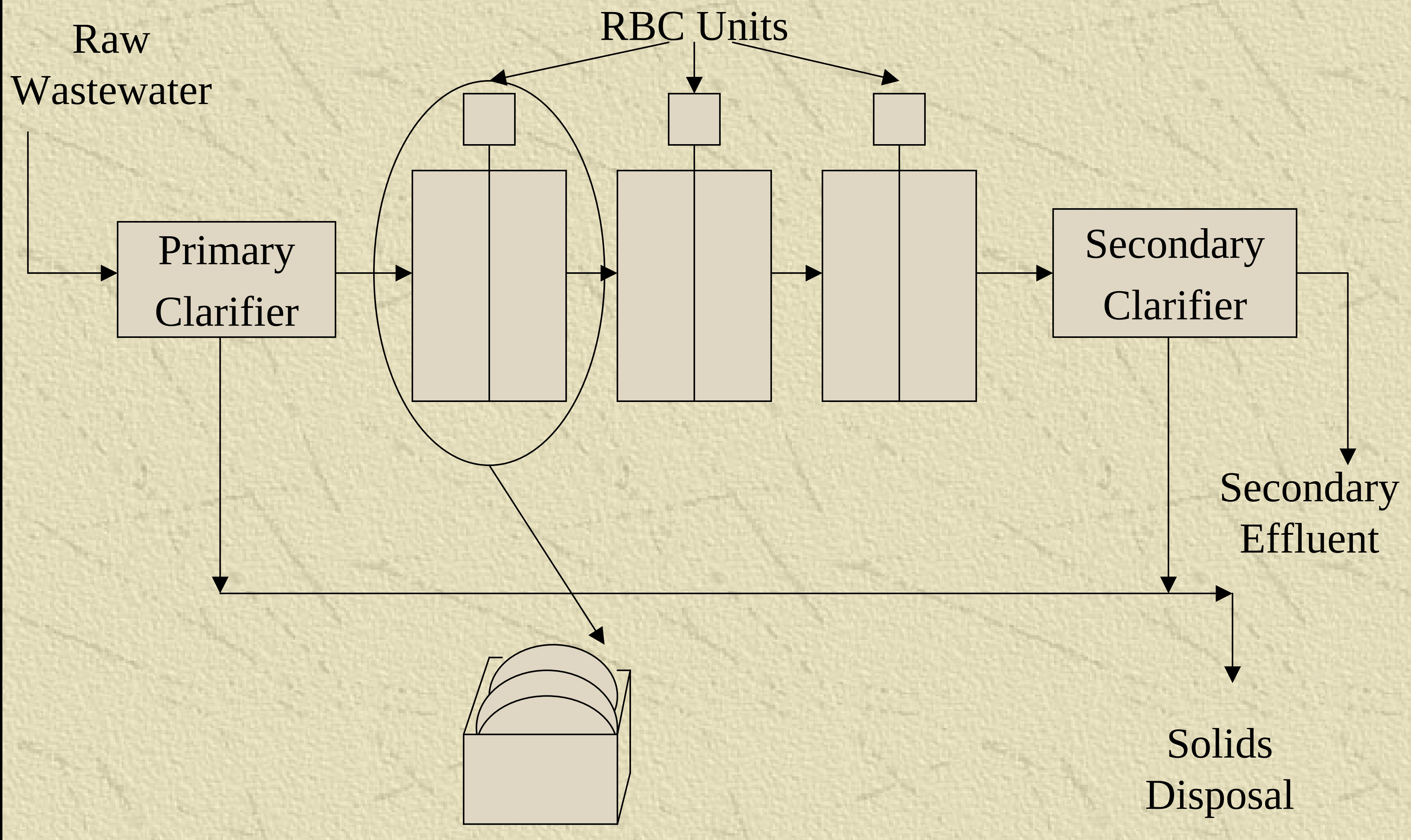
- Consists of a series of closely spaced circular disks of polystyrene or polyvinyl chloride. The disks are partially submerged in wastewater and rotated slowly through it.
- Biological growths become attached to the surfaces of the disks and eventually form a slime layer over the entire wetted surface area of the disks.

Non Soil-Based Systems – Rotating Biological Contactors (cont'd)

OPERATION PRINCIPLES

- The disk rotation alternately contacts the biomass with the organic material in the wastewater and then with the atmosphere for adsorption of oxygen. The rotation of the disks affects oxygen transfer and maintains the biomass in an aerobic condition.

