DESIGN CONCEPTS OF UNSATURATED MEDIA FILTERS

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What is a design concept?

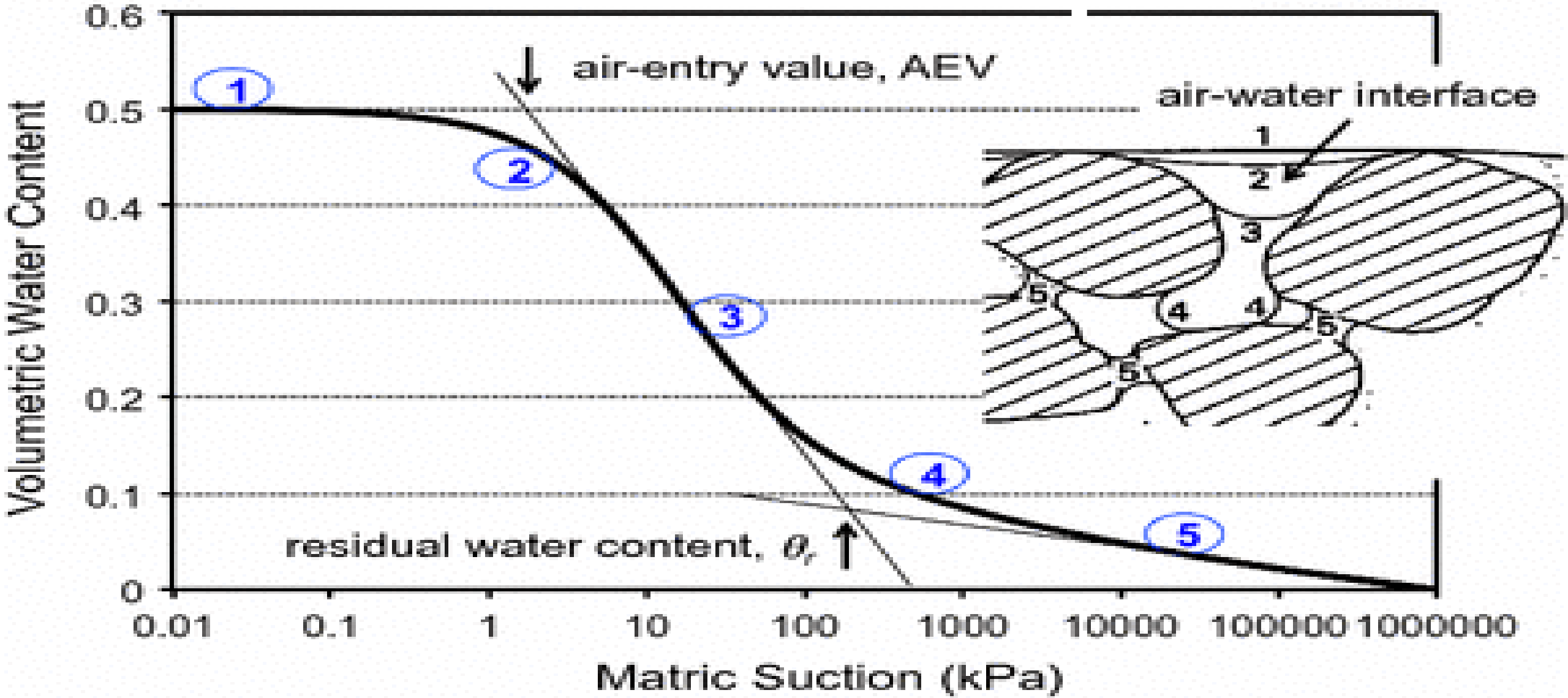
- A brief explanation of what a device is intended to do
- Eyeglasses: improve vision
- Sun glasses : protect vision in bright sun, fashion statement

What does unsaturated mean?

- Opposite of submerged
- In this lecture, unsaturated means larger media pores contain gas
- Smaller media pores contain liquid
- Gas and liquid are both examples of fluids

Media/water characteristic curve

After: Vanapalli & Fredlund, 2000



What are unsaturated media filters?

- Independent class of wastewater treatment systems
- Capable of achieving advanced wastewater treatment levels
- Come in proprietary and non-proprietary configurations
- Distinguishing feature in common: media is unsaturated

Many terms used to describe these systems

- Examples: Attached Growth, Fixed Film, Packed Bed, Biofilter
- Can use natural media (e.g. sand, peat moss, coconut fiber)
- Can use artificial media (e.g. polyurethane, textile fibers)
- Both media types can be use single pass or recirculation
- Some media are absorbent (peat moss, coconut husk)
- Recirculation used to remove nitrogen from effluent