Non Soil-Based Systems – Rotating Biological Contactors



Non Soil-Based Systems – Rotating Biological Contactors (RBC)

DESIGN CRITERIA FOR RBC UNITS

Design Parameter	Typical Values
Hydraulic loading, $m^3/m^2 \cdot d$	0.08- 0.16
Organic loading:	
kg SBOD5/$m^2 \cdot d$	0.004-0.01
kg TBOD5/$m^2 \cdot d$	0.01-0.02
Maximum loading on first stage:	
kg SBOD5/$m^2 \cdot d$	0.02-0.03
kg TBOD5/$m^2 \cdot d$	0.04-0.06
Hydraulic retention time, θ, h	0.7-1.5
Effluent BOD_5, mg/L	15-30

Non Soil-Based Systems – Rotating Biological Contactors

ADVANTAGES

- Successful handling of variations in organic and hydraulic loads
- Low installation and set-up costs
- Easily relocated
- Minimal maintenance
- Required small area
- Low energy costs

DISADVANTAGES

- Sludge handling from primary and secondary clarifiers requires stabilization and disposal.
- Required greater attention to removal of fats, oils and grease before water reaches disks
- Requires daily attendance to biological process and maintenance of equipment

Non Soil-Based Systems – Sequence Batch Reactors

<u>OPERATION PRINCIPLES</u>

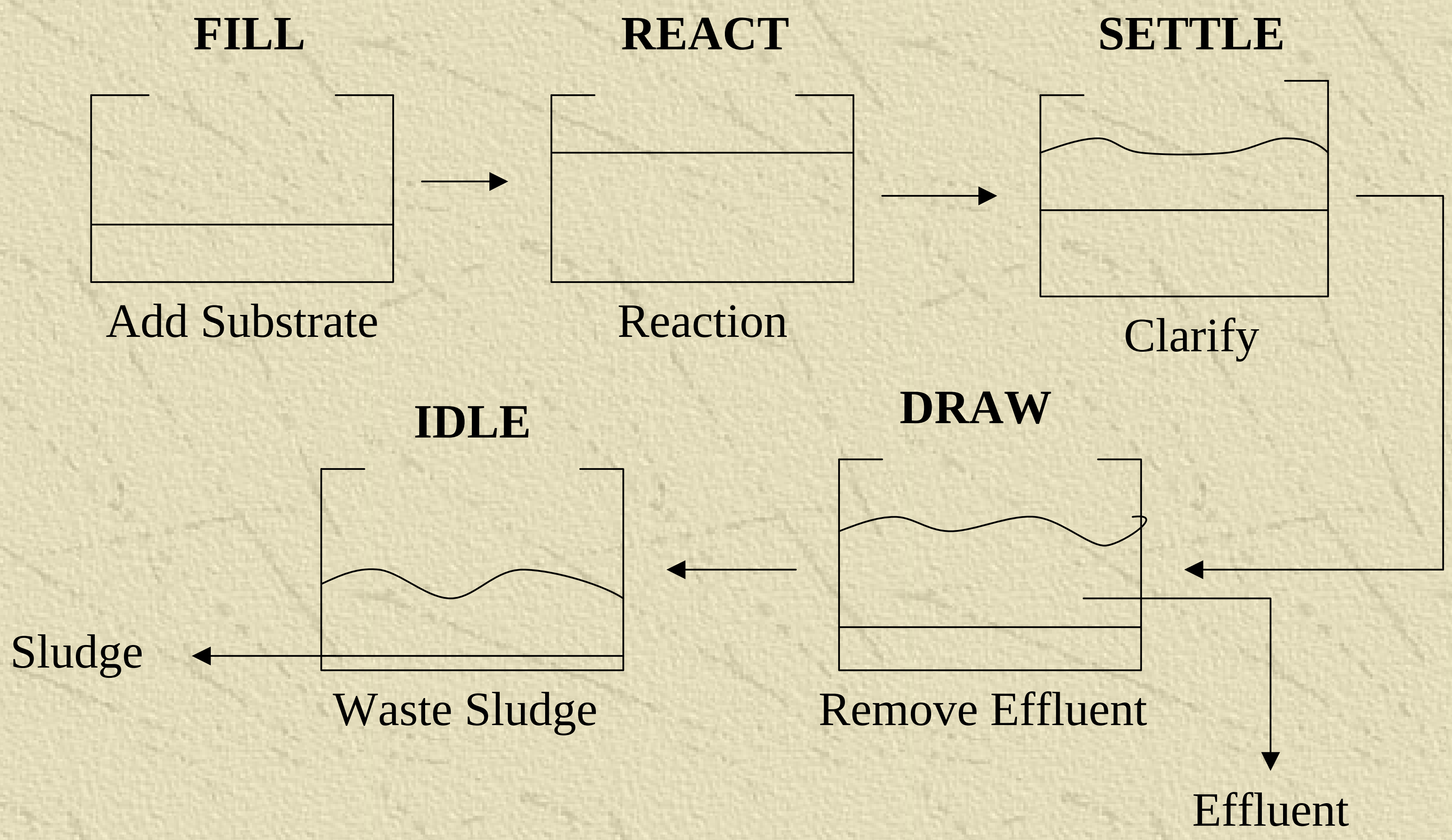
- Sequence Batch Reactors are a form of suspended growth, activated sludge process in which all operations take place in one reactor.
- The operations include fill, react, settle, draw and idle.