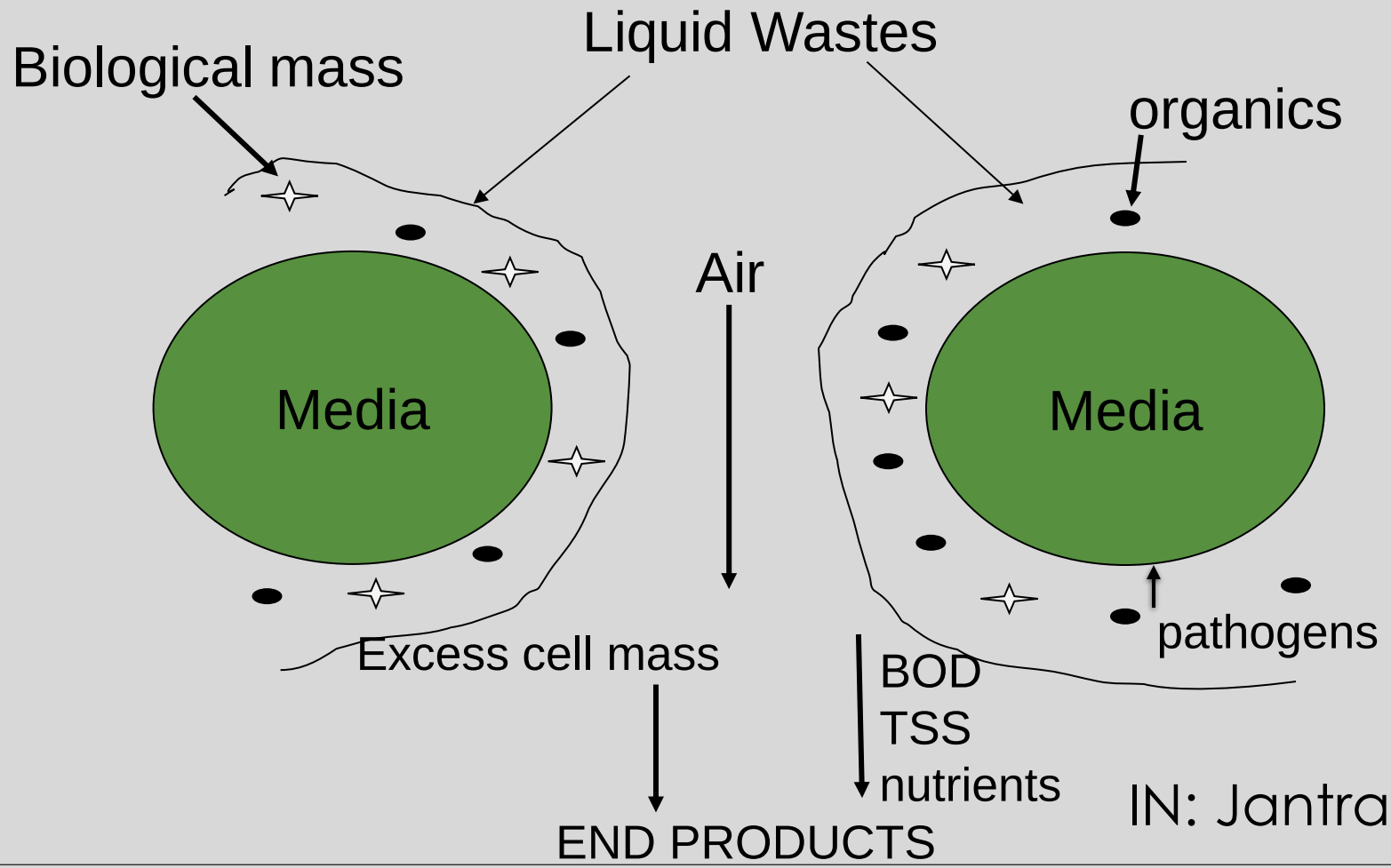
Other treatment approaches excluded from unsaturated media filters

- Suspended growth aerobic treatment units (ATUs)
- Hybrid suspended/attached growth ATUs
- Moving bed bio reactors
- Membrane bio reactors
- Bacterial generators
- Combined treatment and dispersal systems

Design concept of an unsaturated media filter

- Liquid distributed **uniformly** to upper surface (infiltration surface)
- Then passing through and around media with large surface area passively dissolving oxygen into the interstitial liquid coating in a thin film
- Trickling liquid always close to air-filled spaces surrounding the media