Non Soil-Based Systems – Sequence Batch Reactors (cont’d)

<u>OPERATION PRINCIPLES</u>

- **Fill** – wastewater enters the tank and mixes with the settled biological solids (sludge) from previous cycle. The tank is mixed and may be aerated.
- **React** – wastewater is subject to aeration and the reaction completed.
- **Settle** – aeration and mixing are stopped to allow the solids to settle.
- **Draw** – clarified treated water is decanted from the reactor.
- **Idle** – provide time for one reactor to complete its fill cycle before switching to another unit.

Non Soil-Based Systems – Sequence Batch Reactors



Non Soil-Based Systems – Sequence Batch Reactors

DESIGN CRITERIA

Design Parameter	**Typical Values**
F/M, kg BOD_5 applied/kg MLVSS·d	0.05-0.30
Volumetric loading, kg $BOD_5/m^3 \cdot d$	0.08-0.24
MLSS, mg/L	1500-5000[a]
V/Q, h	12-50

[a] MLSS varies depending on the portion of the operating cycle.

Non Soil-Based Systems – Sequence Batch Reactors

ADVANTAGES

- Simple and reliable.
- Suited for wide flow variations.
- Good, consistent effluent quality.
- Less operator attention than other mechanical systems.
- Improvements to hardware with technical advances.
- High operational flexibility.

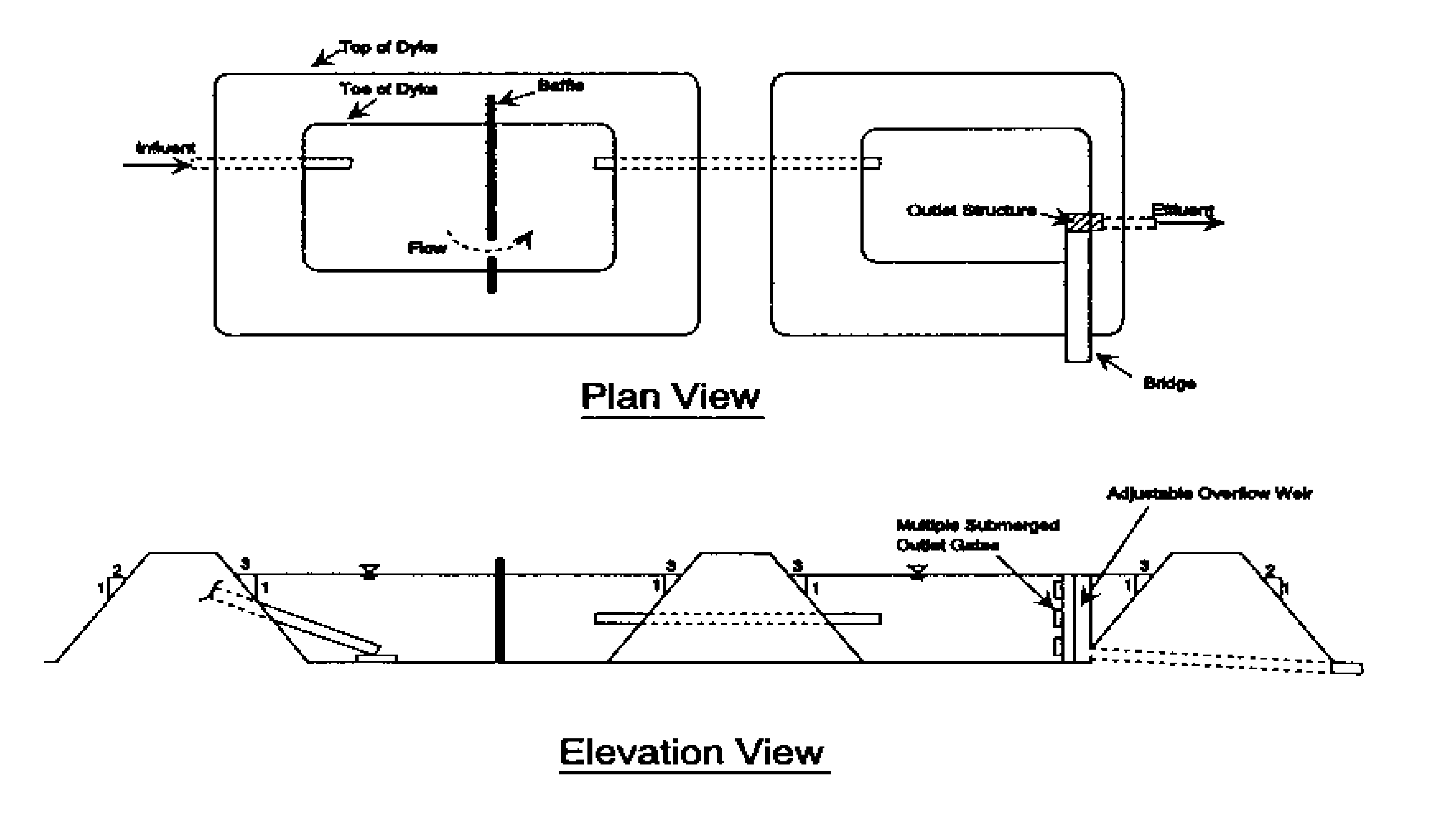
DISADVANTAGES

- Some problems with decant systems still exist.
- Reasonably skilled operator is required as well as regular inspections.