Flow and treatment on media particles

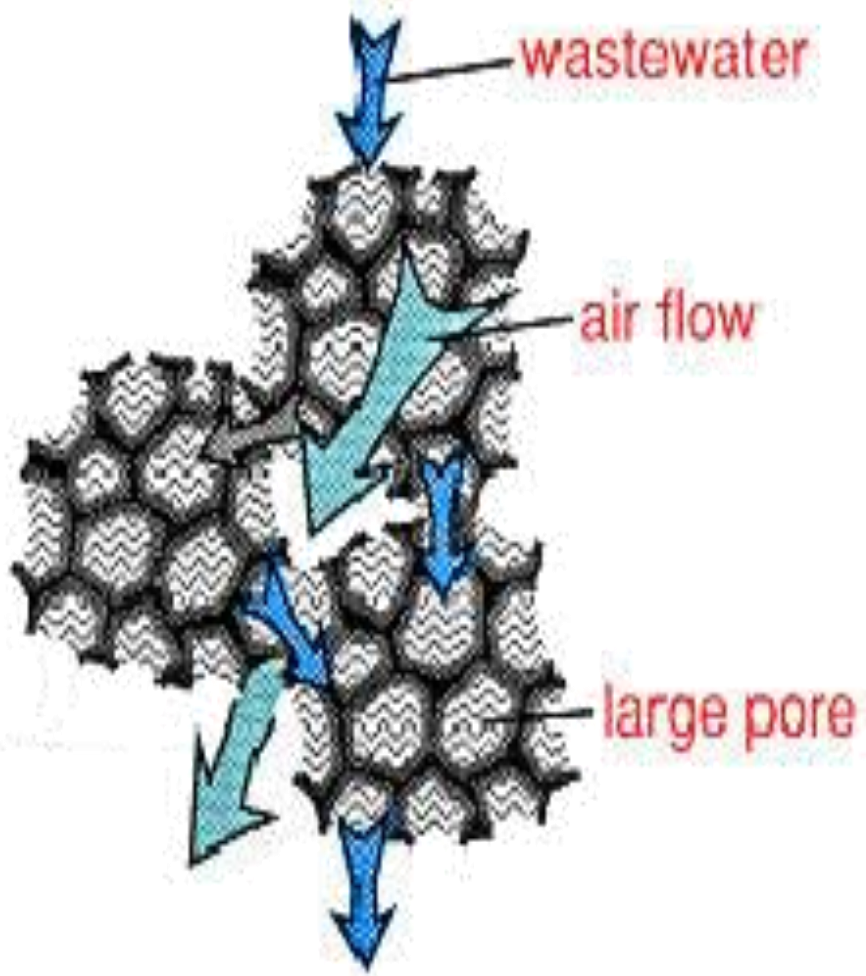


IN: Jantrania & Gross, 2006

When an unsaturated media filter is designed to slough solids

- There must be provisions to hold these solids until they can be removed (pumped)
- Some media filters are designed to operate in the endogenous phase to minimize creation of excess cell mass

What properties are prized in a media?



- High surface area / volume
- Pathways for water and air to enter the media and pass through and around it
- Excess liquid must drain from media (not waterlogged)
- Yet still hold on to residual moisture
- Media must also be structurally sound and resistant to chemical attack

Media characteristics

After: Jantrania and Gross, 2006 Table 3.2

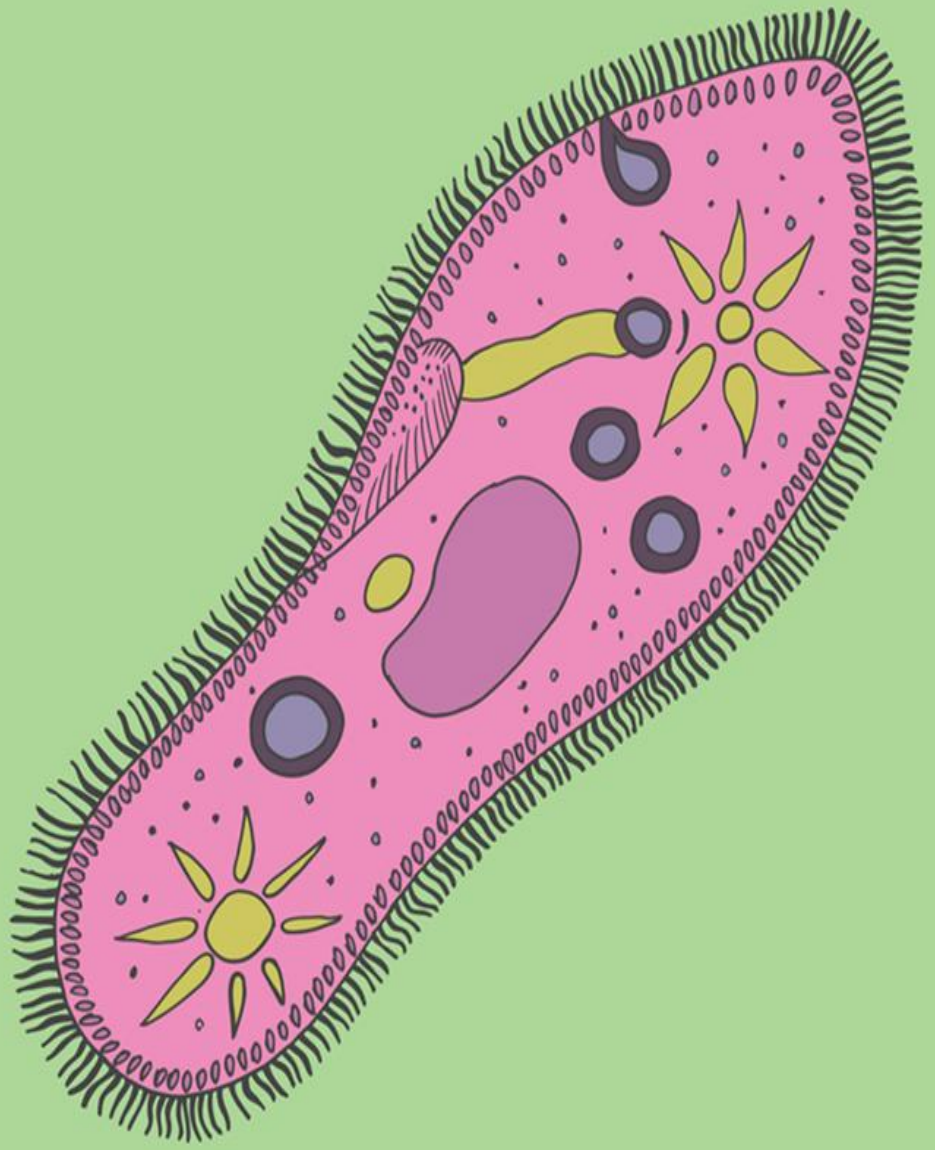
Type	Depth (in)	Media size (d_{10}, mm)	Specific surface area (ft^2/ft^3)
Single-pass sand filter (subsurface)	24 typ.	0.3 to 0.6	800 -1000
Recirculating sand filter	24-30	1.5 to 3.0	500-700
Textile media filter	22	N/A	2400-4800
Open cell foam	30-102	2 inch cube	18,000 *
Peat	24-31.5	0.25 to 2.0	500,000
Coir (coconut fiber) Coconut husk fragment	30-31.5 25.5-31.5	0.25 to 2.0 1.2 to 2.5 mm	500,000 320,000
Polystyrene bead	12-18	0.5 to 1.5	2400

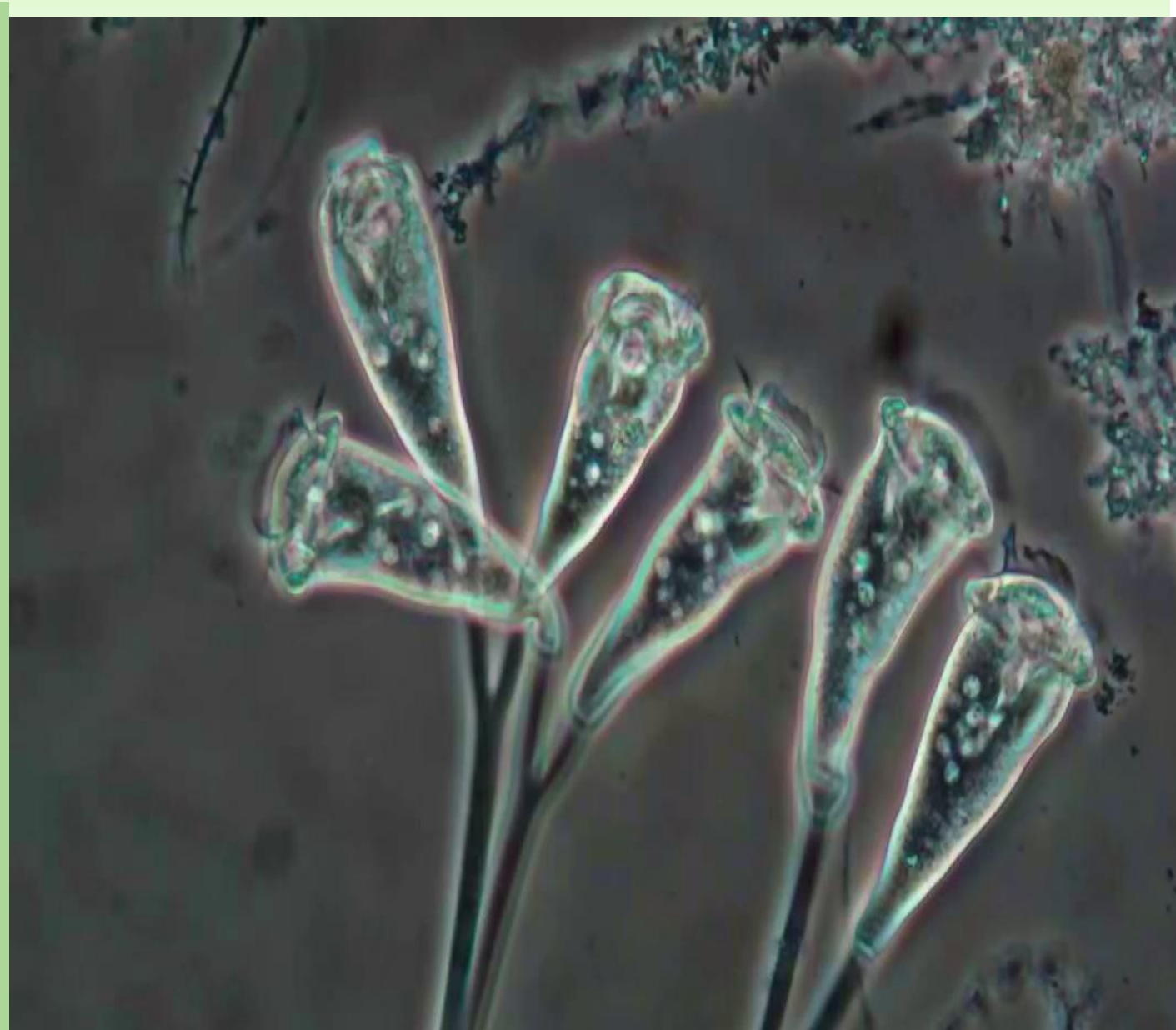
* In: Jowett & McMaster, 1994

How do microorganisms live in a media filter?

- Microorganisms are attached to a surface (sand grain, plastic media, peat moss, coconut husk, foam, textile, etc.) forming a coating over time
- Food must come to them
- Less likely to experience extreme population crashes if food is scarce
- An absorbent media will hold onto moisture longer allowing a longer time period between doses (Gilbert et al, 2015)