Lagoons

- Lagoons are designed, shallow earthen basin for the primary and secondary treatment of wastewater.
- It is operated hydraulically using a submerged outlet.
- There are three types of lagoons:
  - Facultative
  - Aerated
  - Anaerobic

Lagoons



Top of Dyke
Toe of Dyke
Baffle
Influent
Flow
Outlet Structure
Effluent
Bridge
Plan View
Adjustable Overflow Weir
Multiple Submerged
Outlet Gates
Elevation View

Lagoons - Aerated Lagoon

<u>OPERATION PRINCIPLES</u>

- Aerated lagoons use mechanical devices to provide oxygen transfer to the wastewater and incidental mixing.
- Aeration processes can be either mechanical surface aerators or subsurface diffused aerators.
- Usually only provides partial mixing to enable aerobic/anaerobic stratification to occur.
- A large fraction of the solids settle to the bottom of the lagoon and undergo anaerobic decomposition.

Lagoons - Aerated Lagoon

DESIGN CRITERIA

Design Parameter	Typical
Hydraulic retention time, days	10 or less / cell 21-30 (average)
Depth, m	1.2–3.0

Lagoons - Aerated Lagoon

ADVANTAGES

- Minimal operator skills requirement.
- Low capital cost.
- Many means of upgrading are available.
- Sludge disposal is only required at 10 to 20 year intervals.
- Low odours – can be located fairly close to residential areas.
- Disinfection often not required as a results of long retention time and effect of algae.

DISADVANTAGES

- Large land area requirements.
- Appropriate soil conditions are required.
- Have poorer performance in cold climates.
- Possible negative impacts to groundwater if leakage occurs.
- Algae adds to TSS and TBOD.

Lagoons - Facultative Lagoon

OPERATION PRINCIPLES

- Oxygen is maintained in the upper layer by the presence of algae and surface reaeration. Wind and waves also act as passive aeration.
- Aerobic bacteria utilize the dissolved oxygen to stabilize organic material in the upper layer of water.
- Anaerobic fermentation is the dominant activity in the bottom layer of the lagoon.
- The anaerobic reaction rates are significantly reduced during the winter and early spring months in cold climates.

Lagoons - Facultative Lagoon

DESIGN CRITERIA

Design Parameter	Typical Values
Hydraulic retention time, days	20-180 200 (northern climates)
Depth, m	1.2-1.8

Lagoons - Facultative Lagoon

ADVANTAGES

- Minimal operator skills requirement.
- Low capital cost.
- Many means of upgrading are available.
- Sludge disposal is only required at 10 to 20 year intervals

DISADVANTAGES

- Large land area requirements.
- Appropriate soil conditions are required.
- Have poorer performance in cold climates.
- Possible negative impacts to groundwater if leakage occurs.
- Unpleasant odours mean lagoon must be located >1km from residential areas.

Lagoons – Anaerobic Lagoon

OPERATION PRINCIPLES

- Wastewater enters near the center of the bottom of the lagoon where mixing with the active biomass in the sludge blanket occurs.
- The outlet is submerged below the liquid surface.
- Excess sludge is washed out with the effluent.
- The effluent is usually discharged to another treatment process for further treatment.

Lagoons – Anaerobic Lagoon

DESIGN CRITERIA

- Depth of sludge blanket = 2m

Lagoons – Anaerobic Lagoon

ADVANTAGES

- Capable of providing treatment of high strength wastewaters
- Resistant to shock loads.
- Minimal operator skills requirement.
- Low capital cost.
- Many means of upgrading are available.

DISADVANTAGES

- Large land area requirements.
- Appropriate soil conditions are required.
- Have poorer performance in cold climates.
- Possible negative impacts to groundwater if leakage occurs.
- Unpleasant odours mean lagoon must be located >1km from residential areas.

Disinfection

- Disinfection refers to the selective destruction of disease-causing organisms. All the organisms are not destroyed during the process.
- The most common disinfection process are:
  - Chlorination/Dechlorination
  - Ultraviolet
  - Ozone
- Disinfection of wastewater is not always necessary; the decision is based on site specifics and considers whether the receiving water will be negatively impacted by pathogens.

Disinfection - Chlorine

- The most common chlorine compounds used in wastewater treatment plants are chlorine gas, calcium hypochlorite, sodium hypochlorite and chlorine dioxide.

Disinfection - Ultraviolet

- There is no chemical agent employed for ultraviolet disinfection and consequently is considered the safest alternative disinfection system.
- The use of UV radiation can be considered fully-proven at present.