Free-swimming and stalked ciliates



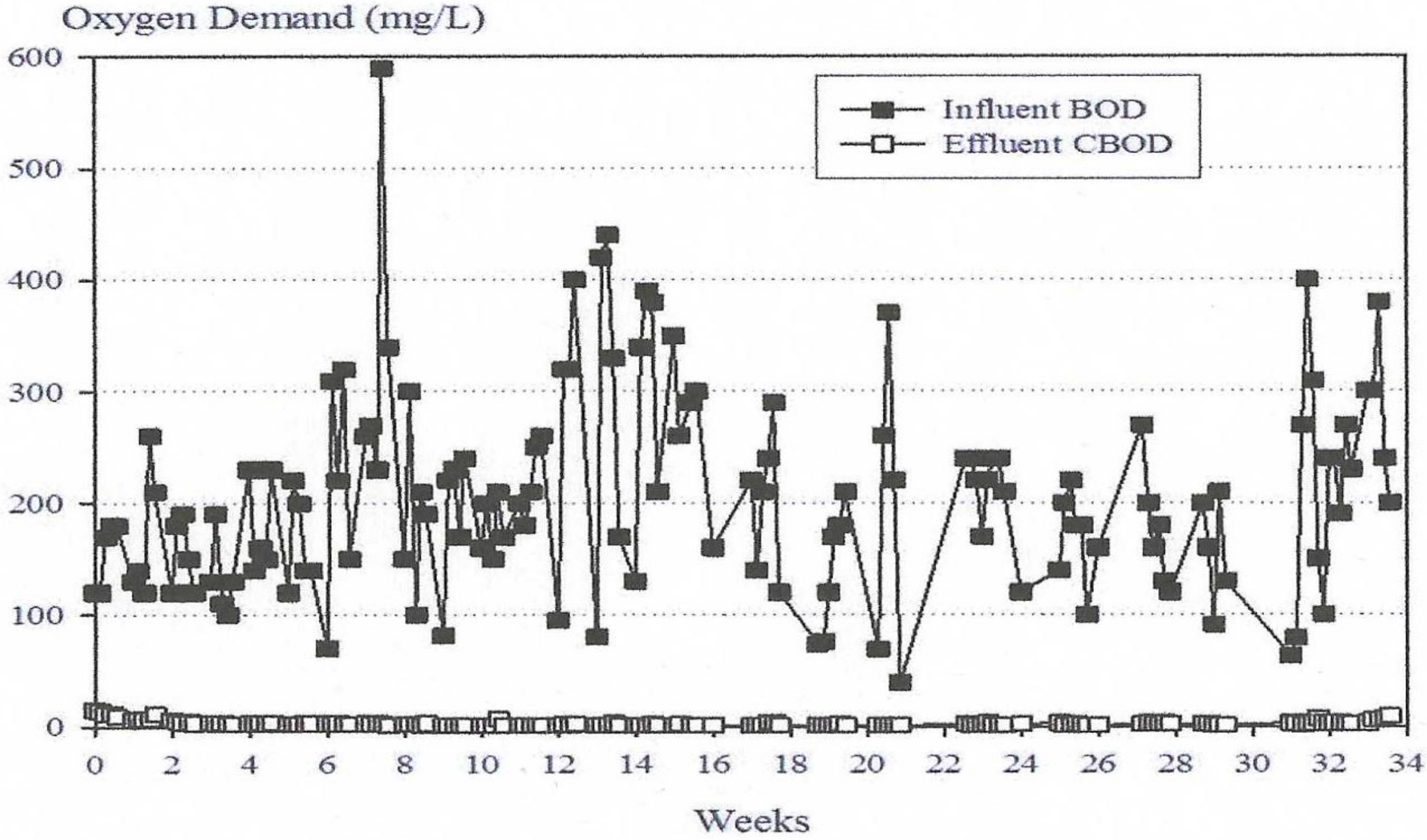


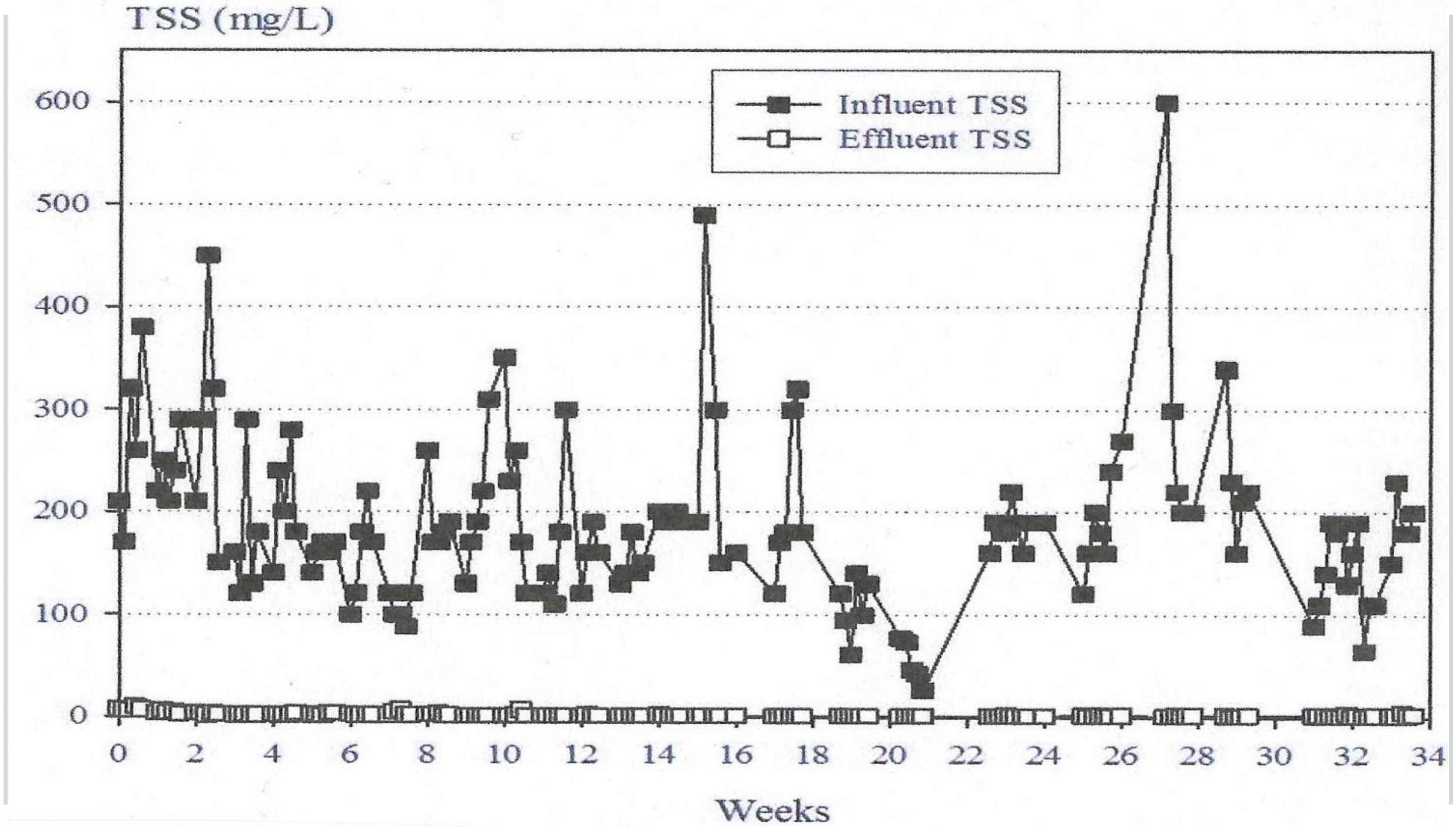
Physical functions of an unsaturated media filter

- Straining
- Entrapment
- Adsorption
- Impaction
- Important in beginning of filter's operation
- Later, biological/biochemical processes become more important as the filter matures

Biological functions of an unsaturated media filter

- Capture of particulates and predation of other microbes
- Adsorption/inactivation of virus
- Biological oxidation of carbon
- Biochemical transformations of nitrogen


Oxygen Demand (mg/L)
600
500
400
300
200
100
0
Influent BOD
Effluent CBOD
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
Weeks


TSS (mg/L)
Influent TSS
Effluent TSS
600
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
Weeks

Typical performance attributes of unsaturated media filters

- Stable process
- Able to handle shocks and stresses
- Efficiently converts ammonia to nitrate
- Excess cell solids (sludge) can be removed easily by media replacement
- Relatively low power consumption
- Moderate operator skill required

Effluent distribution methods

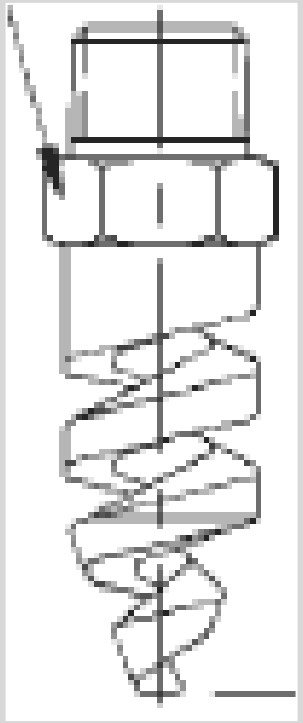
- Perforated pipes (pipes and stone)
- Distribution plates
- Nozzles
- Pipes and splash plates