Disinfection - Ozone

- The ozone is generally diffused from the bottom of the chamber in fine bubbles and provide mixing of the wastewater as well as achieving maximum ozone transfer and utilization.
- The off-gasses from the contact chamber must be treated to destroy any remaining ozone as it is an extremely irritating and toxic gas.

Centralized Systems / Off-Site Systems – Tertiary Treatment

- Polishing
  - Rapid sand filter
- Phosphorus Removal
  - Chemical precipitation
  - Algae-based system
- Ammonia Removal
  - Ion exchange
  - Algae-based system
- Polishing and Nutrient Removal
  - Slow sand filter
  - Constructed wetlands
  - Aquatic systems (duckweed)

Polishing – Rapid Sand Filter

OPERATION PRINCIPLES

- Comprises of a filter bed of granular material within a tank or vessel.
- The removal of suspended solids is accomplished by a complex process including one or more removal mechanisms, such as, straining, interception, impaction, sedimentation and adsorption.
- There are numerous variations in the type and size of filter media used, the operating mode of the filter and the method of backwash.

Polishing – Rapid Sand Filter

DESIGN CRITERIA

- Depth of the bed is typically of the order of one meter.

Polishing – Rapid Sand Filter

ADVANTAGES

- Long established conventional treatment system.
- Achieves high quality effluent that can be discharged to the receiving environment.
- Operate at rates many time faster than slow sand filters.

DISADVANTAGES

- Requires backwashing for cleaning filters.
- Reasonably skilled operator is required.

Phosphorus Removal - Chemical Precipitation

OPERATION PRINCIPLES

- Phosphorus can be removed using chemical precipitation with various multivalent metal ions.
- The metal ions react with the soluble phosphate to produce an insoluble or particulate, metal-phosphate which is then removed from the wastewater by sedimentation in a primary or secondary clarifier.
- Typical chemicals used are aluminum salts such as alum or iron salts such as ferrous or ferric chloride.

Phosphorus Removal - Chemical Precipitation

DESIGN CRITERIA

Recommended surface-loading rates for sedimentation tanks for various chemical suspensions ($m^3/m^2 \cdot d$):

Suspension	Range	Peak Flow
Alum Floc[a]	25-50	50
Iron Floc[a]	25-50	50
Lime Floc[a]	30-60	60
Untreated Wastewater	25-50	50

[a] Mixed with settleable suspended solids in the untreated wastewater and colloidal or other suspended solids swept out by the floc.

Phosphorus Removal - Chemical Precipitation

ADVANTAGES

- Very low phosphorus concentrations in effluent.
- Efficient metal use.

DISADVANTAGES

- High capital cost.
- High metal leakage.

Phosphorus Removal - Algae-based System

OPERATION PRINCIPLES

- Involves culturing a specific pure strain of algae in a reactor using treated wastewater as the source of nutrients.
- The algae utilize the nutrients, reducing the concentrations of N and P to low levels.
- The algae must be seperated from the wastewater, by sedimentation for example, and the purified effluent discharged.

Phosphorus Removal - Algae-based System

DESIGN CRITERIA

- No established design criteria is in place for this technology in NL as yet.
- Proposals would require review by a Technical Review Committee.

Phosphorus Removal - Algae-based System

ADVANTAGES

- Process is relatively straight-forward.

DISADVANTAGES

- Not likely to be suitable for NL due to the complexity of the requirements of the process.

Ammonia Removal - Algae-based System

OPERATION PRINCIPLES

- Same process as algae-based system to remove phosphorus.

Ammonia Removal - Ion Exchange

OPERATION PRINCIPLES

- Ammonia ions are displaced from an insoluble exchange material by ions of a different species in solution.
- It may be operated in either a batch or a continuous mode. In a batch process, the resin is simply stirred with the water to be treated in a reactor until the reaction is complete. In a continuous process, the exchange material is placed in a bed or a packed column, and the water to be treated is passed through it.

Ammonia Removal - Ion Exchange

DESIGN CRITERIA

- As with Algae removal, this would require review by a Technical Review Committee.

Ammonia Removal - Ion Exchange

ADVANTAGES

- There is no process waste containing ammonia for which ultimate disposal must be provided.

DISADVANTAGES

- Compared to other technologies, this process is quite complex.
- Not likely to be suitable for Newfoundland conditions.

Polishing and Nutrient Removal - Slow Sand Filter

OPERATION PRINCIPLES

- Consists of one or more beds of granular material, typically graded sand, underlain with collection drains imbedded in gravel.
- Pretreated wastewater is intermittently applied to the surface of the sand and allowed to percolate through the bed where it receives treatment.
- The percolate is collected by the underdrains, which remove it from the filter for further treatment or disposal.

Polishing and Nutrient Removal - Slow Sand Filter

DESIGN CRITERIA

Design Parameter	Buried	Open	Recirculating
Hydraulic loading (L/m^3/d)	40-60	50-100	120-200
Dosing frequency	2-4/d	1-4/d	5-10 min/30 min
Recirculation ratio	N/A	N/A	3:1 – 5:1
Media Specifications:			
Effective size (mm)	0.7-1.00	0.04-1.00	1.0-1.50
Uniformity coefficient	<4.0	<4.0	<4.0
Depth (m)	0.60-0.90	0.60-0.90	0.60-0.90

Polishing and Nutrient Removal - Slow Sand Filter

ADVANTAGES

- Used for both small communities and individual homes.
- Moderately inexpensive to construct.
- Low energy requirements.
- Does not require highly skilled personnel to operate.
- Can easily be expanded.

DISADVANTAGES

- Dependent on temperature.
- Typically, head required is greater than 1m.
- May have site constraints due to the construction below grade.

Polishing and Nutrient Removal - Constructed Wetlands

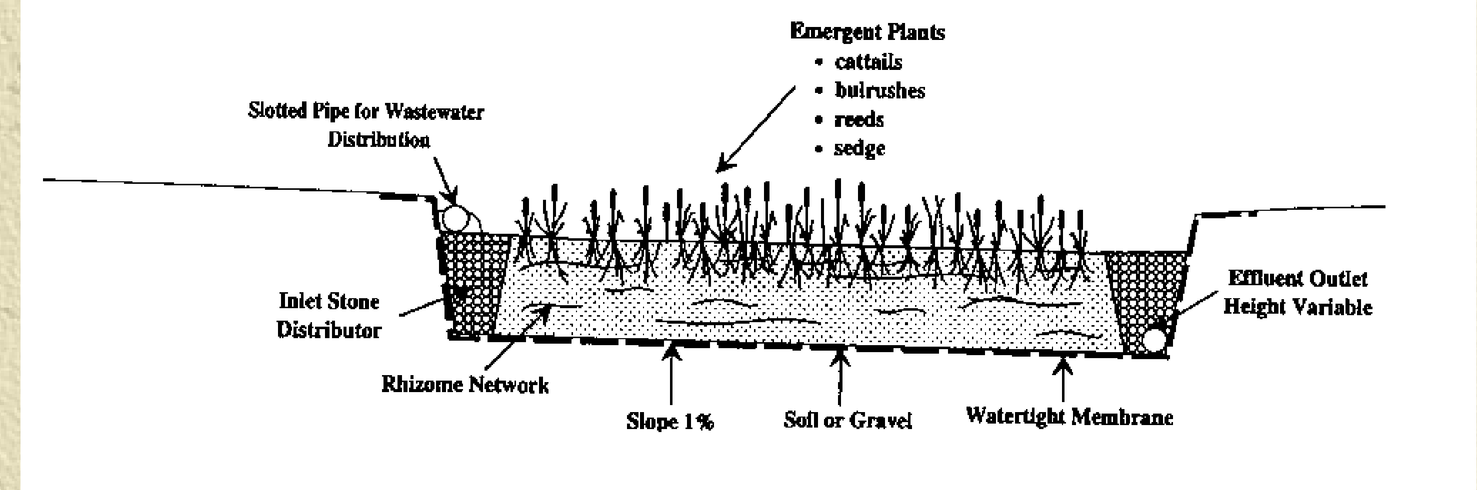
<u>OPERATION PRINCIPLES</u>

- An excavated basin or trench lined with an artificial membrane or impermeable liner of clay. The basin is filled with porous media that permits liquid to flow below the surface.
- The bottom of the basin should be sloped to provide an adequate hydraulic gradient to ensure that the effluent flows at a rate which allows treatment to occur.
- All flow into and through a wetland basin, both wastewater and natural in origin, should be controlled to ensure that the surface of the wastewater remains at or below the ground surface to prevent any short-circuiting of the treatment process.

Polishing and Nutrient Removal - Constructed Wetlands

OPERATION PRINCIPLES

- The emerging vegetation serves a variety of purposes.
- The root mass acts as a location for bacterial films to develop. The plants transfer oxygen to the water column and inhibit algae growth by preventing sunlight from reaching the water surface. The vegetation also aids in the filtration and adsorption of wastewater constituents.



Polishing and Nutrient Removal - Constructed Wetlands

DESIGN CRITERIA

Design Parameter	FWS[a]	SFS[b]
Hydraulic retention time, d	4-15	4-15
Water depth, m	0.09-0.61	0.03-0.76
BOD5 loading rate, kg/ha·d	<67	<67
Hydraulic-loading rate, $m^3/m^2 \cdot d$	0.014-0.047	0.014-0.047
Specific area, $ha/(10^3 m^3/d)$	7.2-2.1	7.2-2.1

[a] FWS – Free water system

[b] SFS – Subsurface flow system

Polishing and Nutrient Removal - Constructed Wetlands

ADVANTAGES

- Very effective at removing BOD_5 and suspended solids.

DISADVANTAGES

- Removal of nitrogen has been found to be quite variable.
- Phosphorus removal is not very effective.