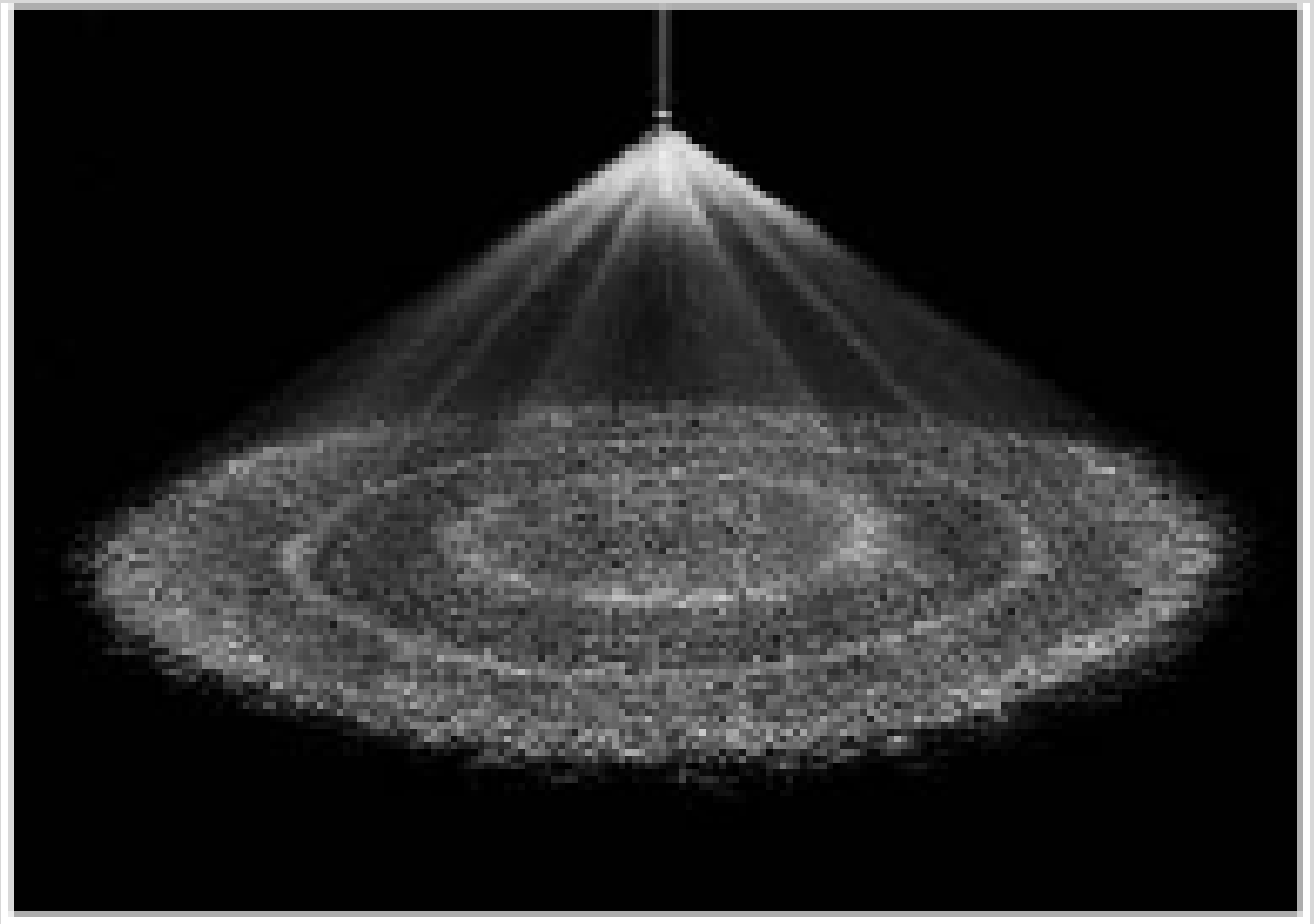
Nozzle wetting pattern

Pattern is a Solid cone a 3” clearance

Can create a cone 5’ wide

170 degrees





Next generation nozzle

Spin Nozzle: Wetting pattern is a Square

Time dose the media surface

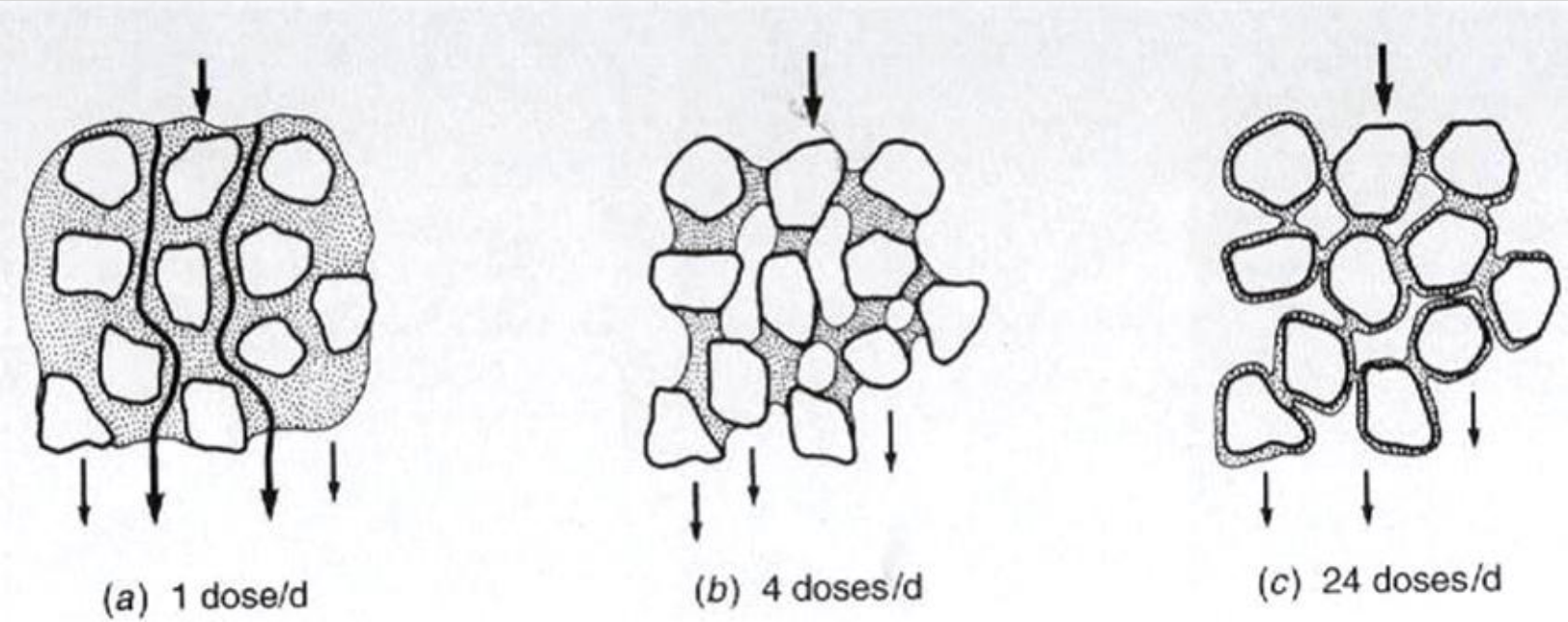
- Allows unsaturated flow throughout the media
- Microorganisms get regular and precise feeding and air is pulled into media after each dose
- Reduces probability of short-circuiting effluent

A pump is not always used

Courtesy of
Premier Tech
Water and Environment

Alternating tipping bucket onto tray: slotted distribution plate with holes at various distances from centered bucket

Benefits of Micro dosing
film flow = improved treatment



After Crites & Tchobanoglous 1998

Design Considerations – Intermittent unsaturated media filters

- **Loading rate** – gal per cu.ft. media or sq.ft. surface
- Uniform effluent distribution critical (why?)
- **Dose volume** – micro dosing over many hours
- Each parcel of water travels through filter **once**
- Convert ammonia to nitrate **(nitrification)** (marginal denitrification also occurs)
- Correct media specification is **essential**

Recirculating Unsaturated Media Filters

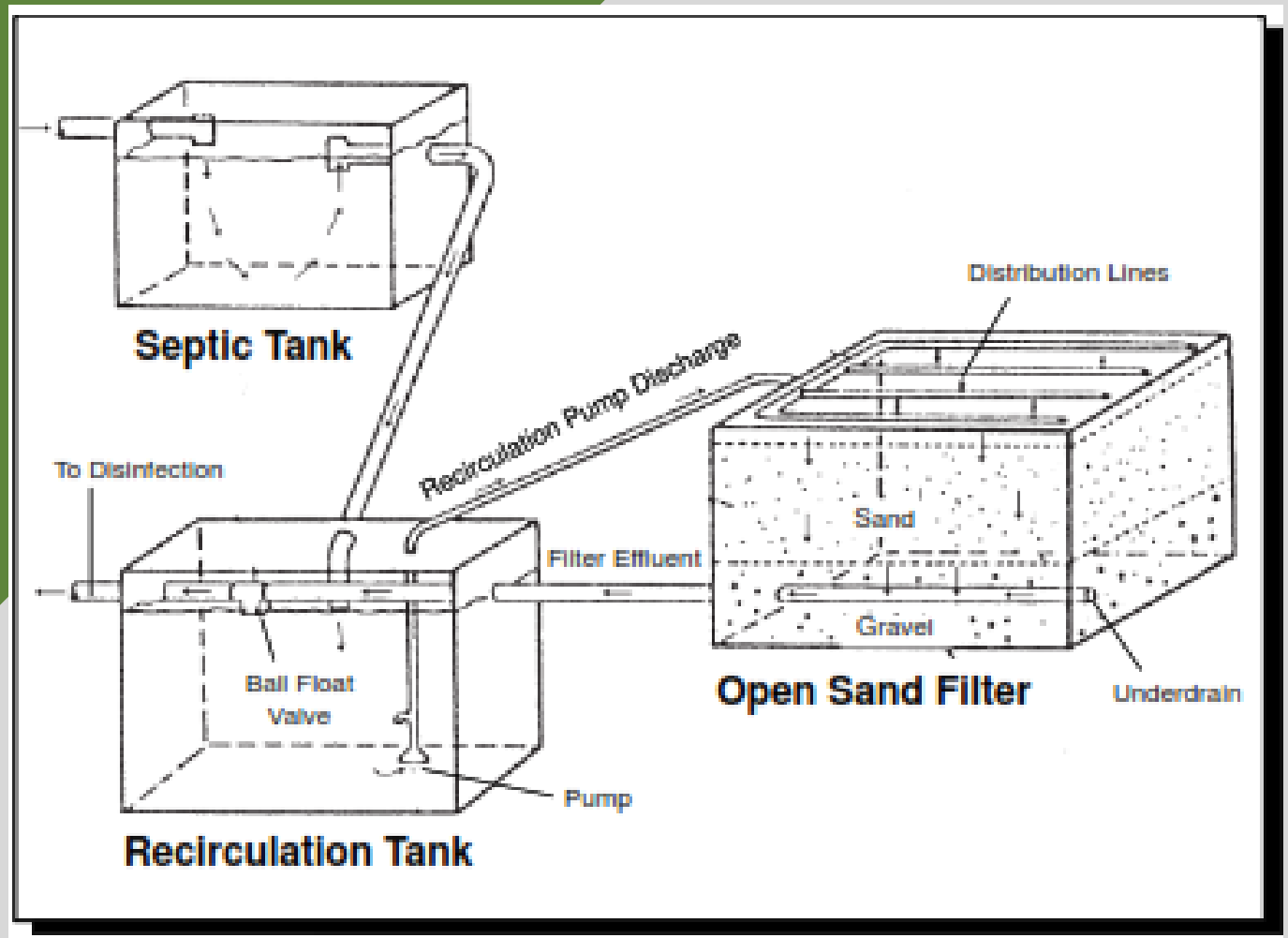


Figure 1: Typical Recirculating Sand Filter System

Adapted from: Hines and Favreau (1974) with permission

Methods / benefits of recirculation

- Reduces filter ‘footprint’
- Enhanced nitrogen removal
- Process flexibility to handle peak loads
- Recirculation rate may be automatically adjusted
- Typically 1:1 to 5:1 recirculation used
- Time dosed with data collected from recirc. & dispersal pumps

Recirculation rate and typical hydraulic retention times*

Percent recycle	Recycle flow : forward Flow	Hydraulic retention time
50%	1:1	24 hours
66.7%	2:1	16 hours
75%	3:1	12 hours
80%	4:1	9.6 hours
83.3%	5:1	8 hours

* Assumes a flow of 500 gpd in a two-tank system (recirculation and processor) of 1,000 gallons each

References, sources of add'l information

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Questions?

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