Reed Bed Pilot - Marystown

Reed Bed Pilot - Marystown

Polishing and Nutrient Removal - Aquatic Systems (Duckweed)

<u>OPERATION PRINCIPLES</u>

- Typically lagoons-based treatments which use aquatic plants to treat domestic wastewater.
- Aquatic plants can be divided into two broad categories:
  - Floating aquatic plants (ie. hyacinth, duckweed, pennyworth).
  - Submerged plants (ie. waterweed, water milfoil, watercress).

Polishing and Nutrient Removal - Aquatic Systems (Duckweed)

DESIGN CRITERIA

- No established design criteria is in place.
- This would also be reviewed by a TRC

Polishing and Nutrient Removal - Aquatic Systems (Duckweed)

ADVANTAGES

- Requires minimal energy input.
- Improves effluent to a secondary or tertiary level.
- Reduces TSS, BOD and nutrients in effluents.

DISADVANTAGES

- Sensitive to cold temperatures.
- Requires large land areas.
- Not likely suitable for coastal communities with steep topography.
- Duckweed does not grow below 7^{o}C and system requires storage for the period that the system will not operate.

On-Site Systems – Primary Treatment – Communal Septic Tanks

OPERATION PRINCIPLES

- Septic tanks have been used for wastewater treatment for over 100 years.
- When installed in a proper location and maintained properly septic tanks operate 100% of the time.
- Prefabricated tanks that serve as a combined settling and skimming tank and as an un-heated anaerobic digester.

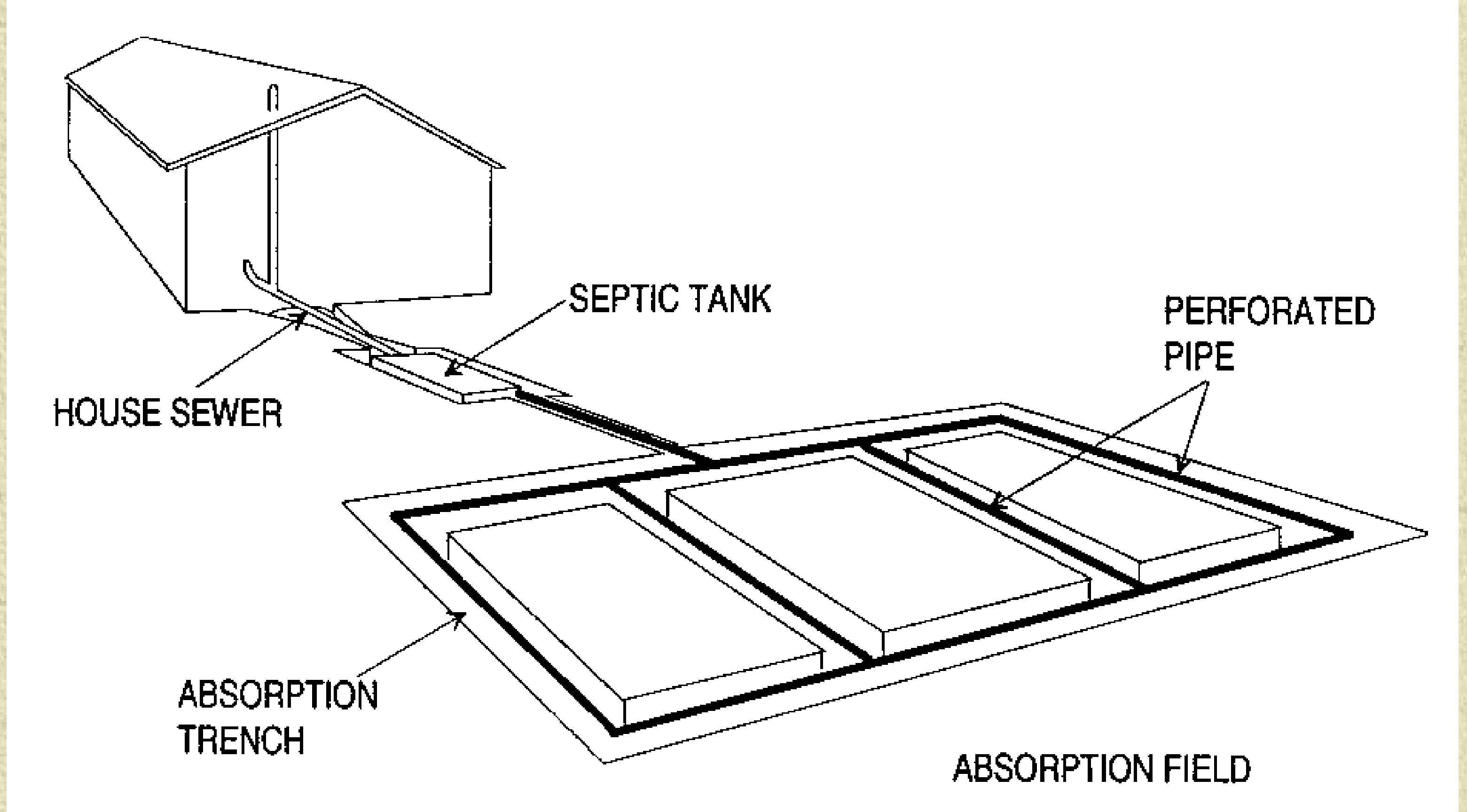
On-Site Systems – Primary Treatment – Communal Septic Tanks

OPERATION PRINCIPLES

- The effluent from the septic tanks flows by gravity to the absorption field.
- Solids, grease and floatables are retained in the septic tank.
- Effluent from the septic tank receives further treatment in the absorption fields using physical and biological means (ie. vegetation uptake and evaporation).

On-Site Systems – Primary Treatment – Communal Septic System

OPERATION PRINCIPLES



On-Site Systems – Primary Treatment – Communal Septic System

DESIGN CRITERIA

Design Parameter	**Range**	**Typical**
Hydraulic retention time, hr	≥ 24	
Length to width	2:1-4:1	3:1
Depth, m	0.3-1.8	1.2
Clear space above liquid, cm	25-30	25
Depth of water surface below inlet, cm	7.6-10.2	7.6

On-Site Systems – Primary Treatment – Communal Septic System

ADVANTAGES

- Does not require the capital cost, construction of a collection system.
- Requires no energy requirements and no moving parts.
- Minimal active maintenance.

DISADVANTAGES

- Not acceptable in highly sensitive areas.
- Requires appropriate soil conditions and sufficient land area.

On-Site Systems – Secondary Treatment – Disposal Fields

<u>OPERATION PRINCIPLES</u>

- Disposal fields typically consist of narrow, relatively shallow trenches with a porous medium fill.
- The porous medium is used for several purposes:
  - Maintain the structure of the trenches
  - Provide partial treatment of effluent
  - Distribute effluent to the infiltrative soil surface
  - Provide temporary storage capacity during peak flows

On-Site Systems – Secondary Treatment – Disposal Fields

DESIGN CRITERIA

Soil Texture	**Percolation rate ($min/10^2 mm$)**	**Application rate ($L/m^2 \cdot d$)**
Gravel, coarse sand	<4	Not recommended
Coarse to medium sand	4-20	48
Fine sand, loamy sand	21-60	32
Sandy loan, loam	61-120	24
Loam, porous silt loam	121-240	18
Silty clay loam, clay loam	241-480	8
Clays, colloidal clays	>4800	Not recommended

On-Site Systems – Secondary Treatment – Disposal Fields

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DISADVANTAGES

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Emerging Technologies

- Waterloo Absorbent Biofilter
- Vortex Separator
- Magnetite Clarification
- Algae-based Systems
- Constructed Wetland
- Freeze Crystallization
- Solar Aquatics
- Biogreen Technology
- Reed Bed

Emerging Challenges

- Endocrine Disruptors
- Pharmaceuticals

Endocrine Disruptors

- Endocrine systems are complex mechanisms, coordinating and regulating internal communication among cells. Endocrine systems release hormones that act as chemical messengers. The messengers interact with receptors in cells to trigger responses and prompt normal biological functions such as growth, embryonic development and reproduction.

Endocrine Disruptors (cont'd)

- Public attention has been drawn to substances that mimic or block the feminizing effects of natural female sex hormones: for example, estrogens such as 17ß-estradiol. This is only part of the story, however. Substances can also affect male sex hormones or other endocrine systems that influence growth, development and behaviour.

Endocrine Disruptors (cont’d)

- Incineration, landfill - PCD’s, PCB’s
- Agricultural & Atmospheric - DDT, dieldrin , lindane, atrazine, trifluralin, permethrin
- Harbours - Organotins (found in antifoulants used to paint the hulls of ships) Tributyltin
- Industrial and municipal effluents - Surfactants - Nonylphenol
- Municipal effluent - 17-b-estradiol, estrone, Testosterone; ethynyl estradiol
- Pulp mill effluents - Phytoestrogens (found in plant material) isoflavones, ligans, coumestans

Pharmaceuticals

- ibuprofin, carbamazepine
- Preliminary tests will be undertaken in order to determine whether there is a link between the potential presence of certain medications and the disturbances observed in aquatic organisms, including the mussels used as bioindicators. The results of these tests will enable researchers to assess the impacts of emerging substances such as pharmaceuticals on the environment.

Current Research Areas

- assessment and management of pharmaceutical and hormone disruptors in effluents and runoff
- screening procedures for identification of reproductive and developmental toxicants
- contaminant transformations in wetlands and biota

Current Research Areas (cont’d)

- occurrence and quantification of pharmaceuticals and emerging contaminants in the environment
- fate and occurrence of pesticides and industrial chemicals in the environment
- bioaccumulation and pharmacokinetics of metals and emerging chemicals of concern

Questions and Discussion?